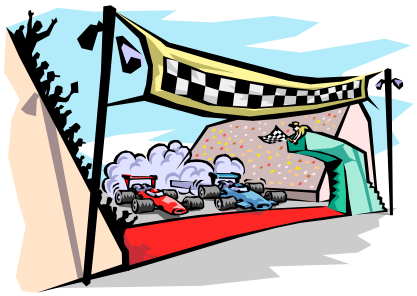
CRC E-77: Permeation Pilot Study
The End is in Sight!



Harold Haskew & Associates, Inc.

December 12, 2006

E-77 Objective(s)

- Originally envisioned as a follow-up to CRC E-41
- Intended to look at evaporative emissions performance of in-use enhanced evaporative emissions control vehicles
- The objectives migrated to an examination of the mechanisms of evap emissions
    - Leaks
    - Permeation
    - Canister losses
- Aid to new inventory models
- Proposed as a pilot study with funding for 10 vehicles

Chronology – E-77

- First draft proposal in May 2004
- Draft SOW October 2005
- Project officially activated February 2006
- First official data early July 2006
- Estimated completion:
  - Data by Year End
  - Report by 2nd quarter 2007

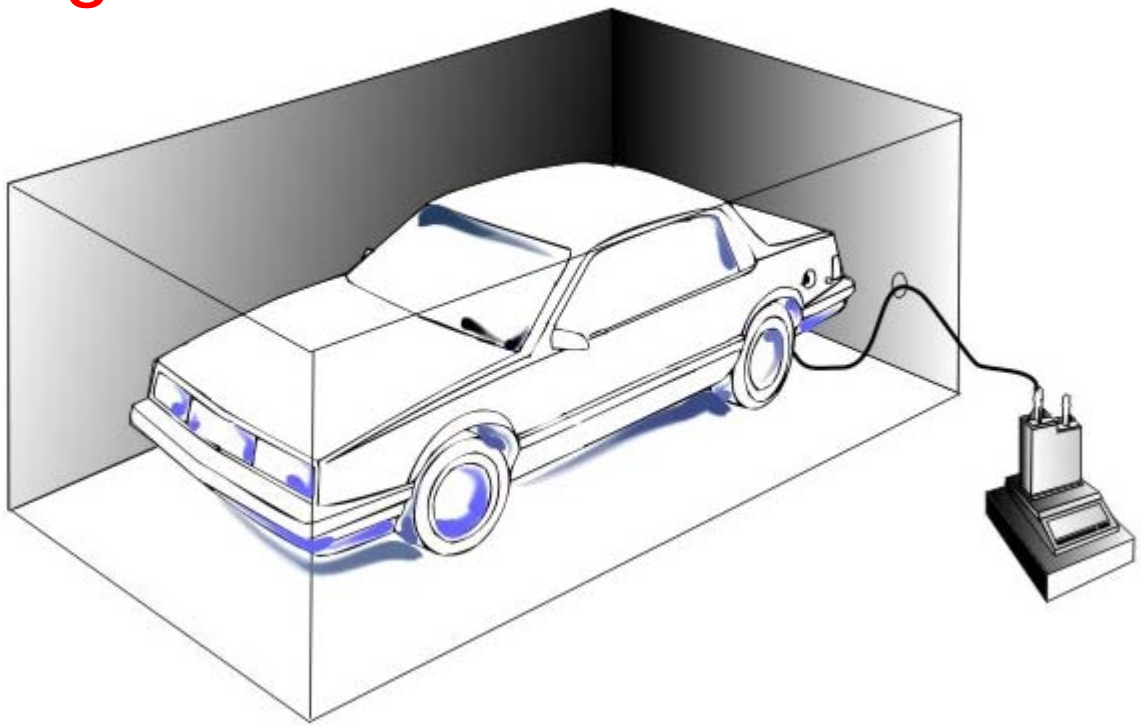
Test Protocol

- Pre-condition vehicles four or more weeks on known oxygenate (ethanol) free fuel
- Instrument and prepare for test
- Pre-condition on-road before each test sequence
- Static permeation test at 86°F
  - Static (temperature stabilized vehicle at rest)
  - Fuel system pressurized to 5”H_2O
  - Fuel pump energized
- Running loss and hot soak test
- Diurnal(s) – used multiple protocols (see next slide)
  - 65-105°F
  - 85-120°F

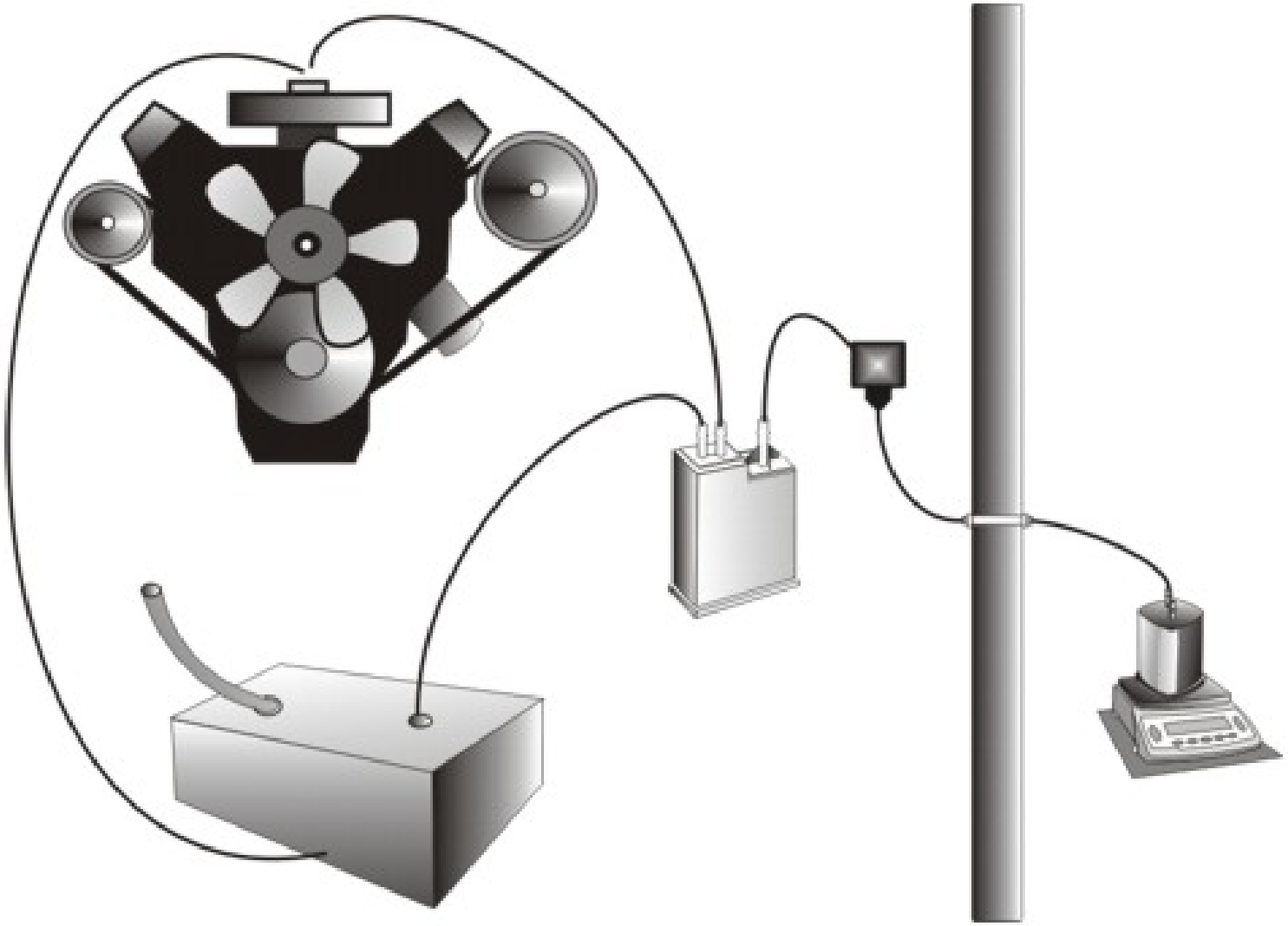
Diurnal Options

- We Ran Diurnals at 2 Temperature Ranges
  - 65 to 105°F
  - 85 to 120°F (Enhanced Evap only)
- With 2 different Fuels
  - 7 psi RVP
  - 9 psi RVP
- And some for One day, Three for Three days

Test Arrangement



Permeation is isolated from vapor emissions venting (canister loss) by connecting the vehicle canister vent to an external trap canister on a precision scale.



Test Vehicles

CRC E-77 Pilot Study Test Fleet

Veh No.	Yr	Make	Model	Displ. L	Fuel Sys.	Odo.	Engine Family	Evap Family
01	1996	Chevrolet	S-10	4.3	PFI	68,420	TGM4.31PGFEK	TGM1082AYMEA
02	2000	Toyota	Tacoma	3.4	PFI	80,557	YTYXTO3.4XBP	YTYXE0095AE0
03	1992	Honda	Accord	2.2	PFI	71,129	NHN2.2V5FNF2	92FG
04	1999	Dodge	Grand Caravan SE	3.3	PFI	98,765	XCRXT0201230	XCRXE0101G2A
05	2007	Ford	Taurus	3.0	PFI	6,916	7FMXV03.0VEY	7FMXR0185GAR
06	1996	Chev	Cavalier	2.2	PFI	112,365	TGM2.2V8GKEK	TGM1089AYMEA
07	1996	Chev	Cavalier	Same Vehicle (06) with implanted leak				
08	1991	Ford	Explorer	4.0	PFI		TFM4.028G2FK	TFM1120AYMED
09	1995	Dodge	Neon	2.0	PFI	103,639	SCR2.0VJGFEB	SCR1050AYM02
10								

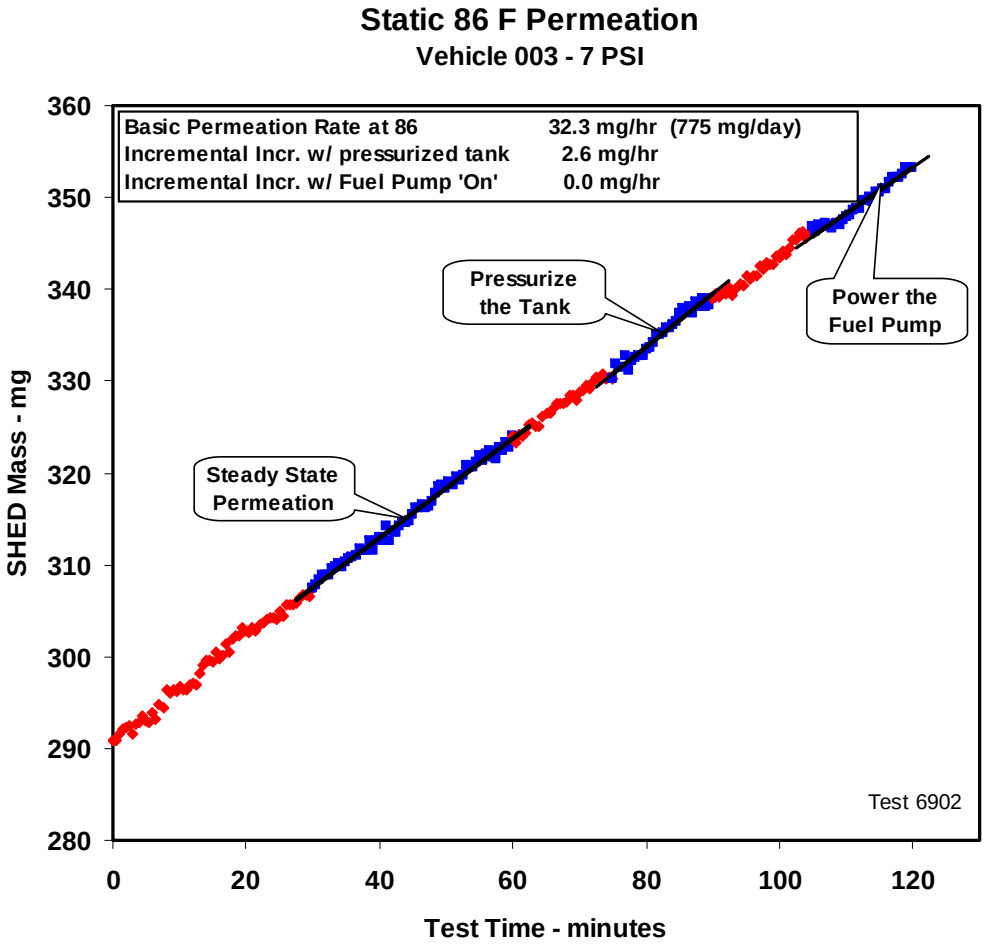
Test Matrix and Status
As of December 7, 2006

CRC E-77 Permeation Pilot Study

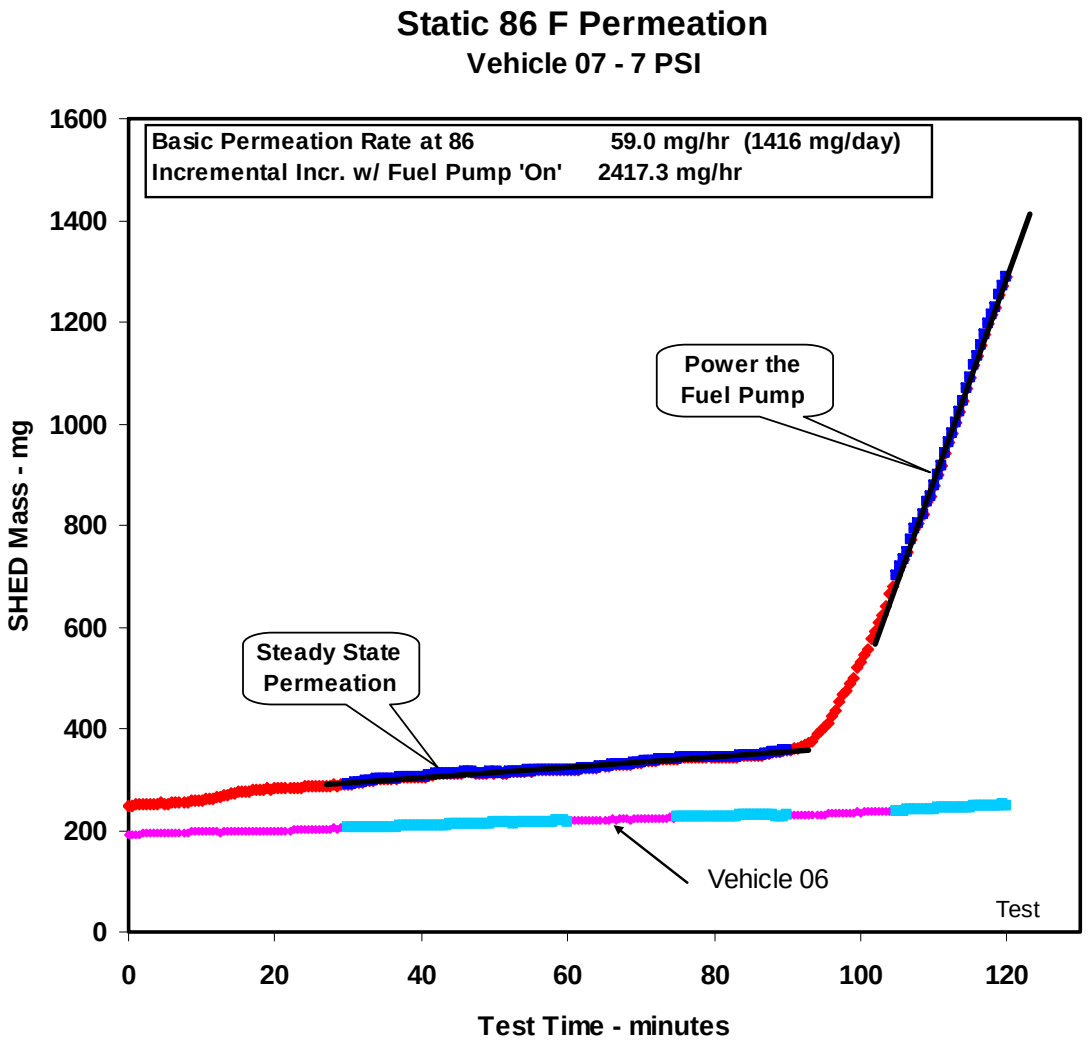
			Diurnal Tests			
	Static Perm & Leak Tests	Running Loss & Hot Soak	7 psi 65-105F	7 psi 85-120F	9 psi 65-105F	9 psi 85-120F
Pre Enhanced Control						
Veh 03 Honda Accord	6902	25635	3 day 6915	3 day 6925		
Veh 09 Dodge Neon						
Veh xx						
Enhanced Control						
Veh 01 S-10 PU	6875	25632	6857	6865	6888	6893
Veh 02 Tocoma PU	6890	25634	6883. 6904	6896	6899	6929
Veh 04 Dodge Caravan	6912	25636	3 day 6919	3 day 6922	3 day 6926	3 day 6927
Veh 06 Chevy Cavalier	6939	25640	6953	6955	6959	6961
Veh 07 Cavalier w/leak	6963	25642	6964	6966		
Veh 08 Ford Explorer	6949	25641	6954	6956	6957	6962
LEV II						
Veh 05 Taurus Sedan	6923	25638	3 day 6928/6931	3 day 6933		

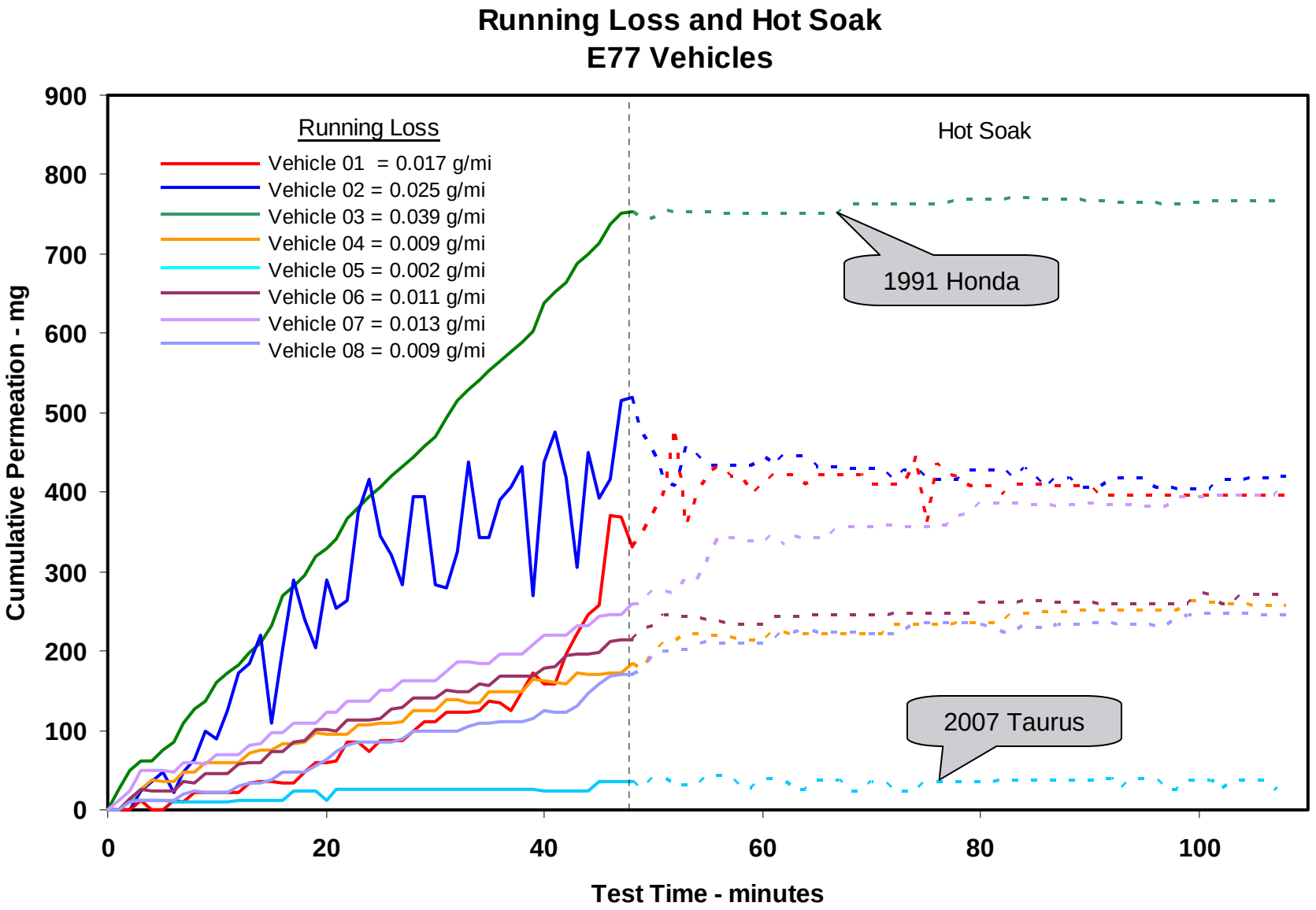
Done
To Do

Characteristic Permeations Results for Static Tests

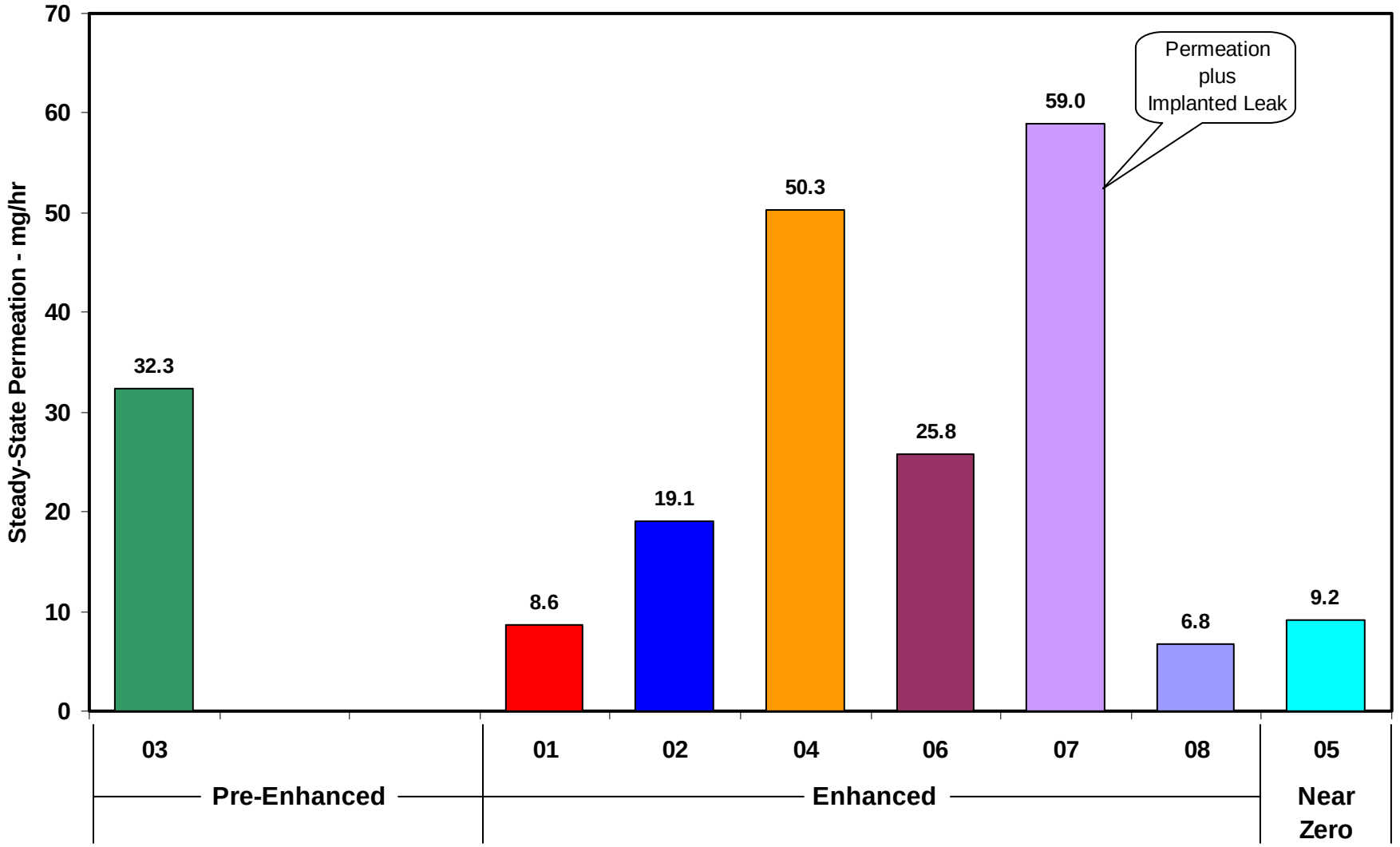


Permeation With and Without Implanted Leak – 1996 Chevrolet Cavalier (Car 06 and 07)

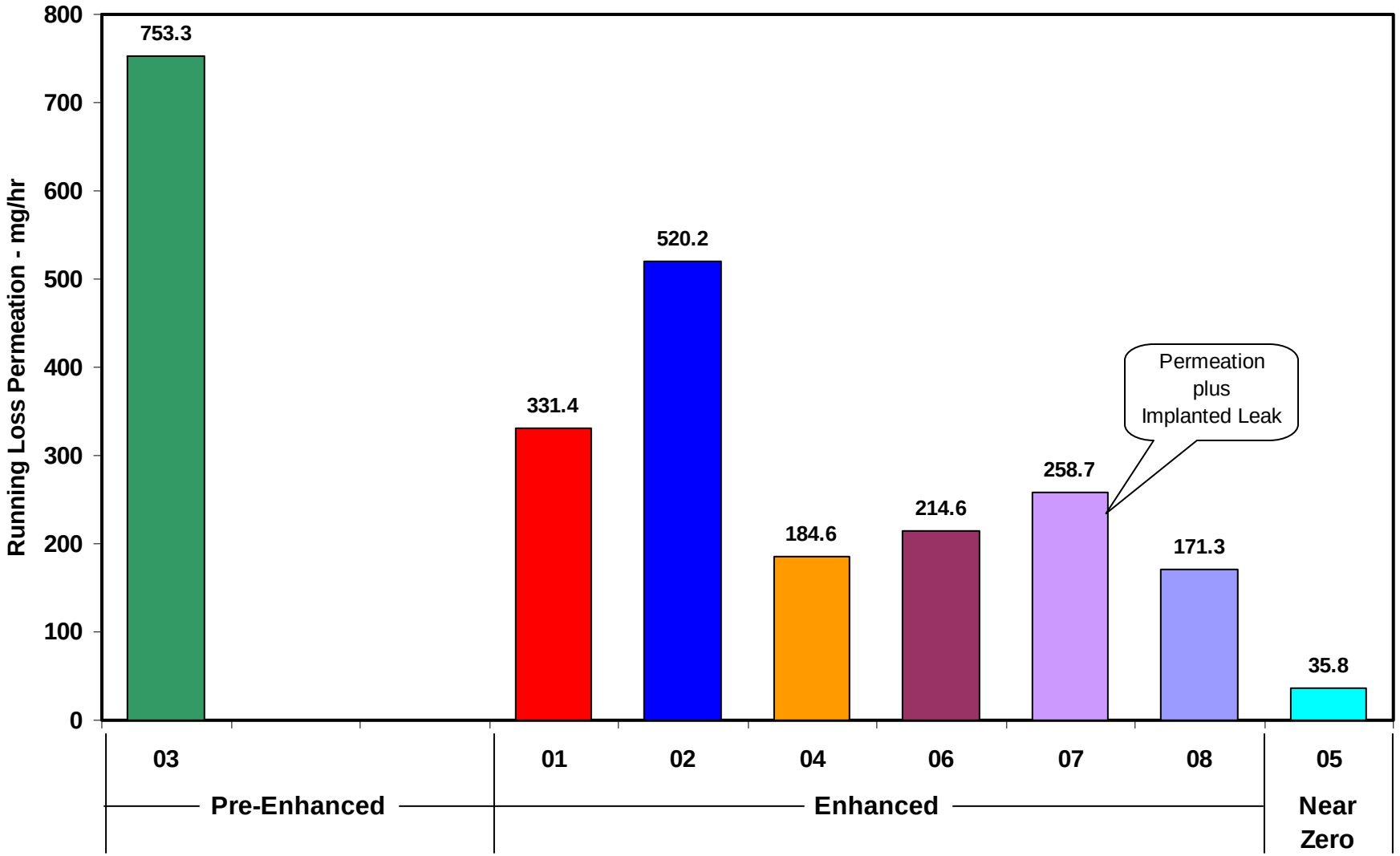


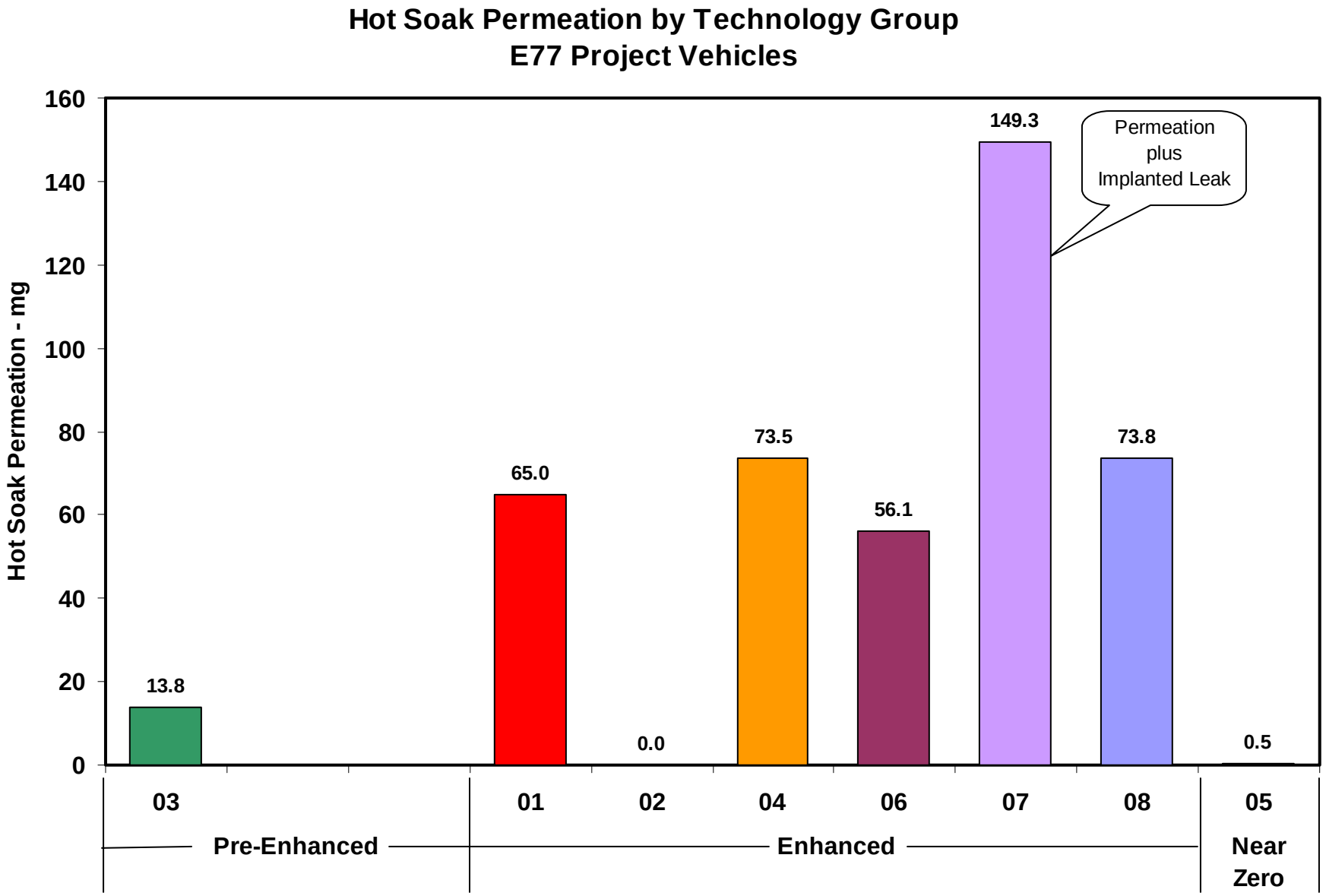

Running Loss and Hot Soak
E77 Vehicles
Running Loss
Vehicle 01 = 0.017 g/mi
Vehicle 02 = 0.025 g/mi
Vehicle 03 = 0.039 g/mi
Vehicle 04 = 0.009 g/mi
Vehicle 05 = 0.002 g/mi
Vehicle 06 = 0.011 g/mi
Vehicle 07 = 0.013 g/mi
Vehicle 08 = 0.009 g/mi
Hot Soak
1991 Honda
2007 Taurus
Cumulative Permeation - mg
Test Time - minutes
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100

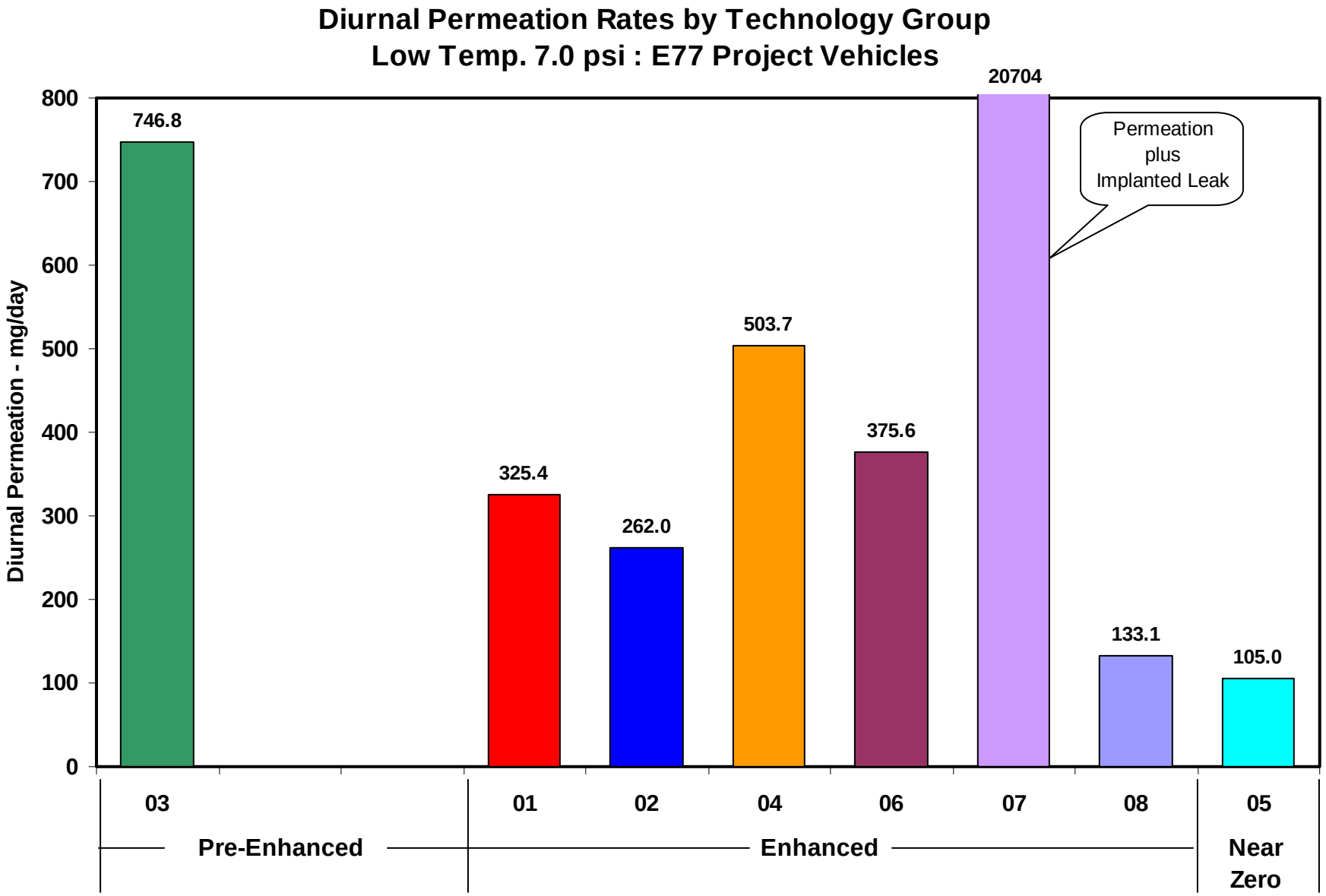
Steady-State Permeation Rates by Technology Group
E77 Project Vehicles



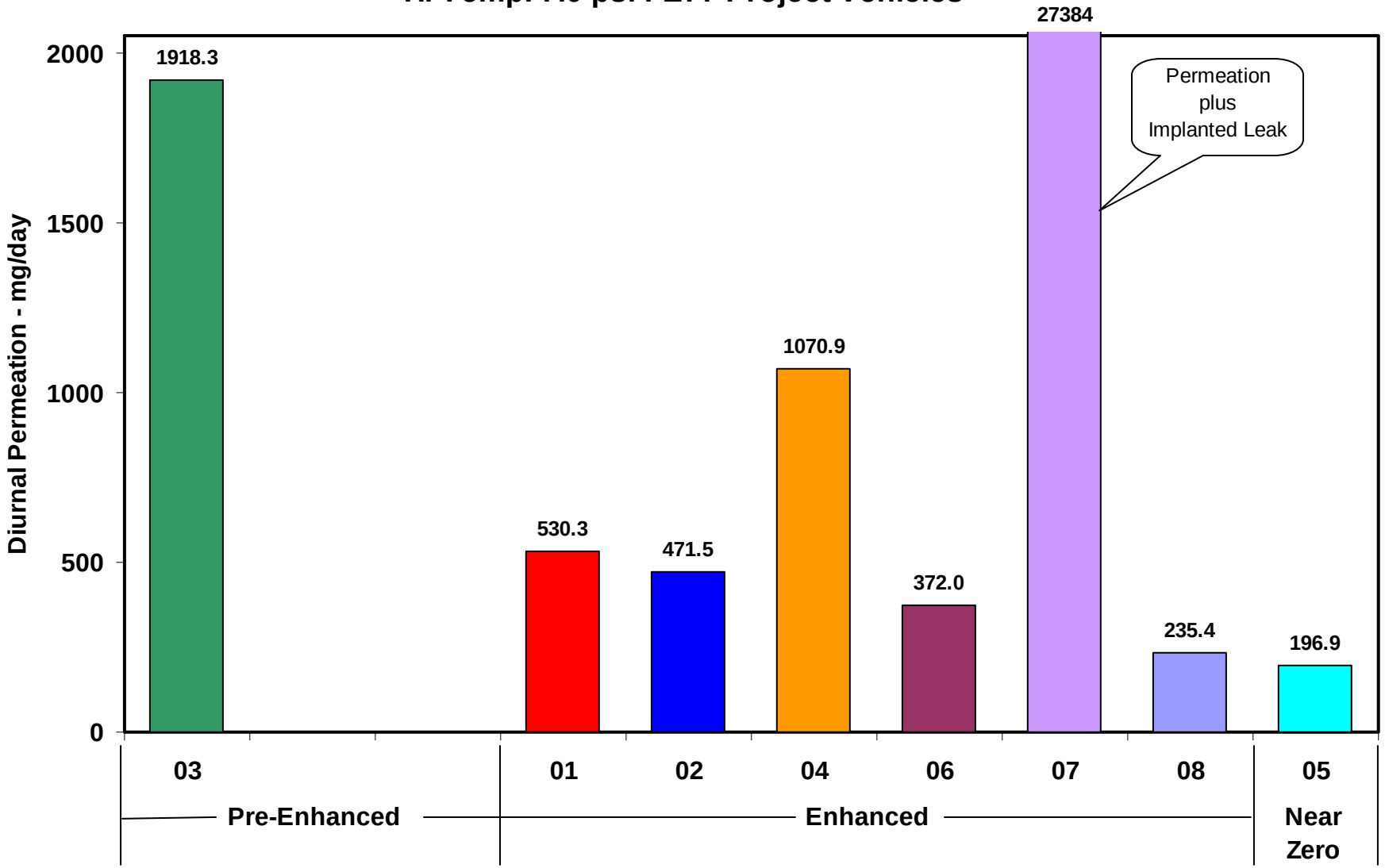
Running Loss Permeation Rates by Technology Group
E77 Project Vehicles



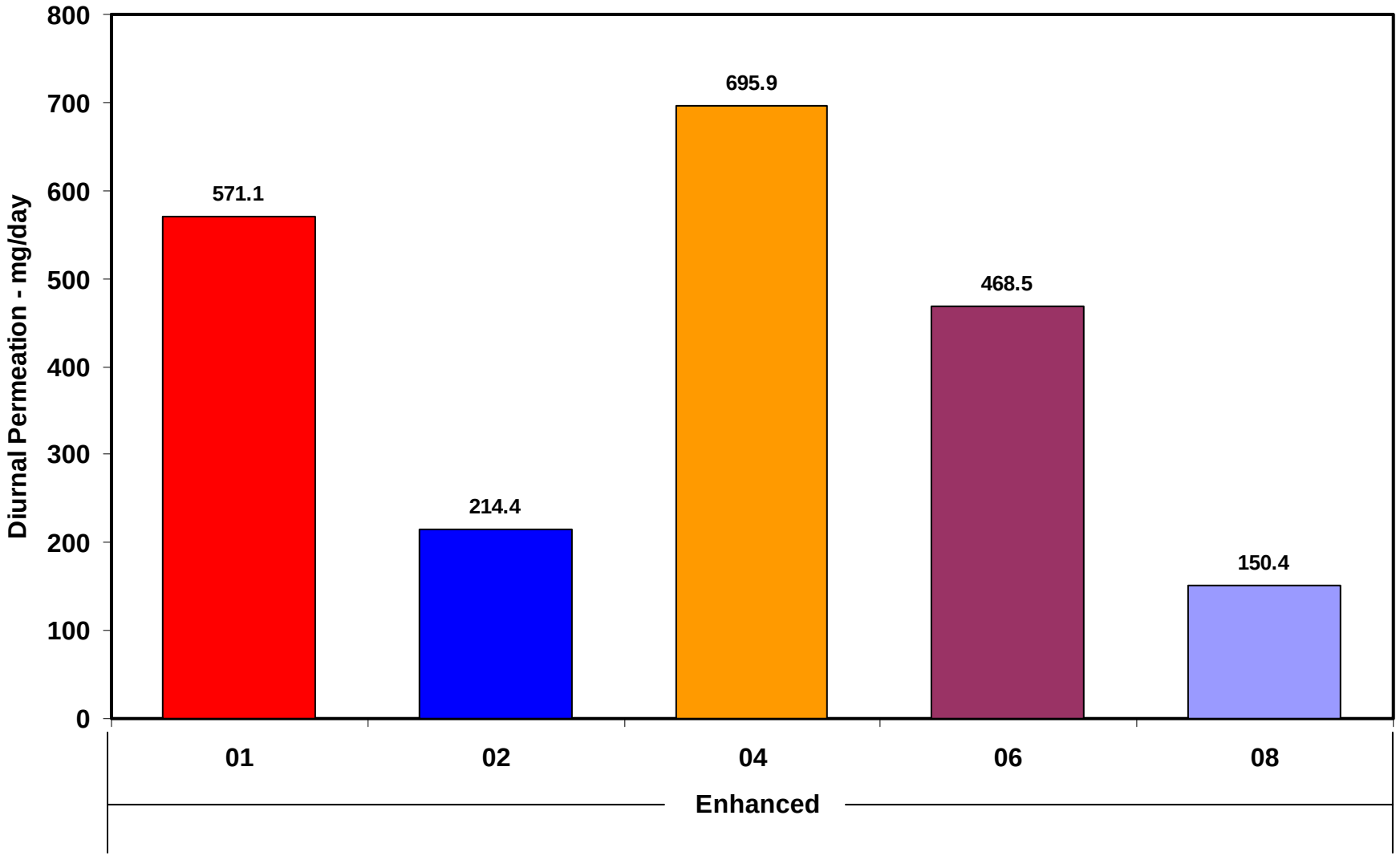

Hot Soak Permeation by Technology Group
E77 Project Vehicles
Hot Soak Permeation - mg
160
140
120
100
80
60
40
20
0
13.8
65.0
0.0
73.5
56.1
149.3
73.8
0.5
Permeation plus Implanted Leak
03
01
02
04
06
07
08
05
Pre-Enhanced
Enhanced
Near Zero


Diurnal Permeation Rates by Technology Group
Low Temp. 7.0 psi : E77 Project Vehicles
Diurnal Permeation - mg/day
800
700
600
500
400
300
200
100
0
746.8
325.4
262.0
503.7
375.6
20704
133.1
105.0
Permeation
plus
Implanted Leak
03
01
02
04
06
07
08
05
Pre-Enhanced
Enhanced
Near
Zero

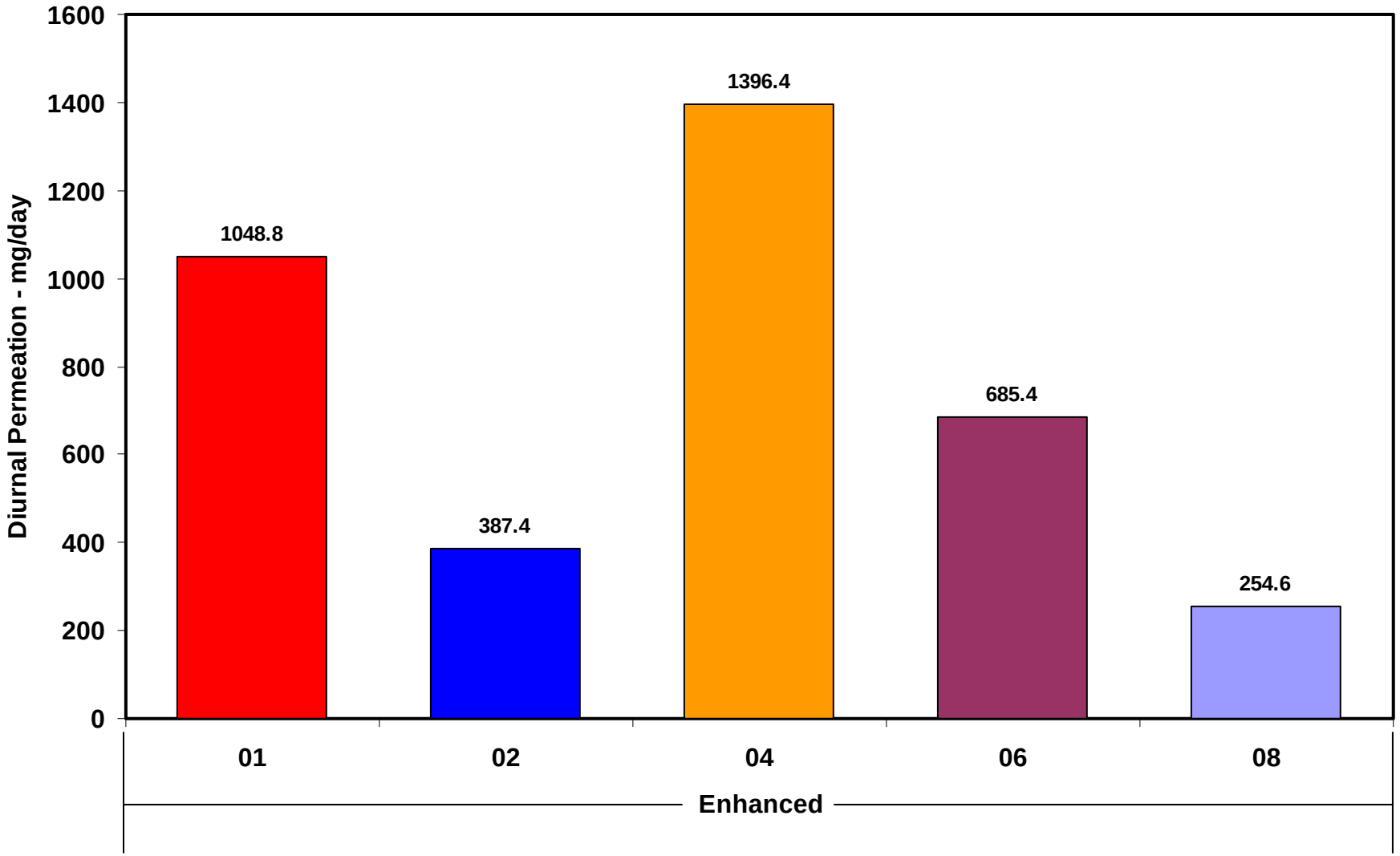
Diurnal Permeation Rates by Technology Group
Hi Temp. 7.0 psi : E77 Project Vehicles

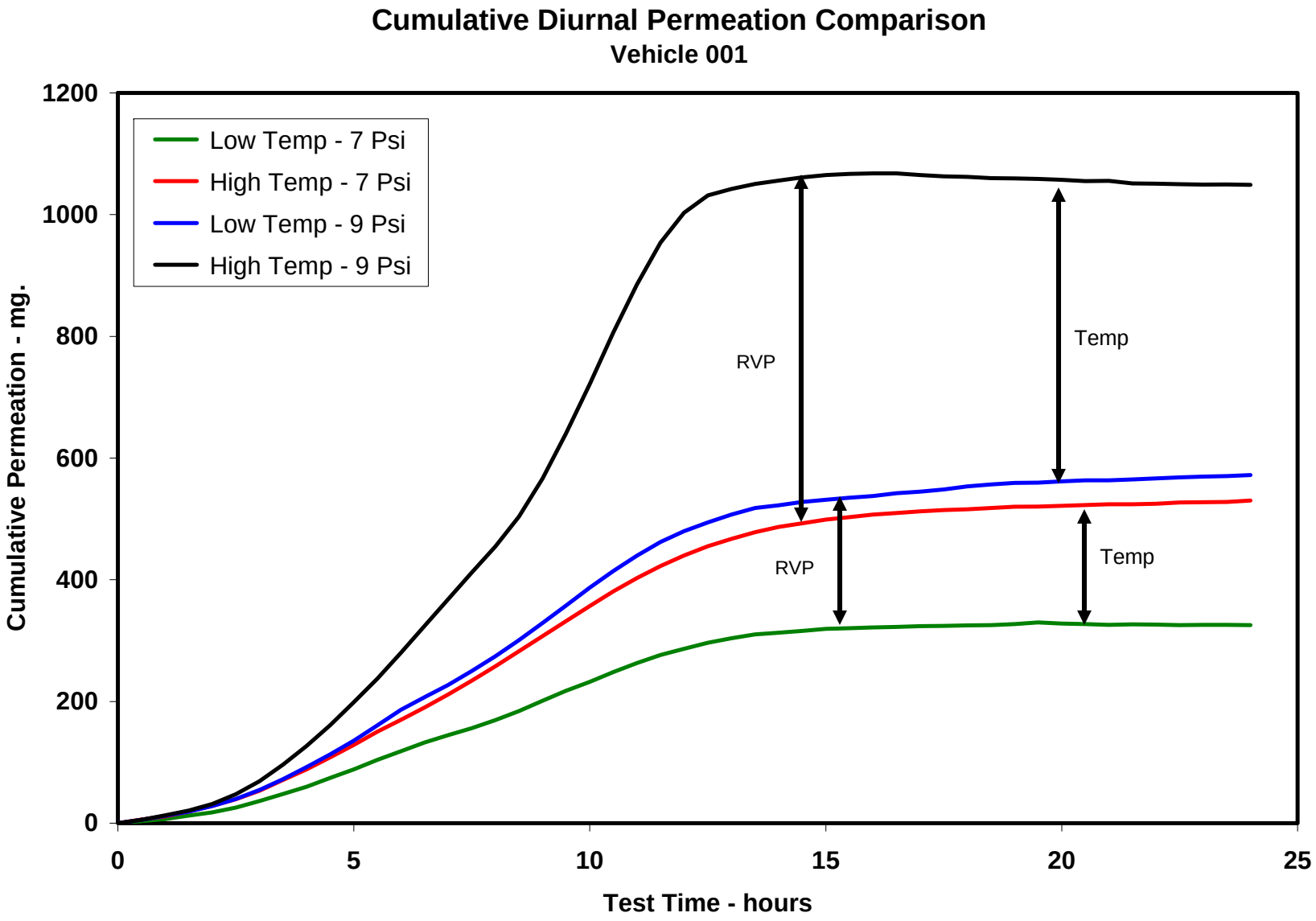


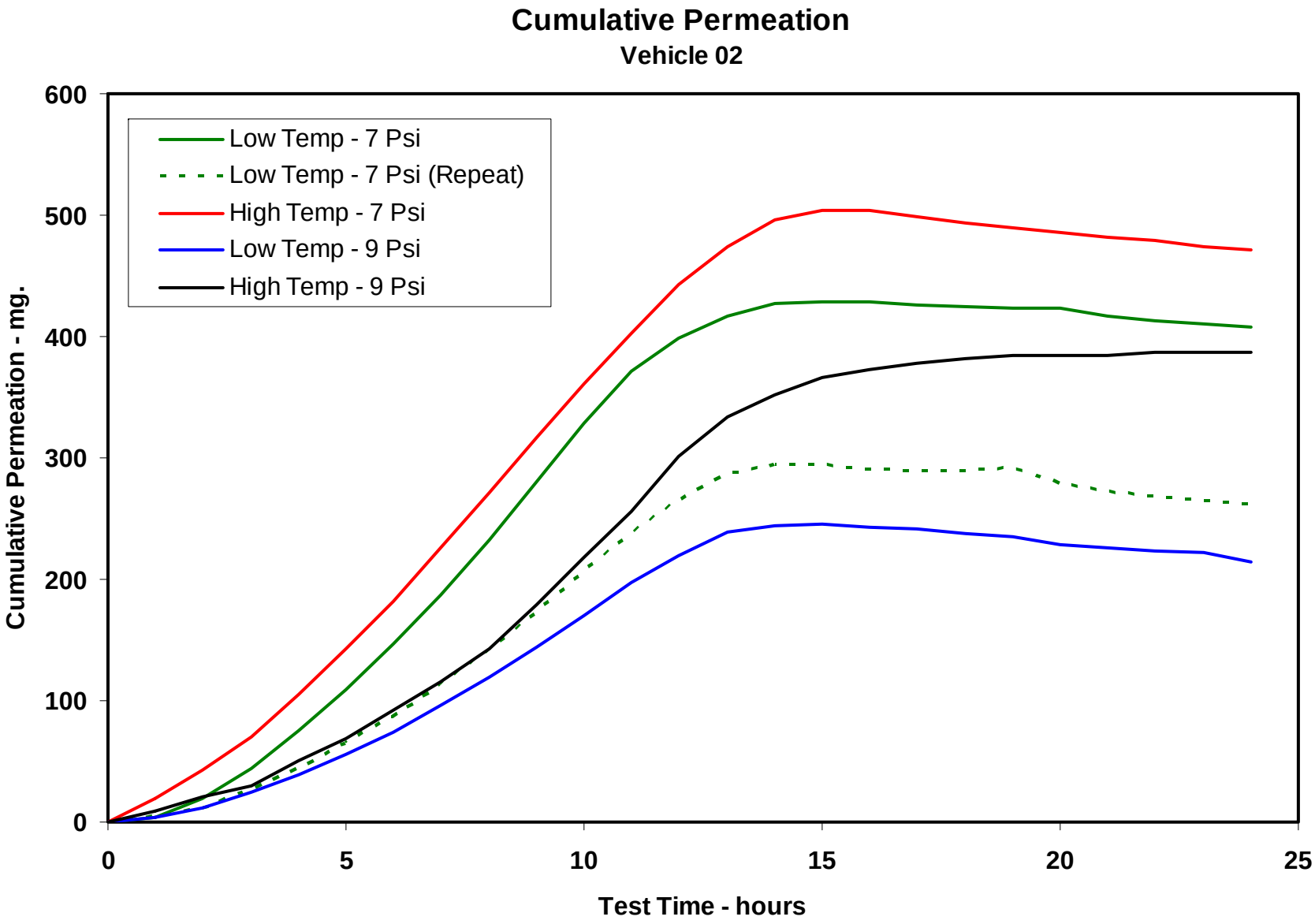
Diurnal Permeation Rates by Technology Group
Low Temp. 9.0 psi : E77 Project Vehicles

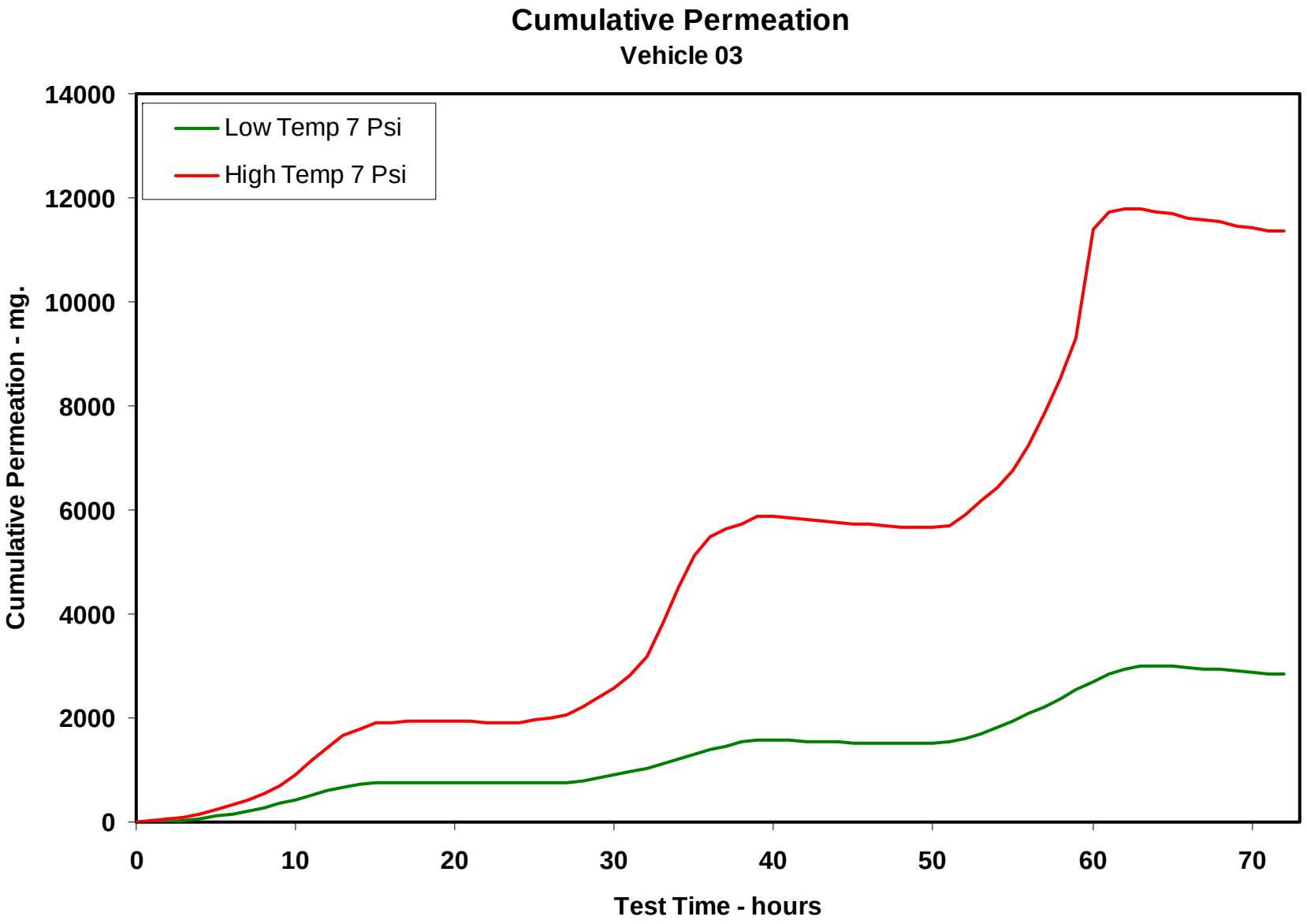


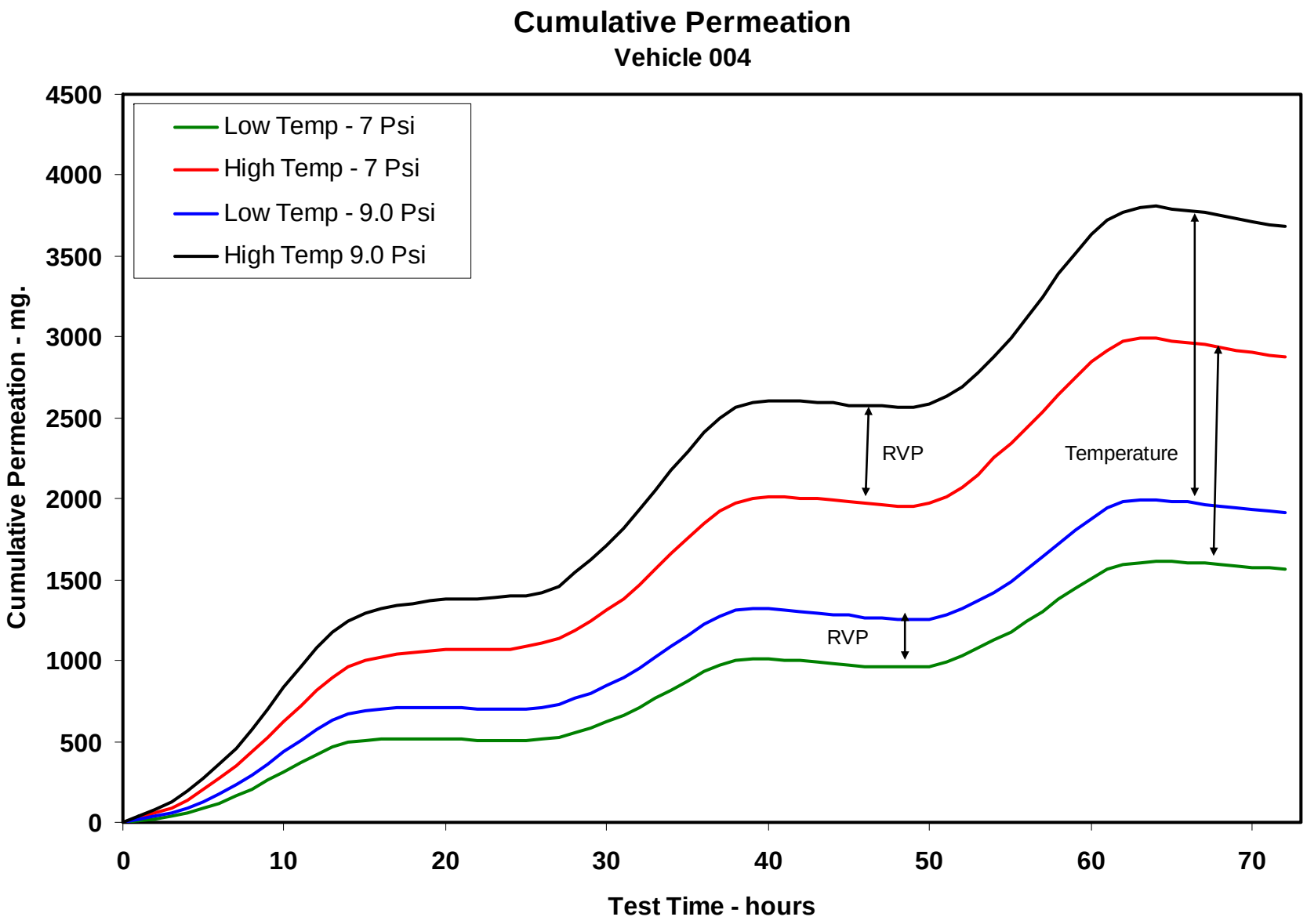
Diurnal Permeation Rates by Technology Group
Hi Temp. 9.0 psi : E77 Project Vehicles

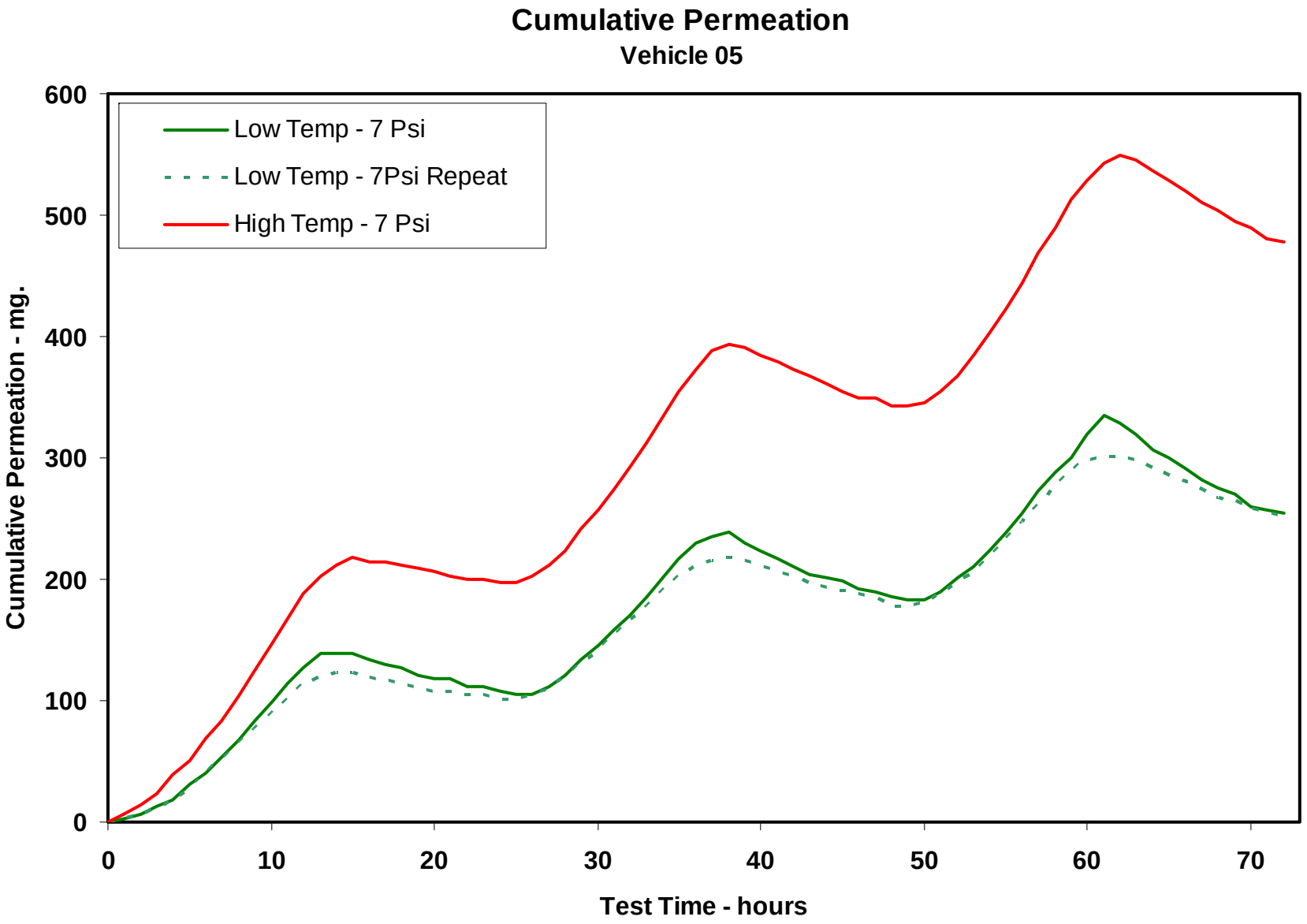


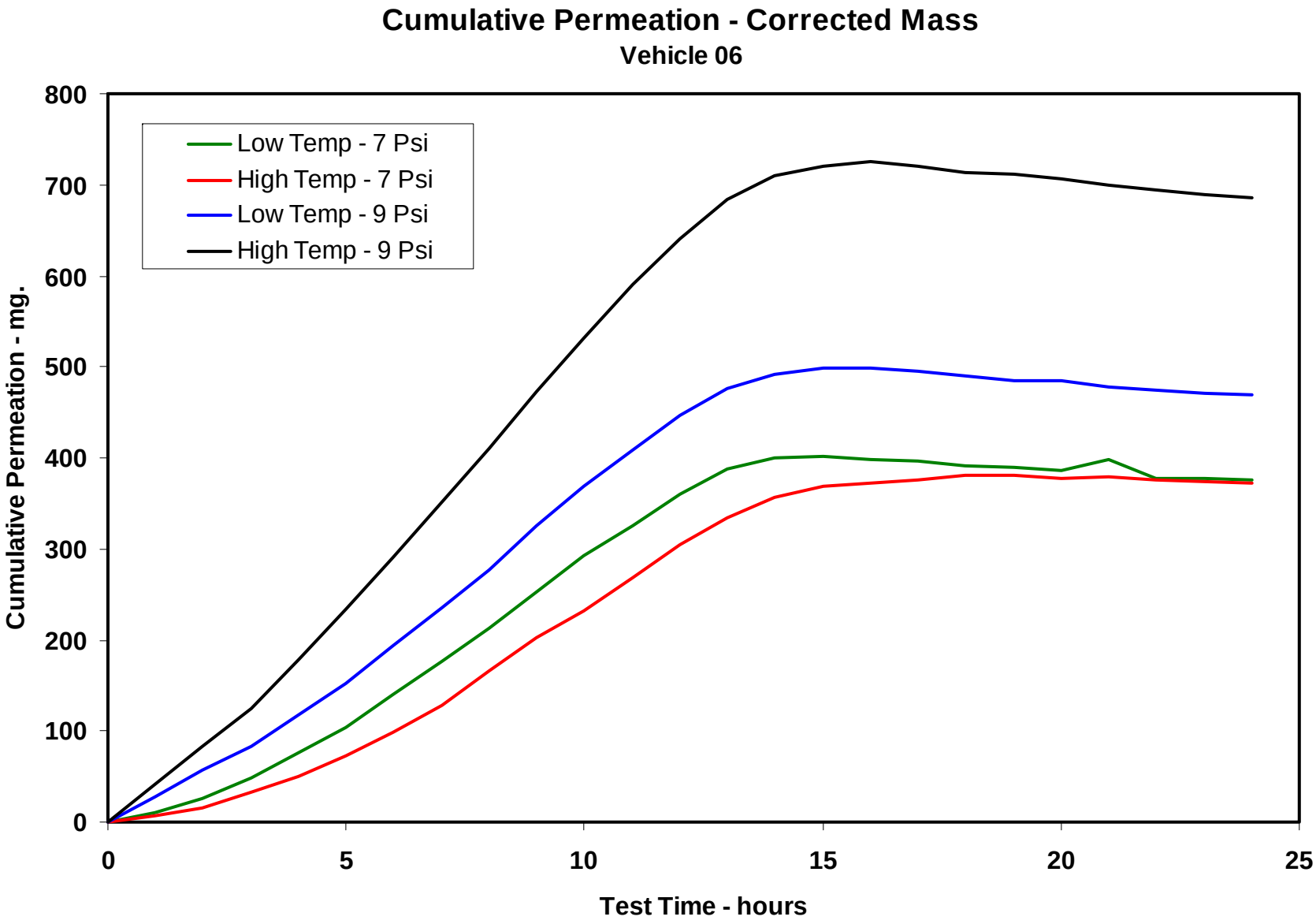

Cumulative Diurnal Permeation Comparison
Vehicle 001
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
RVP
Temp
RVP
Temp
Cumulative Permeation - mg.
1200
1000
800
600
400
200
0
0
5
10
15
20
25
Test Time - hours

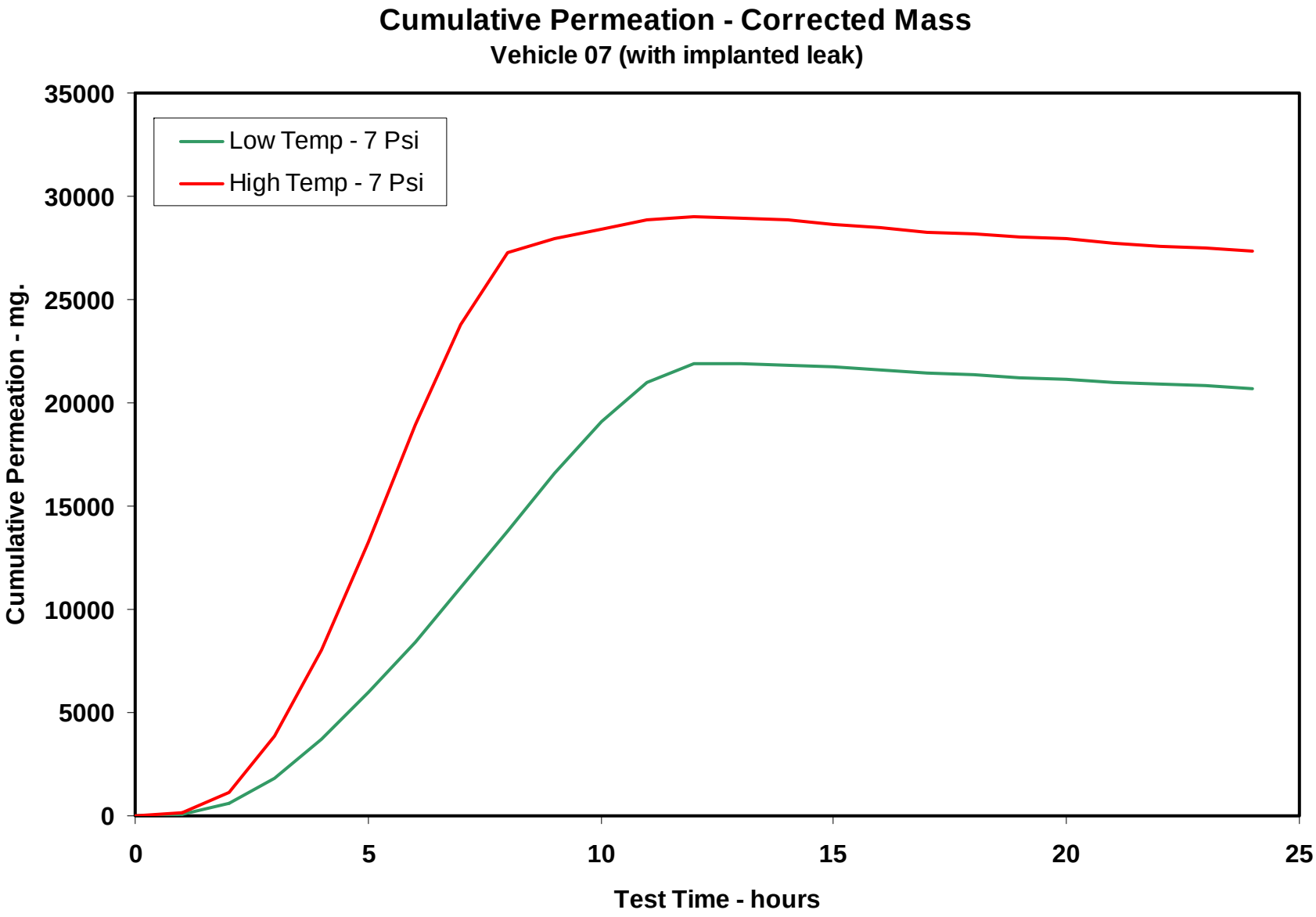

Cumulative Permeation
Vehicle 02
Low Temp - 7 Psi
Low Temp - 7 Psi (Repeat)
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
600
500
400
300
200
100
0
0
5
10
15
20
25
Test Time - hours

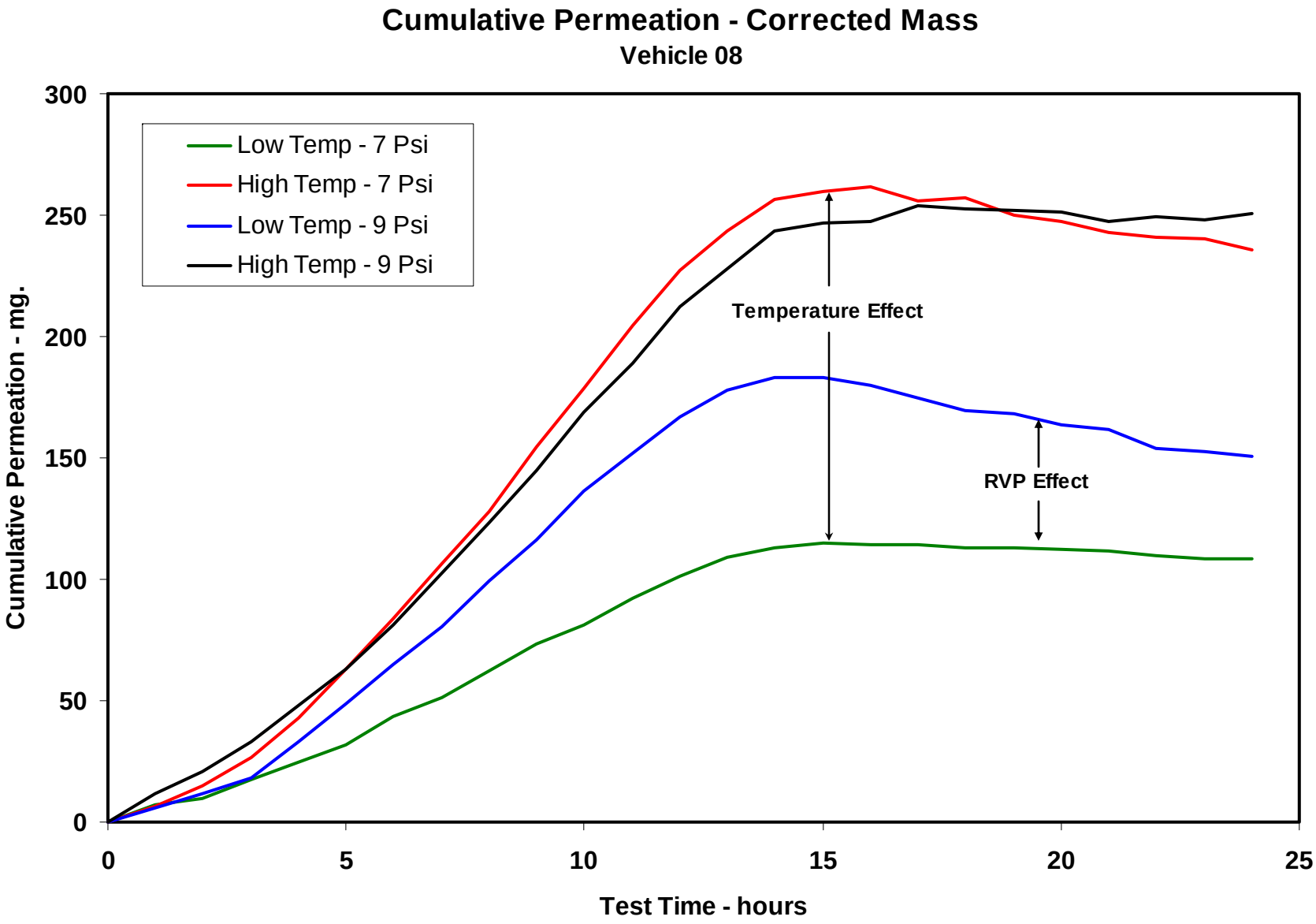

Cumulative Permeation
Vehicle 03
Low Temp 7 Psi
High Temp 7 Psi
Cumulative Permeation - mg.
14000
12000
10000
8000
6000
4000
2000
0
0
10
20
30
40
50
60
70
Test Time - hours

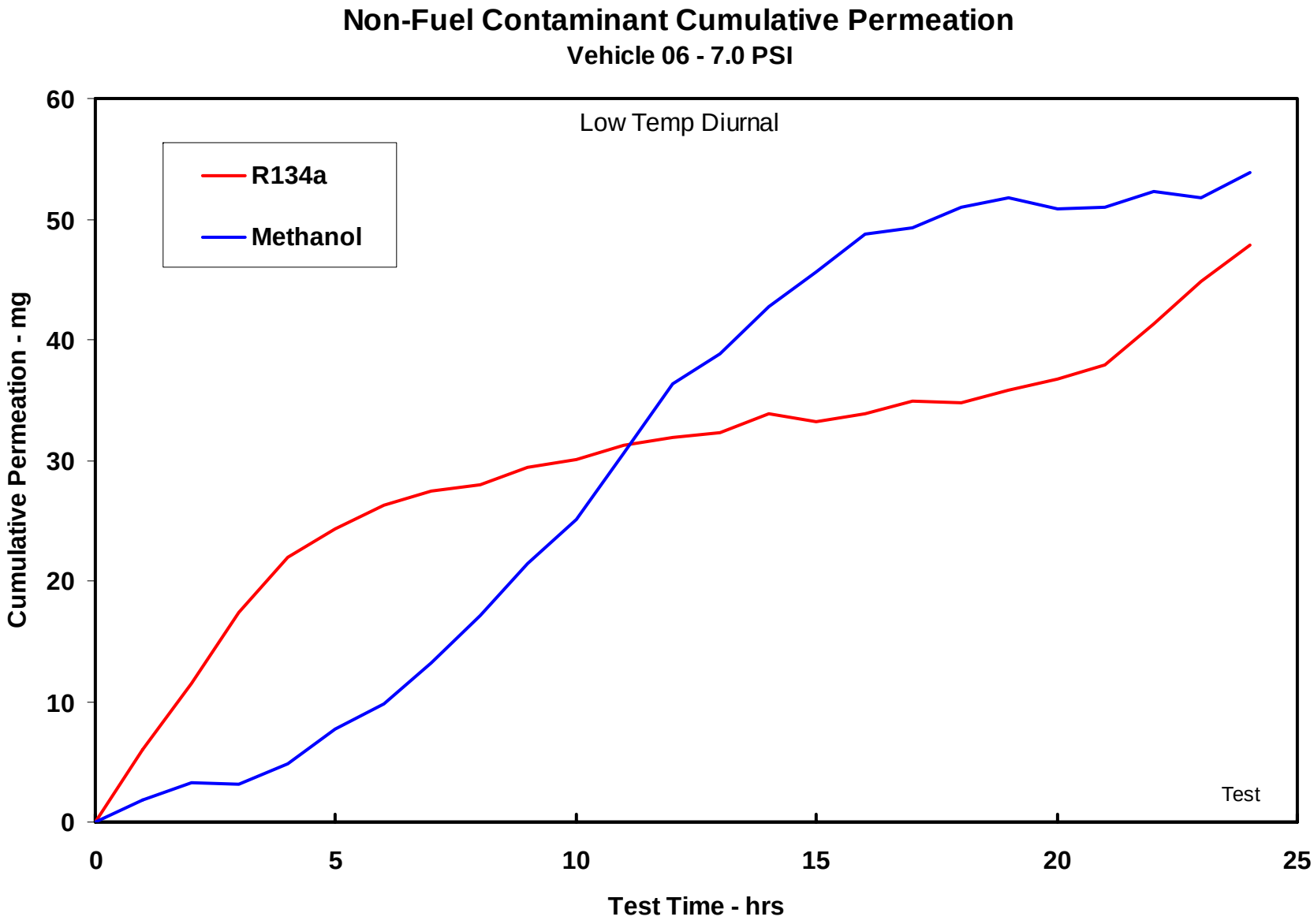

Cumulative Permeation
Vehicle 004
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9.0 Psi
High Temp 9.0 Psi
RVP
Temperature
RVP
Cumulative Permeation - mg.
Test Time - hours
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
10
20
30
40
50
60
70

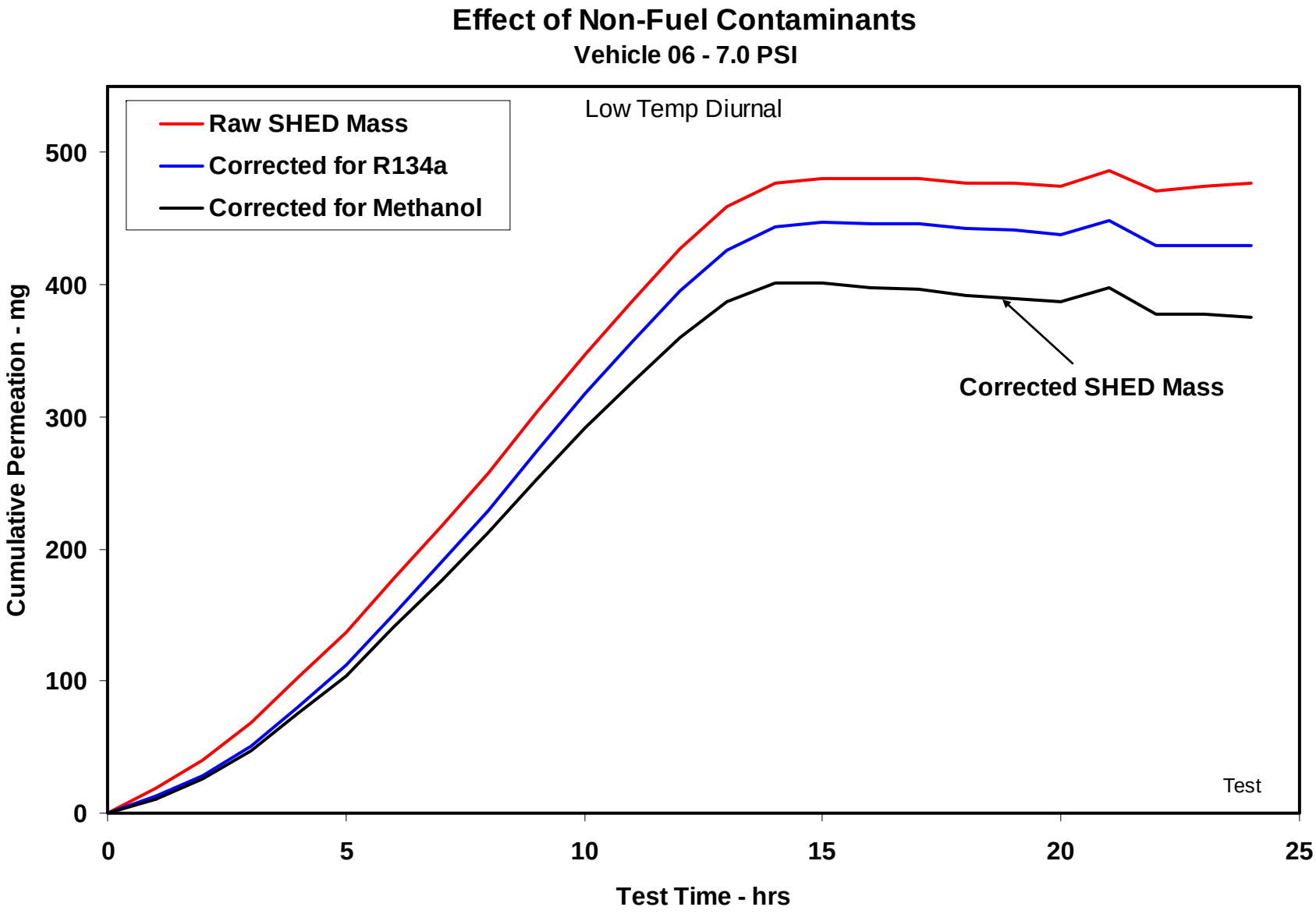

Cumulative Permeation
Vehicle 05
Low Temp - 7 Psi
Low Temp - 7Psi Repeat
High Temp - 7 Psi
Cumulative Permeation - mg.
600
500
400
300
200
100
0
0
10
20
30
40
50
60
70
Test Time - hours


Cumulative Permeation - Corrected Mass
Vehicle 06
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Cumulative Permeation - mg.
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
Test Time - hours


Cumulative Permeation - Corrected Mass
Vehicle 07 (with implanted leak)
Low Temp - 7 Psi
High Temp - 7 Psi
Cumulative Permeation - mg.
35000
30000
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
Test Time - hours

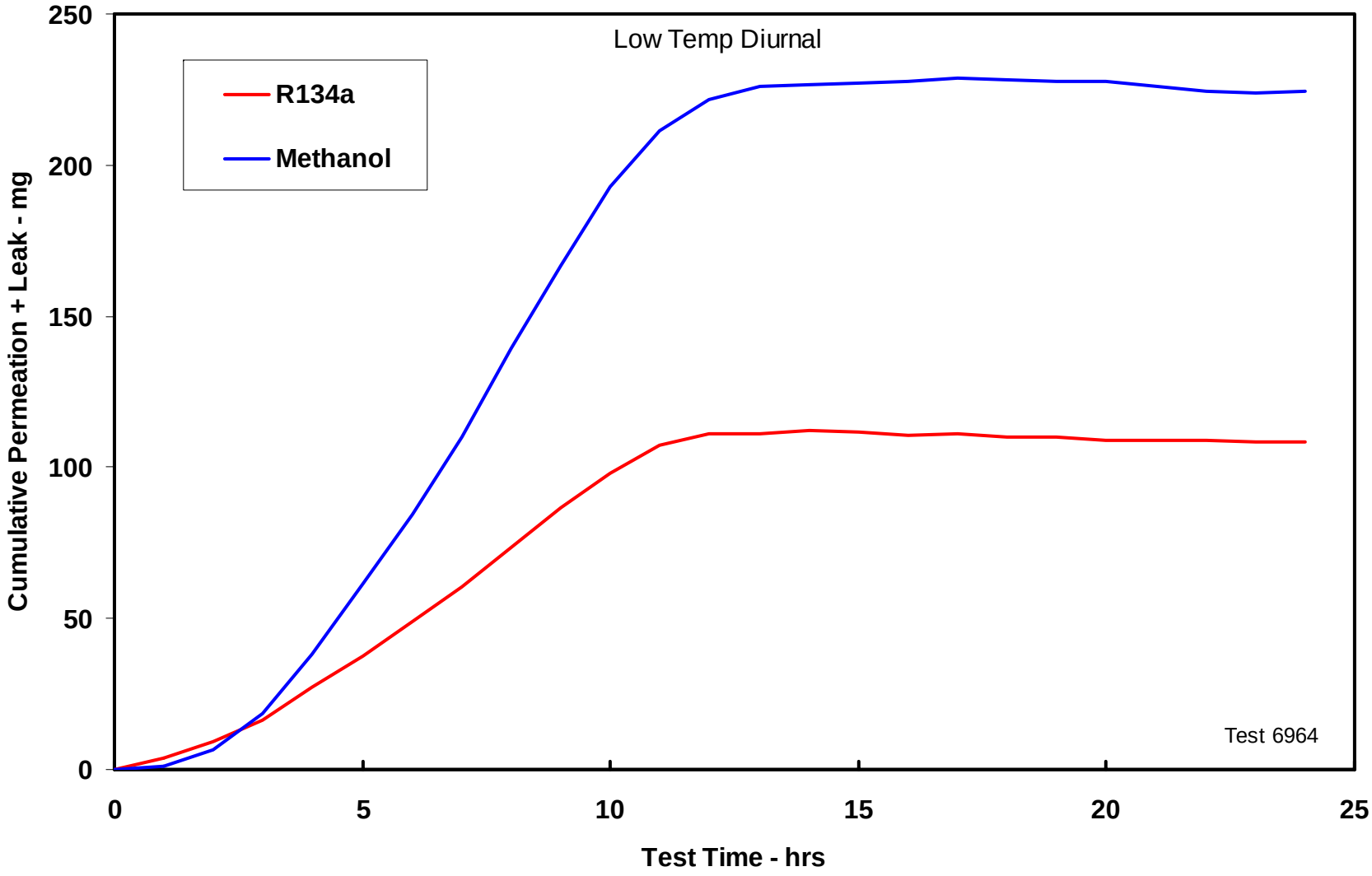

Cumulative Permeation - Corrected Mass
Vehicle 08
Low Temp - 7 Psi
High Temp - 7 Psi
Low Temp - 9 Psi
High Temp - 9 Psi
Temperature Effect
RVP Effect
Cumulative Permeation - mg.
Test Time - hours
0
50
100
150
200
250
300
0
5
10
15
20
25

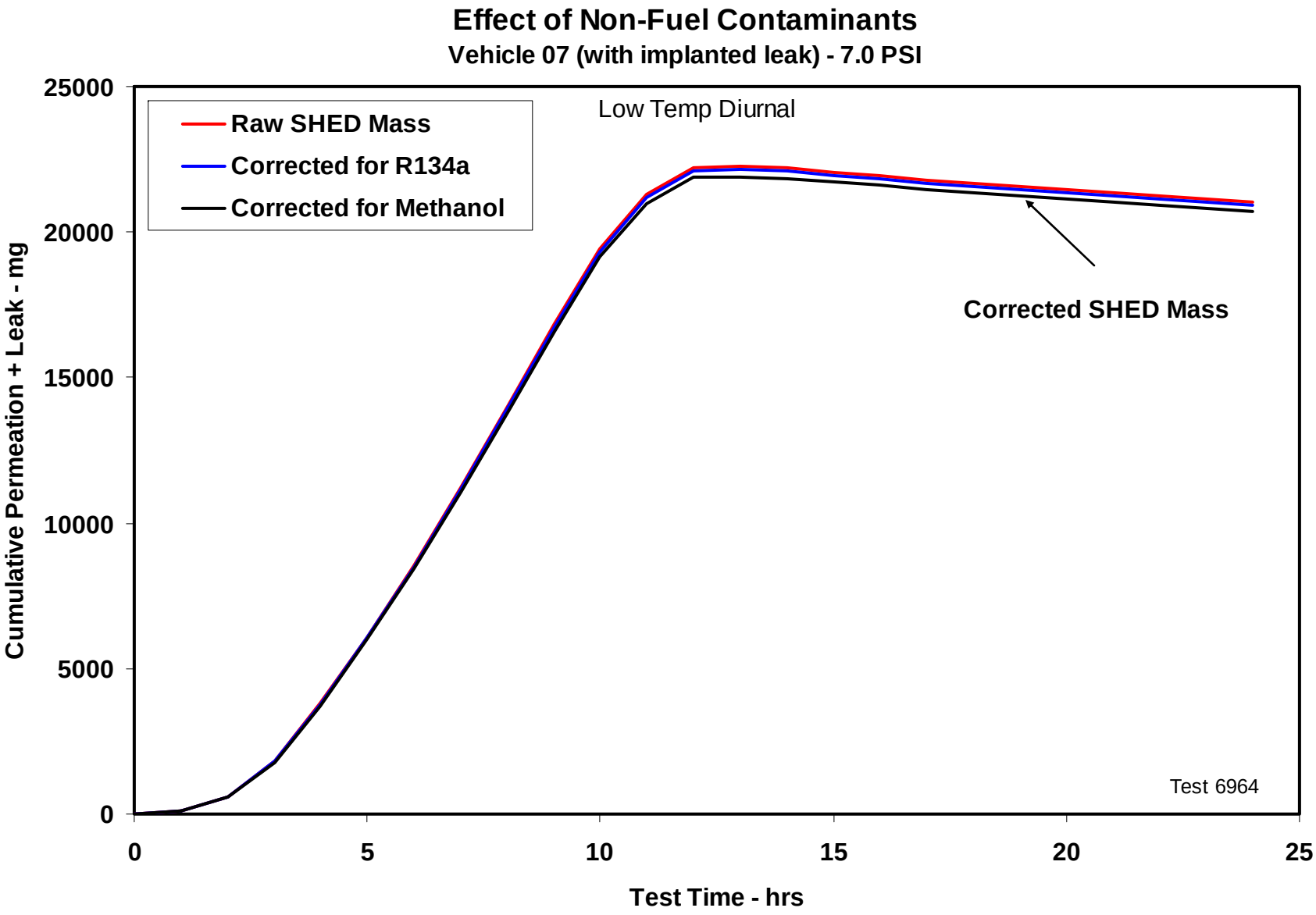

Non-Fuel Contaminant Cumulative Permeation
Vehicle 06 - 7.0 PSI
Low Temp Diurnal
R134a
Methanol
Test
Cumulative Permeation - mg
Test Time - hrs
0
10
20
30
40
50
60
0
5
10
15
20
25

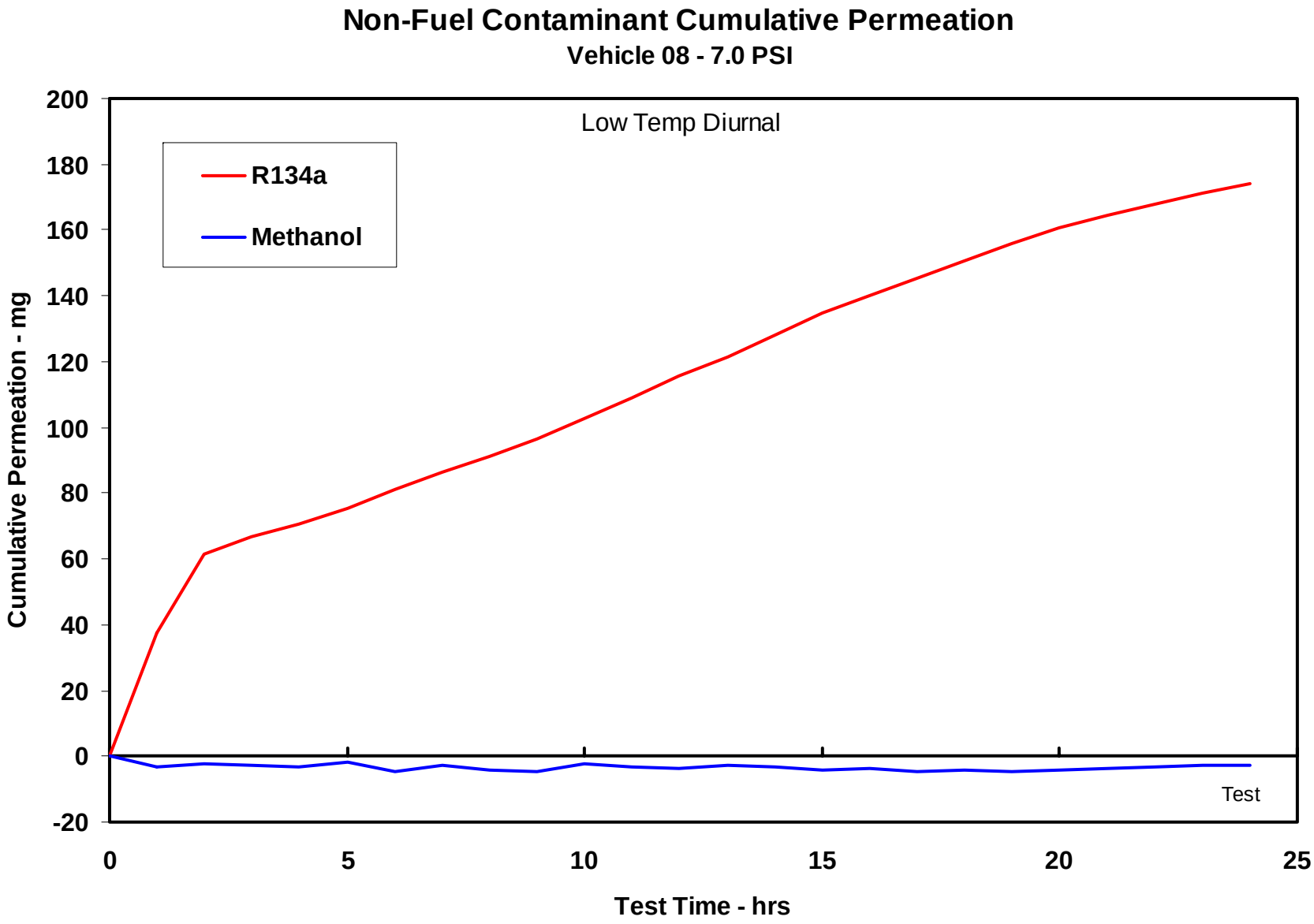

Effect of Non-Fuel Contaminants
Vehicle 06 - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test
Cumulative Permeation - mg
0
100
200
300
400
500
0
5
10
15
20
25
Test Time - hrs

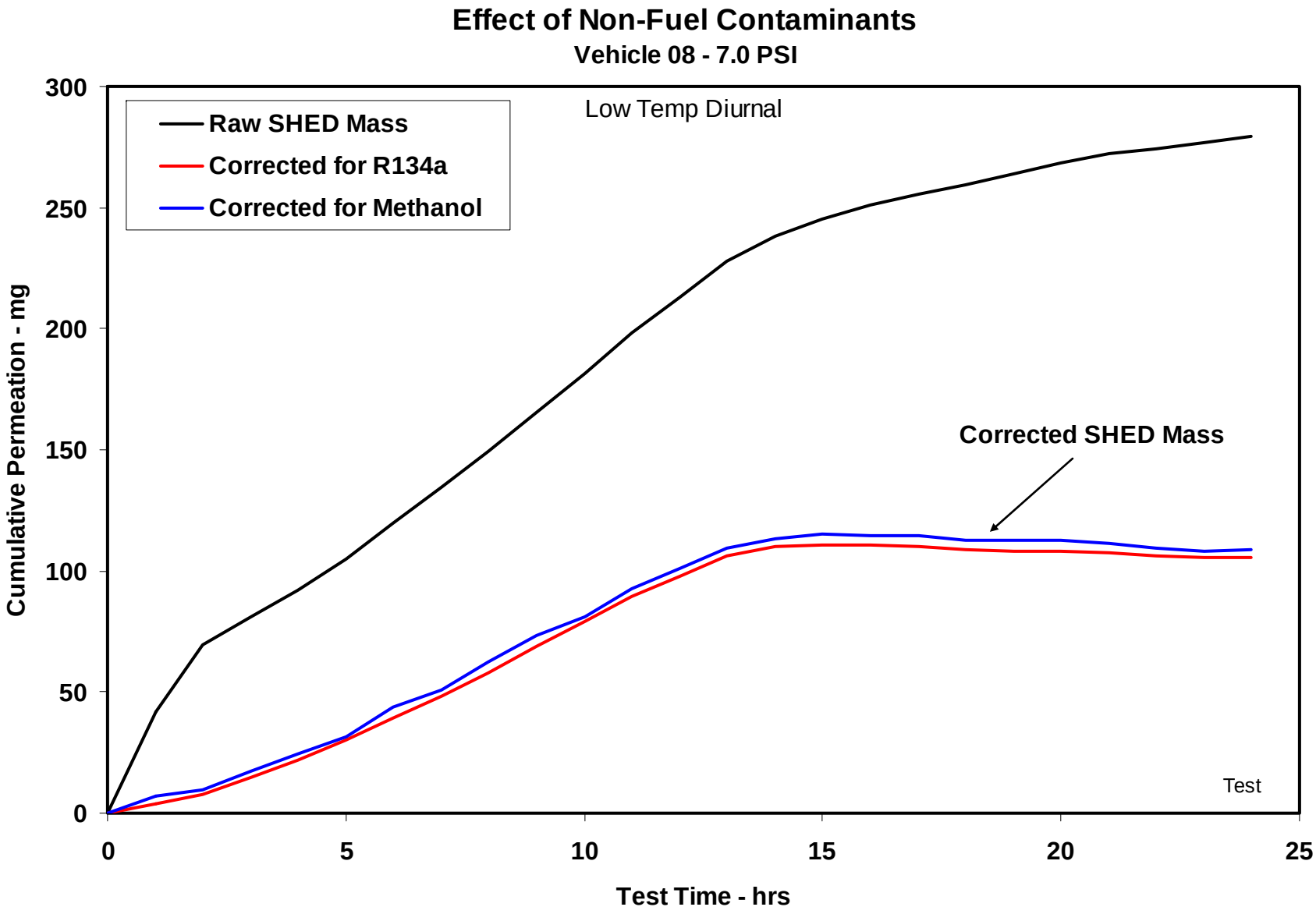
Non-Fuel Contaminant Cumulative Permeation

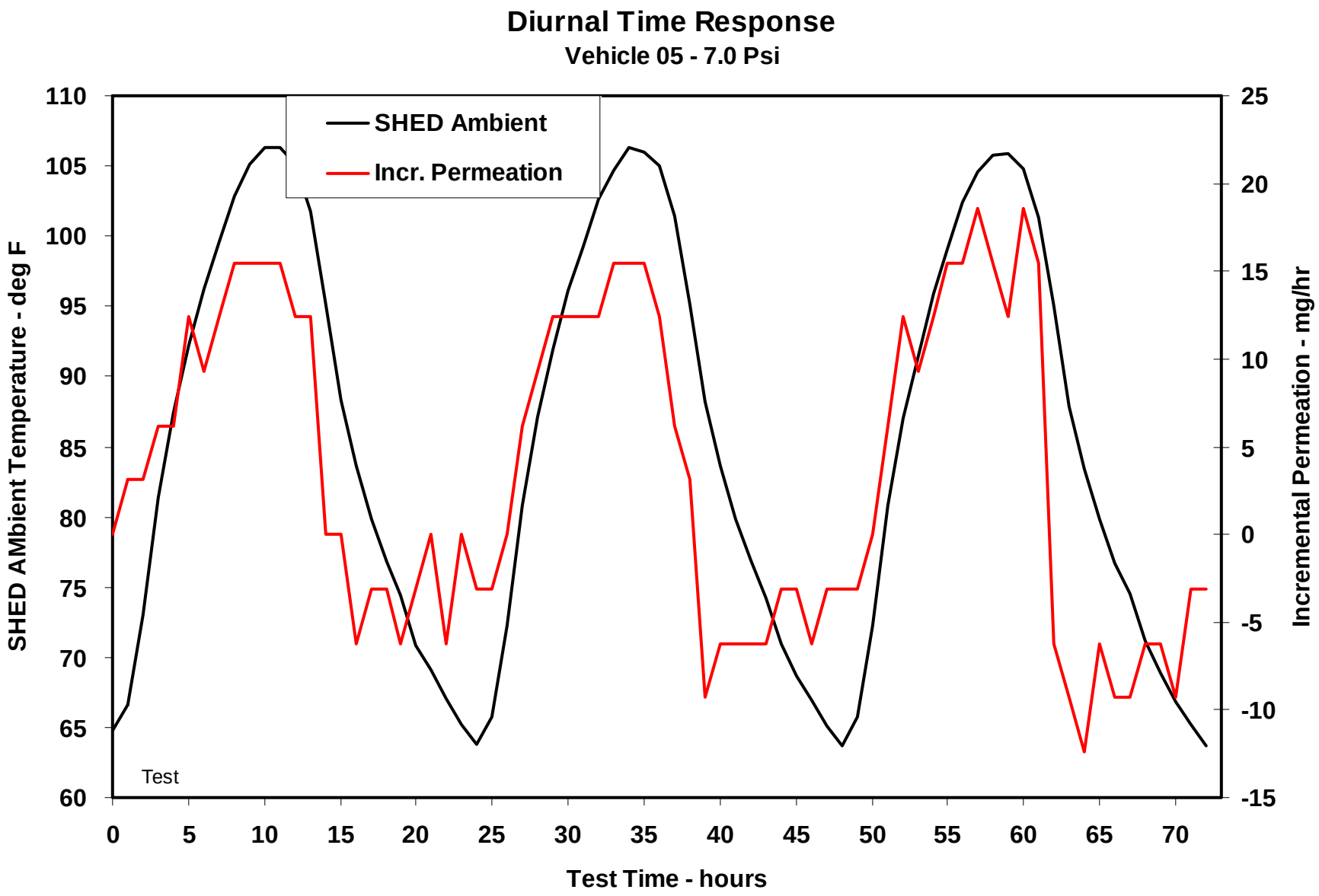
Vehicle 07 (with implanted leak) - 7.0 PSI

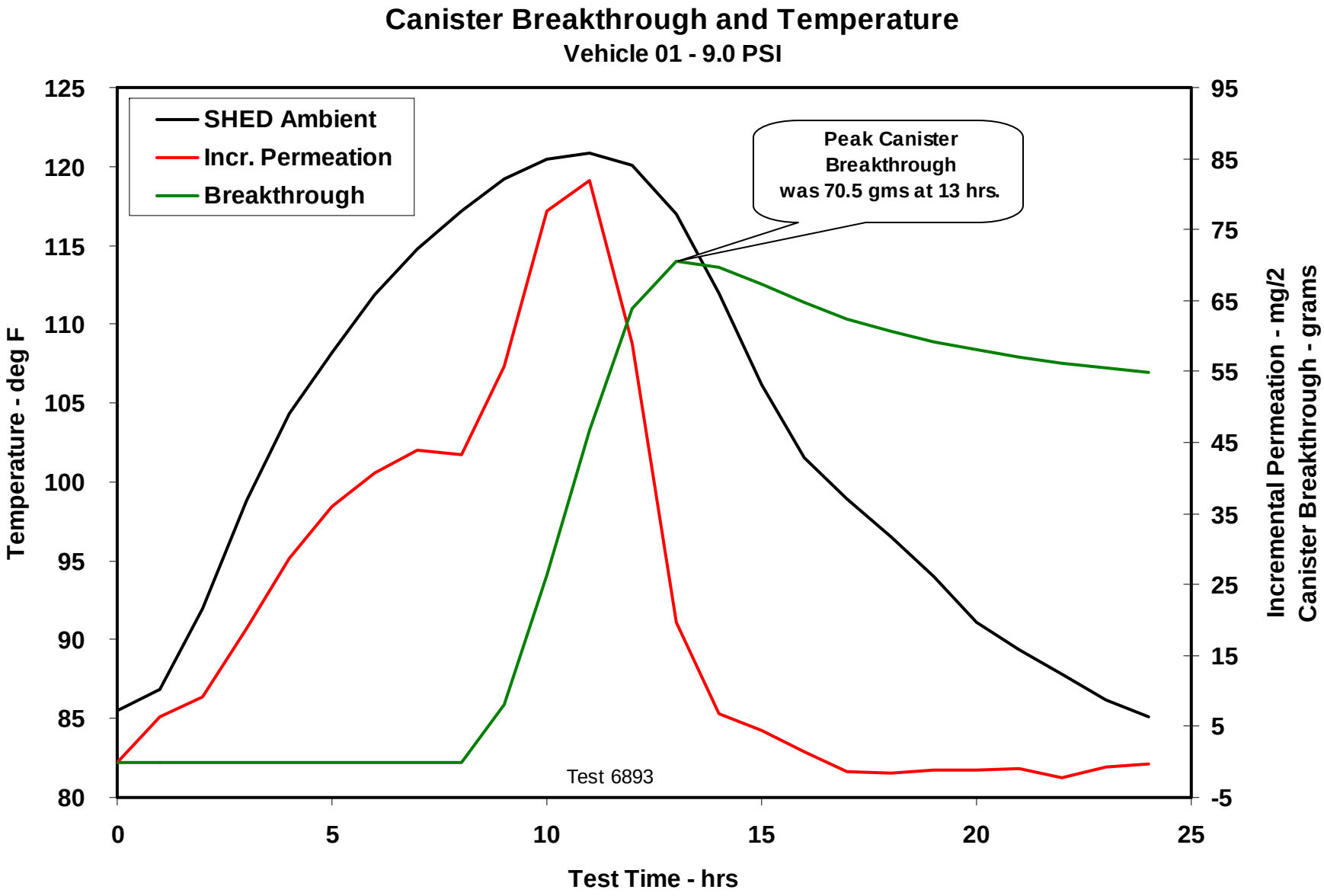


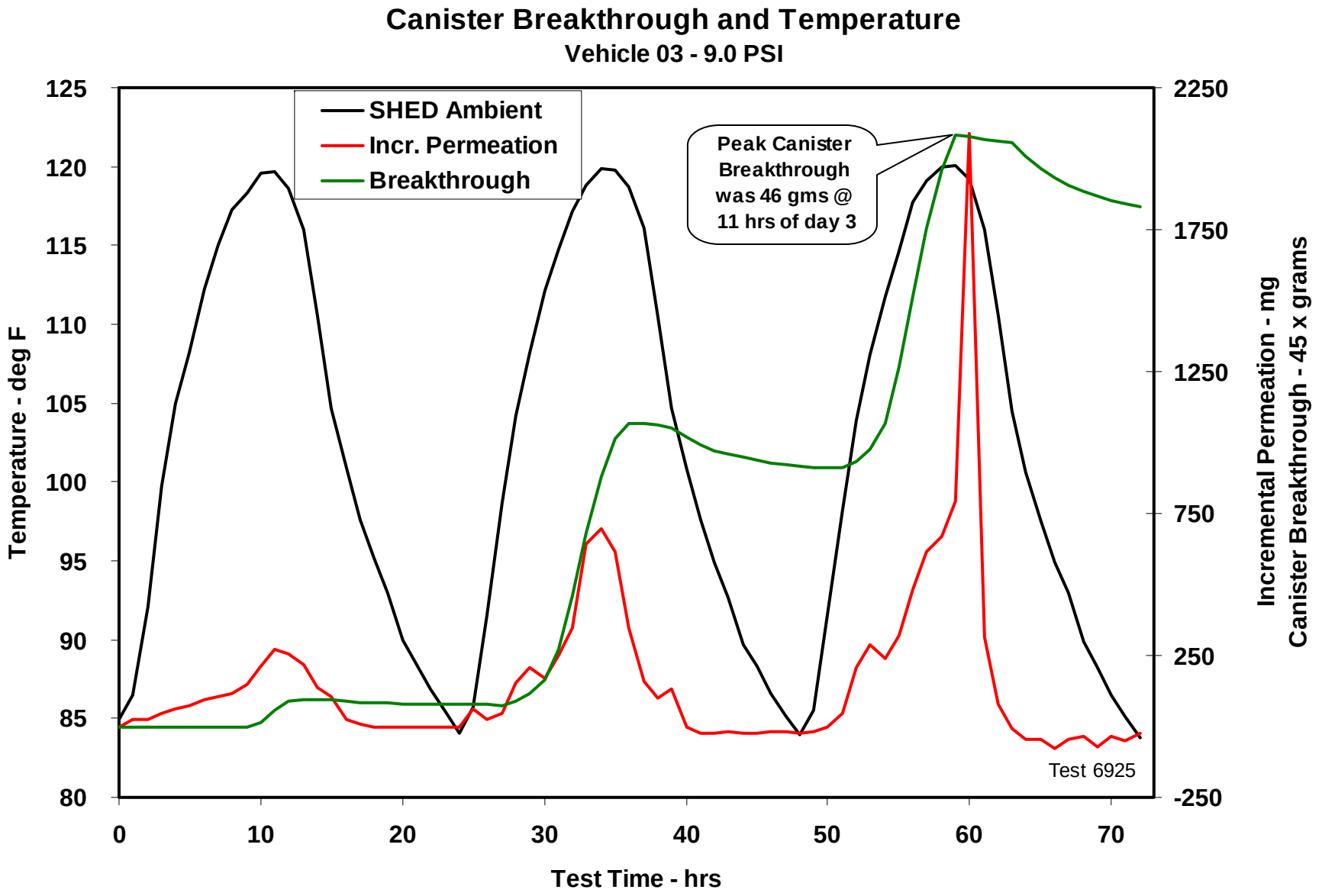

Effect of Non-Fuel Contaminants
Vehicle 07 (with implanted leak) - 7.0 PSI
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Low Temp Diurnal
Corrected SHED Mass
Test 6964
Cumulative Permeation + Leak - mg
25000
20000
15000
10000
5000
0
0
5
10
15
20
25
Test Time - hrs


Non-Fuel Contaminant Cumulative Permeation
Vehicle 08 - 7.0 PSI
Low Temp Diurnal
R134a
Methanol
Test
Cumulative Permeation - mg
200
180
160
140
120
100
80
60
40
20
0
-20
0
5
10
15
20
25
Test Time - hrs


Effect of Non-Fuel Contaminants
Vehicle 08 - 7.0 PSI
Low Temp Diurnal
Raw SHED Mass
Corrected for R134a
Corrected for Methanol
Corrected SHED Mass
Test
Cumulative Permeation - mg
Test Time - hrs
0
50
100
150
200
250
300
0
5
10
15
20
25


Diurnal Time Response
Vehicle 05 - 7.0 Psi
SHED Ambient
Incr. Permeation
Test
SHED AMbient Temperature - deg F
Incremental Permeation - mg/hr
Test Time - hours
110
105
100
95
90
85
80
75
70
65
60
25
20
15
10
5
0
-5
-10
-15
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70


Canister Breakthrough and Temperature
Vehicle 01 - 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


Canister Breakthrough and Temperature
Vehicle 03 - 9.0 PSI
SHED Ambient
Incr. Permeation
Breakthrough
Peak Canister Breakthrough was 46 gms @ 11 hrs of day 3
Test 6925
Temperature - deg F
Incremental Permeation - mg
Canister Breakthrough - 45 x grams
Test Time - hrs
125
120
115
110
105
100
95
90
85
80
2250
1750
1250
750
250
-250
0
10
20
30
40
50
60
70

Preliminary Trends & Observations to Date with Implications for Inventory Models

- We are exploring how permeation may be affected by fuel vapor pressure
- Canister losses are zero on enhanced and later vehicles
- Running losses (as permeation) are constant during test period
- Hot soaks are effectively zero
- Vapor condensation can occur in the SHED