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Vehicle Evaporative Emission Mechanisms:

A Pilot Study

June 24, 2008

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

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A Report on

Vehicle Evaporative Emission Mechanisms: A Pilot Study

CRC Project E-77

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Submitted by
Harold M. Haskew PE
Thomas F. Liberty
Harold Haskew & Associates, Inc.
Milford, Michigan

Acronyms

ATL............... Automotive Testing Laboratories
CRC............... Coordinating Research Council, Inc.
FID .... Flame Ionization Detector
HC .... Hydrocarbon
HH&A........... Harold Haskew & Associates
LA-92............ Unified Driving Cycle
MTBE............ Methyl Tertiary Butyl Ether
NBR .... Nitrile Rubber or Acrylonitrile Butadiene Rubber
PFI................. Port Fuel Injection
RL SHED...... Running Loss Sealed Housing for Evaporative Determination
RVP............... Reid Vapor Pressure
SHED .... Sealed Housing for Evaporative Determination
VT SHED...... Variable Temperature Sealed Housing for Evaporative Determination

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Vehicle Evaporative Emission Mechanisms: A Pilot Study

BACKGROUND

The Coordinating Research Council, Inc. (CRC) has sponsored a variety of timely vehicle evaporative emission test programs over the last two decades, adding greatly to the knowledge base of mobile-source inventory issues. Included in the research were the:

- Auto-Oil Hot Soak Pilot Study (1993) 300 vehicles
- CRC E-9 Real-Time Diurnal Study (1996) 150 vehicles
- CRC E-35 Running Loss Study (1997) 150 vehicles
- CRC E-41 Late Model In-Use Evap Emissions (1998) 50 vehicles

CRC Project E-41 examined the evaporative emissions of fifty 1992 to 1997 model year vehicles. Six of the vehicles were certified to the federal “Enhanced Evaporative Emission” standards, but were tested at low age and miles. The U. S. enhanced evaporative emissions requirements were phased in nationally, starting with the 1996 model year vehicles, with full implementation by the 2000 model year. These requirements had a major impact on the design and content of the systems used for evaporative emissions control. CRC Project E-41 concluded that the six newer vehicles tested performed well against their respective Enhanced Evaporative emissions certification requirements, but suggested that a similar study be conducted after this class of vehicles had aged.

In 2004, CRC committee members recommended a follow-up study to investigate the in-use performance of the “enhanced evaporative emission” fleet after it had accumulated age and miles. The committee discussed the best way to conduct such a study. Determining the vehicle’s total evaporative emission rates is of interest, but the measurements should also be focused on isolating the parameters useful for modeling. This was not to be a “compliance” program.

Vehicles are certified by demonstrating emission performance at levels below published limits. For vehicle evaporative emissions, there are tests that measure three modes of vehicle operation:

1. Running Losses
2. Hot Soaks
3. Diurnal Emissions

Certification tests, which are performed under specific conditions with tightly controlled parameters, may represent extreme conditions of temperature and duration. The running loss test, for example, consists of a single drive lasting more than one hour, certainly longer than the typical urban trip.

Inventory modelers have used information from the certification tests to help estimate the contribution of vehicle emissions to the atmosphere, but more information is needed to determine the emission rates at different temperatures, different trip lengths, and with different fuels. In 2005, EPA contracted Harold Haskew & Associates, Inc. to suggest a different approach for gathering the data necessary to model evaporative emissions. The resulting report, “A New Approach to Modeling On-Road Vehicle Evaporative Emissions,” was published June 2, 2005. This new approach suggested measuring the mechanisms of evaporative emissions, instead of the modes.

The mechanisms were defined as:

- Leaks
- Diurnal displacement vapors
- Permeation

Diurnal vapors and permeation were thought to be functions of ambient and vehicle temperature and fuel composition. Emissions from leaks are not thought to be a property of the fuel. The challenge was to invent a procedure or test that would allow the separation of leaks from diurnal vapors and leaks from permeation. Characterization of the emission mechanisms of the fleet could lead to more informed estimates of the evaporative emission rates at various temperatures, with different fuels, and driving conditions.

A separate CRC Project, E-65, "Fuel Permeation from Automotive Systems," measured and reported the permeation of ten different vehicle fuel systems with three different gasolines. This project vented the tank vapor emissions outside the VT-SHED to allow an independent measurement of permeation. That experience suggested that it should be possible to measure both permeation and the tank venting loss during a real-time (24 hour) diurnal event, if a separate trap canister was placed outside the VT-SHED and the vehicle's canister loss collected.

CRC Project E-77 evolved as a pilot study to determine if the mechanisms of evaporative emissions could be measured effectively. If the pilot study were a success, a follow-on program could continue to develop additional data, suitable for input to current and proposed inventory models, which could assist in modeling current and future mobile-source emissions. This work is timely as this category of newer vehicles will become the predominant class of vehicles in the light-duty fleet.

This report focuses on the process of measuring emission mechanisms and the lessons learned to date. Plots of the test data are presented in this report's appendix. The raw data are available in MS Excel® format from the CRC website (www.crcao.org).

DISCUSSION

There were a number of elements involved in this pilot study.

- Project timing
- Vehicle selection and procurement
- Fuels and test parameters
- Pre-test stabilization on the test fuel
- The test concept: measuring leaks, permeation, and diurnal vapor losses
- Examples of measurements
- Non-fuel emissions
- Overview of what was learned

Project Timing - The first draft proposal was considered by CRC in May 2004, emphasizing the need for follow-up to Project E-41 given the accumulation of time and miles by enhanced evaporative control vehicles. A request for proposals was issued in October 2005. HH&A's proposal was based on the use of new concepts to measure the "mechanisms" of evaporative emissions, rather than conventional "certification-type" tests. HH&A was awarded the contract in February 2006 for a "Pilot Study of Ten Vehicles" to investigate this new concept. Data collecting began in early July 2006 and ended in early 2007.

Vehicle Selection and Procurement - Nine vehicles were recruited from the Phoenix area. One vehicle (Vehicle 6, a 1996 Chevrolet Cavalier) was tested twice. It was tested the second time with an implanted leak in the fuel cap to represent a "leaker" (renumbered Vehicle 7). The sample was not intended to represent the entire in-use fleet, but rather a small sample distributed between makes, models, and technologies.

The test vehicles came from a population that was comprised almost entirely of port fuel injection models with in-tank fuel pumps. The test procedures would have to be modified if older, carbureted, or advanced design new vehicles were included.

The following mix, certified for sale in all fifty states (i.e., meeting both federal and California evaporative emission standards) was chosen:

- Three 1990-1995 MY vehicles certified to Pre-Enhanced standards
- Five 1996-2000 MY vehicles certified to Enhanced standards
- One 2007 MY vehicle certified to the new Tier II standards

Table 1 - CRC E-77 Pilot Study Test Fleet

Vehicle Number	Model Year	Make	Model	Eng. Size L.	Fuel System	Odo. Miles	Tank Size Gallons	Fuel Tank Material
Pre-Enhanced Evap								
3	1992	Honda	Accord	2.2	PFI	71,129	17.0	Metal
10	1992	Toyota	Camry	2.2	PFI	162,838	18.5	Metal
9	1995	Plymouth	Neon	2.0	PFI	106,220	11.2	Metal
Enhanced Evap								
1	1996	Chevrolet	S-10	4.3	PFI	68,420	19.0	Metal
6	1996	Chevrolet	Cavalier	2.2	PFI	112,768	15.3	Metal
7	1996	Chevrolet	Cavalier (w/leak)	2.2	PFI	113,125	15.3	Metal
8	1996	Ford	Explorer	4.0	PFI	114,822	21.0	Metal
4	1999	Dodge	Grand Caravan SE	3.3	PFI	98,765	20.0	Plastic
2	2000	Toyota	Tacoma	3.4	PFI	80,557	15.1	Metal
Tier II (near zero)								
5	2007	Ford	Taurus	3.0	PFI	6,916	18.0	Metal

Candidate owners were offered incentives to participate in the program. The incentives were the use of a loner car (a pre-paid rental vehicle) and free fuel during the vehicle pre-conditioning and the vehicle test period. The test plan required having the owner drive the selected (and committed) vehicle for a minimum of four weeks on ethanol-free road fuel before the vehicle was submitted for testing. Vehicle owners signed an agreement to use only fuel provided by the laboratory for the four-week minimum period prior to testing. Unlimited fuel fills were permitted during normal working hours. During non-working hours and weekends, owners were permitted to contact laboratory personnel to obtain any needed additional fuel. Fuel usage for each vehicle fill was logged and compared to accumulated odometer readings to validate that the fuel usage and mileage accumulation were in order. No discrepancies were noted during the pilot study.

Initial screening included a review of the emission sticker to determine the certification category and documentation of the make, model year, engine family, evaporative family, and accumulated odometer reading. The owner was asked if the vehicle had undergone collision repairs or had recently been repainted. New tires and paint emit at an unrepresentative rate, and were excluded from the program. The tires on each vehicle were visually inspected, and the purchase date of obviously new tires was determined. The engine compartment was inspected. Signs of collision repair and/or engine modifications were noted. Tampering, extreme odometer readings, and/or unusual equipment configurations were excluded. A final inspection looked for any unusual hydrocarbon odors or signs of spills. All exceptions were resolved prior to acceptance of a particular candidate.

Testability issues were also noted during this initial inspection. Tire conditions, cooling systems, brakes, and exhaust systems were inspected to insure the vehicle could be successfully tested. All vehicles had accumulated at least 4,000 miles (a project requirement) prior to entering the test program. ATL's Project Manager reviewed each specific recommended candidate with the HH&A Program Director prior to final acceptance.

Fuels and Test Parameters - The statement of work specified that the pilot study focus on a non-oxygenated (E0) fuel at two volatility levels, 7 and 9 psi RVP. CRC supplied the fuel for the project at 7 psi volatility. The laboratory added butane to the base fuel for the 9 psi evaluation.

The test temperature for the static and dynamic tests was 86ºF. This is approximately the average temperature of the Federal (72º to 96ºF) and California (65º to 105ºF) diurnal certification tests, and a typical temperature for a summer day.

The diurnal test temperature range was specified at two levels, 65º to 105ºF (the California certification specification), and a higher temperature range, 85º to 120ºF (representing a severe temperature day).

Pre-Test Stabilization on the Test Fuel - Many areas of the United States were required 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. 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. Project E-65 also demonstrated that if ethanol had been used, it could take two to four weeks for the ethanol increase to dissipate. With that in mind, the design of the pilot program required that vehicles be operated for four or more weeks with a known oxygenate-free fuel before starting the test sequence.

The Test Concept: Measuring Leaks, Permeation and Diurnal Vapor Losses - This pilot study evaluated the use of a new methodology for understanding and quantifying vehicle evaporative emission rates. This new 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 in a vehicle fuel system[1]. 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.

Tank vapor venting emissions are controlled by fitting a carbon canister to the atmospheric tank vent. Figure 1 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.

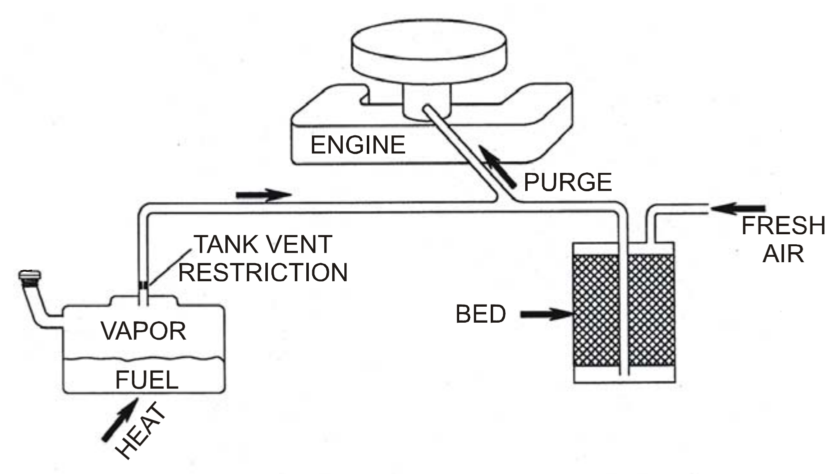


Figure 1 - Control System Schematic

[1] "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.

Leaks can be liquid or vapor. Mass emissions are measured in a VT SHED. The SHED test method combines all three emission mechanisms (leaks, diurnal venting, and permeation) into a single test result.

The SHED technique[2,3] 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.

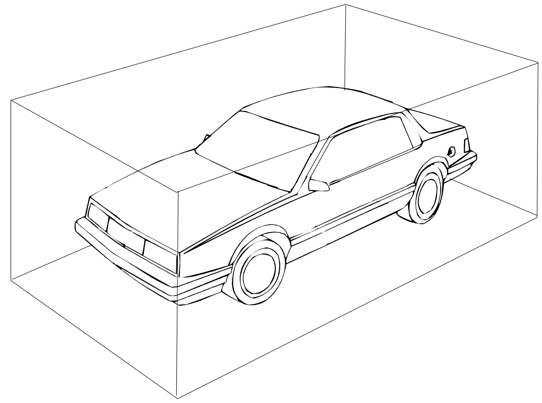


Figure 2 - Sealed Housing for Evaporative Determination

The goals of this pilot study were to determine if the three evaporative emission mechanisms could be separated and individually quantified, as well as to provide an indication of how the "enhanced evaporative emission" vehicles were performing as they aged.

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 - Previous CRC Project E-65 had separated the canister loss 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 3. 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. This vent was closed to pressurize the system for the leak evaluations. The resulting SHED increase in HC mass was

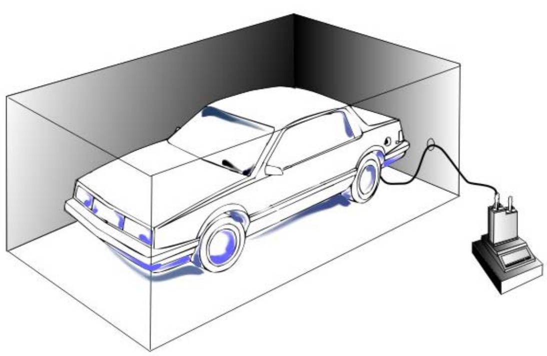


Figure 3 - Trap Canister

[2] SAE 891121 "Evaporative Emissions Under Real-Time Conditions."
[3] SAE 901110 "The Development of a Real-Time Evaporative Emission Test."

permeation[4]. 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.

Leaks from the vehicles chosen for this pilot study[5] were quantified in a three-step test process. The first step was to measure the permeation rate of the vehicle at 86ºF. The vehicle was allowed to stabilize at 86ºF in the SHED and the permeation rate was measured. The experience gained was that a vehicle's permeation rate lies in the 20 to 90 mg/hour range. The presence of a static liquid leak is thought to overwhelm this value; such a leak would (or could) be apparent by inspection. 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 the fuel cap and tubing from outside the SHED (Figure 4). The special fuel cap, the hose and the pressurization apparatus was 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 was compared to the static permeation rate. If there was no (or insignificant) rate of increase, it was deduced that no vapor leak is present.

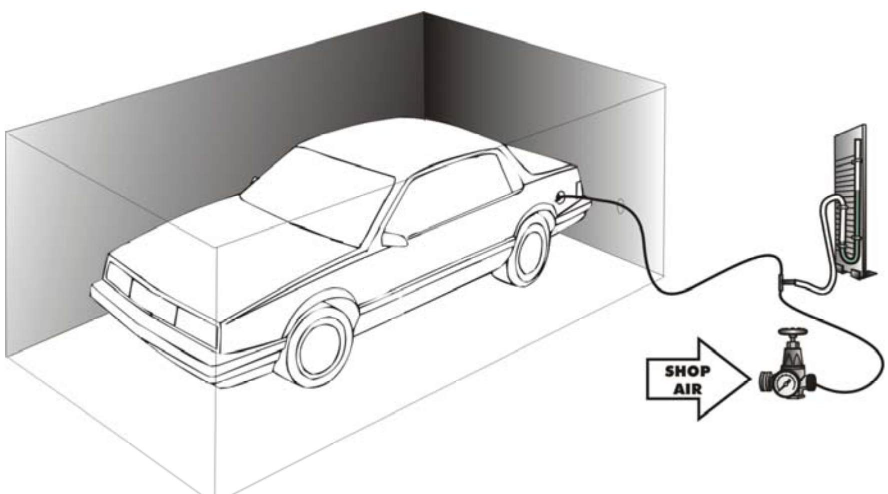


Figure 4 - Static Test – Tank Pressurization

[4] 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.
[5] The early and enhanced evaporative emission control vehicles tested had port fuel injected (PFI) engines with in-tank fuel pumps and carbon control of venting emissions.

A final test was to energize the vehicle's fuel pump and pressurize the system up to and including the injectors (Figure 5). If there were a pressure leak in the liquid system, an increase in the SHED mass over time would be seen, i.e., the leak would be additive to the permeation rate.   Example of this test methodology follows.

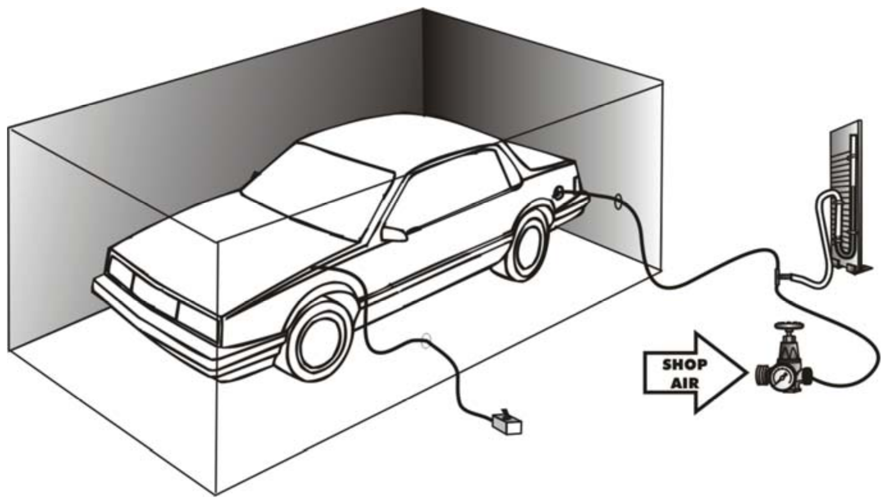


Figure 5 - Static Test – Fuel Pump Energized

Examples of Measurements – There were three basic tests used in this study;

1. Static Permeation and Leak Test
2. Running Loss and Hot Soak Test
3. Diurnal Tests

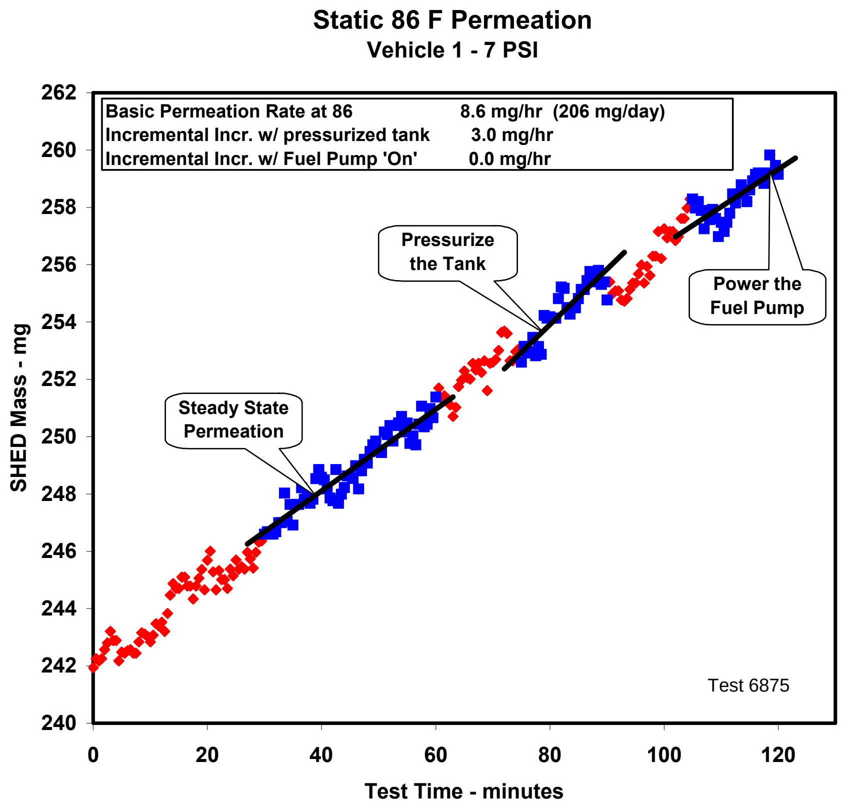


Figure 6 – Static Test

<u>The Static Permeation and Leak Test</u> Figure 6 illustrates the test results from one of the pilot tests (Vehicle 1 – 1996 Cavalier on 7 psi fuel). The horizontal axis is the test time in minutes, and the vertical axis is the calculated HC mass in the SHED in milligrams. The SHED analysis system included a Rosemont FID calibrated on propane, but expressed as ppm C1.

The first 60 minutes of the test were devoted to the static permeation measurement. The vehicle was placed[6] in the constant temperature (86°F), allowed to stabilize for an appropriate amount of time, and then the test began. At time zero in Figure 6, the SHED mass estimate was 242 milligrams. The HC concentration in the SHED was recorded every 30 seconds, and the mass for that time calculated, using the hot soak SHED calculation method defined in 40 CFR § 86.138-90. The red dots indicate the mass estimate for each of the first 30 minutes of measurements. These data were retained but not used in the permeation rate measurement. The next 30 minutes of measurement were made in the same fashion, and the time/mass values entered in an Excel® file where the "SLOPE" value was returned and became the "static

[6] The vehicle was set up to run two types of leak tests during this test period, the "system pressurization," and the "fuel pump energized." Both require that the canister (tank) vent be sealed. The procedure used to do this is block off the canister's vent path at the external bulk-head fitting at the SHED wall at the start of the pressurization, and throughout the remainder of the test.

permeation rate" for that vehicle and fuel (expressed as an hourly rate). In this example, the rate is 8.6 mg/hour.

At the 60 minute point, the tank was pressurized using the apparatus shown in Figure 4 to 5" H_2O. This pressure was actively maintained for the next 60 minutes during the "system pressure test" and the "fuel pump energized" parts of the leak tests[7]. The mass results from the constant pressure portion of the test from 75 to 90 minutes were used to validate a negative, i.e., to document that there was no vapor system leak in the test vehicle. If the time rate of emissions measured in the SHED was the same as the previously measured "permeation rate," there was no vapor leak of consequence present in the vehicle at that time.

During the time period from 90 to 120 minutes (the last 30 minutes of the test period), the vehicle's in-tank fuel pump was externally energized to create pressure in the vehicle's liquid fuel system, up to and including the fuel injectors.

Static Permeation Test Results with a Leak Present - One of the vehicles was evaluated with an implanted leak to see if the test procedures could identify and quantify the impact of a leak.

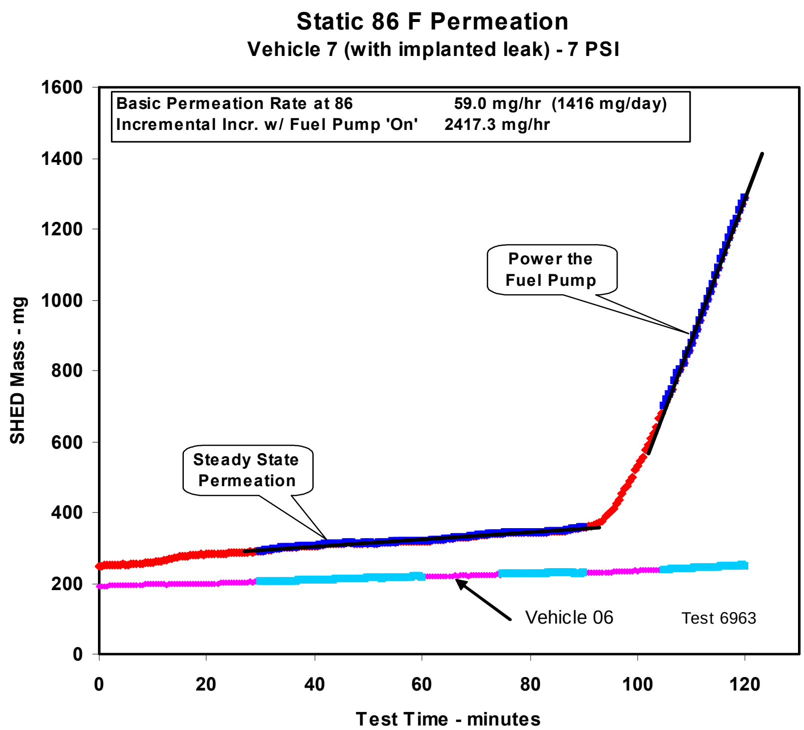


Figure 7 - Static Permeation- Implanted Leak

The vehicle chosen for this evaluation was Vehicle 6, the 1996 Chevrolet Cavalier. We replaced the vehicle's fuel cap with a similar cap with a 0.02" diameter hole in it. This is a common test cap tool used for on-board diagnostics development. The vehicle was renamed as Vehicle 7. The static test results are shown in Figure 7 above.

7 The "actively maintained" comment means that the test operator had to watch and adjust the supply during this time period to hold it at the desired level.

The static permeation rate for Vehicle 6 was 26 mg/hour. With the implanted leak, the measured value increased to 59 mg/hour. Therefore, the leak added an estimated 33 mg/hour to the vehicle emission rate, or more than double the original value.

The step where the vehicle vapor system is pressurized to 5" H_2O was not performed with the implanted leak. Forty-five minutes of SHED measurement were used to calculate the static performance rate, rather than the 15 minutes used on the other vehicle tests. The plot of the measurements indicated that the increase in SHED mass was constant for this period.

The effect of energizing the fuel pump to pressurize the fuel liquid system gave a dramatic increase in the SHED measurement during this period. The increase of 2.3 g/hour was attributed to the agitation and heating occurring in the fuel tank as energy was supplied to the pump (thought to be in the range of 60 to100 watts) and the return fuel sprayed into the fuel vapor space.

This demonstration confirmed that the pilot test procedure concept could identify vapor leaks.

Dynamic (Running Loss) and Hot Soak Test - The preceding section addressed the concepts of separating the permeation emission rate from the tank venting emission rate, and establishing the presence or absence of leaks. The second part of the pilot study included a dynamic test to measure the permeation and tank venting emission rate during vehicle operation ("running losses") and the temporary condition following vehicle operation known as the "hot soak."

The "dynamic" part of the dynamic test comes from the fact that the vehicle is driven and the system temperatures rise during the test. The ambient temperature in the Running Loss SHED 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 during the running loss measurements, consecutively, with no soak between. During this period fuel temperature was expected to rise on average approximately 18°F above the initial ambient temperature. The running loss air handling system includes a proportional speed under-car blower that is slaved to dynamometer speed. This apparatus was used during running loss testing with minor tuning for specific vehicles. It is, without additional input, capable of reasonable fuel tank temperature control. Each vehicle was fitted with a "skin" thermocouple at the front of the tank, at approximately the 1/8th fill level to represent 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.

Vehicle running loss emissions are measured in a special version of a "SHED" known as the "Running Loss SHED," (RL-SHED) (Figure 8), which includes a chassis dynamometer for simulating the vehicle driving loads. The vehicle is operated inside this sealed enclosure over some chosen driving cycle. The increase in HC emissions inside the enclosure are measured and calculated as mass emissions (40 CFR §86.163-96). The execution is complicated by several factors, including:

1. The engine must be supplied with external induction air.
2. The exhaust must be conducted externally without any leaks.
3. The load supplied to the vehicle through the chassis dynamometer must not create or allow external leaks.

4. The internal SHED temperature must be maintained while sizable heat is rejected to the ambient by the running engine and exhaust.
5. The cooling air supplied to the radiator must be modulated to represent the vehicle's road speed.
6. The underbody (and especially the fuel system) temperature should represent the rate of rise experienced by a real road-drive.

Figure 8 - Running Loss SHED

Canister vent losses were isolated from the permeation emissions using the same technique, by venting the carbon canister's fresh air vent to the outside of the RL-SHED with a leak-tight Teflon® hose, where it was connected to a small carbon "trap" canister, on a top-loading precision scale. The scale was capable of measuring changes of 0.01 grams (10 milligrams). There were no tank venting emissions measured on any of the running loss test measurements. All of the vehicles appeared to be actively "purging" the vehicle's control canister during the tests, and drawing fresh air in during the test. If there were any emissions from the vehicle's canister, as might have occurred if there were no vehicle purge, or if very high volatility fuels with excessive vapor generation were used, it 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 is shown in Figure 9.

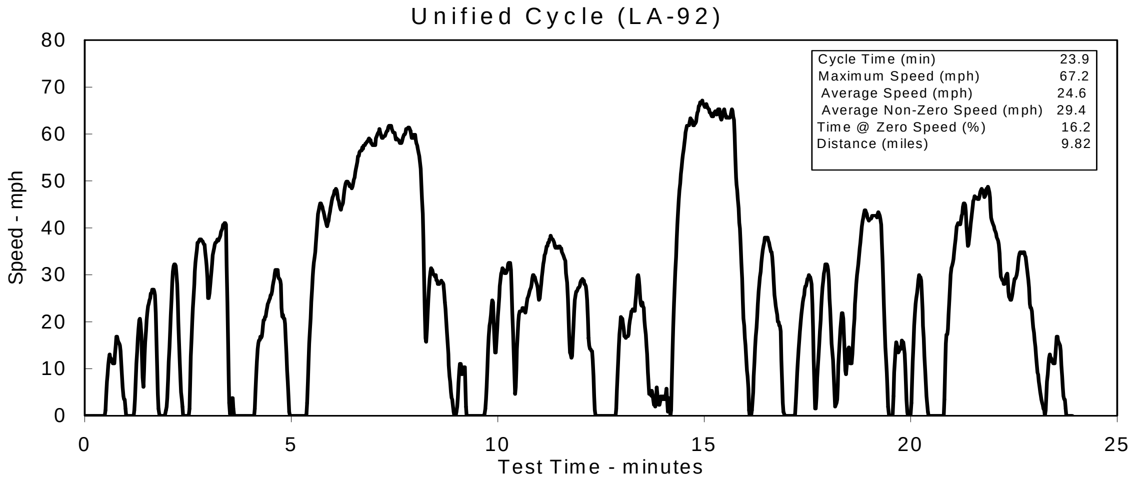


Figure 9 - RL Driving Cycle

The cycle takes 24 minutes to complete, and covers 9.8 miles, with many speed changes. Two back-to-back cycles were driven, the first a “cold start,” the second immediately following the cold start. The “cold start” condition is usually 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 the 48+ minutes of engine operation, and then continuously for one hour after the engine was turned off. This one hour is the “hot soak” period. The total test time is 1 hour and 48 minutes.

Figure 10 on the next page shows the test results from the 7 psi fuel test on Vehicle 4. 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 SHED mass emissions for the first 48 minutes of the test are shown with the green line in the plot. The regression analysis capability in Excel® was used to calculate a second order curve to the 96 data points in the 30-second measurements during the 48 minute drive. That relationship is shown with the black smooth trace through the green line.

The engine was shut off at the end of the drive, and the analysis system continued to measure the HC emissions in the SHED. This represents the “hot soak” portion of the test.

A comparison plot of the ten vehicle tests are shown in Figure 11 on the next page.

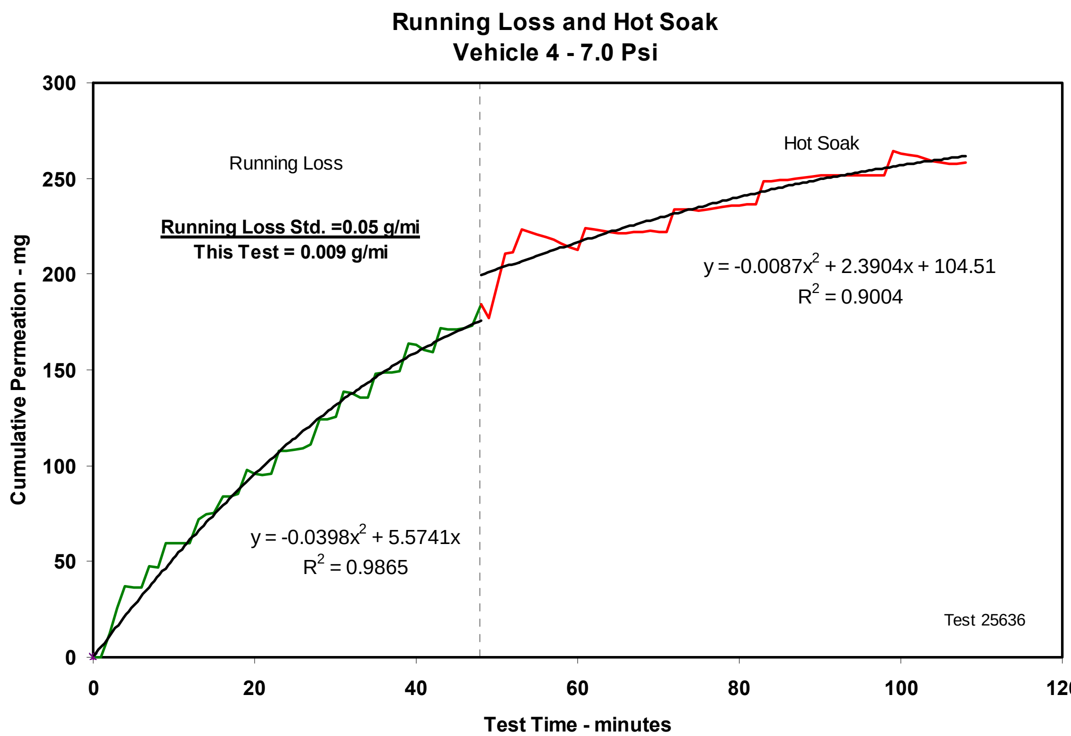


Figure 10 – Dynamic Test Results

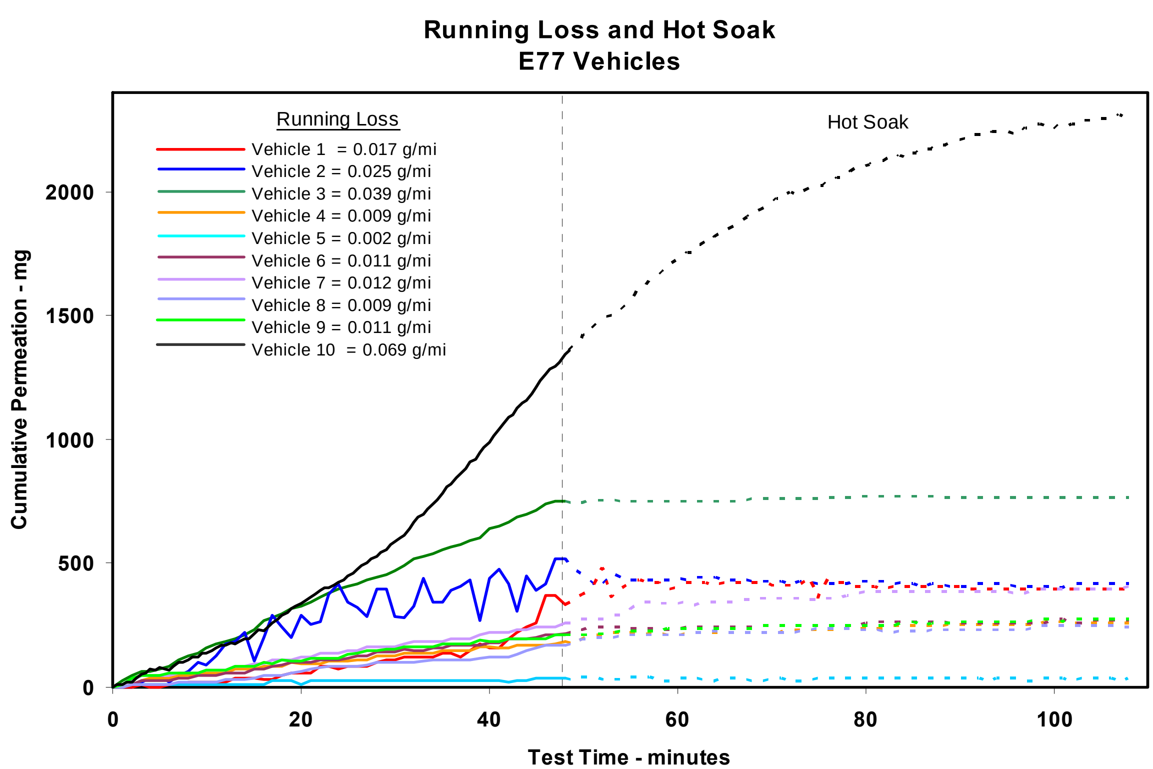


Figure 11 – Dynamic Test Results – All Ten Vehicles

Diurnal Testing - The third major element of the pilot program was diurnal testing using the external vent for the vehicle's carbon canister to separate the tank venting emissions from the permeation.

Table 2 - CRC E-77 Permeation Pilot Study Tests

			Diurnal Tests			
	Static Perm & Leak Tests	Running Loss & Hot Soak	7 psi 65-105°F	7 psi 85-120°F	9 psi 65-105°F	9 psi 85-120°F
Pre Enhanced						
Veh 3 Honda Accord	6902	25635	3 day 6915	3 day 6925		
Veh 9 Plymouth Neon	6969/6975	25646	6973	6974		
Veh 10 Toyota Camry	6977	25648		6983		
Enhanced						
Veh 1 S-10 PU	6875	25632	6857	6865	6888	6893
Veh 2 Tacoma PU	6890	25634	6883. 6904	6896	6899	6929
Veh 4 Dodge Caravan	6912	25636	3 day 6919	3 day 6922	3 day 6926	3 day 6927
Veh 6 Chevy Cavalier	6939	25640	6953	6955	6959	6961
Veh 7 Cavalier w/leak	6963	25642	6964	6966		
Veh 8 Ford Explorer	6949	25641	6954	6956	6957	6962
LEV II						
Veh 5 Taurus Sedan	6923	25638	3 day 6928/6931	3 day 6933		

Table 2 shows a summary of the tests performed. The vehicles, classified by the emissions standards to which they are certified, are shown on the left side of the table. The numbers in the various boxes identify the laboratory's test ID numbers for the individual tests. In some cases, two numbers indicate that repeat tests were conducted. The purpose of this table is to indicate the mixture of one and three-day diurnals that were performed, and to indicate the vehicles tested on the 9 psi (higher volatility) fuel.

Immediately following completion of the hot soak test, the vehicle was moved to a VT-SHED for diurnal testing. The diurnal SHED was used to soak the vehicle at 65°F overnight. The vehicle soaked a minimum of 16 hours before the diurnal test was initiated. Again using Project E-65 procedures, the vapor space at the fuel cap and the canister outlet were plumbed to the outside of the SHED enclosure. A third well-purged collector canister was used to continuously monitor canister outlet emissions.

The California 65°F–105°F–65°F diurnal temperature profile was used for the baseline test on all vehicles, normally terminating after one 24-hour cycle. One of each vehicle group continued for a total of three 24-hour cycles. Continuous measurements of HC levels, ambient conditions, tank weights, and tank temperature were recorded throughout.

At the end of the baseline diurnal, the SHED was purged and the internal ambient temperature was raised to 85°F. The vehicle remained in the enclosure for a minimum of 16 hours. The enclosure was purged again, the temperature was allowed to stabilize, and a second diurnal was performed. The second diurnal followed an extreme 85°–120°F cycle. This new cycle rose in proportion to the California 65°–105°F cycle in the first 9 hours, and then dropped back to 85°F over the remaining 16 hours. This is a 35°F temperature change as opposed to the 40°F temperature change in the 65°-105° cycle.

The three vehicles selected for 72-hour tests in the baseline test also received a 72-hour extreme diurnal test. All five vehicles certified to enhanced evaporative standards were also tested with 9.0 psi RVP fuel.

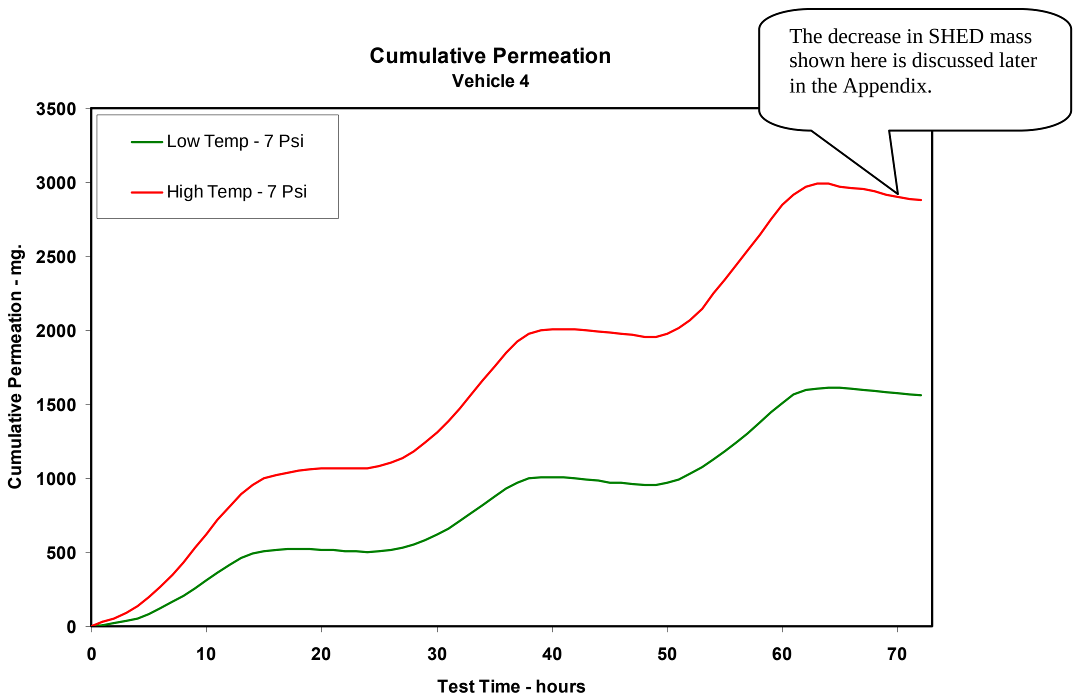


Figure 12 – 3 Day Diurnal Permeation

Figure 12 shows an example of the diurnal results obtained during the pilot study for Vehicle 4. The horizontal axis is the time in hours (72 hours for the 3-day test), and the vertical scale is the HC mass in the SHED for the test period. The high temperature diurnal (85°-120°-85°F) gave about twice the diurnal permeation rate on Vehicle 4, the 1999 Dodge Caravan. The continuous measurement of the tank venting emissions on the trap canister outside the SHED reported zero change for the test period.

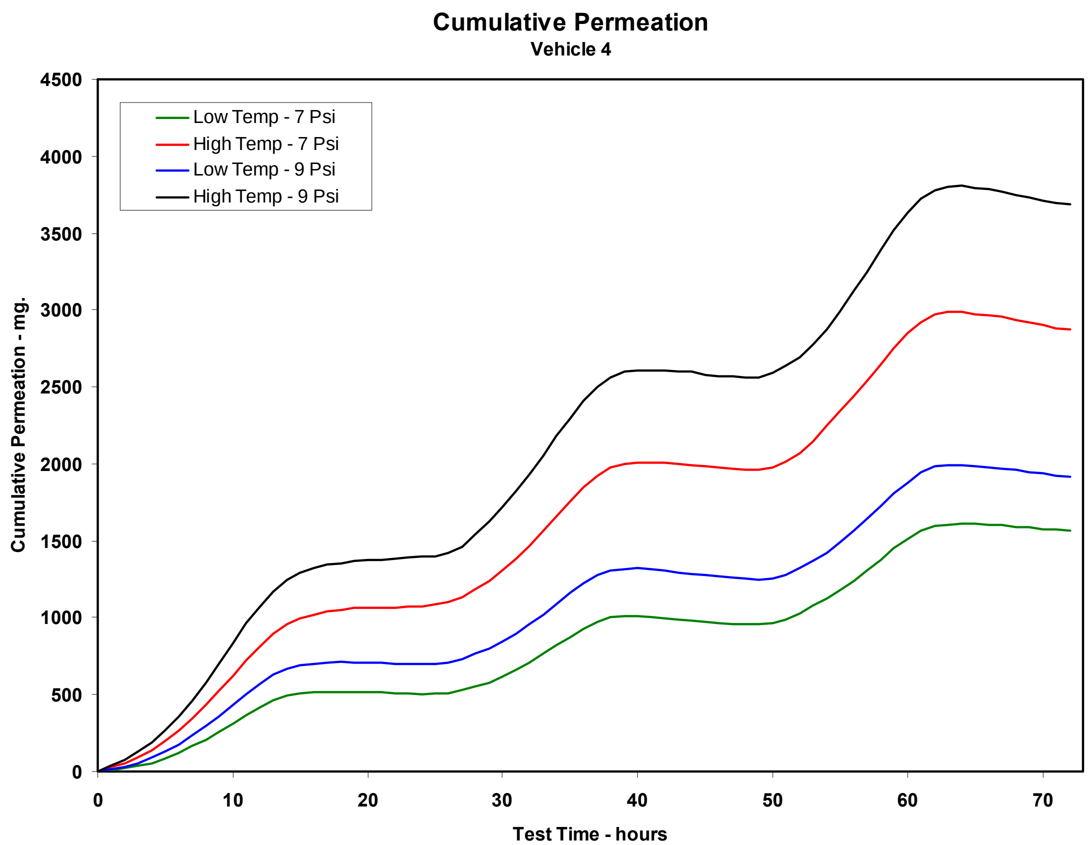


Figure 13 – Temperature and RVP Effects

Another example of the permeation data, again from Vehicle 4, is offered in Figure 13. This chart shows both the diurnal temperature and the RVP effect. The lower pair of traces (green and blue) offers a comparison of the RVP effect at the lower diurnal temperature test conditions. The upper pair (red and black) compares the volatility effect at the higher test temperature. At both temperatures, the tests with the higher volatility fuel indicated higher permeation levels.

Comparison plots for the diurnal results for the pilot study are summarized in Figures 14-17, arranged by emission control system technology.

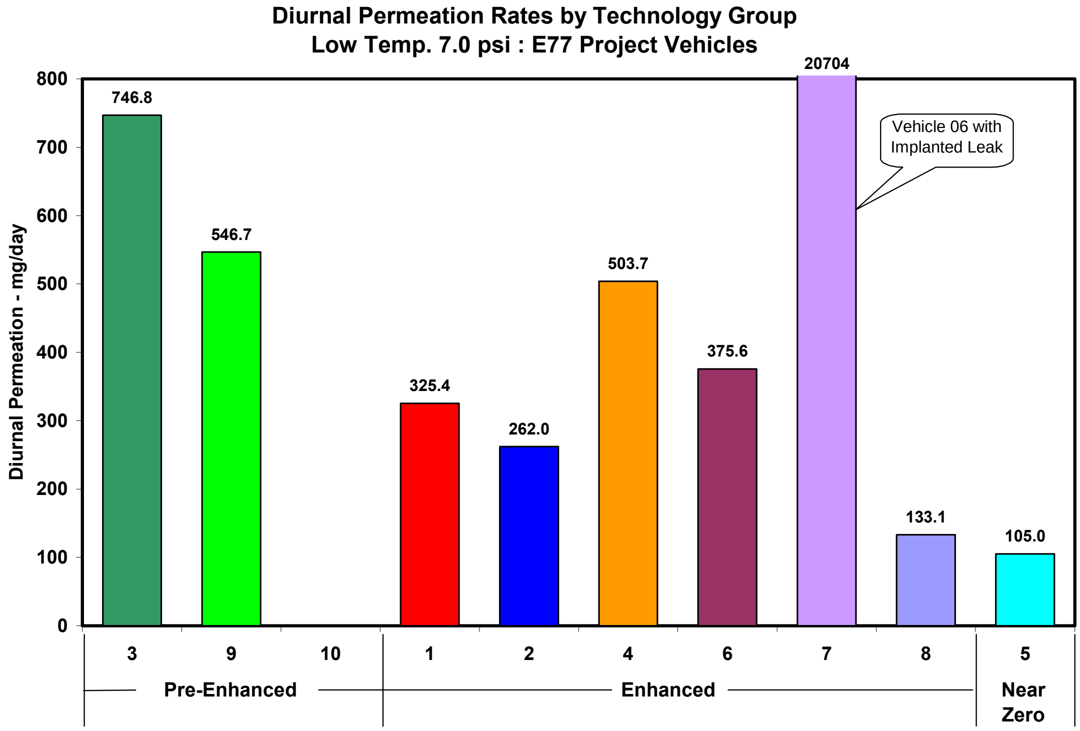


Figure 14 – Low Temperature Diurnal 7 psi Fuel

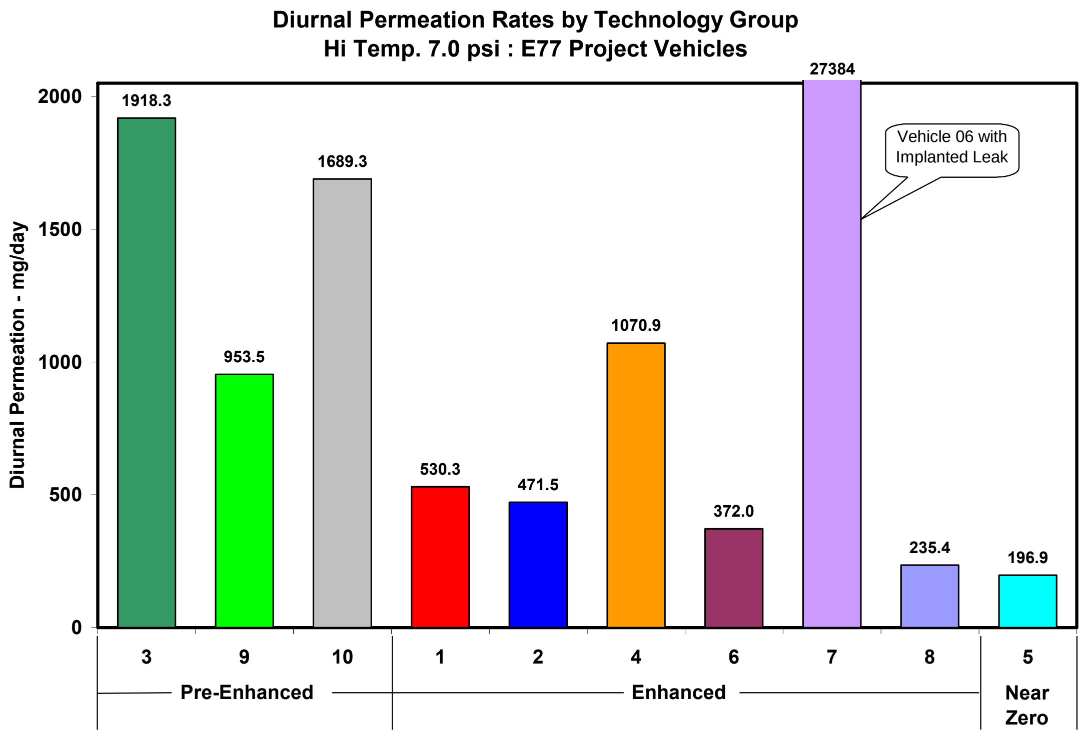


Figure 15 – High Temperature Diurnal 7 psi Fuel

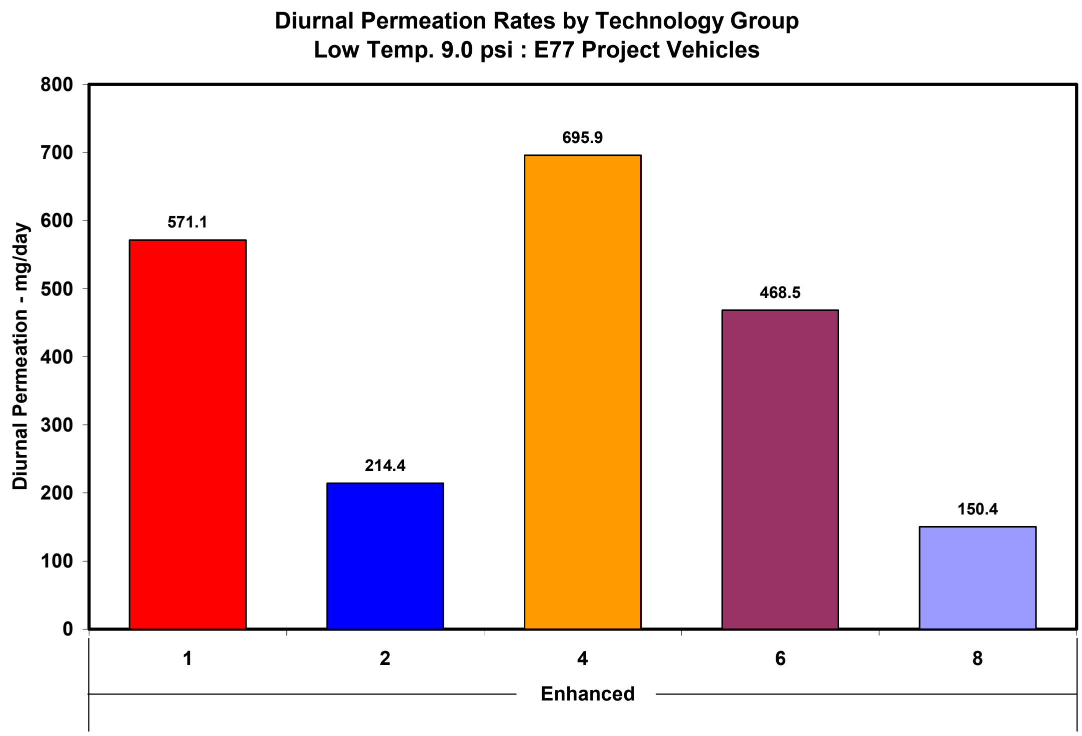


Figure 16 – Low Temperature Diurnal 9 psi Fuel

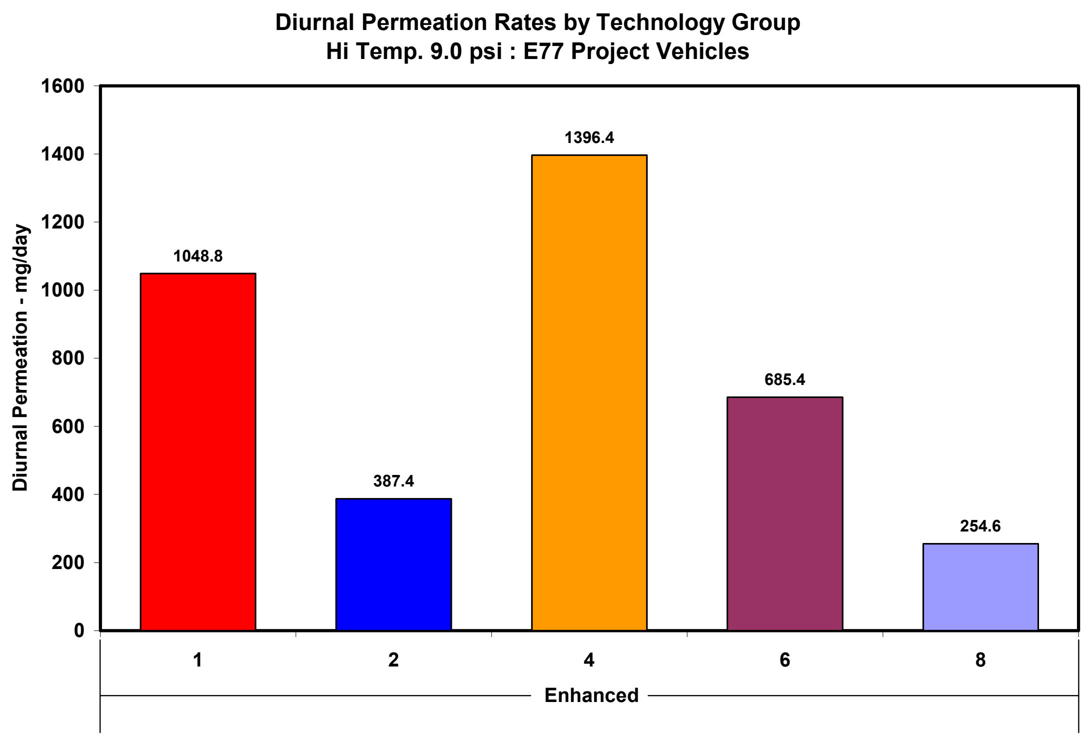


Figure 17 – High Temperature Diurnal 9 psi Fuel

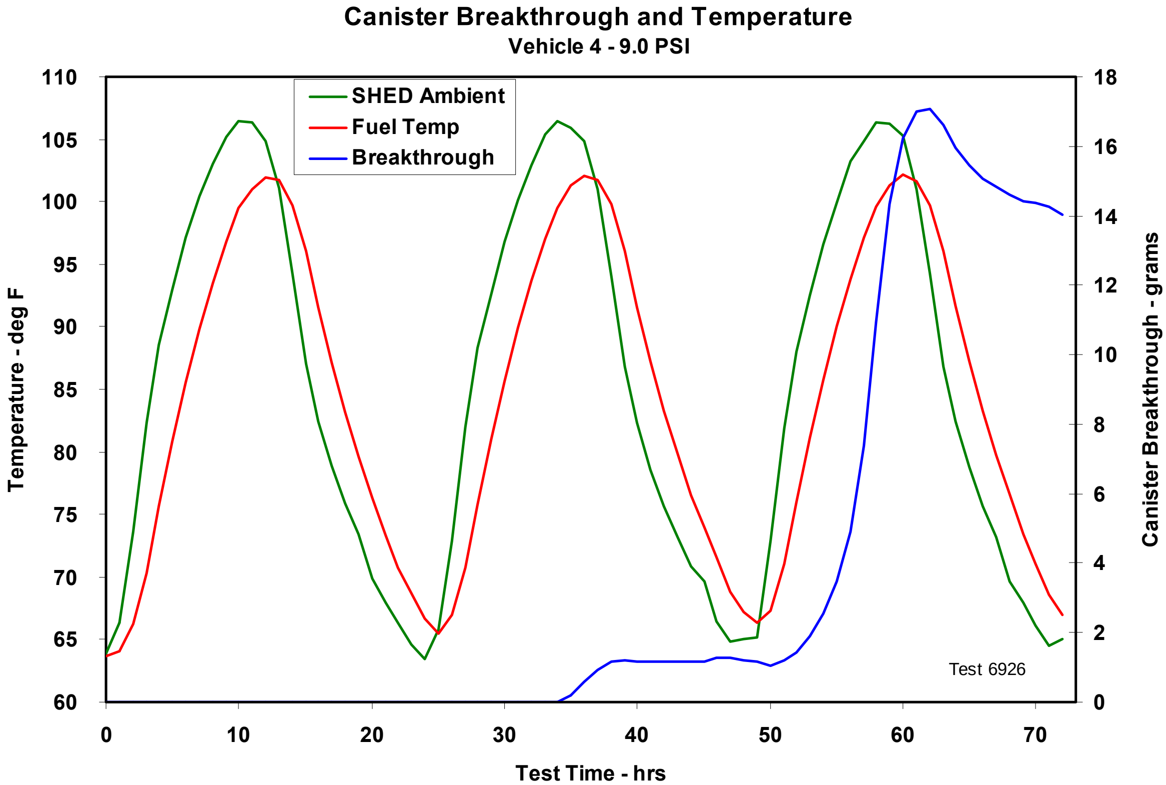


Figure 18 – Canister Breakthrough

An example of the canister breakthrough performance on Vehicle 4 is shown in Figure 18. These data are from the 3-day test at the lower diurnal temperatures with the 9 psi RVP fuel. The horizontal axis of the plot is the test time in hours for the 3 days. The left vertical axis shows the temperatures scale in degrees F. The green trace represents the VT-SHED ambient temperature as it is varied from 65° to 105°F, and the red trace is the fuel temperature as measured with the fuel tank skin thermocouple during the test. The blue trace is the change in the weight of the trap canister (shown on the right vertical scale in grams) used to capture the vehicle's canister vent loss.

No canister breakthrough was measured on the first day. On the second day at about the peak ambient temperature, the scale indicated about a gram of breakthrough. On the third day, more canister breakthrough was indicated, as the trap canister weight rose to a maximum of 17 grams.

The decrease in the trap canister weight that occurred during the last few hours of the test was the result of the "back-purging" of the system as the fuel tank temperature decreased. During this cooling period, the equilibrium partial pressure of the HC in the tank vapor space decreased, and air was drawn back into the tank to maintain the system pressure. This flow of air back into the vehicle's fuel system purged the trap canister.

Table 3
Diurnal Vapor Generation (grams) for a 19 gallon tank at 40% fill

Cert Target

	Fuel Tank Temperature Change	
	65°-103°F	85°-118°F
7 psi Fuel	29.5	55.7
9 psi Fuel	56.2	125.0

The GM Reddy model was used to estimate the vapor generation for a 19 gallon tank for the four diurnal test combinations that were included in the pilot study. These results are shown in Table 3. These calculations indicate that the vapor generation roughly doubles for both the increase in test temperature and the increase from 7 to 9 psi in fuel volatility. The high temperature and the higher volatility fuels create a fourfold increase in vapor generation.

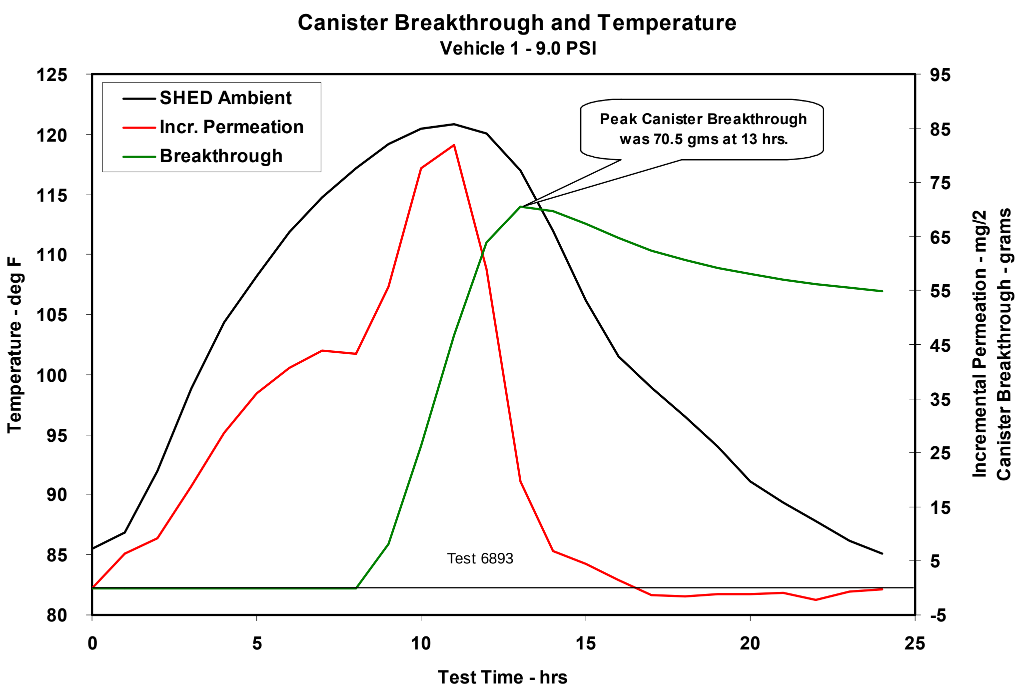


Figure 19 - Canister Breakthrough

Another example of the canister breakthrough measurement is shown in Figure 19, from a test on Vehicle 1. The combination of high RVP and high temperature produced the first evidence of canister breakthrough, as shown with the green trace in the plot above. More interestingly, this plot shows that the permeation rate (red trace) increased significantly as the vehicle's canister started to break-through into the external trap canister. This pointed out that the connection for the canister loss plumbing has to be made at the canister, rather than at the external vent solenoid. This is explained further in the following section.

The Original Hose Configurations on the Test Vehicles

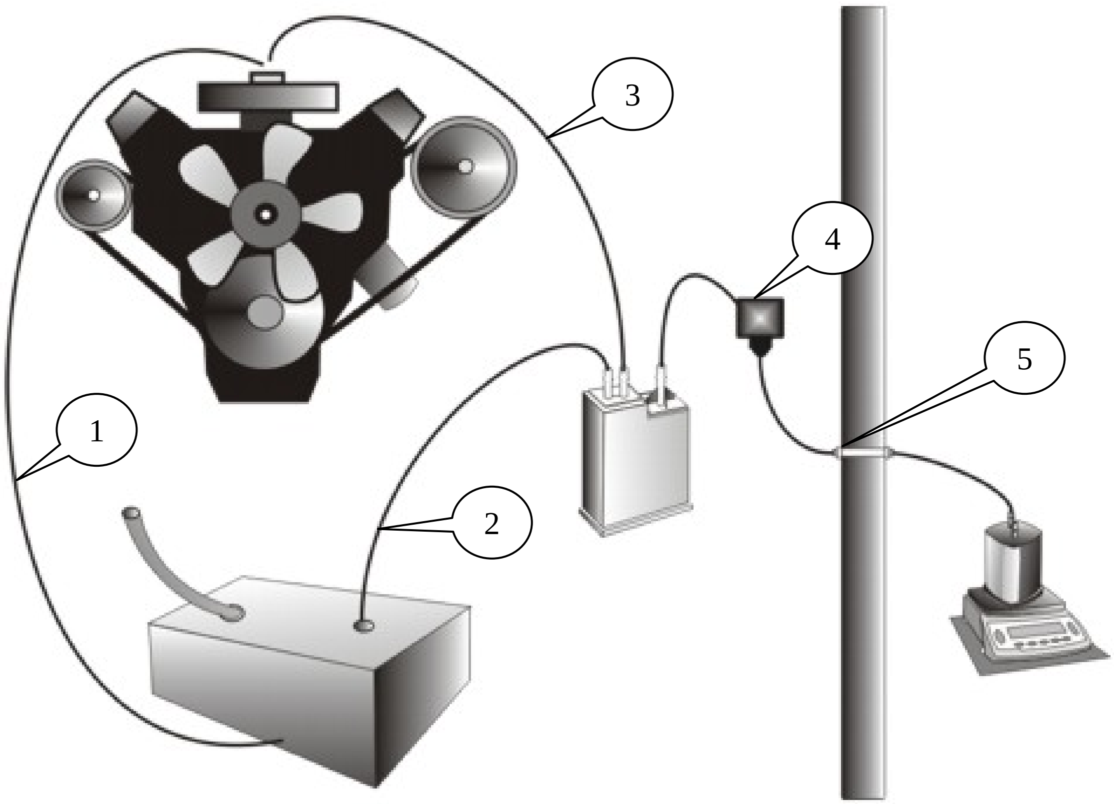


Figure 20– Hose Configurations

1. The fuel feed hose from the tank to the engine - contains liquid fuel
2. The vapor hose from the tank to the canister - contains fuel vapor – during diurnal heating conditions, it carries head space vapor from the tank to the canister - during diurnal cooling conditions, it has purge vapors from the carbon bed at something less than the head space vapor concentration.
3. The purge hose from the canister to the engine – during engine operation and at the start of the purge, it may have high concentration HC vapors, but for a majority of the purge, it contains mainly air, with low level HC concentration.
4. The vent hose from the carbon canister to the vent solenoid/fresh air inlet filter for the canister. On rare occasions when the canister is overloaded and breaking through, it contains high level HC vapors. Otherwise, it contains only air. This hose is not required to be a low permeation material, and may be simply NBR.
5. The laboratory's affixed connection hose to route the canister breakthrough vapors to the SHED external trap canister for collection and quantification.

The hose that was to be circumvented is the vent hose identified as #4 in Figure 20. Another illustration is shown in Figure 21.

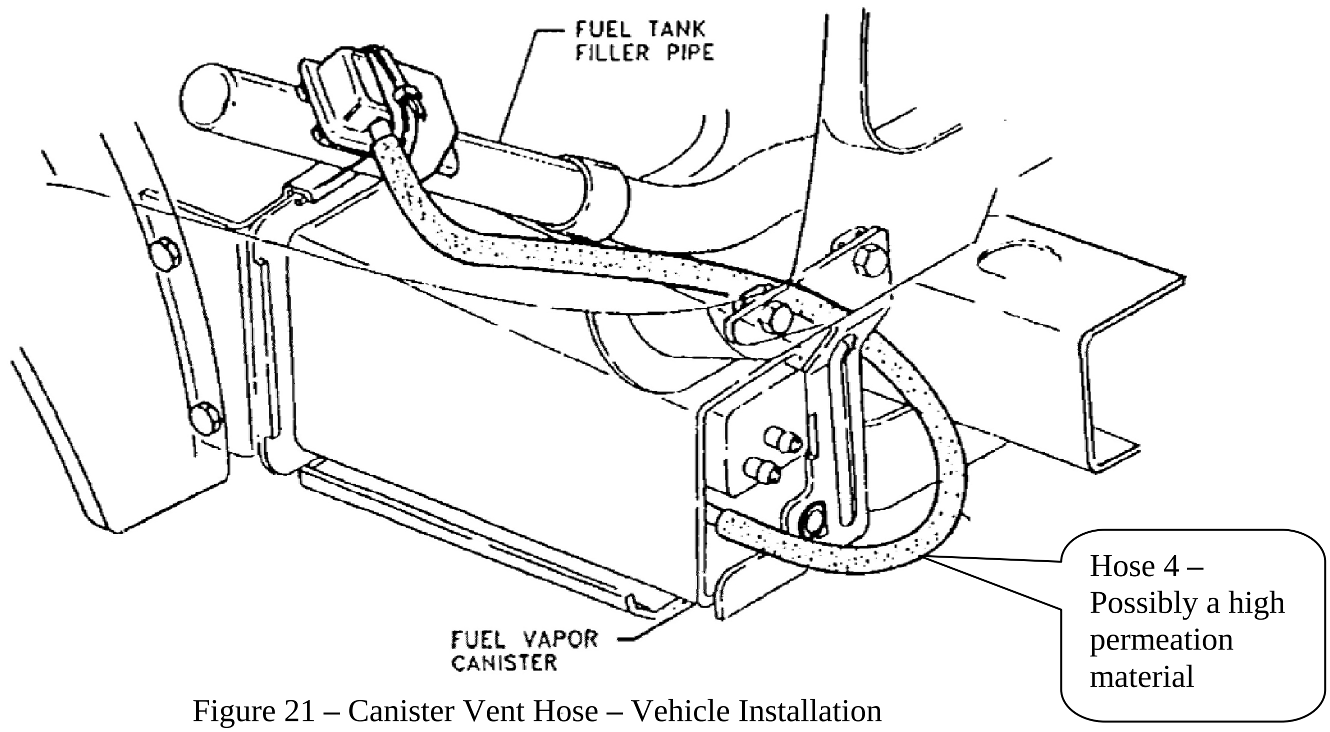


Figure 21 – Canister Vent Hose – Vehicle Installation

Procedures were revised to make the test connection directly at the canister, rather than at the original site, the remote vent. The Teflon® hose material used to route the canister vent loss to the outside of the SHED (identified as # 5 in a previous figure) was verified to be low permeation material. A discussion of this investigation is offered in the Appendix.

THE ISSUE OF NON-FUEL EMISSIONS

One major goal of this pilot study was to quantify the fuel emissions from vehicles under the chosen test conditions. Non-fuel (background) emissions[8] are known to be present in the ambient samples measured. These background emissions were to be minimized or identified in this study. Vehicle selection eliminated candidates with recent paint repairs or newly replaced tires, or any vehicles with identifiable HC odors or spills detectable with a sniffer in the trunk or interior. The remaining paint and vinyl contributions are confounded into the vehicle level measurements.

Other non-fuel emissions can originate from washer solvent (methanol) and refrigerant (R-12, R-134a). The laboratory purchased and experimented with an INNOVA[9] analyzer to identify methanol and refrigerants present in the measurements on a routine basis towards the end of the pilot program.

[8] See SAE 912373, "Real-Time Non-Fuel Background Emissions," H. Haskew, et al.
[9] Model 1412 Photoacoustic Multigas Analyzer from California Analytical Instruments, Inc.

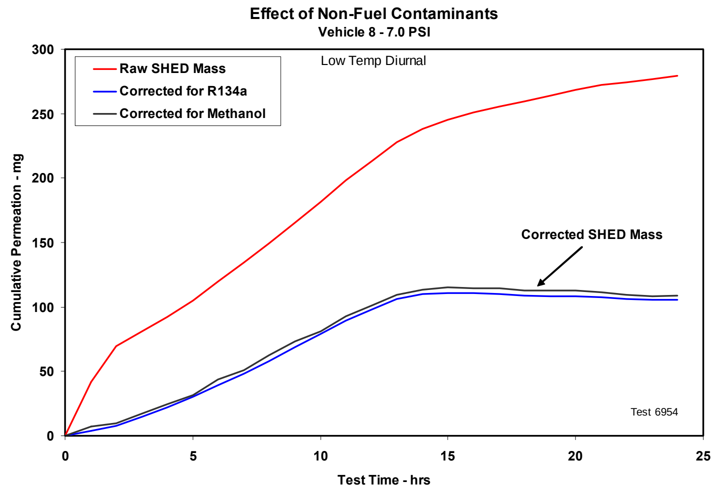


Figure 22 – Non-Fuel Emissions

The discussion that follows concerns the issues with Vehicle 8, and how they were resolved once the anomaly was identified as a large refrigerant leak. The diurnal permeation plot for Vehicle 8 (Figure 22) showed an atypical increase in the permeation during the last four hours of the test. The INNOVA allowed continual measurement of methanol and refrigerant (R134a) in the SHED during the diurnal test. Subtracting those contaminants from the HC (FID) reading provided insight into the source of the unusual data.

The Explorer (Vehicle 8) had a refrigerant leak that was identified by the FID as a hydrocarbon, and thought to be gasoline. When the FID reading was corrected, the diurnal mass was reduced from 280 mg/ day to 109, a 61% reduction. The methanol correction was insignificant. The R134a measurement, shown in the red trace in Figure 23, is calculated as if it were a fuel molecule, using the customary density of fuel vapors (16.83 grams per cubic foot per ppm carbon). The actual mass of refrigerant is much higher, due to the additional non-carbon and hydrogen atoms contained in the molecule.
The methanol measured was very low in this test, and the ethanol identified by the INNOVA was ~ 20 mg, a trace hang-over measurement. The ethanol is included in the corrected SHED mass, since it is fuel.

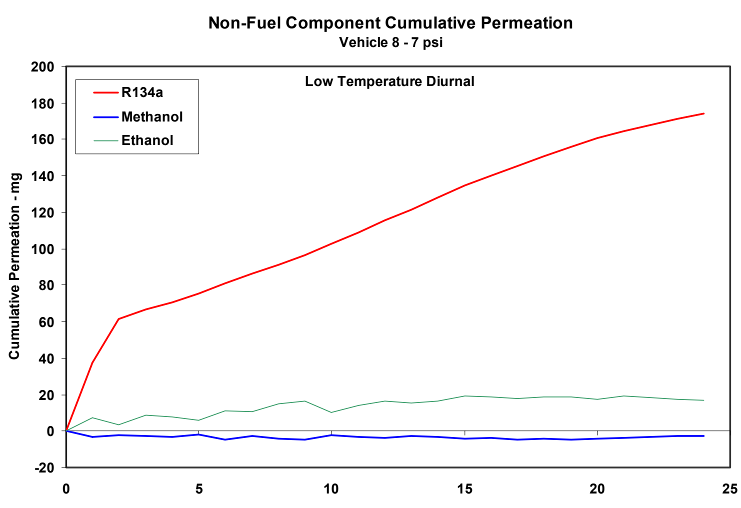
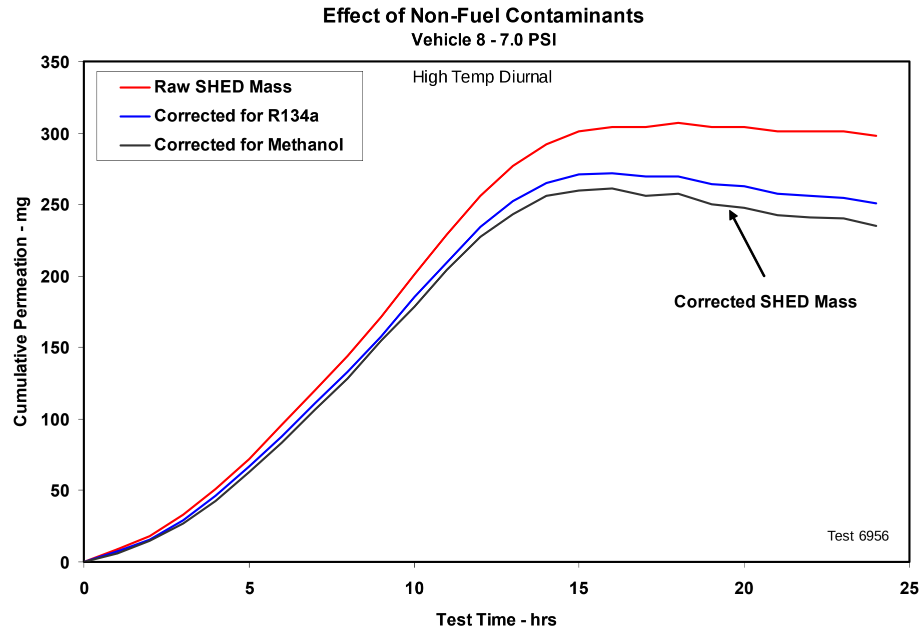


Figure 23 – Non-Fuel Component Permeation

Figure 24 shows the effect of the non-fuel components on the total high temperature diurnal permeation on Vehicle 8.



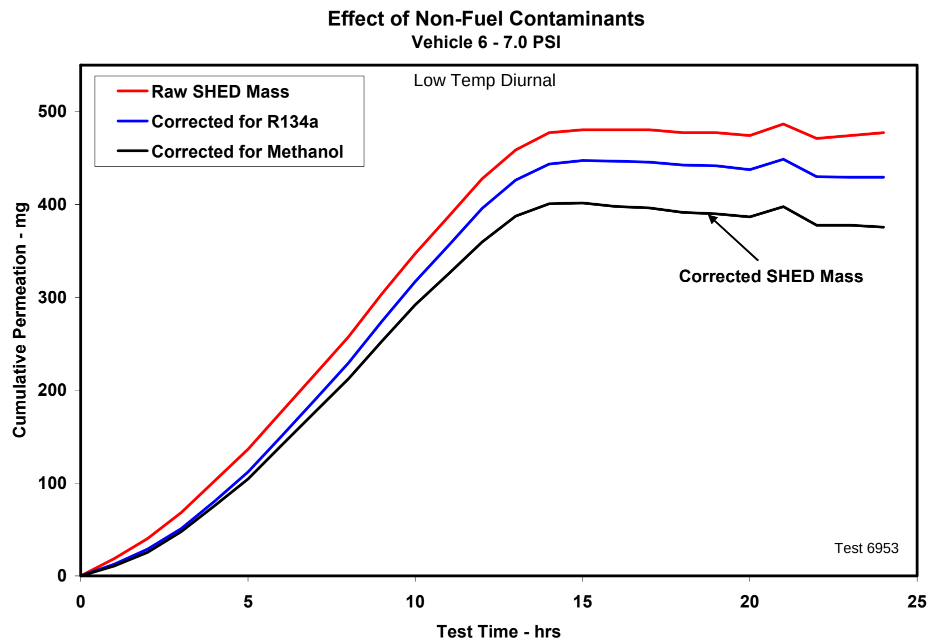


Figure 25 – Non-Fuel Effects - Low Temperature Diurnal

The low temperature 7 psi diurnal test on the Cavalier Vehicle 6 had both refrigerant and methanol present at significant levels. Figure 25 shows the test results with the red trace indicating the "normal" FID measurement, and the two corrections performed in a step-wise method, first subtracting the R134a misidentified as gasoline (blue trace), and then subtracting the methanol to obtain the final corrected diurnal result as shown in the black trace. The diurnal measurement is corrected from 477 to 376 mg day, a 21% reduction.

The R134a and methanol measurements for this test (6953) are shown in Figure 26 on the following page.

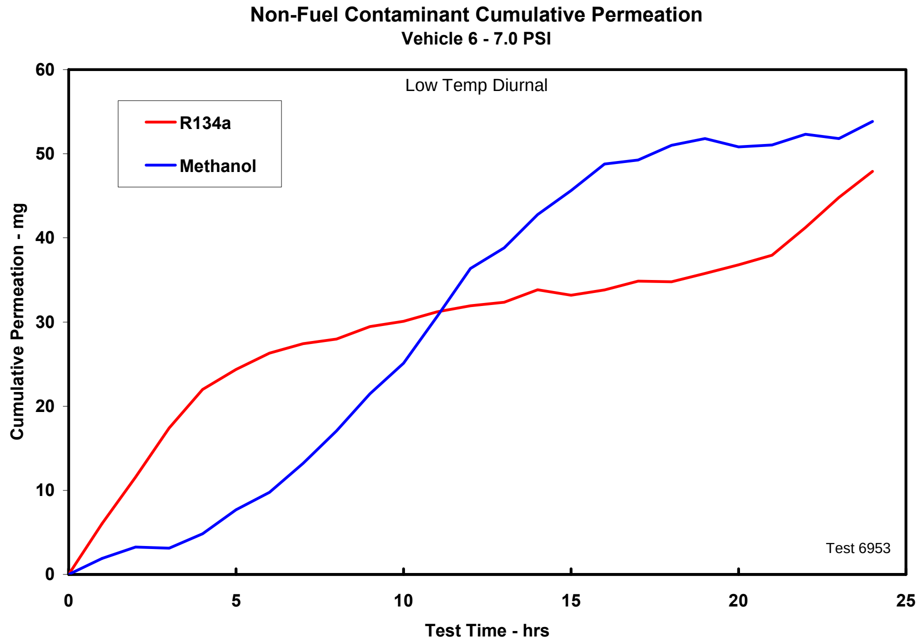


Figure 26 - Non-Fuel Component Permeation

AN OVERVIEW OF WHAT WAS LEARNED

The Pilot Study accomplished the objectives of the project and added to the bank of knowledge that helps in understanding the mechanisms and magnitude of vehicle evaporative emissions. These are summarized as:

- **Tank Venting (Canister Losses) can be separated from the permeation.** See the plot at Figure 18, “Canister Breakthrough” that illustrates the tank venting, or canister breakthrough, occurring during heating periods on the third day, and then decreasing during the “back-purge” period.

- **Permeation rates increase with temperature.** See the many plots of permeation rate versus time (“Diurnal Time Response”) in Appendix II organized by vehicle number.

- **Permeation emissions are higher when measured with 9 psi RVP E0 gasoline than with 7 psi E0 gasoline.** See figure 13 at page 18. Permeation is not thought to be a function of system pressure, but we found it to increase with higher vapor pressure fuel. The explanation is that the higher vapor pressure creates higher vapor concentrations in the fuel vapor components (head space, fuel cap seal, vapor handling lines).

- **Canister venting connection must be made at the canister.** Review the text starting at page 22, and Figures 19, 20 and 21.

- **High volatility and temperature can create excessive fuel vapors that exceed canister capacity.** See examples of the high temperature tests on 9 psi fuel in Figures 18 and 19.

- **Refrigerant and methanol (non-fuel components) can be a significant fraction of the SHED measurement.** See “The Issue of Non-Fuel Emissions” starting at page 25 of this report.

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Brent Bailey	CRC
Jane Beck	CRC
Chris Tennant	CRC
David Brzezinski	EPA
Connie Hart	EPA
Dominic DiCicco	Ford
Cynthia Williams	Ford
Steve Cadle	GM
Jeff Jetter	Honda
Mani Natarajan	Marathon
David N. Patterson	Mitsubishi
King D. Eng	Shell
Hannah Murray	Toyota

Appendix I

Additional Information

The following discussion is intended to show that the permeation of the test vent hoses used by ATL are, for these purposes, zero. The basic contamination level inherent in a SHED is discussed first, followed by a presentation of test data intended to measure the permeation of the test vent hose. The trap canister HC collection is also compared to the value predicted by the Reddy model.

Discussion: Any variable temperature SHED has an inherent contamination level which can be as high as 50 mg per day under the regulations for an enhanced evap certification test. The contamination is thought to be leftover HC from previous experiences that have condensed on the SHED internal surfaces during the cooling period. One can measure the contamination level by performing a diurnal test with nothing in the SHED, i.e., a "blank SHED."

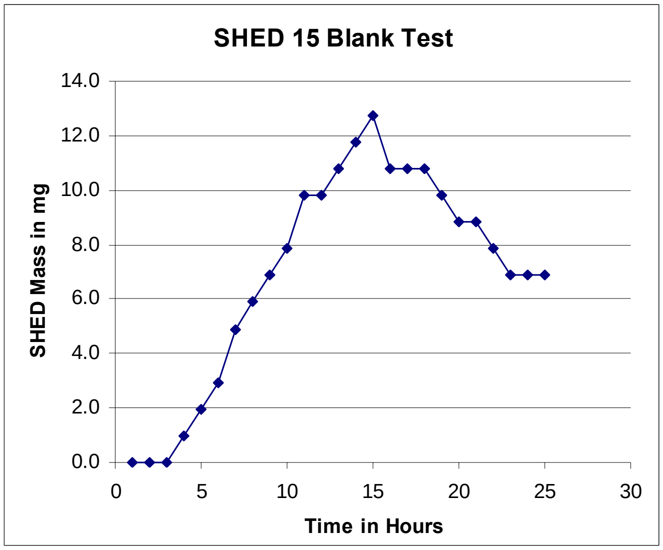


Figure 27 – Blank SHED Test

Figure 27 shows a recent (9/15/06) "blank SHED" test result in ATL's SHED 15, one of the two that are used for the CRC Projects E-77 and E-65 evaluations. An almost identical value was measured in SHED 14 during the same period. The HC mass in a blank SHED increases as the SHED is heated, and then decreases slightly during cooling. The mass in the SHED was estimated to be as high as ~13 mg at the peak value, decreasing to ~7 mg at the test end. The contamination level can be minimized by repeated heating and purging of the SHED, washing the internal surfaces with a non-HC soap, and avoiding tests of vehicles or objects with high emission levels. A 5 to 10 mg level is a realistic goal for day-to-day performance.

Vent Hose Evaluation - The laboratory located a 3 gallon steel tank, previously used to hold calibration gases. The single inlet fitting was replaced with a stainless fitting that mated to the 3/8" ID Teflon® vent hose that was used in the SHED to vent the fuel system to the outside of the enclosure. The vent hose is approximately 6' long and terminates at either end with a Swagelok compression fitting. The test set-up is shown in Figure 28. The intent is for the only item that can permeate in the SHED to be the vent hose. The 3 gallon container was filled with 1.5 gallons (50%) of the E77 7 psi test fuel. The trap canister outside the SHED was used to collect any HC vapors that were emitted from the tank. Several diurnal tests were performed in SHEDs 14 and 15 with this test configuration.

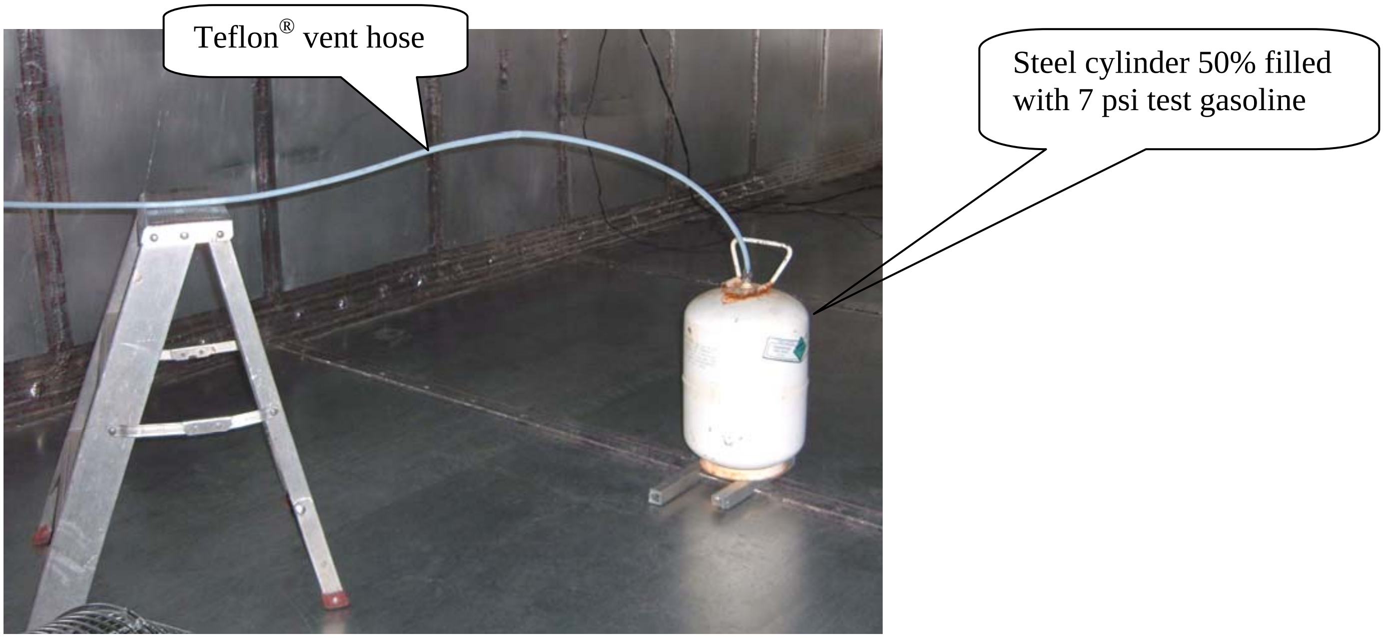


Figure 28 – Blank SHED Test Set-up

The test results for the vent hose in SHED 14 were lower than the blank SHED results (Figure 29), i.e., no permeation from the hose. Similar results were obtained in SHED 15, as shown in Figure 30.

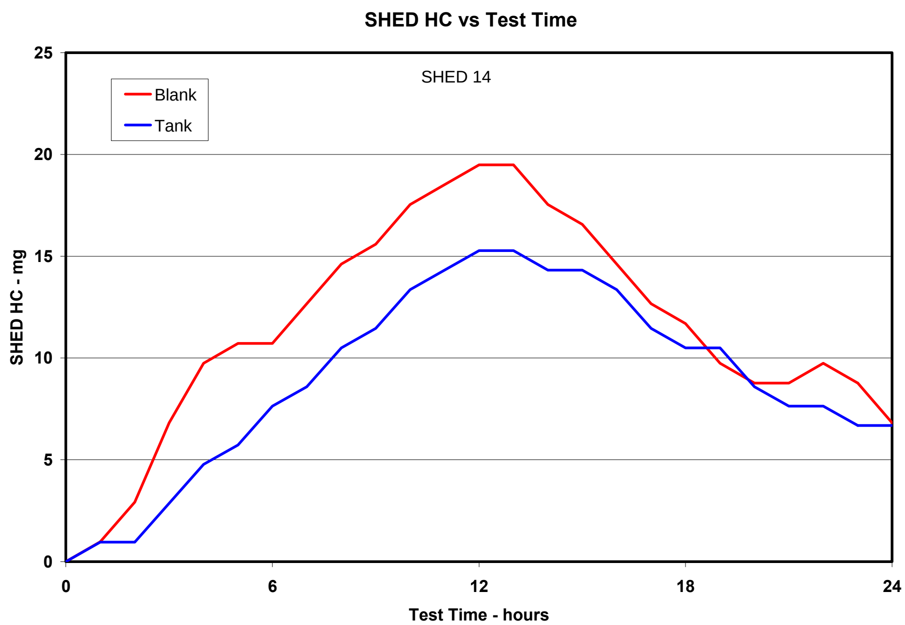


Figure 29 – Blank SHED Test Results – SHED 14

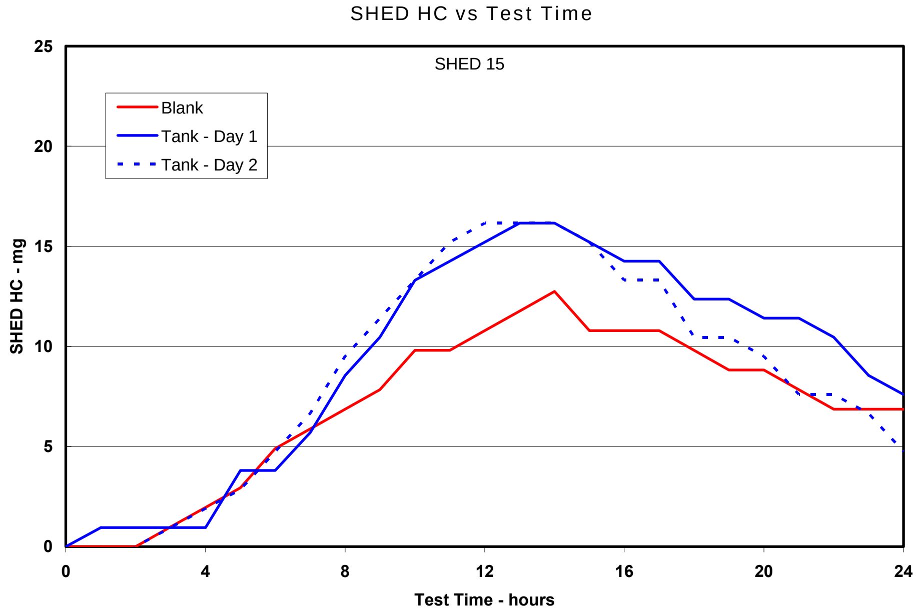


Figure 30 – Blank SHED Test Results – SHED 15

The two day test results in SHED 15 are shown in the blue traces in Figure 30, as if they were both run as single day results. The blank SHED results are shown in the red trace. Again, the conclusion is the same: there is no significant permeation from the Teflon® vent hose used in the test program for E-65 and E-77.

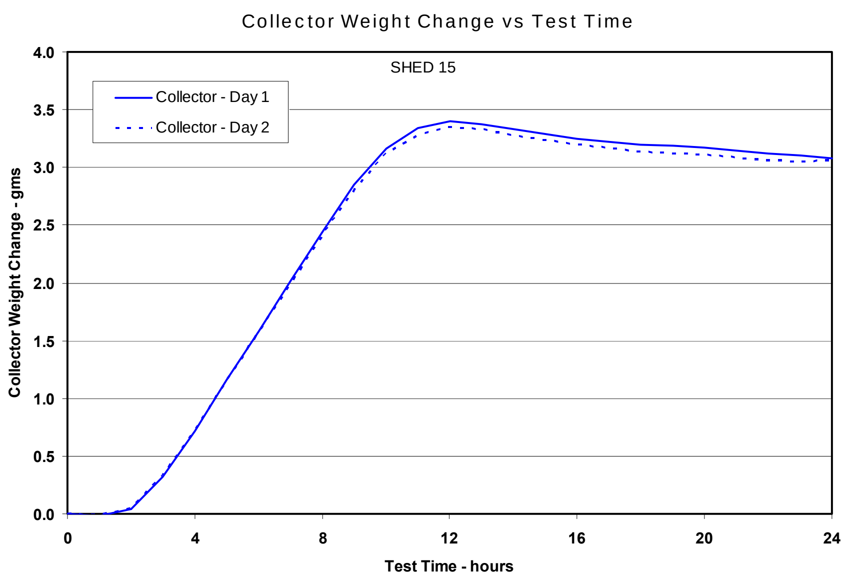


Figure 31 – Trap Canister Emissions – Blank SHED Test

The trap canister collected the venting emissions from the steel cylinder. The results were repeated very closely from day-to-day, as shown in Figure 31. The measured emissions were ~3.4 grams during the heating cycle from the 1.5 gallon of vapor space. The back purge of the trap canister as the fuel tank cools is apparent. The Reddy model predicts 3.205 grams for a 67 to 103°F temperature heating excursion, which compares favorably with the measured values.

Comment:

The Teflon® vent hose does not materially contribute to the evaluation, and it appears that the trap canister works.

Mass "Loss" during the Diurnal Cooling Period

Plots of diurnal mass results sometimes indicate an apparent mass "loss" during the cooling period. Figure 12 is repeated below to illustrate this result, most apparent in the third day's test results with the high temperature test conditions (red trace). The vertical scale is the calculated mass in the SHED. That the mass is shown to decrease suggests a "leak" or other problem in the test results.

This condition has been observed in many test programs, and usually is more evident when the HC concentration in the SHED is high. We believe that this is a result of partial adsorption, or condensation, of the HC vapors on the cool surfaces in the heat exchanger as it tries to drive the SHED ambient temperature down during the cooling cycle.

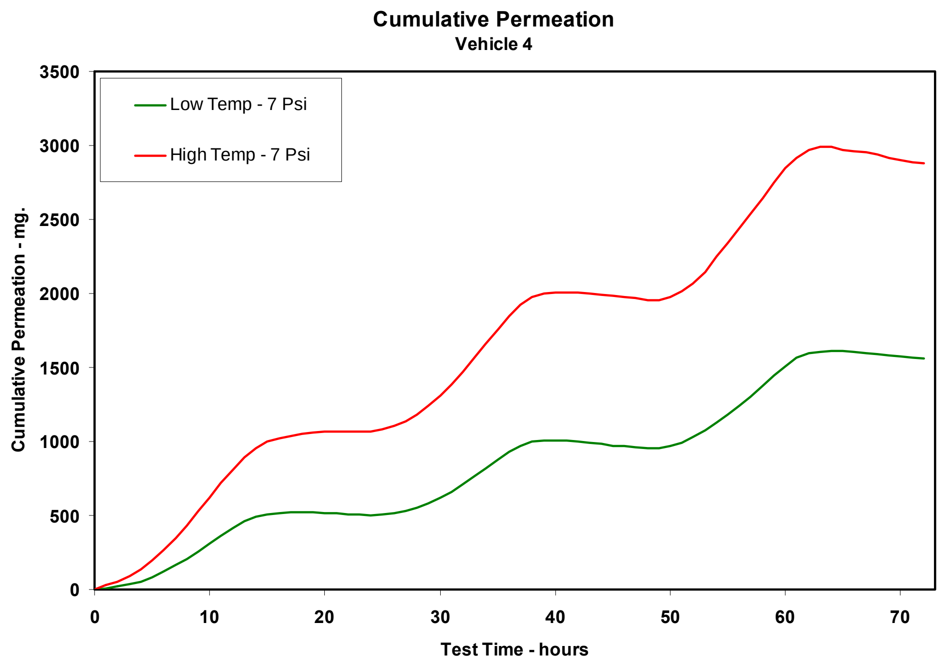


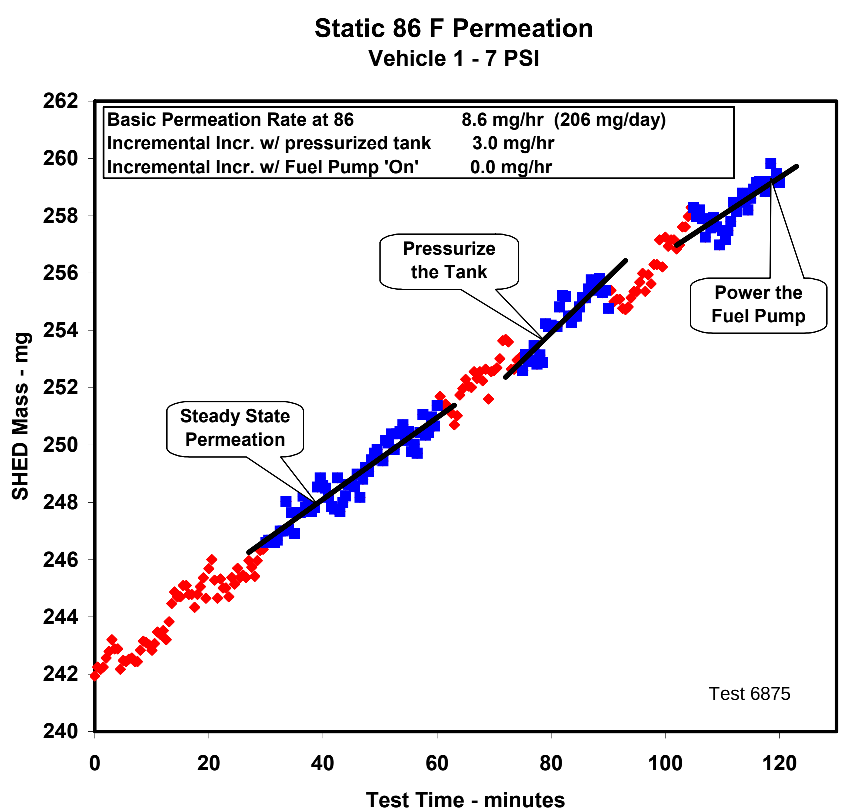
Figure 32 - Repeat of Figure 12-Three Day Diurnal Permeation

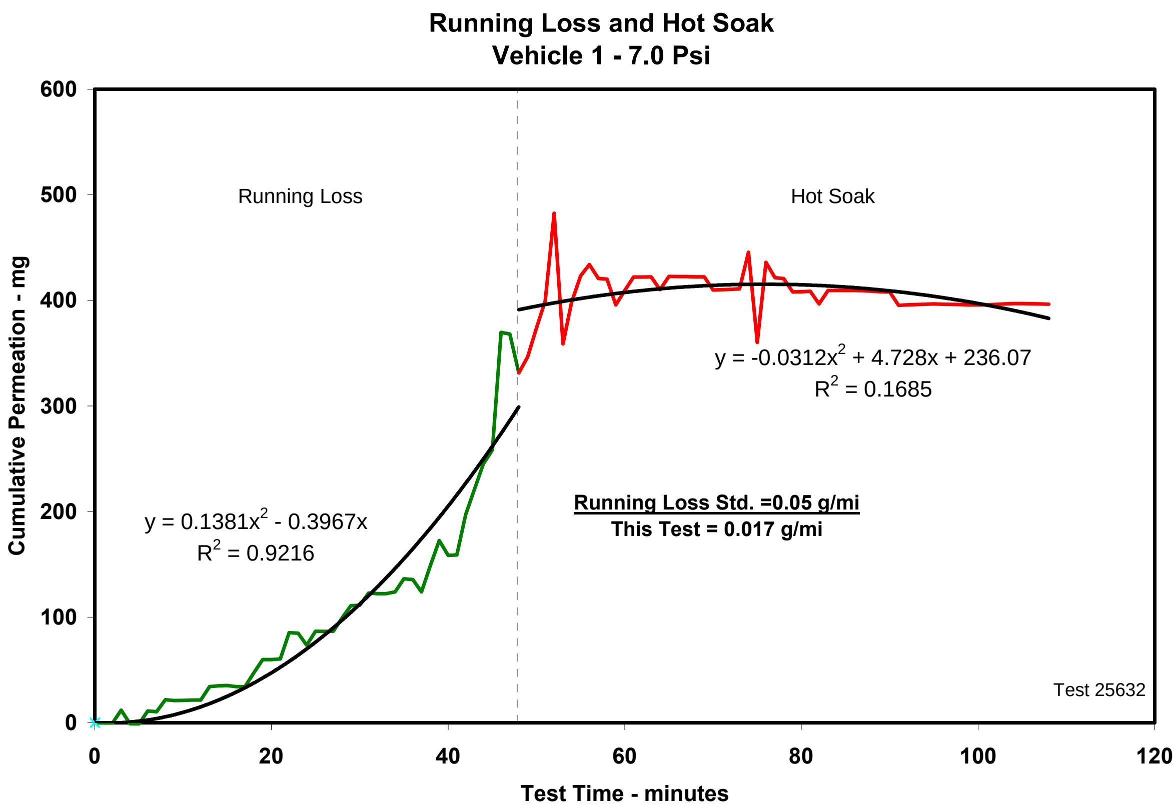
Appendix II

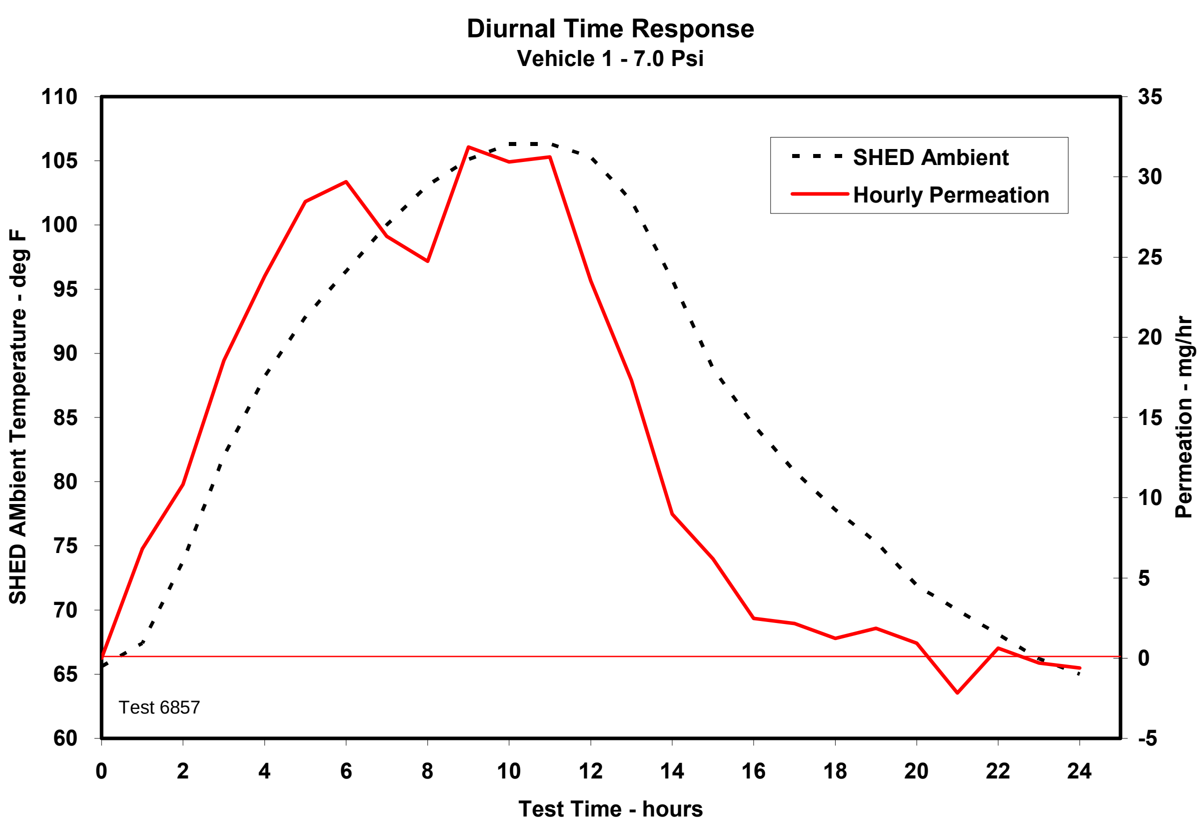
Test Data Plots
All Vehicles

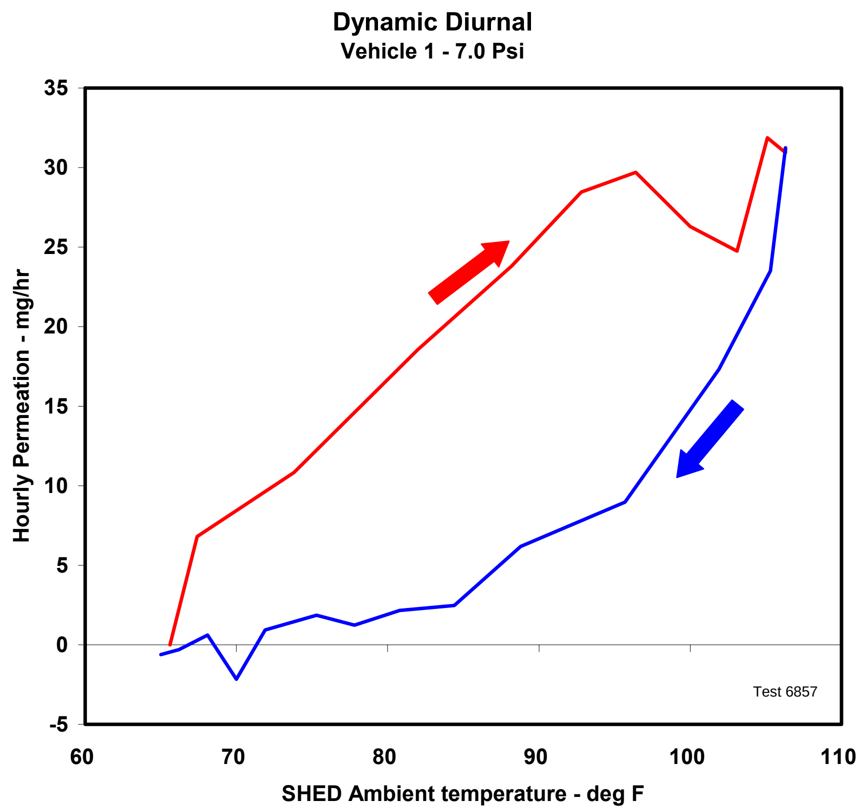
Vehicle 1

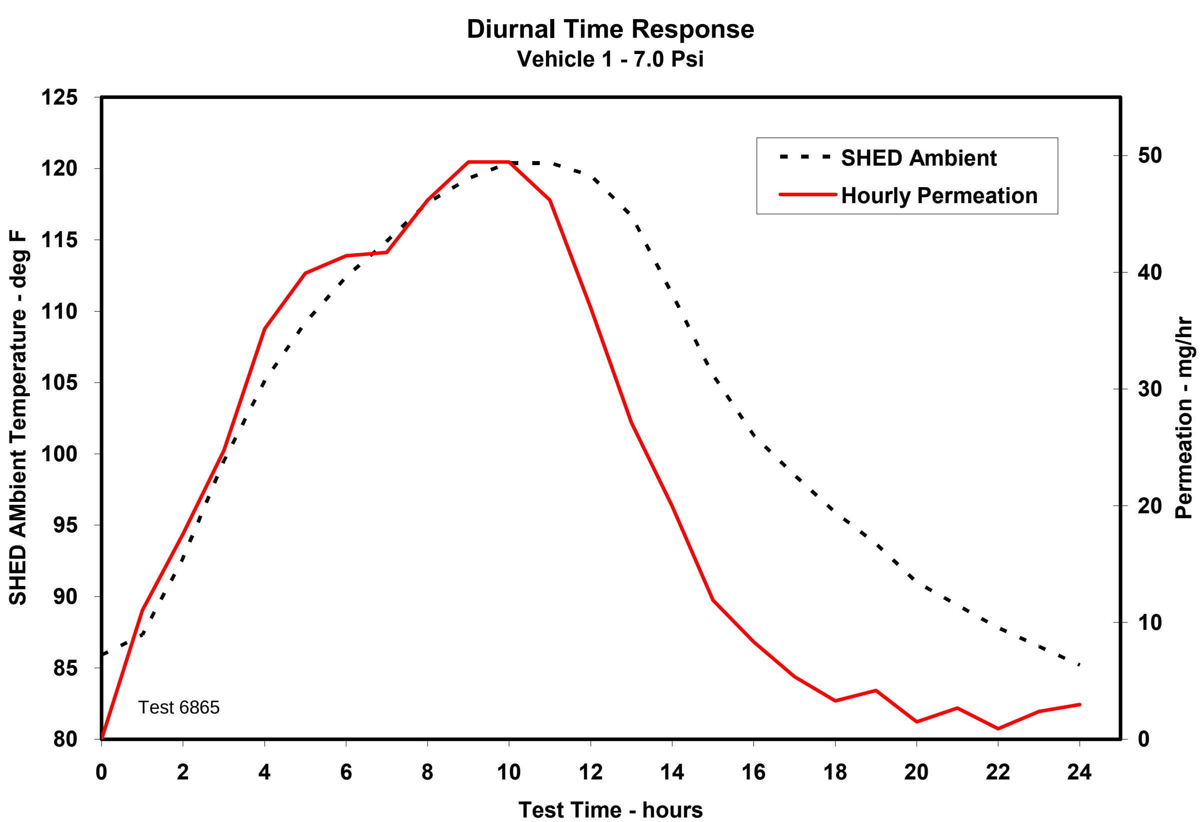
1996 Chevrolet S-10			Enhanced				SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
Veh	**Fuel**	**Test**	**Type**	**Date**	**Test#**	**Permeation mg/hr**			
01	7.0	Static	Perm	07/06/06	6875	8.6			
			Press. Incr.			3.0			
			Prs+Fuel Incr.			0.0			
						mg			
	7.0	Dynamic	RL	07/07/06	25632	331.4			
			HS			65.0			
			RL + HS			396.4			
	7.0	DHB	65-105	06/23/06	6857		325.4		0.0
	7.0	DHB	85-120	06/28/06	6865		530.3		0.0
	9.0	DHB	65-105	07/18/06	6888		572.1		0.0
	9.0	DHB	85-120	07/20/06	6893		1048.8		70.5

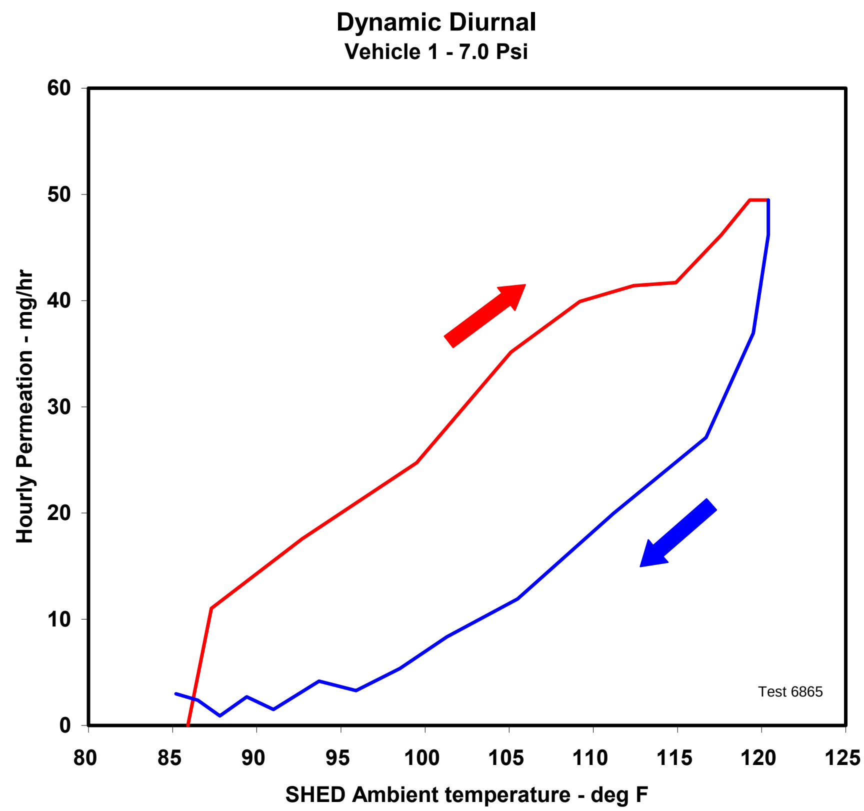


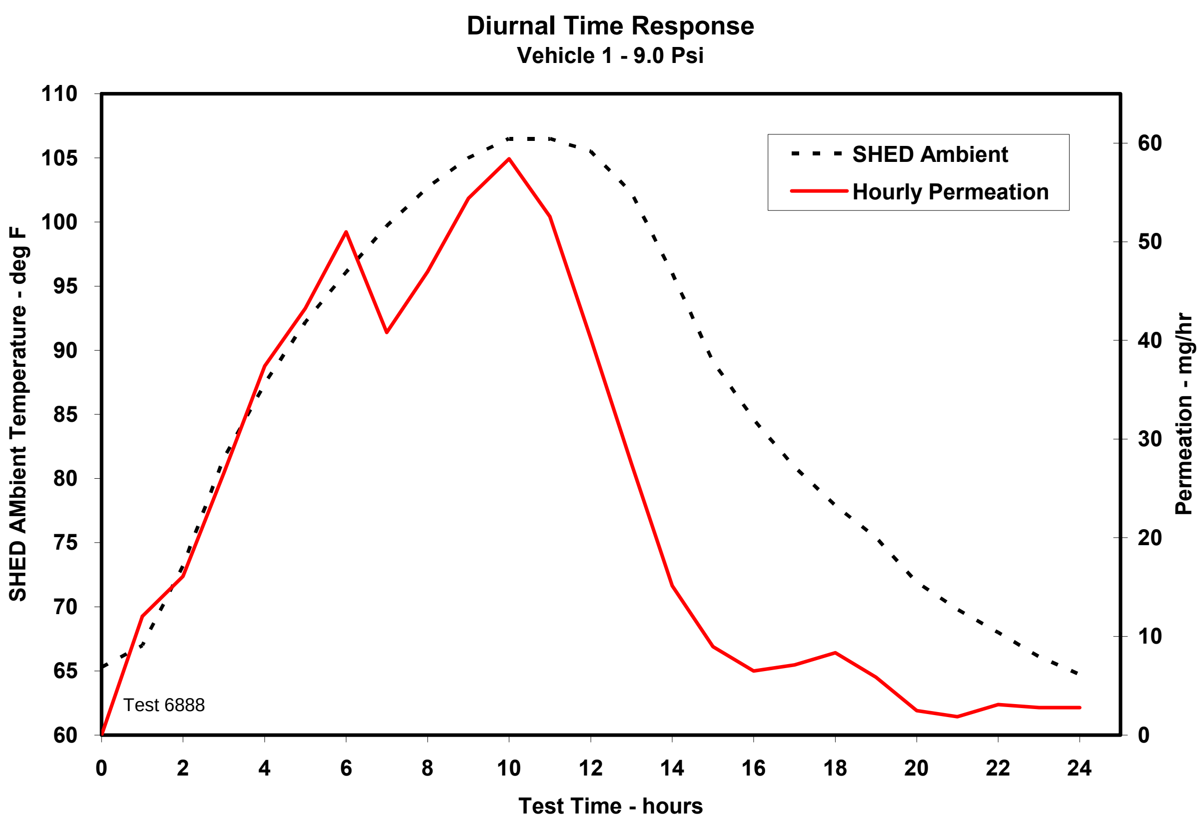

Running Loss and Hot Soak
Vehicle 1 - 7.0 Psi
Running Loss
Hot Soak
y = -0.0312x2 + 4.728x + 236.07
R2 = 0.1685
y = 0.1381x2 - 0.3967x
R2 = 0.9216
Running Loss Std. =0.05 g/mi
This Test = 0.017 g/mi
Test 25632
Cumulative Permeation - mg
Test Time - minutes

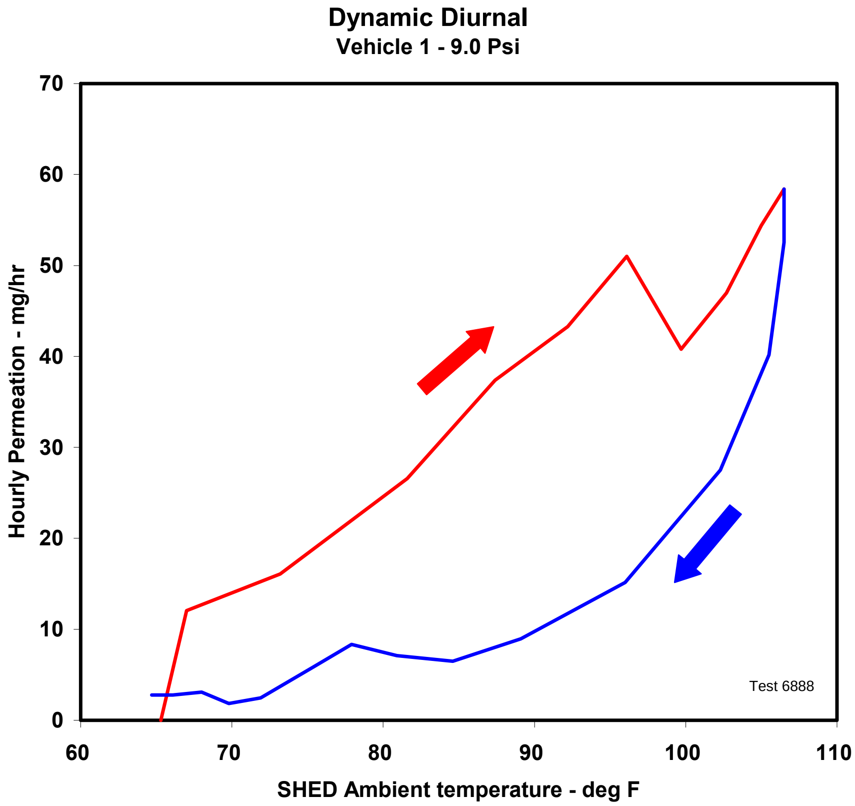

Diurnal Time Response
Vehicle 1 - 7.0 Psi
SHED Ambient
Hourly Permeation
Test 6857
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours

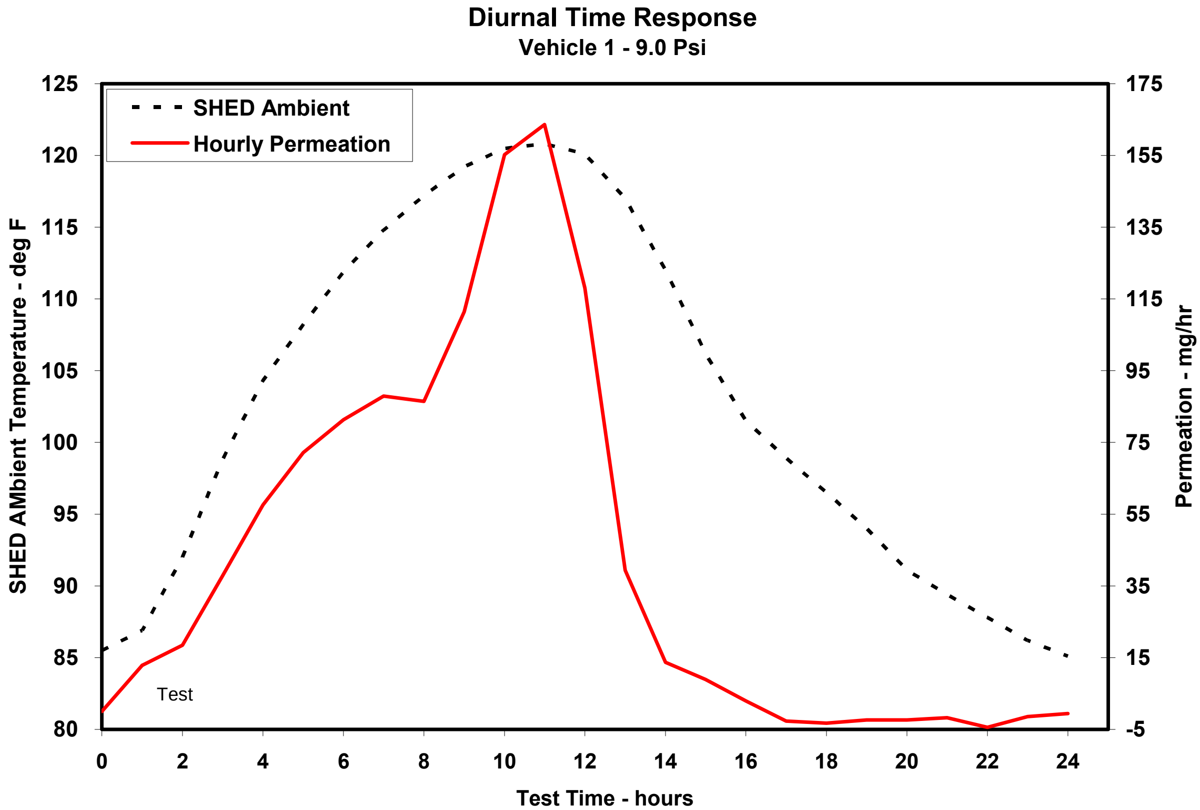

Dynamic Diurnal
Vehicle 1 - 7.0 Psi
Hourly Permeation - mg/hr
35
30
25
20
15
10
5
0
-5
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6857

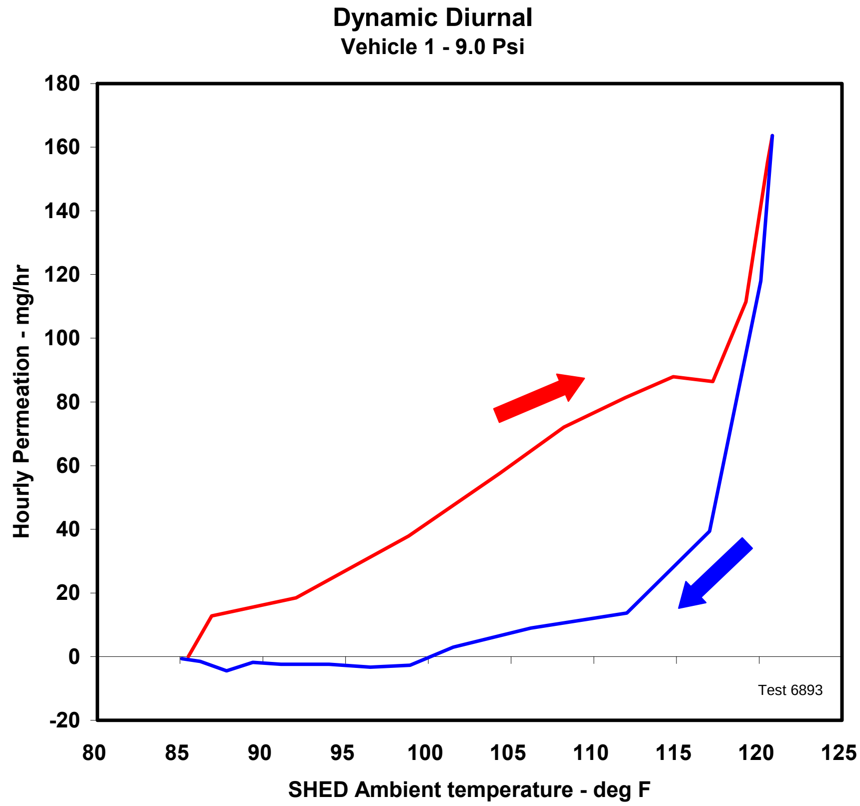

Diurnal Time Response
Vehicle 1 - 7.0 Psi
SHED AMbient Temperature - deg F
125
120
115
110
105
100
95
90
85
80
SHED Ambient
Hourly Permeation
Permeation - mg/hr
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test 6865

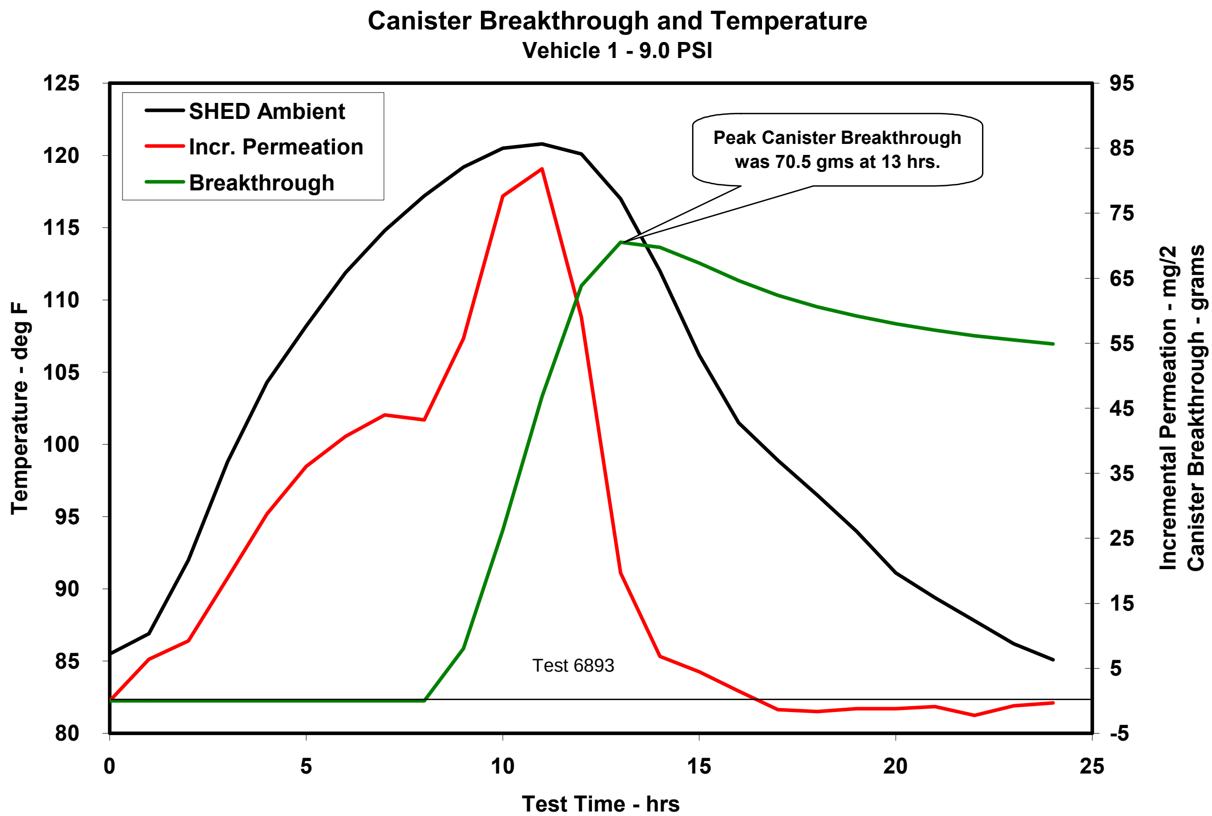

Dynamic Diurnal
Vehicle 1 - 7.0 Psi
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6865
0
10
20
30
40
50
60
80
85
90
95
100
105
110
115
120
125

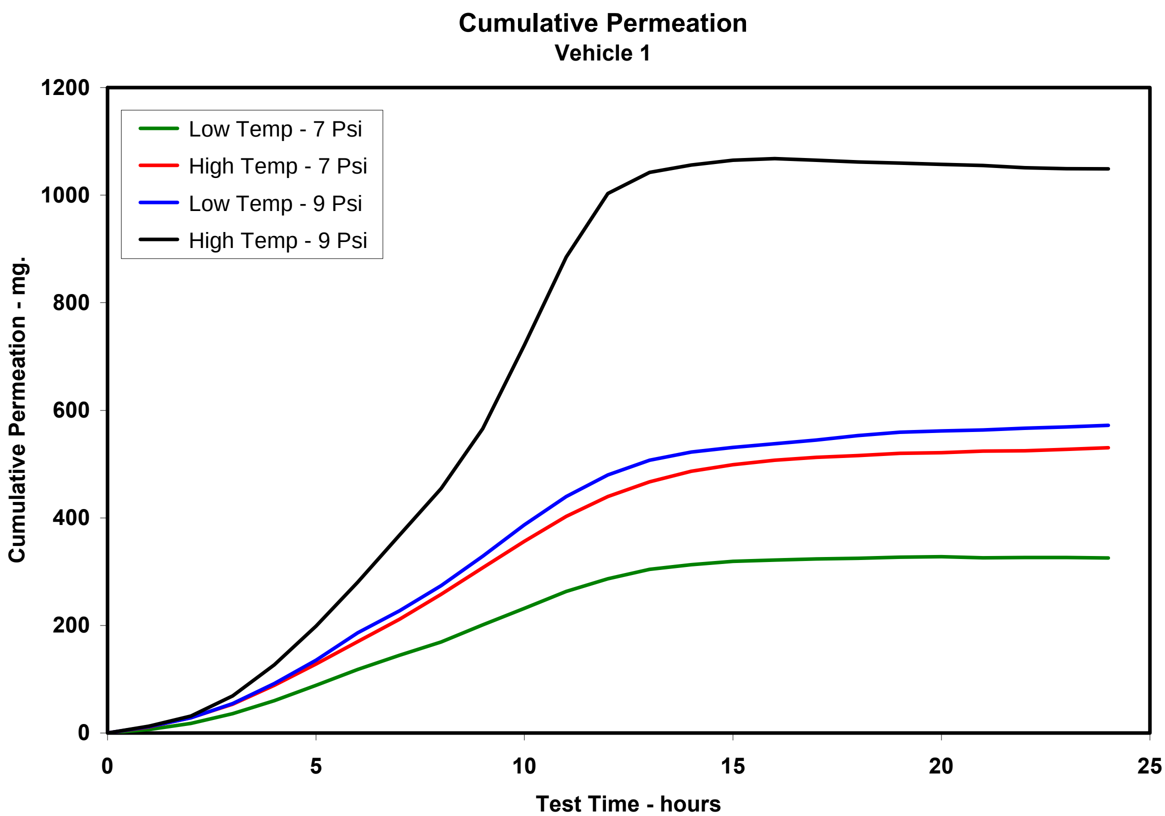

Diurnal Time Response
Vehicle 1 - 9.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
Test 6888
60
65
70
75
80
85
90
95
100
105
110
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24


Dynamic Diurnal
Vehicle 1 - 9.0 Psi
Hourly Permeation - mg/hr
70
60
50
40
30
20
10
0
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6888


Diurnal Time Response
Vehicle 1 - 9.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
125
120
115
110
105
100
95
90
85
80
Permeation - mg/hr
175
155
135
115
95
75
55
35
15
-5
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test


Dynamic Diurnal
Vehicle 1 - 9.0 Psi
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6893
180
160
140
120
100
80
60
40
20
0
-20
80
85
90
95
100
105
110
115
120
125


Canister Breakthrough and Temperature
Vehicle 1 - 9.0 PSI
SHED Ambient
Incr. Permeation
Breakthrough
Peak Canister Breakthrough was 70.5 gms at 13 hrs.
Test 6893
Temperature - deg F
Incremental Permeation - mg/2
Canister Breakthrough - grams
Test Time - hrs
125
120
115
110
105
100
95
90
85
80
95
85
75
65
55
45
35
25
15
5
-5
0
5
10
15
20
25

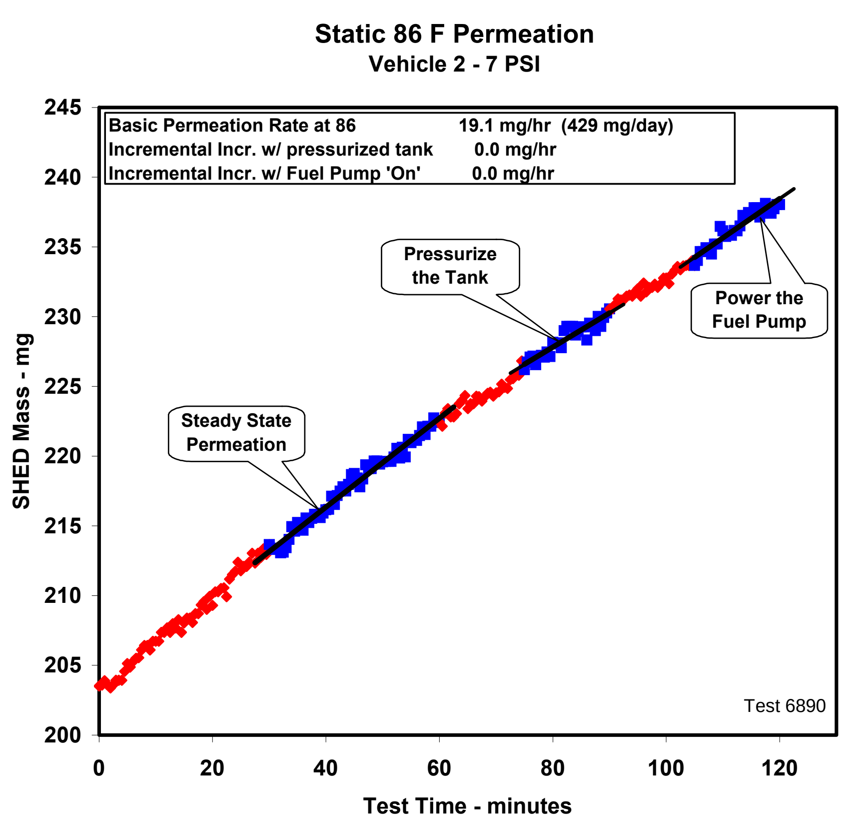


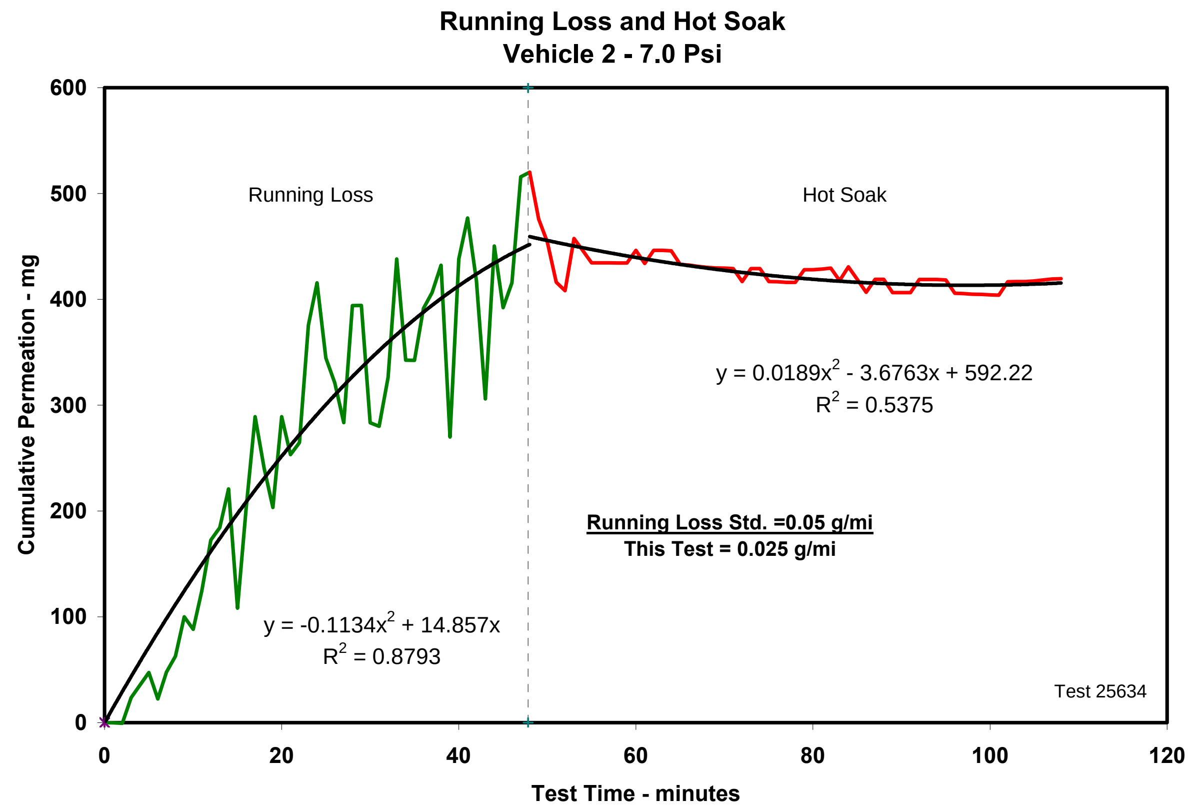
Cumulative Permeation
Vehicle 1
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
Test Time - hours
0
200
400
600
800
1000
1200
0
5
10
15
20
25

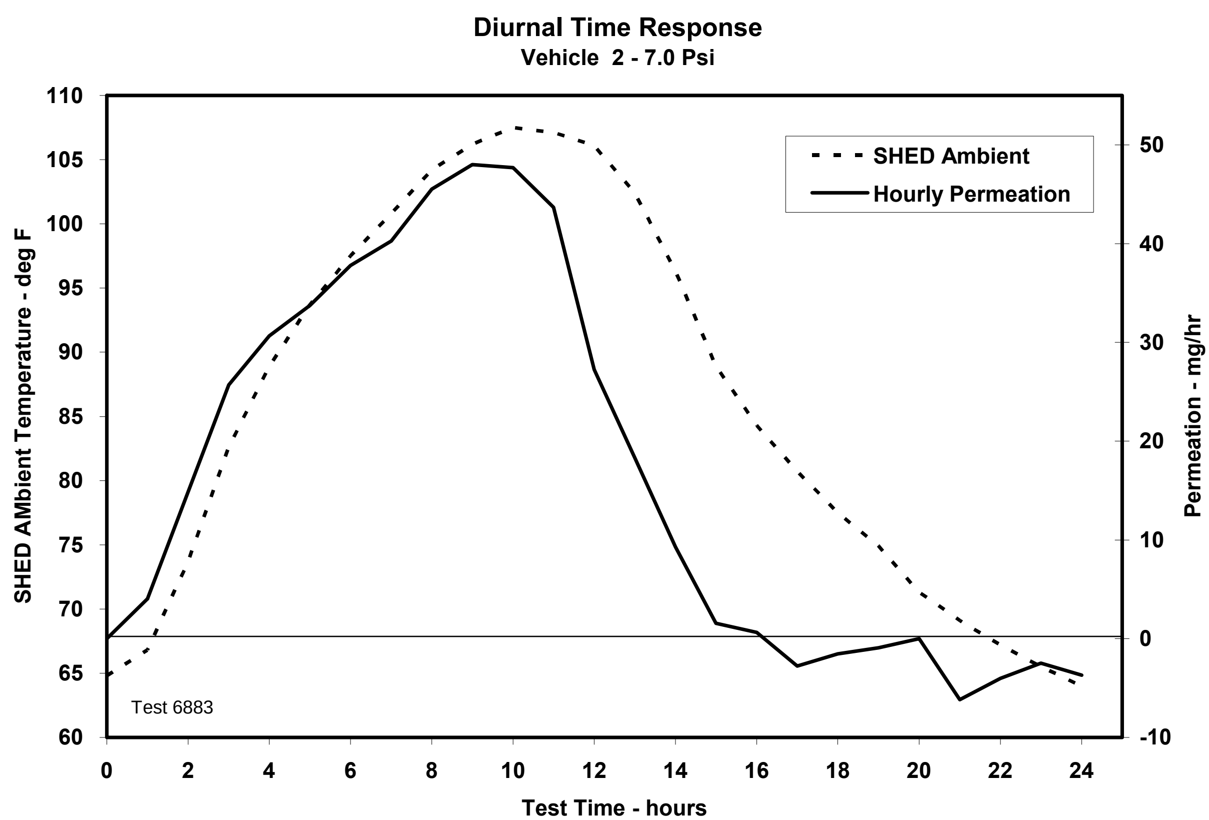
Vehicle 2

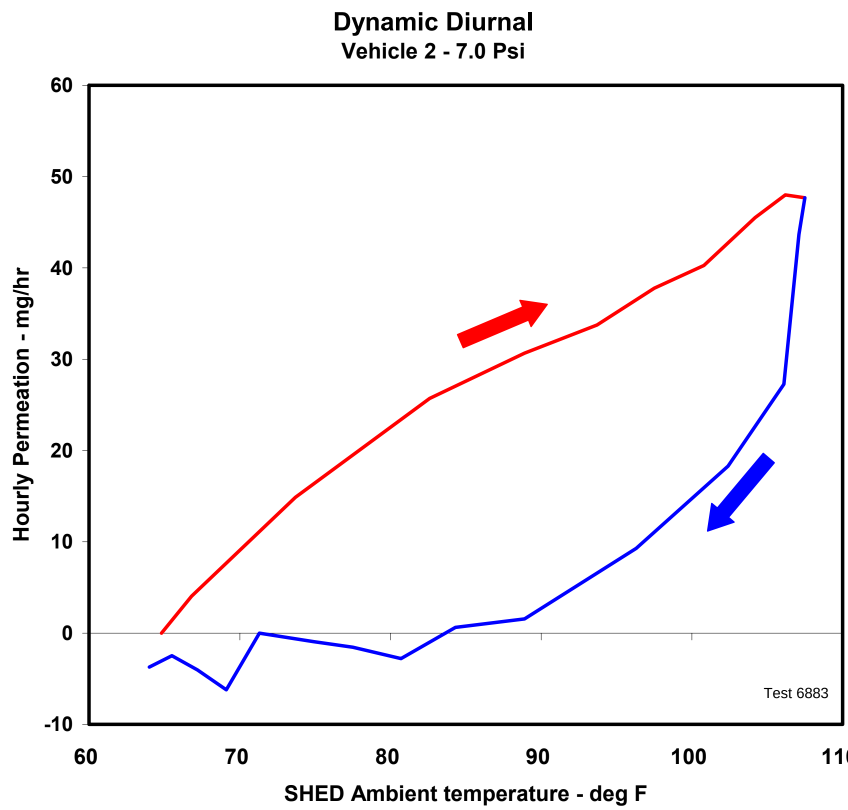
2000 Toyota Tacoma Enhanced

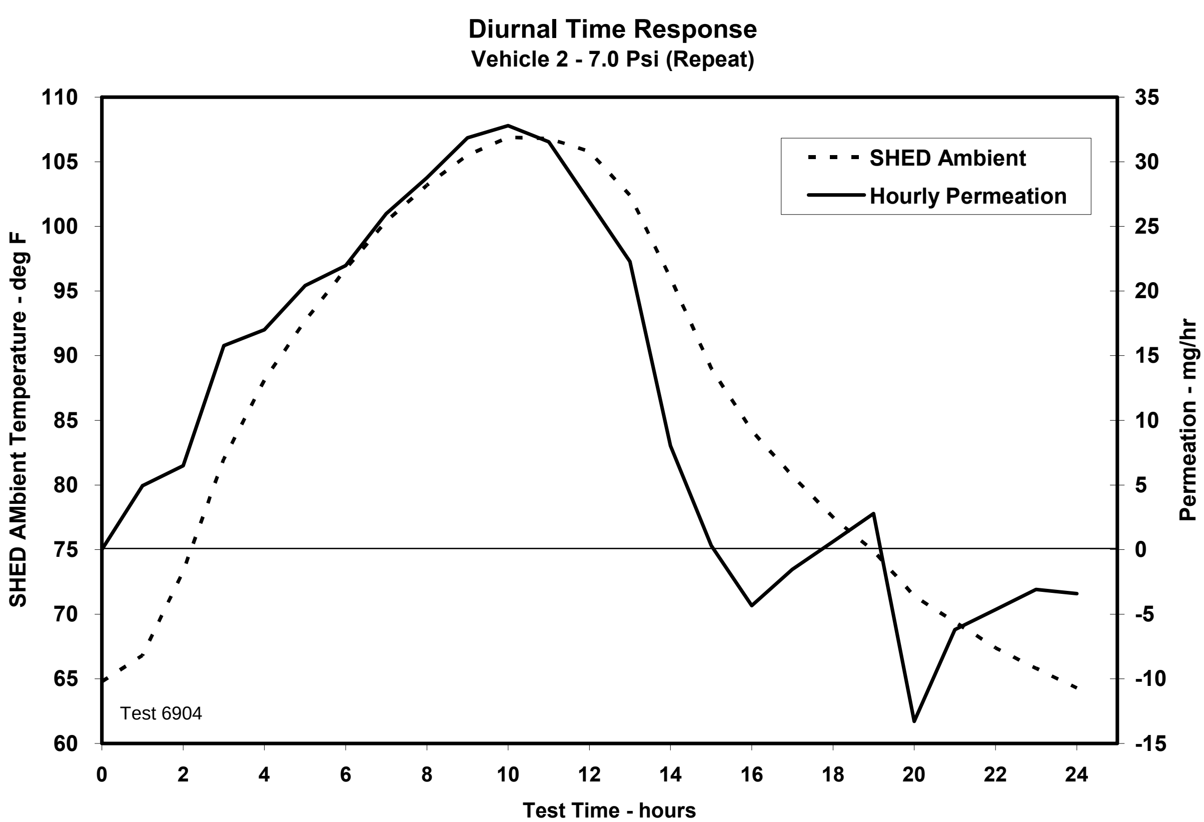
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
2	7.0	Static	Perm	07/19/06	6890	19.1			
			Press. Incr.			0.0			
			Prs+Fuel Incr.			0.0			
	7.0	Dynamic	RL	07/19/06	25634	520.2			
			HS			0.0			
			RL + HS			520.2			
	7.0	DHB	65-105	07/13/06	6883		407.2		0.0
	7.0	DHB	65-105	08/01/06	6904		262.0		0.0
	7.0	DHB	85-120	07/21/06	6896		471.5		0.0
	9.0	DHB	65-105	07/25/06	6899		214.4		0.0
	9.0	DHB	85-120	09/12/06	6929		387.4		6.3

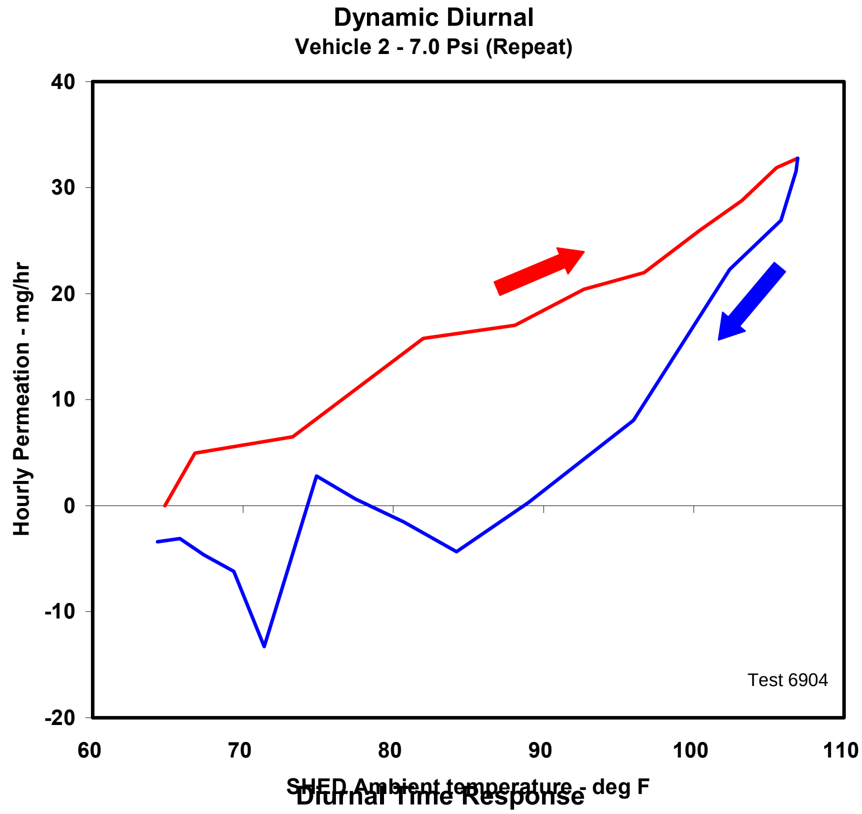


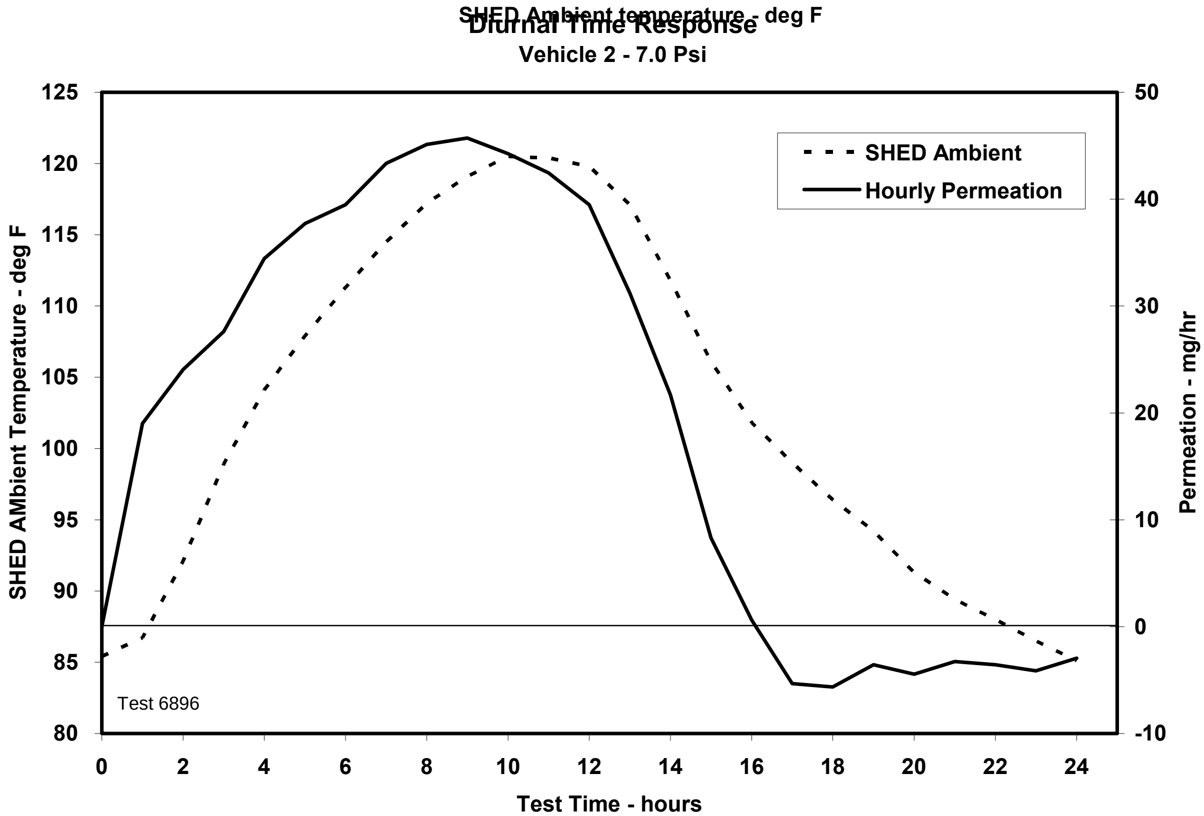

Running Loss and Hot Soak
Vehicle 2 - 7.0 Psi
Running Loss
Hot Soak
y = 0.0189x2 - 3.6763x + 592.22
R2 = 0.5375
Running Loss Std. =0.05 g/mi
This Test = 0.025 g/mi
y = -0.1134x2 + 14.857x
R2 = 0.8793
Test 25634
Cumulative Permeation - mg
Test Time - minutes
0
100
200
300
400
500
600
20
40
60
80
100
120

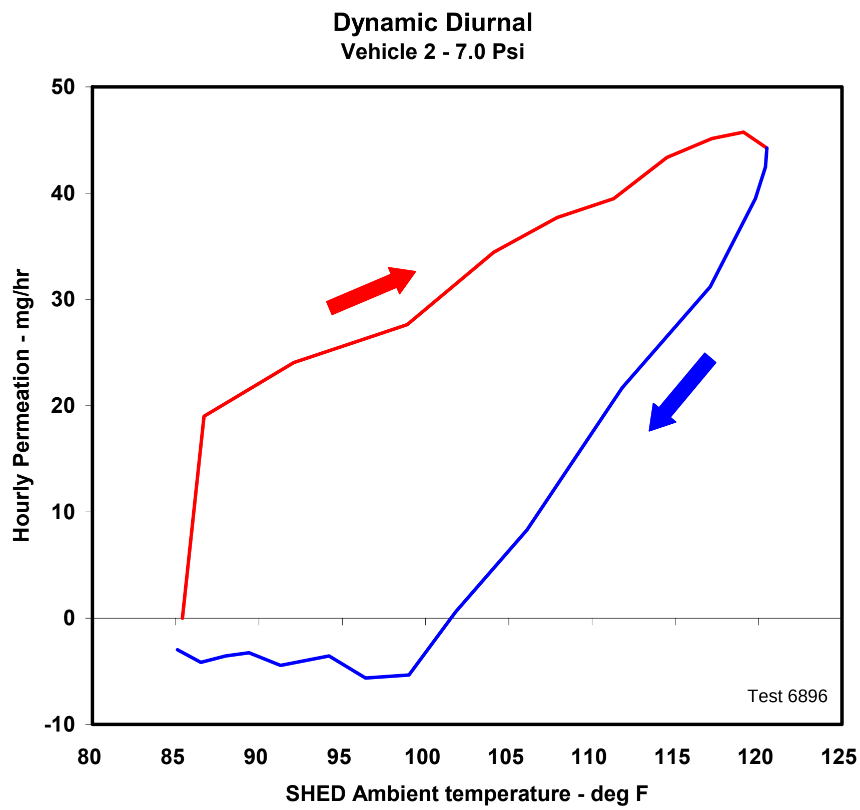

Diurnal Time Response
Vehicle 2 - 7.0 Psi
SHED Ambient
Hourly Permeation
Test 6883
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-10
0
10
20
30
40
50
2
4
6
8
10
12
14
16
18
20
22
24

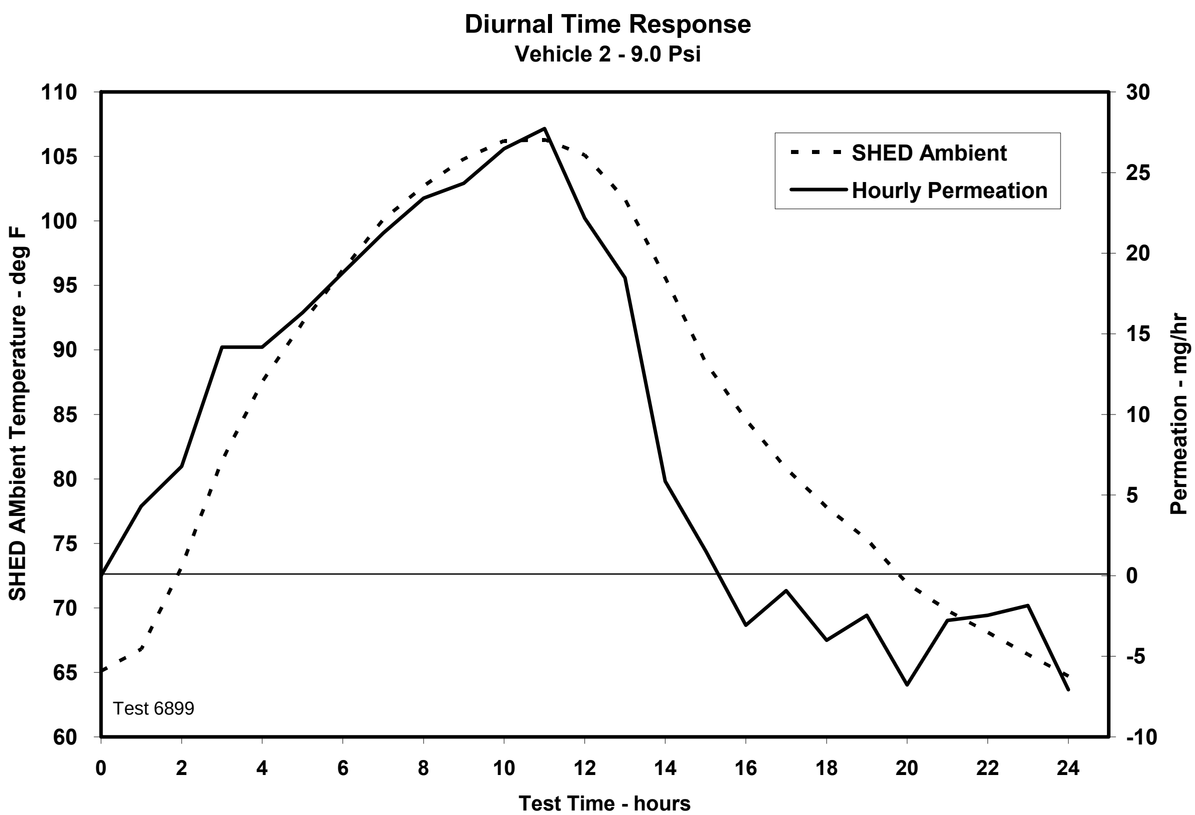

Dynamic Diurnal
Vehicle 2 - 7.0 Psi
Hourly Permeation - mg/hr
60
50
40
30
20
10
0
-10
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6883

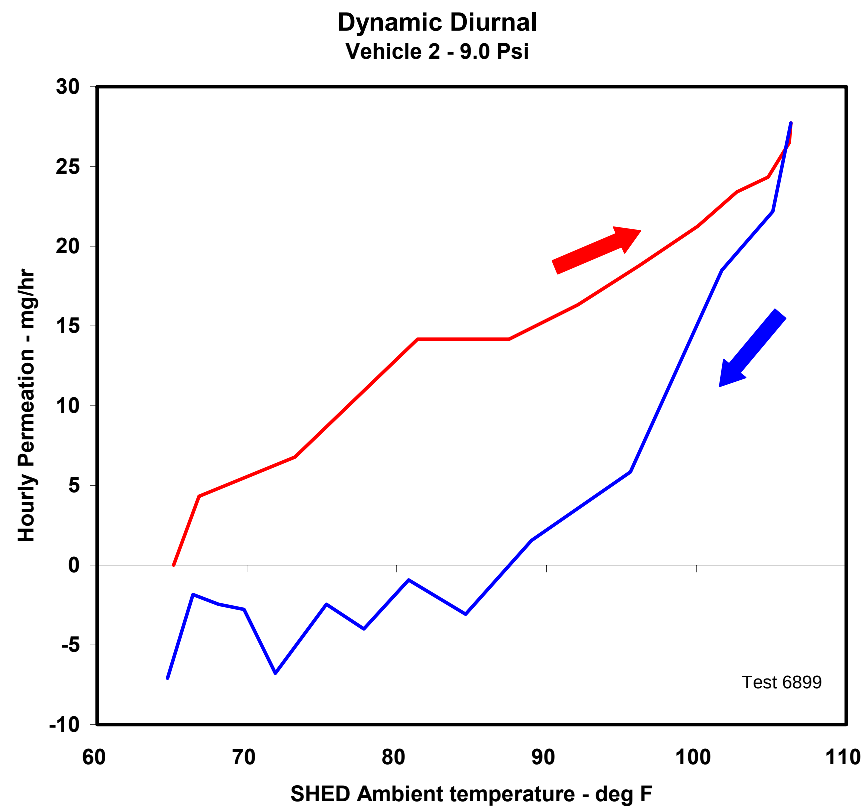

Diurnal Time Response
Vehicle 2 - 7.0 Psi (Repeat)
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
110
105
100
95
90
85
80
75
70
65
60
35
30
25
20
15
10
5
0
-5
-10
-15
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test 6904

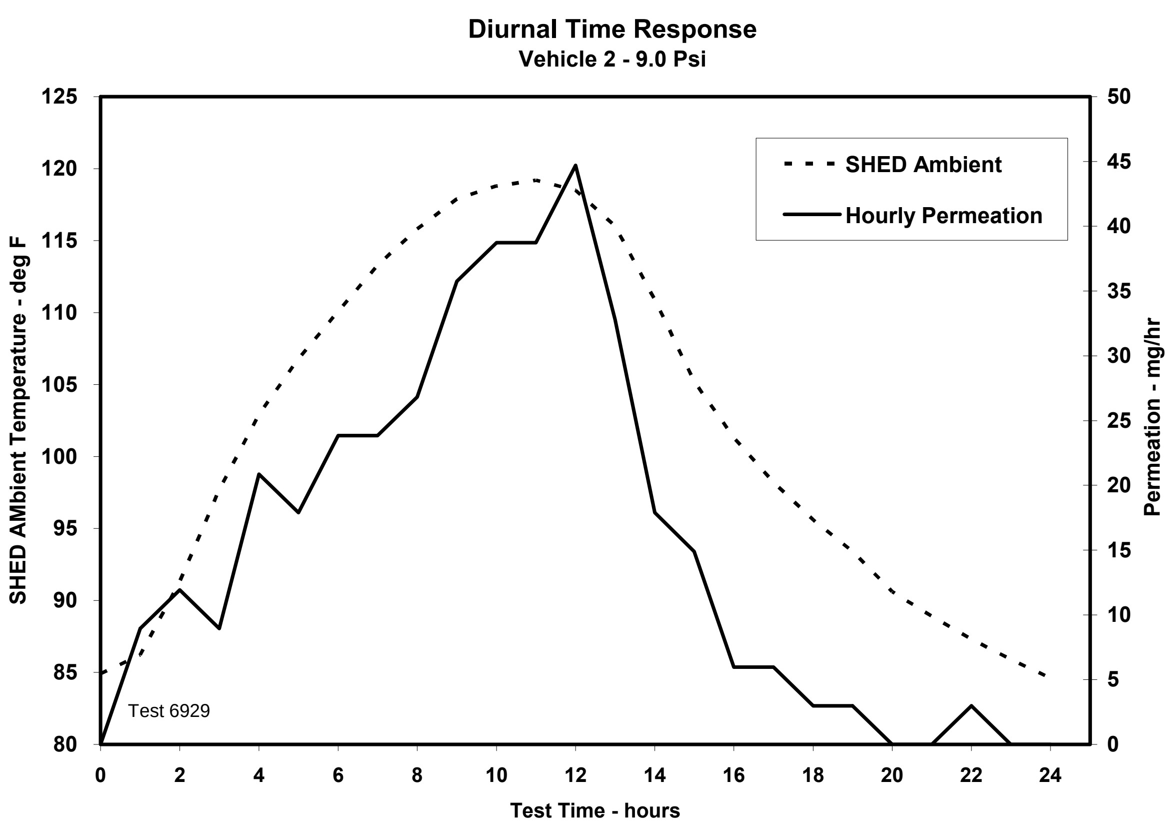

Dynamic Diurnal
Vehicle 2 - 7.0 Psi (Repeat)
40
30
20
10
0
-10
-20
Hourly Permeation - mg/hr
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6904

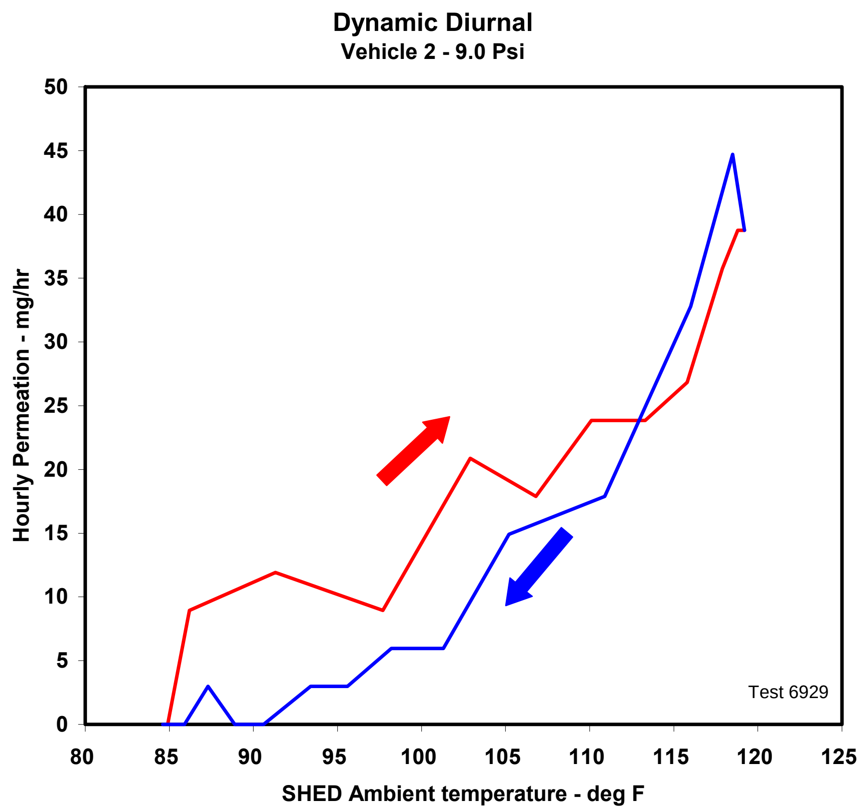

Diurnal Time Response
Vehicle 2 - 7.0 Psi
SHED Ambient
Hourly Permeation
125
120
115
110
105
100
95
90
85
80
SHED AMbient Temperature - deg F
50
40
30
20
10
0
-10
Permeation - mg/hr
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test 6896


Dynamic Diurnal
Vehicle 2 - 7.0 Psi
Hourly Permeation - mg/hr
50
40
30
20
10
0
-10
80
85
90
95
100
105
110
115
120
125
SHED Ambient temperature - deg F
Test 6896

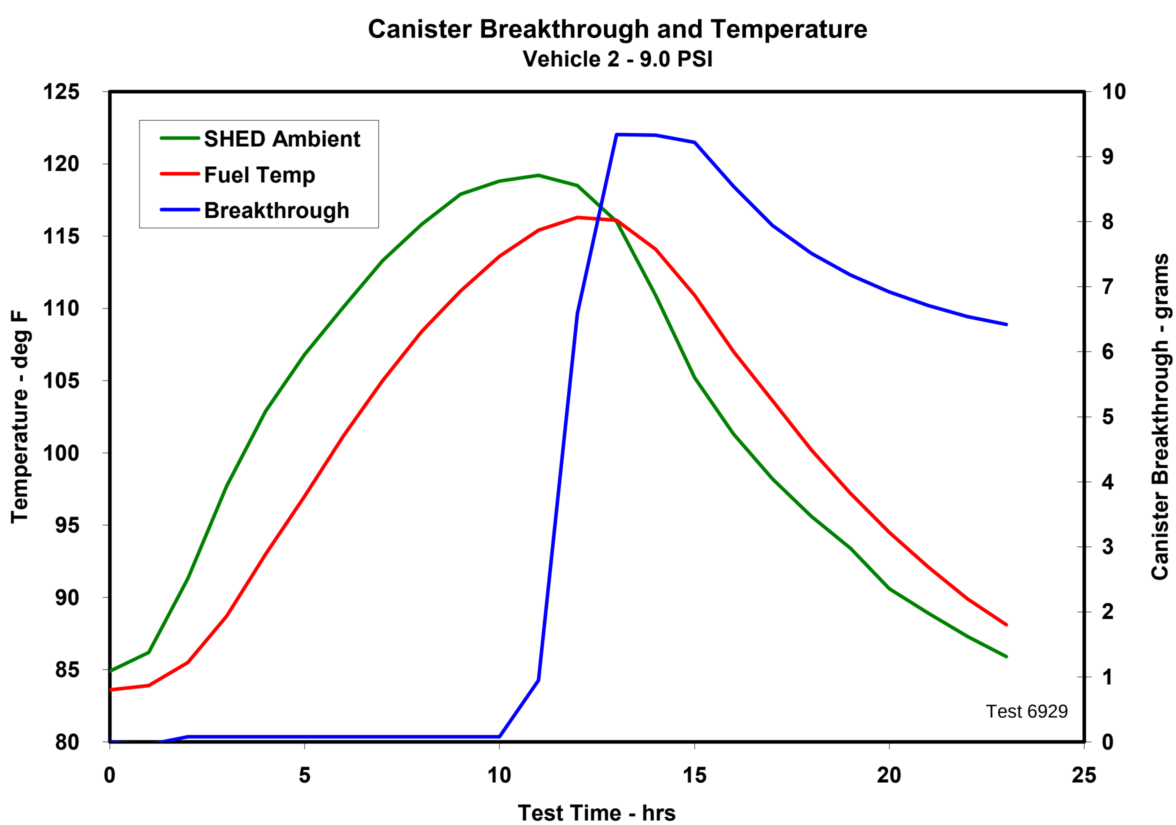

Diurnal Time Response
Vehicle 2 - 9.0 Psi
SHED AMbient Temperature - deg F
Permeation - mg/hr
SHED Ambient
Hourly Permeation
110
105
100
95
90
85
80
75
70
65
60
30
25
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test 6899


Dynamic Diurnal
Vehicle 2 - 9.0 Psi
Hourly Permeation - mg/hr
30
25
20
15
10
5
0
-5
-10
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6899

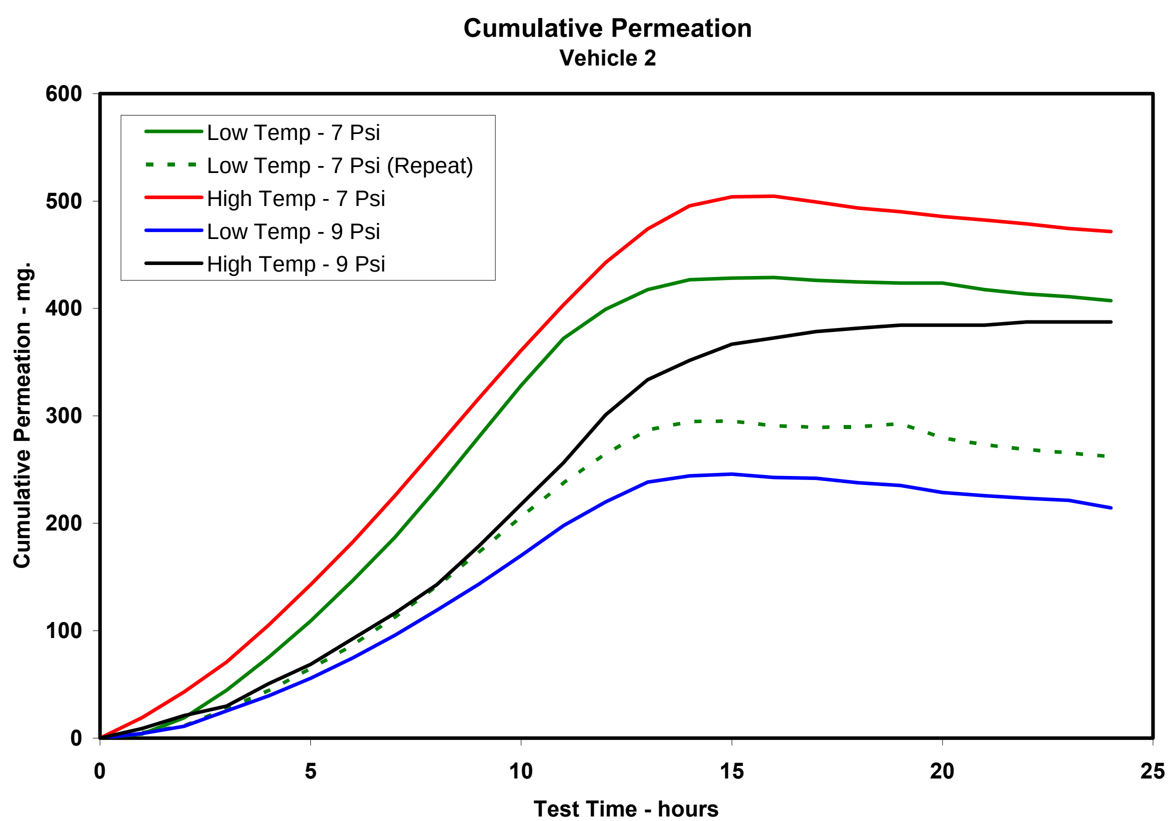

Diurnal Time Response
Vehicle 2 - 9.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
125
120
115
110
105
100
95
90
85
80
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
14
16
18
20
22
24
Test Time - hours
Test 6929



Dynamic Diurnal
Vehicle 2 - 9.0 Psi
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6929
0
5
10
15
20
25
30
35
40
45
50
80
85
90
95
100
105
110
115
120
125



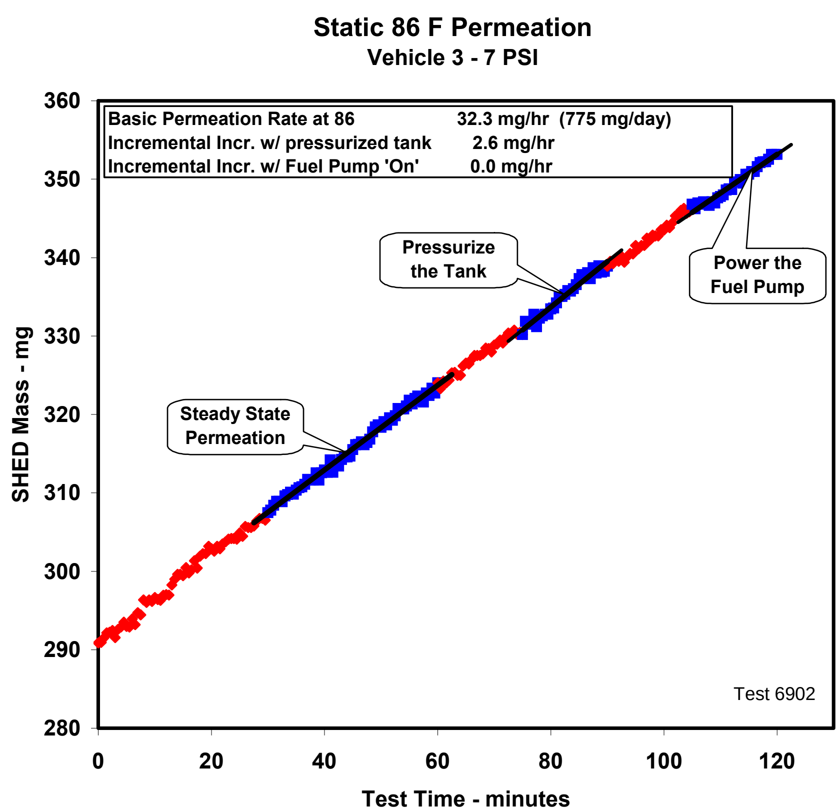
Canister Breakthrough and Temperature
Vehicle 2 - 9.0 PSI
SHED Ambient
Fuel Temp
Breakthrough
Temperature - deg F
Canister Breakthrough - grams
Test Time - hrs
Test 6929
80
85
90
95
100
105
110
115
120
125
0
1
2
3
4
5
6
7
8
9
10
0
5
10
15
20
25

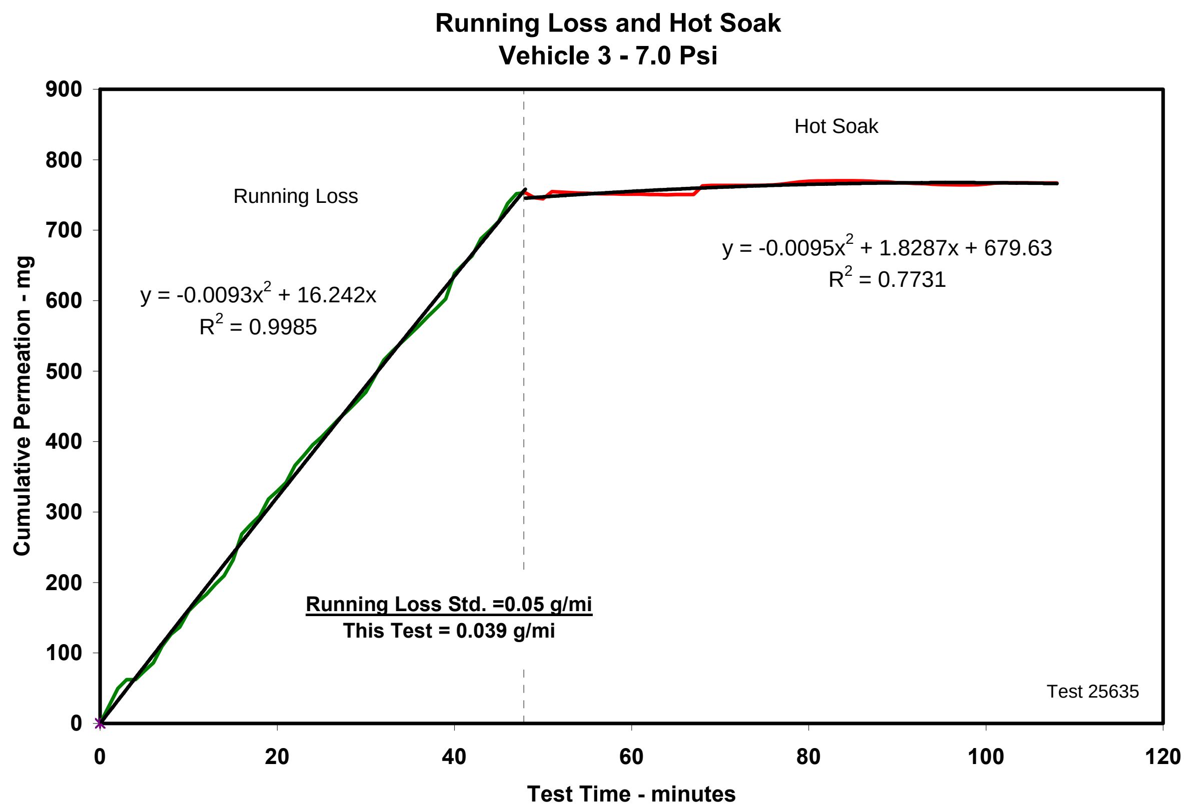

Cumulative Permeation
Vehicle 2
Low Temp - 7 Psi
Low Temp - 7 Psi (Repeat)
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
600
500
400
300
200
100
0
0
5
10
15
20
25
Test Time - hours

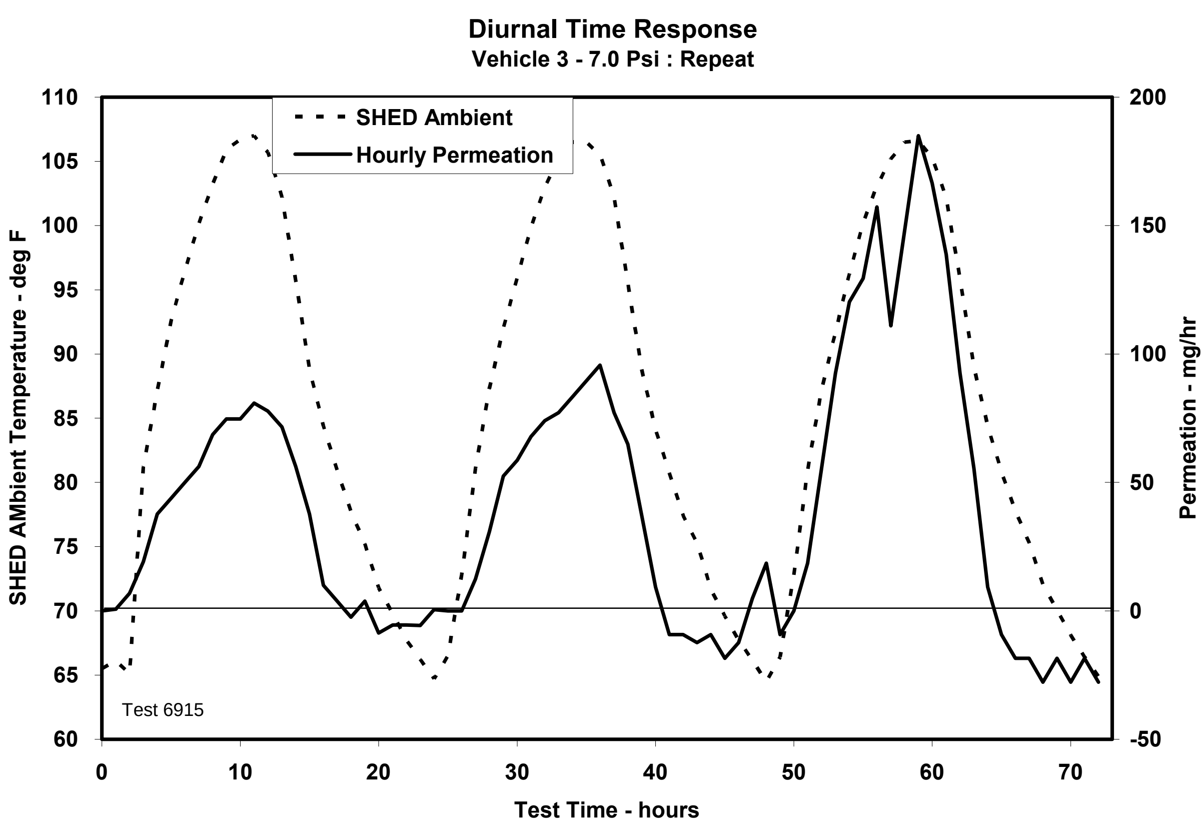
Vehicle 3

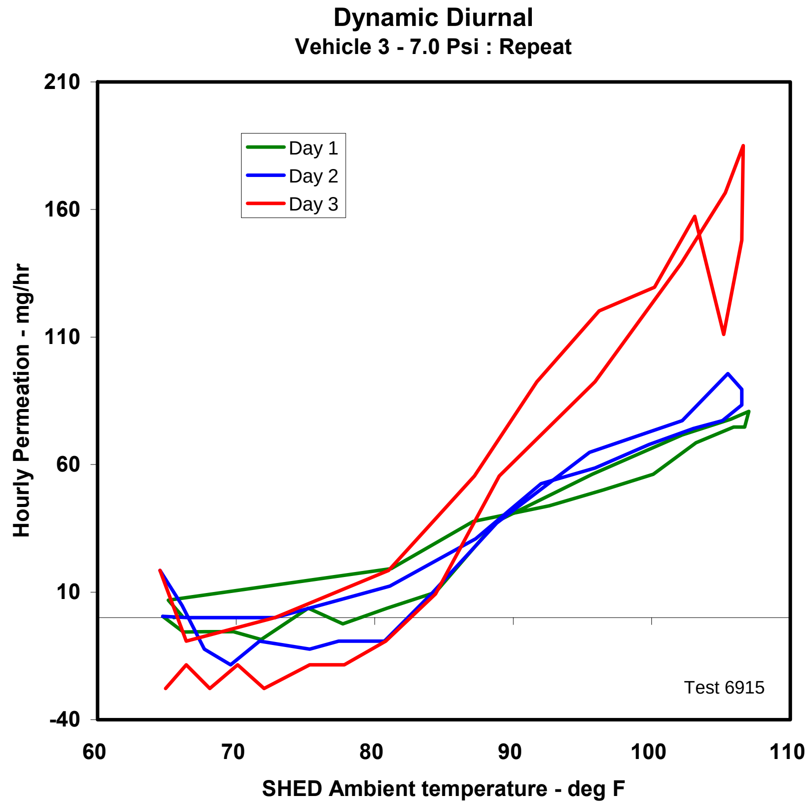
1992 Honda Accord Pre-enhanced

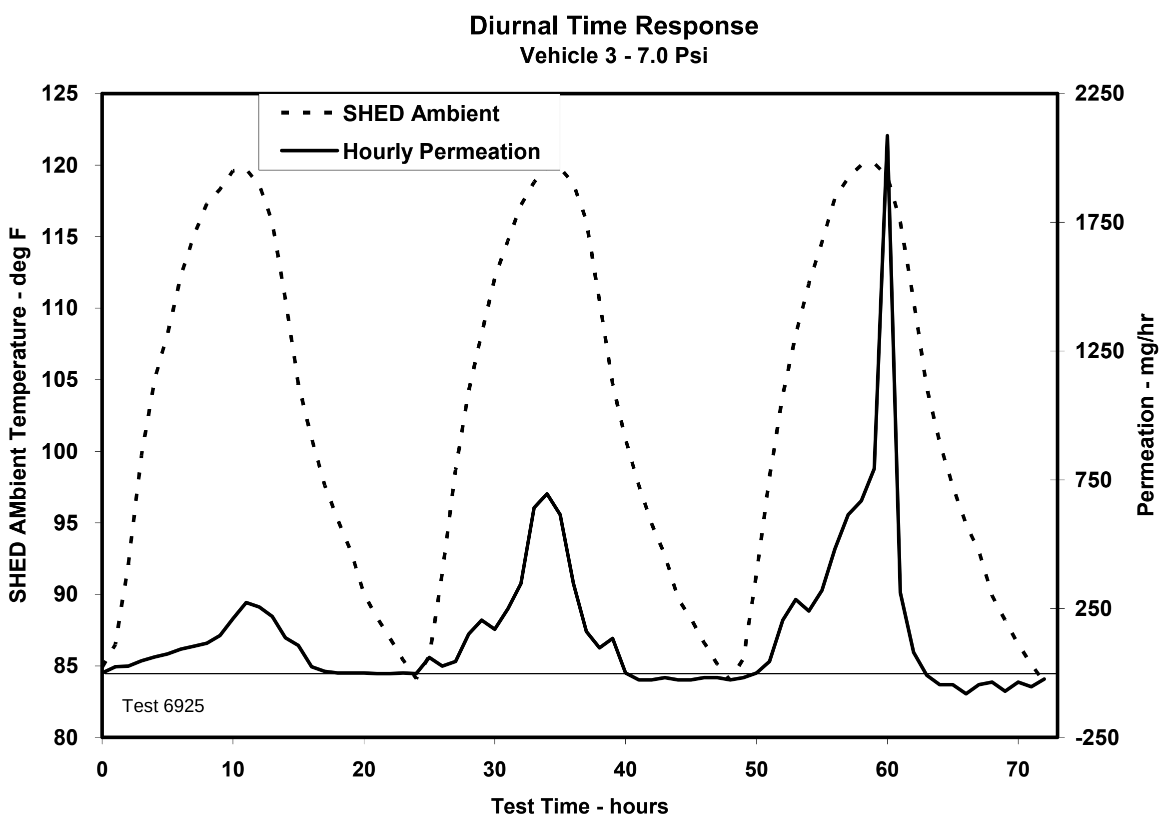
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
3	7.0	Static	Perm	07/28/06	6902	32.3			
			Press. Incr.			2.6			
			Prs+Fuel Incr.			0.0			
	7.0	Dynamic	RL	08/01/06	25635	753.3			
			HS			13.8			
			RL + HS			767.0			
	7.0	72 DHB	65-105	08/11/06	6915	Day 1	746.8		0.1
						Day 2	782.5		0.4
						Day 3	1304.4		2.4
	7.0	72 DHB	85-120	09/01/06	6925	Day 1	1918.3		1.7
						Day 2	3760.8		18.7
						Day 3	5674.1		20.4

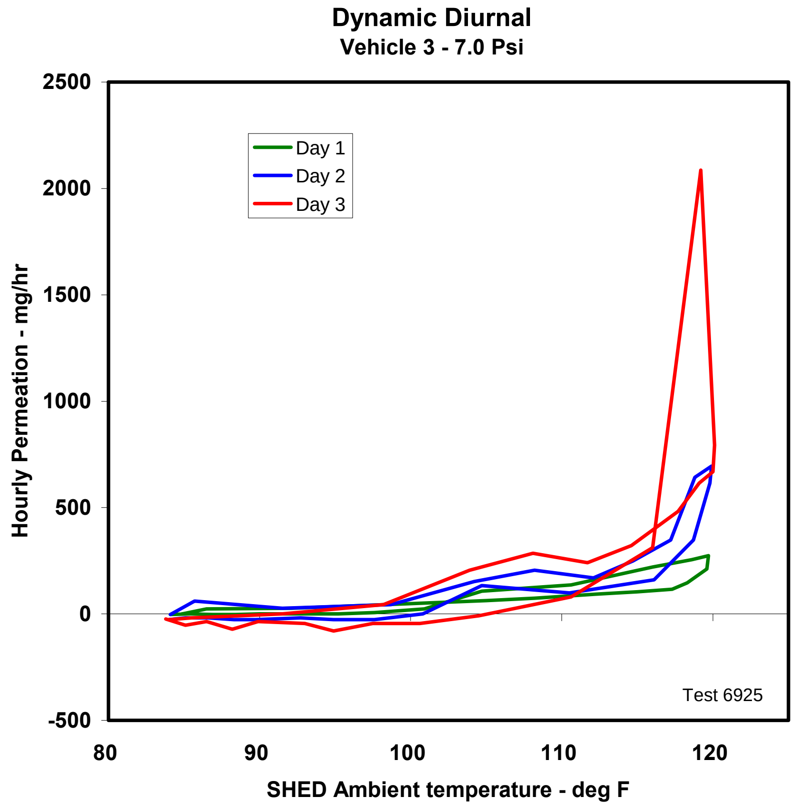


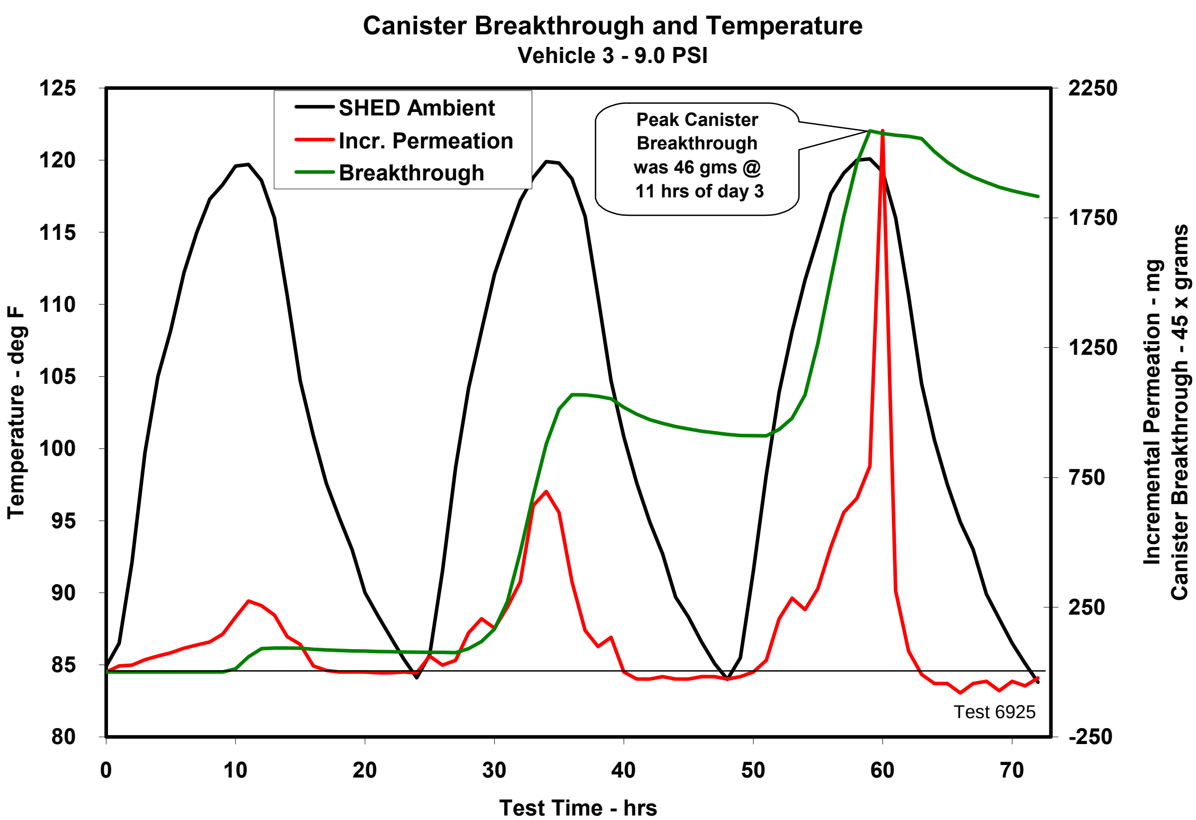

Running Loss and Hot Soak
Vehicle 3 - 7.0 Psi
Hot Soak
Running Loss
y = -0.0095x^2 + 1.8287x + 679.63
R^2 = 0.7731
y = -0.0093x^2 + 16.242x
R^2 = 0.9985
Running Loss Std. =0.05 g/mi
This Test = 0.039 g/mi
Test 25635
Cumulative Permeation - mg
Test Time - minutes
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
120

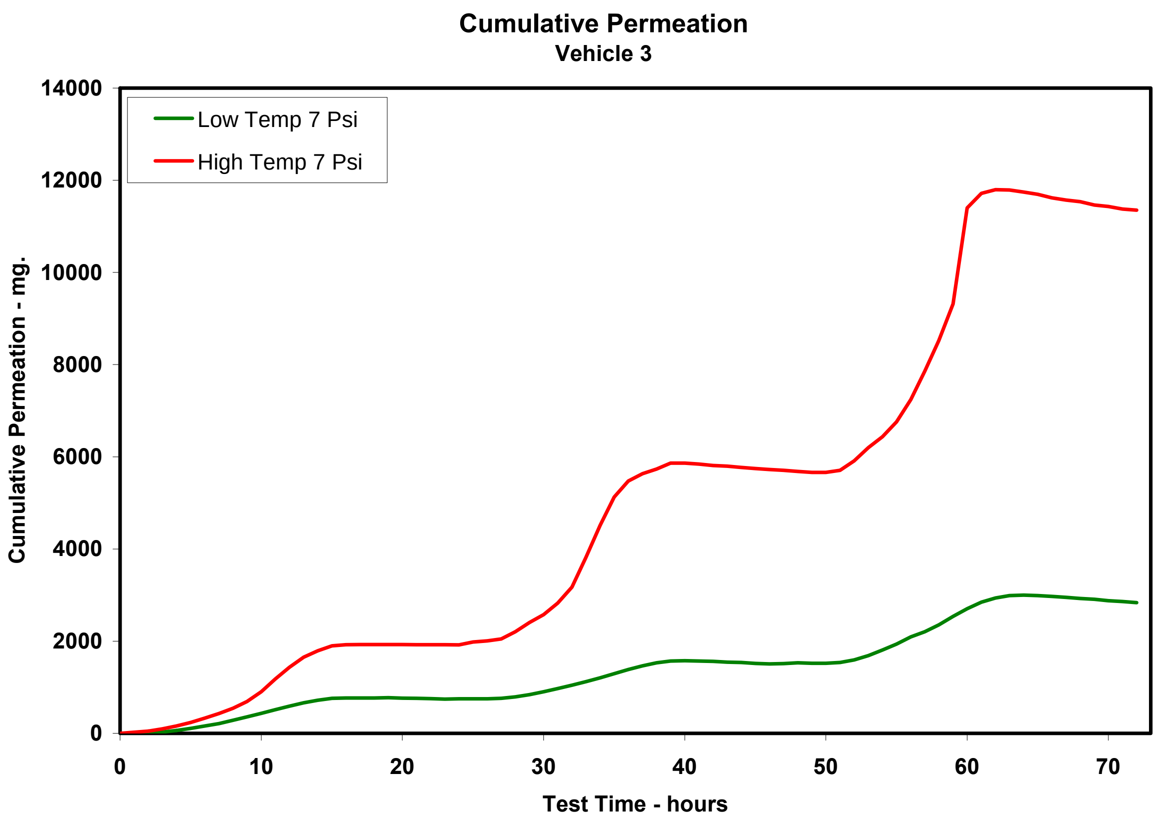

Diurnal Time Response
Vehicle 3 - 7.0 Psi : Repeat
SHED Ambient
Hourly Permeation
Test 6915
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-50
0
50
100
150
200
0
10
20
30
40
50
60
70


Dynamic Diurnal
Vehicle 3 - 7.0 Psi : Repeat
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
210
160
110
60
10
-40
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6915


Diurnal Time Response
Vehicle 3 - 7.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
125
120
115
110
105
100
95
90
85
80
Permeation - mg/hr
2250
1750
1250
750
250
-250
0
10
20
30
40
50
60
70
Test Time - hours
Test 6925


Dynamic Diurnal
Vehicle 3 - 7.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
2500
2000
1500
1000
500
0
-500
80
90
100
110
120
SHED Ambient temperature - deg F
Test 6925

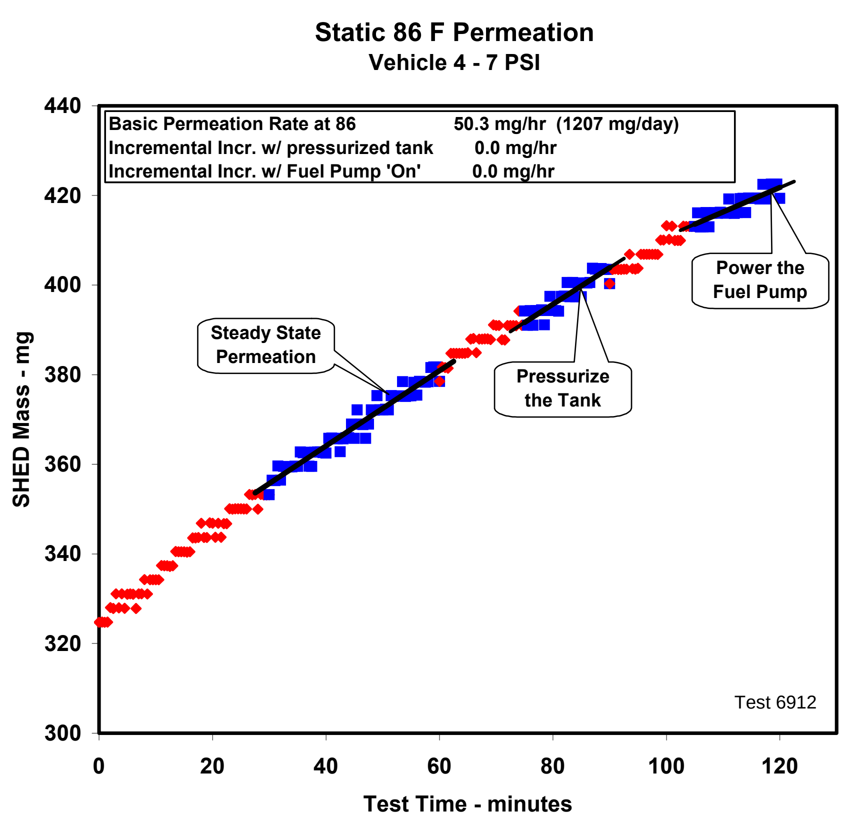

Canister Breakthrough and Temperature
Vehicle 3 - 9.0 PSI
SHED Ambient
Incr. Permeation
Breakthrough
Peak Canister Breakthrough was 46 gms @ 11 hrs of day 3
Temperature - deg F
125
120
115
110
105
100
95
90
85
80
Incremental Permeation - mg
Canister Breakthrough - 45 x grams
2250
1750
1250
750
250
-250
0
10
20
30
40
50
60
70
Test Time - hrs
Test 6925

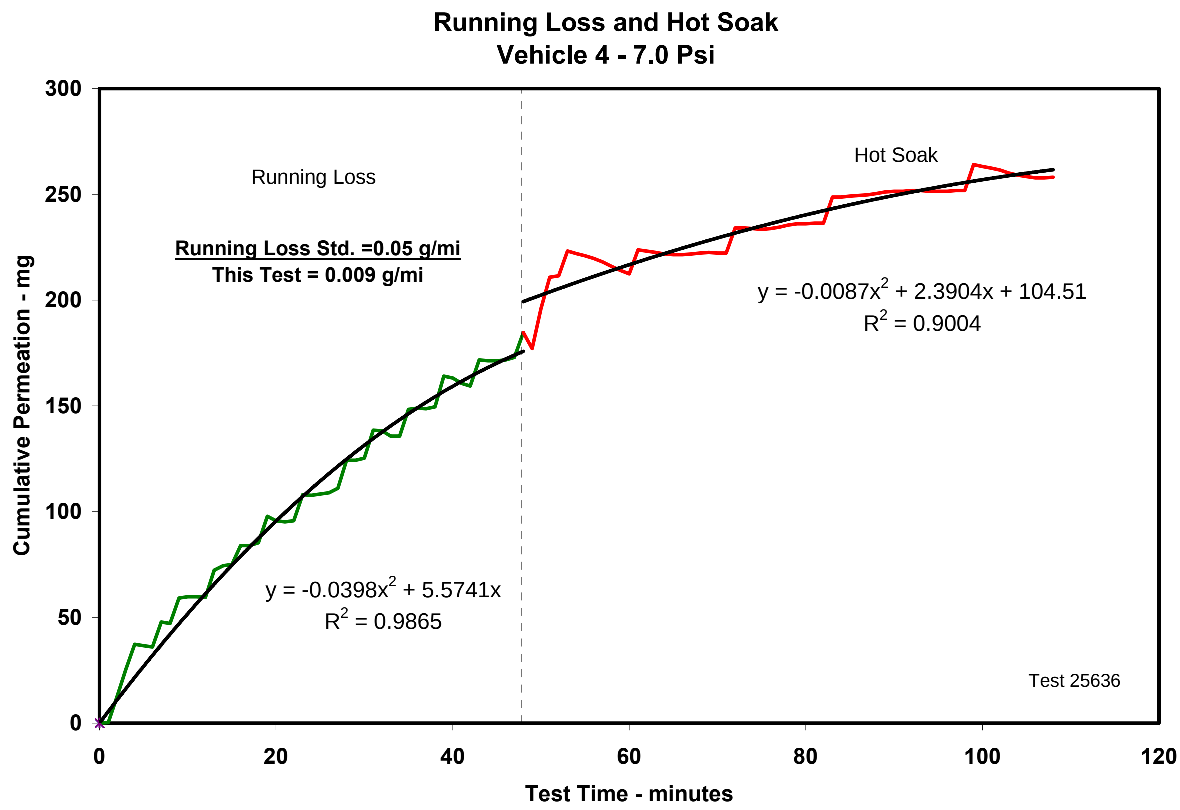

Cumulative Permeation
Vehicle 3
Low Temp 7 Psi
High Temp 7 Psi
Cumulative Permeation - mg.
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
Test Time - hours

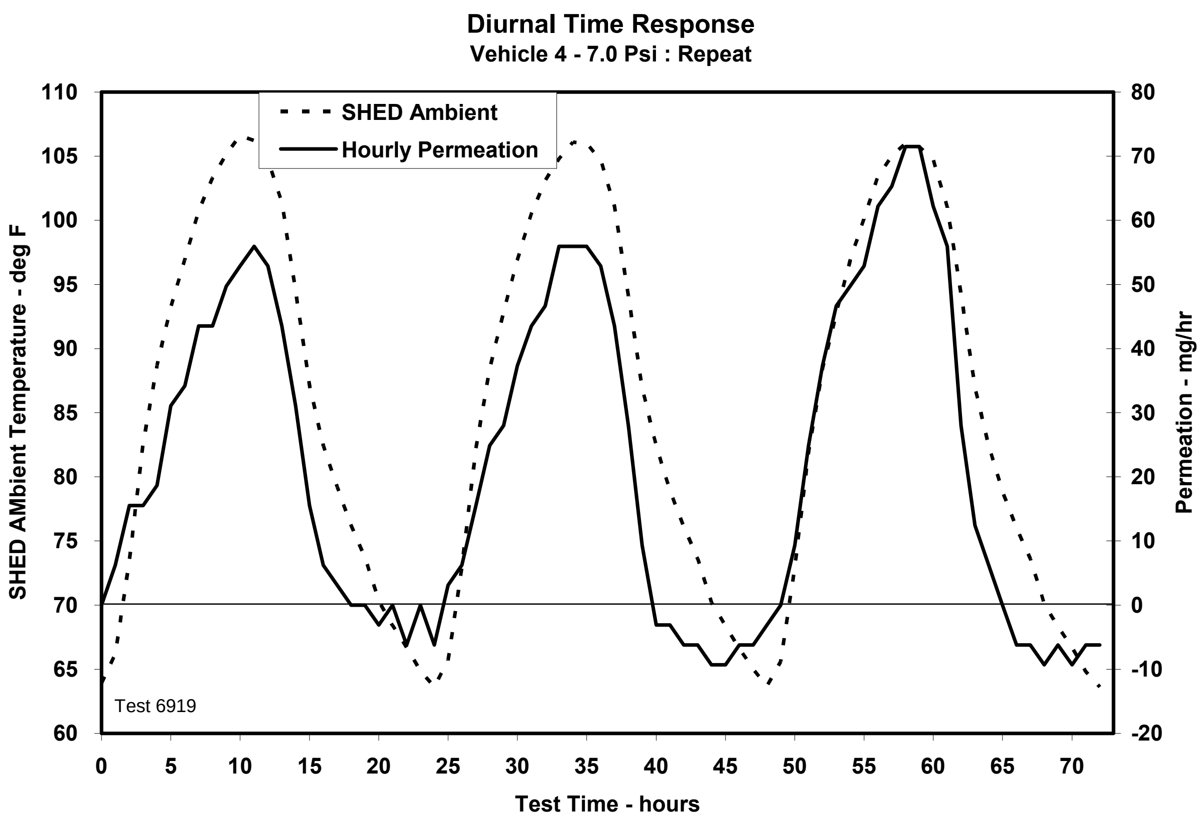
Vehicle 4

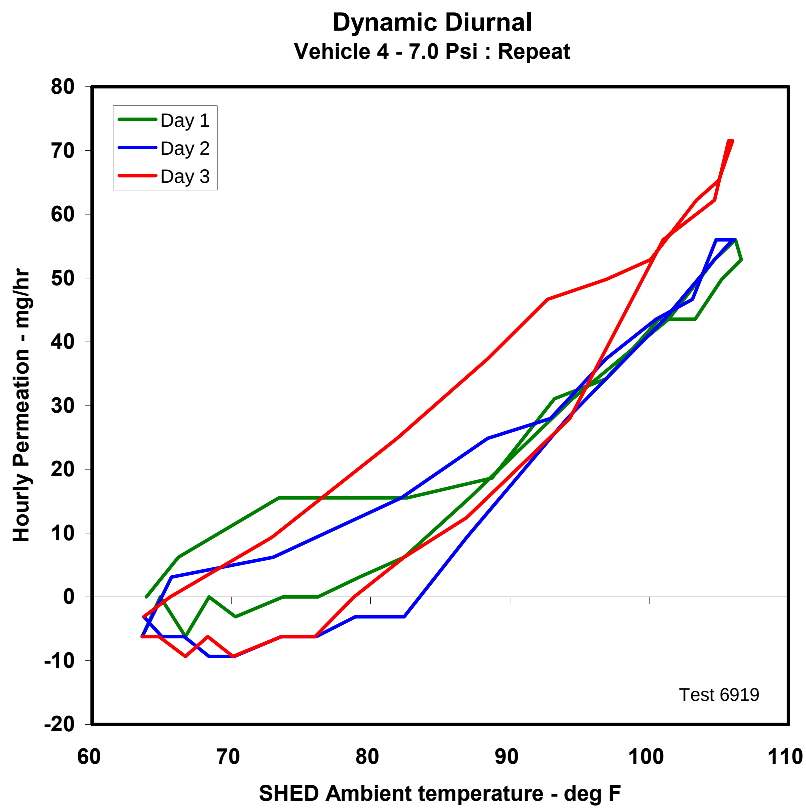
1999 Dodge Caravan Enhanced

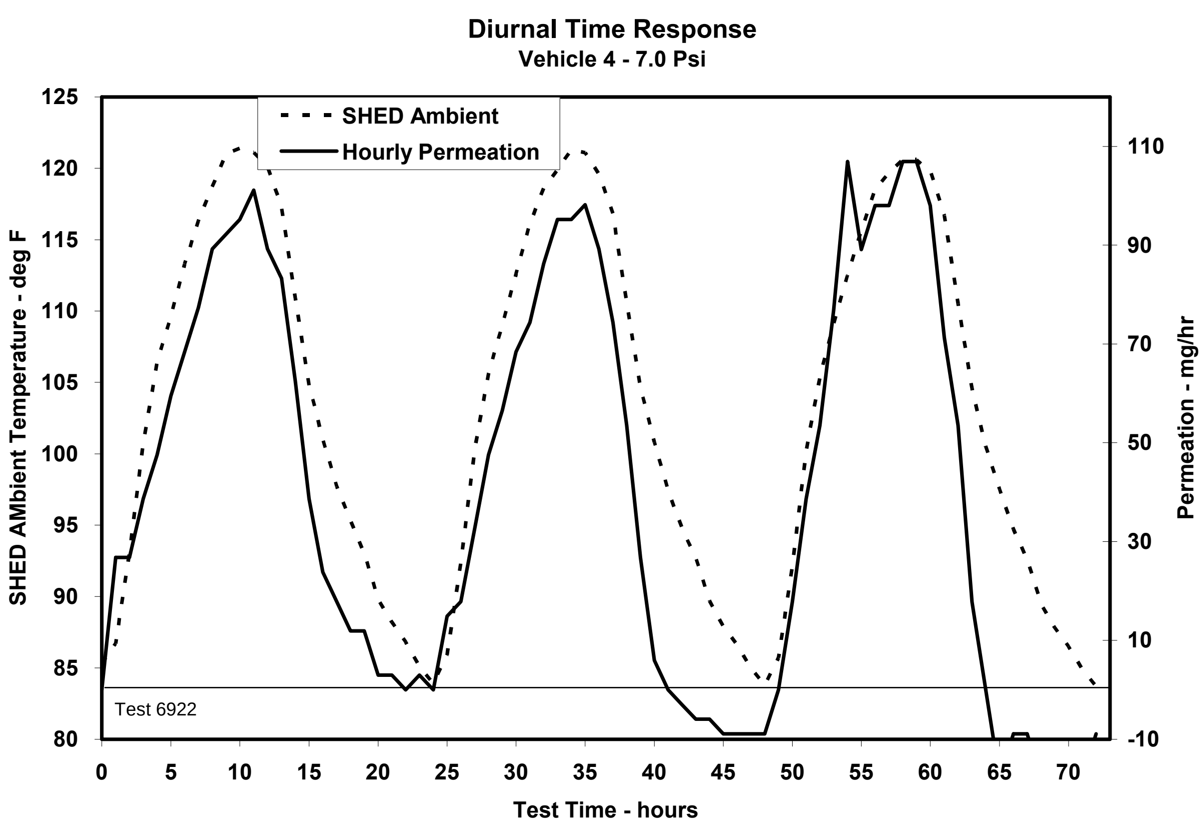
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
4	7.0	Static	Perm	08/09/06	6912	50.3			
			Press. Incr.			0.0			
			Prs+Fuel Incr.			0.0			
	7.0	Dynamic	RL	08/10/06	25636	184.6			
			HS			73.5			
			RL + HS			258.1			
	7.0	72 DHB	65-105	08/22/06	6919	Day 1	503.7		0.00
						Day 2	454.0		0.00
						Day 3	606.3		0.00
	7.0	72 DHB	85-120	08/29/06	6922	Day 1	1070.9		0.00
						Day 2	886.5		0.48
						Day 3	1804.1		0.31
	9.0	72 DHB	65-105	09/03/06	6926	Day 1	695.9		0.00
						Day 2	556.7		1.19
						Day 3	665.0		12.85
	9.0	72 DHB	85-120	09/07/06	6927	Day 1	1396.4		23.79
						Day 2	1175.1		71.43
						Day 3	1114.9		80.49

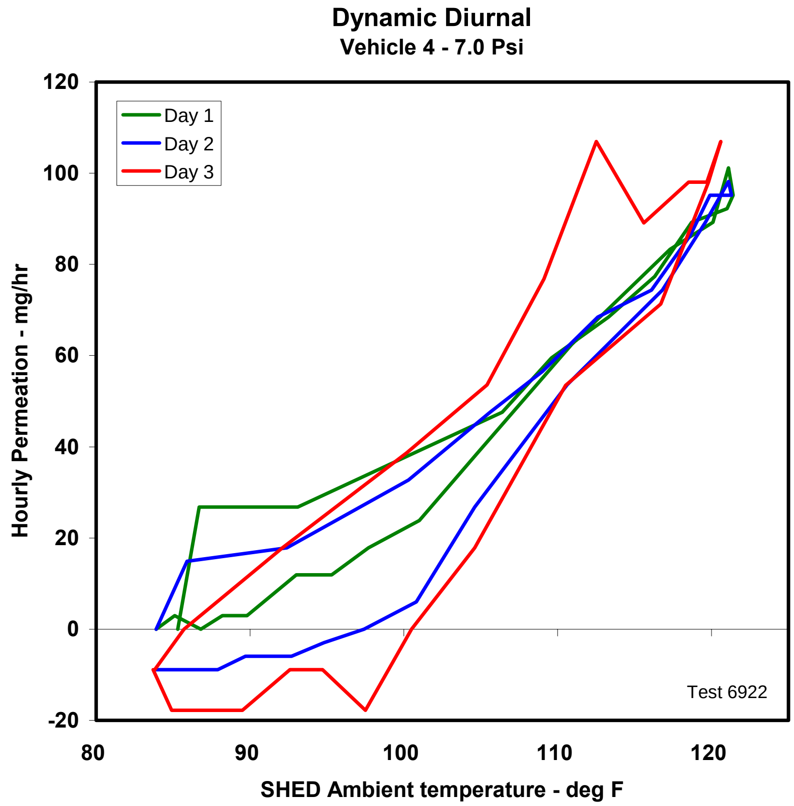


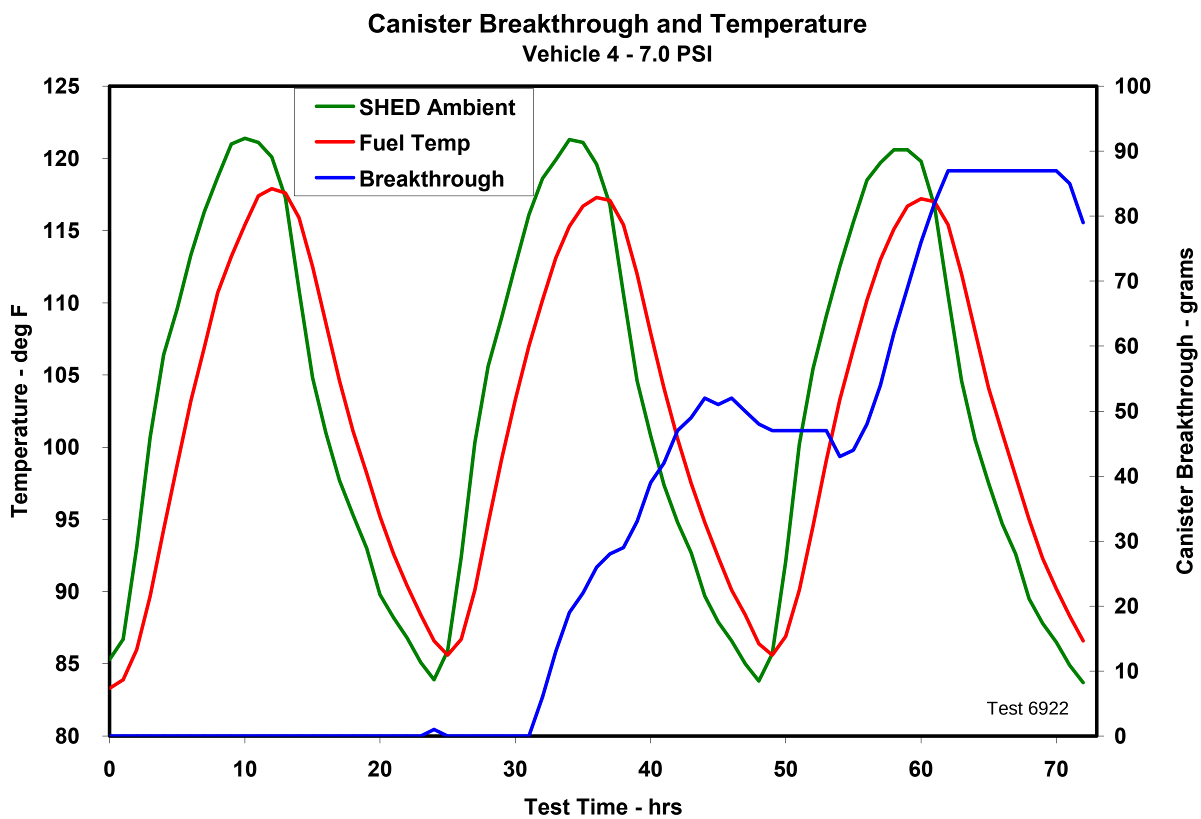

Running Loss and Hot Soak
Vehicle 4 - 7.0 Psi
Running Loss
Hot Soak
Running Loss Std. =0.05 g/mi
This Test = 0.009 g/mi
y = -0.0087x2 + 2.3904x + 104.51
R2 = 0.9004
y = -0.0398x2 + 5.5741x
R2 = 0.9865
Test 25636
Cumulative Permeation - mg
Test Time - minutes
0
50
100
150
200
250
300
0
20
40
60
80
100
120

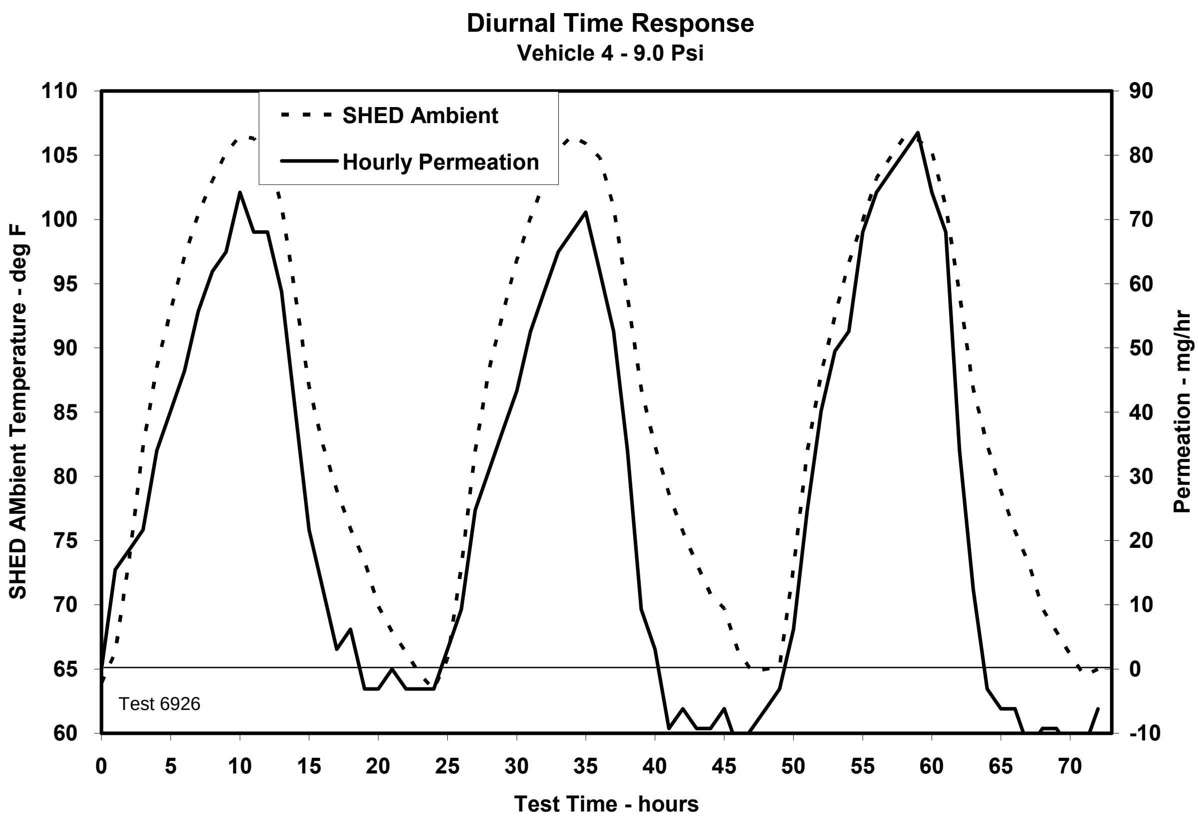

Diurnal Time Response
Vehicle 4 - 7.0 Psi : Repeat
SHED Ambient
Hourly Permeation
Test 6919
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-20
-10
0
10
20
30
40
50
60
70
80
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Dynamic Diurnal
Vehicle 4 - 7.0 Psi : Repeat
Day 1
Day 2
Day 3
Test 6919
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
80
70
60
50
40
30
20
10
0
-10
-20
60
70
80
90
100
110

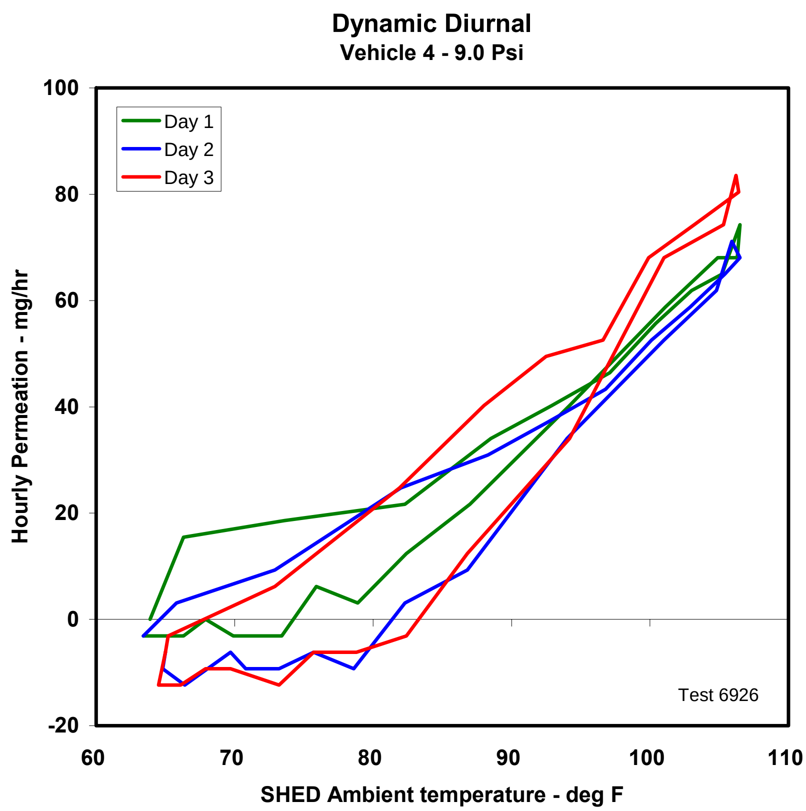

Diurnal Time Response
Vehicle 4 - 7.0 Psi
SHED Ambient
Hourly Permeation
Test 6922
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
125
120
115
110
105
100
95
90
85
80
110
90
70
50
30
10
-10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Dynamic Diurnal
Vehicle 4 - 7.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6922
120
100
80
60
40
20
0
-20
80
90
100
110
120

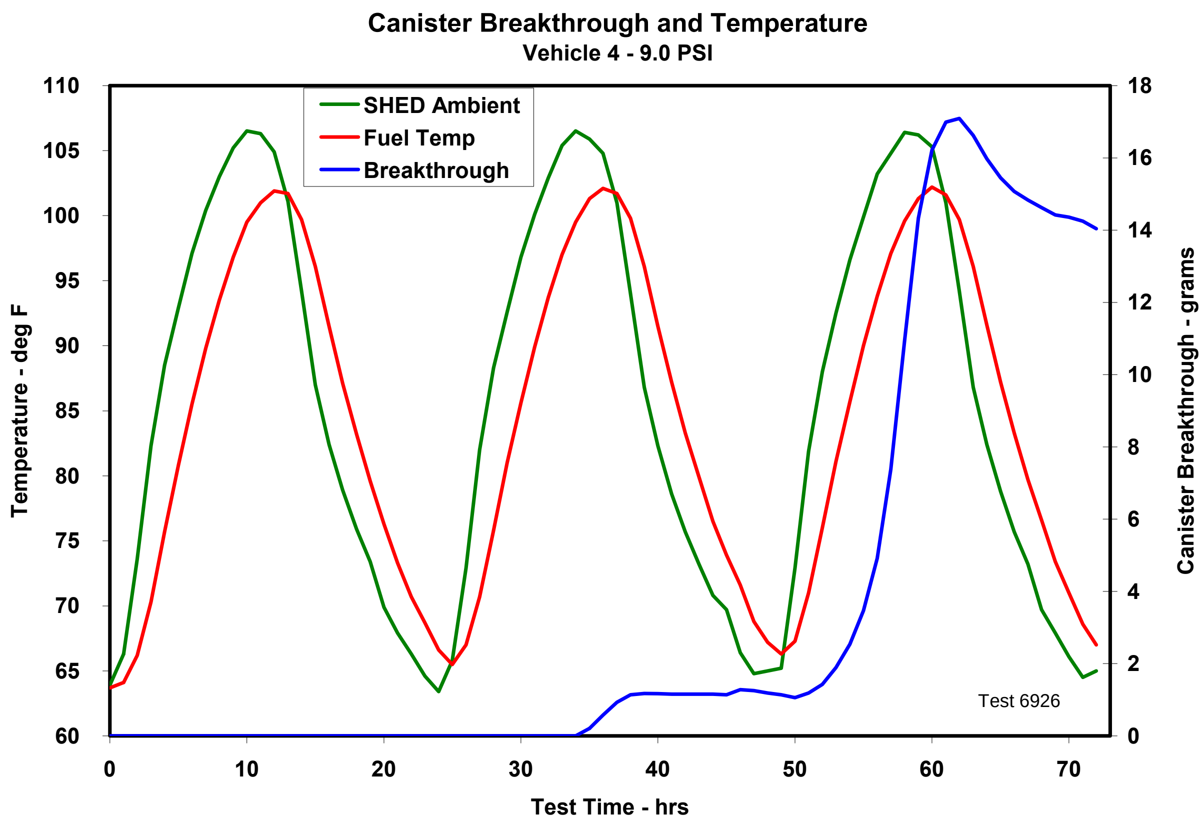

Canister Breakthrough and Temperature
Vehicle 4 - 7.0 PSI
SHED Ambient
Fuel Temp
Breakthrough
Temperature - deg F
Canister Breakthrough - grams
Test Time - hrs
Test 6922
125
120
115
110
105
100
95
90
85
80
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70

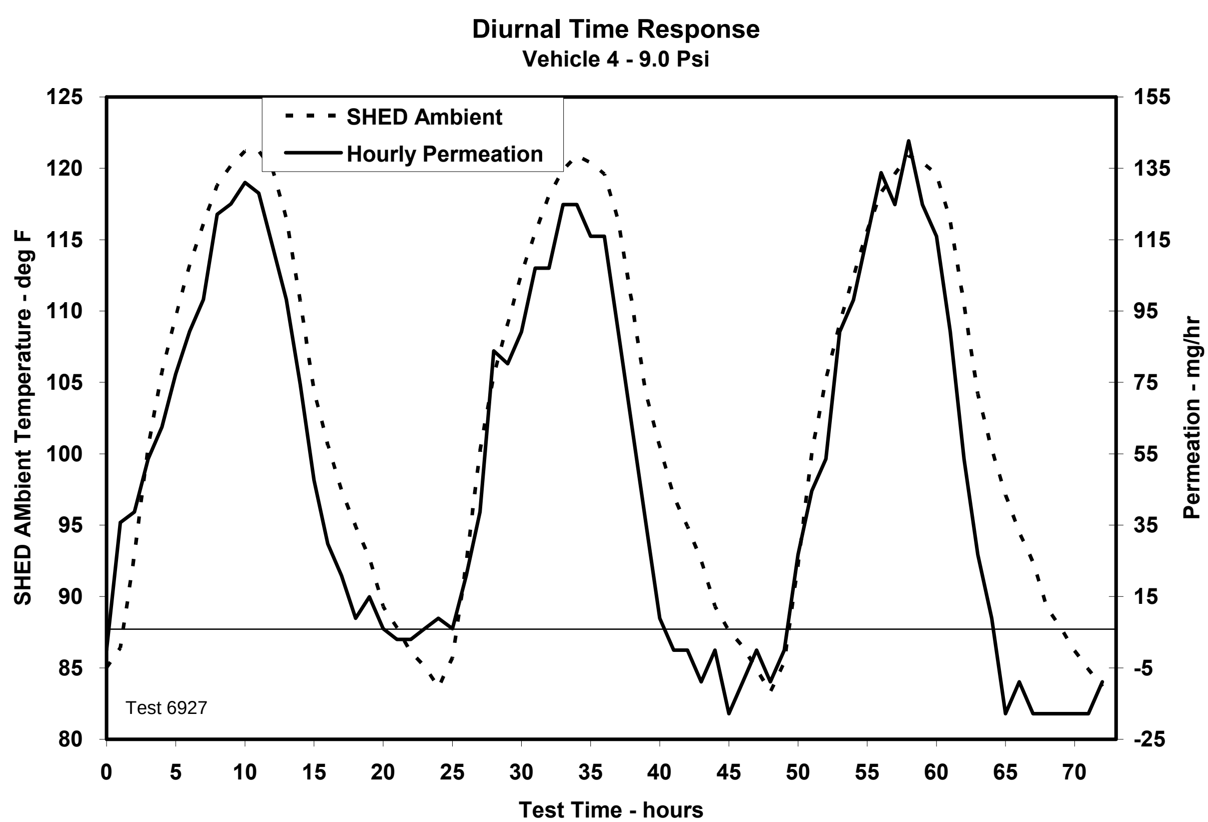


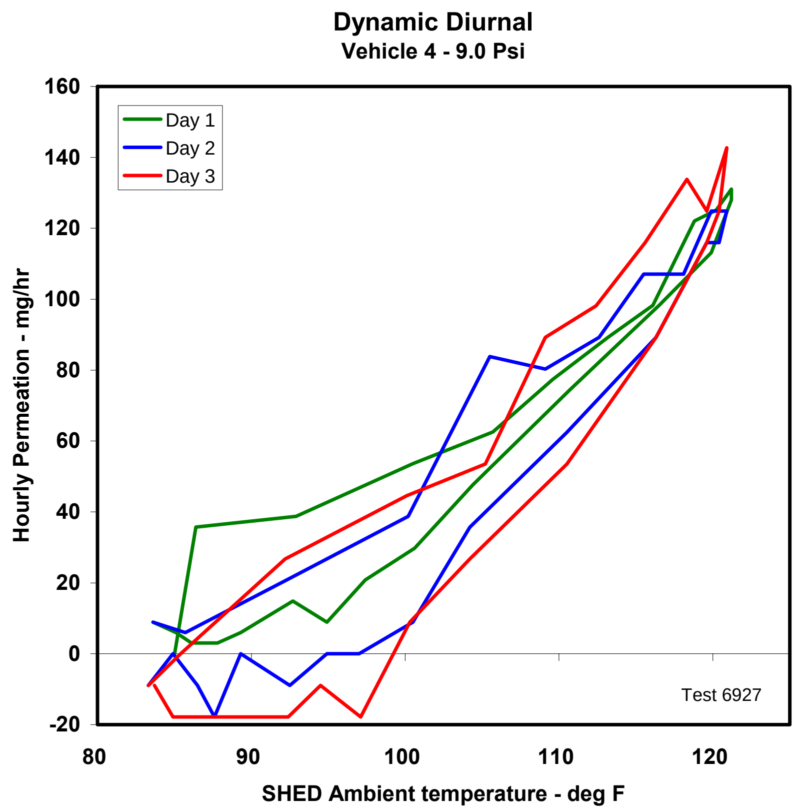
Diurnal Time Response
Vehicle 4 - 9.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
Test 6926
110
105
100
95
90
85
80
75
70
65
60
90
80
70
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70

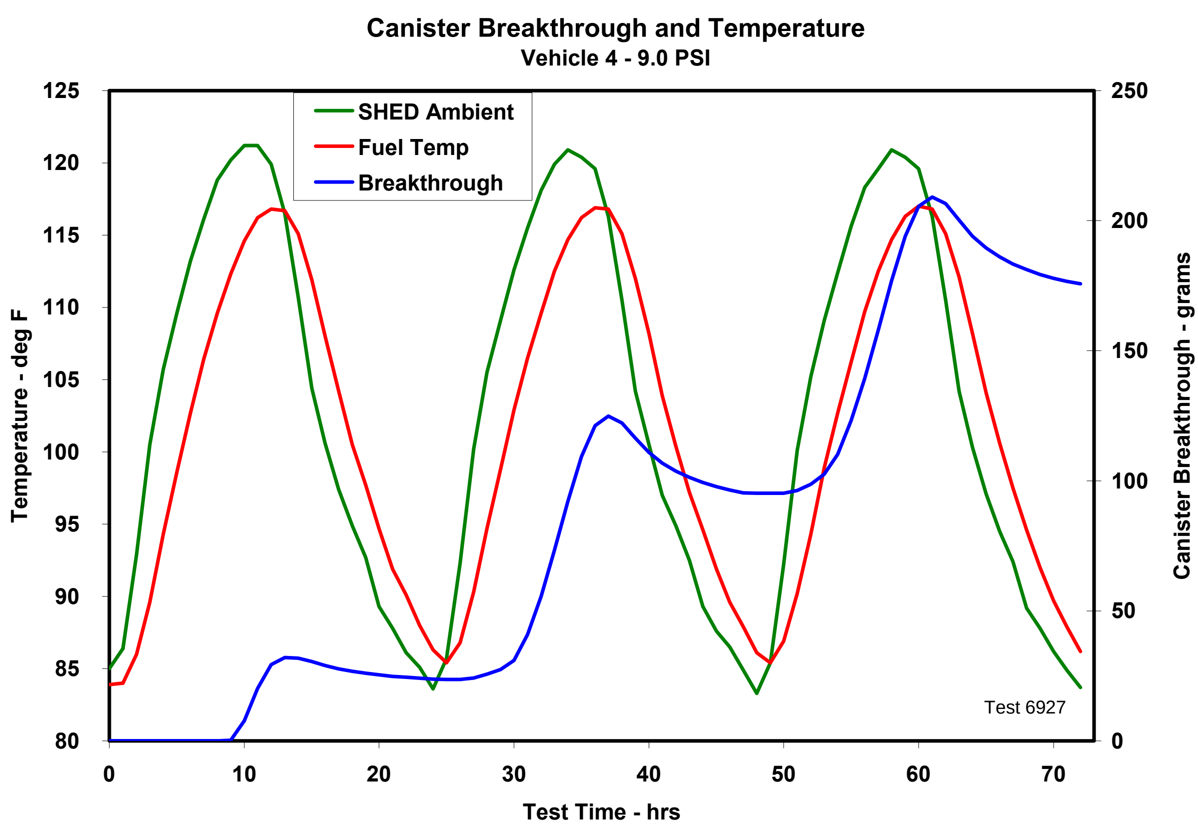


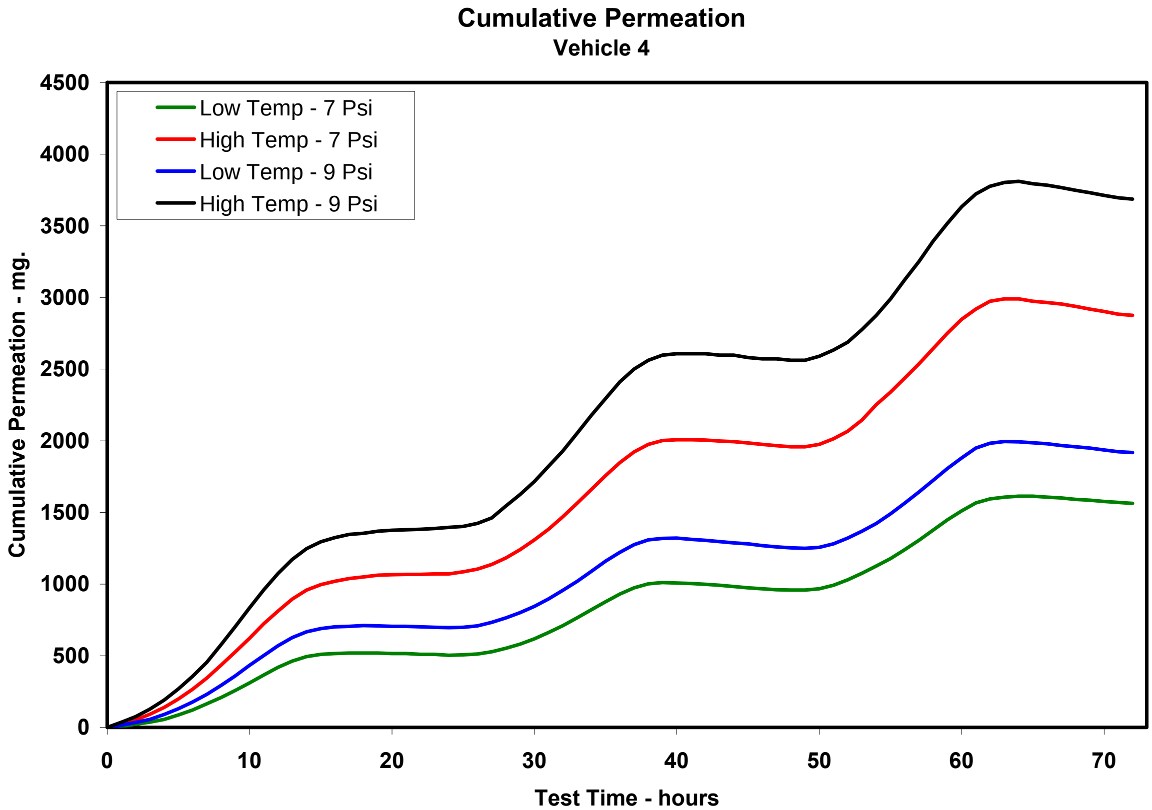
Dynamic Diurnal
Vehicle 4 - 9.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6926
100
80
60
40
20
0
-20
60
70
80
90
100
110

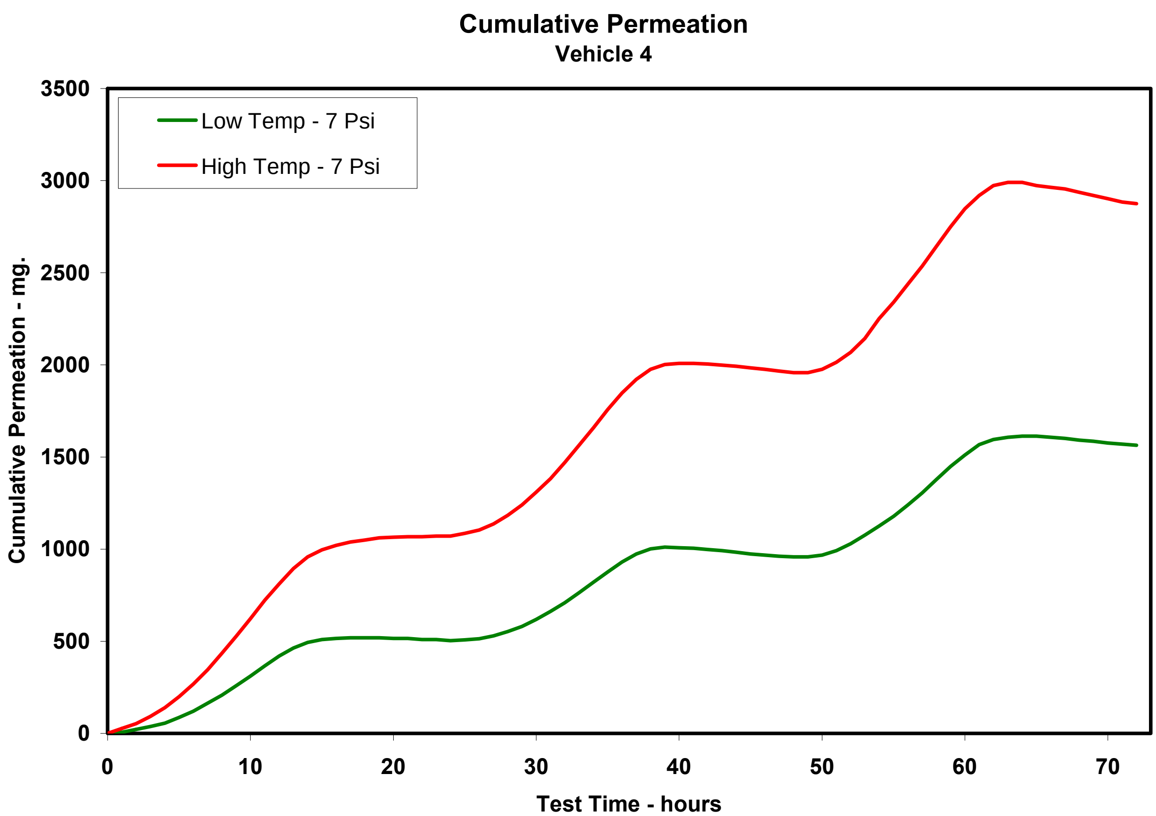

Canister Breakthrough and Temperature
Vehicle 4 - 9.0 PSI
SHED Ambient
Fuel Temp
Breakthrough
Temperature - deg F
Canister Breakthrough - grams
Test Time - hrs
Test 6926
110
105
100
95
90
85
80
75
70
65
60
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70


Diurnal Time Response
Vehicle 4 - 9.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
Test 6927
125
120
115
110
105
100
95
90
85
80
155
135
115
95
75
55
35
15
-5
-25
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Dynamic Diurnal
Vehicle 4 - 9.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
160
140
120
100
80
60
40
20
0
-20
80
90
100
110
120
SHED Ambient temperature - deg F
Test 6927

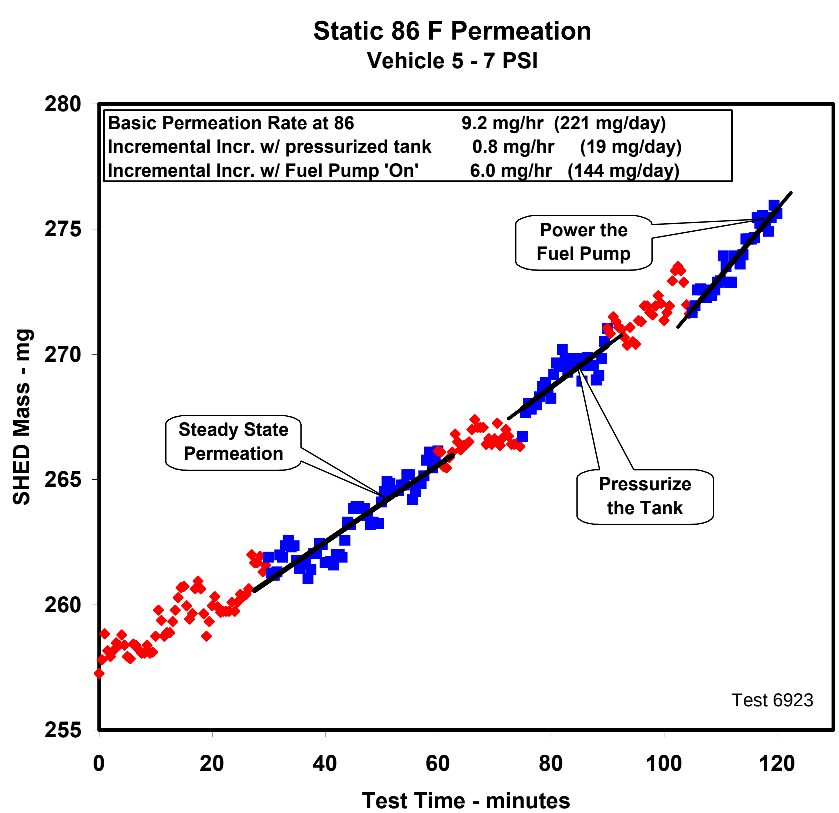

Canister Breakthrough and Temperature
Vehicle 4 - 9.0 PSI
SHED Ambient
Fuel Temp
Breakthrough
Temperature - deg F
125
120
115
110
105
100
95
90
85
80
Canister Breakthrough - grams
250
200
150
100
50
0
0
10
20
30
40
50
60
70
Test Time - hrs
Test 6927

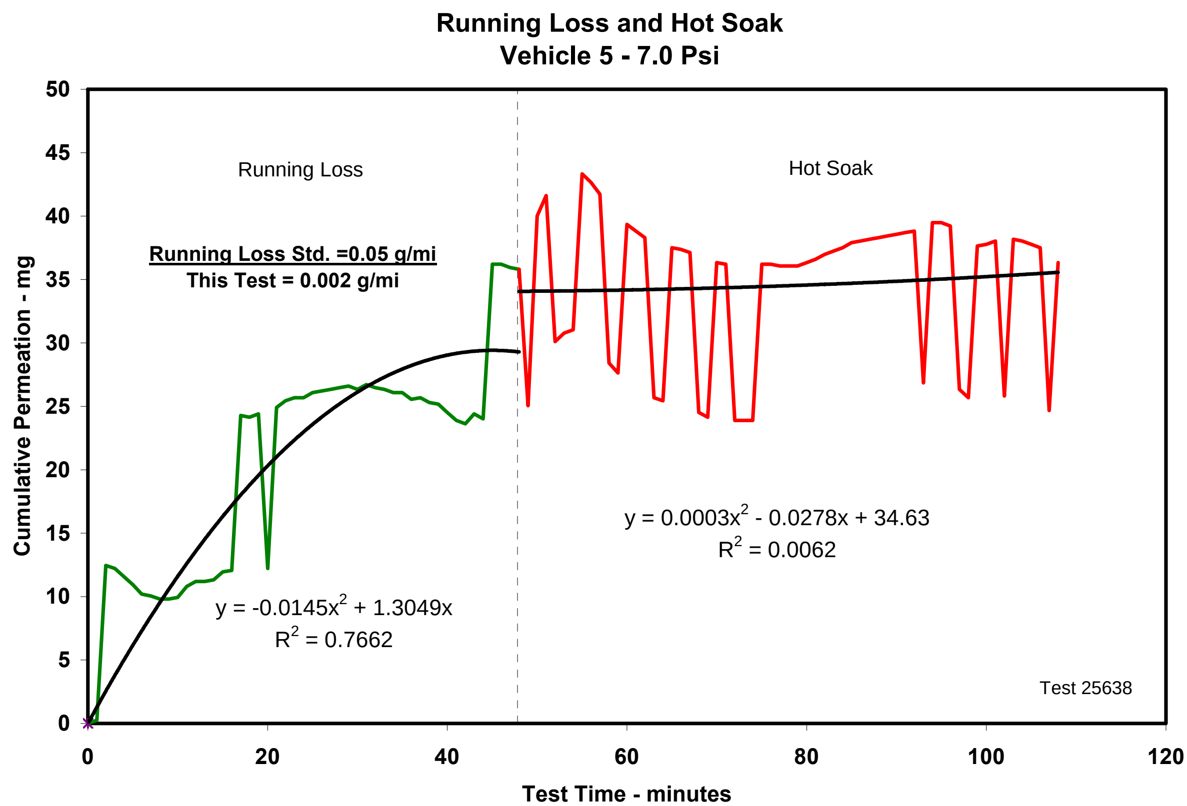

Cumulative Permeation
Vehicle 4
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
0
10
20
30
40
50
60
70
Test Time - hours

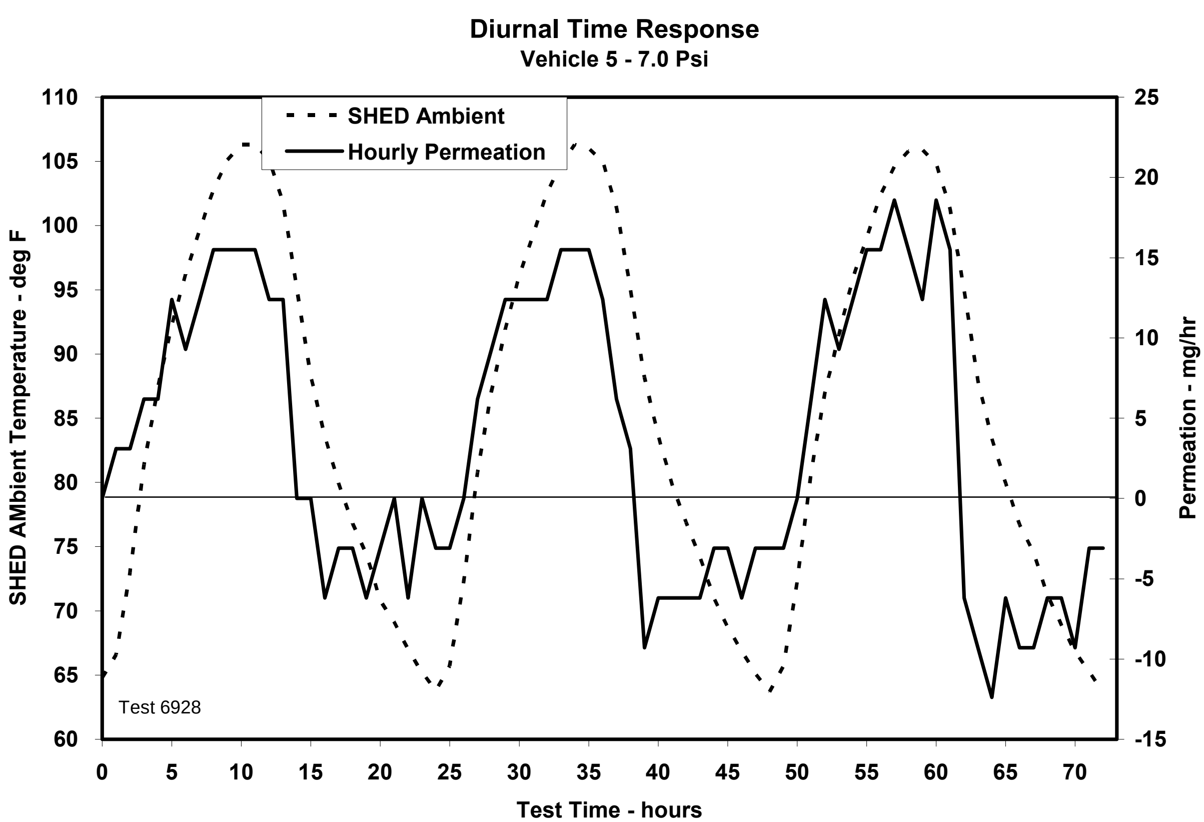

Cumulative Permeation
Vehicle 4
3500
3000
2500
2000
1500
1000
500
0
Low Temp - 7 Psi
High Temp - 7 Psi
Cumulative Permeation - mg.
0
10
20
30
40
50
60
70
Test Time - hours

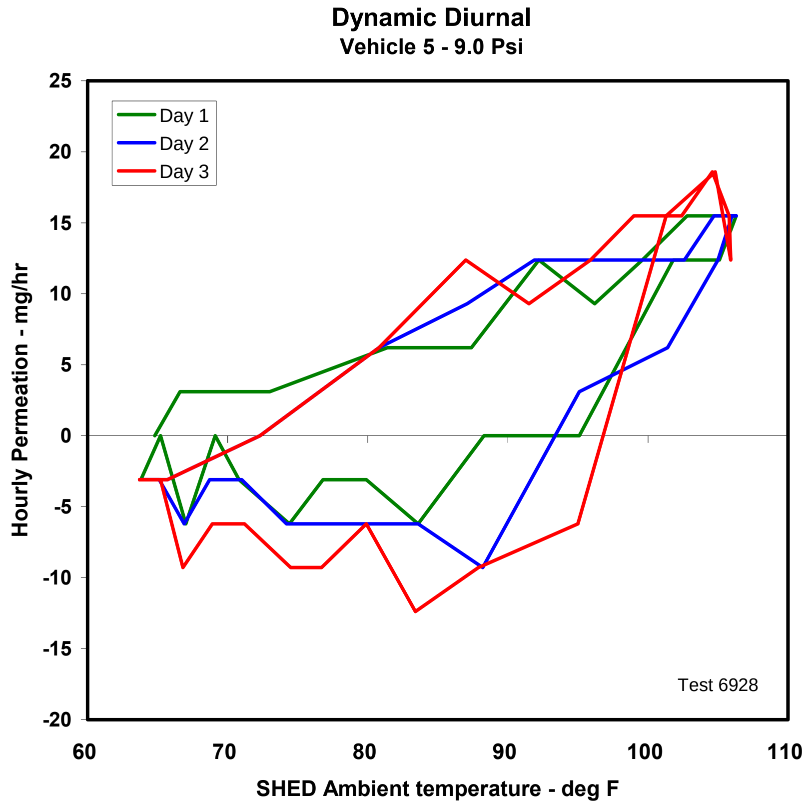
Vehicle 5

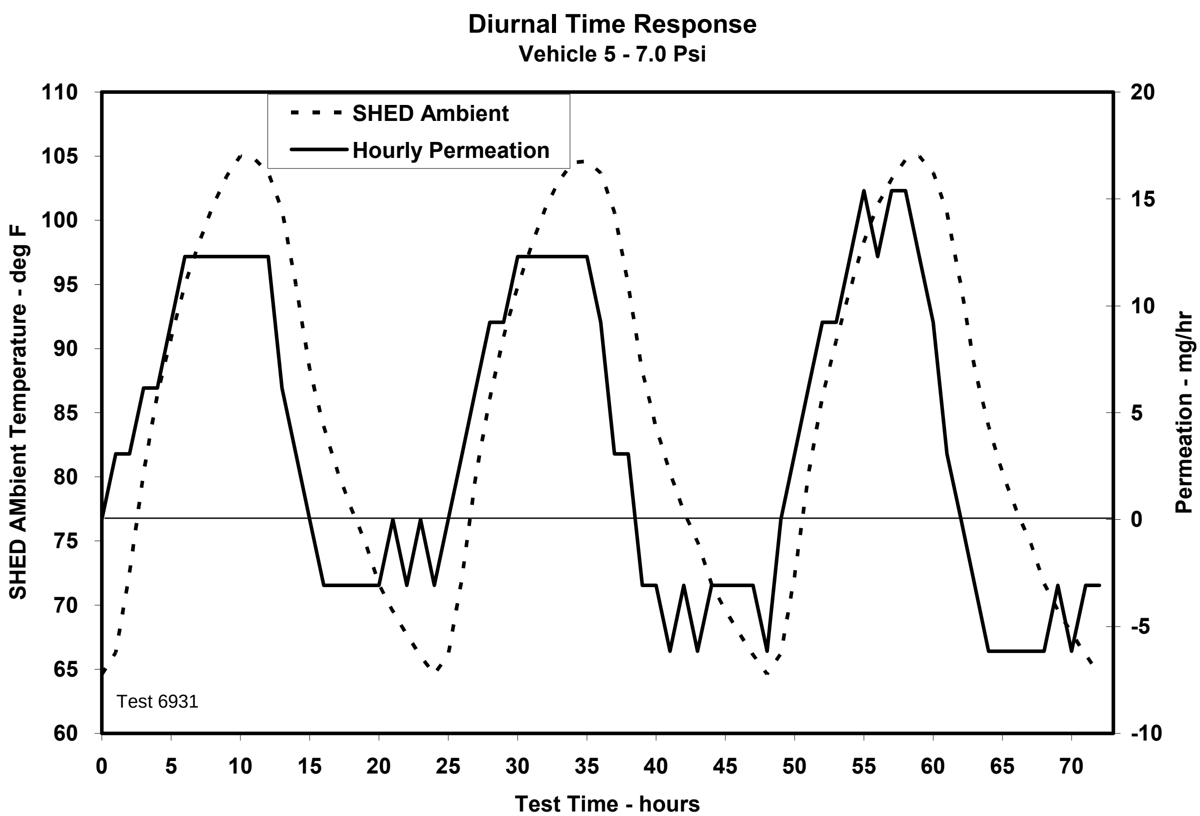
2007 Ford Taurus			LEV II				SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
Veh	**Fuel**	**Test**	**Type**	**Date**	**Test#**	**Permeation mg/hr**			
5	7.0	Static	Perm	08/30/06	6923	9.2			
			Press. Incr.			0.8			
			Prs+Fuel Incr.			6.8			
	7.0	Dynamic	RL	09/07/06	25638	35.8			
			HS			0.5			
			RL + HS			36.3			
	7.0	72 DHB	65-105	09/09/06	6928	Day 1	108.4		0.00
						Day 2	52.7		0.00
						Day 3	92.9		0.00
	7.0	72 DHB	65-105	09/15/06	6931	Day 1	101.5		0.00
						Day 2	55.4		0.00
						Day 3	95.4		0.00
	7.0	72 DHB	85-120	09/19/06	6933	Day 1	196.9		0.00
						Day 2	146.2		0.00
						Day 3	134.2		0.00

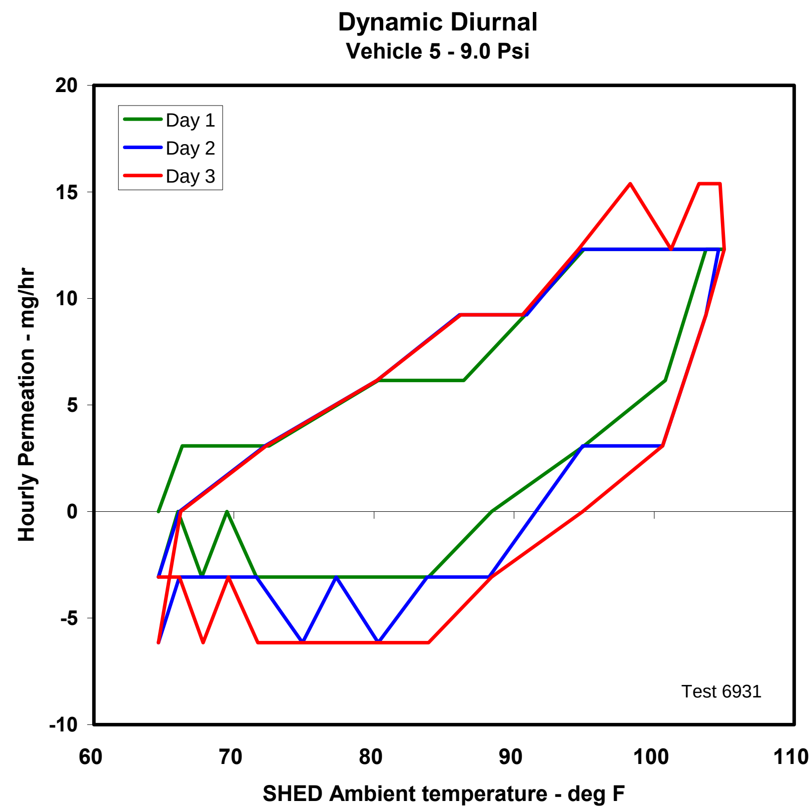



Running Loss and Hot Soak
Vehicle 5 - 7.0 Psi
Running Loss
Hot Soak
Running Loss Std. =0.05 g/mi
This Test = 0.002 g/mi
y = 0.0003x2 - 0.0278x + 34.63
R2 = 0.0062
y = -0.0145x2 + 1.3049x
R2 = 0.7662
Test 25638
Cumulative Permeation - mg
Test Time - minutes
0
5
10
15
20
25
30
35
40
45
50
0
20
40
60
80
100
120

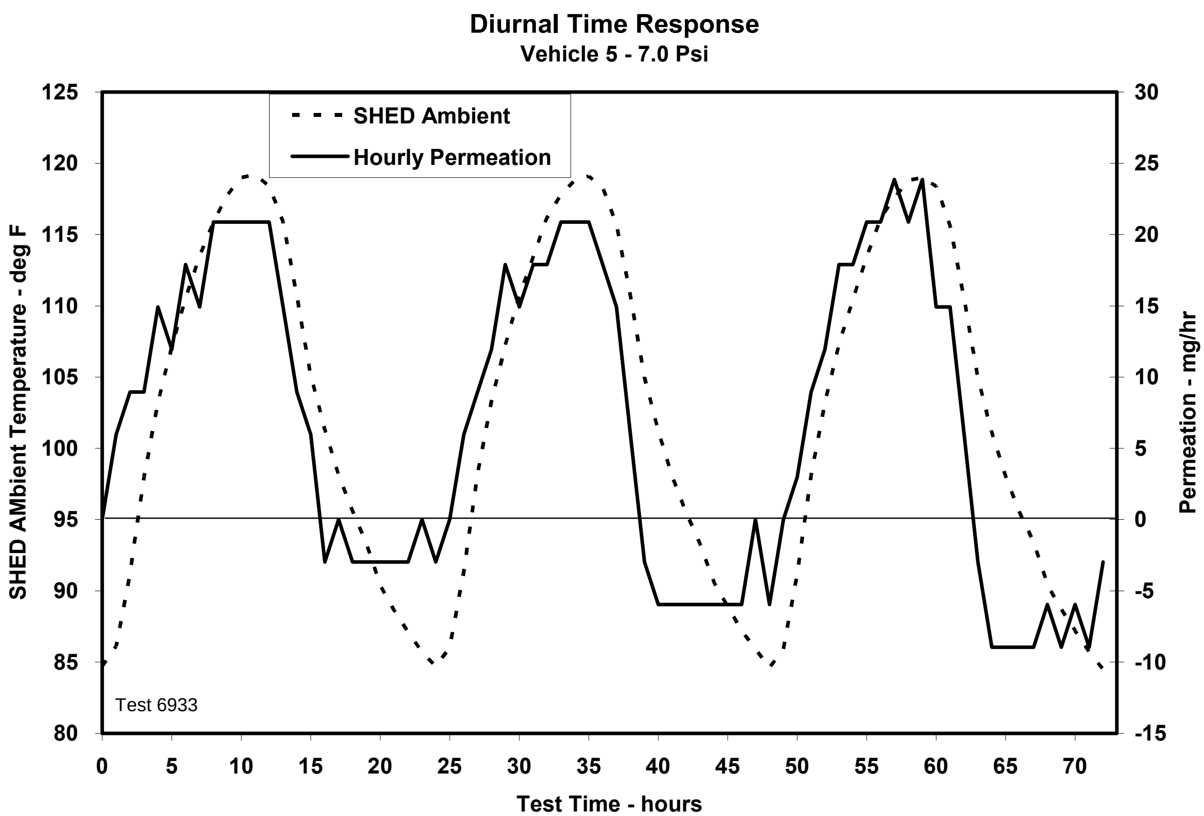

Diurnal Time Response
Vehicle 5 - 7.0 Psi
SHED Ambient
Hourly Permeation
Test 6928
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-15
-10
-5
0
5
10
15
20
25
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Dynamic Diurnal
Vehicle 5 - 9.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6928
25
20
15
10
5
0
-5
-10
-15
-20
60
70
80
90
100
110

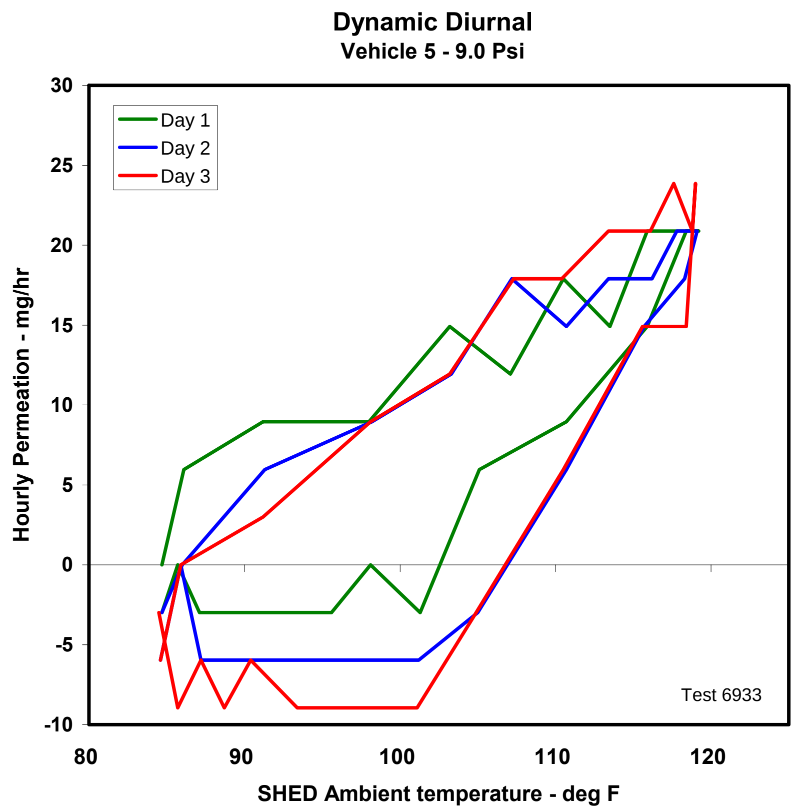

Diurnal Time Response
Vehicle 5 - 7.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
Test 6931
110
105
100
95
90
85
80
75
70
65
60
20
15
10
5
0
-5
-10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70



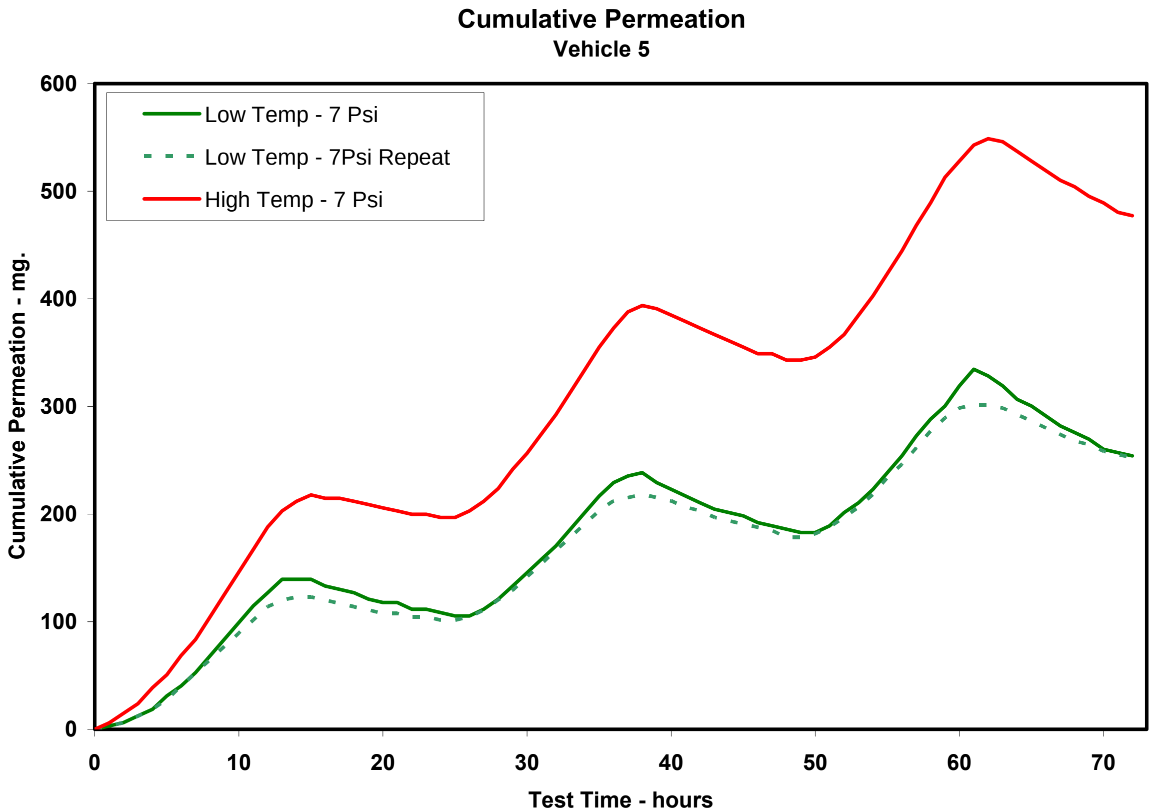
Dynamic Diurnal
Vehicle 5 - 9.0 Psi
Day 1
Day 2
Day 3
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6931
20
15
10
5
0
-5
-10
60
70
80
90
100
110



Diurnal Time Response
Vehicle 5 - 7.0 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Permeation - mg/hr
Test Time - hours
Test 6933
125
120
115
110
105
100
95
90
85
80
30
25
20
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70



Dynamic Diurnal
Vehicle 5 - 9.0 Psi
Day 1
Day 2
Day 3
Test 6933
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
30
25
20
15
10
5
0
-5
-10
80
90
100
110
120

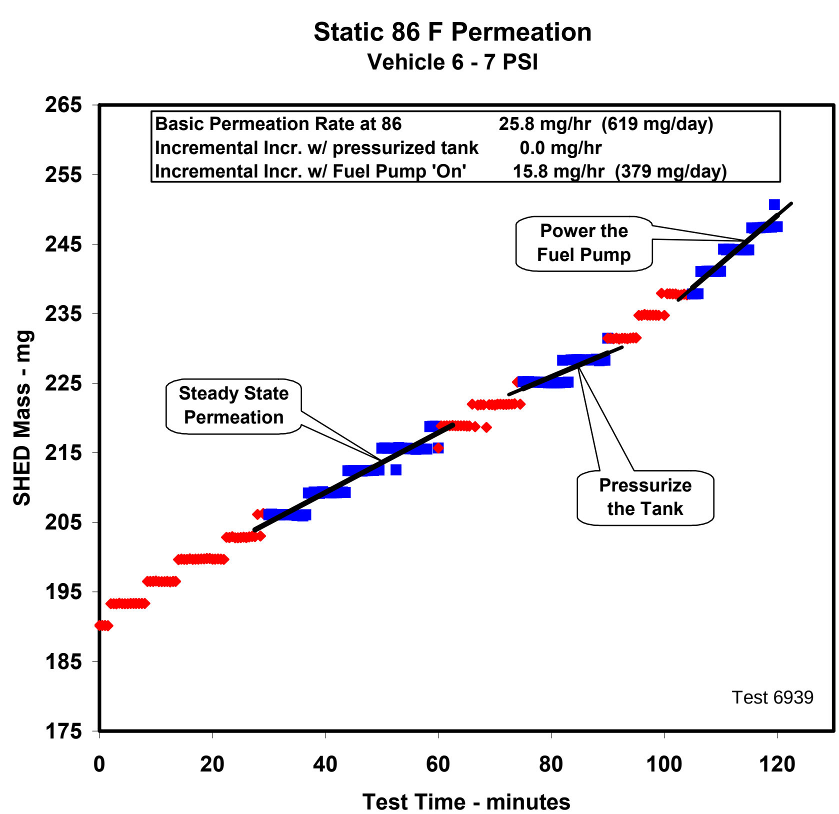


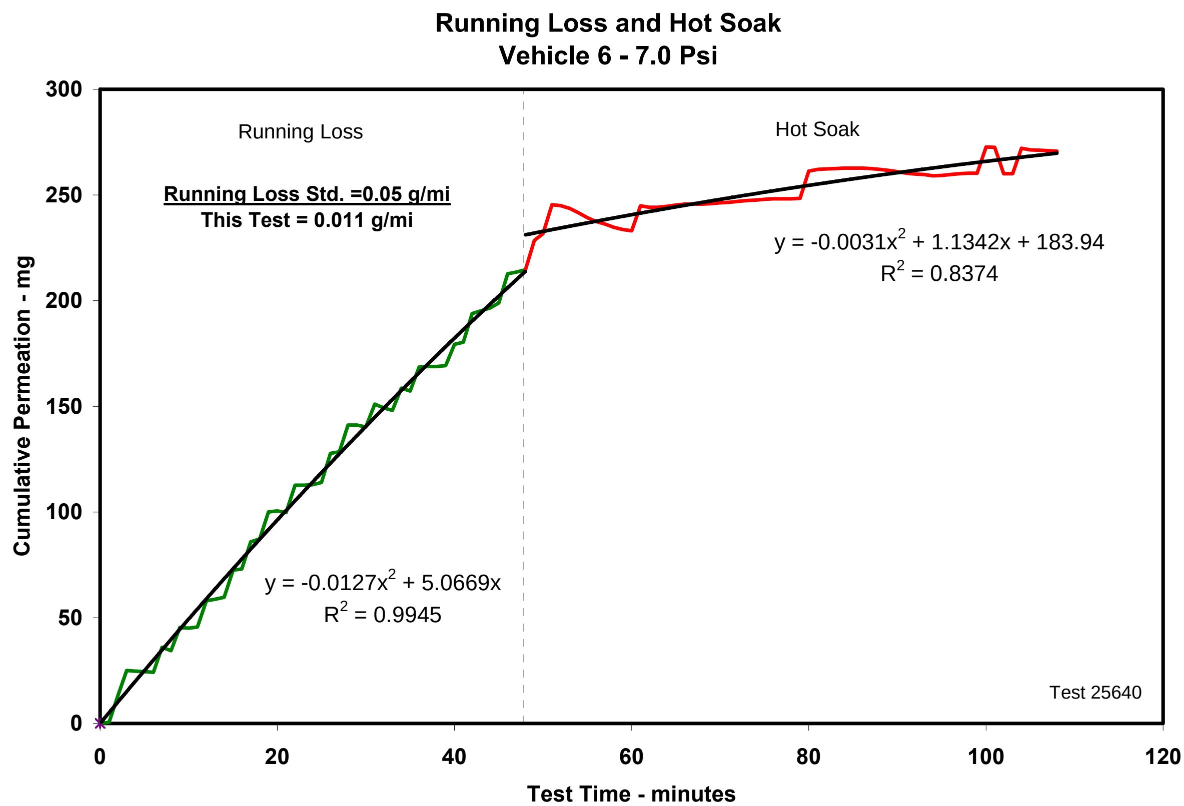
Cumulative Permeation
Vehicle 5
Low Temp - 7 Psi
Low Temp - 7Psi Repeat
High Temp - 7 Psi
Cumulative Permeation - mg.
Test Time - hours
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70

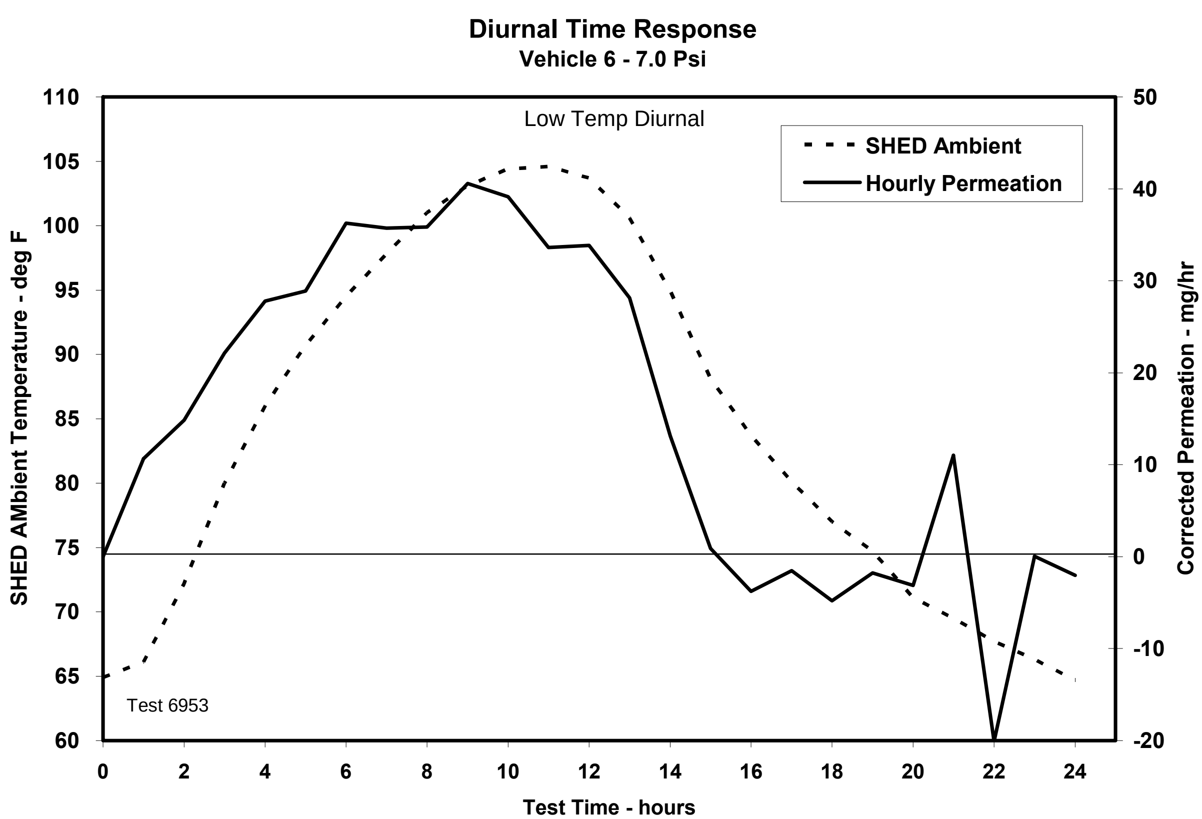
Vehicle 6

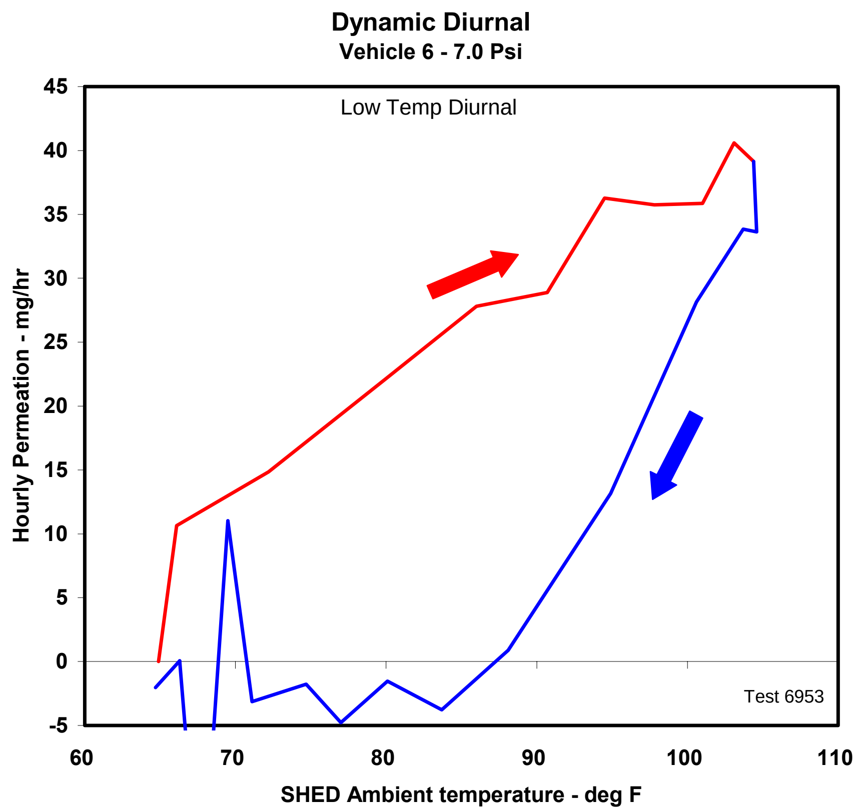
1996 Chevrolet Cavalier

Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
6	7.0	Static	Perm	09/27/06	6939	25.8			
			Press. Incr.			0.0			
			Prs+Fuel Incr.			15.8			
	7.0	Dynamic	RL	09/27/06	25640	214.6			
			HS			56.1			
			RL + HS			270.8			
	7.0	24 DHB	65-105	10/19/06	6953	Day 1	477.3	375.6	0.00
	7.0	24 DHB	85-120	10/24/06	6955	Day 1	468.2	372.0	0.00
	9.0	24 DHB	65-105	11/02/06	6959	Day 1	569.2	468.5	0.00
	9.0	24 DHB	85-120	11/08/06	6961	Day 1	785.1	685.4	18.92

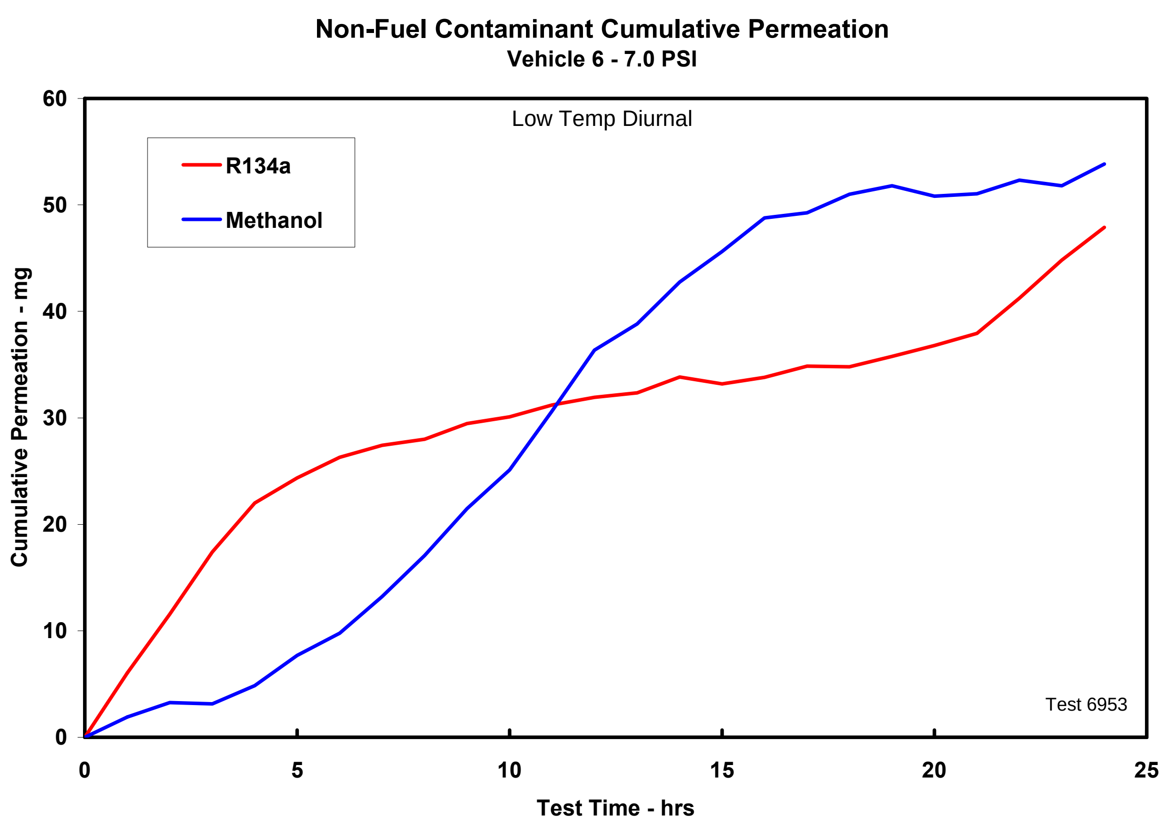



Running Loss and Hot Soak
Vehicle 6 - 7.0 Psi
Running Loss
Hot Soak
Running Loss Std. =0.05 g/mi
This Test = 0.011 g/mi
y = -0.0031x2 + 1.1342x + 183.94
R2 = 0.8374
y = -0.0127x2 + 5.0669x
R2 = 0.9945
Test 25640
Cumulative Permeation - mg
Test Time - minutes
300
250
200
150
100
50
0
0
20
40
60
80
100
120

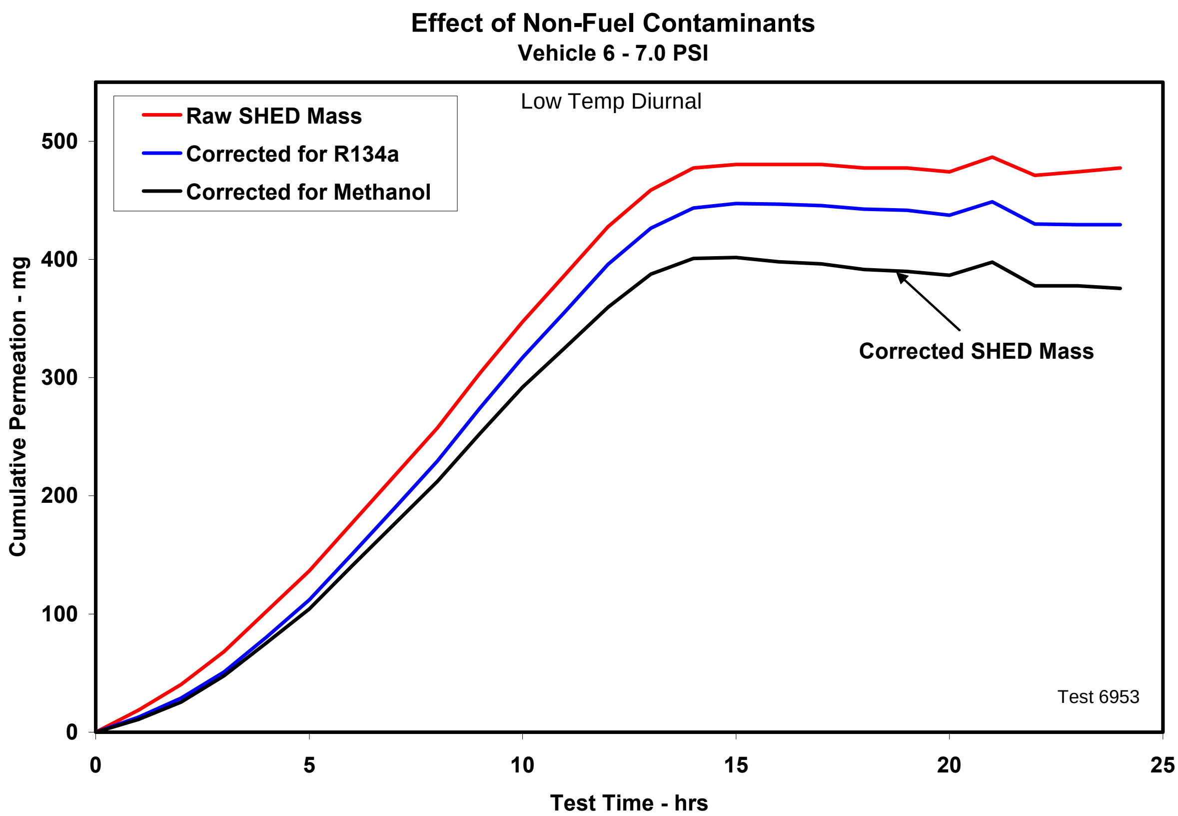

Diurnal Time Response
Vehicle 6 - 7.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6953
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
110
105
100
95
90
85
80
75
70
65
60
50
40
30
20
10
0
-10
-20
0
2
4
6
8
10
12
14
16
18
20
22
24

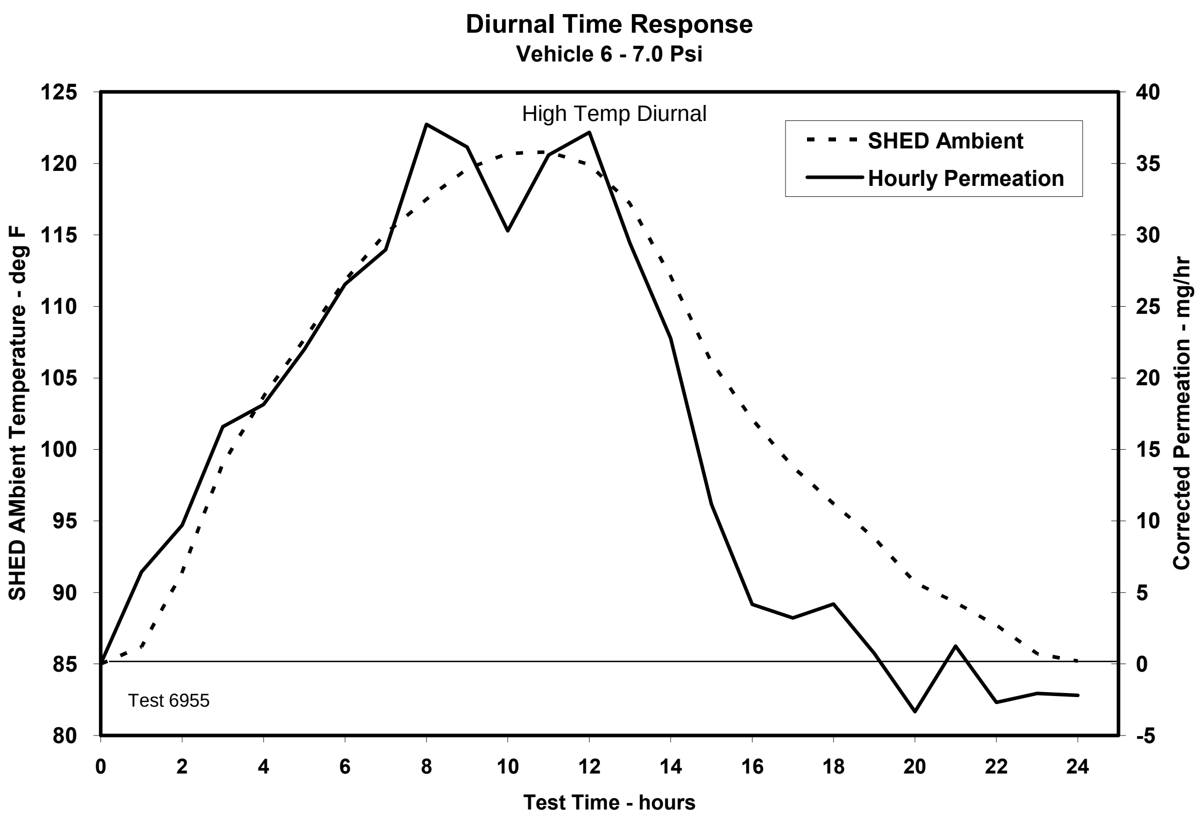


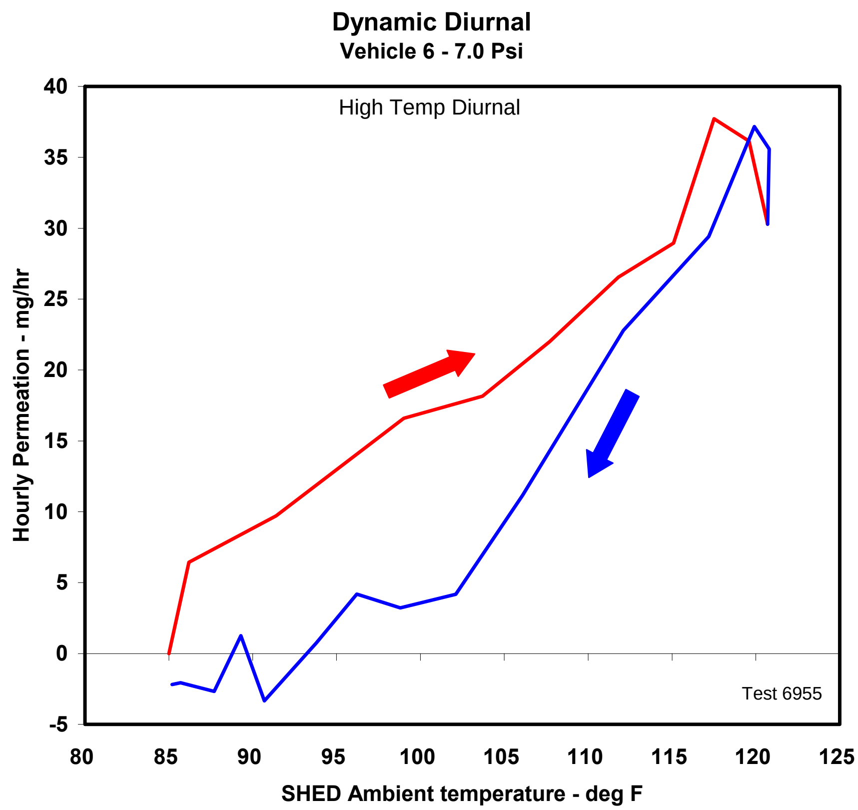
Dynamic Diurnal
Vehicle 6 - 7.0 Psi
Low Temp Diurnal
Hourly Permeation - mg/hr
45
40
35
30
25
20
15
10
5
0
-5
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6953

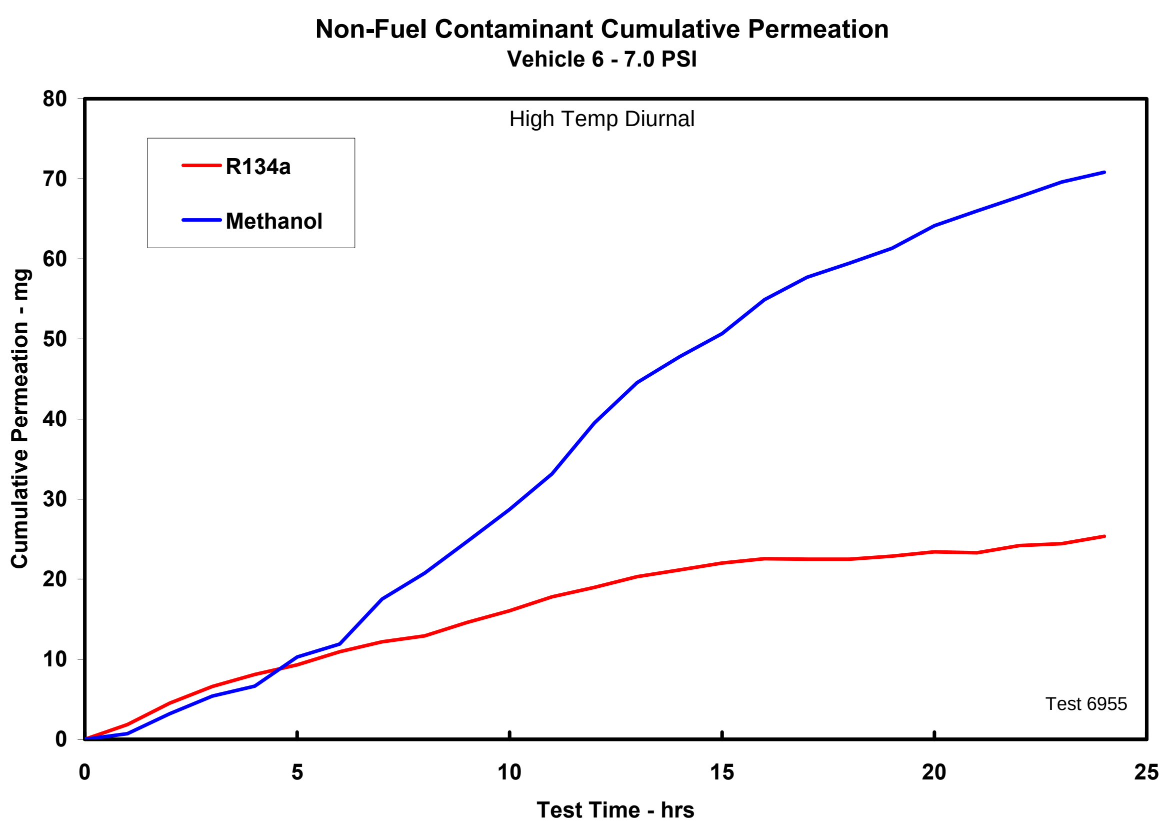


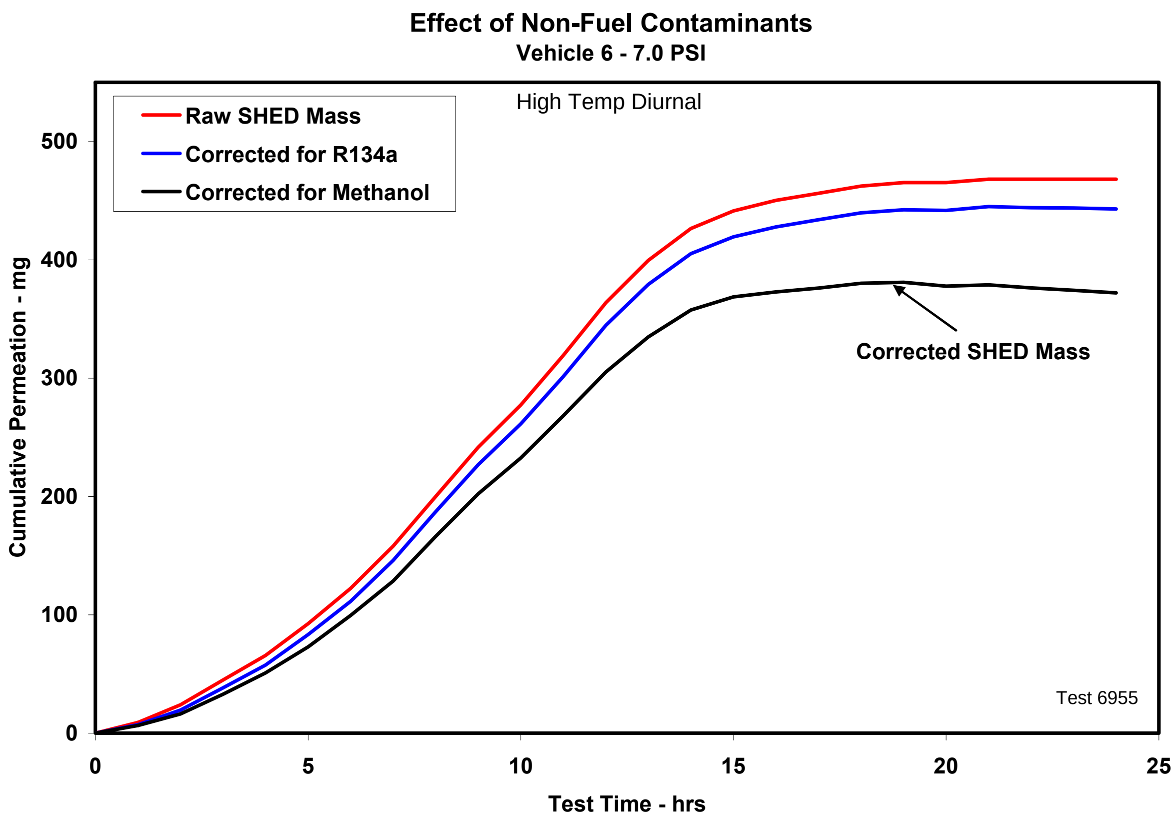
Non-Fuel Contaminant Cumulative Permeation
Vehicle 6 - 7.0 PSI
Low Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
60
50
40
30
20
10
0
0
5
10
15
20
25
Test Time - hrs
Test 6953

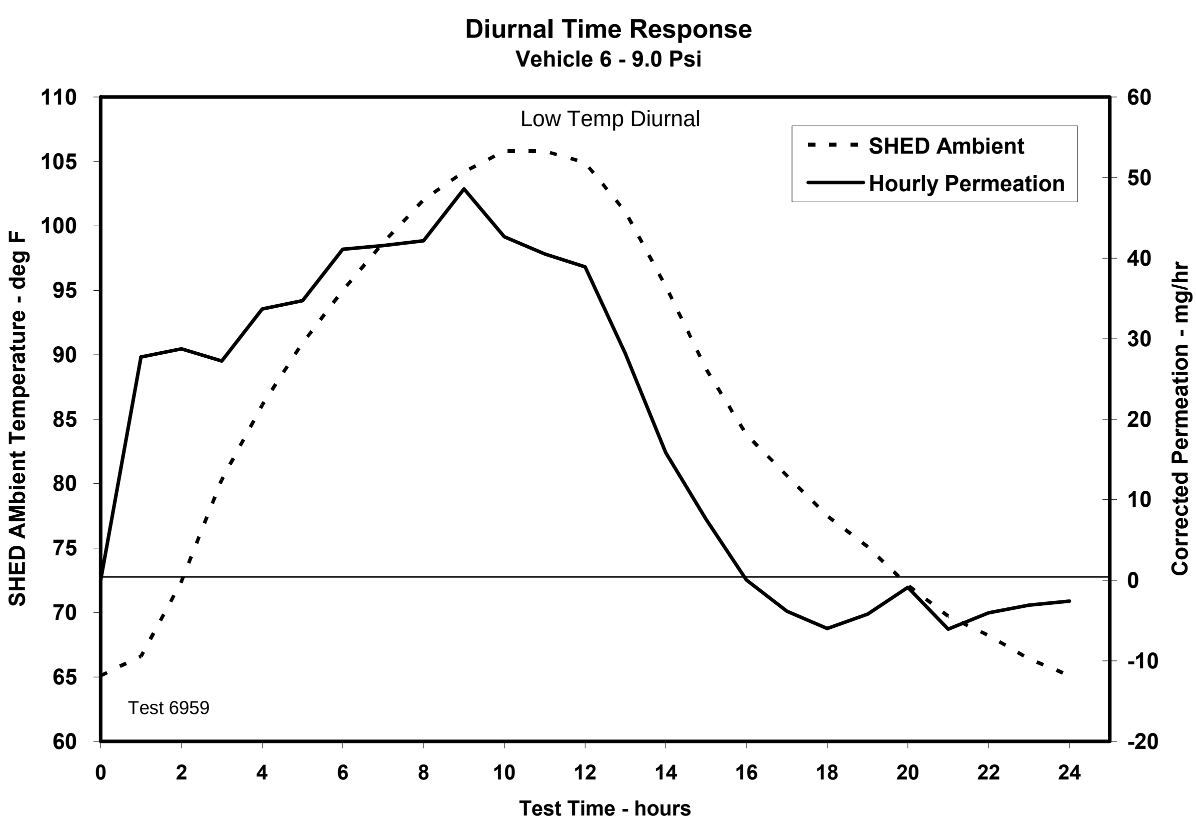

Effect of Non-Fuel Contaminants
Vehicle 6 - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6953
Cumulative Permeation - mg
Test Time - hrs
0
100
200
300
400
500
0
5
10
15
20
25

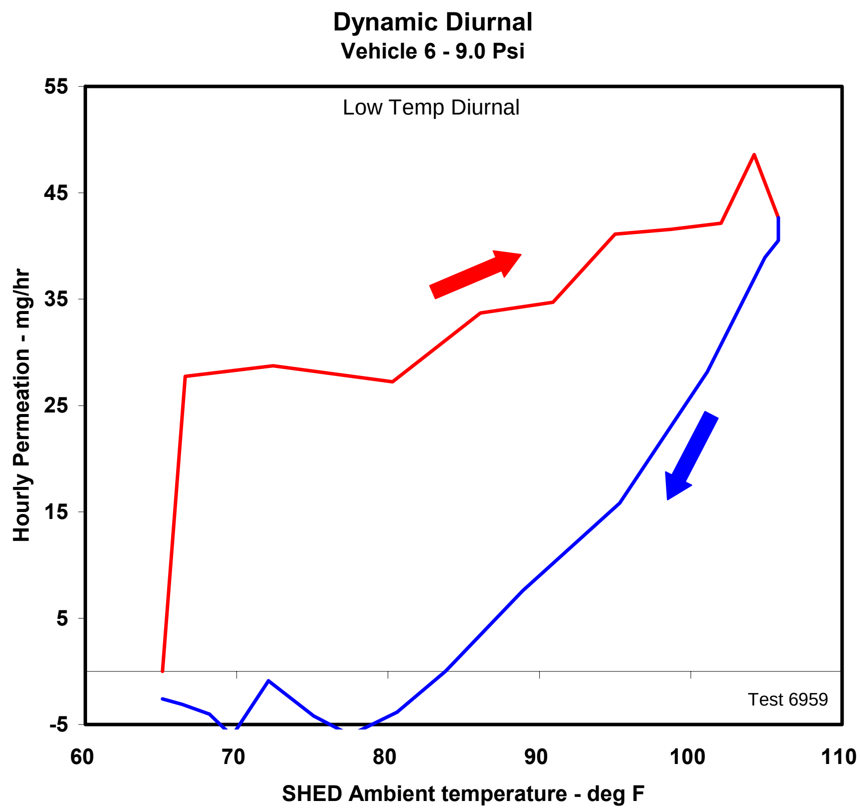

Diurnal Time Response
Vehicle 6 - 7.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6955
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
80
85
90
95
100
105
110
115
120
125
-5
0
5
10
15
20
25
30
35
40
0
2
4
6
8
10
12
14
16
18
20
22
24

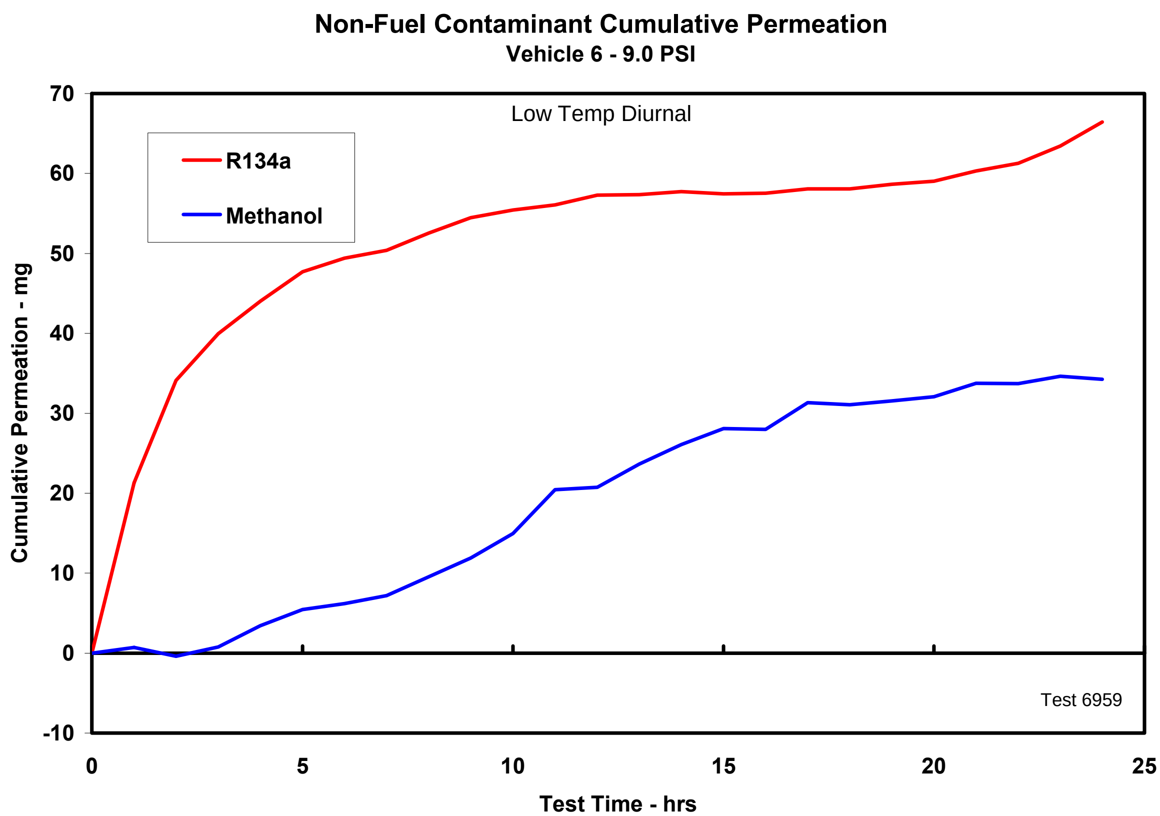

Dynamic Diurnal
Vehicle 6 - 7.0 Psi
High Temp Diurnal
Hourly Permeation - mg/hr
40
35
30
25
20
15
10
5
0
-5
80
85
90
95
100
105
110
115
120
125
SHED Ambient temperature - deg F
Test 6955

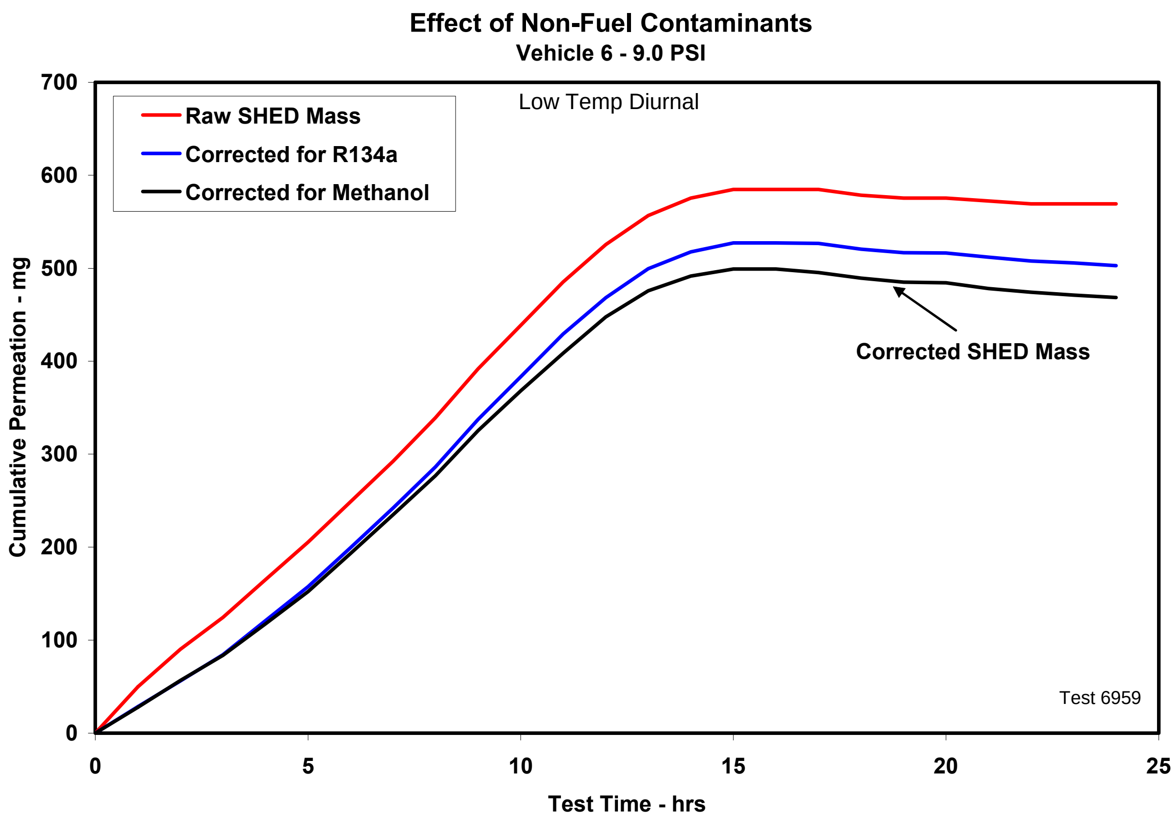

Non-Fuel Contaminant Cumulative Permeation
Vehicle 6 - 7.0 PSI
High Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Test Time - hrs
Test 6955

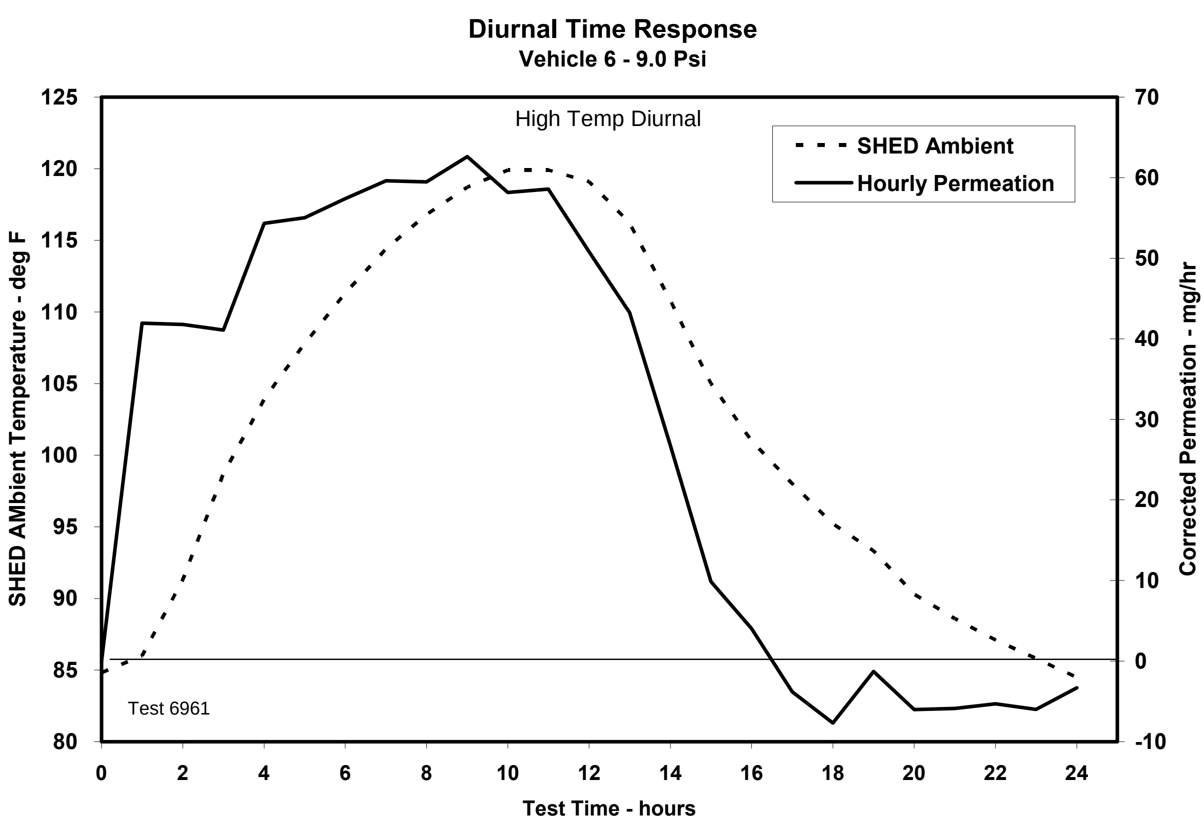

Effect of Non-Fuel Contaminants
Vehicle 6 - 7.0 PSI
High Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6955
Cumulative Permeation - mg
Test Time - hrs
0
100
200
300
400
500
0
5
10
15
20
25

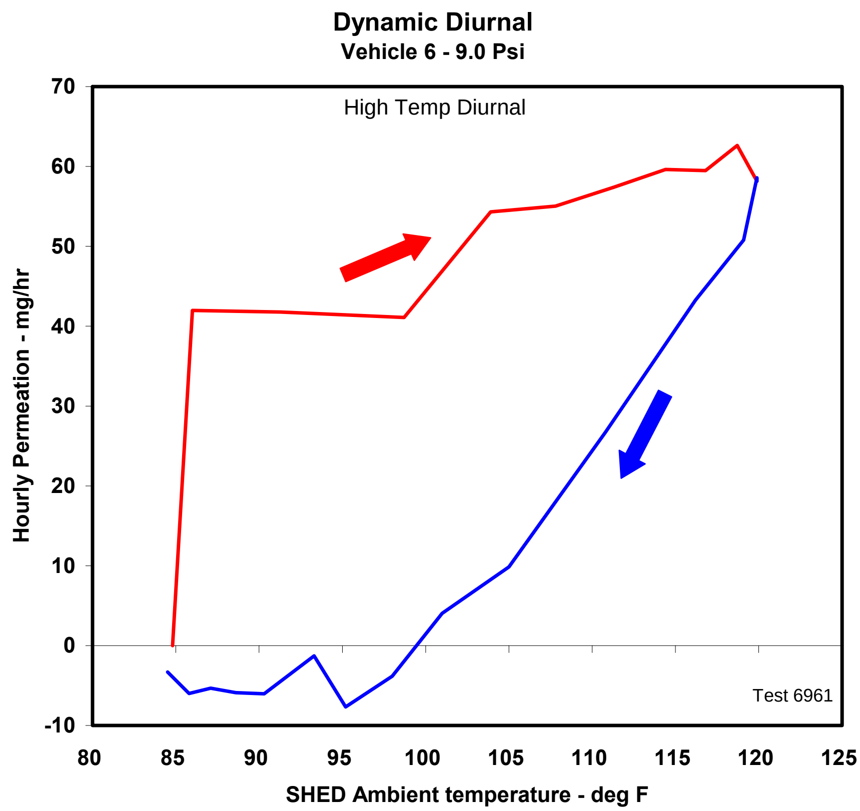

Diurnal Time Response
Vehicle 6 - 9.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6959
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-20
-10
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24

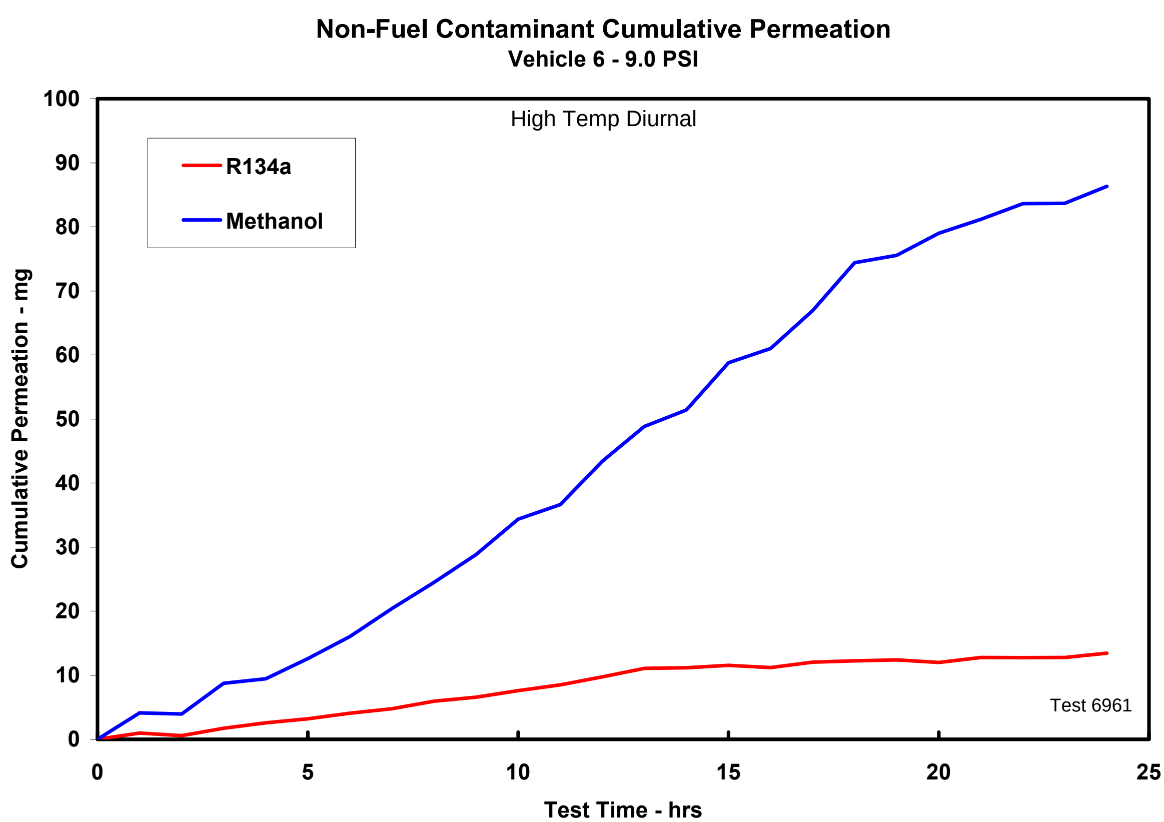

Dynamic Diurnal
Vehicle 6 - 9.0 Psi
Low Temp Diurnal
Hourly Permeation - mg/hr
55
45
35
25
15
5
-5
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6959

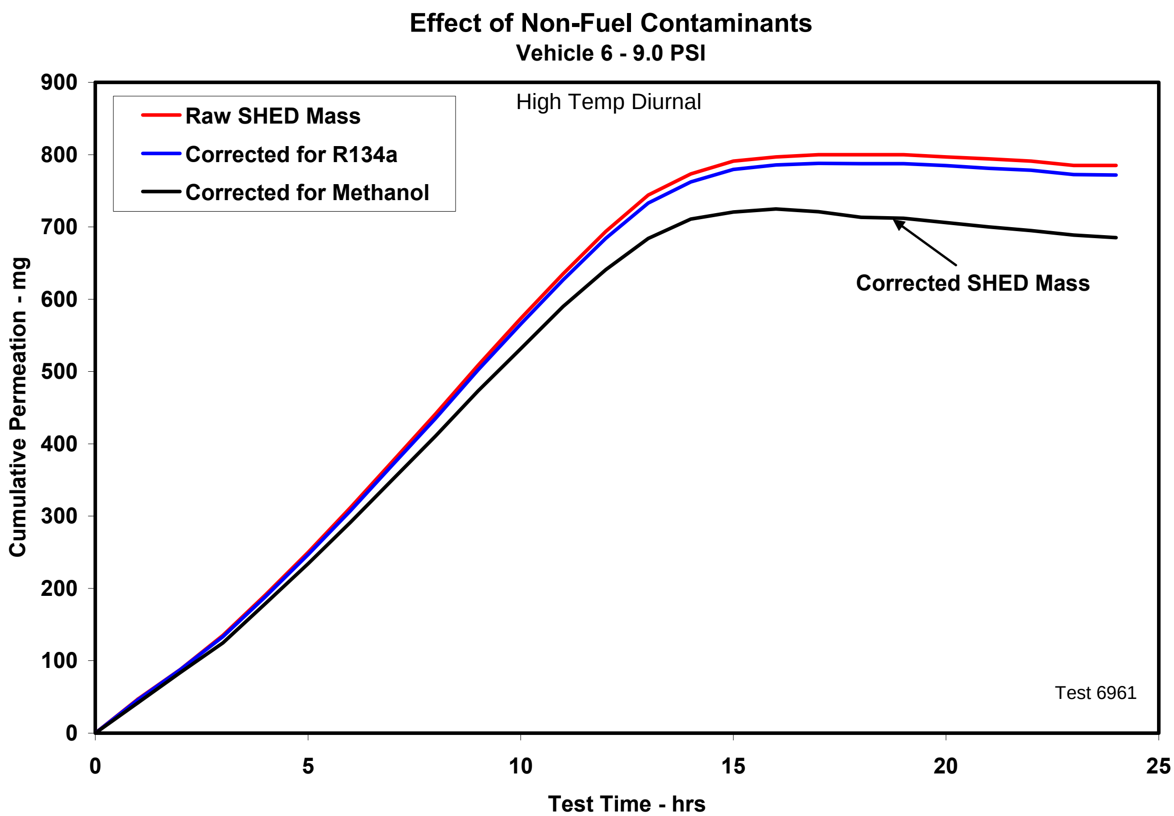

Non-Fuel Contaminant Cumulative Permeation
Vehicle 6 - 9.0 PSI
Low Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
70
60
50
40
30
20
10
0
-10
0
5
10
15
20
25
Test Time - hrs
Test 6959

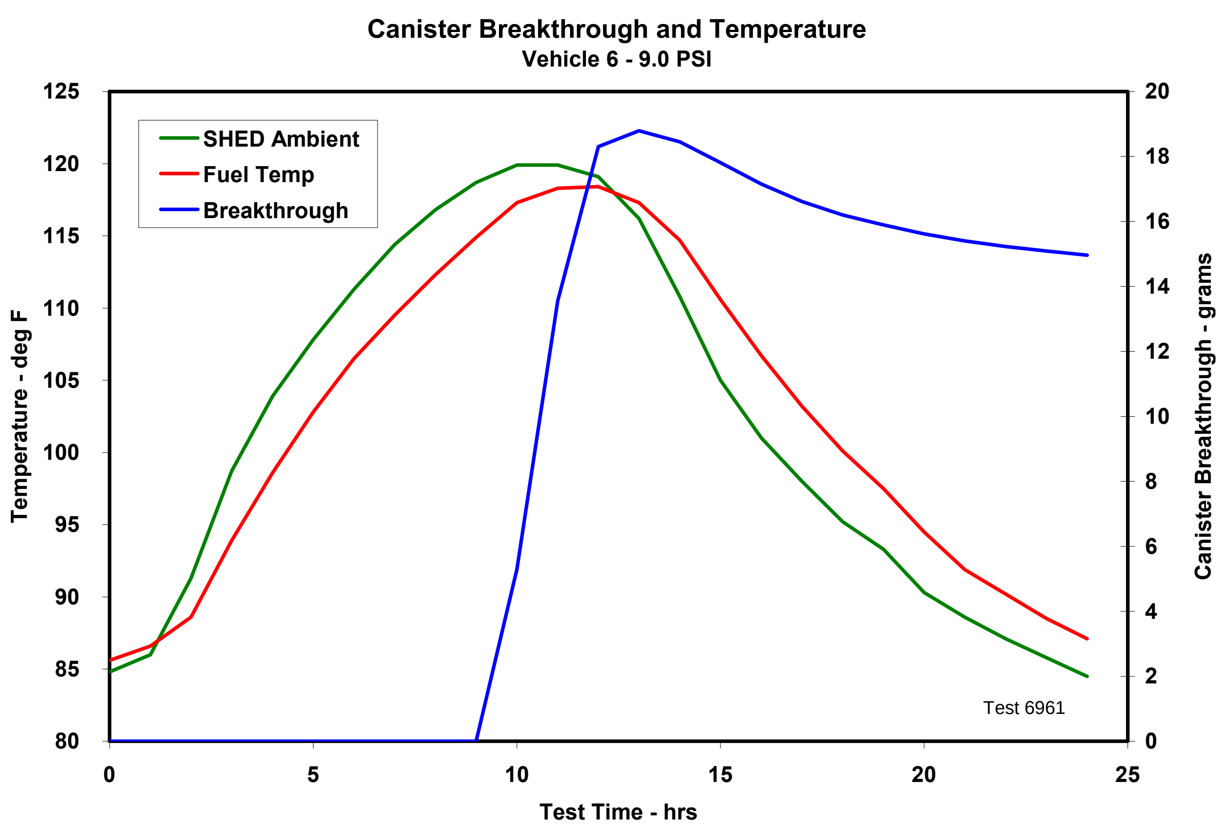

Effect of Non-Fuel Contaminants
Vehicle 6 - 9.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6959
Cumulative Permeation - mg
Test Time - hrs
0
100
200
300
400
500
600
700
0
5
10
15
20
25

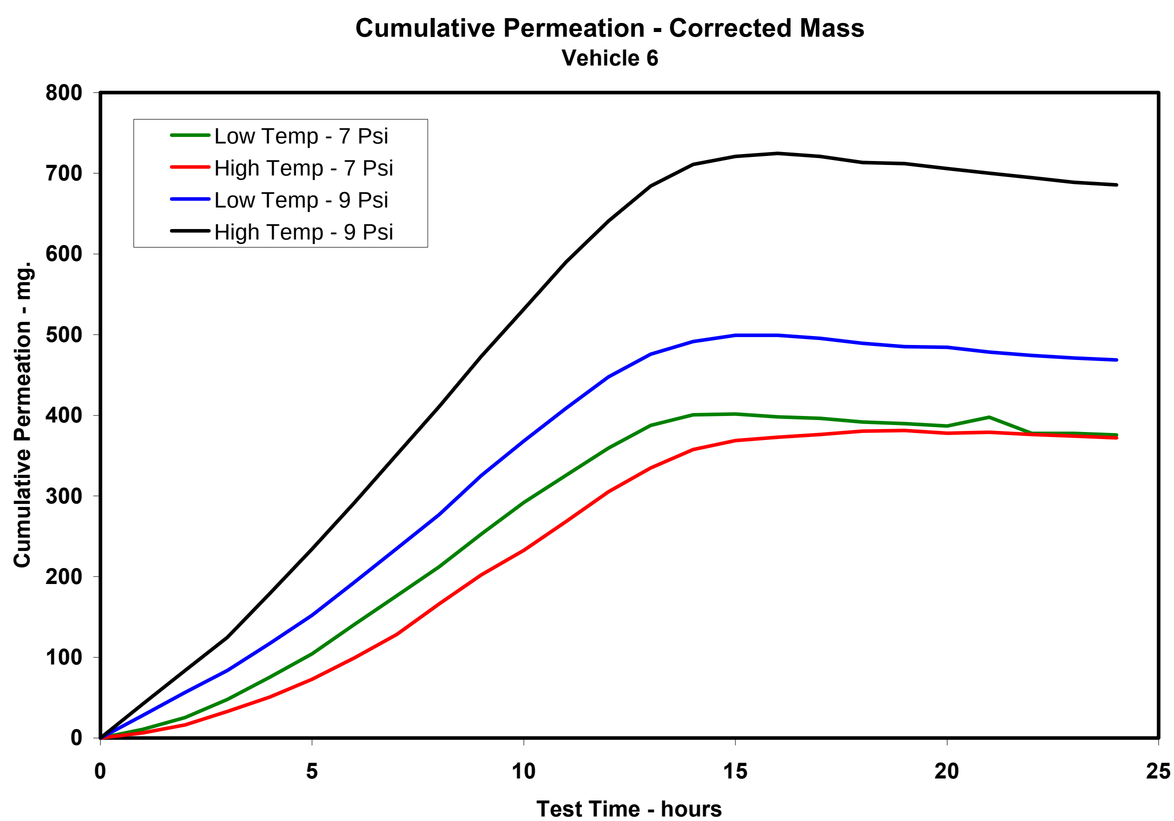

Diurnal Time Response
Vehicle 6 - 9.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6961
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
80
85
90
95
100
105
110
115
120
125
-10
0
10
20
30
40
50
60
70
0
2
4
6
8
10
12
14
16
18
20
22
24


Dynamic Diurnal
Vehicle 6 - 9.0 Psi
High Temp Diurnal
Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6961
70
60
50
40
30
20
10
0
-10
80
85
90
95
100
105
110
115
120
125


Non-Fuel Contaminant Cumulative Permeation
Vehicle 6 - 9.0 PSI
High Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
Test Time - hrs
Test 6961
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25


Effect of Non-Fuel Contaminants
Vehicle 6 - 9.0 PSI
High Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Cumulative Permeation - mg
Test Time - hrs
Test 6961
0
100
200
300
400
500
600
700
800
900
0
5
10
15
20
25

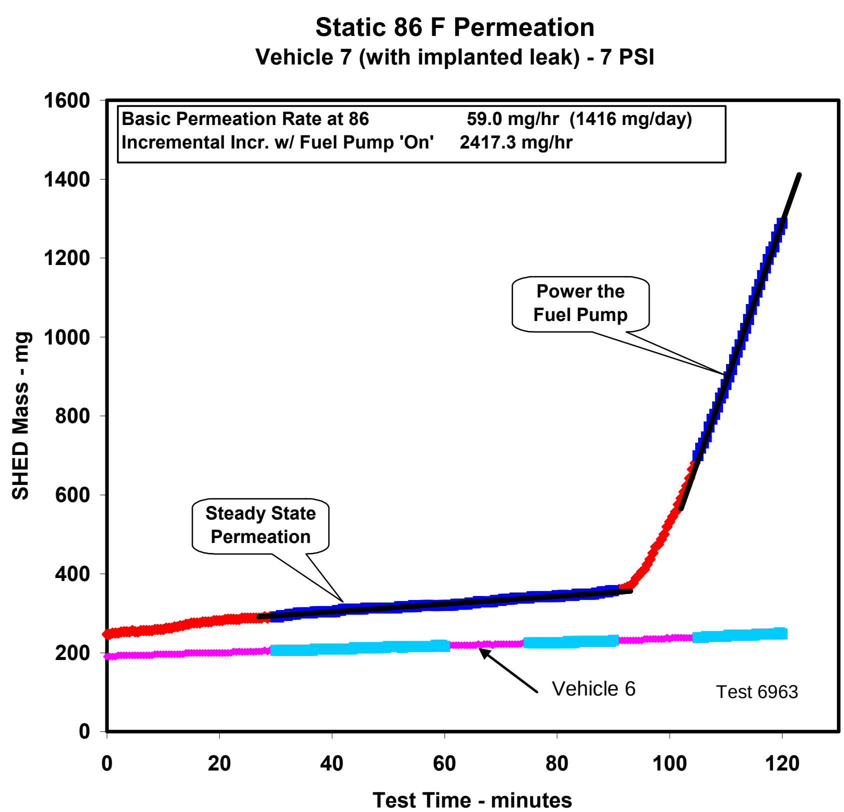

Canister Breakthrough and Temperature
Vehicle 6 - 9.0 PSI
SHED Ambient
Fuel Temp
Breakthrough
Temperature - deg F
Canister Breakthrough - grams
Test Time - hrs
Test 6961
80
85
90
95
100
105
110
115
120
125
0
2
4
6
8
10
12
14
16
18
20
0
5
10
15
20
25

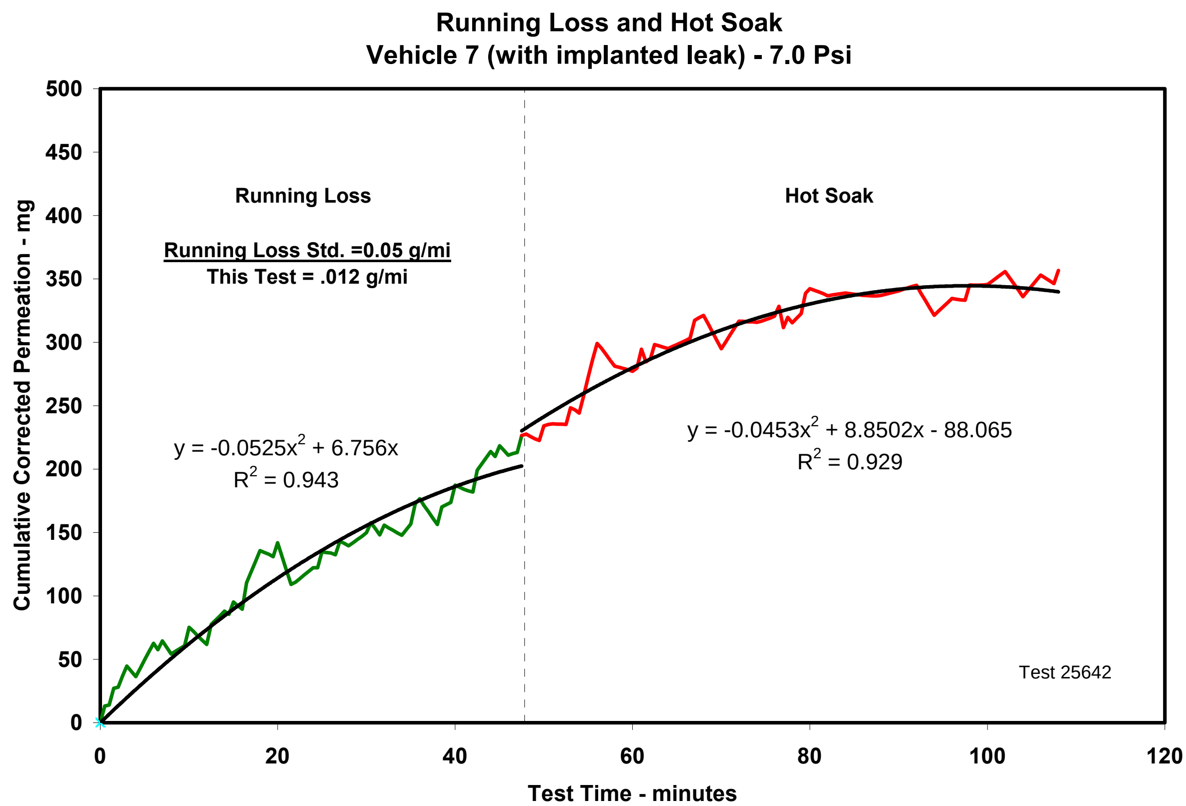

Cumulative Permeation - Corrected Mass
Vehicle 6
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
0
100
200
300
400
500
600
700
800
0
5
10
15
20
25
Test Time - hours

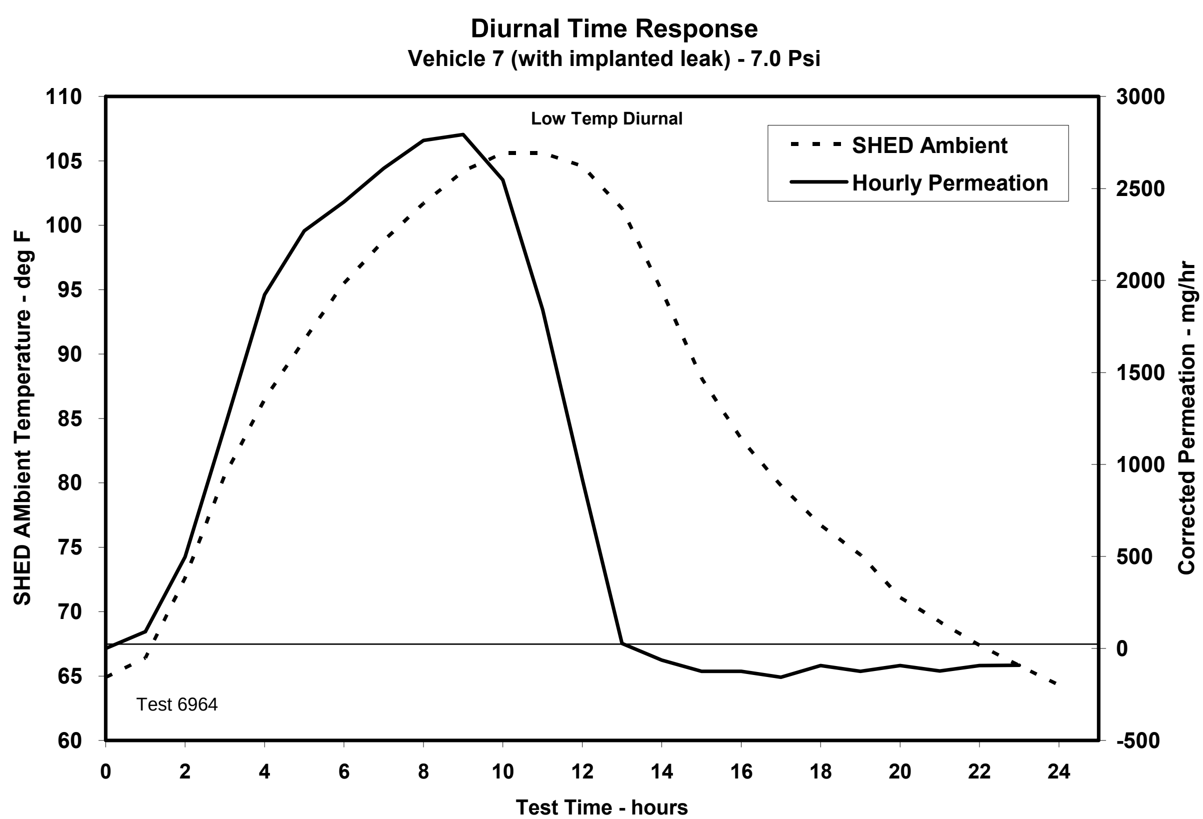
Vehicle 7

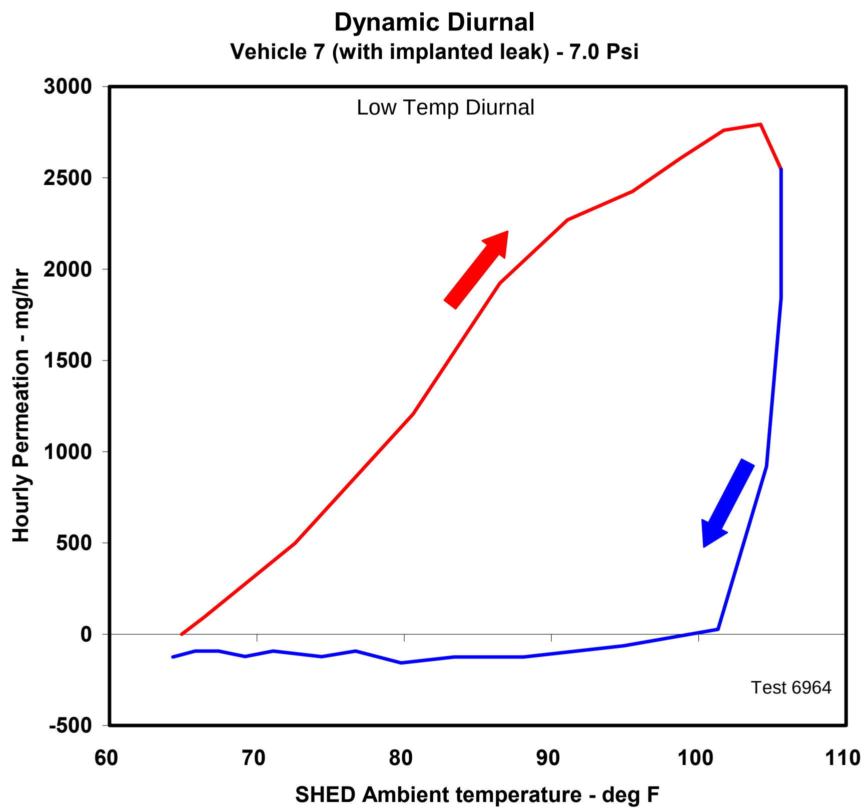
1996 Chevrolet Cavalier Enhanced (with implanted leak)

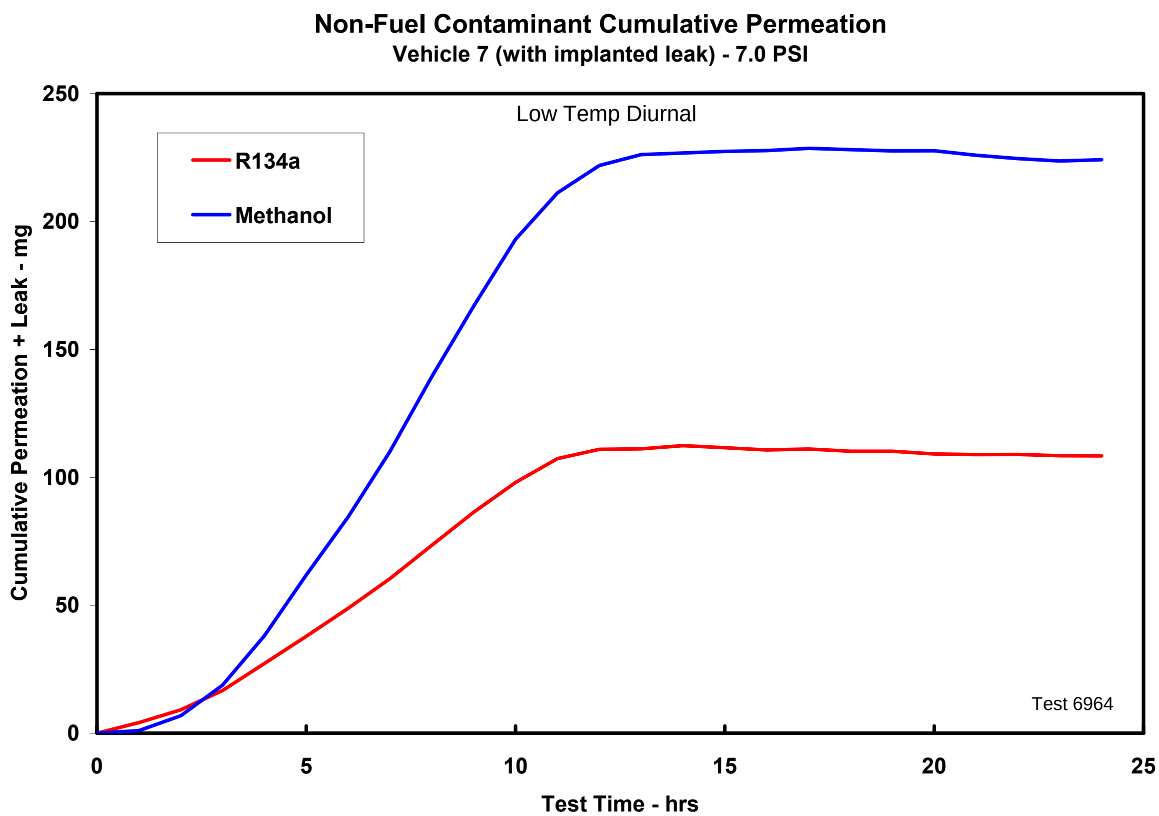
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr (Raw)	Permeation mg/hr (Corrected)	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
7	7.0	Static	Cap (.020")	11/14/06	6963	59.0				
			Fuel Incr.			2358.3				
	7.0	Dynamic	RL	11/17/06	25642	258.7	227.6			
			HS			149.3	129.0			
			RL + HS			408.1	356.6			
	7.0	24 DHB	65-105	11/21/06	6964		Day 1	21036	20704	0
	7.0	24 DHB	85-120	11/30/06	6966		Day 1	27824	27384	0

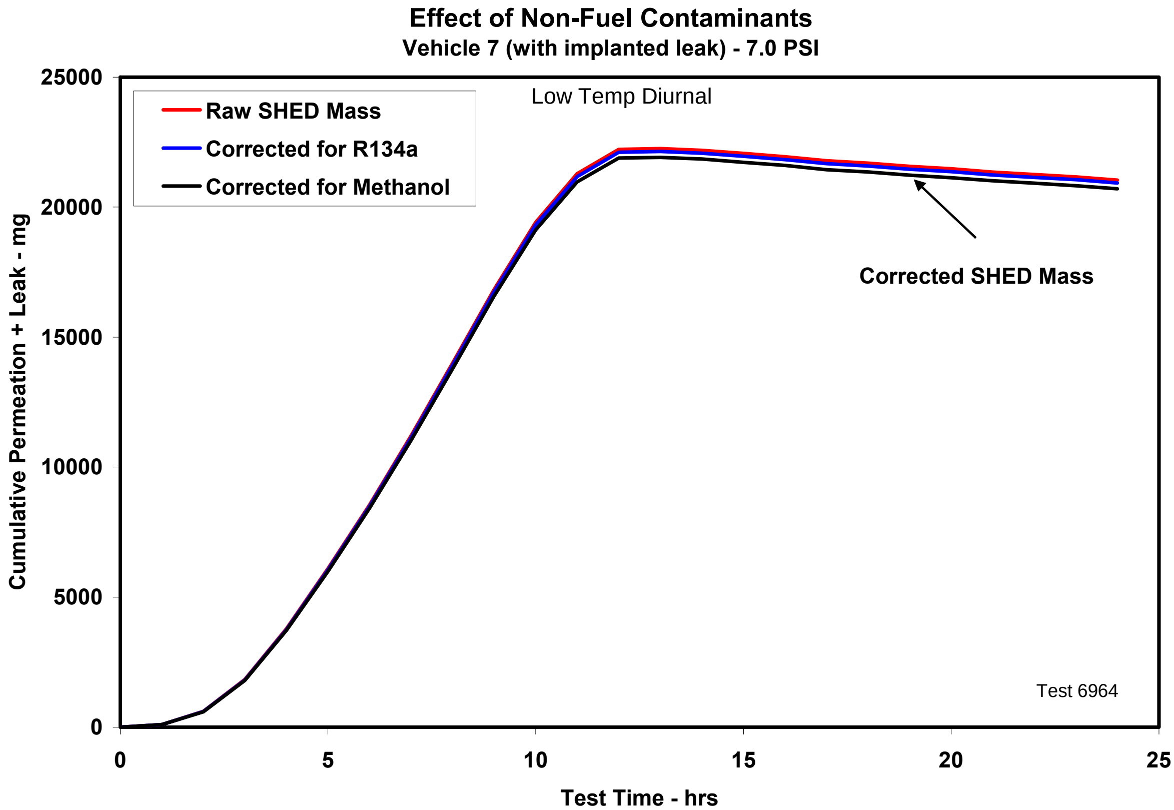


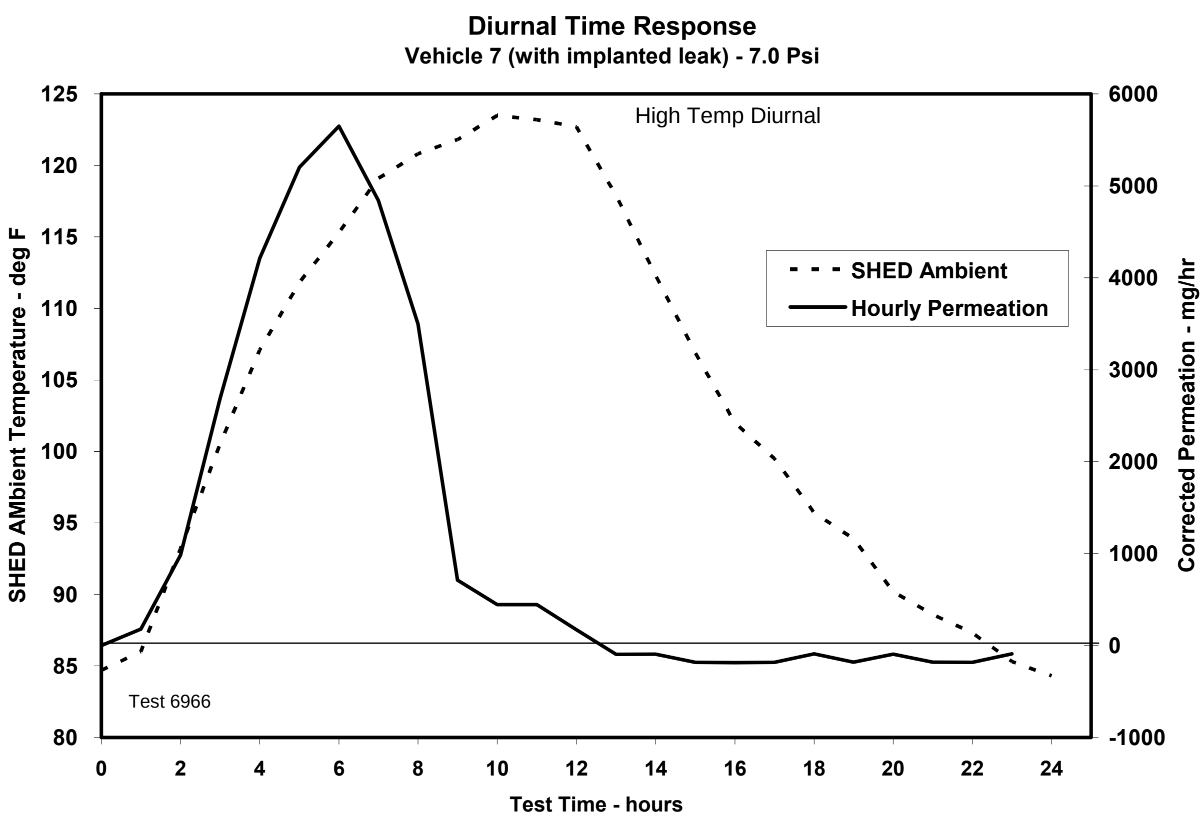

Running Loss and Hot Soak
Vehicle 7 (with implanted leak) - 7.0 Psi
Running Loss
Running Loss Std. =0.05 g/mi
This Test = .012 g/mi
Hot Soak
y = -0.0525x2 + 6.756x
R2 = 0.943
y = -0.0453x2 + 8.8502x - 88.065
R2 = 0.929
Test 25642
Cumulative Corrected Permeation - mg
Test Time - minutes
0
50
100
150
200
250
300
350
400
450
500
0
20
40
60
80
100
120

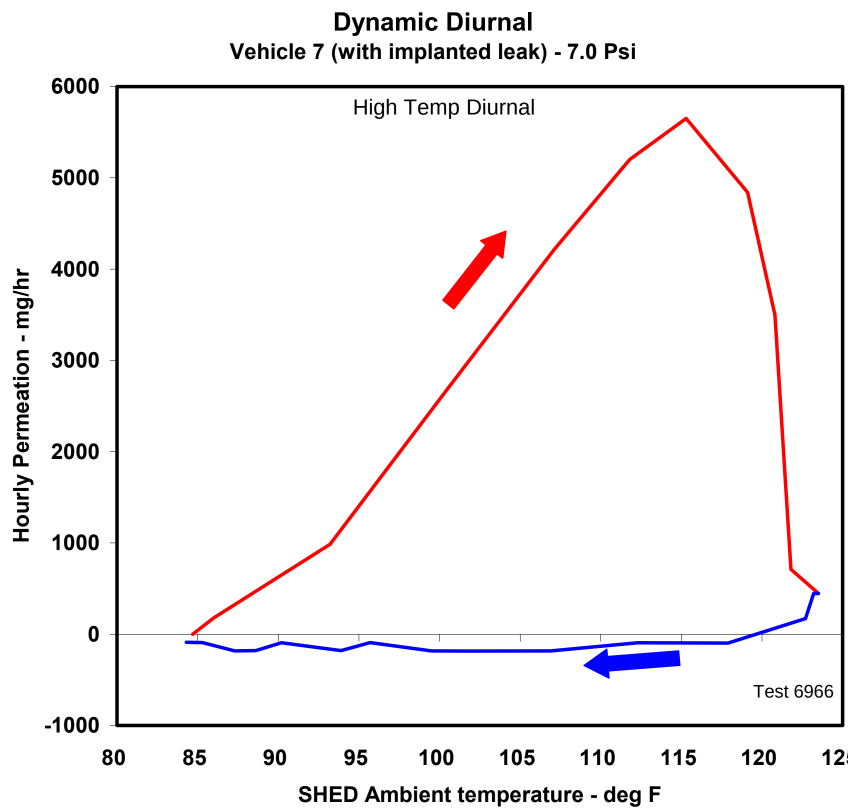

Diurnal Time Response
Vehicle 7 (with implanted leak) - 7.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6964
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-500
0
500
1000
1500
2000
2500
3000
0
2
4
6
8
10
12
14
16
18
20
22
24

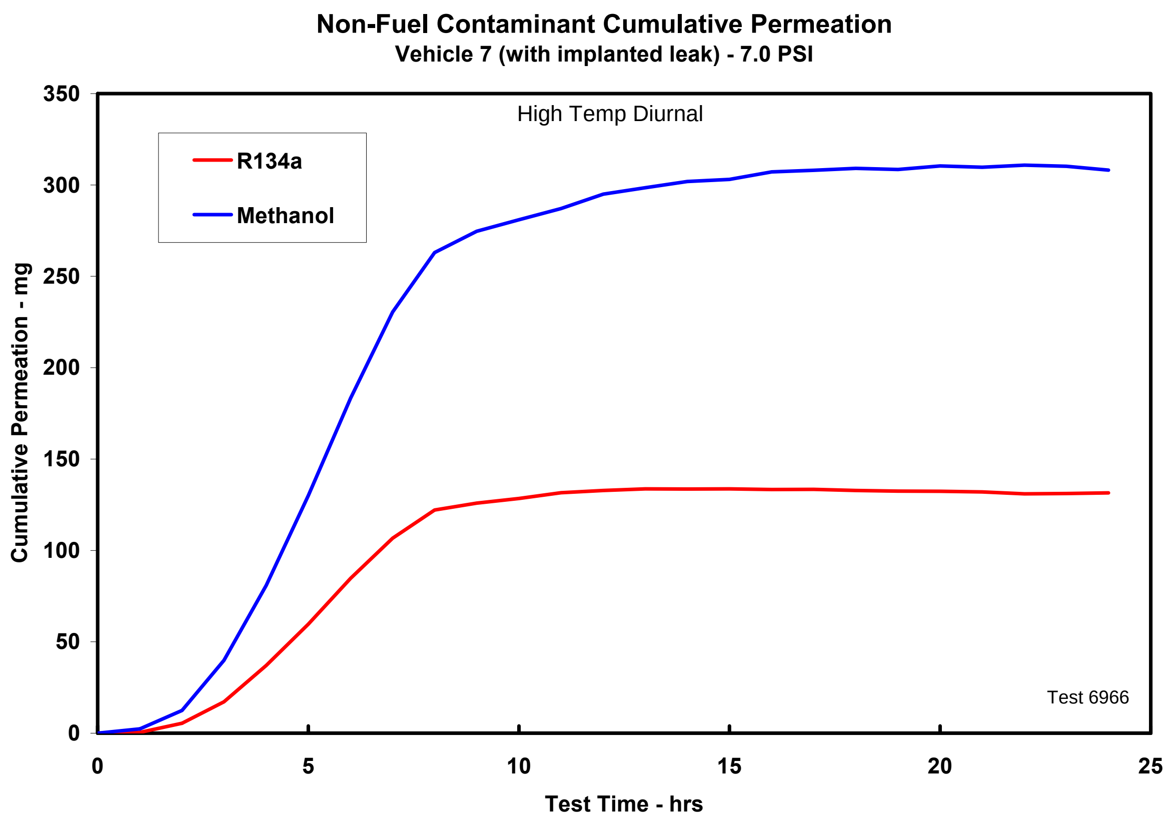

Dynamic Diurnal
Vehicle 7 (with implanted leak) - 7.0 Psi
Low Temp Diurnal
Hourly Permeation - mg/hr
3000
2500
2000
1500
1000
500
0
-500
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6964

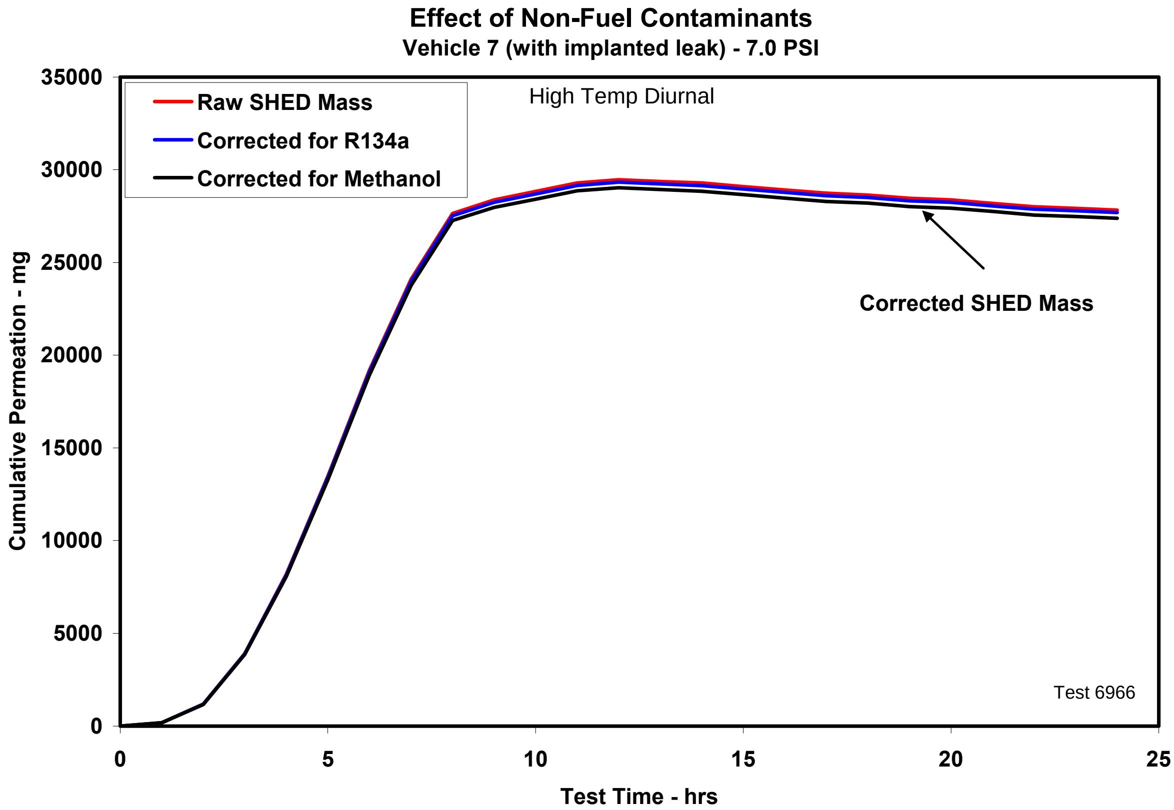

Non-Fuel Contaminant Cumulative Permeation
Vehicle 7 (with implanted leak) - 7.0 PSI
Low Temp Diurnal
R134a
Methanol
Cumulative Permeation + Leak - mg
250
200
150
100
50
0
0
5
10
15
20
25
Test Time - hrs
Test 6964

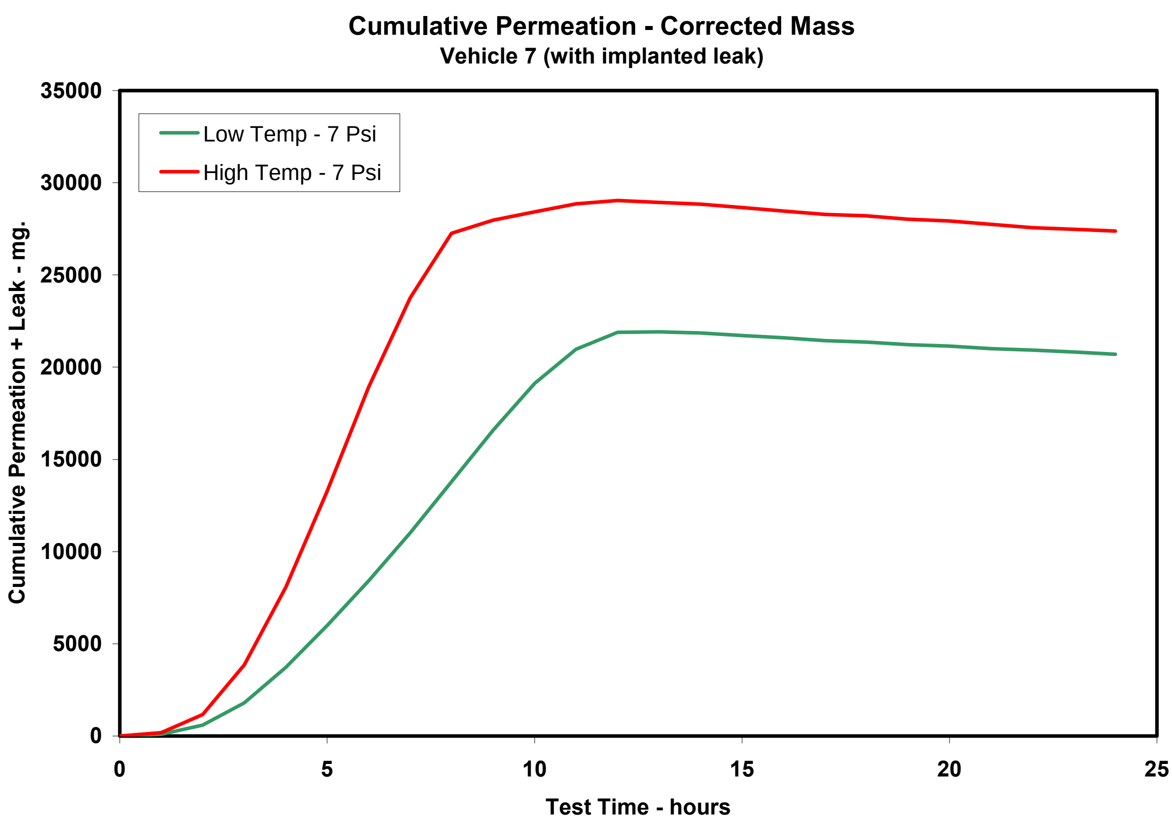

Effect of Non-Fuel Contaminants
Vehicle 7 (with implanted leak) - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6964
Cumulative Permeation + Leak - mg
Test Time - hrs
0
5000
10000
15000
20000
25000
0
5
10
15
20
25


Diurnal Time Response
Vehicle 7 (with implanted leak) - 7.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6966
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
80
85
90
95
100
105
110
115
120
125
-1000
0
1000
2000
3000
4000
5000
6000
0
2
4
6
8
10
12
14
16
18
20
22
24


Dynamic Diurnal
Vehicle 7 (with implanted leak) - 7.0 Psi
High Temp Diurnal
Hourly Permeation - mg/hr
6000
5000
4000
3000
2000
1000
0
-1000
Test 6966
80
85
90
95
100
105
110
115
120
125
SHED Ambient temperature - deg F


Non-Fuel Contaminant Cumulative Permeation
Vehicle 7 (with implanted leak) - 7.0 PSI
High Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
350
300
250
200
150
100
50
0
Test 6966
0
5
10
15
20
25
Test Time - hrs

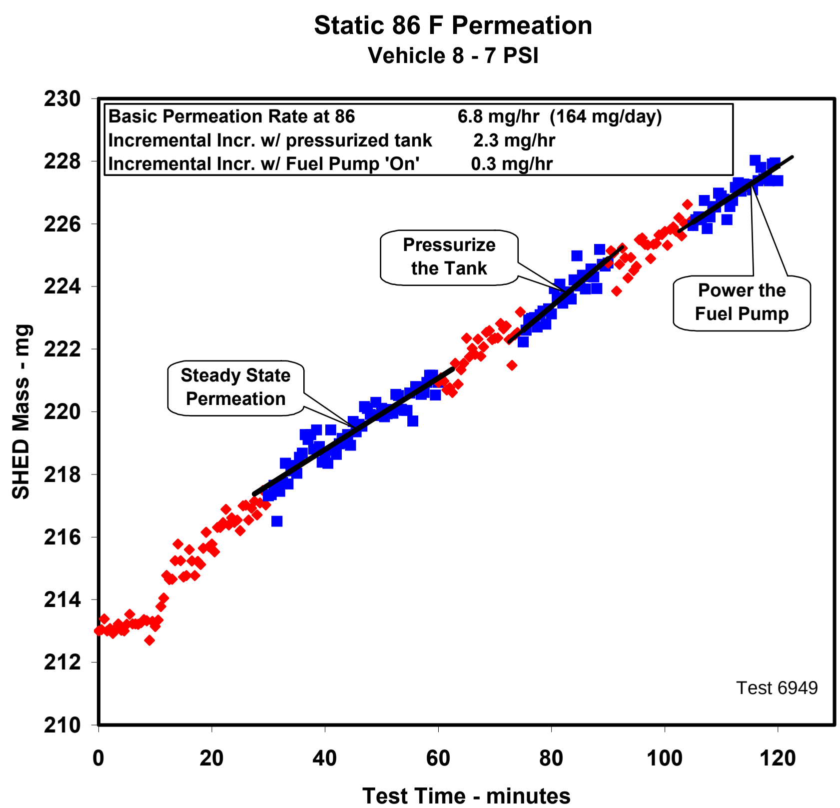

Effect of Non-Fuel Contaminants
Vehicle 7 (with implanted leak) - 7.0 PSI
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
High Temp Diurnal
Corrected SHED Mass
Test 6966
Cumulative Permeation - mg
Test Time - hrs
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25

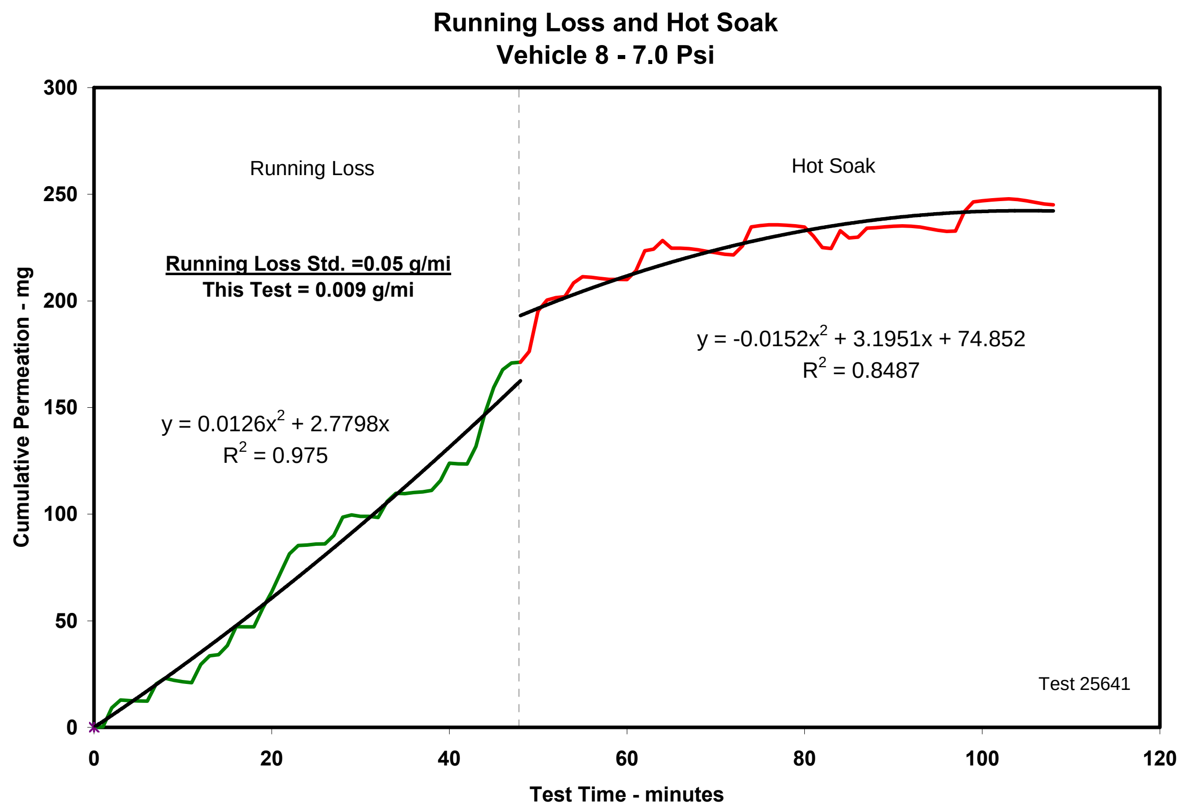

Cumulative Permeation - Corrected Mass
Vehicle 7 (with implanted leak)
Low Temp - 7 Psi
High Temp - 7 Psi
Cumulative Permeation + Leak - mg.
Test Time - hours
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25

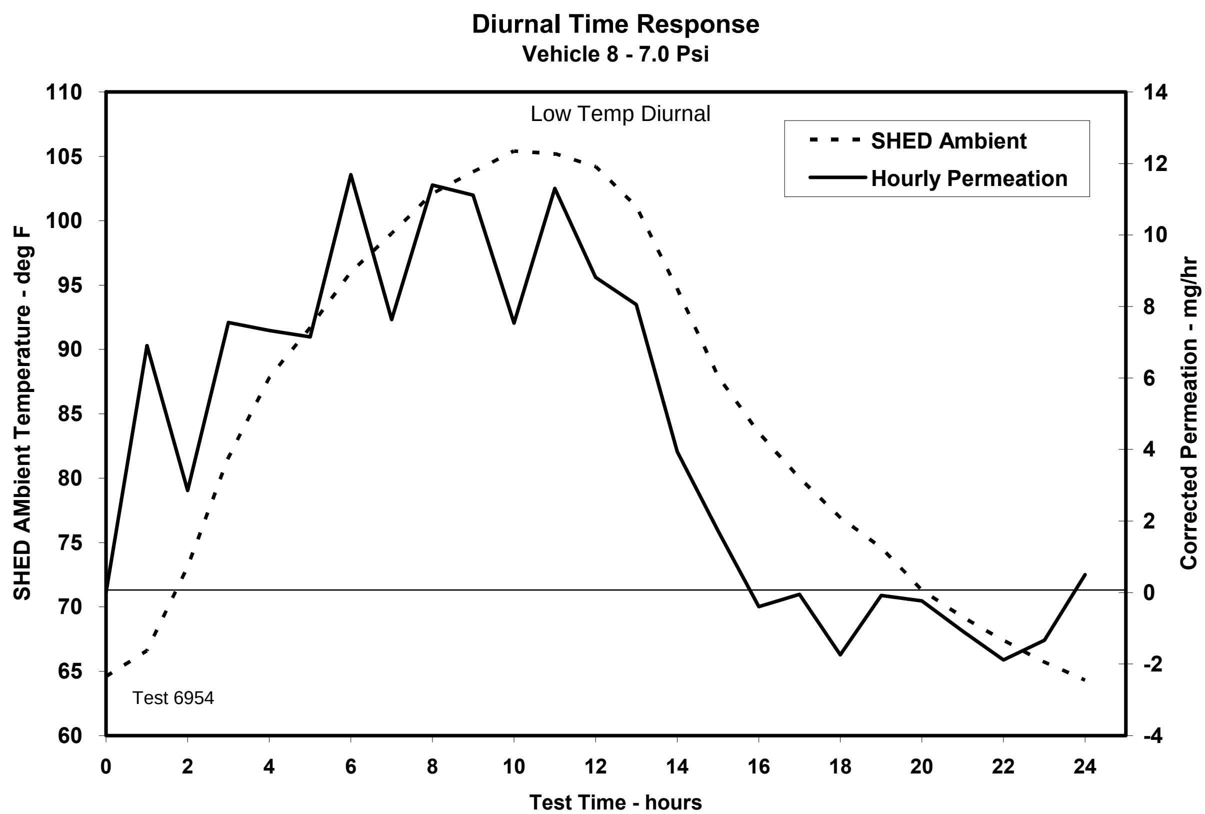
Vehicle 8

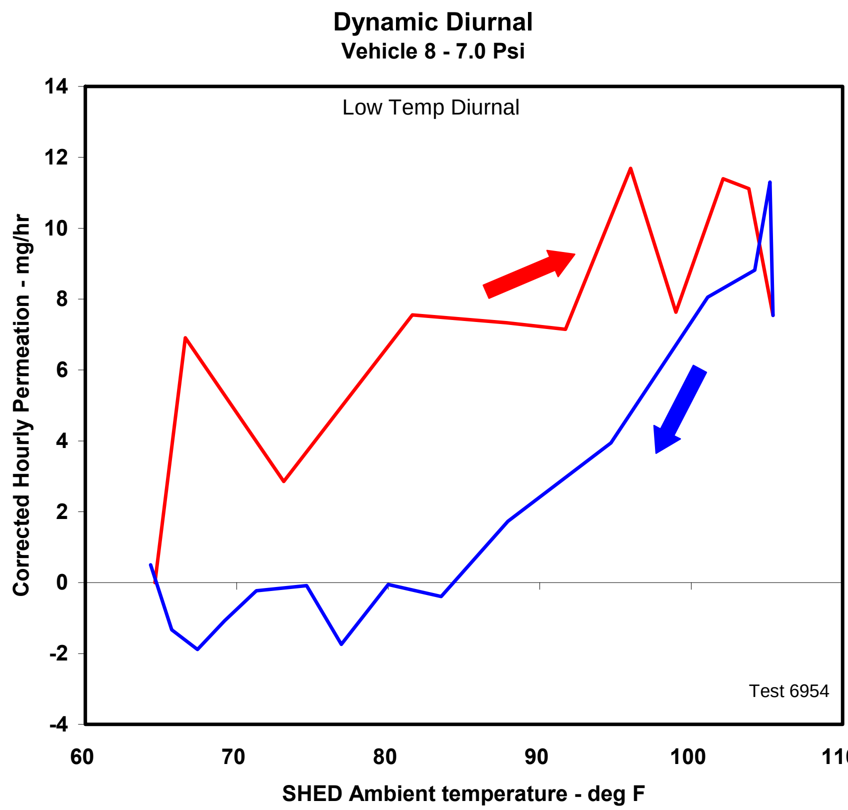
1996 Ford Explorer

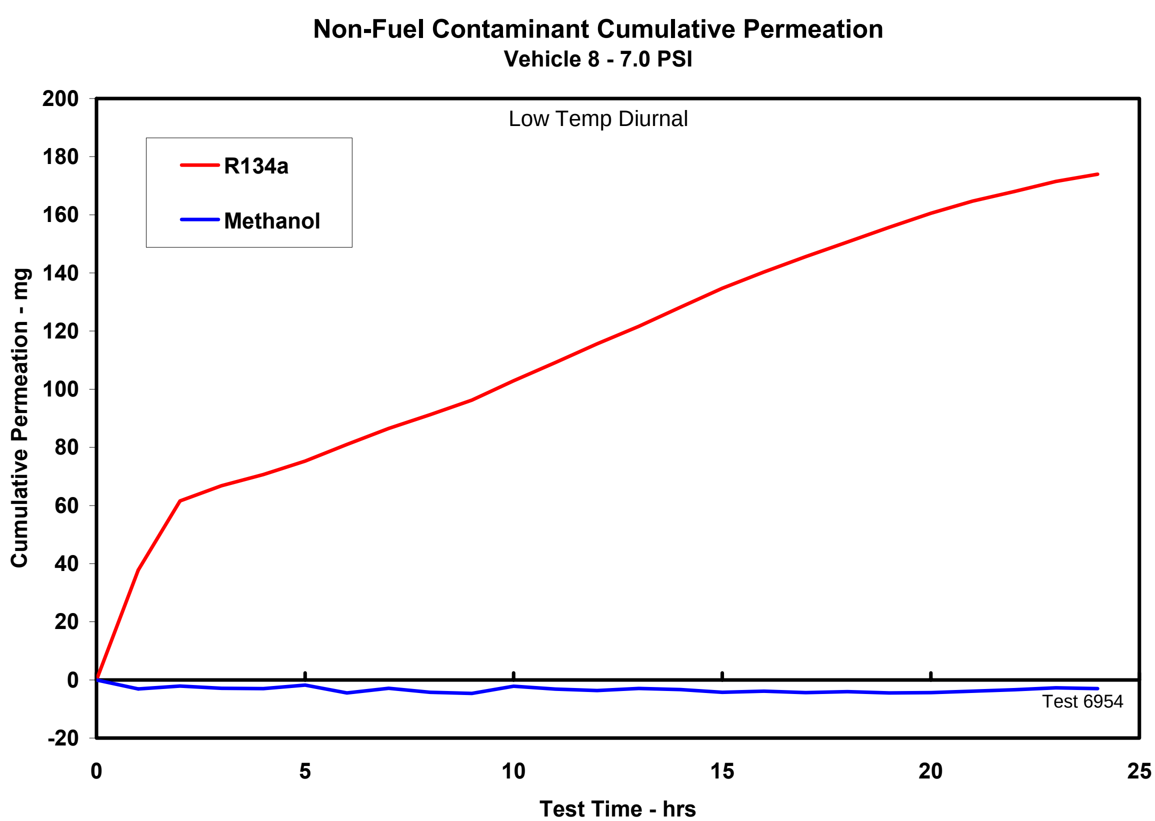
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
8	7.0	Static	Perm	10/10/06	6949	6.8			
			Press. Incr.			2.3			
			Prs+Fuel Incr.			0.3			
	7.0	Dynamic	RL	10/12/06	25641	171.3			
			HS			73.8			
			RL + HS			245.0			
	7.0	24 DHB	65-105	10/21/06	6954	Day 1	279.7	133.1	0.00
	7.0	24 DHB	85-120	10/26/06	6956	Day 1	298.0	235.4	0.00
	9.0	24 DHB	65-105	10/28/06	6957	Day 1	227.5	150.4	0.00
	9.0	24 DHB	85-120	11/09/06	6962	Day 1	346.2	254.6	128.68

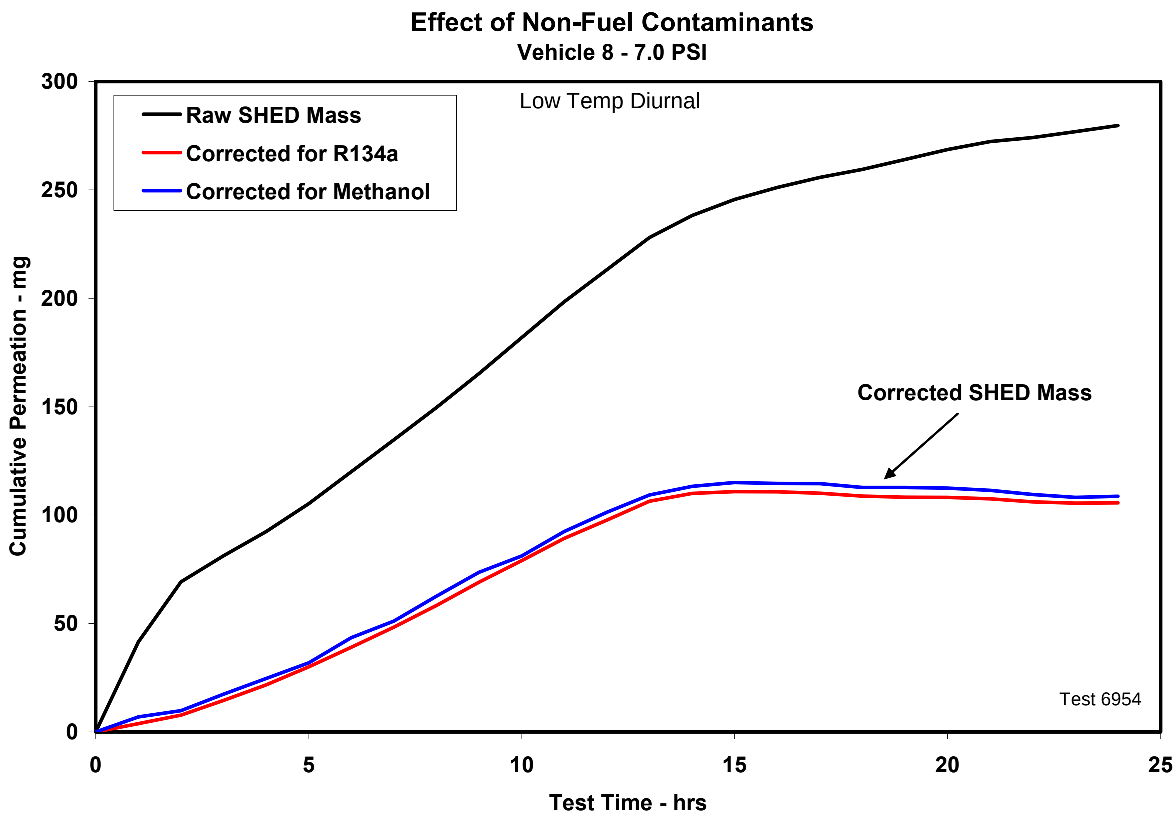


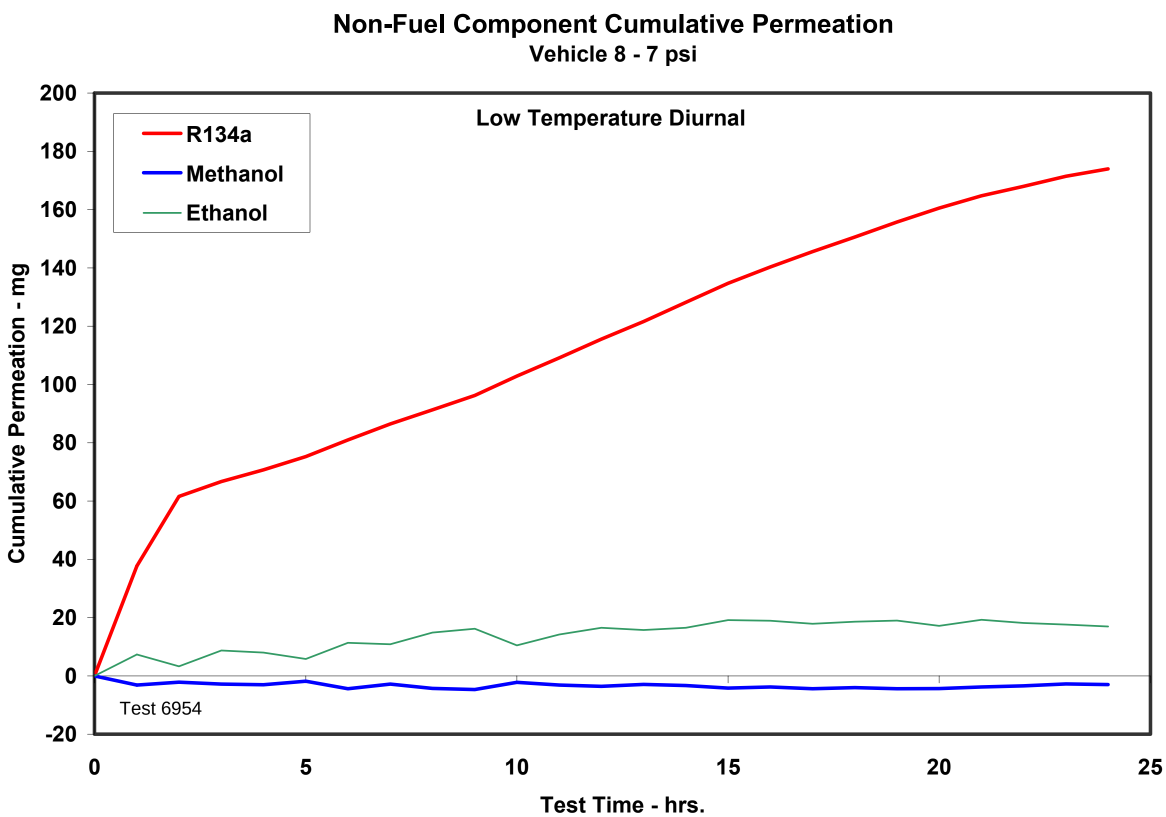

Running Loss and Hot Soak
Vehicle 8 - 7.0 Psi
Running Loss
Hot Soak
Running Loss Std. =0.05 g/mi
This Test = 0.009 g/mi
y = 0.0126x2 + 2.7798x
R2 = 0.975
y = -0.0152x2 + 3.1951x + 74.852
R2 = 0.8487
Test 25641
Cumulative Permeation - mg
Test Time - minutes
300
250
200
150
100
50
0
0
20
40
60
80
100
120

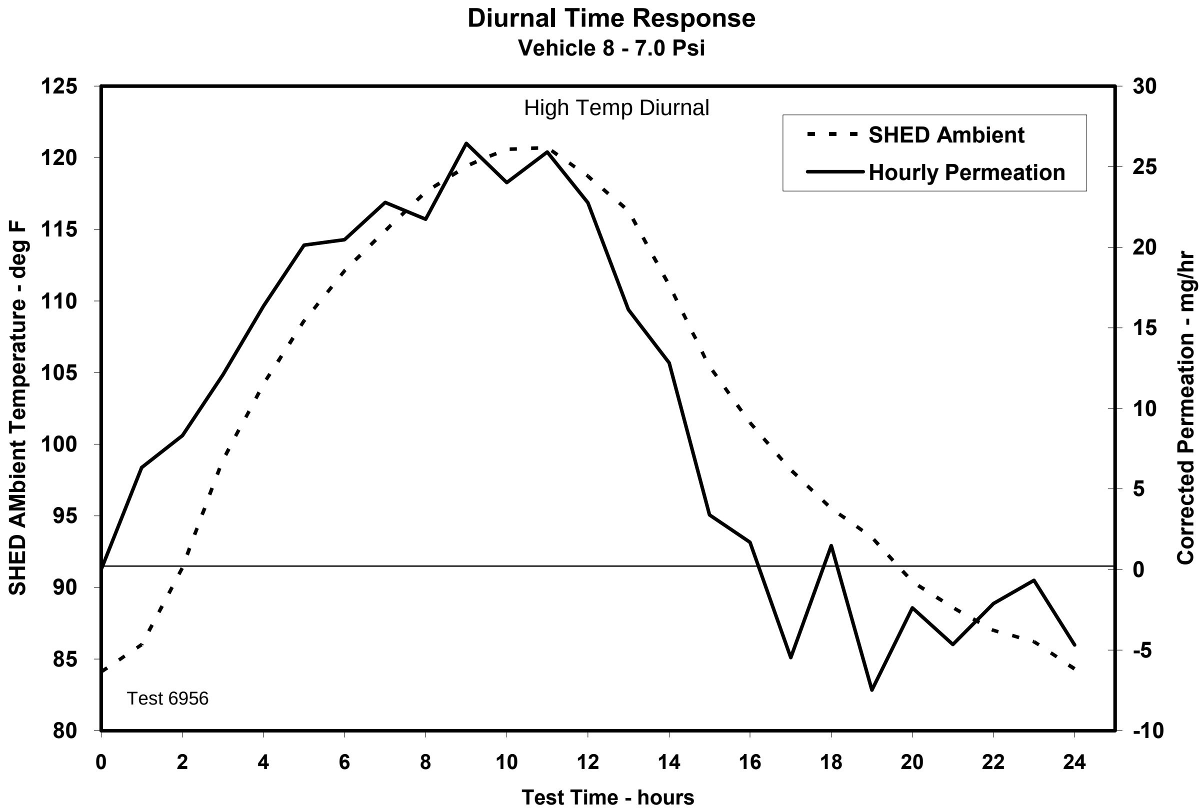

Diurnal Time Response
Vehicle 8 - 7.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6954
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
110
105
100
95
90
85
80
75
70
65
60
14
12
10
8
6
4
2
0
-2
-4
0
2
4
6
8
10
12
14
16
18
20
22
24

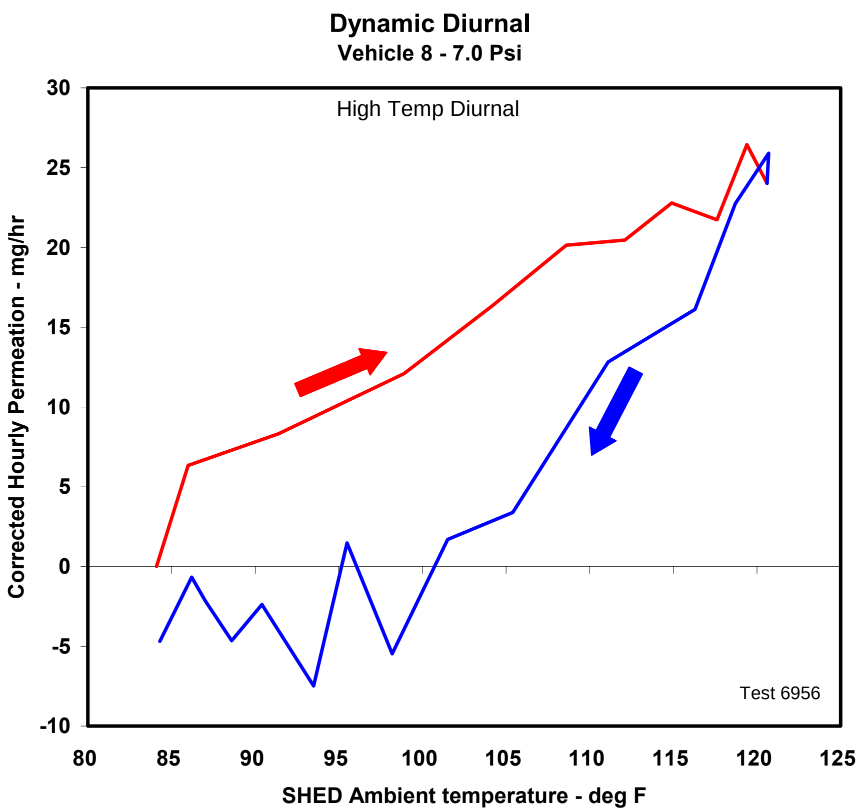

Dynamic Diurnal
Vehicle 8 - 7.0 Psi
Low Temp Diurnal
Test 6954
Corrected Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
14
12
10
8
6
4
2
0
-2
-4
60
70
80
90
100
110

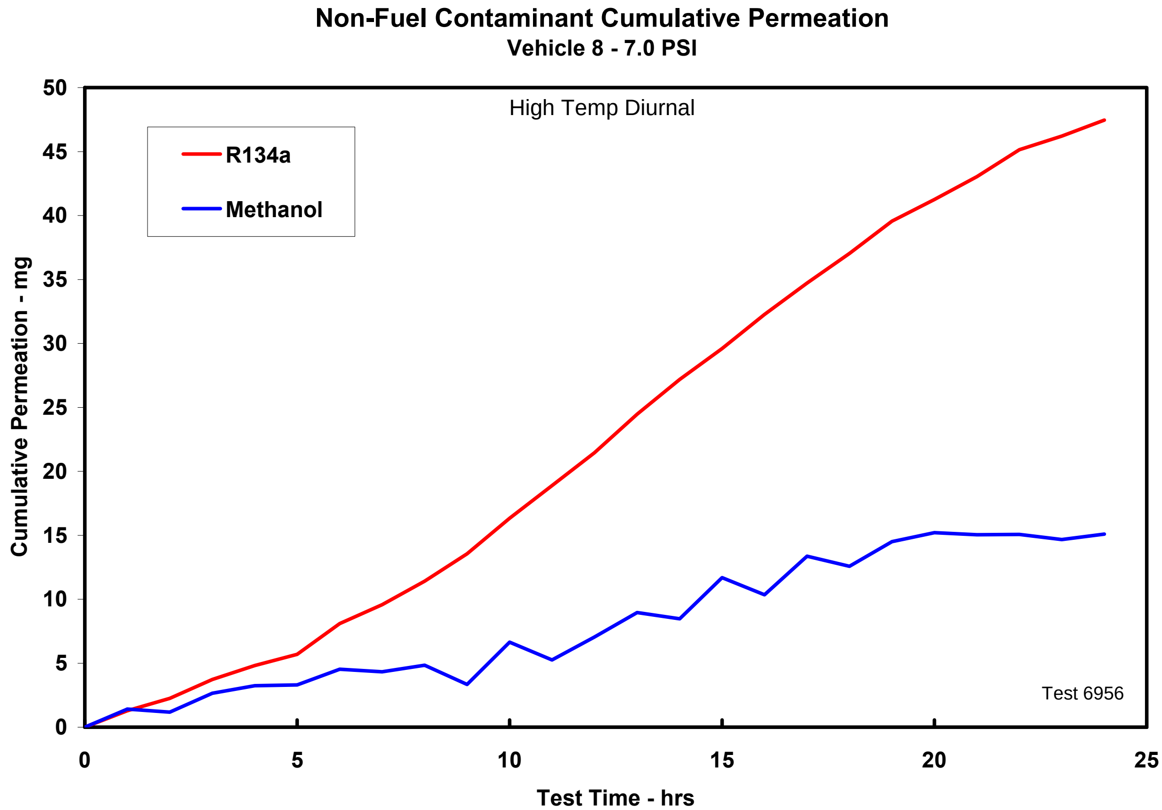

Non-Fuel Contaminant Cumulative Permeation
Vehicle 8 - 7.0 PSI
Low Temp Diurnal
R134a
Methanol
Test 6954
Cumulative Permeation - mg
Test Time - hrs
200
180
160
140
120
100
80
60
40
20
0
-20
0
5
10
15
20
25


Effect of Non-Fuel Contaminants
Vehicle 8 - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6954
Cumulative Permeation - mg
Test Time - hrs
0
50
100
150
200
250
300
5
10
15
20
25

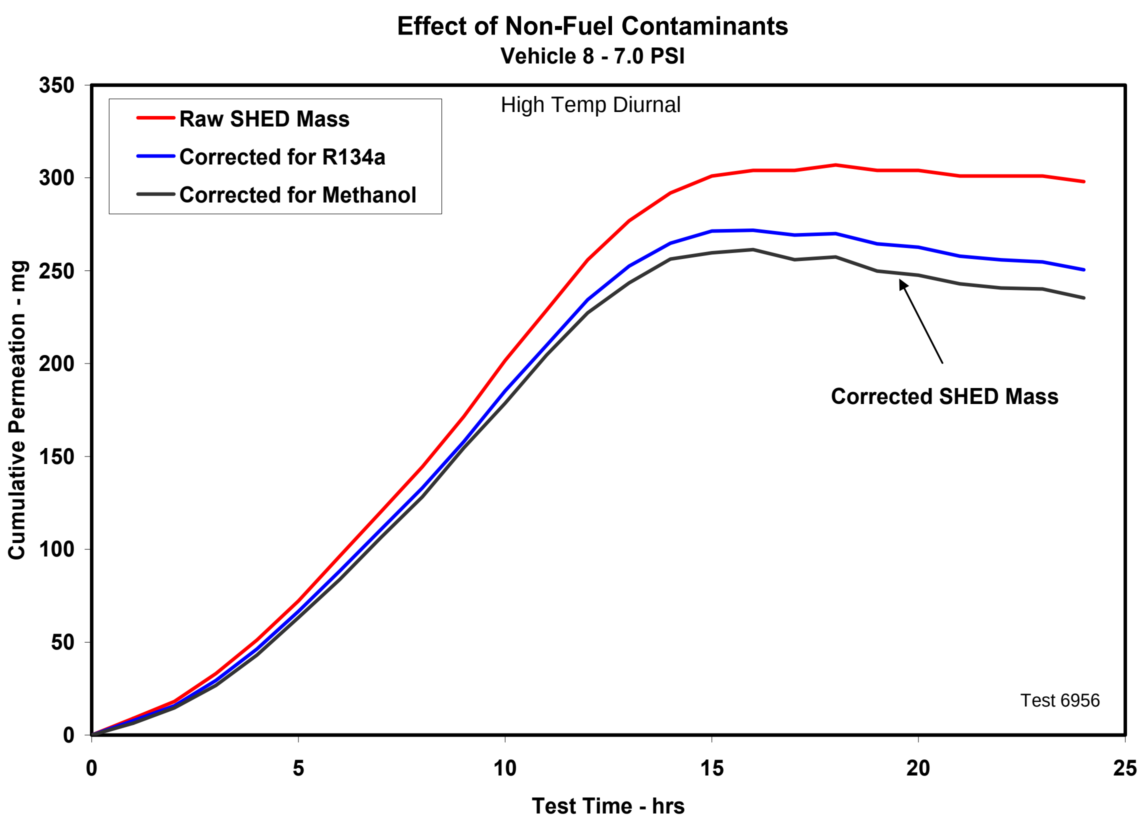

Non-Fuel Component Cumulative Permeation
Vehicle 8 - 7 psi
Low Temperature Diurnal
R134a
Methanol
Ethanol
Test 6954
Cumulative Permeation - mg
Test Time - hrs.
-20
0
20
40
60
80
100
120
140
160
180
200
5
10
15
20
25


Diurnal Time Response
Vehicle 8 - 7.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6956
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
125
120
115
110
105
100
95
90
85
80
30
25
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12
14
16
18
20
22
24

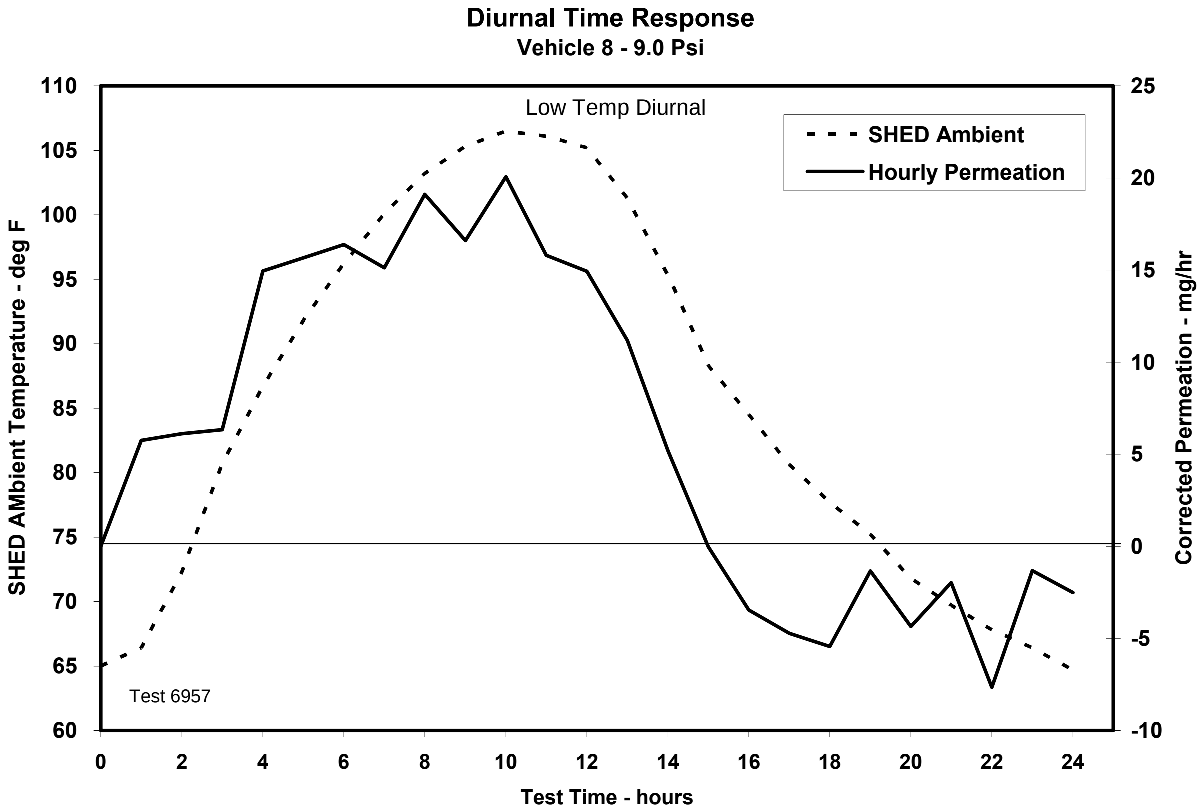

Dynamic Diurnal
Vehicle 8 - 7.0 Psi
High Temp Diurnal
Test 6956
Corrected Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
30
25
20
15
10
5
0
-5
-10
80
85
90
95
100
105
110
115
120
125

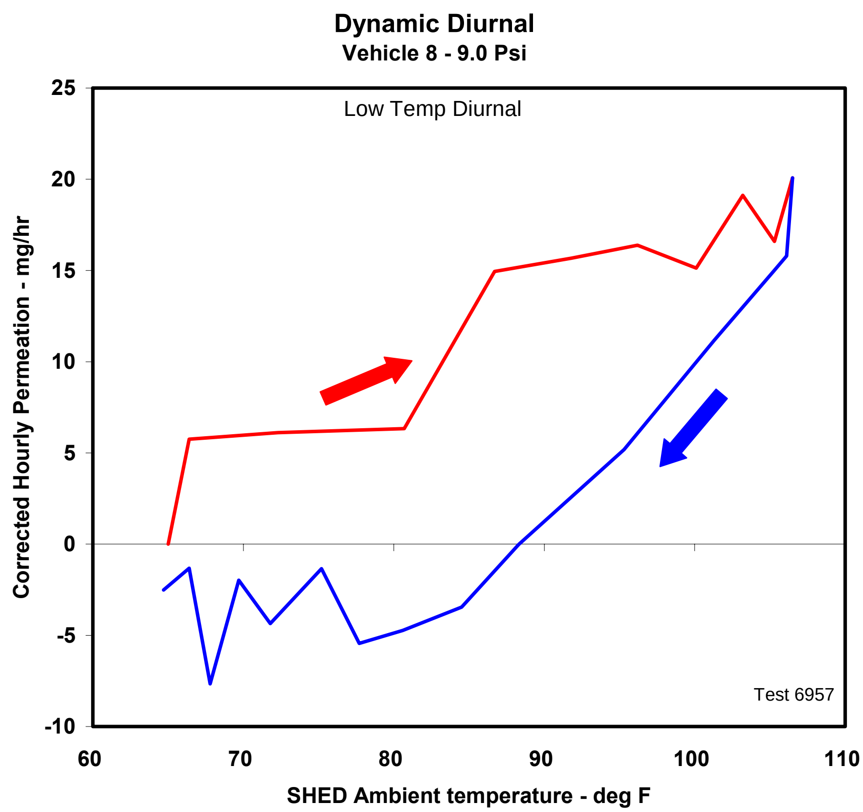


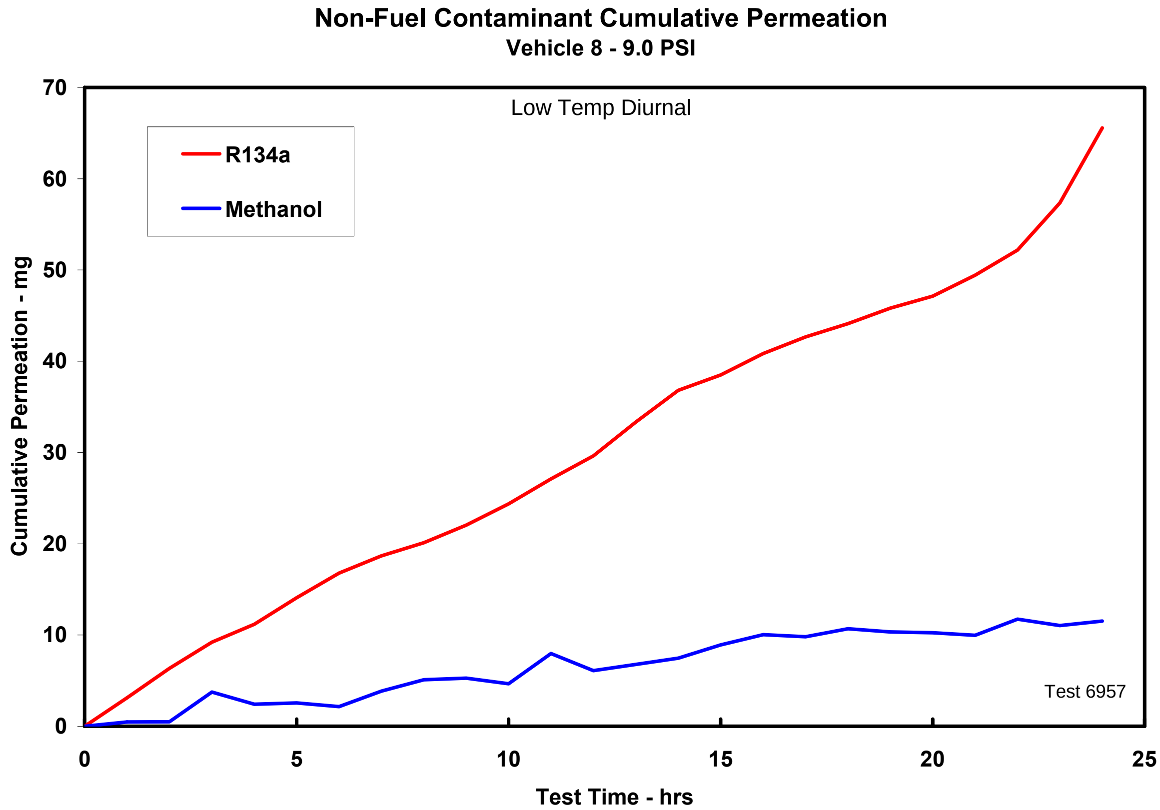
Non-Fuel Contaminant Cumulative Permeation
Vehicle 8 - 7.0 PSI
High Temp Diurnal
R134a
Methanol
Test 6956
Cumulative Permeation - mg
Test Time - hrs
0
5
10
15
20
25
30
35
40
45
50

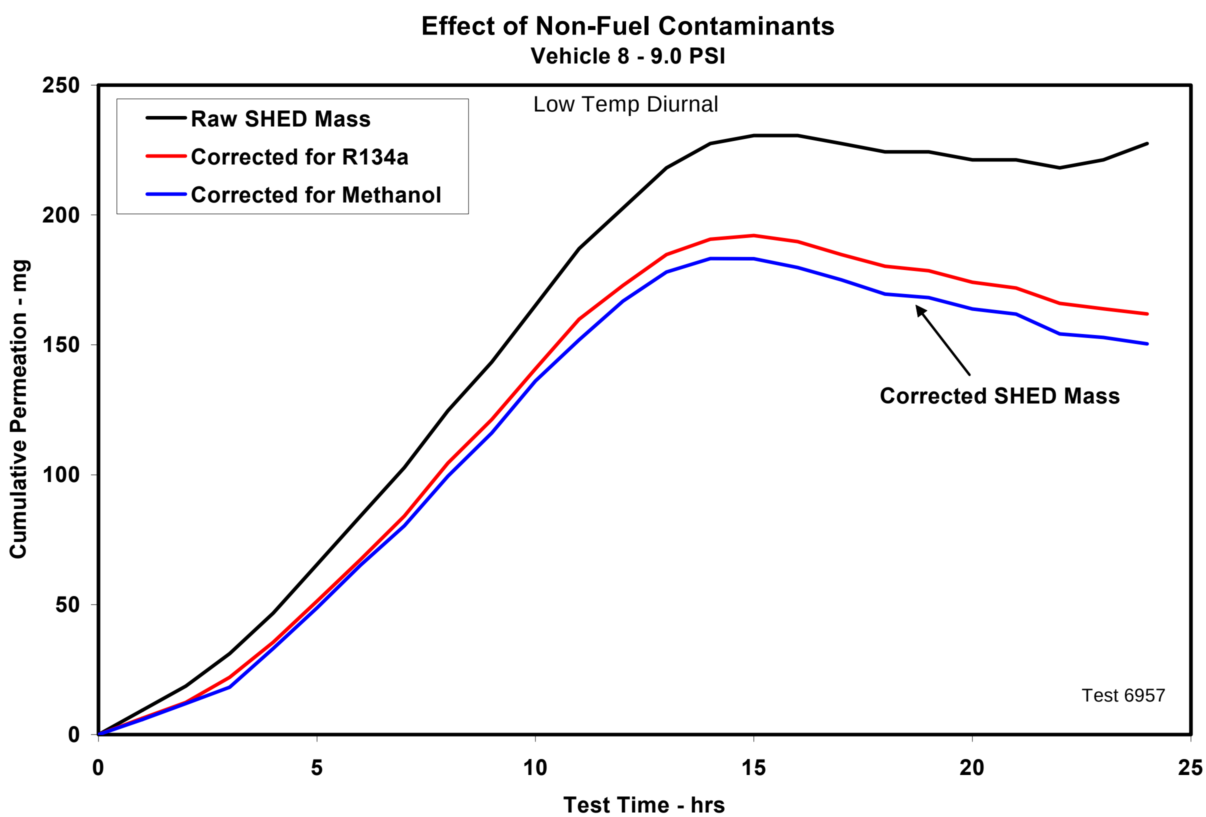


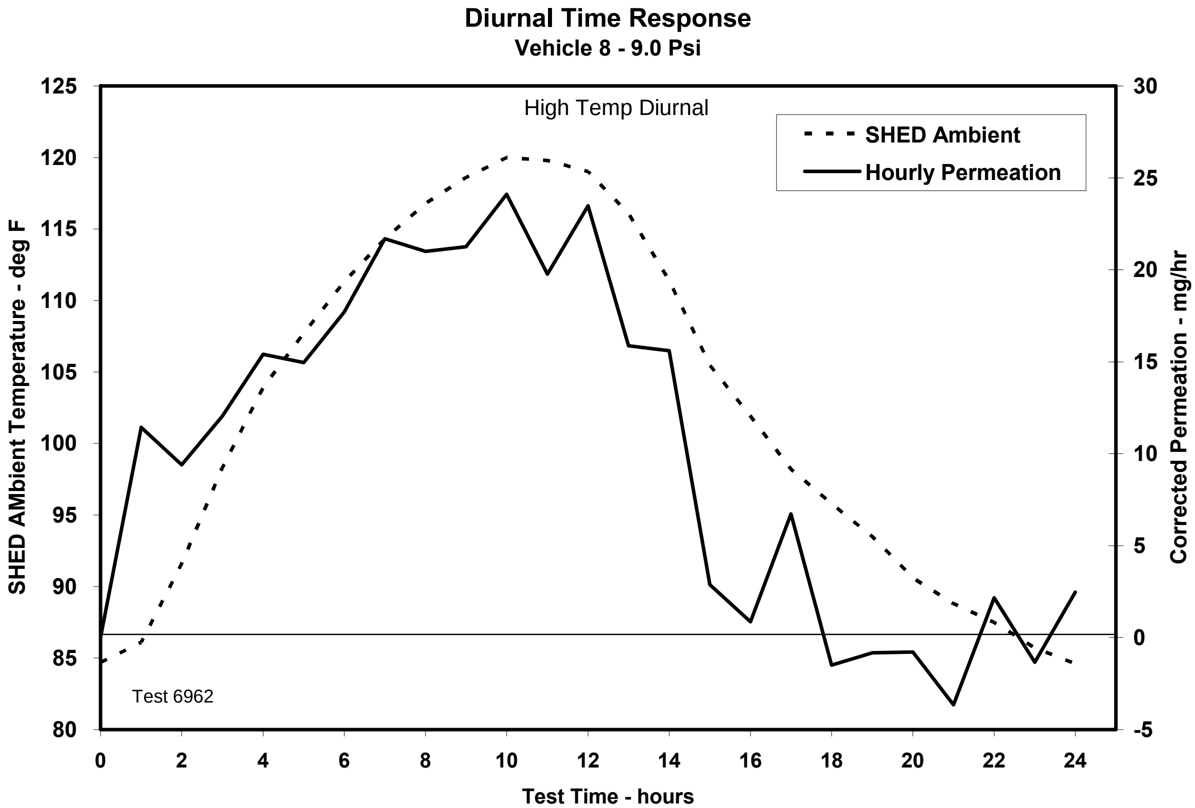
Effect of Non-Fuel Contaminants
Vehicle 8 - 7.0 PSI
High Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6956
Cumulative Permeation - mg
Test Time - hrs
0
50
100
150
200
250
300
350

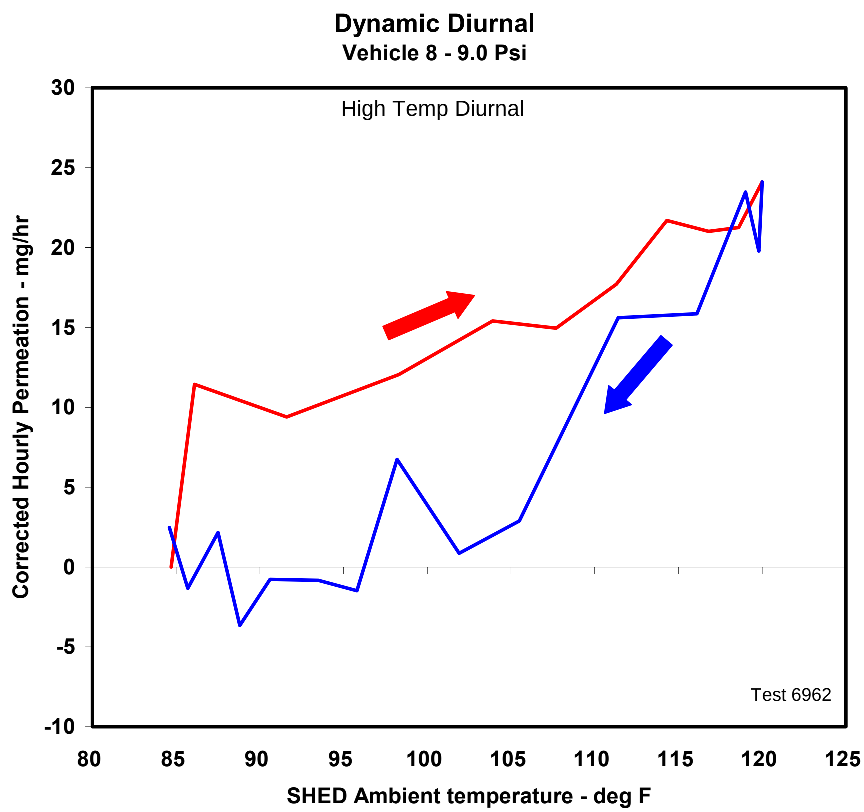

Diurnal Time Response
Vehicle 8 - 9.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
Test 6957
110
105
100
95
90
85
80
75
70
65
60
25
20
15
10
5
0
-5
-10
0
2
4
6
8
10
12
14
16
18
20
22
24

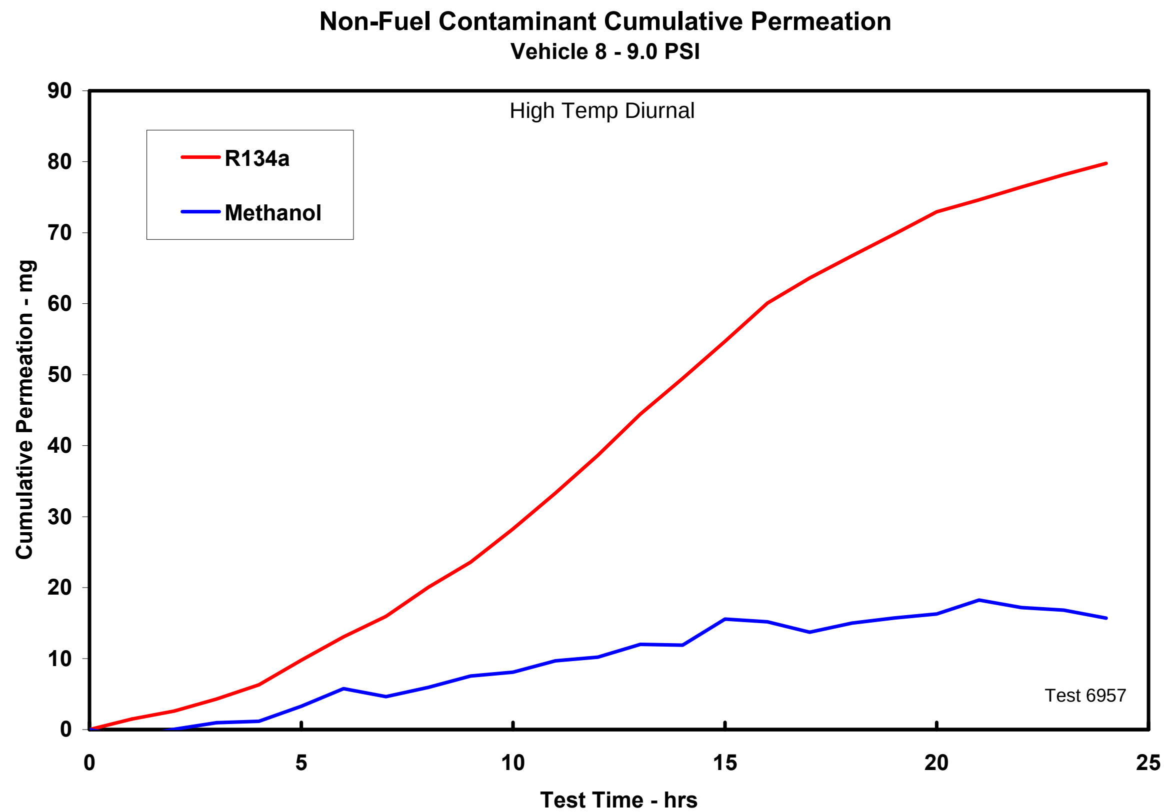

Dynamic Diurnal
Vehicle 8 - 9.0 Psi
Low Temp Diurnal
Corrected Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6957
25
20
15
10
5
0
-5
-10
60
70
80
90
100
110

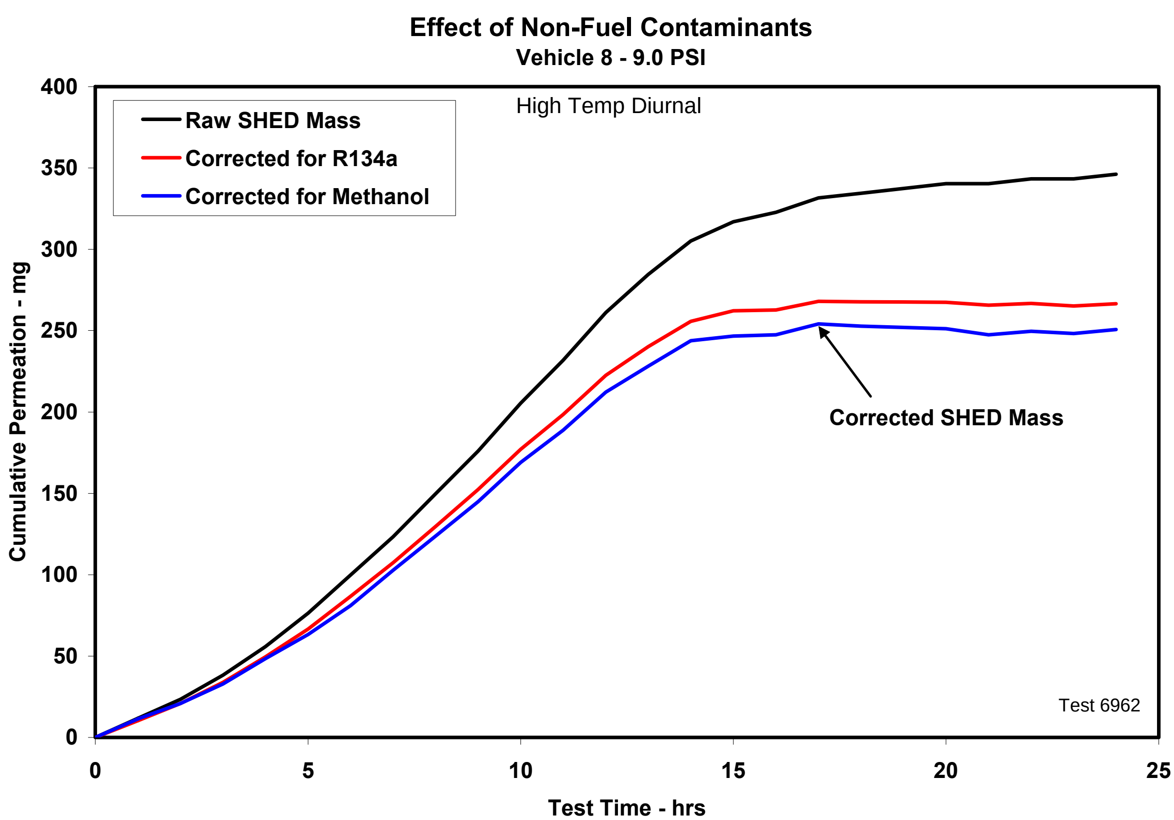

Non-Fuel Contaminant Cumulative Permeation
Vehicle 8 - 9.0 PSI
Low Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
Test Time - hrs
Test 6957
0
10
20
30
40
50
60
70
0
5
10
15
20
25

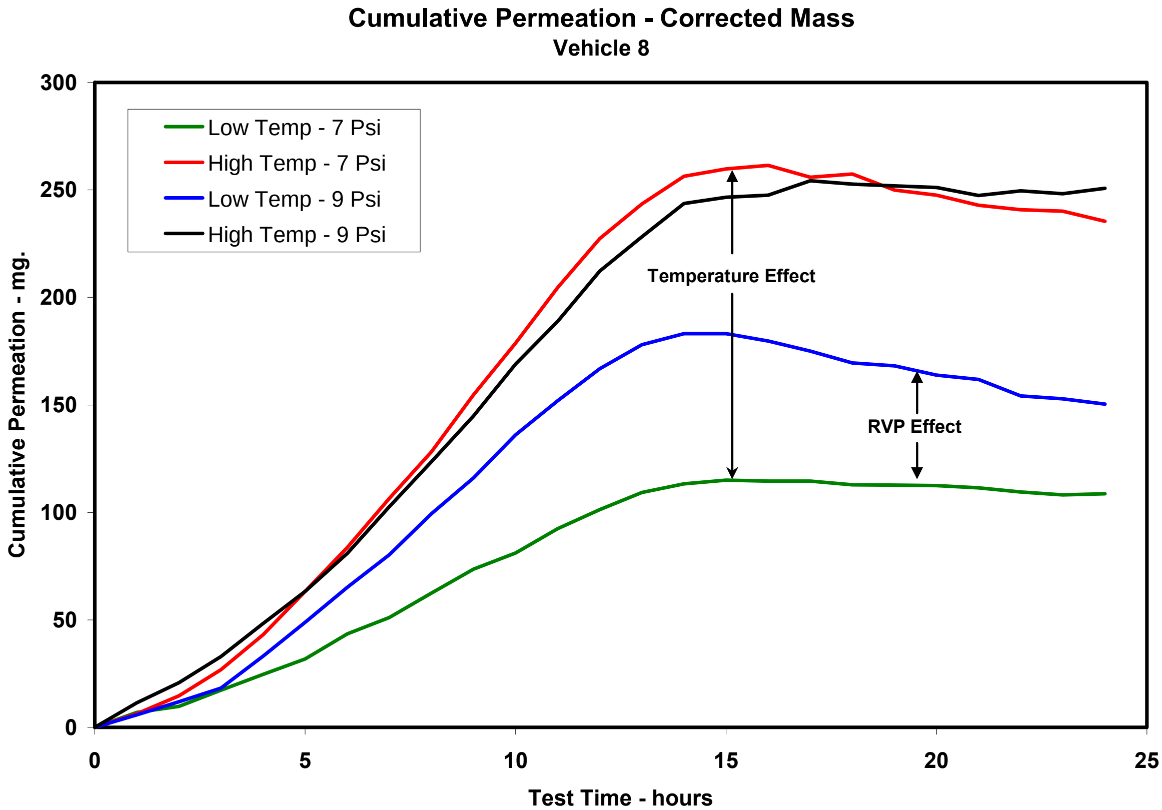

Effect of Non-Fuel Contaminants
Vehicle 8 - 9.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Cumulative Permeation - mg
Test Time - hrs
Test 6957
0
50
100
150
200
250
0
5
10
15
20
25


Diurnal Time Response
Vehicle 8 - 9.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
Test 6962
125
120
115
110
105
100
95
90
85
80
30
25
20
15
10
5
0
-5
0 2 4 6 8 10 12 14 16 18 20 22 24


Dynamic Diurnal
Vehicle 8 - 9.0 Psi
High Temp Diurnal
Corrected Hourly Permeation - mg/hr
SHED Ambient temperature - deg F
Test 6962
30
25
20
15
10
5
0
-5
-10
80 85 90 95 100 105 110 115 120 125


Non-Fuel Contaminant Cumulative Permeation
Vehicle 8 - 9.0 PSI
High Temp Diurnal
R134a
Methanol
Cumulative Permeation - mg
Test Time - hrs
Test 6957
0
10
20
30
40
50
60
70
80
90
0
5
10
15
20
25


Effect of Non-Fuel Contaminants
Vehicle 8 - 9.0 PSI
High Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Cumulative Permeation - mg
Test Time - hrs
Test 6962
0
50
100
150
200
250
300
350
400
0
5
10
15
20
25



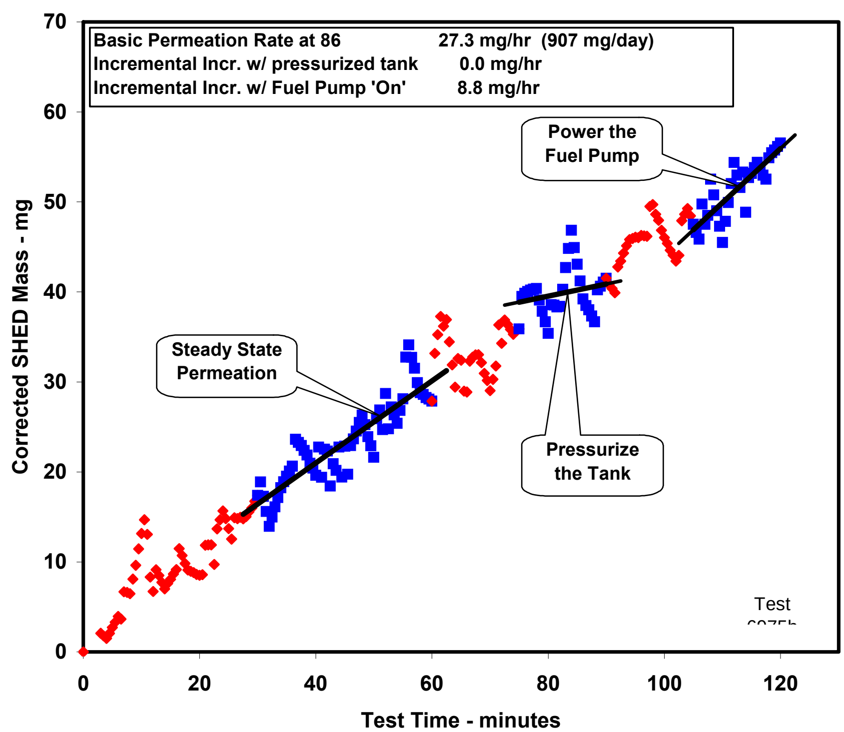
Cumulative Permeation - Corrected Mass
Vehicle 8
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Temperature Effect
RVP Effect
Cumulative Permeation - mg.
Test Time - hours
0
50
100
150
200
250
300
0
5
10
15
20
25

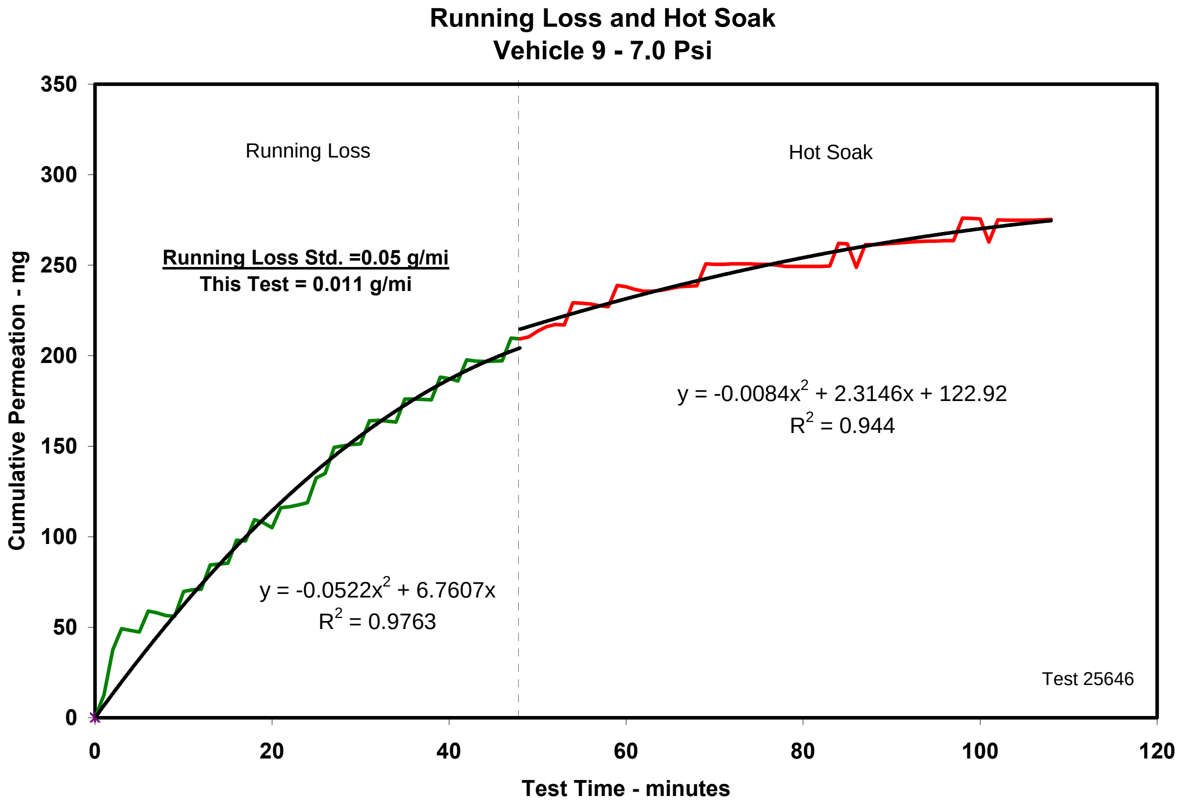
Vehicle 9

1995 Plymouth Neon Pre-Enhanced

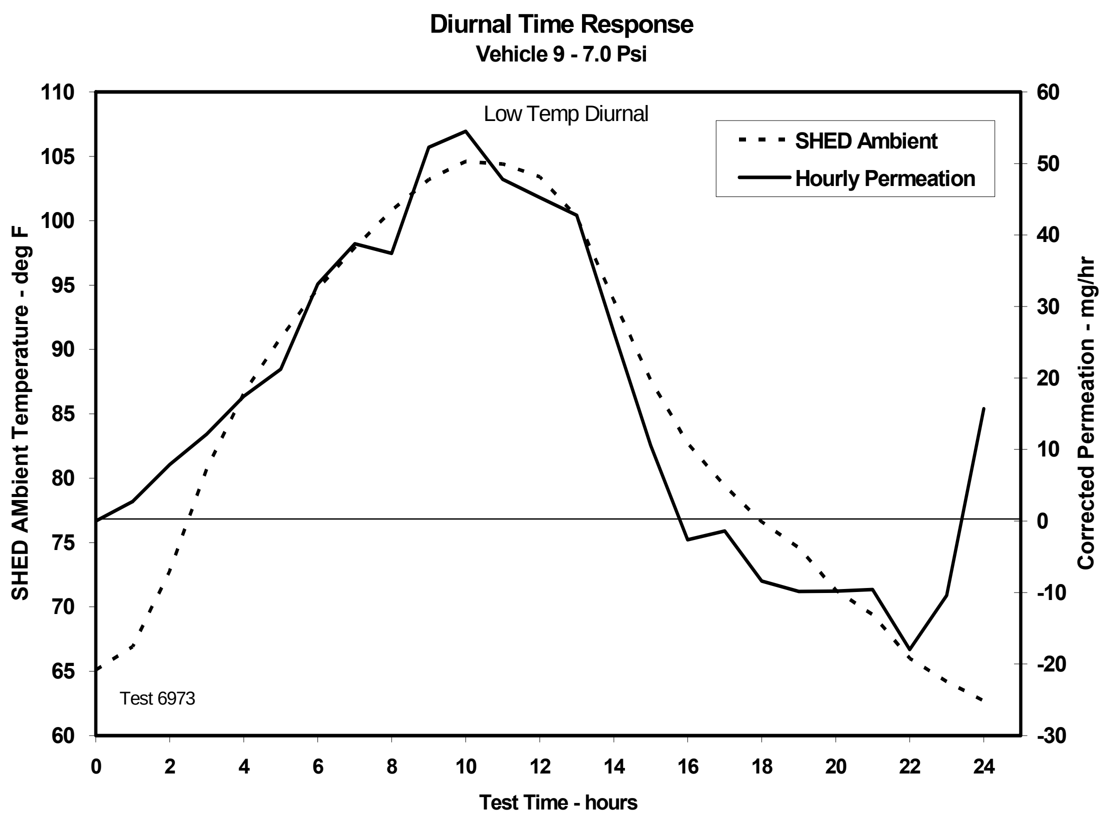
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr (Raw)	Permeation mg/hr (Corrected)	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
9	7.0	Static	Perm	01/09/07	6975	37.8	27.3			
			Press. Incr.			0.0	0.0			
			Prs+Fuel Incr.			0.4	8.8			
	7.0	Dynamic	RL	12/21/06	25646	209.3				
			HS			66.0				
			RL + HS			275.3				
	7.0	24 DHB	65-105	01/03/07	6973		Day 1	1633.6	546.7	0.13
	7.0	24 DHB	85-120	01/06/07	6974		Day 1	1053.8	953.5	9.42

Static 86 F Permeation
Vehicle 9 - 7 PSI

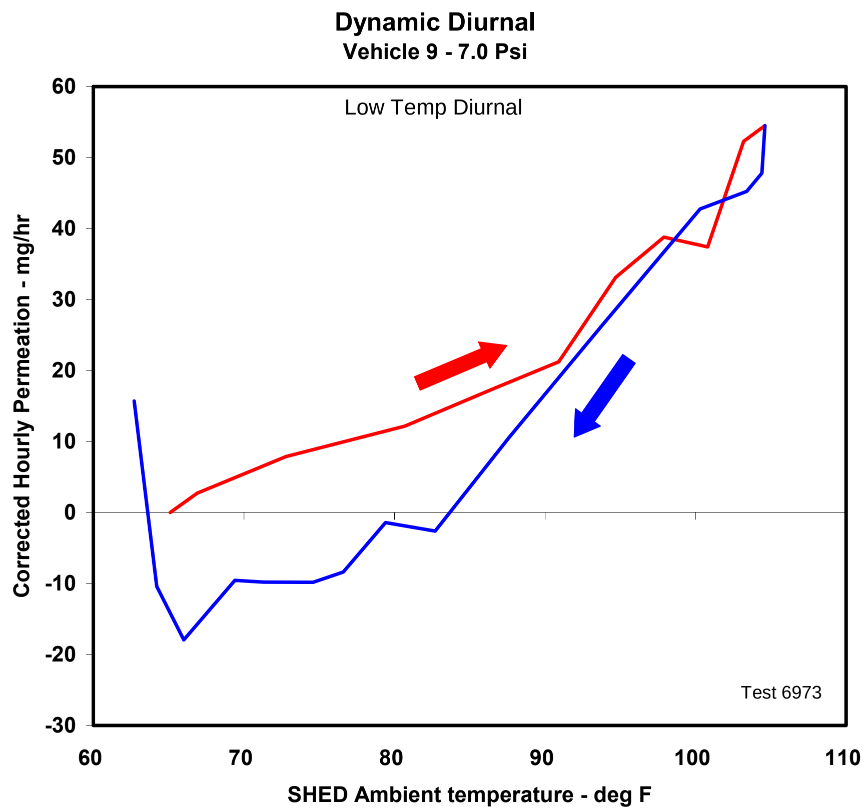


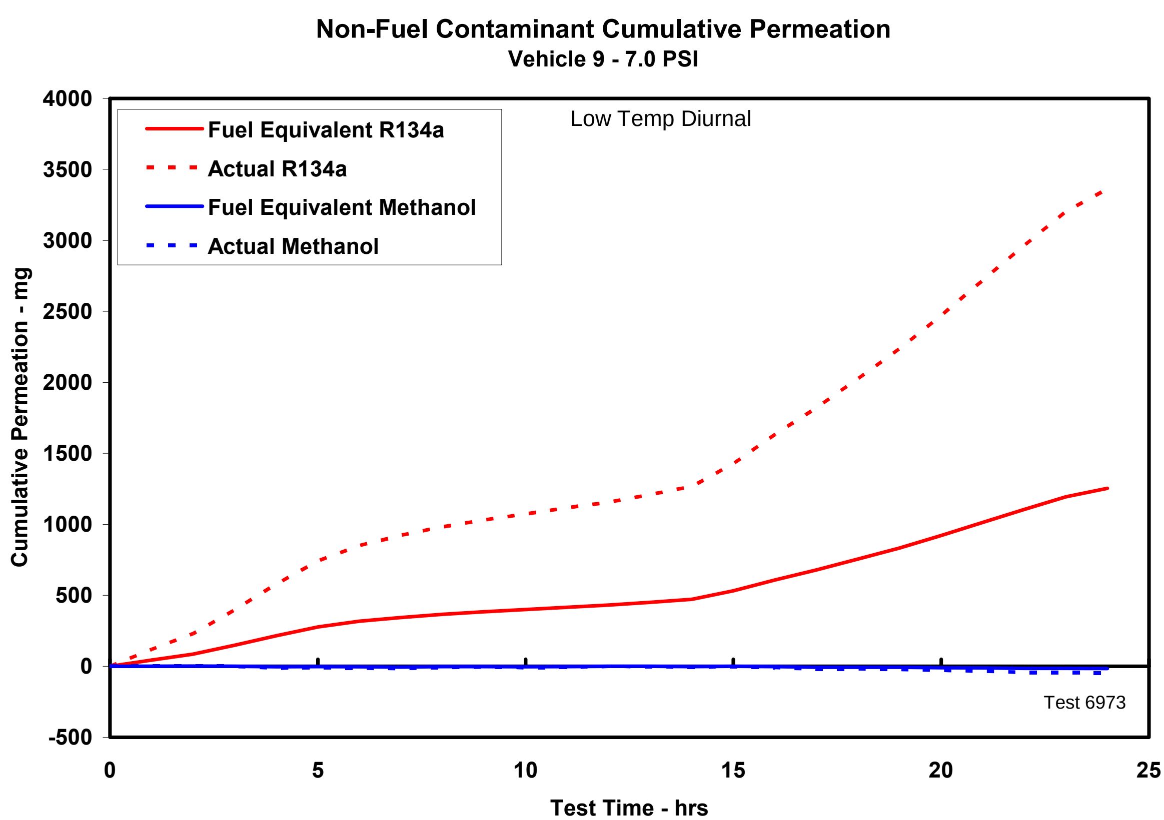


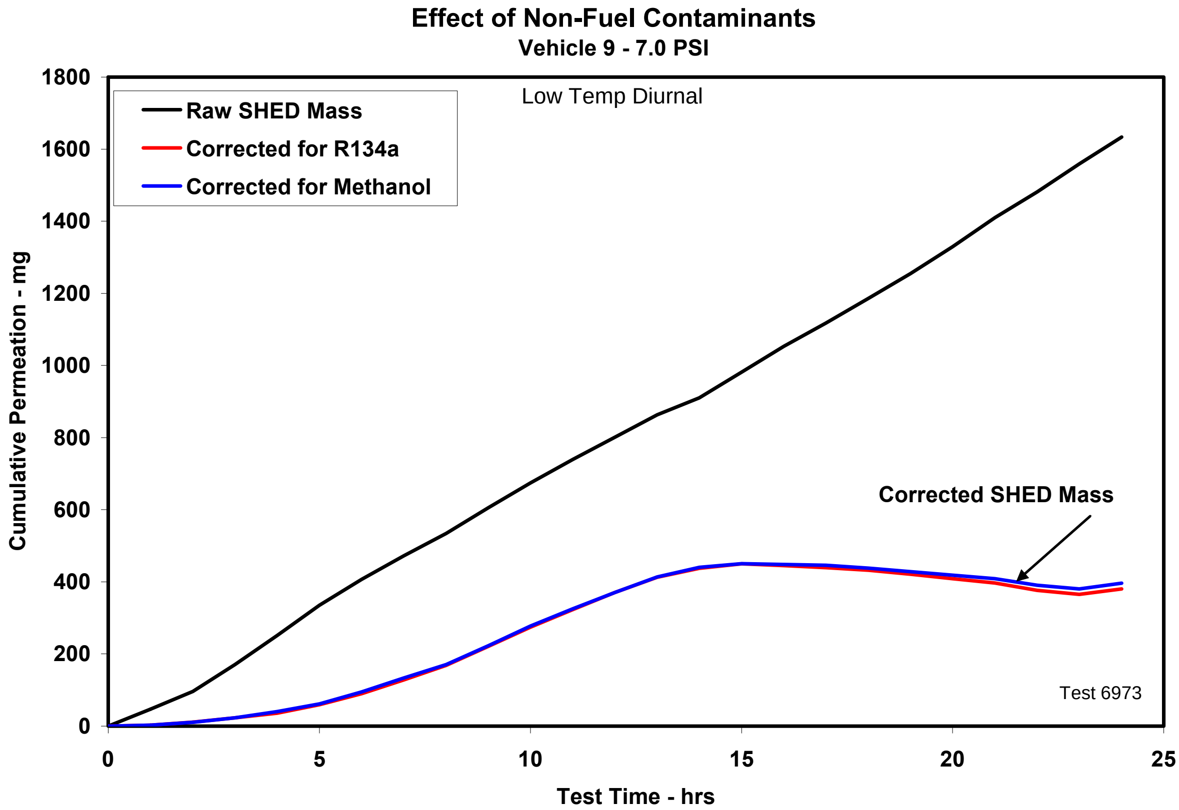
Running Loss and Hot Soak
Vehicle 9 - 7.0 Psi
Running Loss
Hot Soak
Running Loss Std. =0.05 g/mi
This Test = 0.011 g/mi
y = -0.0084x2 + 2.3146x + 122.92
R2 = 0.944
y = -0.0522x2 + 6.7607x
R2 = 0.9763
Test 25646
Cumulative Permeation - mg
Test Time - minutes
0
50
100
150
200
250
300
350
0
20
40
60
80
100
120

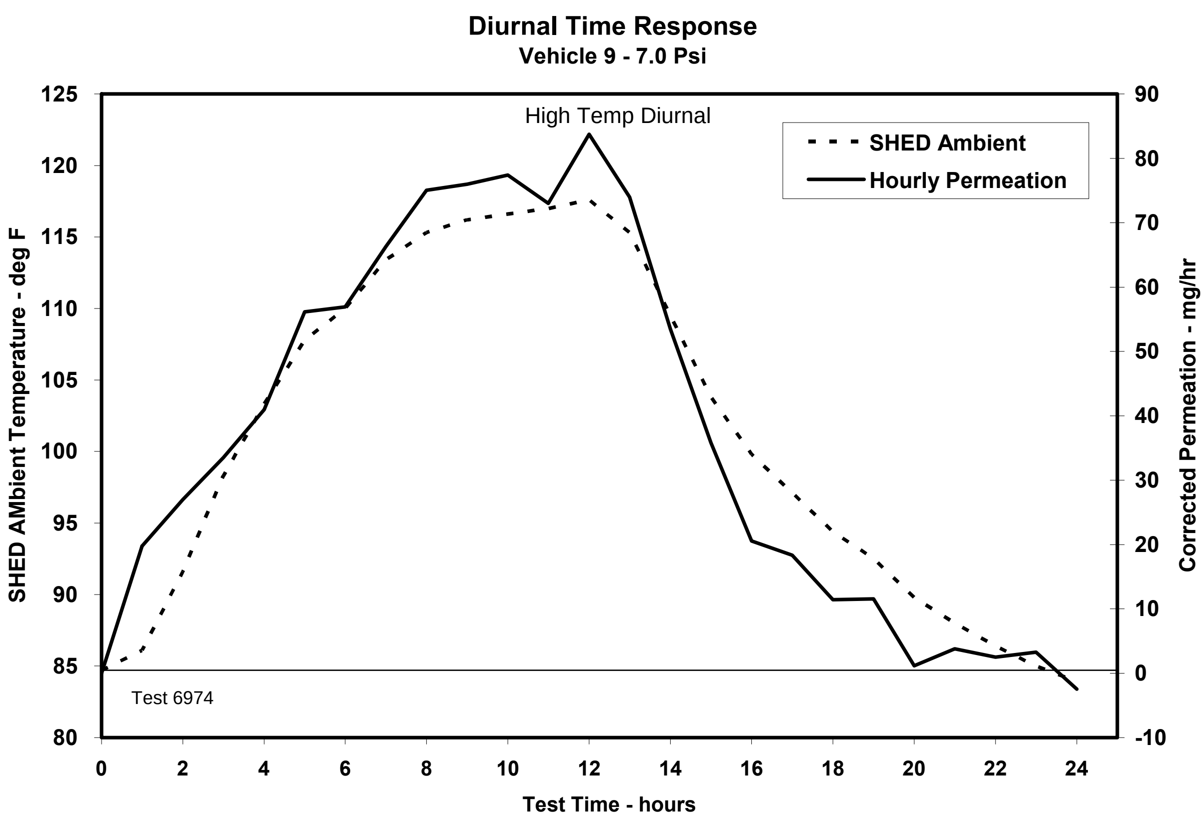


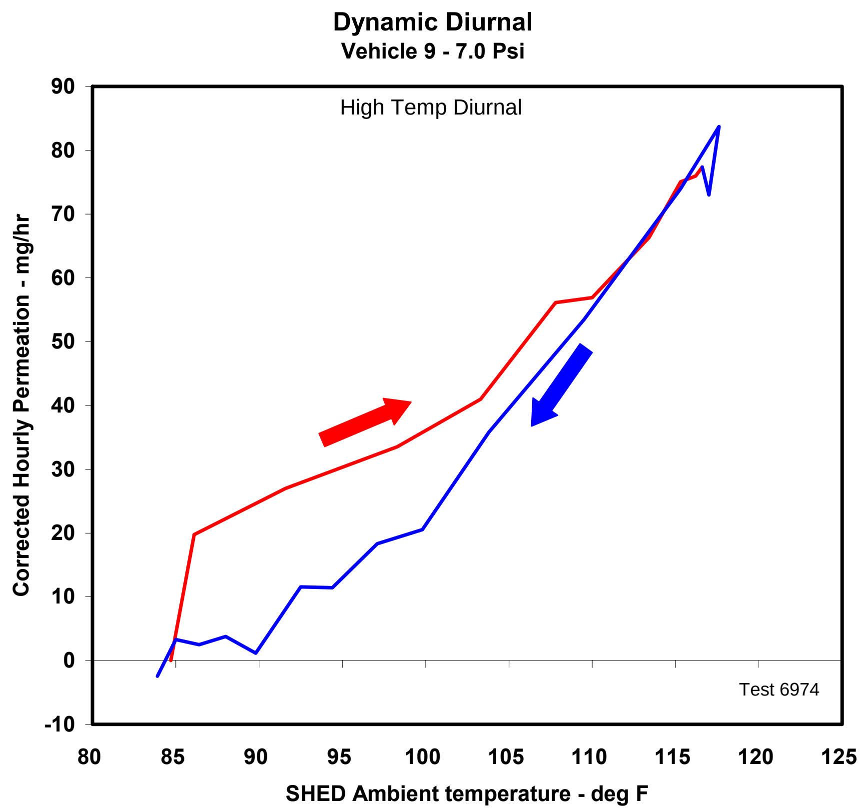
Diurnal Time Response
Vehicle 9 - 7.0 Psi
Low Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6973
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
60
65
70
75
80
85
90
95
100
105
110
-30
-20
-10
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
24

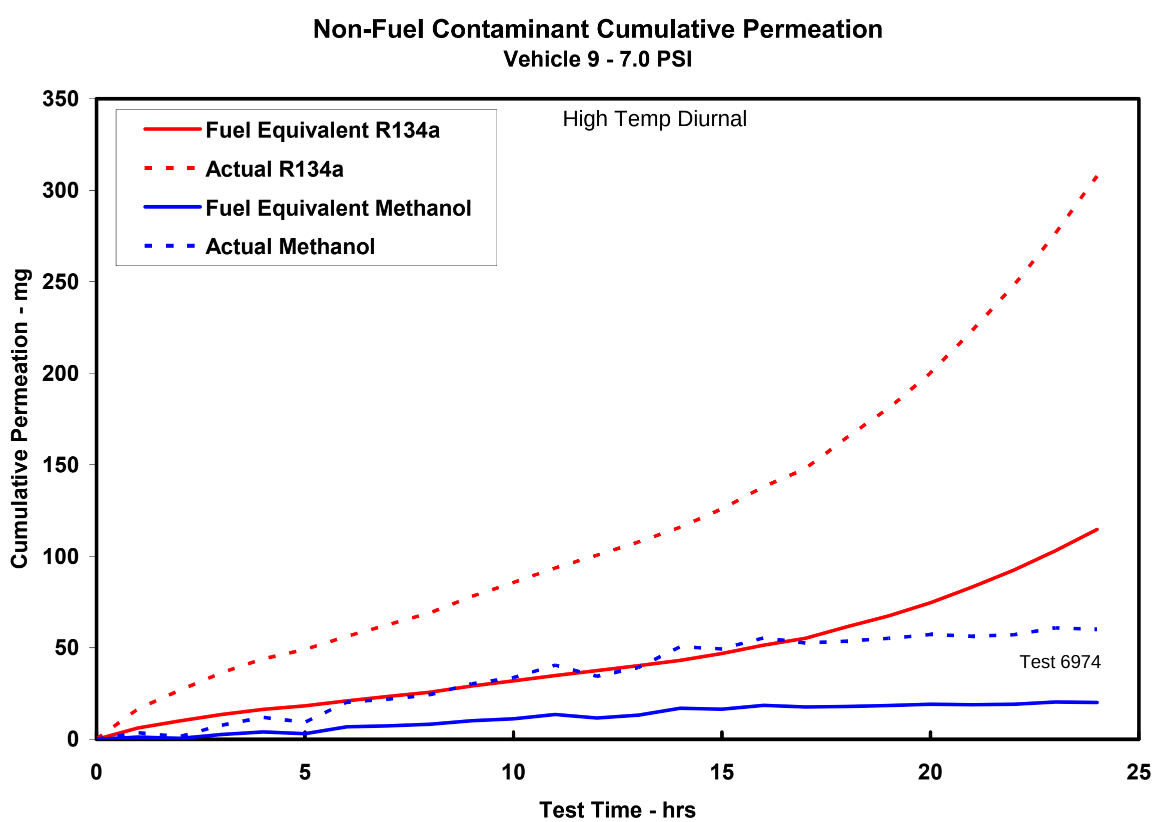

Dynamic Diurnal
Vehicle 9 - 7.0 Psi
Low Temp Diurnal
Corrected Hourly Permeation - mg/hr
60
50
40
30
20
10
0
-10
-20
-30
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6973

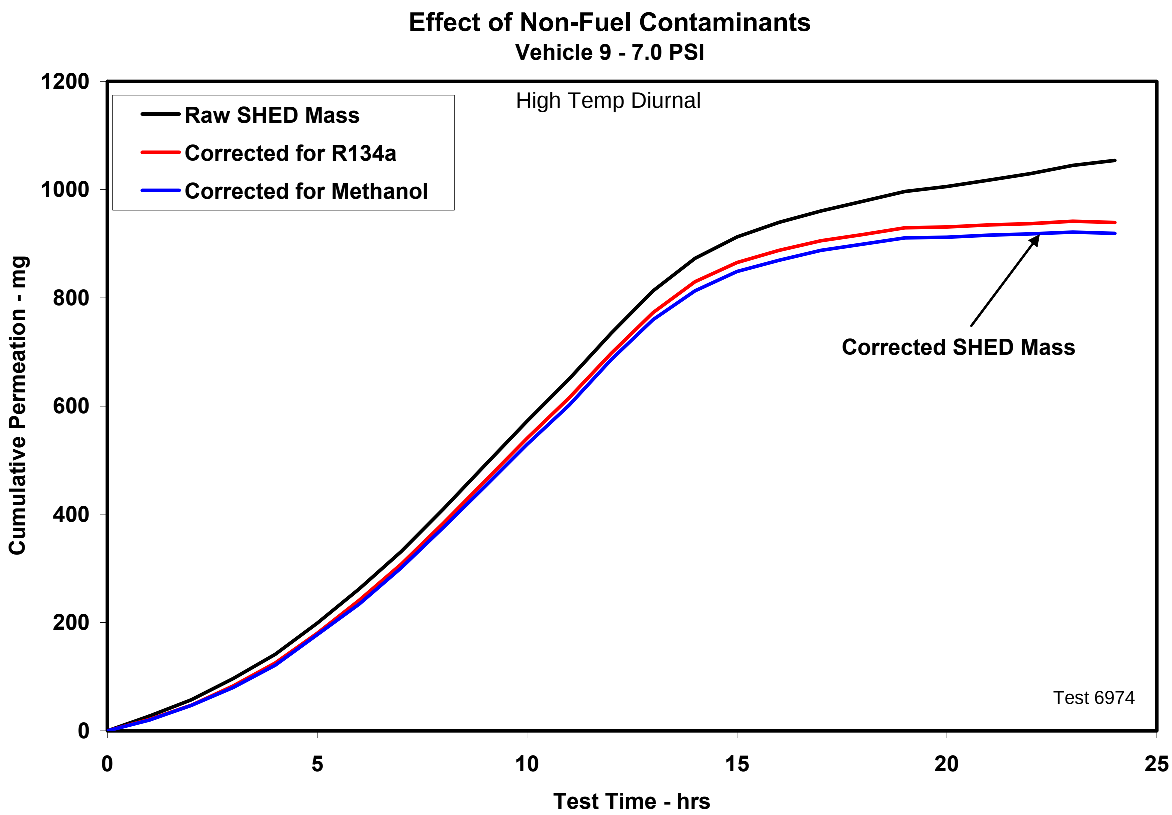

Non-Fuel Contaminant Cumulative Permeation
Vehicle 9 - 7.0 PSI
Fuel Equivalent R134a
Actual R134a
Fuel Equivalent Methanol
Actual Methanol
Low Temp Diurnal
Cumulative Permeation - mg
4000
3500
3000
2500
2000
1500
1000
500
0
-500
0
5
10
15
20
25
Test Time - hrs
Test 6973


Effect of Non-Fuel Contaminants
Vehicle 9 - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6973
Cumulative Permeation - mg
Test Time - hrs
0
200
400
600
800
1000
1200
1400
1600
1800
0
5
10
15
20
25

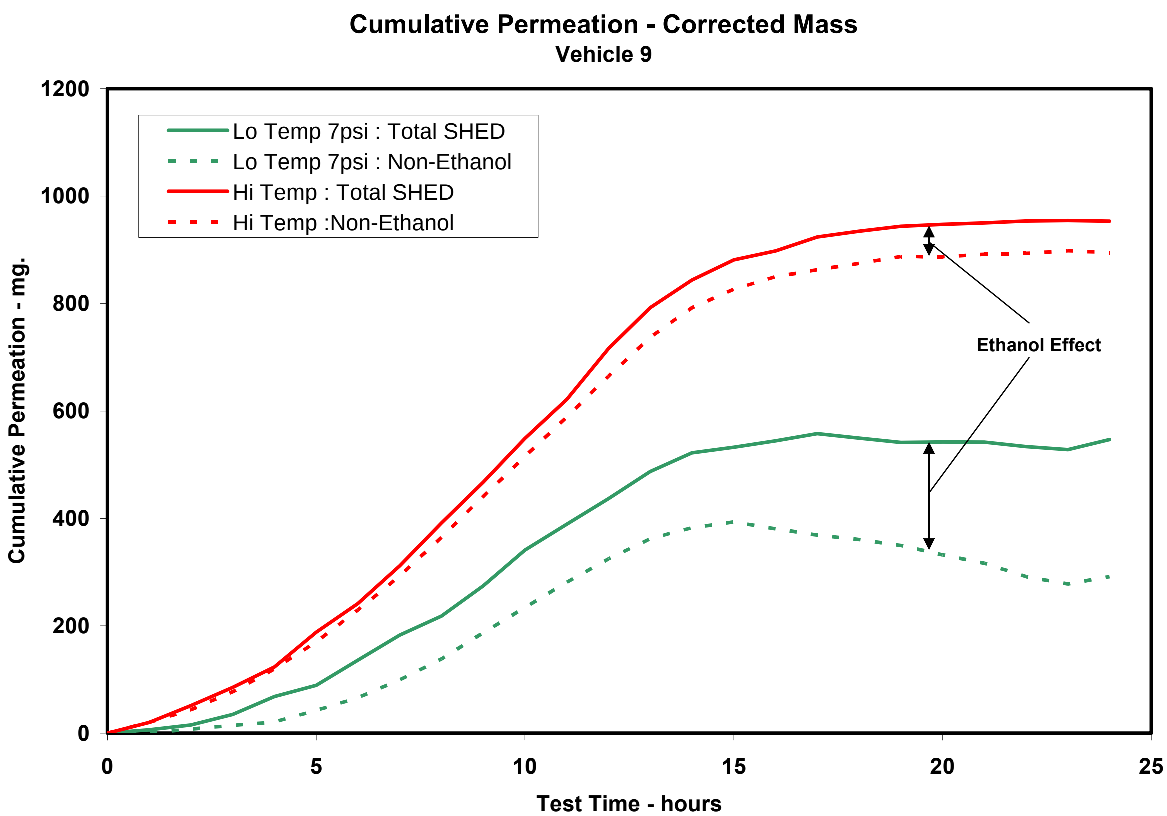

Diurnal Time Response
Vehicle 9 - 7.0 Psi
High Temp Diurnal
SHED Ambient
Hourly Permeation
Test 6974
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
80
85
90
95
100
105
110
115
120
125
-10
0
10
20
30
40
50
60
70
80
90
0
2
4
6
8
10
12
14
16
18
20
22
24


Dynamic Diurnal
Vehicle 9 - 7.0 Psi
High Temp Diurnal
Corrected Hourly Permeation - mg/hr
90
80
70
60
50
40
30
20
10
0
-10
80
85
90
95
100
105
110
115
120
125
SHED Ambient temperature - deg F
Test 6974


Non-Fuel Contaminant Cumulative Permeation
Vehicle 9 - 7.0 PSI
High Temp Diurnal
Fuel Equivalent R134a
Actual R134a
Fuel Equivalent Methanol
Actual Methanol
Cumulative Permeation - mg
350
300
250
200
150
100
50
0
0
5
10
15
20
25
Test Time - hrs
Test 6974



Effect of Non-Fuel Contaminants
Vehicle 9 - 7.0 PSI
High Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test 6974
Cumulative Permeation - mg
Test Time - hrs
0
200
400
600
800
1000
1200
0
5
10
15
20
25

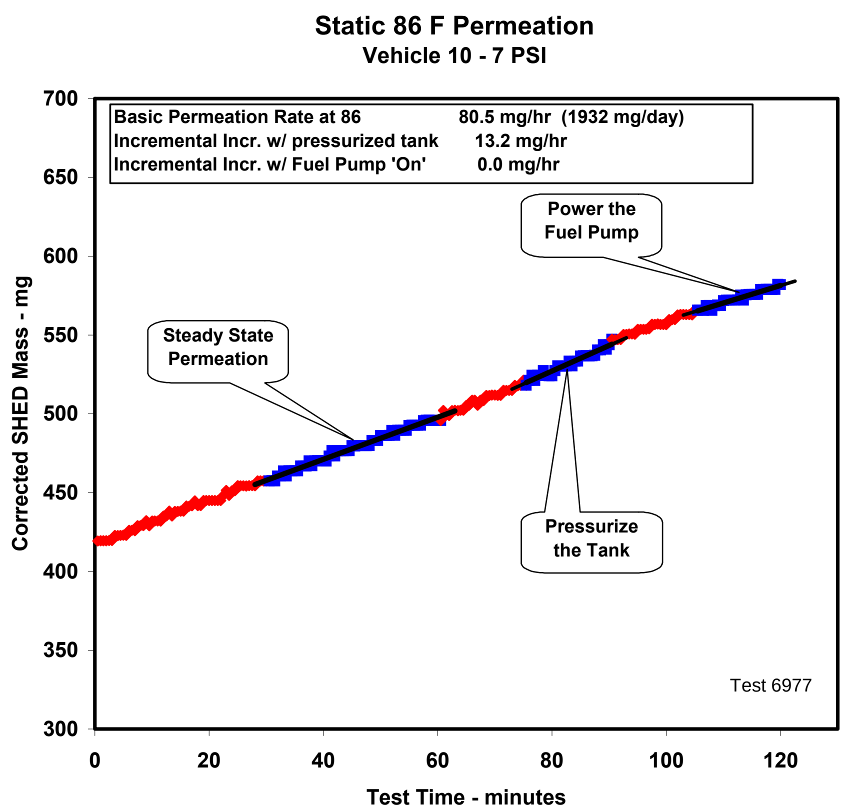


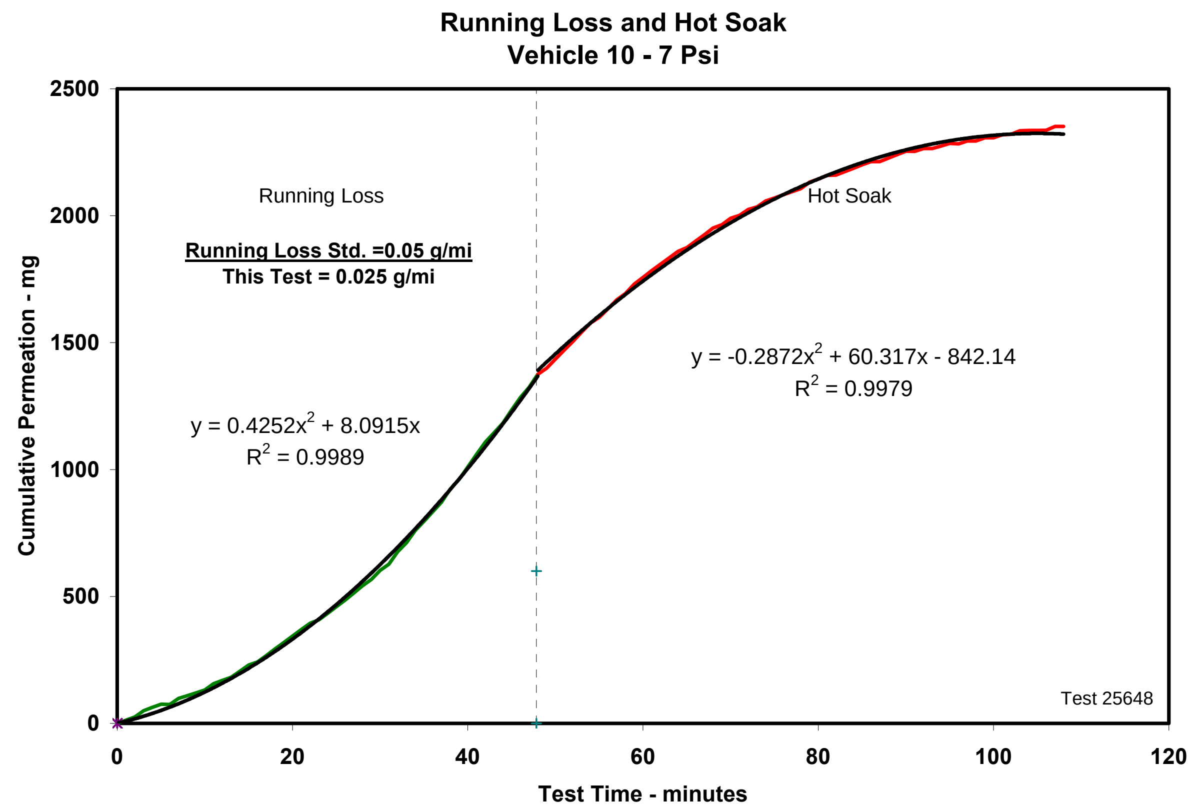
Cumulative Permeation - Corrected Mass
Vehicle 9
Lo Temp 7psi : Total SHED
Lo Temp 7psi : Non-Ethanol
Hi Temp : Total SHED
Hi Temp :Non-Ethanol
Ethanol Effect
Cumulative Permeation - mg.
Test Time - hours
0
200
400
600
800
1000
1200
0
5
10
15
20
25

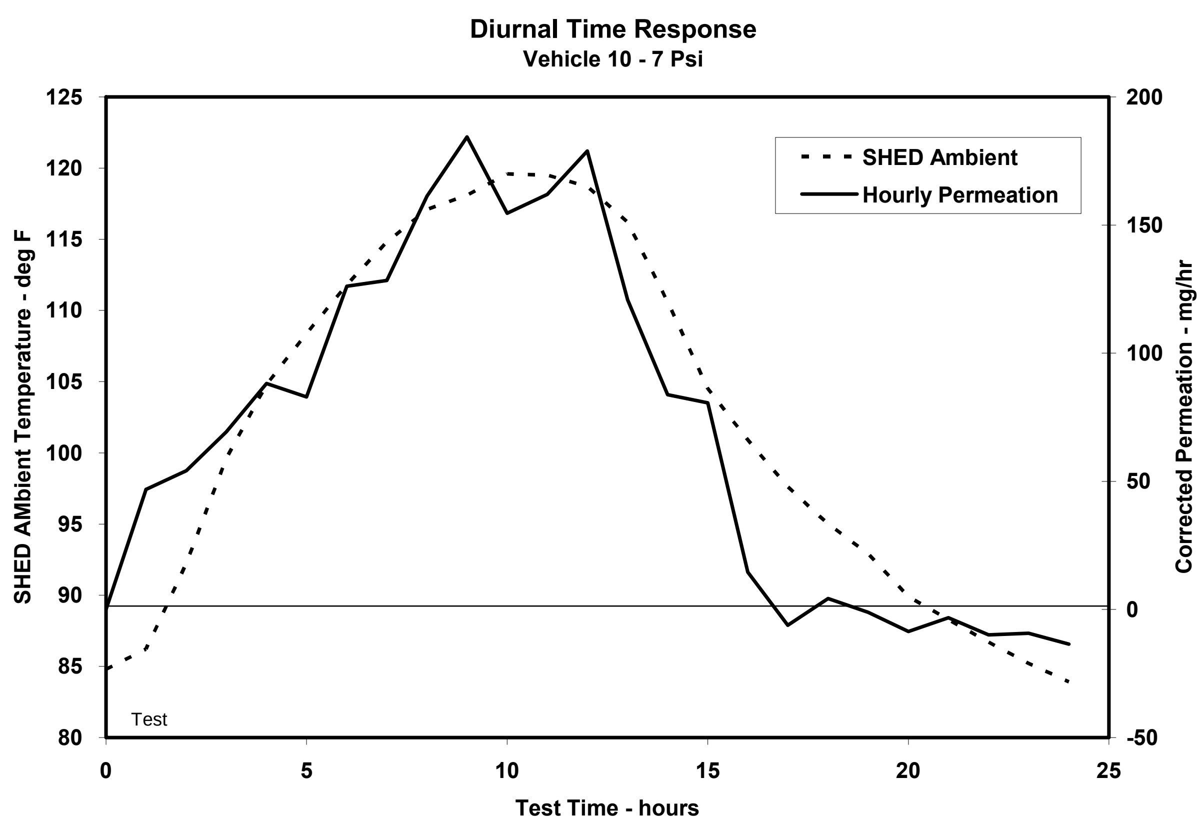
Vehicle 10

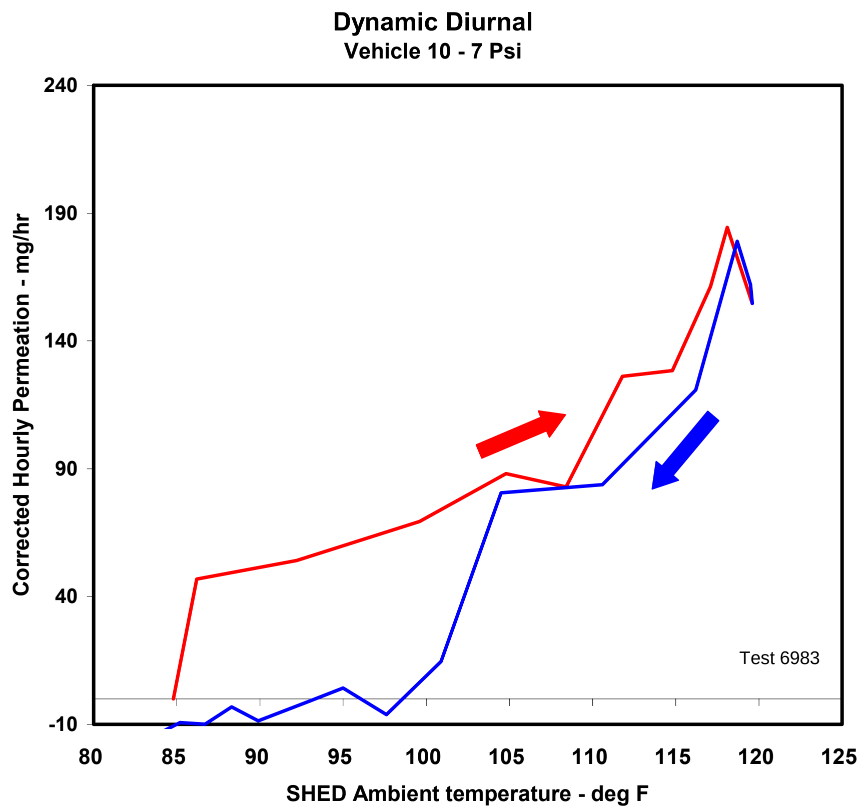
1992 Toyota Camry

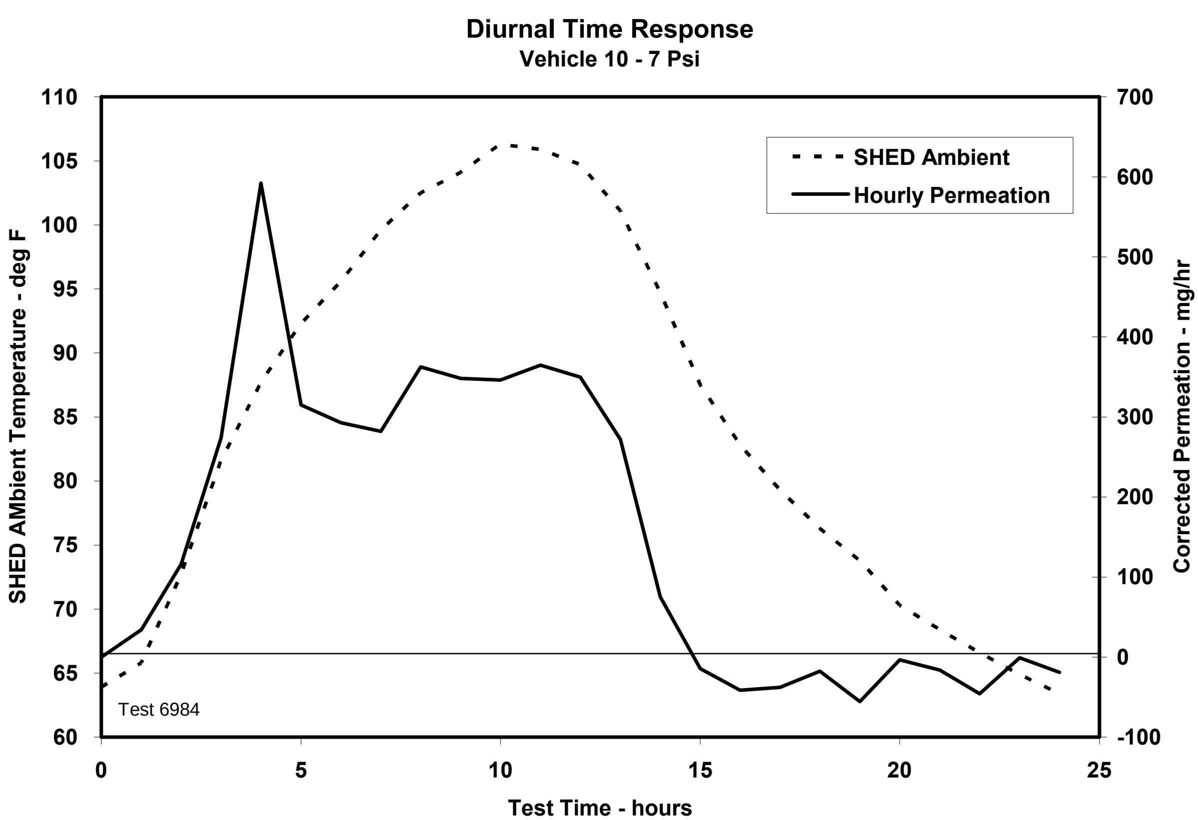
Veh	Fuel	Test	Type	Date	Test#	Permeation mg/hr	SHED Results mg/day (Raw)	SHED Results mg/day (Corrected)	Canister Loss g
10	7.0	Static	Perm	02/07/07	6977	80.5			
			Press. Incr.			13.2			
			Prs+Fuel Incr.			0.0			
	7.0	Dynamic	RL	02/07/07	25648	1375.0			
			HS			977.1			
			RL + HS			2352.1			
	7.0	24 DHB Day 1	65-105	02/21/07	6984		3831.3	3773.7	0.00
	7.0	24 DHB Day 1	65-105	02/23/07	6985		3150.4	3107.8	0.00
	7.0	24 DHB Day 1	85-120	02/16/07	6983		1655.8	1689.3	4.98

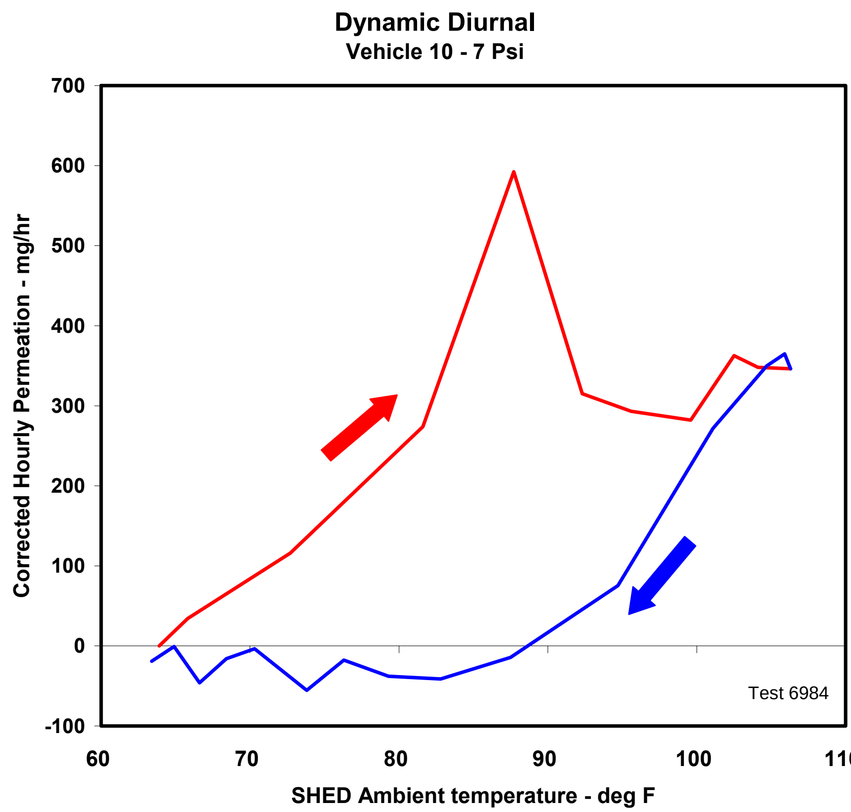


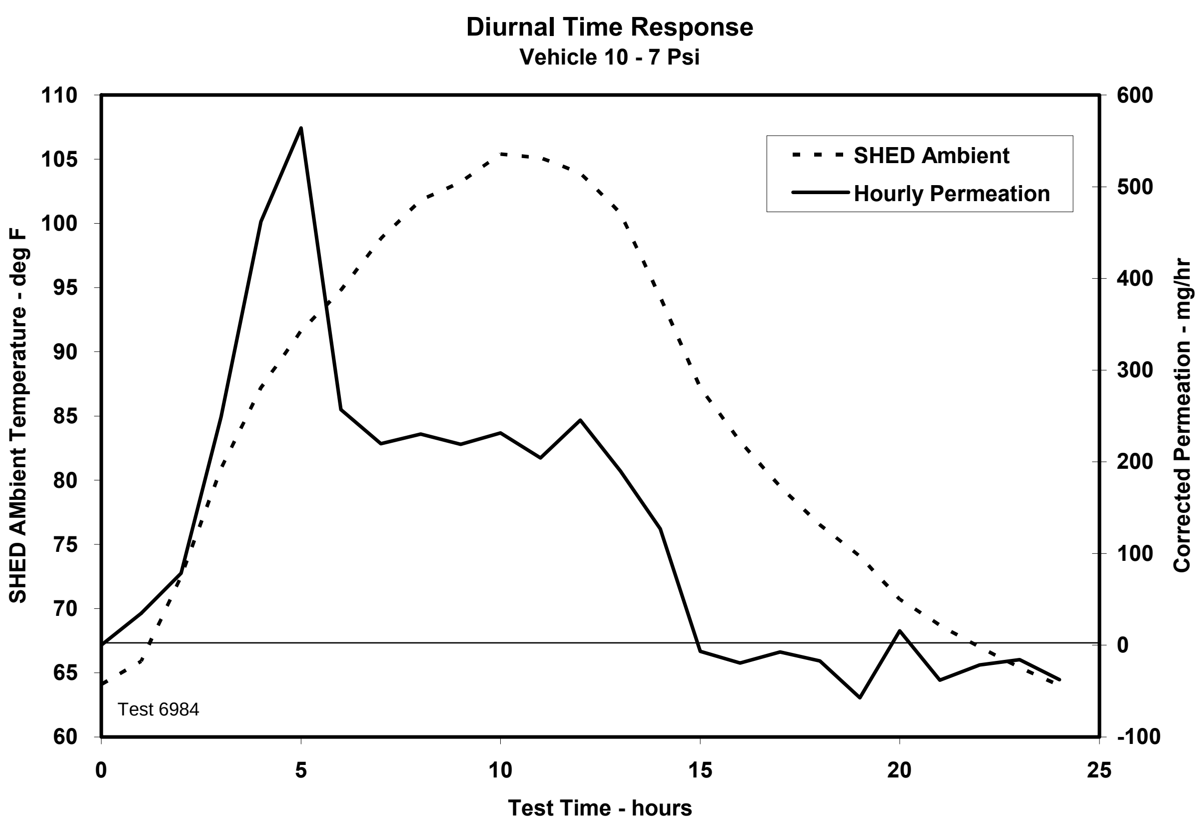

Running Loss and Hot Soak
Vehicle 10 - 7 Psi
Running Loss
Running Loss Std. =0.05 g/mi
This Test = 0.025 g/mi
y = 0.4252x2 + 8.0915x
R2 = 0.9989
Hot Soak
y = -0.2872x2 + 60.317x - 842.14
R2 = 0.9979
Test 25648
Cumulative Permeation - mg
Test Time - minutes
0
500
1000
1500
2000
2500
0
20
40
60
80
100
120

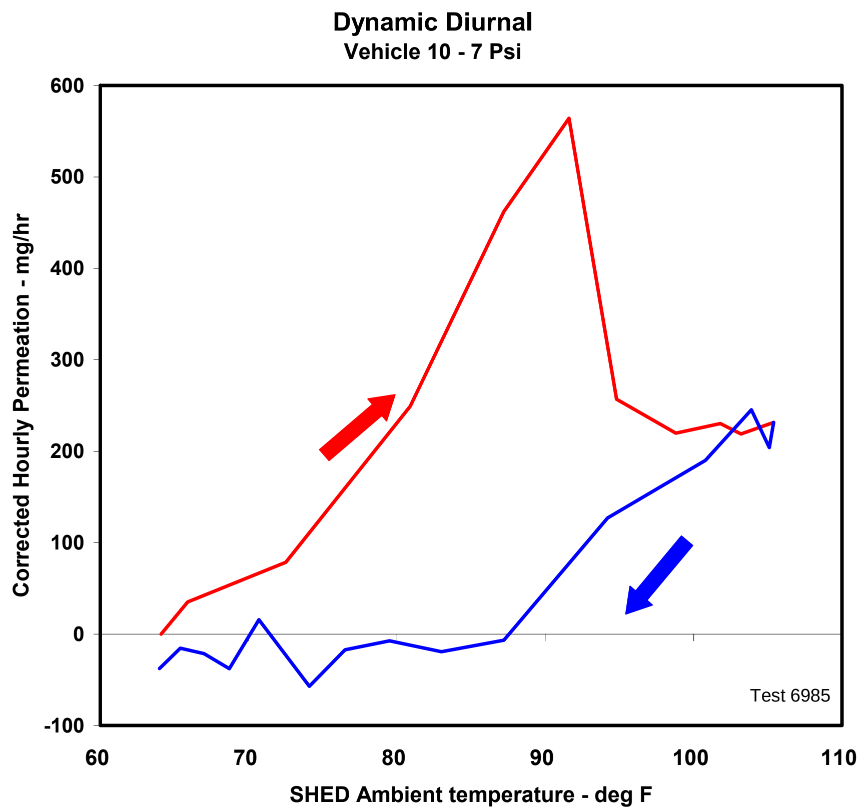

Diurnal Time Response
Vehicle 10 - 7 Psi
SHED Ambient
Hourly Permeation
Test
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
Test Time - hours
80
85
90
95
100
105
110
115
120
125
-50
0
50
100
150
200
0
5
10
15
20
25

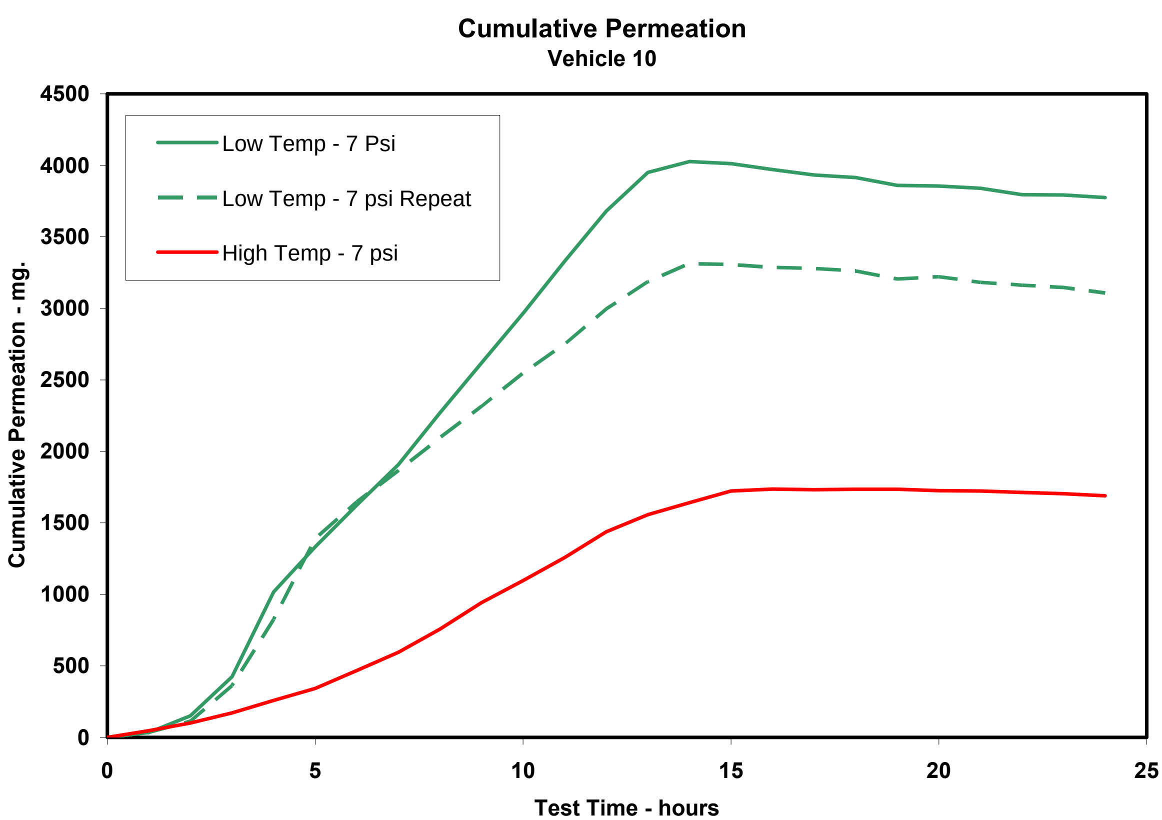

Dynamic Diurnal
Vehicle 10 - 7 Psi
Corrected Hourly Permeation - mg/hr
240
190
140
90
40
-10
80
85
90
95
100
105
110
115
120
125
SHED Ambient temperature - deg F
Test 6983


Diurnal Time Response
Vehicle 10 - 7 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
Corrected Permeation - mg/hr
110
105
100
95
90
85
80
75
70
65
60
700
600
500
400
300
200
100
0
-100
0
5
10
15
20
25
Test Time - hours
Test 6984


Dynamic Diurnal
Vehicle 10 - 7 Psi
Corrected Hourly Permeation - mg/hr
700
600
500
400
300
200
100
0
-100
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6984


Diurnal Time Response
Vehicle 10 - 7 Psi
SHED Ambient
Hourly Permeation
SHED AMbient Temperature - deg F
110
105
100
95
90
85
80
75
70
65
60
Corrected Permeation - mg/hr
600
500
400
300
200
100
0
-100
0
5
10
15
20
25
Test Time - hours
Test 6984


Dynamic Diurnal
Vehicle 10 - 7 Psi
Corrected Hourly Permeation - mg/hr
600
500
400
300
200
100
0
-100
60
70
80
90
100
110
SHED Ambient temperature - deg F
Test 6985


Cumulative Permeation
Vehicle 10
Cumulative Permeation - mg.
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
5
10
15
20
25
Test Time - hours
Low Temp - 7 Psi
Low Temp - 7 psi Repeat
High Temp - 7 psi