Day 3 Agenda
(Advanced Course – Day 1)

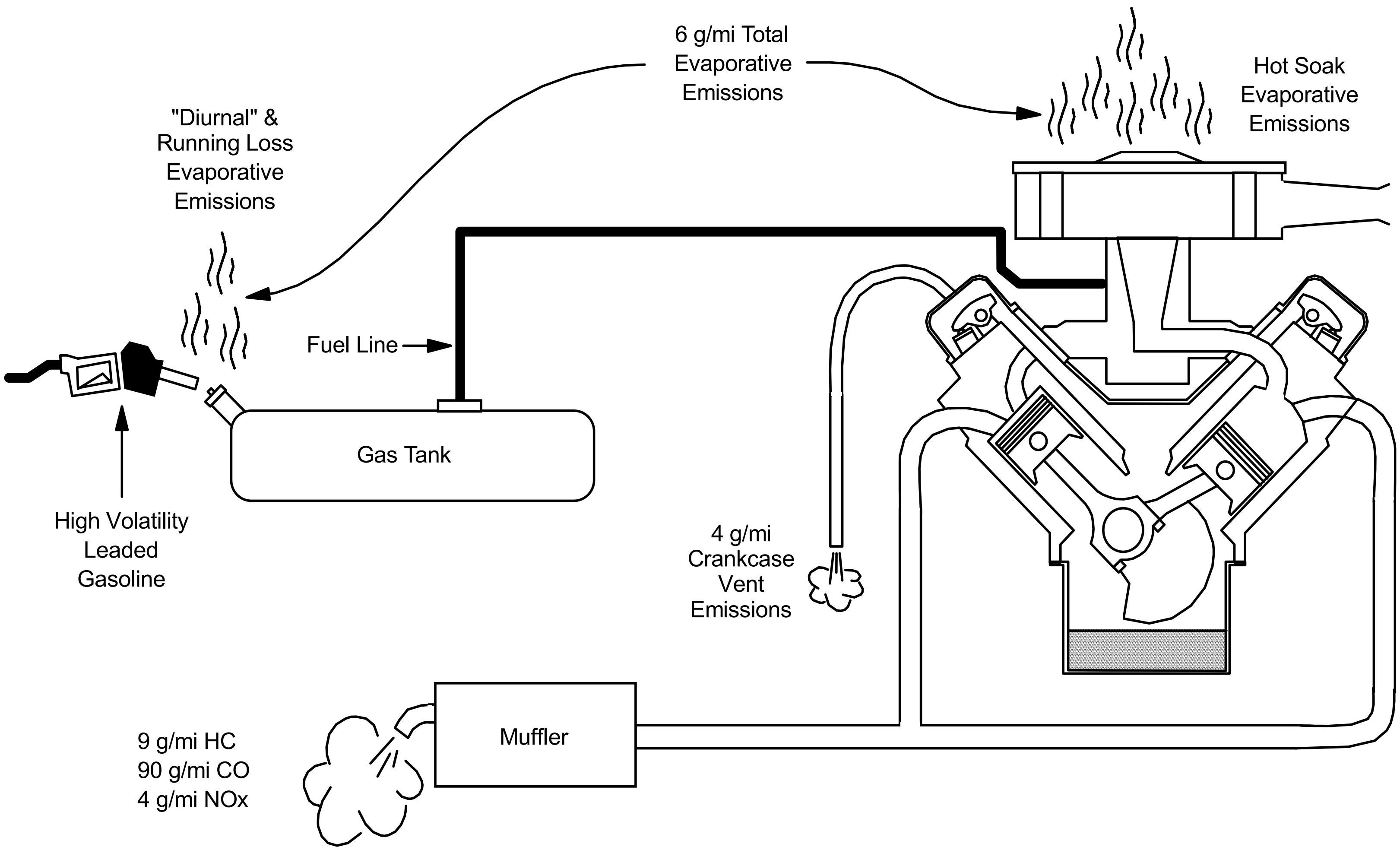
- More detailed discussion of the following topics:
  - Emission control system basics
  - Exhaust base emission rates and I/M program modeling
  - Corrections to exhaust emissions
  - Evaporative emission rates and evaporative I/M checks
  - Draws heavily upon June 1999 MOBILE6 workshop materials and technical reports
- SIP-based inventory preparation
  - HPMS and TDMs
  - EPA Guidance (Volume IV)
  - Configuring MOBILE6

VI. ADVANCED TOPICS IN MOBILE6

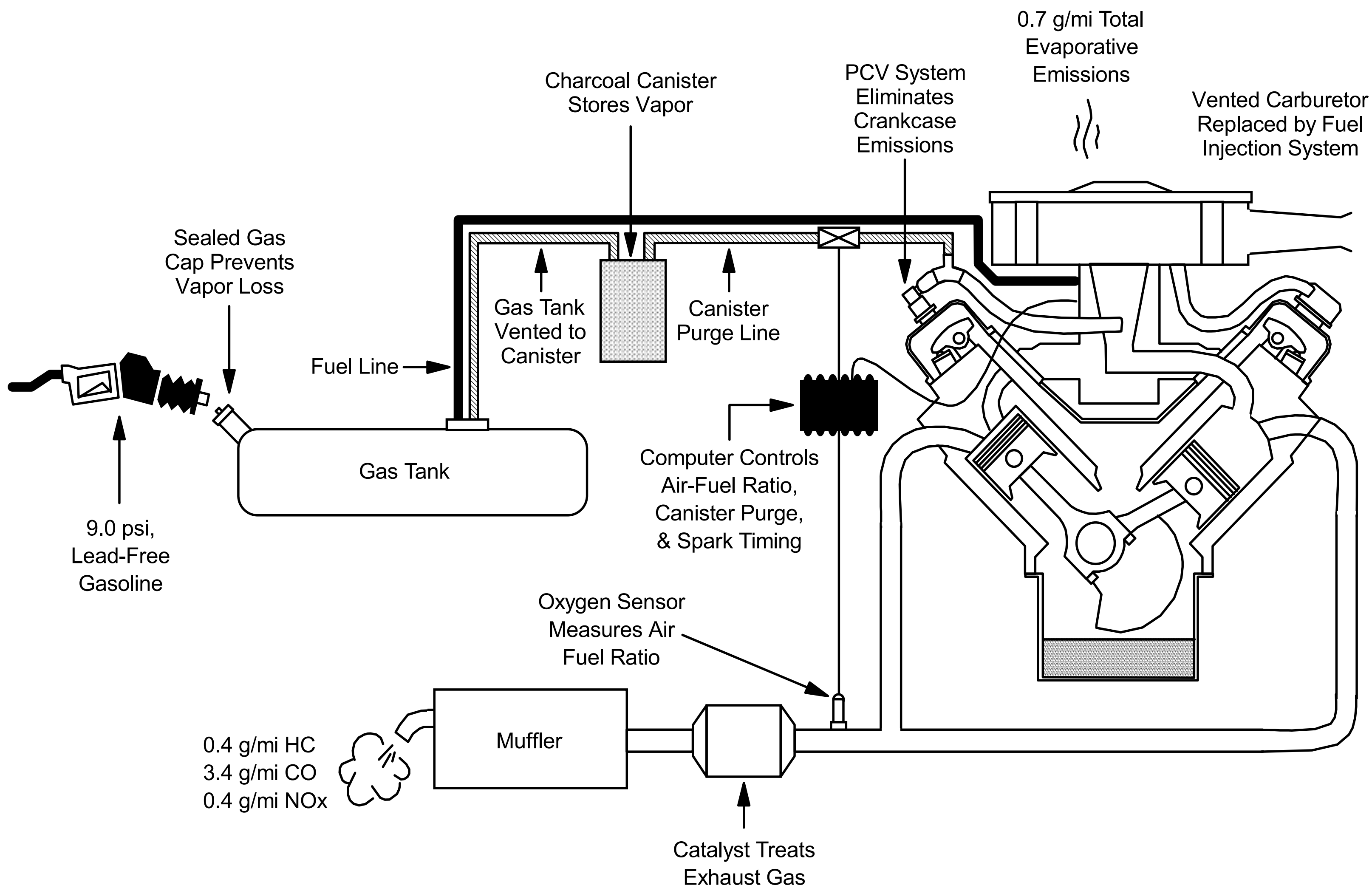
Emission Control System Basics
Uncontrolled emission sources

- Tailpipe emissions
- Fuel evaporation and leaks
- Crankcase emissions
- Refueling emissions

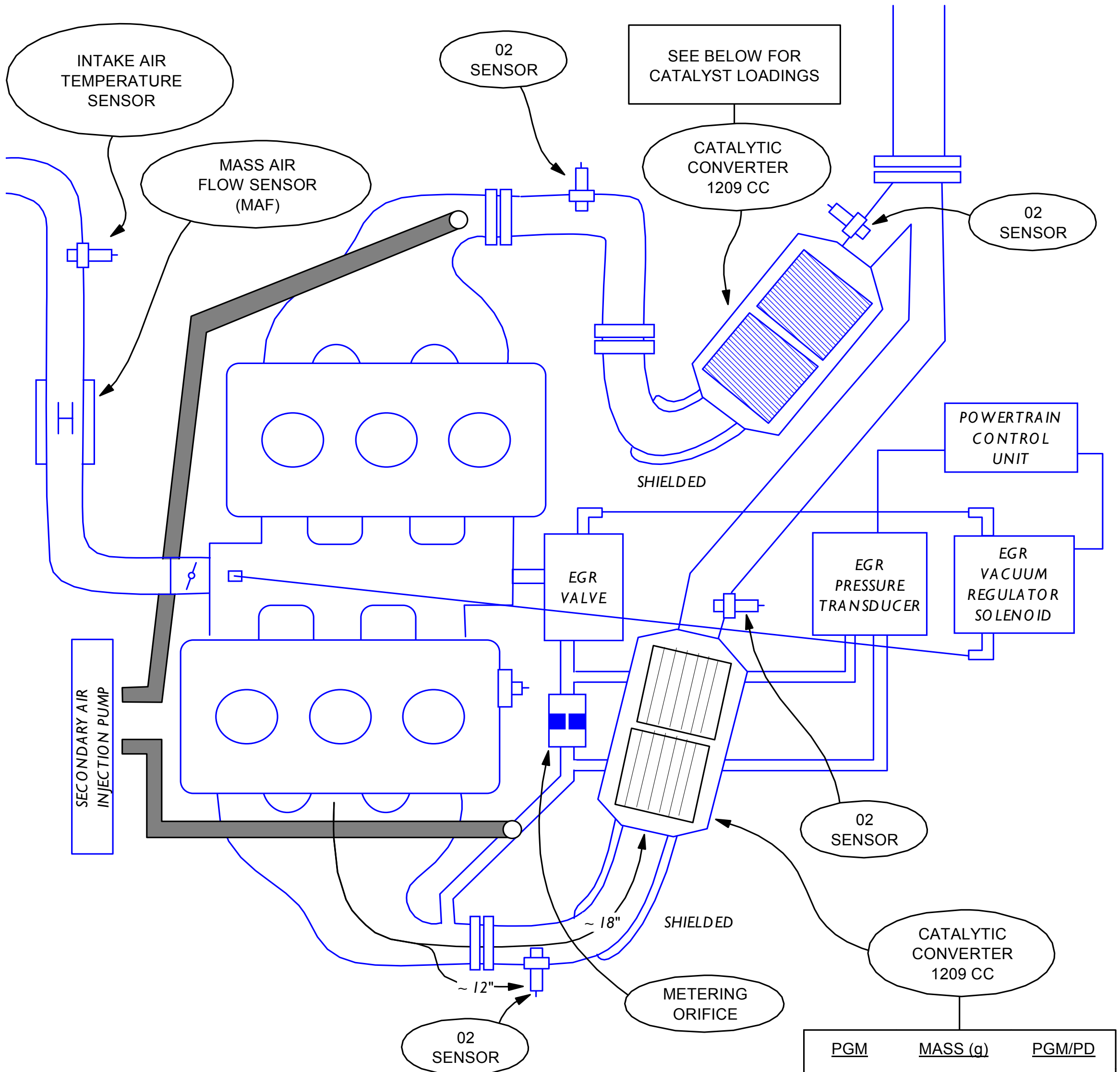
No Emissions Control



1990 Vintage Emissions Control System



1997 FORD TAURUS (LEV)
VFM3.0V8G3EK



PGM	MASS (g)	PGM/PD
Pd	8.18	1
Pt	<0.02	0
Rh	0.48	0.06
TOTAL	8.69	- -
Ceramic	Monolith	Substrate

Note: Each catalyst consists of two bricks that appear very similar. Values are for combined bricks within each catalyst can.

FRONT OF CAR

1997 Ford Taurus/Sable Low Emission Vehicle
Engine Family VFM3.0V8G3EK

Basic Engine Description - 2980cc, V-6, water cooled, pushrod, 2 valves per cylinder, 9.25:1 compression ratio.

System Description - Electronic microprocessor controlled sequential multiport fuel injection.

Primary Air Flow Measurement - Mass air flow sensor

Injector Frequency Input Parameters -

- Primary heated O_2 sensor
- Secondary heated O_2 sensor
- Intake air temperature
- Engine coolant temperature
- Camshaft position
- Engine speed
- Cranking speed
- Throttle position
- Transmission position

Oxygen Sensors - Two HO_2S per bank.

Catalysts - Single canister per bank, each containing two “bricks.” Not close coupled.

Exhaust Gas Recirculation (EGR) - Vacuum modulated with backpressure transducer and ECU controlled solenoid. Uses exhaust pressure for primary control, not manifold absolute pressure (MAP).

Secondary Air Injection - ECU controlled electric pump injects air, near outlet of exhaust manifold. It actively functions for only 20 to 120 seconds after start of engine, based on engine temperature.

Exhaust Emissions Control

- Although the catalyst is often thought of as the backbone of the exhaust emission control system, proper fuel management is critical for maintaining optimal emissions performance

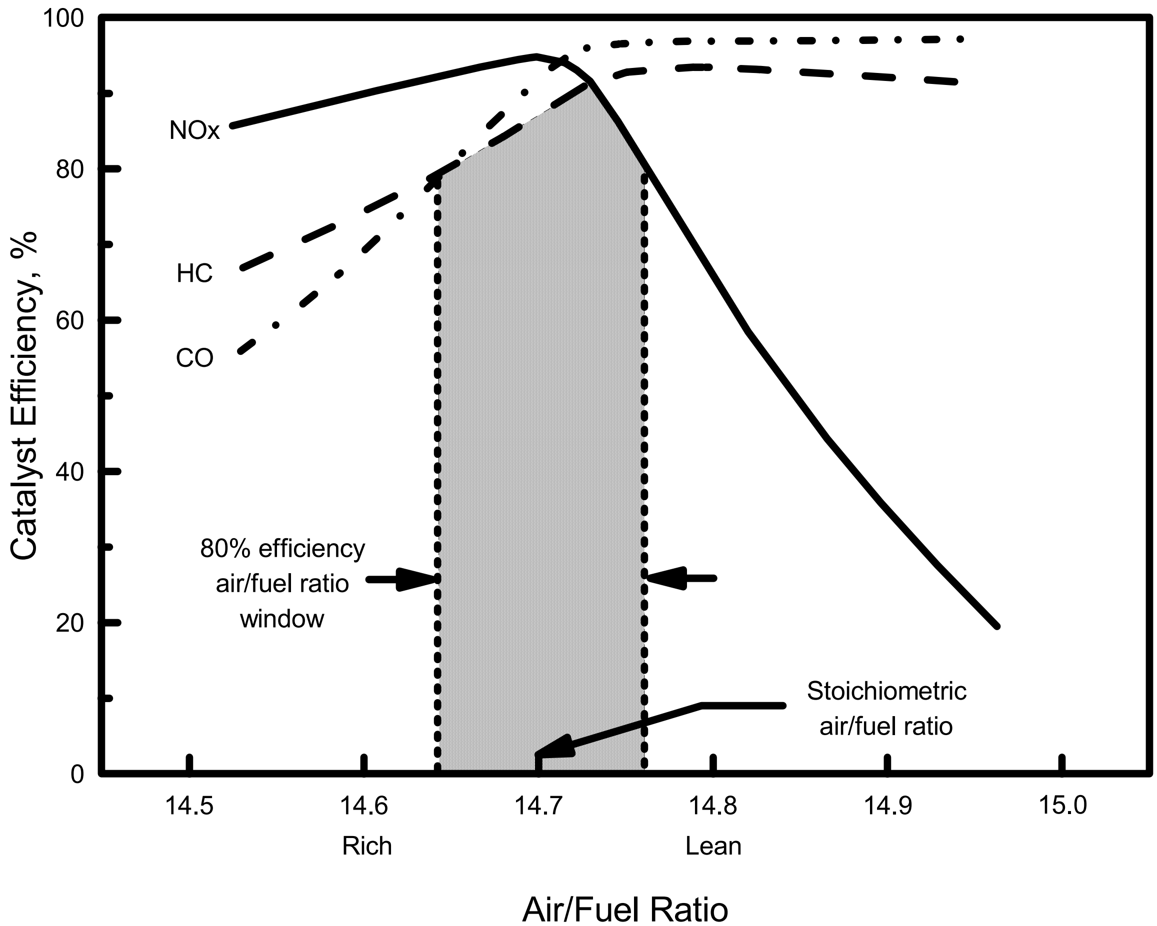
- The air/fuel (A/F) ratio must be kept within very tight tolerances for effective catalytic destruction of HC, CO, and NOx with today's three-way catalyst systems

- This is accomplished with "feed-back" fuel control:

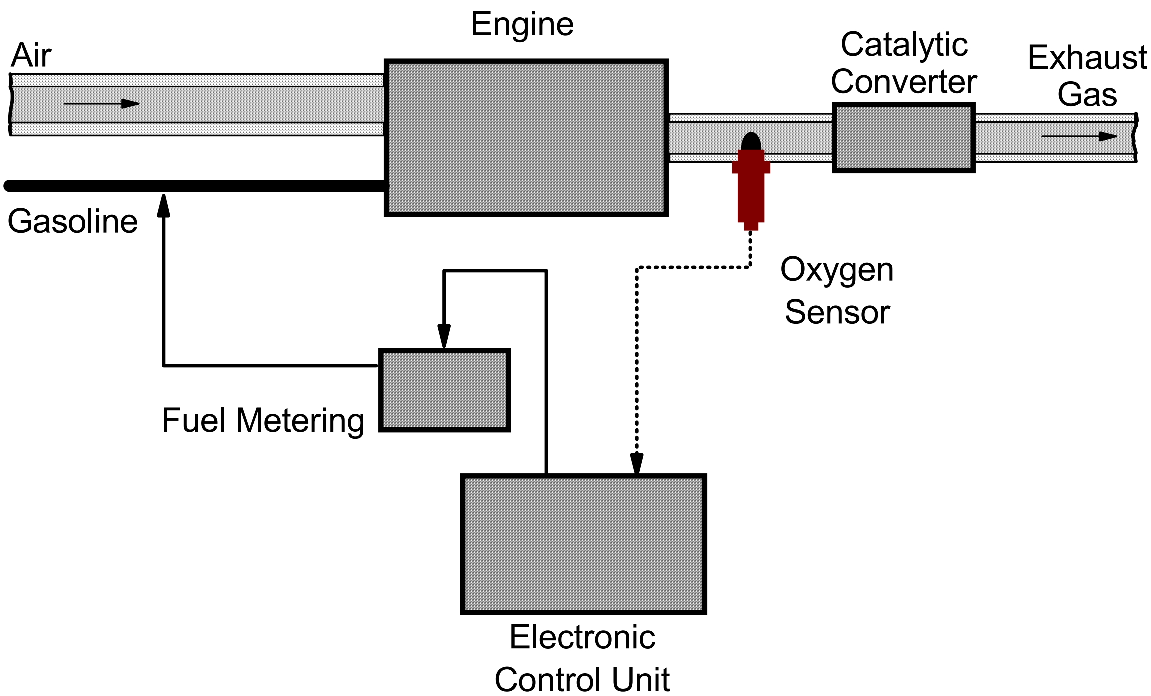
  - Signals from the exhaust gas oxygen sensor are processed by the electronic control unit (ECU)

  - The ECU then signals the injectors to add or trim fuel to maintain a balance about the stoichiometric A/F ratio

3-Way Catalyst Efficiency vs. Air/Fuel Ratio



Feedback Fuel Control System



Oxygen Sensor Operation

- Responds to changes in air/fuel ratio like a switch

- Rich conditions → Output ≈ 0.8-0.9 volts

- Lean conditions → Output ≈ 0.0-0.1 volts

- Needs a source of reference air and needs to be at elevated temperature to operate

Oxygen Sensor Design

- Older "Unheated" Sensors

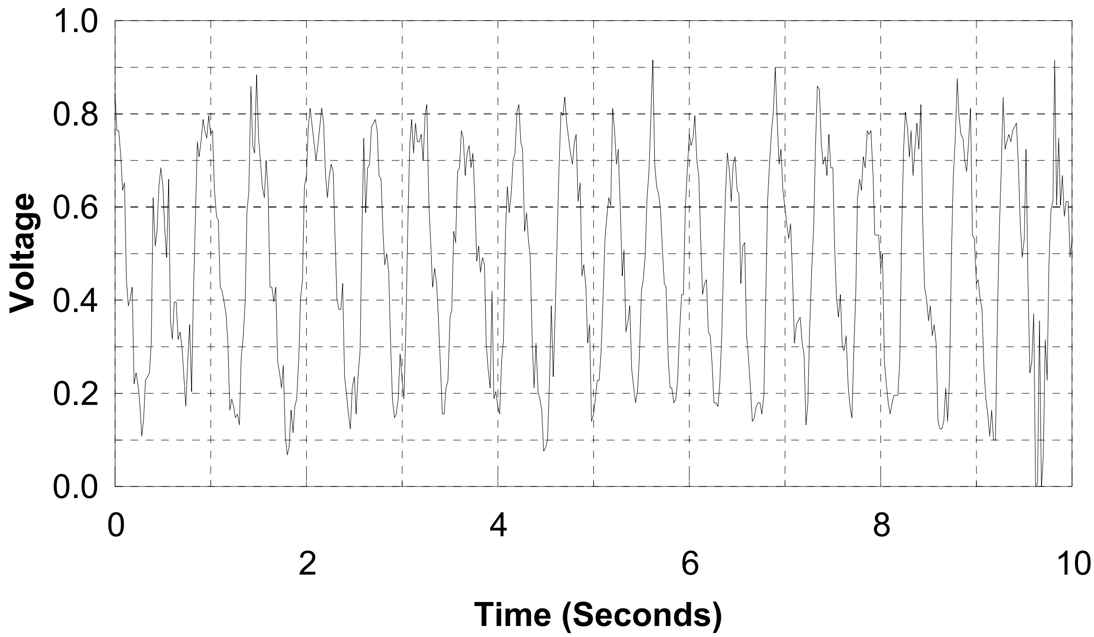
  - Exhaust gas used to heat to operating temperature
  - Placed close to engine
  - Large volume of exhaust gas in contact with sensor element
  - More susceptible to poisoning

- Newer "Heated" Sensors

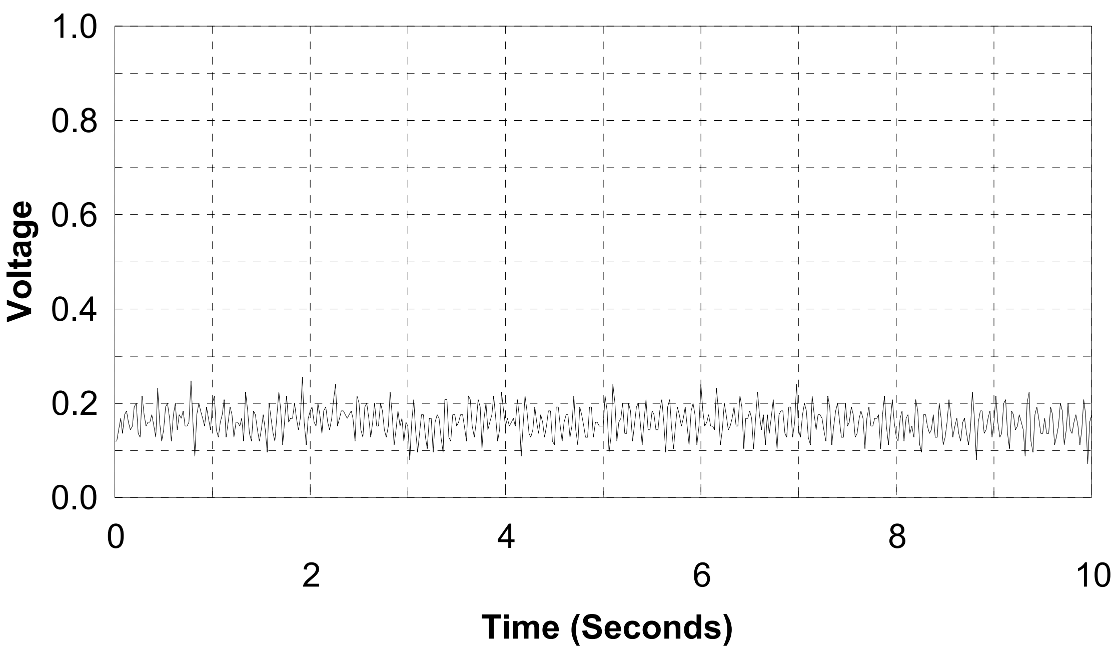
  - Internal heater
  - Placed further away from engine
  - Smaller volume of exhaust gas in contact with sensor element
  - Reach higher operating temperature, permitting self-cleaning of sensor element

- "Rear" sensor used to determine catalyst efficiency (OBD II requirement)

Voltage-Time Trace of a Functioning Oxygen Sensor



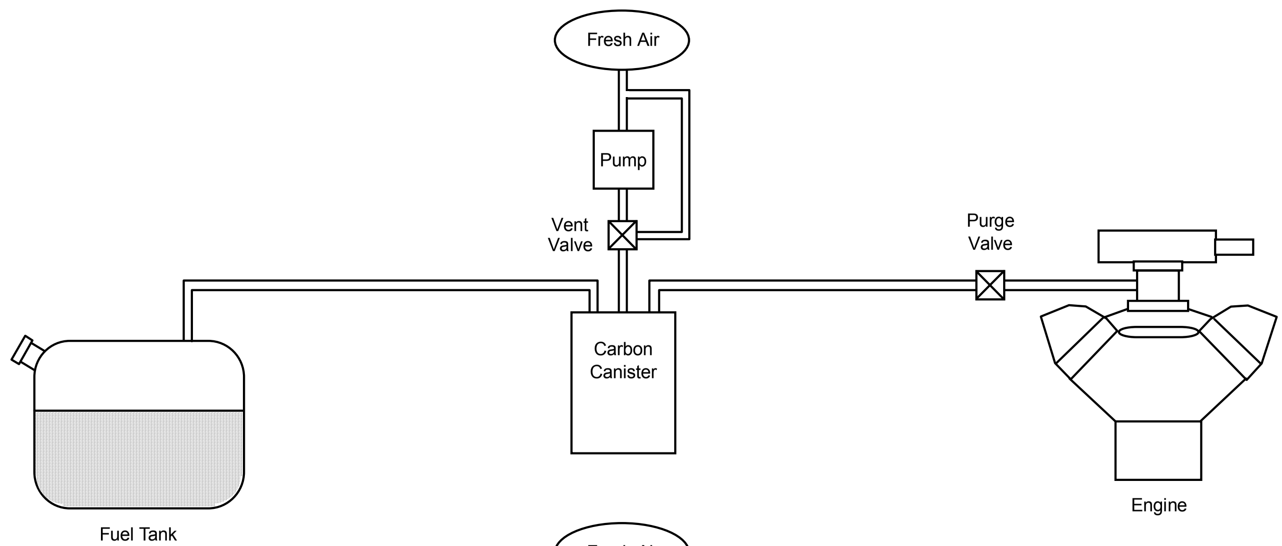
Voltage-Time Trace of a Lean Failure

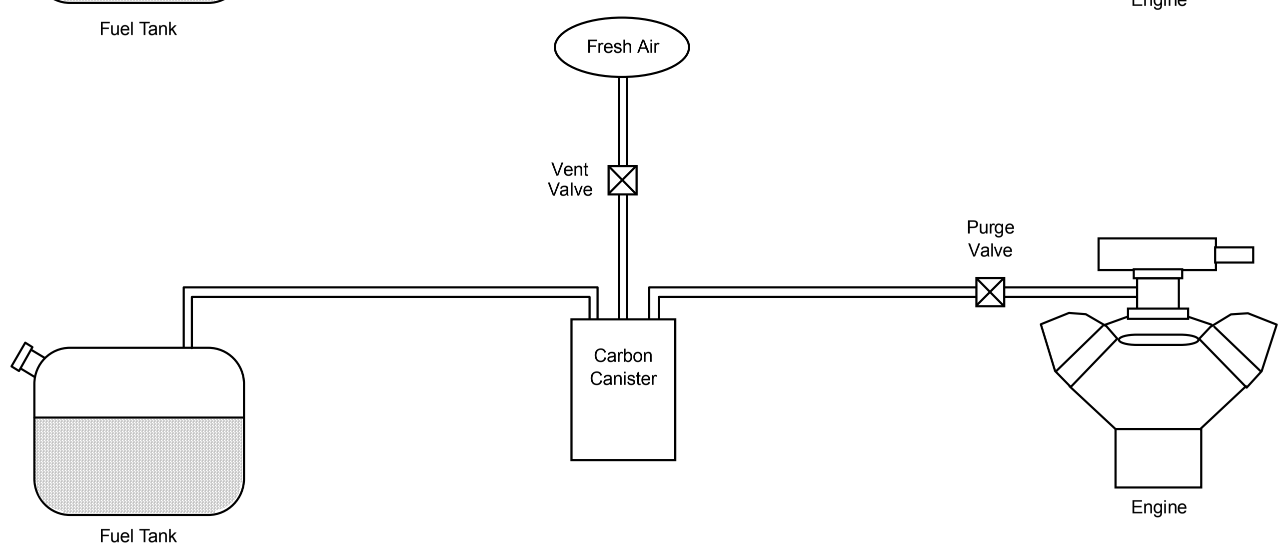


Evaporative Control System Design

- Little has changed to the basic design elements:
  - Vapor hoses route gasoline vapors to an evaporative canister
  - HC vapors are adsorbed onto the activated carbon in the canister
  - Fresh air is drawn through the canister and is pulled into the intake manifold (controlled by the purge valve)
  - Adsorbed HC vapors are released into the fresh air stream and then burned in the engine
- Significant improvements have been made to materials and fittings (diurnal and resting losses)
- More emphasis has been placed on reducing fuel heating (running losses), e.g., heat shields, returnless fuel systems, etc.
- Purge strategies are very sophisticated to maintain exhaust emission control

Evaporative Control System Schematic
(OBD II Compliant)





EXHAUST EMISSION RATES

Exhaust Base Emission Rates
Light-Duty Gasoline Vehicles

- Focus on 1988 and newer model year emission rates (basis for all LEV and Tier 1 emission rates)
- Primary sources of FTP data
- Separating starting from running emissions
- MOBILE6 modeling methodologies
- Comparison of modeled results to data

LDGV Base Emission Rates
Sources of Data

- MOBILE5 emission factors were based on IM240 data that were converted to an FTP basis

- For MOBILE6, a decision was made to only use FTP data; however, those data were adjusted for possible recruitment bias based on IM240 data

- Sources of FTP data:

  - *EPA Emission Factors Database* – Data collected by EPA and EPA contractors; historically used for emission factors development

  - *AAMA In-Use Data* - Test program sponsored by AAMA, this database consists of over 2,200 in-use 1990 to 1993 MY cars and trucks tested at 3 to 4 years of age

  - *API High-Mileage Data* - Test program sponsored by API, consists of 75 in-use 1985 to 1992 MY vehicles that had accumulated at least 100,000 miles

Sample Sizes of EPA/AAMA/API FTP Databases Used in EPA's Evaluation of In-Use Exhaust Deterioration Rates (1988 and Later Model Year Light-Duty Fuel-Injected Vehicles Only)

Model Year	Database	Odom < 50K	Odom 50K - 99K	Odom >= 100K	Total
1988 to 1989	EPA	89	155	37	281
	AAMA	--	--	--	--
	API	--	--	42	42
1990 to 1993	EPA	174	69	5	248
	AAMA	1,207	244	13	1,464
	API	--	--	14	14

Converting FTP Data into Running and Starting Emissions

- As noted previously, MOBILE6 treats starting and running exhaust emissions entirely differently from MOBILE5

- FTP data had to be broken up into:

  - Running LA4 emission rates (no start emissions)

    - “Hot Running 505” correlations were developed from a smaller test sample

      HR505 = f(FTP Bag 1, Bag 2, Bag 3)

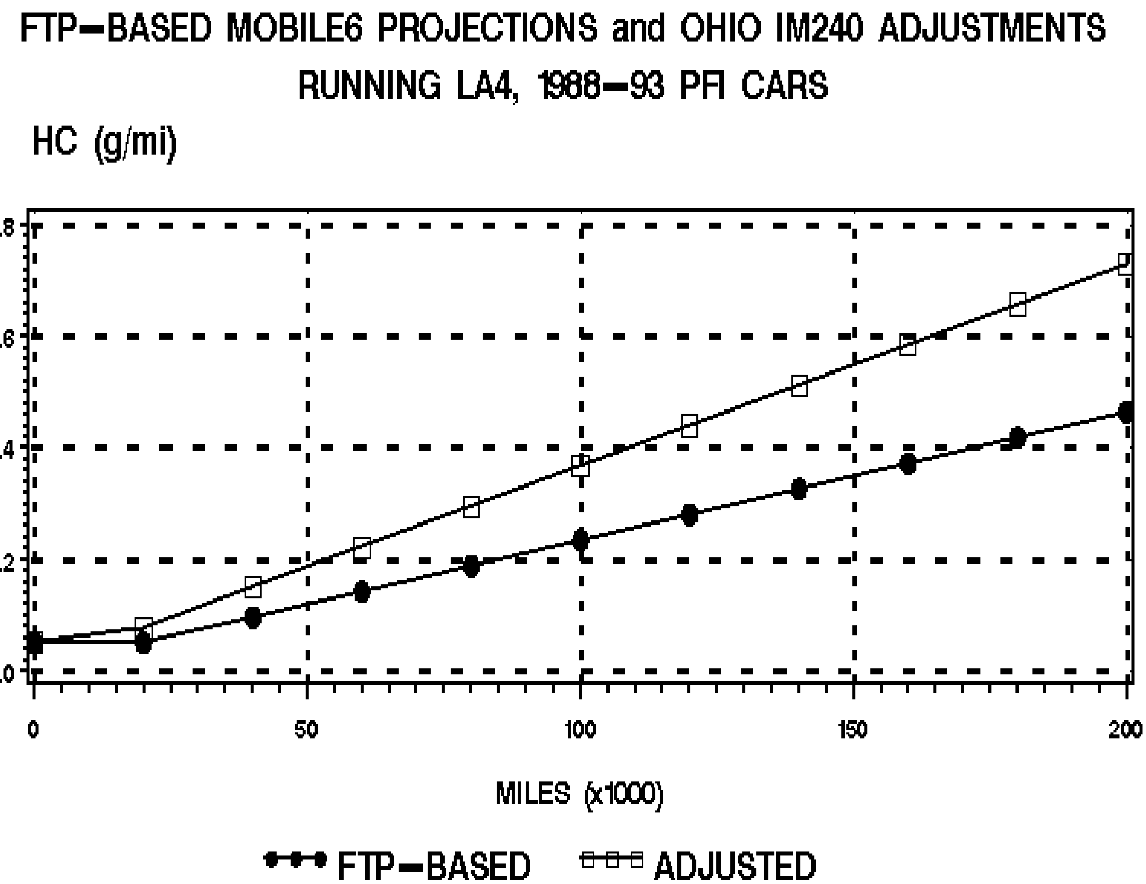
    - Running LA4 (g/mi) =
      (HR505 (g/mi) × 0.479) +
      (Bag 2 (g/mi) × 0.521)

  - Start offset

    - Start (grams) =
      {Bag 1 (g/mi) - HR505 (g/mi)} × 3.59 miles

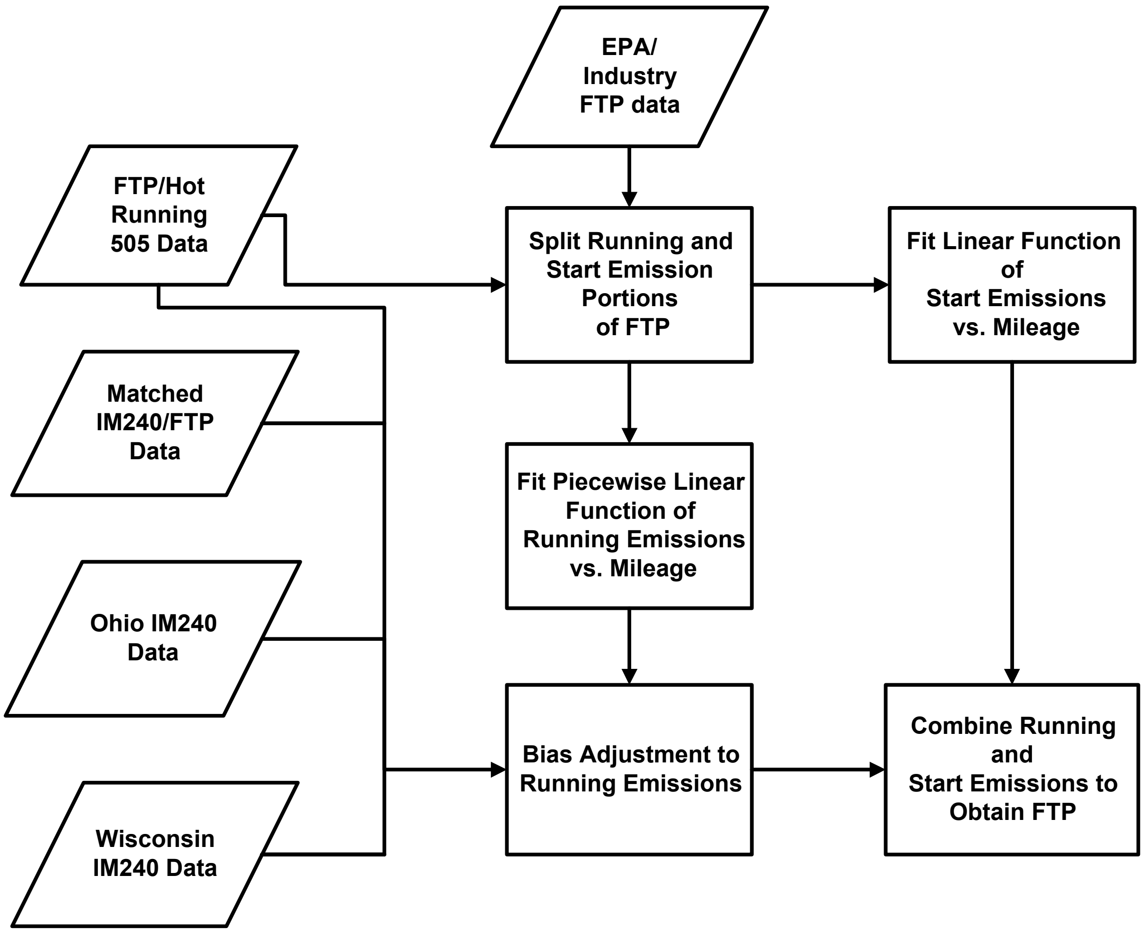
“High Emitter” Correction

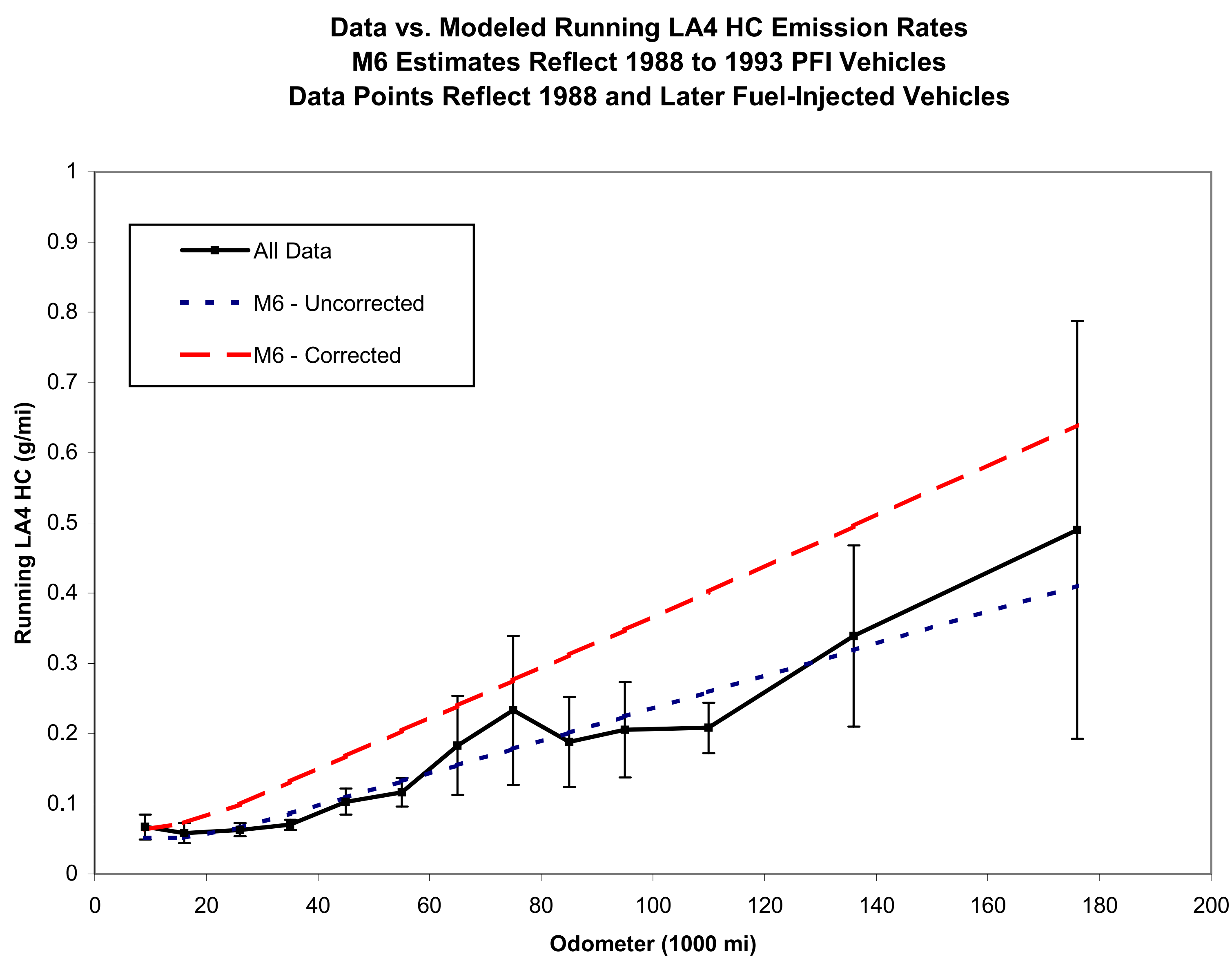
- Because of concerns about sample bias, a “high-emitter” correction was applied to the FTP data
  - Historically, vehicles in very poor shape were sometimes thrown out of test programs
  - It is thought that owners who have tampered with their vehicles are less likely to participate in a test program
- The FTP data were therefore adjusted to account for potential sampling bias, using data from the Dayton, Ohio I/M program
- The adjustment was implemented by:
  - Converting IM240 data to running LA4
  - Computing model year means (as a function of mileage)
  - Adjusting the FTP-based running LA4 line to agree with the means from the larger, I/M program sample
  - Start data were corrected by adjusting the fraction of high emitters to be consistent with the adjusted running LA4 line



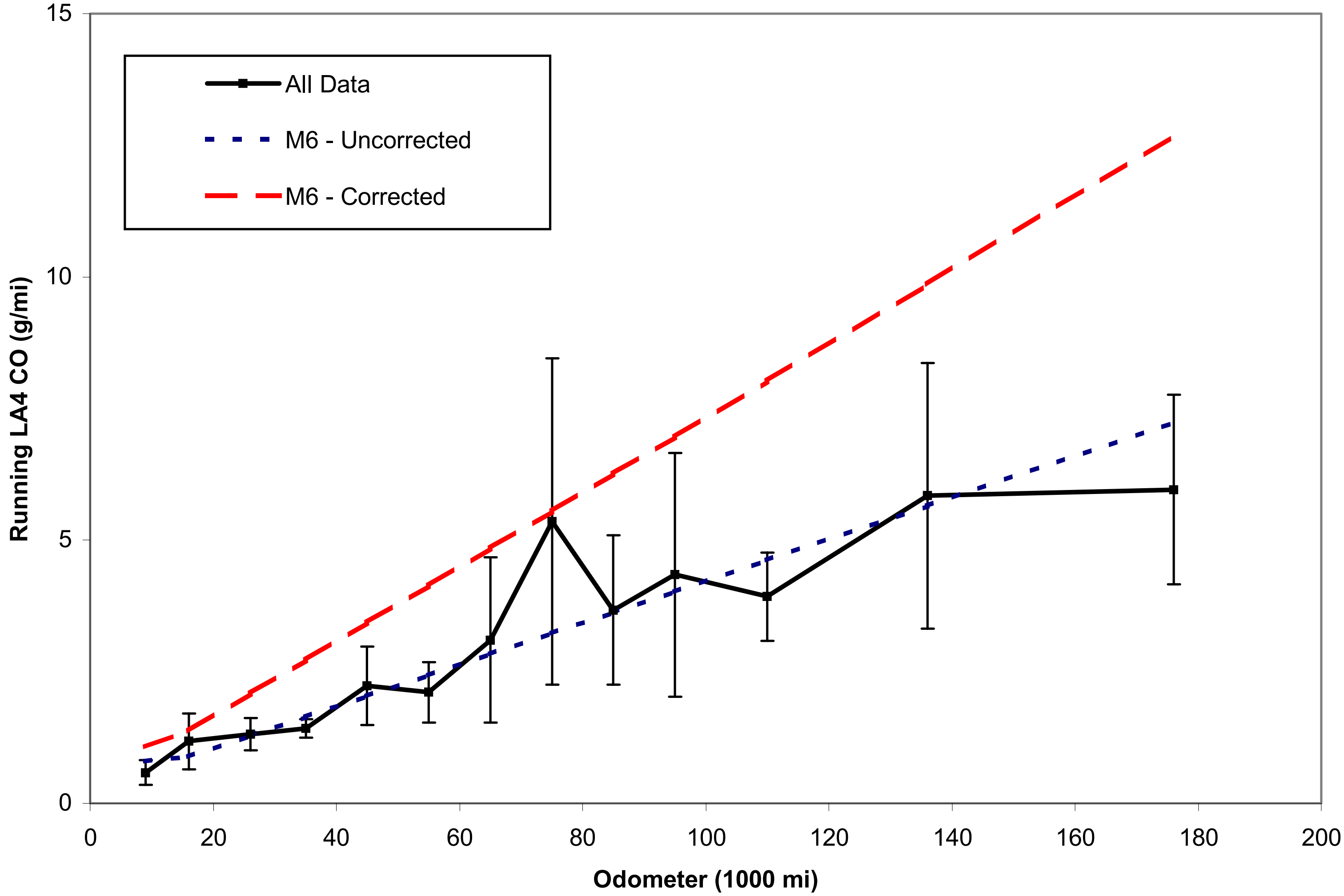
Source: June 1999 MOBILE6 Workshop

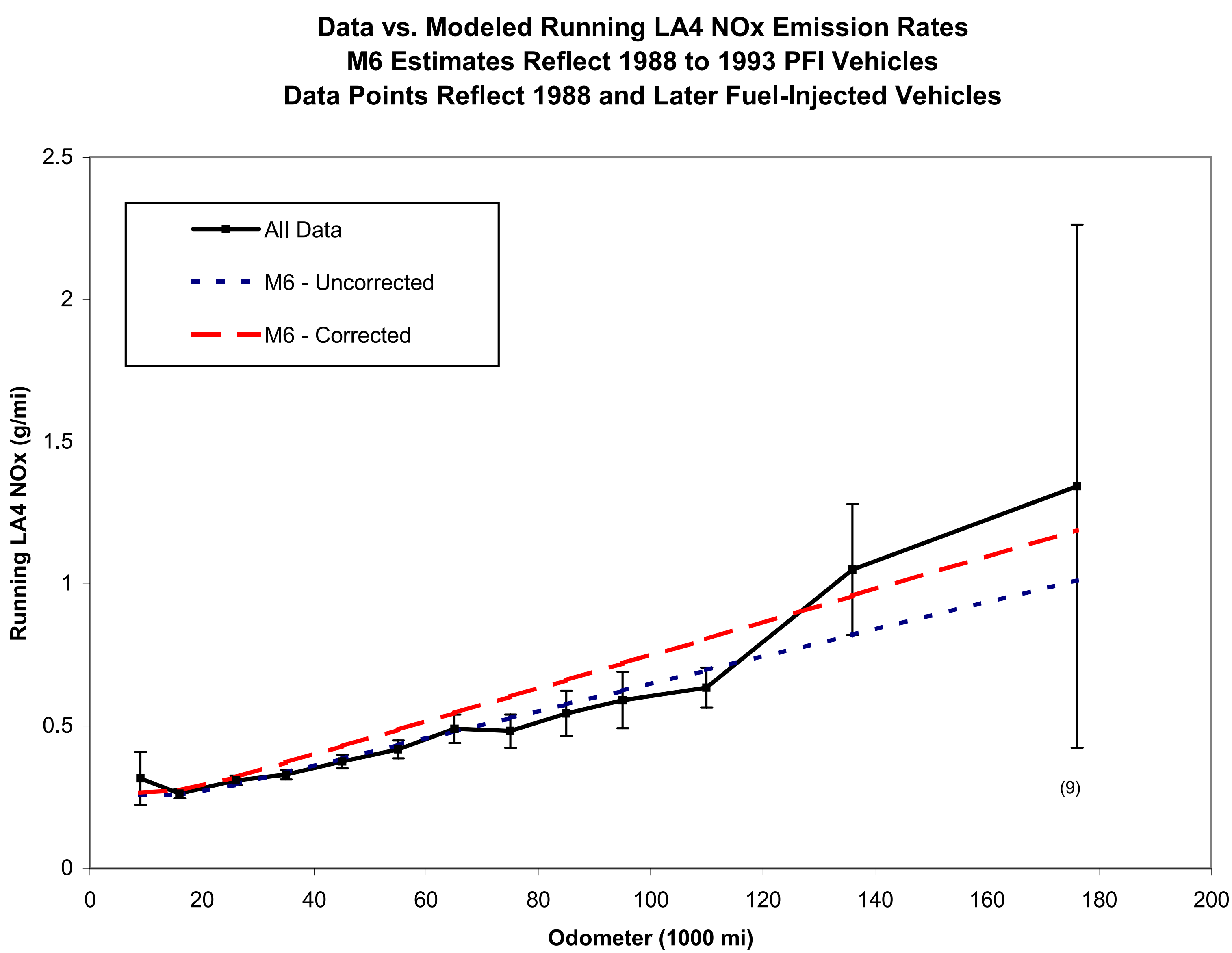
Putting it All Together
(From June 1999 MOBILE6 Workshop)




Data vs. Modeled Running LA4 HC Emission Rates
M6 Estimates Reflect 1988 to 1993 PFI Vehicles
Data Points Reflect 1988 and Later Fuel-Injected Vehicles
Running LA4 HC (g/mi)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Odometer (1000 mi)
0
20
40
60
80
100
120
140
160
180
200
All Data
M6 - Uncorrected
M6 - Corrected

Data vs. Modeled Running LA4 CO Emission Rates
M6 Estimates Reflect 1988 to 1993 PFI Vehicles
Data Points Reflect 1988 and Later Fuel-Injected Vehicles




Data vs. Modeled Running LA4 NOx Emission Rates
M6 Estimates Reflect 1988 to 1993 PFI Vehicles
Data Points Reflect 1988 and Later Fuel-Injected Vehicles
All Data
M6 - Uncorrected
M6 - Corrected
(9)
Running LA4 NOx (g/mi)
0
0.5
1
1.5
2
2.5
Odometer (1000 mi)
0
20
40
60
80
100
120
140
160
180
200

Exhaust Base Emission Rate Equations
Heavy-Duty Vehicles

- General approach for HDVs
- Emission factor development
- Conversion factor development

Heavy-Duty Vehicle Modeling Approach

- Heavy-duty engines are removed from the vehicle and tested on an engine dynamometer

- Emission rates are specified in g/bhp-hr (i.e., mass per unit of work) units

- The emission factors (in g/bhp-hr) are converted to g/mi units with "conversion factors"

- Conversion factors are a function of:

  - Brake specific fuel consumption
  - Fuel density
  - Fuel economy

Update of Emission Rates (M6.HDE.001)

- Updated emission rates for 1988-2009+ model years
- Certification data used for MY 1988-1995
- 1996+ model years based on standards differences
- HDGE Results
  - HC: Much lower ZMLs and DRs
  - CO: Lower ZMLs and DRs
  - NOx: Lower ZMLs, slightly lower DRs
- HDDE Results
  - HC: Much lower ZMLs; DRs very low (but were zero in M5)
  - CO: Much lower ZMLs and DRs
  - NOx: Lower ZMLs, slightly lower DRs (but were zero in M5)

Conversion Factors

- Units of bhp-hr/mi
- Convert engine test data to units that can be used with available activity data (i.e., miles)
- Distinct for gasoline/Diesel and for weight classes within each
- CFs were revised for 1987-1996 MY; 1996 values were used for future model years
- Same methodology as for previous versions of MOBILE
- Conversion Factor (bhp-hr/mi) =

$$\frac{\textit{Fuel Density (lb/gal)}}{\textit{BSFC (lb/hp-hr) * FE (mi/gal)}}$$

Heavy-Duty Vehicle Classes

Class 2b Heavy-Duty Gasoline Vehicles (8501-10,000 lbs. GVWR)
Class 3 Heavy-Duty Gasoline Vehicles (10,001-14,000 lbs. GVWR)
Class 4 Heavy-Duty Gasoline Vehicles (14,001-16,000 lbs. GVWR)
Class 5 Heavy-Duty Gasoline Vehicles (16,001-19,500 lbs. GVWR)
Class 6 Heavy-Duty Gasoline Vehicles (19,501-26,000 lbs. GVWR)
Class 7 Heavy-Duty Gasoline Vehicles (26,001-33,000 lbs. GVWR)
Class 8a Heavy-Duty Gasoline Vehicles (33,001-60,000 lbs. GVWR)
Class 8b Heavy-Duty Gasoline Vehicles (>60,000 lbs. GVWR)
Class 2b Heavy-Duty Diesel Vehicles (8501-10,000 lbs. GVWR)
Class 3 Heavy-Duty Diesel Vehicles (10,001-14,000 lbs. GVWR)
Class 4 Heavy-Duty Diesel Vehicles (14,001-16,000 lbs. GVWR)
Class 5 Heavy-Duty Diesel Vehicles (16,001-19,500 lbs. GVWR)
Class 6 Heavy-Duty Diesel Vehicles (19,501-26,000 lbs. GVWR)
Class 7 Heavy-Duty Diesel Vehicles (26,001-33,000 lbs. GVWR)
Class 8a Heavy-Duty Diesel Vehicles (33,001-60,000 lbs. GVWR)
Class 8b Heavy-Duty Diesel Vehicles (>60,000 lbs. GVWR)
Gasoline Buses (School, Transit and Urban)
Diesel Transit and Urban Buses
Diesel School Buses

Sources of Data for Conversion Factors

- Truck fuel economy – 1992 Truck Inventory and Use Survey (TIUS)
- Transit & intercity bus fuel economy – NREL study, APTA “1995 Transit Passenger Vehicle Fleet Inventory” and “1996 Transit Fact Book”
- School bus fuel economy – National Transportation Statistics 1997, School Bus Fleet magazine
- Gasoline transit & intercity bus fuel economy – previous work (Machiele, 1987)
- Fuel density data, for summer & winter seasons 1987-1996 – NIPER Petroleum Product Surveys
- BSFC data – requested from 8 mfrs (6 supplied); estimates for others based on hp, specifications, engineering judgment
- Sales data from EPA used to weight BSFC within classes

MOBILE6 vs. MOBILE5 Conversion Factors

- Heavy-Duty Gasoline Engines
  - New CFs higher than MOBILE5 for Class IIb (8500-10,000 lb)
  - New CFs lower for Classes III thru VIII
- Heavy-Duty Diesel Engines
  - Slightly higher than MOBILE5 for Classes IIb thru VII
  - Lower for Class VIIIa (33,001-60,000 lb)
  - Very similar for Class VIIIb (60,001+ lb); slightly higher for MY1987-92, slightly lower for MY 1993+
- Buses
  - Higher for all Diesel buses (transit, intercity, and school)
  - Higher for gasoline school buses

INSPECTION AND MAINTENANCE PROGRAMS

Modeling the Impacts of Exhaust I/M Programs

- Overview of test types
- Definition of terms
  - network type
  - compliance rate
  - waiver rates
  - error of commission/omission
  - etc...
- Identification rates
- Repair effectiveness
- Sawtooth curve and after-repair deterioration
- OBD checks

Overview of Tailpipe Test Types

- *Idle testing* - Emissions are measured with the vehicle in park or neutral at idle (i.e., "curb" idle)

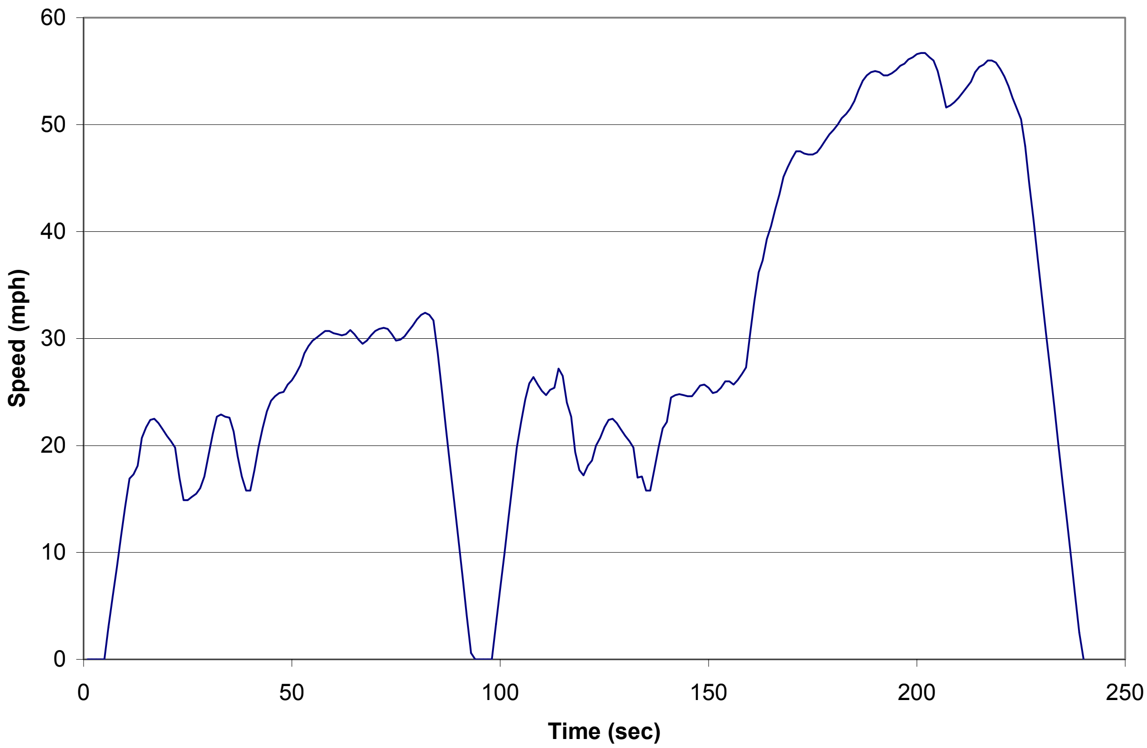
- *Two-speed idle (TSI) testing* - Emissions are measured with the vehicle at curb idle and at a higher speed idle (usually about 2,500 rpm)

- *Loaded test* - The vehicle is operated on a dynamometer and is run at a low-speed cruise (20 - 35 mph) with a light load placed on the vehicle

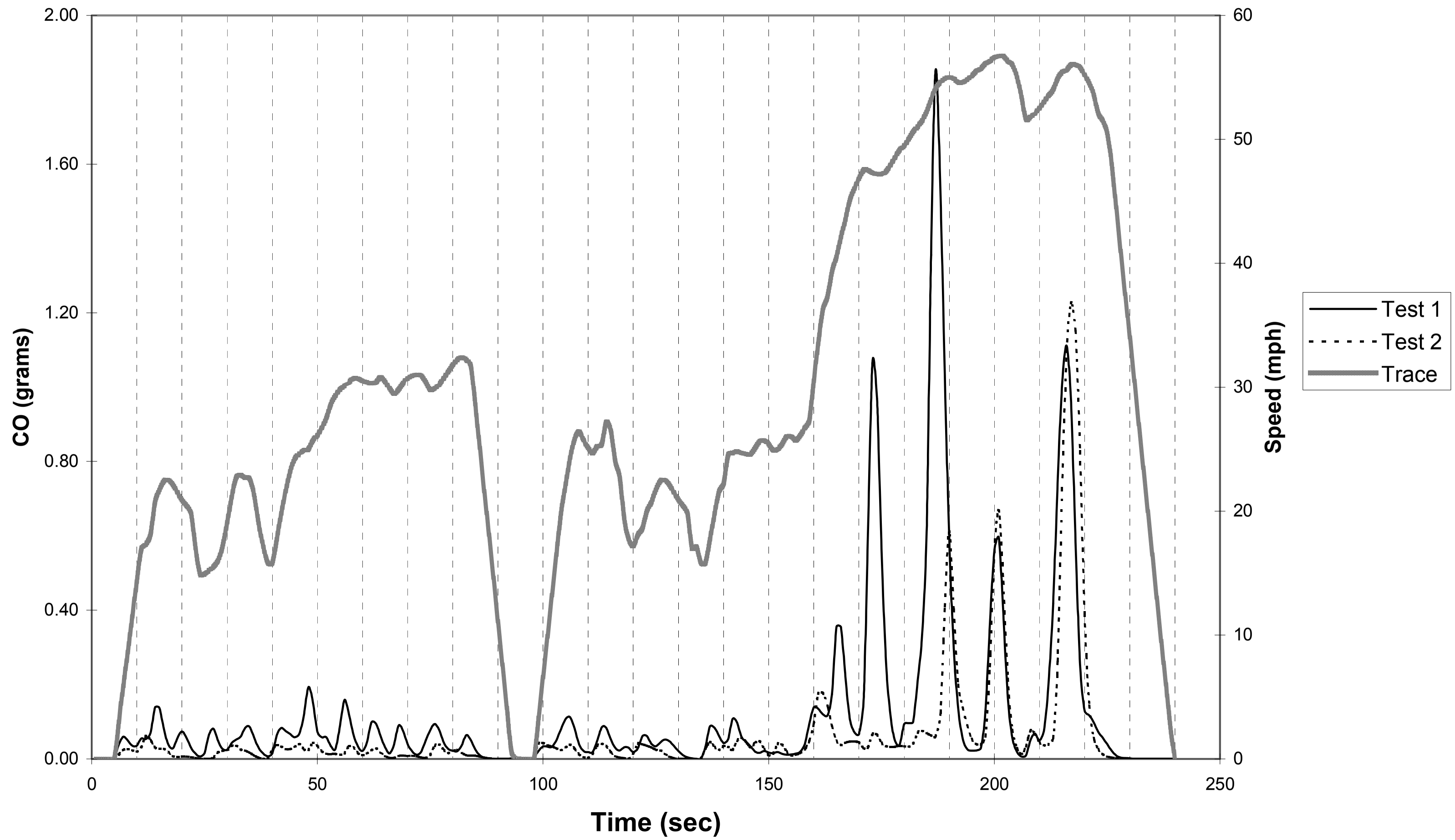
- *Acceleration Simulation Mode (ASM) testing* - The vehicle is operated on a dynamometer with sufficient load applied to simulate acceleration (during which emissions tend to be highest)

- *IM240 Testing* - The vehicle is placed on a dynamometer and is driven over a prescribed transient (i.e., stop-and-go) speed-time profile while emissions are measured

IM240 Driving Trace



Sec-by-Sec CO Mass for Back-to-Back IM240s
1990 Toyota Camry (CO_1=15.19 g/mi; CO_2=7.89 g/mi)



Inspection and Maintenance Programs
Definition of Terms and Parameters

- Emission standards or cutpoints – Each tailpipe test type has an associated set of cutpoints that are used to distinguish passing from failing vehicles

- Network type – Two primary network types:

  - Test-only
  - Test-and-repair

- Compliance rate – Fraction of vehicles subject to the program that complete requirements to the point of receiving a passing score or a cost waiver

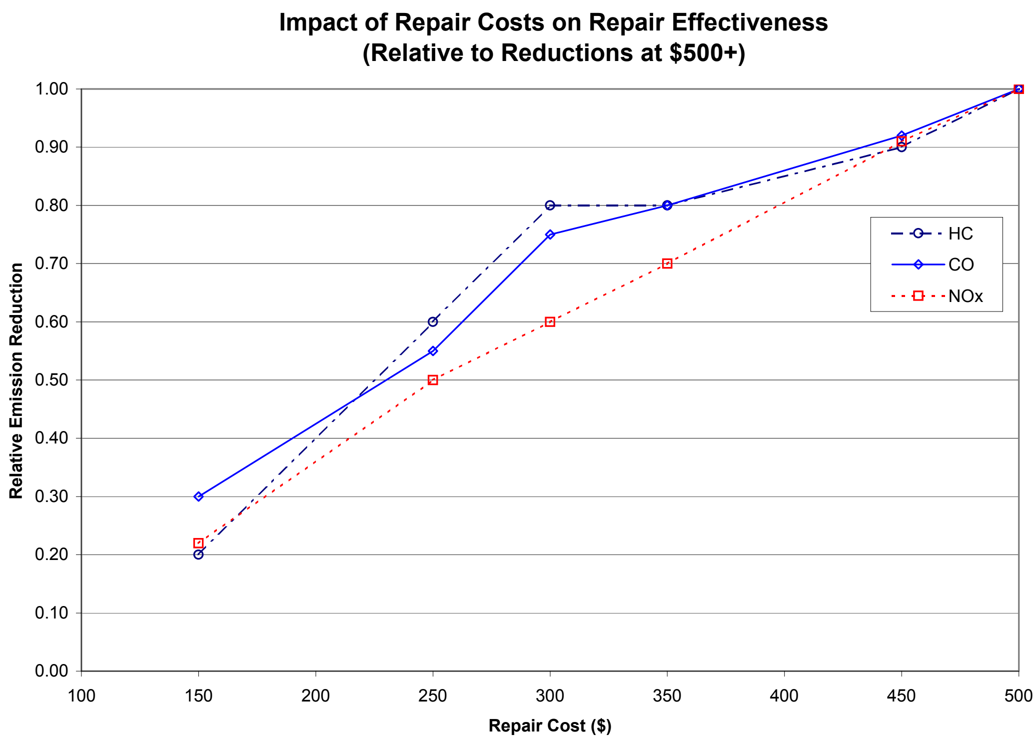
- Cost waiver – Issued if a motorist has spent a preset limit on repair but is unable to obtain a passing score; usually a function of vehicle age; higher cost limits result in greater emissions benefits

- Inspection frequency – Simply refers to how often vehicles are inspected; typically annual or biennial

Inspection and Maintenance Programs
Definition of Terms and Parameters
(Continued)

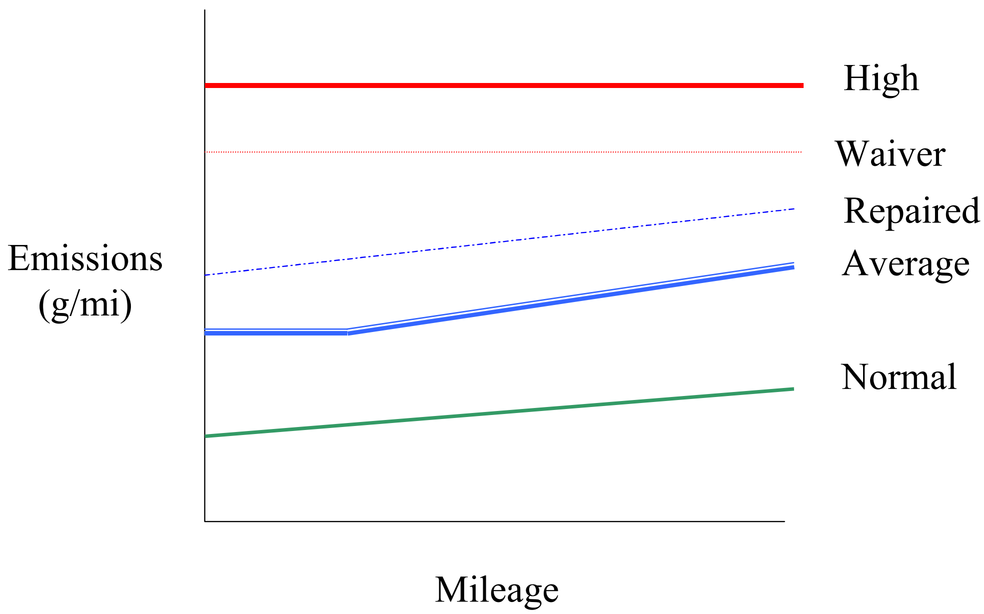
- Technician training and certification – Program aimed at improving the effectiveness of in-use repair efficiency
- Error of commission – Vehicles that are incorrectly failed by an I/M program short test (i.e., no repairable defect); EOC rates increase as cutpoints are tightened
- Error of omission – Vehicles that are incorrectly passed by an I/M program short test; result in loss of potential benefits
- Antitampering program – Consists of visual and/or functional checks of various emission control components
- Clean screen programs – Vehicles expected to pass a test are exempted from testing; simplest form is new vehicle exemptions

Figure 1

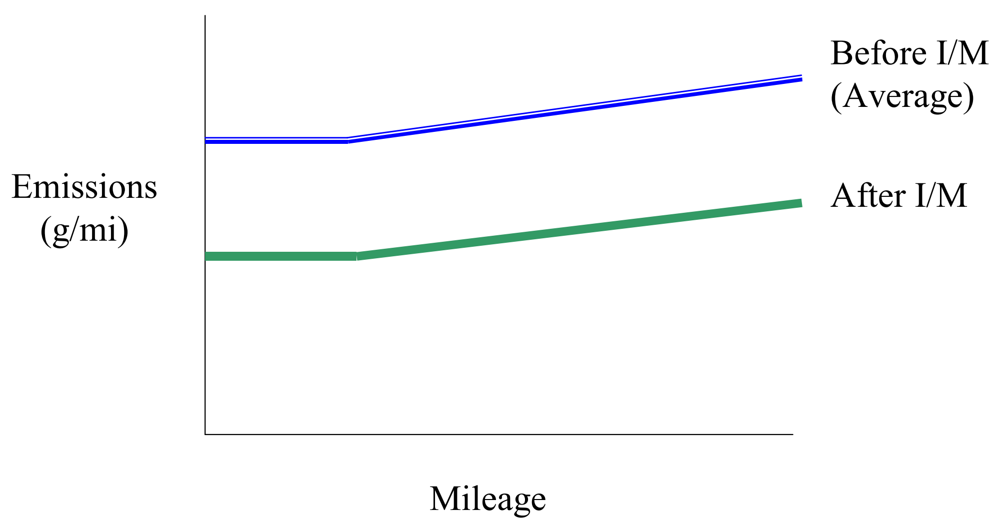


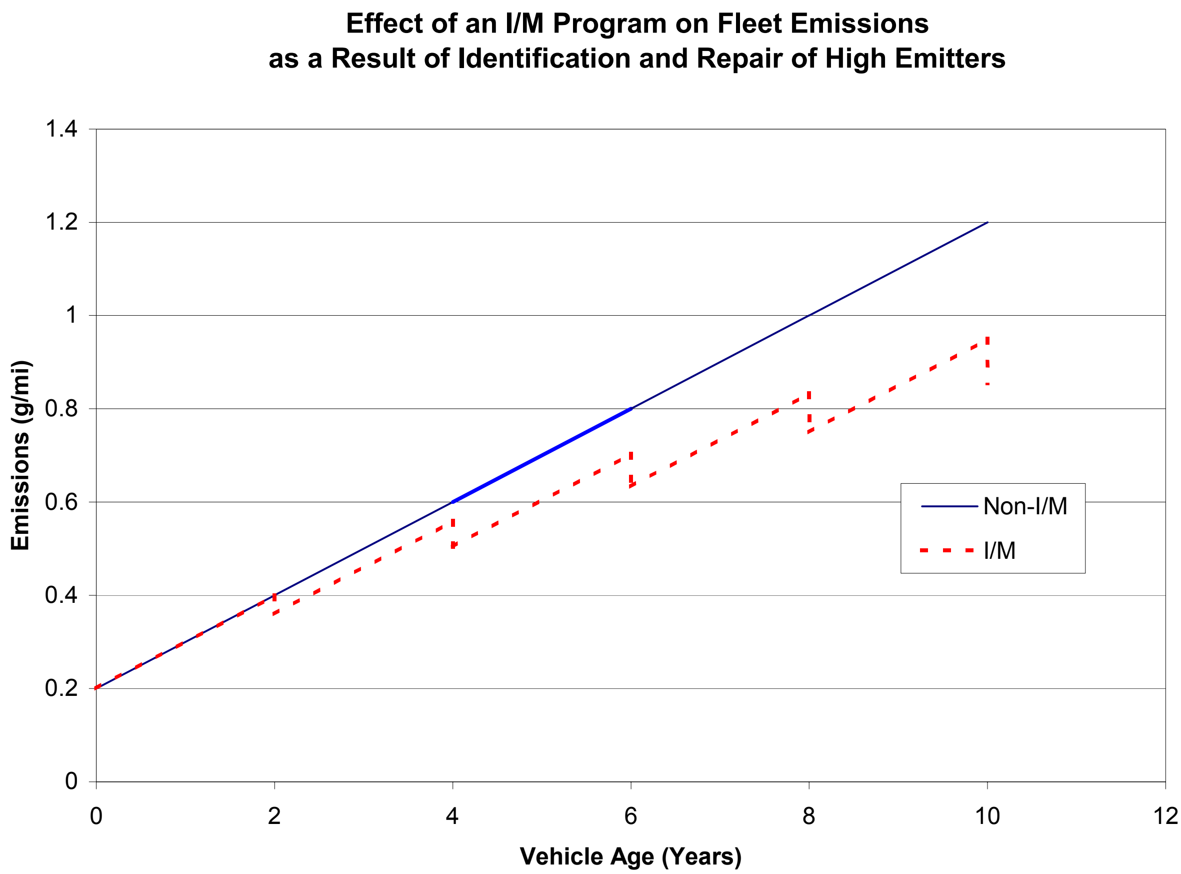
Impact of Repair Costs on Repair Effectiveness
(Relative to Reductions at $500+)
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
Relative Emission Reduction
100
150
200
250
300
350
400
450
500
Repair Cost ($)
HC
CO
NOx

General I/M Model



General I/M Model (Continued)




Effect of an I/M Program on Fleet Emissions
as a Result of Identification and Repair of High Emitters
Emissions (g/mi)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
Vehicle Age (Years)
Non-I/M
I/M

I/M Modeling Parameters

- Normal Emitters (Tier0)

  - Generated from EPA / AAMA FTP Dataset
  - Vehicles less than 2x standards for HC & NOx; 3x for CO
  - Analysis - Linear regression of the data versus mileage

- High Emitters (Tier0)

  - Generated from EPA / AAMA FTP Dataset
  - Vehicles greater than 2x standards for HC & NOx; 3x for CO
  - Mean emission value used (no regression)
  - Fraction of highs in the fleet

- After repair level (Tier0 and Tier1 Non OBD) – generated from Arizona IM240 test lane data

- Waivers – Assumed 20 percent emission reduction from repairs

I/M Identification Rates

- IM240 Testing

  HC & CO General Equation:
  $$IDR = A + B*\ln(HCCut) + C*\ln(COCut)$$

  NOx General Equation:
  $$IDR = A + B*NOCut + C*NOCut^2 + D*NOCut^3$$

- IM240 Testing – IDR approximately = 0.8 for final cutpoints

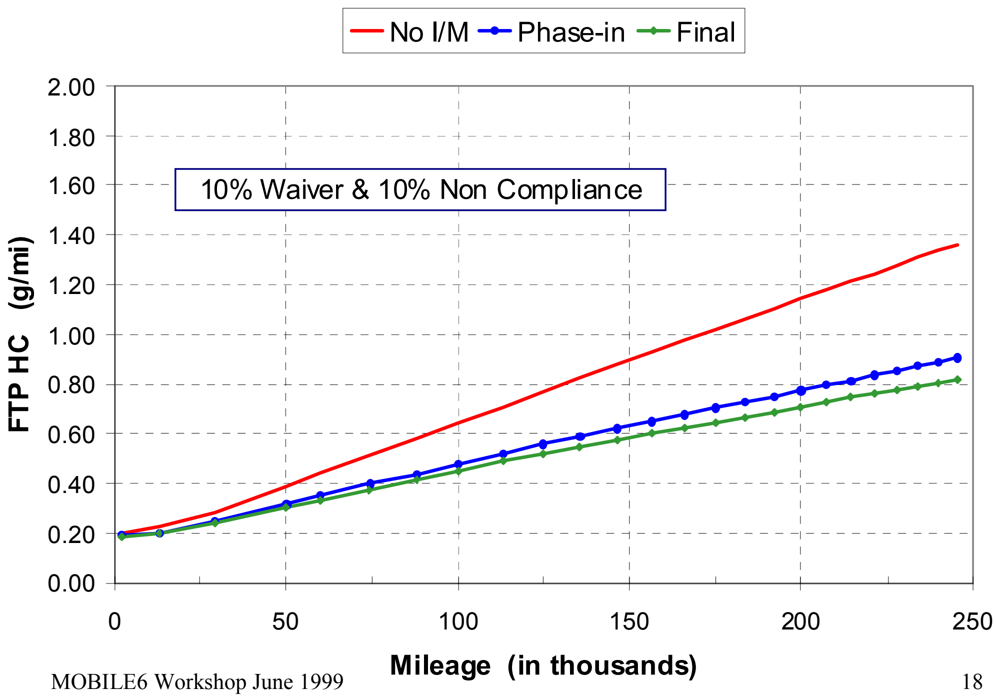
- ASM Testing – IDR = function(IM240 IDR); based on MOBILE5

- Idle Testing – IDRs are based on FTP and IDLE test dataset

OBD Assumptions

- OBD II equipped vehicles are treated in I/M by assuming:
  - 85% of high emitters are identified;
  - 90% of them are repaired (i.e., motorist response to MIL illumination); and
  - after-repair level is equivalent to normal-emitter level, capped at 1.5 times the certification standard
- Motorist response to MIL illumination outside of I/M:
  - Under 36,000 miles: 90%
  - Between 36,000 and 80,000 miles: 10%
  - Over 80,000 miles: 0%

I/M and No I/M FTP **HC** Emission Levels - 1988-93 PFI Cars



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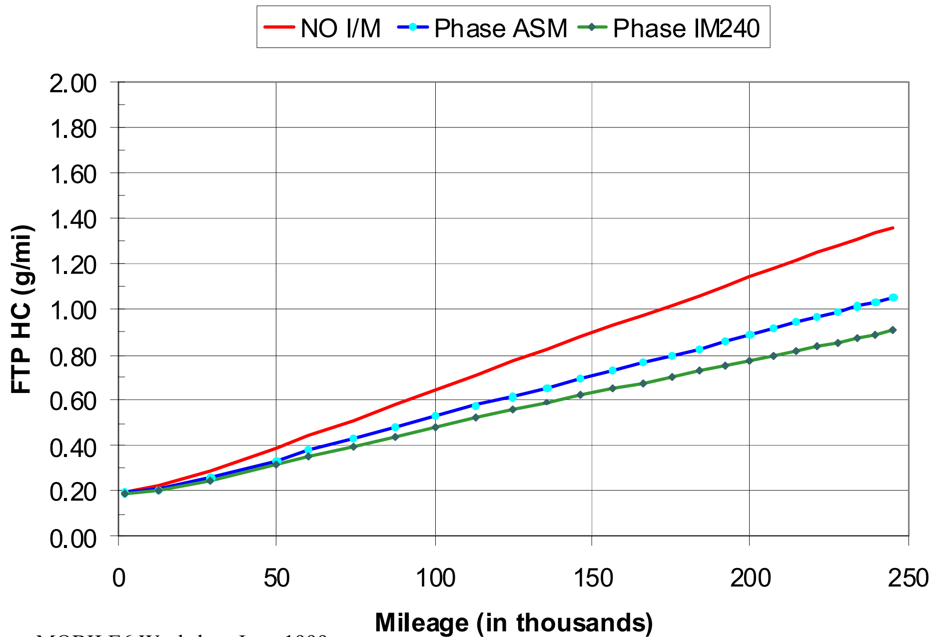
Phase-in IM240 versus Phase-in ASM2525
for 1988-93 PFI **HC** Emissions



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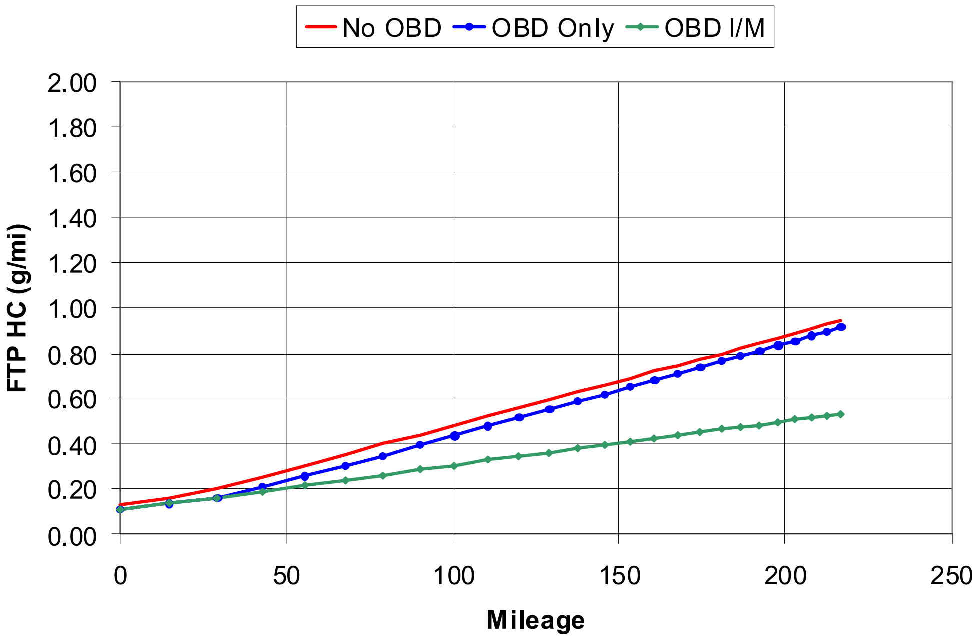
FTP **HC** Emission Effect of OBD and OBD I/M on **Tier1** Cars



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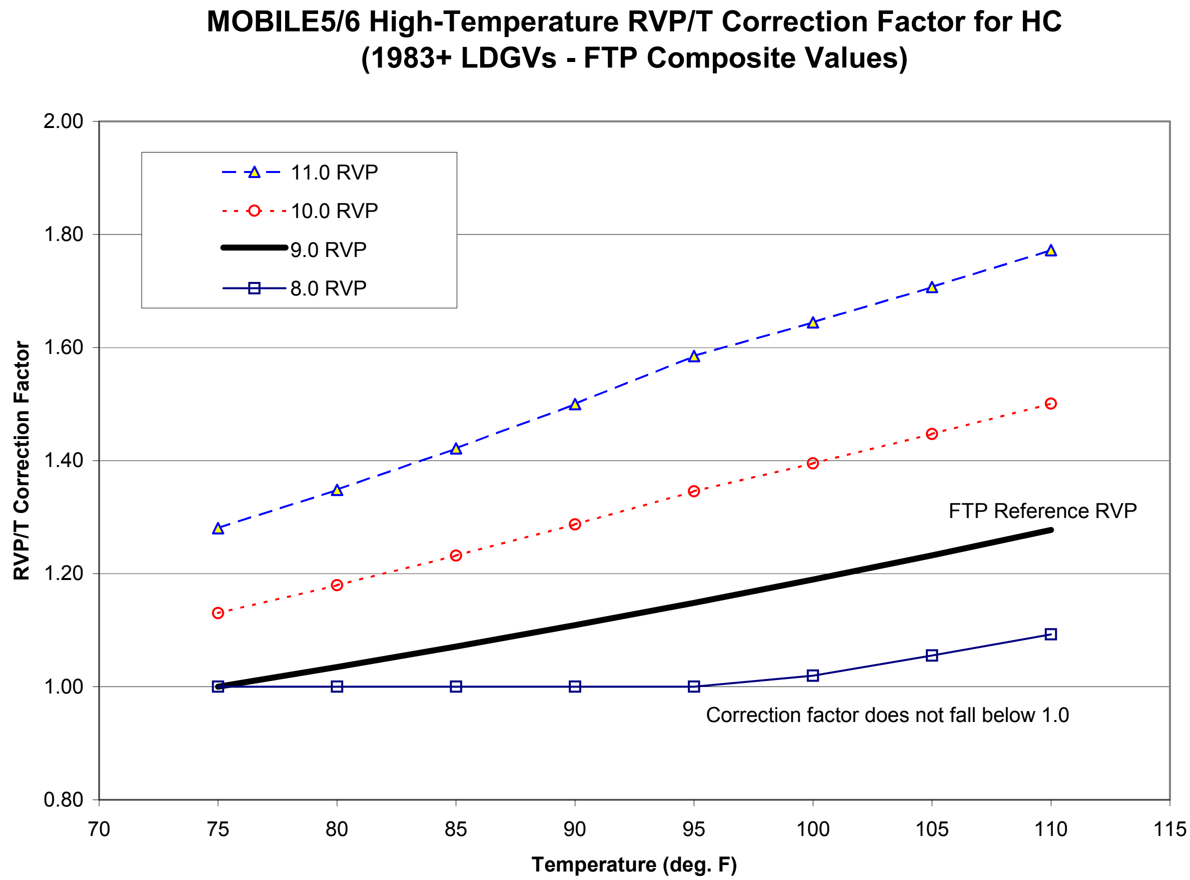
CORRECTIONS TO EXHAUST EMISSIONS ESTIMATES

Corrections to Exhaust Emission Rates

- Fuel Corrections
  - RVP corrections
  - Oxygenates
  - Sulfur
  - RFG
- Speed/cycle corrections
- Air conditioning effects

MOBILE6 Exhaust RVP Corrections

- Gasoline volatility primarily impacts exhaust emissions as a result of vapor storage and purge
- Higher RVP results in greater evaporative emissions stored in the canister and therefore a larger impact from purge
- New vehicles, however, have much more sophisticated purge strategies as a result of very tight tailpipe standards
- For MOBILE6, the RVP/temperature correction factors are the essentially same as MOBILE5 except that modifications were made to convert bag-specific factors into running and starting correction factors


MOBILE5/6 High-Temperature RVP/T Correction Factor for HC
(1983+ LDGVs - FTP Composite Values)
11.0 RVP
10.0 RVP
9.0 RVP
8.0 RVP
FTP Reference RVP
Correction factor does not fall below 1.0
RVP/T Correction Factor
Temperature (deg. F)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
70
75
80
85
90
95
100
105
110
115

MOBILE6 Fuel Corrections
Gasoline Sulfur Level

- Modern gasoline-fueled vehicles use catalysts to reduce HC, CO, and NOx emissions

- Sulfur acts as a catalyst poison; increased sulfur levels in fuels increase emissions through catalyst deactivation

- MOBILE6 includes specific accounting for gasoline sulfur content

- The impact of sulfur on exhaust emissions is more severe (on a percentage basis) for more advanced technology vehicles

- Equations relating fuel sulfur to emissions were based on an extensive body of test data

- Separate regression equations were developed by:

  - Pollutant
  - Emitter class
  - Vehicle technology (Tier 0, Tier 1, LEV/Tier 2)
  - Emission mode (composite, running, start)

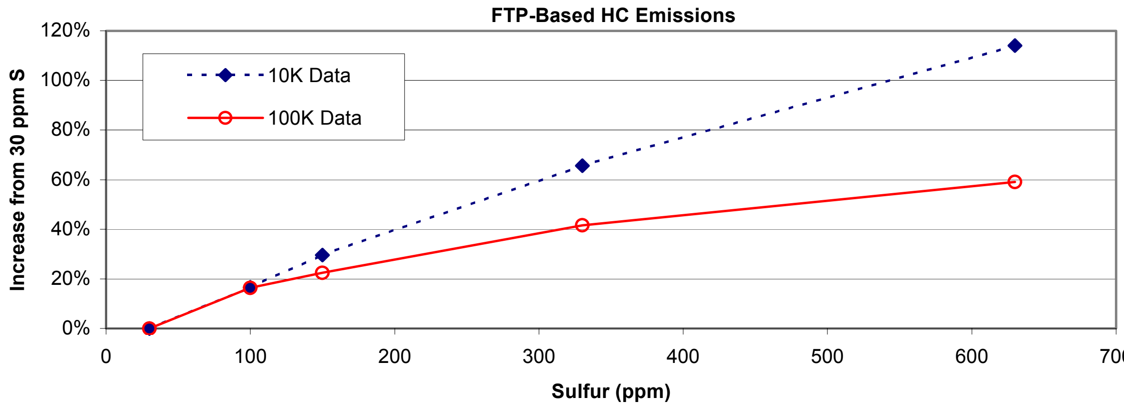
Data Used for Draft MOBILE6 Sulfur Impacts

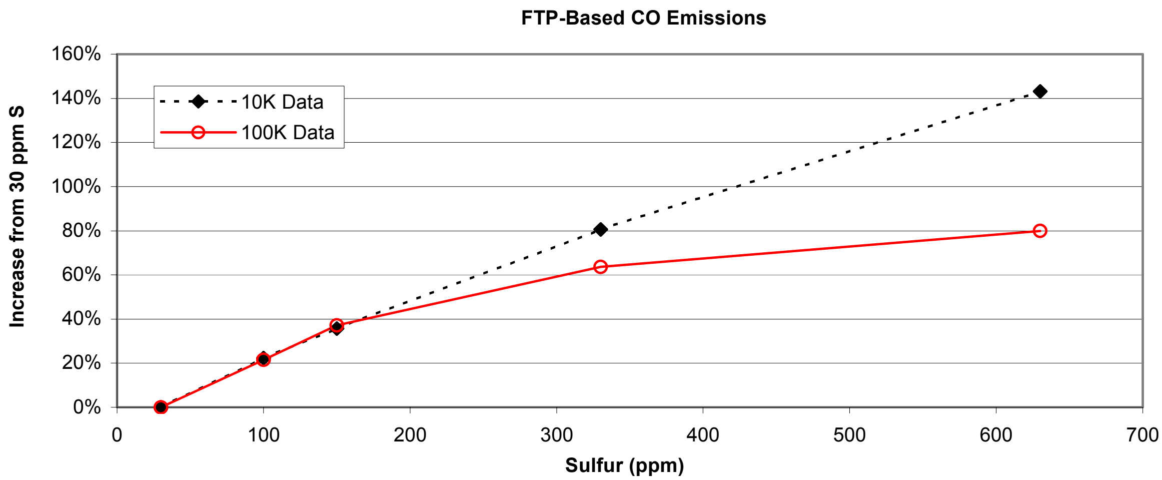
- The draft sulfur corrections that EPA developed initially (i.e., in the mid-1999 timeframe) were based on the following data sets:

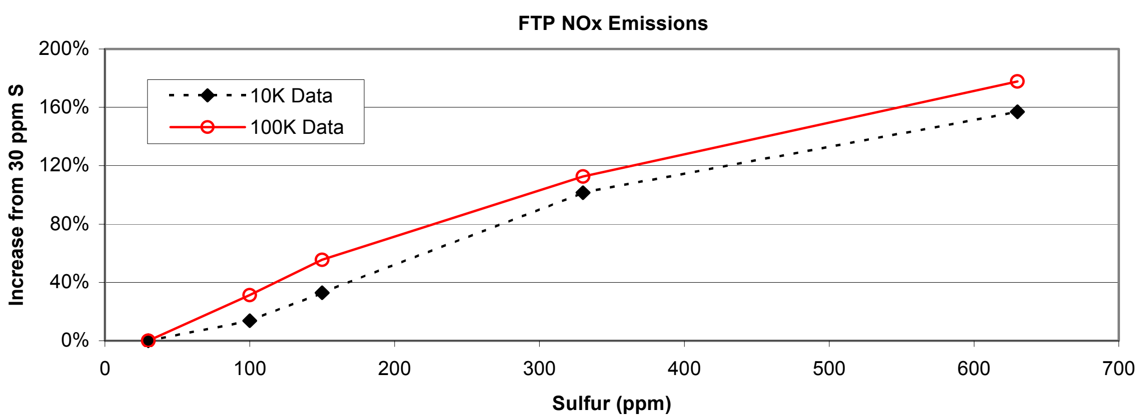
Study	# of Vehicles	Vehicle Technlgy	Range of S tested	Normal Emitters	High Emitters
A/O-Phase I Sulfur	**10**	**Tier 0**	**49-->466 (2 levels)**	**10**	**0**
A/O-Phase II Sulfur	**10**	**Tier 0**	**49-->466 (5 levels)**	**10**	**0**
A/O-T50/T90/Sul	**16**	**Tier 0, Tier 1**	**33-->318 (2 levels)**	**10 Tier 0 6 Tier 1**	**0**
EPA - ATL I	**39**	**Tier 0**	**112->371 (2 levels)**	**20**	**19**
EPA - ATL II	**39**	**Tier 0**	**59->327 (2 levels)**	**24**	**15**
CRC	**12**	**LEV**	**40->600 (5 levels)**	**12**	**0**
AAMA/AIAM	**21**	**LEV,ULEV, Trucks**	**40->600 (5 levels)**	**21**	**0**
API Extension	**1**	**LEV**	**40->540 (2 levels)**	**1**	**0**

- Prior to finalization of the Tier 2 rule, additional data were collected and used to estimate sulfur impacts, particularly with respect to reversibility effects

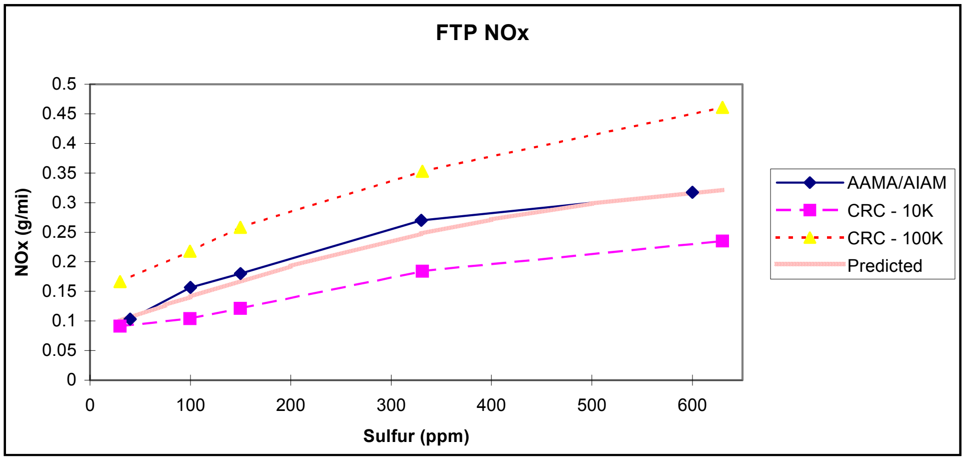
Comparison of 10K and 100K CRC Data
Percentage Increase from 30 ppm Sulfur

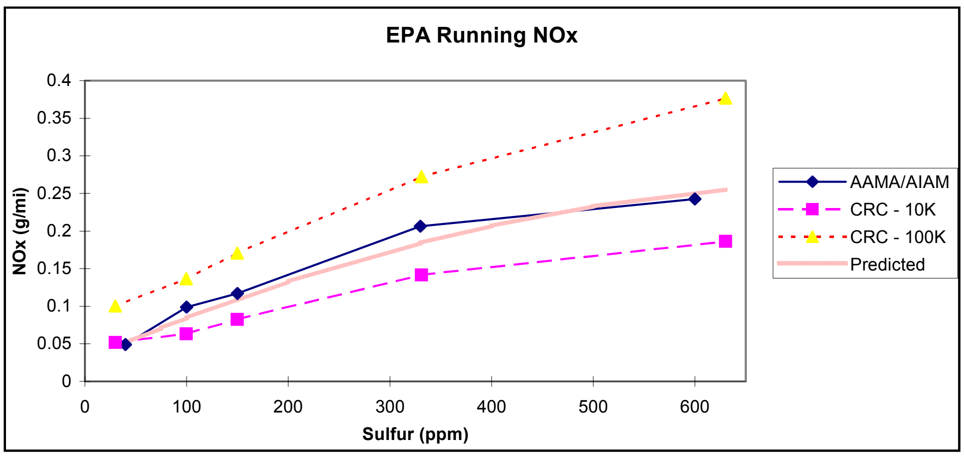


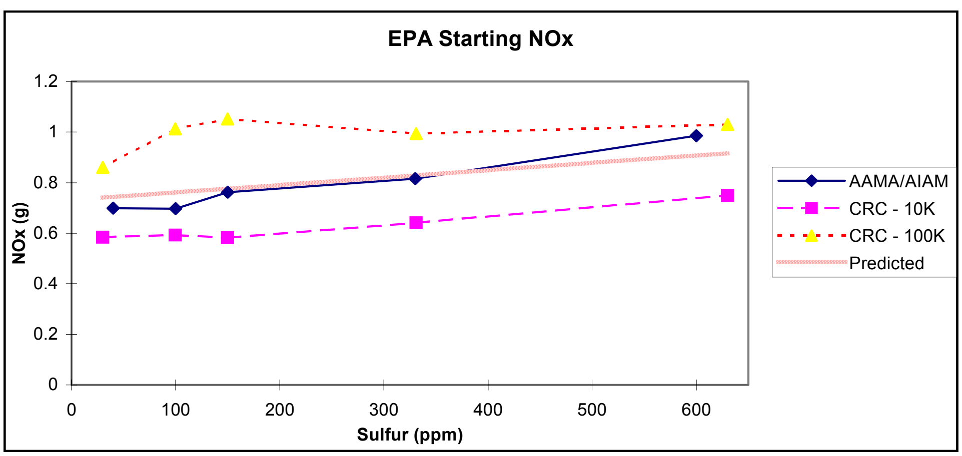




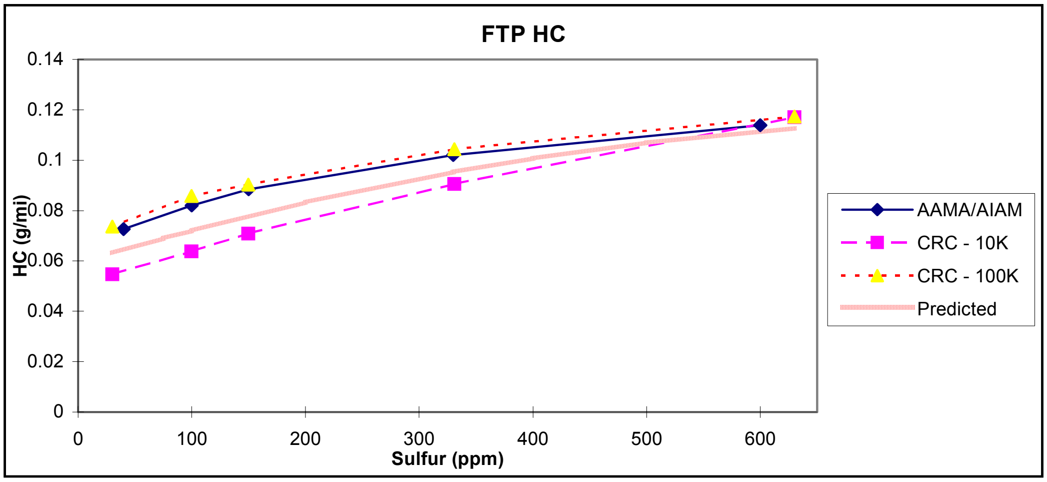
Fleet-Average NOx Emission Rates from the CRC and AAMA/AIAM Sulfur/LEV Studies (PC/LDT1 LEVs Only)

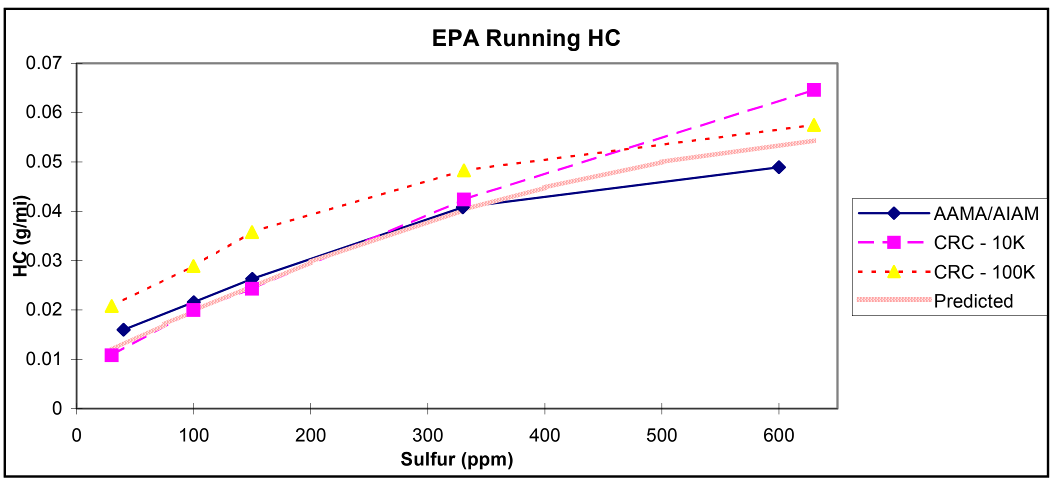


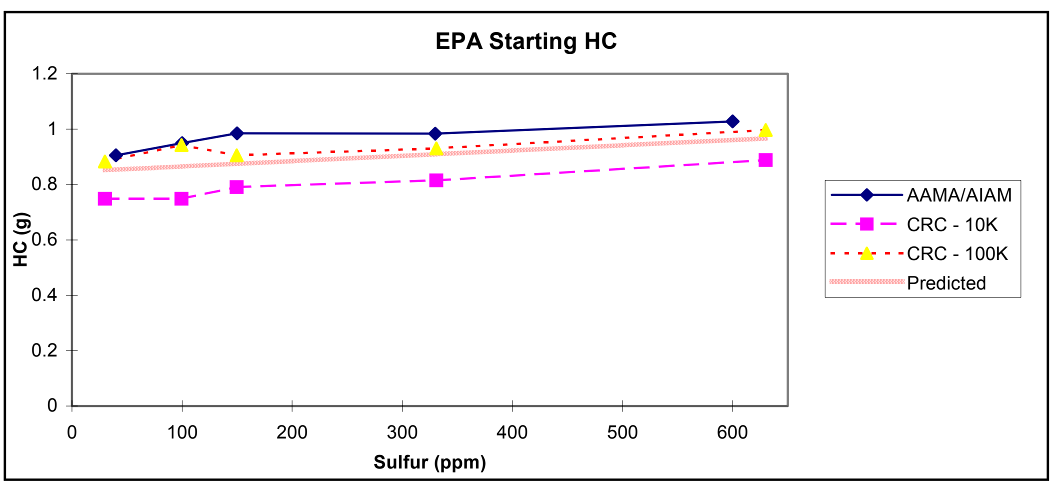




Fleet-Average HC Emission Rates from the CRC and AAMA/AIAM Sulfur/LEV Studies (PC/LDT1 LEVs Only)







Emissions Impacts from Varying Sulfur Levels in Gasoline
(Draft MOBILE6 Estimates -- FTP Basis)

Vehicle Category	Pollutant	% Increase when Sulfur is Increased from 30 ppm to:			
		75	150	330	600
Tier 0 Normals	HC	5.8	10.4	15.8	20.1
	CO	7.2	13.0	20.0	25.6
	NOx	2.9	5.1	7.7	9.7
Tier 1 Normals	HC	3.7	10.1	27.3	34.8
	CO	2.9	7.9	20.8	26.6
	NOx	1.4	3.9	10.0	12.6
LEV and ULEV Normals	HC	16.7	31.1	49.8	65.6
	CO	24.3	46.5	76.7	103.6
	NOx	38.3	76.8	133.6	188.7
High Emitters	HC	0.2	0.5	1.1	2.2
	CO	0.0	0.1	0.2	0.4
	NOx	1.4	3.7	9.6	19.0

MOBILE6 Fuel Corrections
Reformulated Gasoline
Default Summer Assumptions

Reformulated Gasoline Parameters—Summer						
Year	RVP (pounds per square inch, or psi)		Oxygenated Fuels		Sulfur Content (ppm)	
	North	South	Ether Oxygen Content (% by weight)	Ether Market Share (%)	Average	Max
1995-1999	8.0	7.1	2.1	100	300	N/A
2000	6.7	6.7	2.1	100	150	1000
2001	6.7	6.7	2.1	100	149	1000
2002	6.7	6.7	2.1	100	129	1000
2003	6.8	6.8	2.1	100	120	1000
2004	6.8	6.8	2.1	100	120	303
2005	6.8	6.8	2.1	100	90	303
2006	6.8	6.8	2.1	100	30	87
2007	6.8	6.8	2.1	100	30	87
2008	6.8	6.8	2.1	100	30	80

MOBILE6 Fuel Corrections

Reformulated Gasoline
Default Winter Assumptions

Reformulated Gasoline Parameters—Winter (1)							
Year (2)	RVP (psi)	Oxygenated Fuels (3)				Sulfur Content (ppm) (4)	
	North or South	Ether Oxygen Content (% by weight)	Ether Market Share (%)	Ethanol Oxygen Content (% by weight)	Ethanol Market Share	Average	Max
1995-1999	as set by user	1.5	70	3.5	30	300 (5)	N/A
2000		1.5	70	3.5	30	300	1000
2001		1.5	70	3.5	30	299	1000
2002		1.5	70	3.5	30	279	1000
2003		1.5	70	3.5	30	259	1000
2004		1.5	70	3.5	30	121	303
2005		1.5	70	3.5	30	92	303
2006		1.5	70	3.5	30	33	87
2007		1.5	70	3.5	30	33	87
2008		1.5	70	3.5	30	30	80

Notes for Reformulated Gasoline Parameter tables:

Speed/Cycle Corrections

- Four roadway types are modeled:

  - Freeway (function of speed)
  - Ramp (single speed)
  - Arterial (function of speed)
  - Local (single speed)

- Test cycles used for developing SCFs and corresponding **average speed**:

  - FWY High Speed.................. 63.2 mph
  - FWY, LOS A-C..................... 59.7 mph
  - FWY, LOS D......................... 52.9 mph
  - FWY, LOS E......................... 30.5 mph
  - FWY, LOS F......................... 18.6 mph
  - FWY, LOS "G"..................... 13.1 mph
  - FWY, Ramp.......................... 34.6 mph
  - ART, LOS A-B..................... 24.8 mph
  - ART, LOS C-D..................... 19.2 mph
  - ART, LOS E-F...................... 11.6 mph
  - Local Roadways.................... 12.9 mph

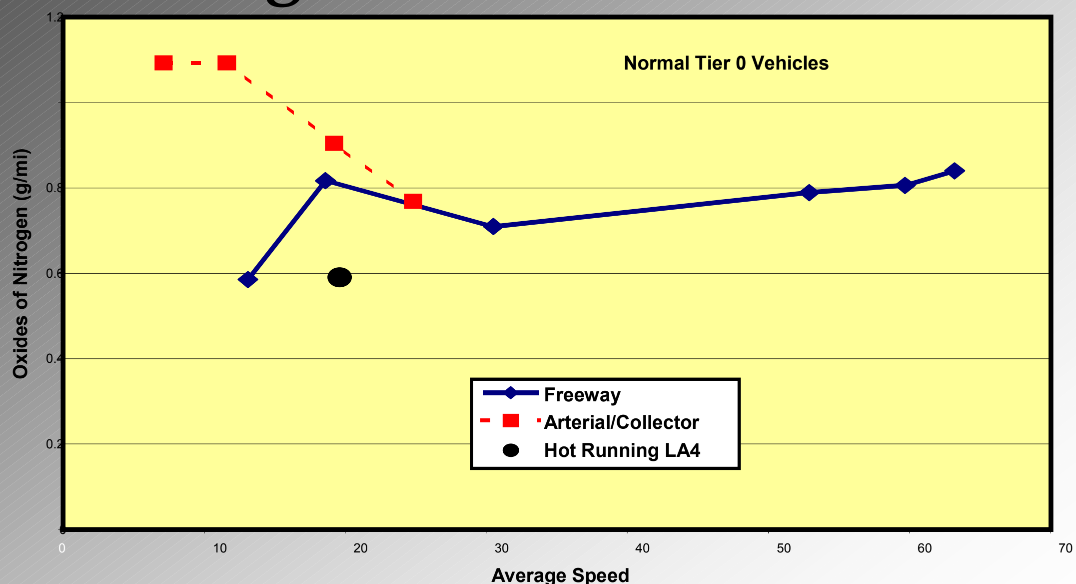
- SCFs were developed as a function of emission level, with lower-emitting vehicles typically being more sensitive to speed

- Arterial and freeway SCFs converge above 30 mph and below 7.1 mph

SCF Emission Test Data

- 85 recent model year passenger cars and light-duty trucks
- Tests included the FTP
- Test order was randomly varied
- For analysis, the sample was segregated by:
  - Emission standards (Tier 0 vs. Tier 1)
  - Emission level (high vs. normal) for Tier 0 vehicles
- Resulted in three emission levels

Example of Raw Data Averages



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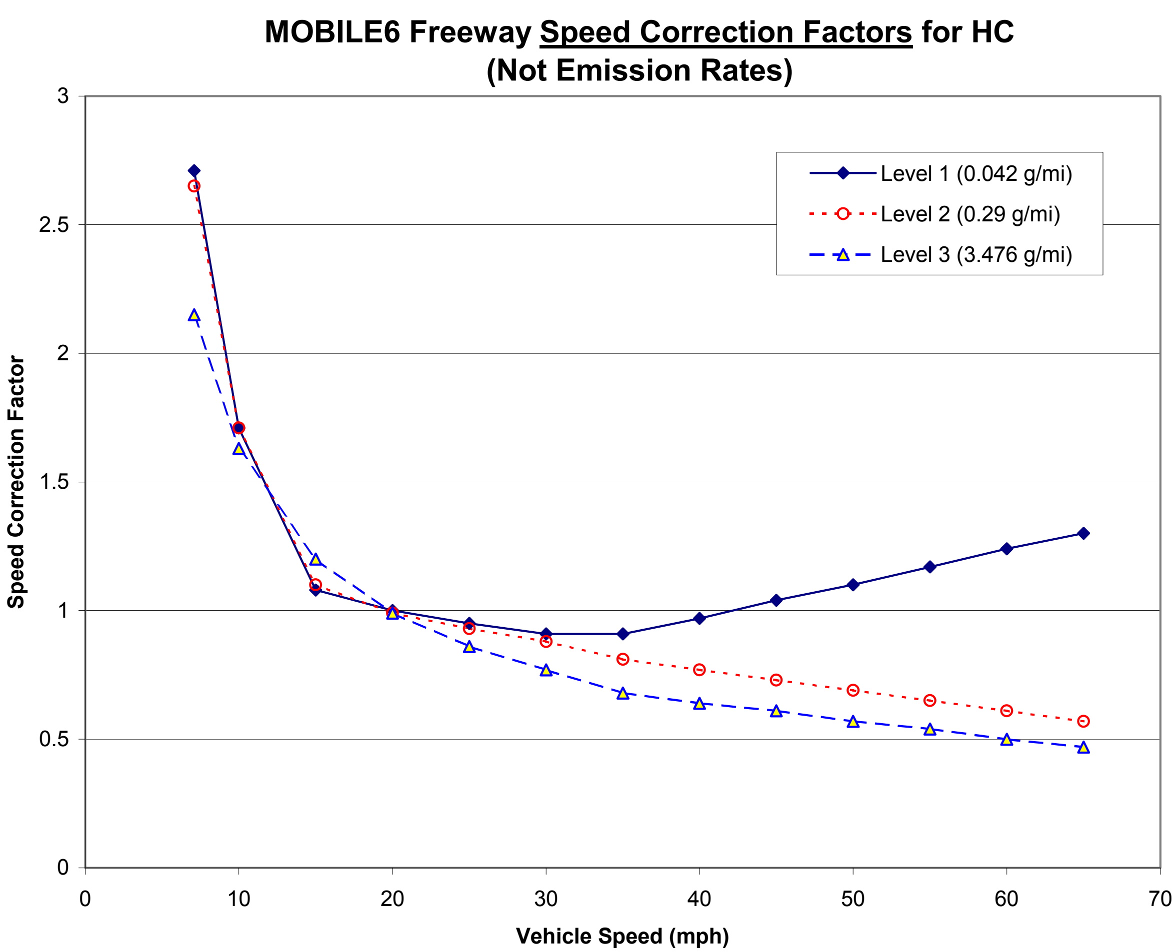
MOBILE6 Workshop June 1999

Calculation of Speed Correction Factors

$$SCF_{speed} = \frac{\text{Freeway Emissions}_{speed}}{\text{Freeway Emissions}_{19.6\ mph}}$$



Adjustment of the Basic Emission Rate

- Calculate the basic running exhaust emission rate (i.e., the running LA4 at 19.6 mph)

- Calculate the freeway emission rate at 19.6 mph

  - Requires addition of an offset (i.e., the off-cycle effect)

  - The offset is a function of pollutant and emission level

- Multiply adjusted freeway emission rate by the appropriate SCF

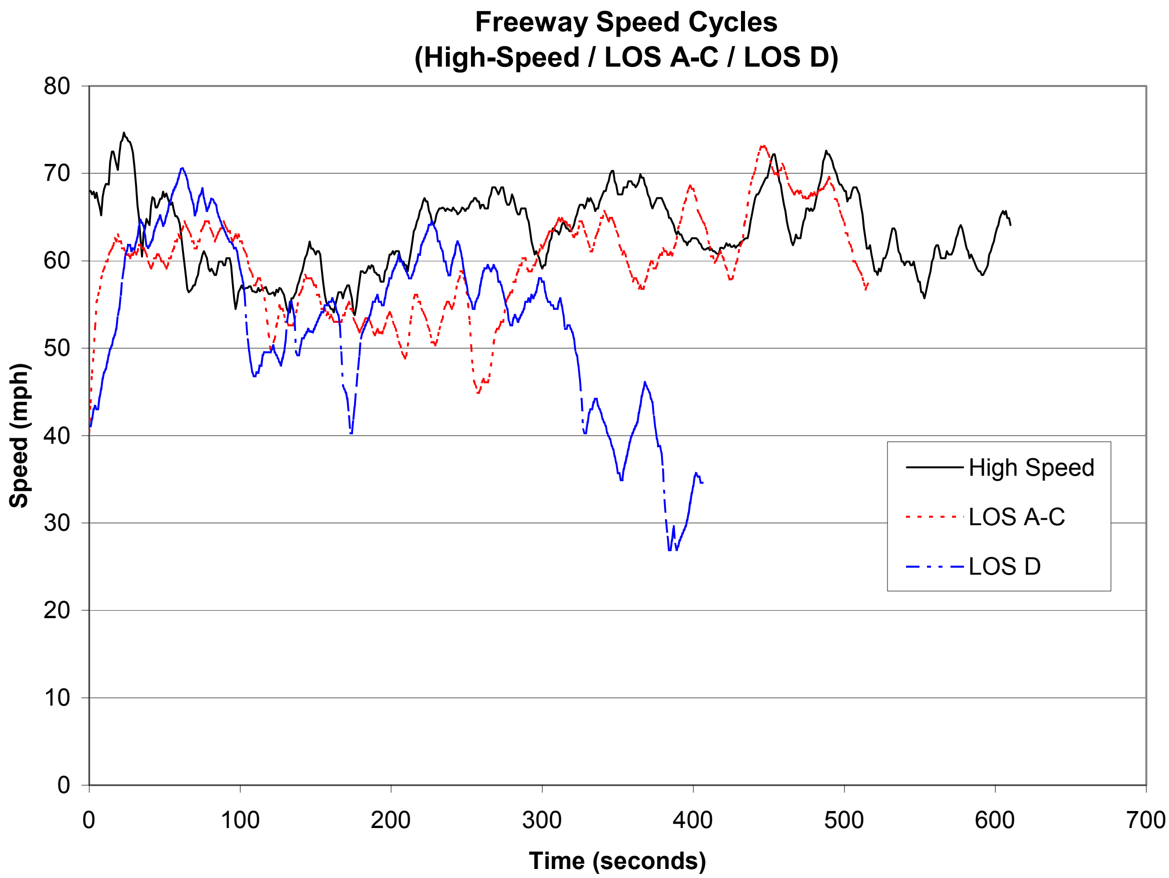
- Arterials get an additional offset that is a function of vehicle speed and emissions

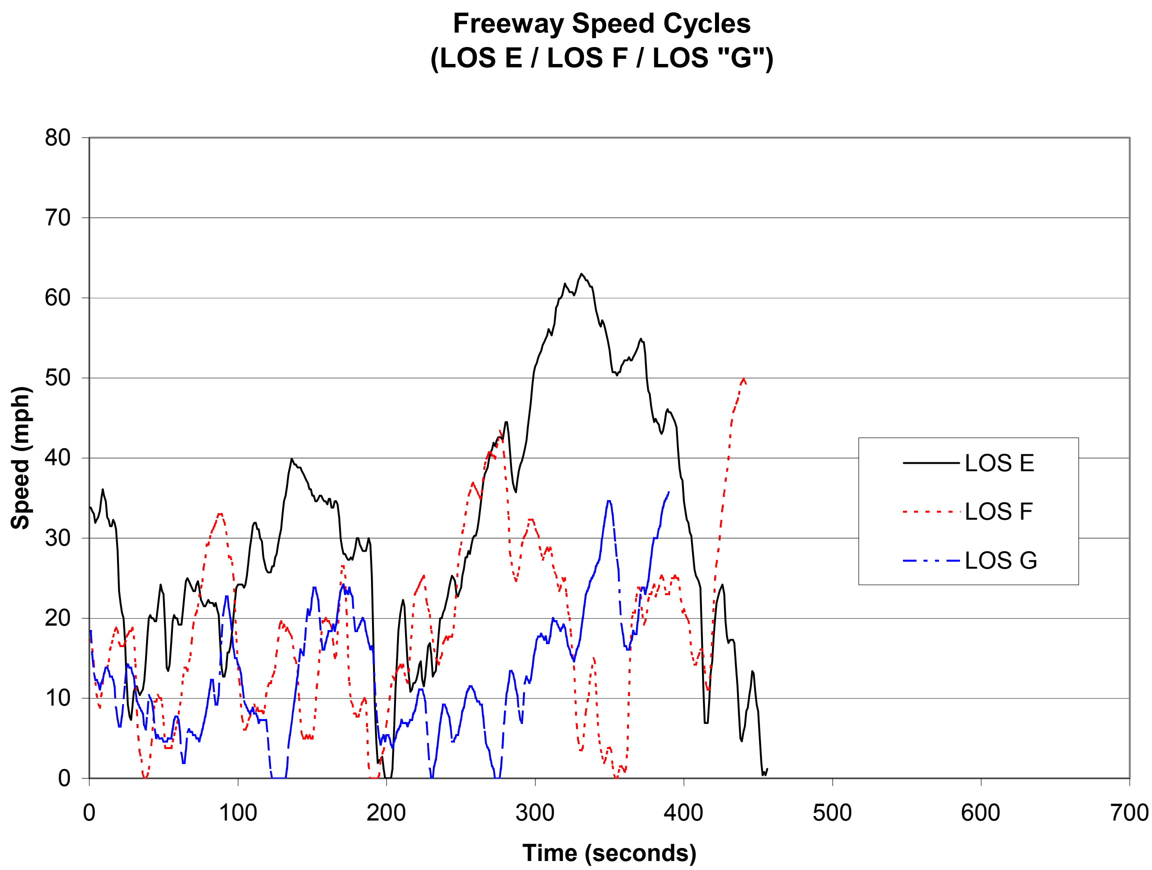
- Overall:

  Adjusted BER = (BER + EO) * SCF + AEO

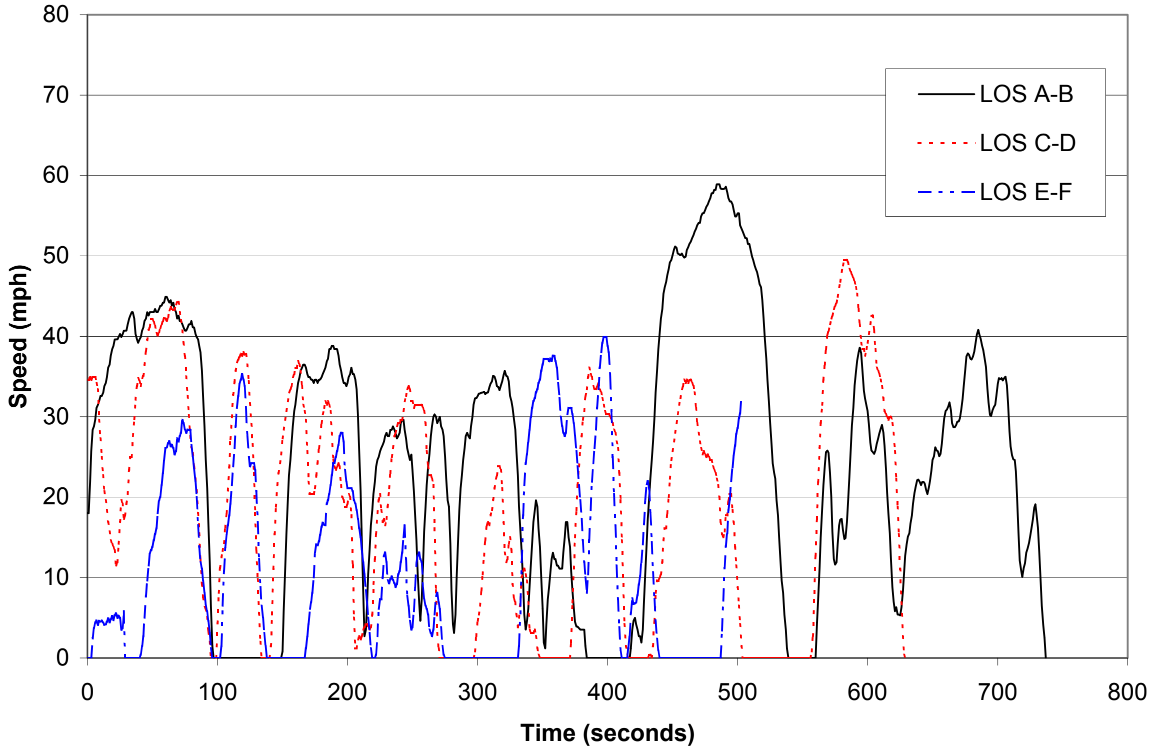
Summary of Speed Correction Factors

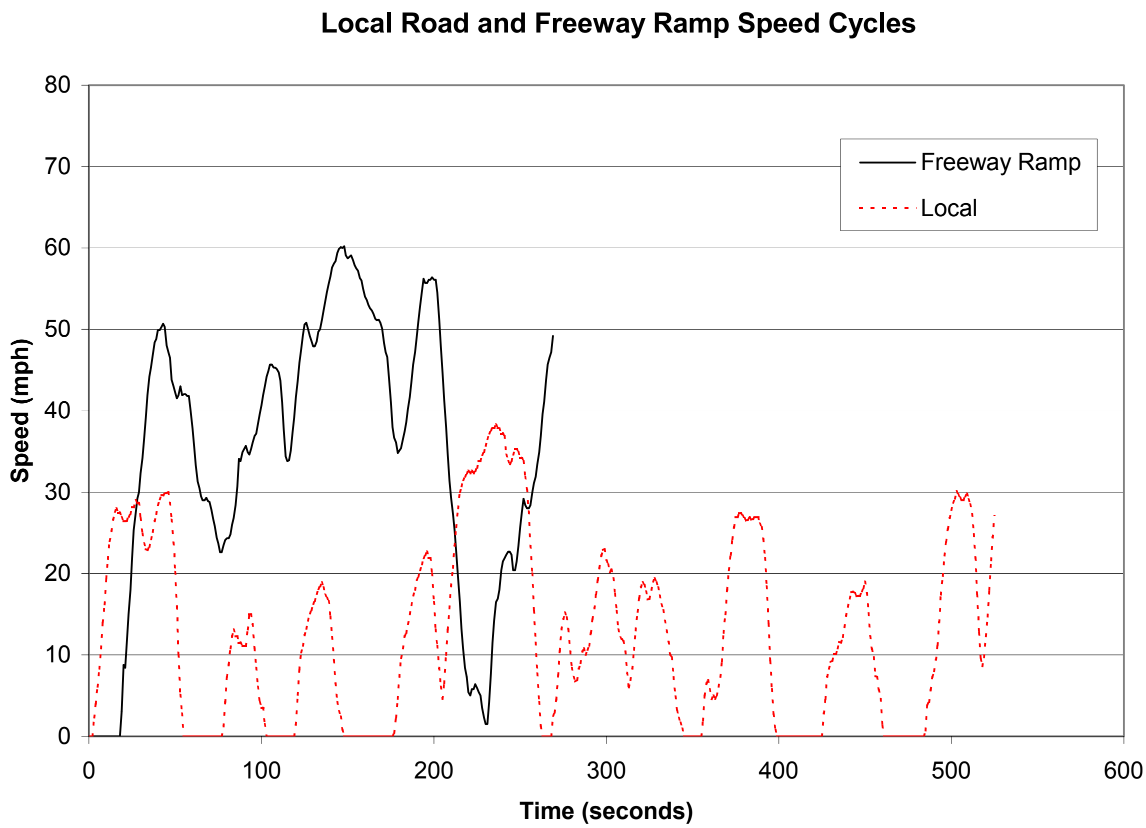
- SCFs were developed for normal and high emitting Tier 0 vehicles and for normal emitting Tier 1 vehicles
- Tier 0 SCFs were used for pre-1981 MY light-duty vehicles
- Tier 0 SCFs used for high-emitting Tier 1 vehicles
- Adjusted Tier 1 SCFs used for LEVs


Freeway Speed Cycles
(High-Speed / LOS A-C / LOS D)
80
70
60
50
40
30
20
10
0
Speed (mph)
0
100
200
300
400
500
600
700
Time (seconds)
High Speed
LOS A-C
LOS D


Freeway Speed Cycles
(LOS E / LOS F / LOS "G")
Speed (mph)
Time (seconds)
LOS E
LOS F
LOS G
0
10
20
30
40
50
60
70
80
100
200
300
400
500
600
700

Arterial/Collector Speed Cycles



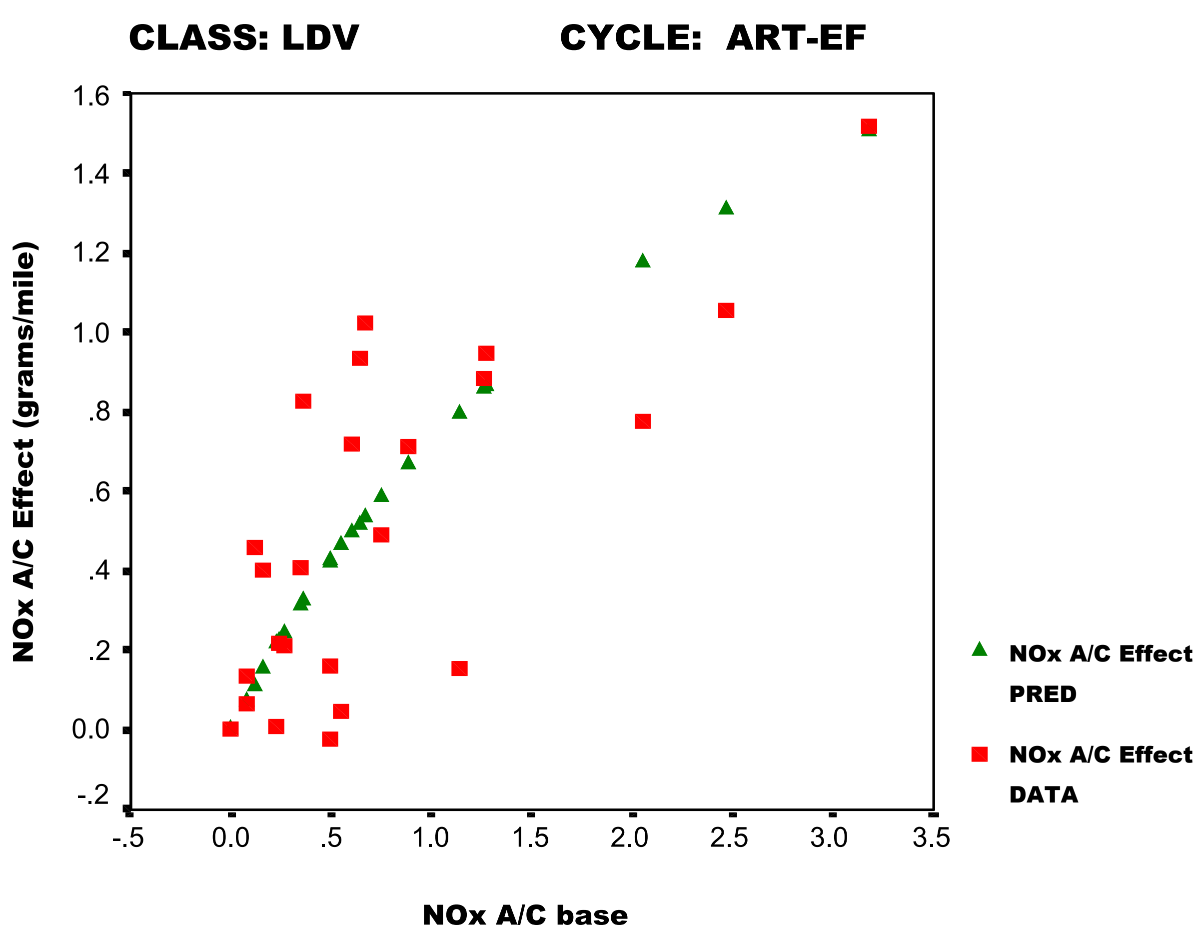

Local Road and Freeway Ramp Speed Cycles
Freeway Ramp
Local
Speed (mph)
Time (seconds)
0
10
20
30
40
50
60
70
80
0
100
200
300
400
500
600

Air Conditioning Effects

- Although MOBILE5 contained a user option to include A/C effects, the data and algorithms were outdated
- Based on data collected during the development of the SFTP, the A/C adjustment was significantly revised for MOBILE6
- In MOBILE6, a "full-usage" A/C adjustment factor is developed first, which is then scaled by:
  - A/C demand factor (based on temperature and humidity)
  - Fraction of functioning A/C systems
- Based on modeling prepared for the Tier 2 rule, the air conditioning demand factor is 0.68 for a typical ozone season day
- Depending on pollutant, the full-usage A/C adjustment factor is a function of speed, vehicle class, and/or emitter category

Air Conditioning Effects
Test Data

- 38 vehicles tested at EPA, ATL
- "EPA Simulation" – 95°F, driver window down
- Represents emission levels under full A/C system loading ("Full Usage")



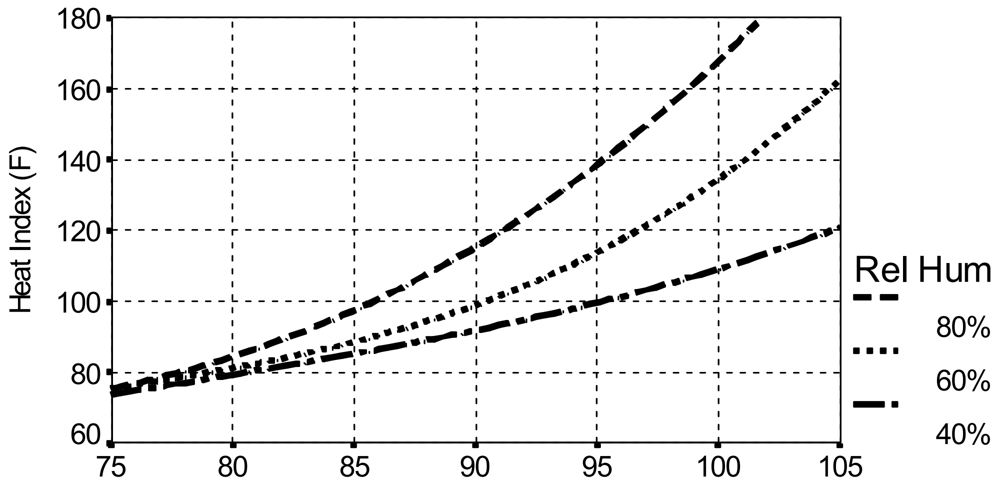
Results

- NOx
  - Separate factors for LDVs vs. LDTs
  - Function of speed and base emission rate
- HC
  - Vehicle class not significant
  - Emitter classes are significant
- CO
  - Separate factors for LDVs vs. LDTs
  - Emitter classes are significant

Air Conditioning Activity

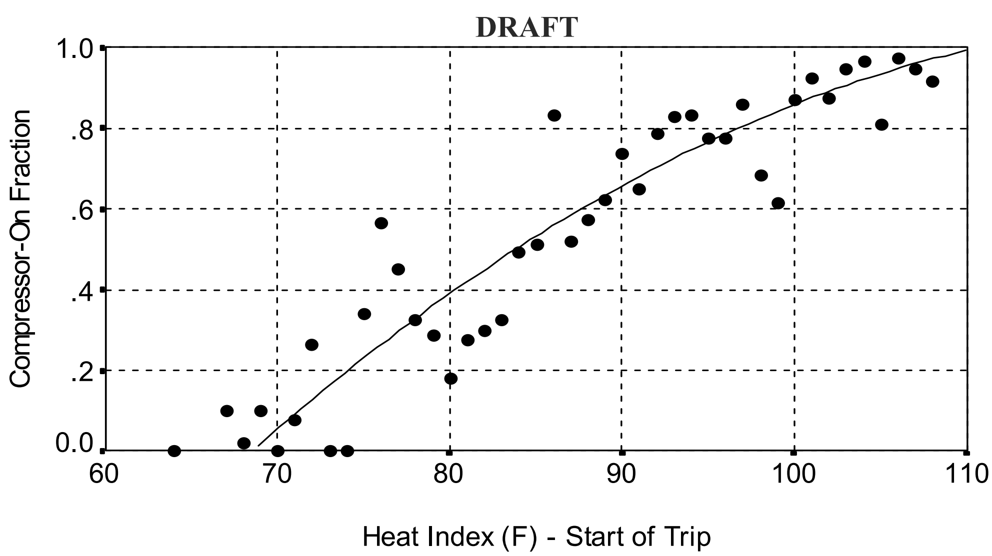
- Account for in-use conditions
- Demand factor- Scales back full usage emissions based on temperature and humidity
- Demand factor = Fraction of time A/C compressor is engaged at given temperature and humidity (full usage = compressor engaged 100% of time)
- Compressor-on fraction is a function of heat index

Heat Index



Note: Heat Index values based on shady conditions

Compressor-On vs. Heat Index



Non-idle trips (weighted by number of trips)

Air Conditioning Activity
(Continued)

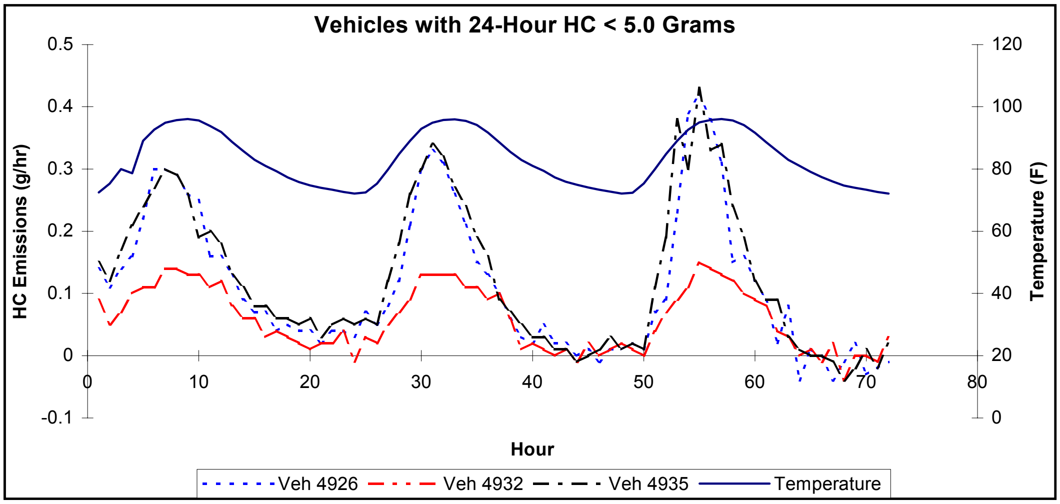
- Also impacted by
  - Solar load
  - Cloud cover
  - Market penetration
  - Unrepaired A/C malfunctions

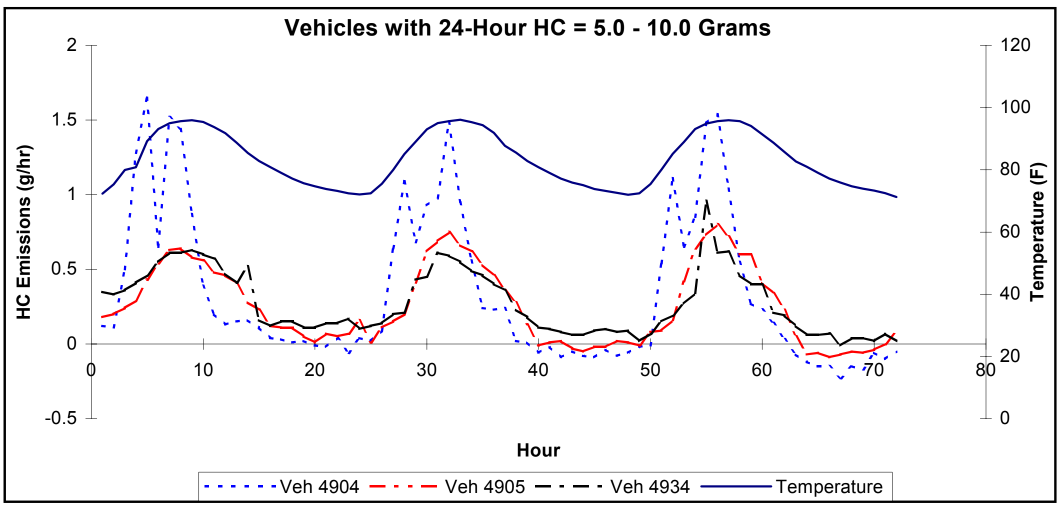
EVAPORATIVE EMISSIONS MODELING

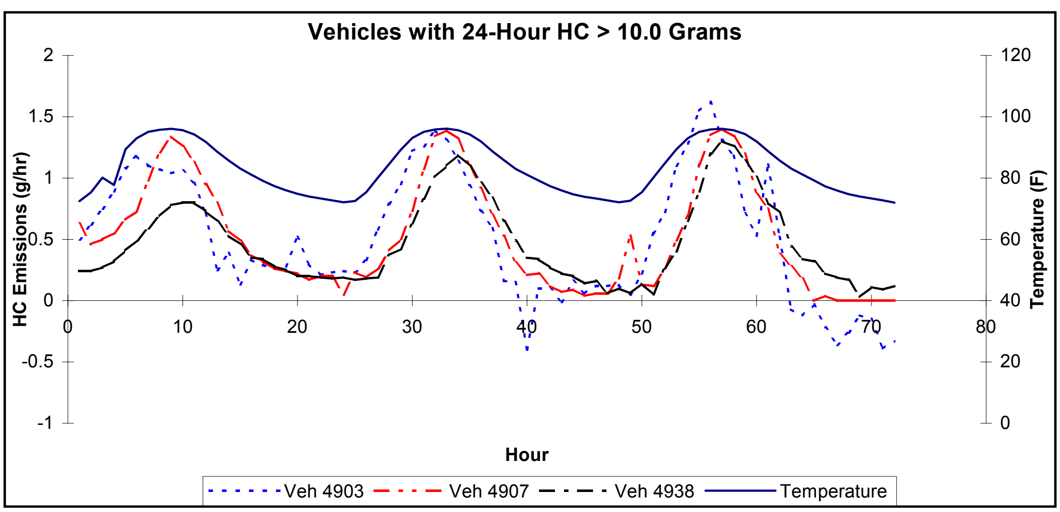
Evaporative/Non-Exhaust Emissions

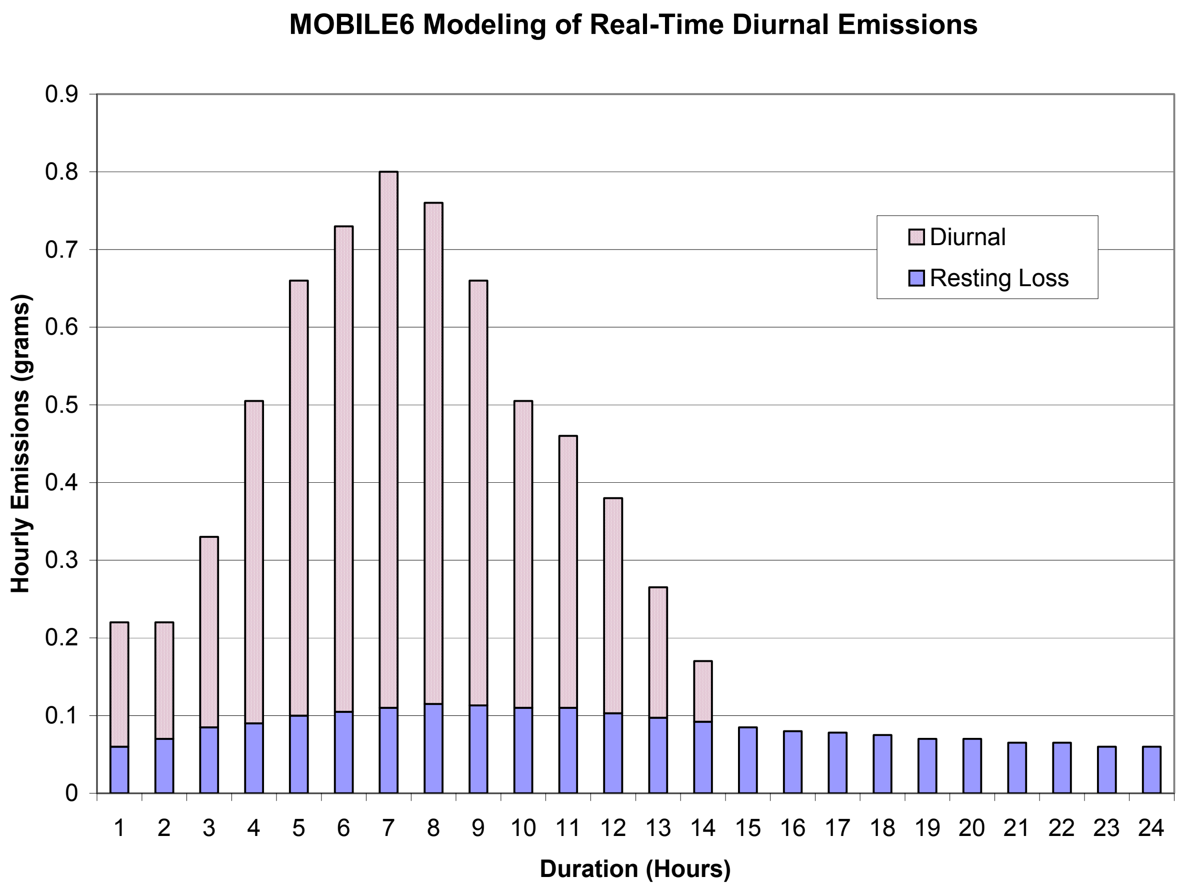
- Diurnal breathing losses occur as the fuel tank heats up during the day.
- Resting losses result from vapor permeation and liquid leaks through various parts of the evaporative control system.
- Hot Soak losses occur after the vehicle has been turned off and result from evaporation of fuel in the engine and fuel delivery system.
- Running evaporative losses occur as the vehicle is being operated over the road.
- Refueling losses are a result of vapor space displacement and spillage.
- Crankcase losses are primarily the result of defective PCV systems.

Baseline Hourly Diurnal Emissions for Vehicles in the IM92 Program
(6.7 psi RVP Fuel - 72° to 96° F Temperature Profile)








MOBILE6 Modeling of Real-Time Diurnal Emissions
Hourly Emissions (grams)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Duration (Hours)
Diurnal
Resting Loss

Modeling Evaporative Emissions

- Evaporative emissions are modeled by segregating the fleet by fuel delivery technology and by pressure/purge (P/P) passing and failing vehicles.

- In addition, MOBILE6 includes another emissions category for evap – Gross Liquid Leaker (GLL).

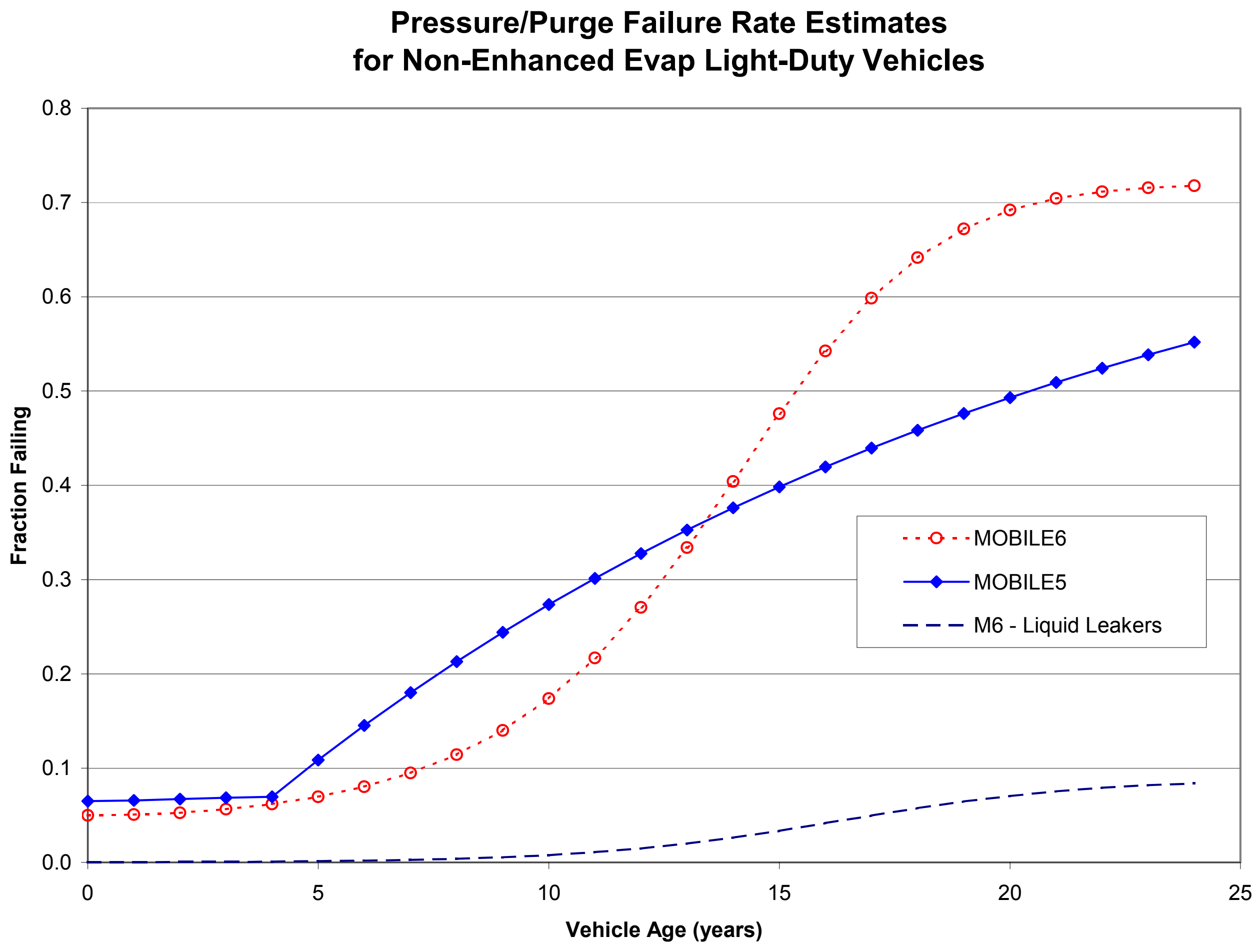
- Composite emission rate (by vehicle age) is determined by applying the fraction of passing and failing vehicles to the emission rates of passing and failing vehicles.

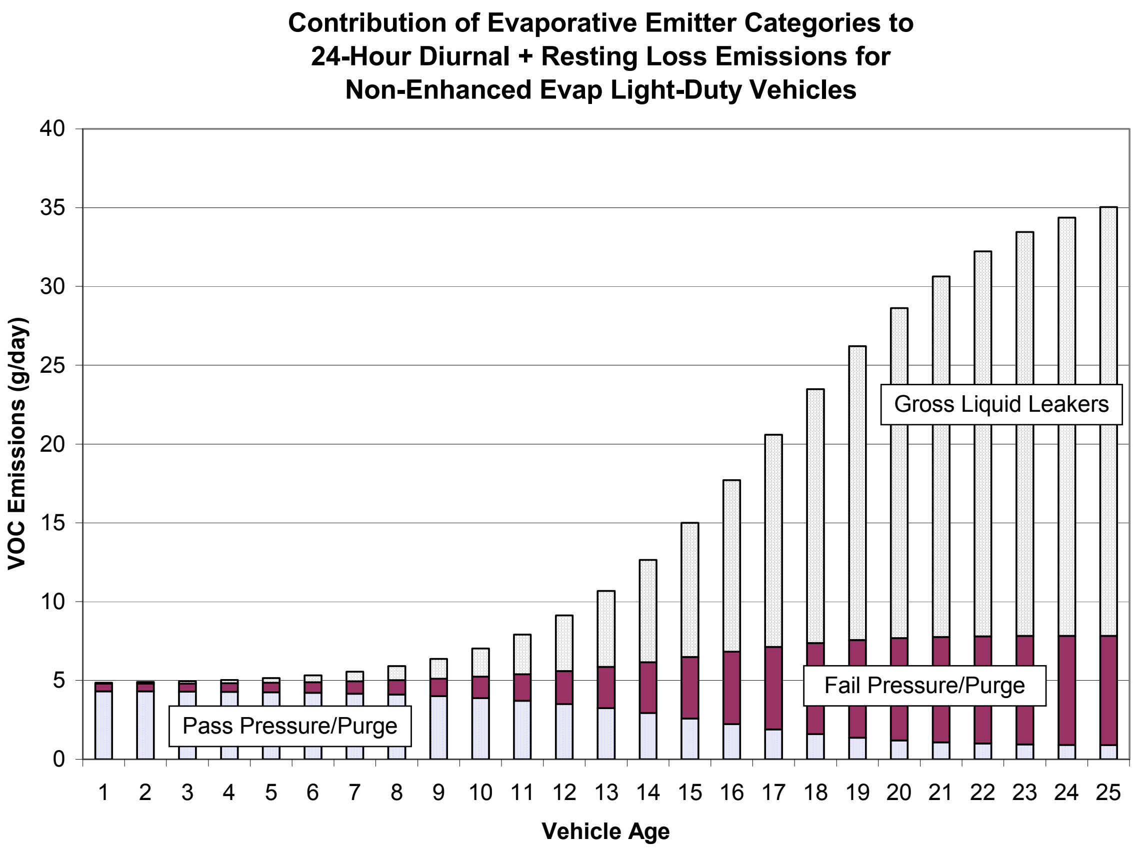
- MOBILE5 example – full-day diurnal rates from a 5-year old 1990 MY vehicle:

  - passing vehicle - 1.47 g/day
  - fail purge - 7.40 g/day
  - fail pressure - 14.28 g/day

  DI = 1.47*0.891 + 7.40*0.039 + 14.28*0.070
  = 2.60 g/day

- Emissions deterioration results from an increase in P/P failing vehicles as the fleet ages.


Pressure/Purge Failure Rate Estimates
for Non-Enhanced Evap Light-Duty Vehicles
Fraction Failing
Vehicle Age (years)
MOBILE6
MOBILE5
M6 - Liquid Leakers
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0
5
10
15
20
25



Contribution of Evaporative Emitter Categories to
24-Hour Diurnal + Resting Loss Emissions for
Non-Enhanced Evap Light-Duty Vehicles
VOC Emissions (g/day)
0
5
10
15
20
25
30
35
40
Vehicle Age
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Gross Liquid Leakers
Fail Pressure/Purge
Pass Pressure/Purge

Modeling Evaporative Emissions (Continued)

- Evaporative emissions estimates are adjusted to account for local RVP and ambient temperature.

- MOBILE5 corrects hot soaks for the fraction that run to completion; MOBILE6 includes a distribution of soak times and different HS emission estimates depending on soak time.

- Running losses are also corrected for speed and trip length – longer trips have more fuel heating and higher running losses; MOBILE6 will use MOBILE5-based factors except for GLLs.

- MOBILE5 calculated diurnal losses over three “partial-day” periods, a full-day period, and for multi-day events; MOBILE6 is much more detailed in its calculations.

Comparison of Running Loss Emissions from MOBILE5a and the RL95 Test Program (95°F, 9.0 psi RVP, 19.6 mph)				
Trip Length (min)	P/P Passes (g/mi)		P/P Failures (g/mi)	
	MOBILE5a	RL95	MOBILE5a	RL95
≤10	0.14	0.07	1.19	1.14
11-20	0.30	0.09	2.94	3.35
21-30	0.35	0.09	3.88	4.04
31-40	0.51	0.09	5.03	4.69
41-50	0.61	0.09	5.50	4.99
>50	0.77	0.21	6.14	5.69

- MOBILE6 gross liquid leaker (GLL) running loss emission rate:

  - 17.65 g/mi (including resting losses)

  - GLL resting loss emission rate = 9.16 g/hr

Comparison of Hot Soak Results from the Auto/Oil Test Program and the HS95 Test Program		
Parameter	A/O Fleet	HS95 Fleet
Sample Size	299	181
Mean Model Year/Age	1987.9 / 5.5 yrs	1988.0 / 7.5 yrs
Mean Temperature (°F)	100	98
Mean RVP (psi)	6.6	6.4
Mean HS Emissions (g)	1.53	1.76

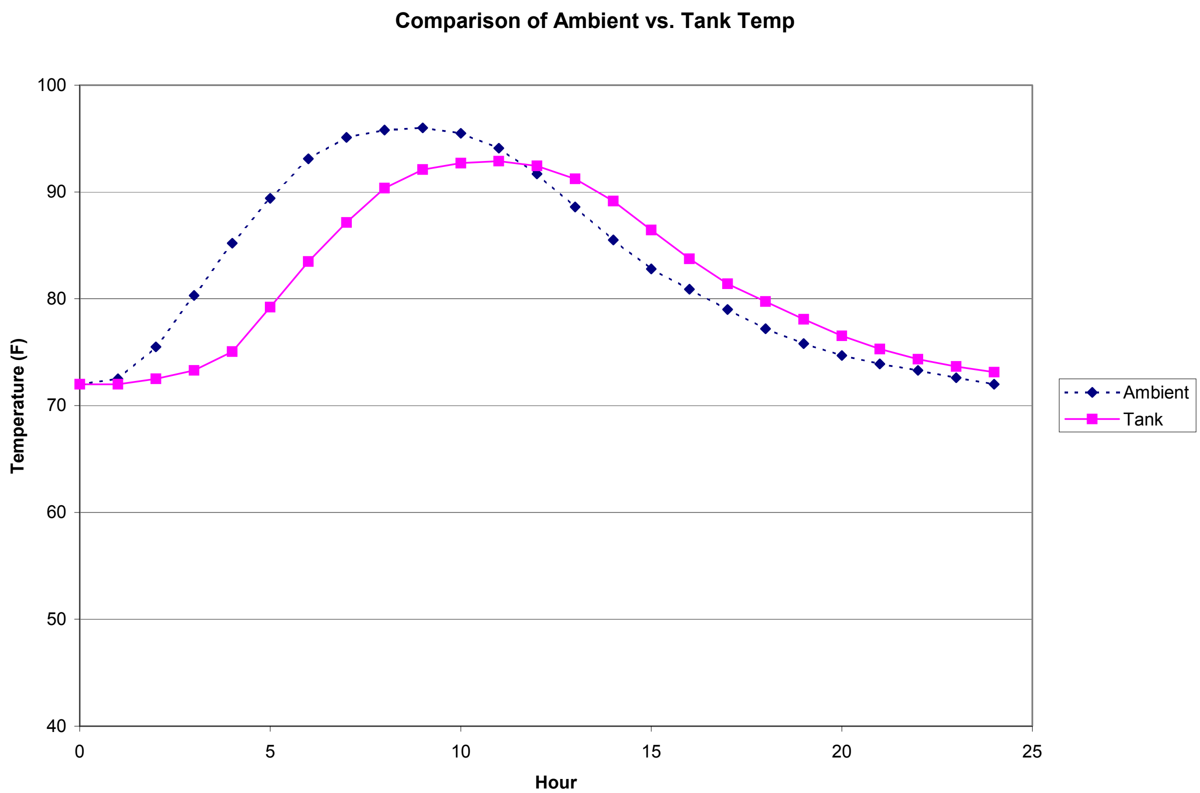
- MOBILE6 GLL hot soak emission rate (including resting losses):

  - 16.95 g/hr for carbureted vehicles
  - 45.00 g/hr for TBI vehicles
  - 57.14 g/hr for MPFI vehicles

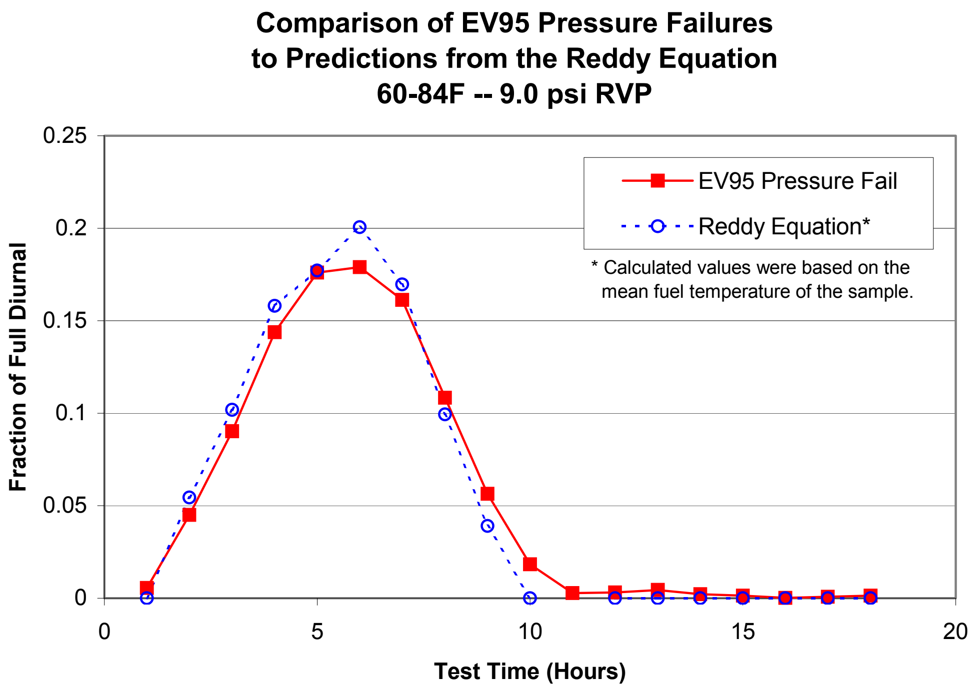
Single-Day Real-Time Diurnal Results from the IM92 Test Program (Grams per Day)				
Pressure/ Purge Status	Fuel RVP (psi)	Temperature Range		
		60° to 84°F	72° to 96°F	82° to 106°F
All (n=21)[a]	9.0	6.23	10.07	--
	6.7	--	6.73	10.38
Pass (n=12)	9.0	4.00	6.83	--
	6.7	--	4.54	6.93
Fail (n=9)	9.0	9.21	14.21	--
	6.7	--	9.66	14.98

[a] Sample size is in parentheses.

- MOBILE6 GLL full-day diurnal emission rate (not including resting losses):
  - 104.36 g/day
  - GLL resting loss emission rate = 220 g/day



Comparison of Ambient vs. Tank Temp
Temperature (F)
100
90
80
70
60
50
40
0
5
10
15
20
25
Hour
Ambient
Tank


Comparison of EV95 Pressure Failures
to Predictions from the Reddy Equation
60-84F -- 9.0 psi RVP
Fraction of Full Diurnal
0.25
0.2
0.15
0.1
0.05
0
0
5
10
15
20
Test Time (Hours)
EV95 Pressure Fail
Reddy Equation*
* Calculated values were based on the
mean fuel temperature of the sample.

EVAPORATIVE I/M CHECKS

Modeling the Impact of Evaporative I/M Checks

- Pressure checks
- Functional cap checks
- Purge checks (for historical perspective)
- OBD checks
  - What OBD does and doesn’t cover
  - Modeling approach for MOBILE6

Evaporative Test Procedures

- *Pressure test* - Consists of pressurizing the evaporative control system and monitoring the pressure over a two-minute period. If the system holds sufficient pressure, the vehicle passes. In the "fillpipe pressure test" the system is pressurized at the fuel inlet; in the "canister pressure test" the system is pressurized at the canister.

- *Functional Cap Test* - An alternative to a full pressure test, the gas cap is removed from the vehicle and placed on a separate test stand. The cap is then pressurized and if too high a volume of air is able to pass through the cap, the cap fails.

- *Purge test* - Consists of putting a flow meter in the vapor line from the canister to the intake manifold and monitoring the purge flow while the vehicle is driven on a dynamometer. If the cumulative flow is below a pre-set cutpoint, the vehicle fails.

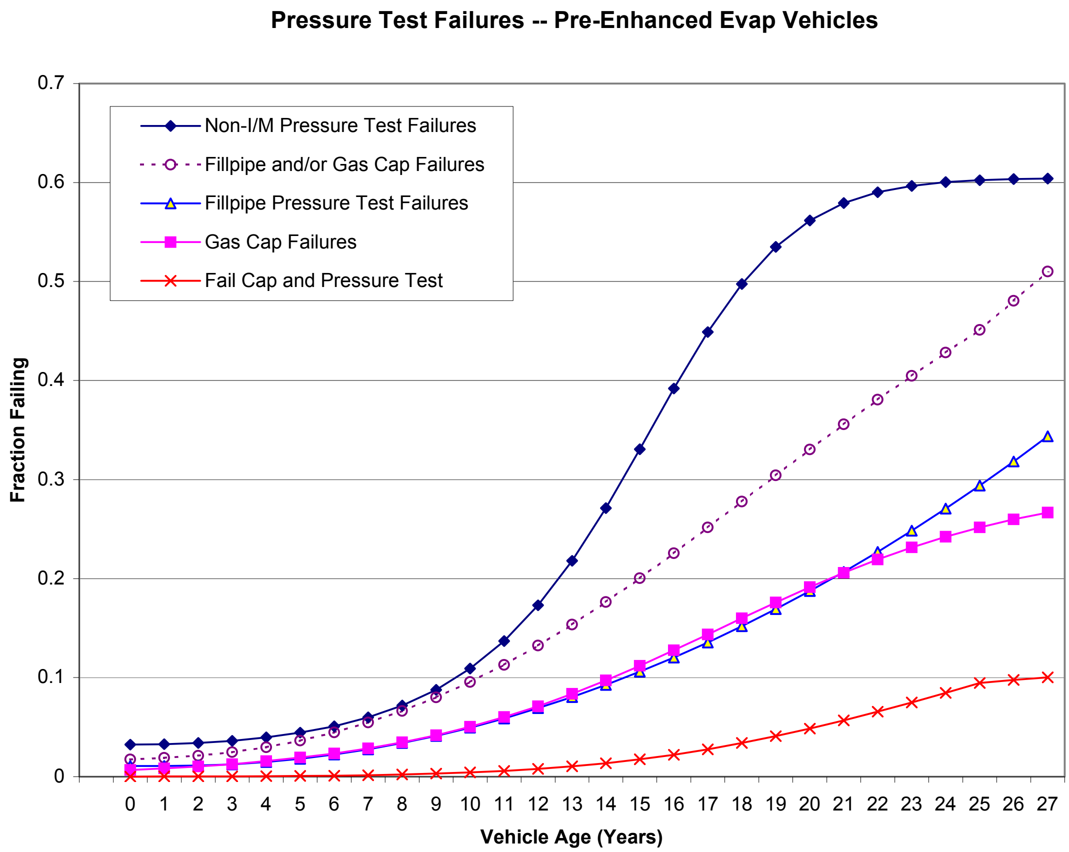
- *OBD Checks* - The OBD II system checks for evaporative system pressure integrity and for purge function.

Evaporative OBD Checks

- The OBD evaporative leak check monitoring requirements were phased-in beginning in model year 1996 at a rate of 40% in 1996, 80% in 1997, and 100% in 1998. Thus, not all 1996 and newer vehicles are equipped with OBD evaporative leak check monitoring systems.

- The evaporative system monitor was one of the most difficult OBD strategies to implement. As a result, a number of early generation systems received deficiencies during certification and their evaporative leak check monitors are marginally or non-functional.

- Up until the 2002 model year, OBD systems were required to identify leaks greater than 0.040 inches in diameter. However, leaks down to a size of 0.020 inches will have to be detected on new vehicles. Thus, continuing gas cap checks at least through 2002 model year will ensure that a portion of smaller leaks are identified and repaired.



Pressure Test Failures -- Pre-Enhanced Evap Vehicles
Non-I/M Pressure Test Failures
Fillpipe and/or Gas Cap Failures
Fillpipe Pressure Test Failures
Gas Cap Failures
Fail Cap and Pressure Test
Fraction Failing
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
Vehicle Age (Years)

Corrections to Evaporative Emission Rates

- Temperature effects
- RVP effects
- Trip length and running loss emissions

VII. SIP INVENTORY DEVELOPMENT WITH MOBILE6

SIP-Based Inventory Development

- HPMS and TDMs
- EPA Guidance (Volume IV)
- Configuring MOBILE6
- Examples

SIP-Based Inventory Development

- Historically, the primary guidance document for inventory preparation was:

  "Procedures for Emission Inventory Preparation. Volume IV: Mobile Sources"

- Last updated in 1992

- Will likely be updated when MOBILE6 is finalized (EPA is currently developing a guidance document)

- Nonetheless, it is useful to review Volume IV guidance and its implications for MOBILE6

Volume IV Contents

- On-road motor vehicles
- Nonroad sources
- Aircraft
- Locomotives

Volume IV – Highway Vehicles

- Primary components of the highway vehicle inventory process are:
  - Motor vehicle emission factors (from MOBILE)
  - Vehicle miles traveled (VMT)
- Output from two disparate models is combined to generate an inventory

MOBILE (g/mi)	×	TDM/HPMS (miles)	=	Inventory (tons/day)

- Not only is VMT from the transportation models used, but speed estimates are also required
- Over the past several years, effort has been devoted to linking emission models and emissions models (e.g., TRANSIMS), but it will be a number of years before they are routinely used
- Judicious use of existing models is recommended

MOBILE6 Inputs for SIP Modeling

- During this course, nearly every input used to tailor MOBILE6 to local conditions has been discussed (or will be discussed)
- Volume IV also discusses the configuration of MOBILE for local conditions (e.g., temperature, RVP, registration fractions, etc.); those will not be repeated here
- However, there are several new inputs to MOBILE6 that will require more direct knowledge of VMT and speed estimating procedures
- Those procedures were also included in Volume IV, but they have generally been downplayed in discussions of MOBILE
- The linkage between MOBILE6 and transportation models must be understood to get the most out of the model

Methods for Developing VMT and Speed Estimates

- There are two basic approaches to generating VMT and speed estimates for use in inventory preparation:

  - Highway Performance Monitoring System (HPMS) data

  - Transportation Network Demand Models (TDMs)

- These are discussed below, followed by EPA guidance on how to use output and data from these approaches to configure VMT and speed inputs for MOBILE6

- WARNING:

  "Selection of vehicle speeds is a difficult and complex process" (Volume IV)

Highway Performance Monitoring System

What is it?

- Urbanized areas with >50,000 population are required to maintain a formal transportation plan to secure federal funding for transportation projects
- Although not required, HPMS is often used in developing those plans
- HPMS was developed in the mid-1970s by FHWA to collect and report information on the nation's highways
- HPMS includes all public highways or roads within a state
- One of the more important parameters collected is annual average daily traffic (AADT)
- 24- or 48-hour vehicle counts are taken on each sample segment every three years (non-sampled years are estimated with growth factors)
- These short counts are adjusted based on day of week and season to develop an annual average count

Converting Traffic Counts to VMT

- The following steps are used to convert the traffic count data to VMT:

    1. Calculate the sum of counts (AADT) in each functional class

    2. Determine sample size for each functional class (number of counters)

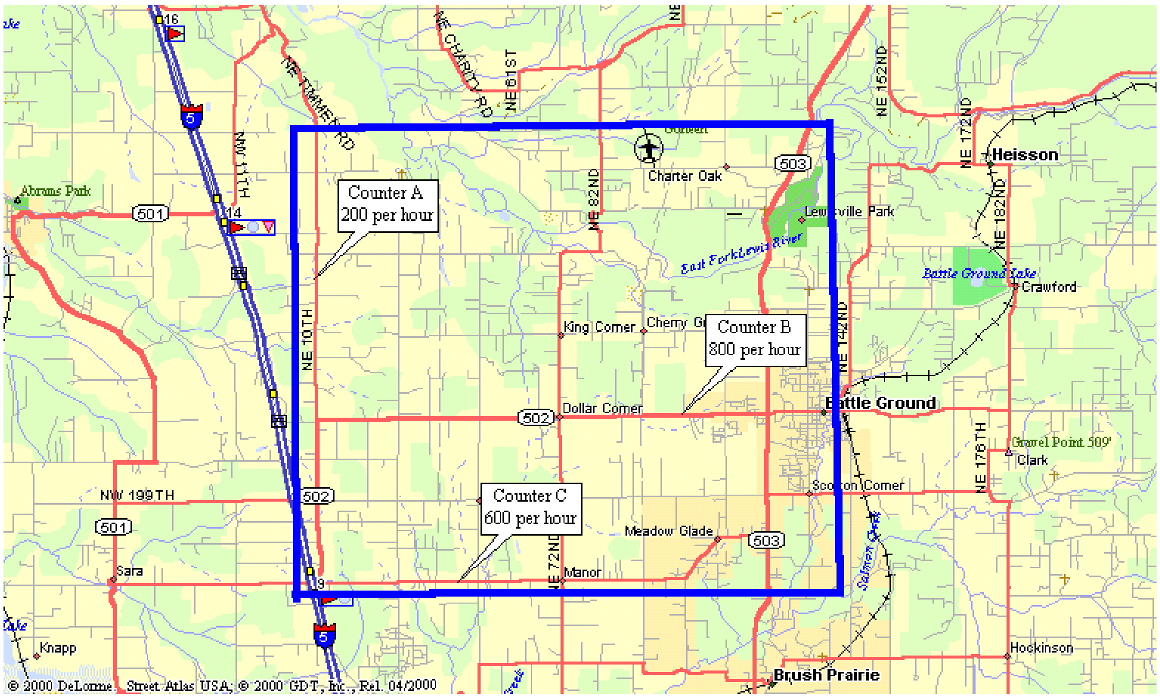
    3. Determine average volume (by functional class) by dividing total counts by sample size

    4. Obtain number of miles for each functional class (from DOT or GIS software)

    5. Calculate VMT by functional class as average volume X number of miles of facility

Example 12

Traffic Counts to VMT



Assuming that the square above is 6 miles on a side, generate an estimate of daily VMT for the major arterials within the square based on the given traffic counts.

HPMS VMT Adjustments for Inventory Preparation

HPMS data must be adjusted for:

- Nonattainment area boundaries
- Local roads must be added (not generally based on ground counts, so often a source of error)
- Seasonal adjustments (i.e., summer for ozone inventories; winter for CO inventories)
- Weekday adjustments (e.g., typical summer day to typical summer weekday)

HPMS-Based VMT in Rural and Small Urban Areas

- Statewide VMT is reported to FHWA; these data are published in Highway Statistics

- Highway Statistics is based on HPMS

- For rural and small urban areas, apportioning factors are developed to allocate statewide totals to the area of interest

- VMT apportioning can be done based on:

  - Roadway miles (recommended approach)

  - Motor vehicle registrations

  - Population

  - Fuel sales

ANNUAL VEHICLE-MILES OF TRAVEL - 1995
BY FUNCTIONAL SYSTEM 1/

APRIL 1997 (MILLIONS) TABLE

STATE	RURAL							URBAN						
	INTERSTATE	OTHER PRINCIPAL ARTERIAL	MINOR ARTERIAL	MAJOR COLLECTOR	MINOR COLLECTOR	LOCAL	TOTAL	INTERSTATE	OTHER REEWAYS AN EXPRESSWAY	OTHER PRINCIPAL ARTERIAL	MINOR ARTERIAL	COLLECTOR	LOCAL	TOTAL
Alabama	5,137	5,351	4,247	5,041	1,209	4,713	25,698	4,945	387	6,461	4,996	2,417	5,724	24,930
Alaska	785	295	123	332	101	457	2,093	517	0	399	676	204	234	2,030
Arizona	5,442	2,299	1,668	2,707	315	1,619	14,050	3,691	1,826	9,005	5,359	2,823	2,899	25,603
Arkansas	3,245	4,371	3,220	5,022	663	1,130	17,651	2,093	831	2,638	1,964	776	700	9,002
California	14,245	15,396	8,893	9,693	2,716	2,395	53,338	55,184	42,768	53,574	41,202	13,915	16,390	223,033
Colorado	4,265	3,478	2,251	1,926	701	1,402	14,023	4,365	2,749	6,354	3,905	1,559	2,103	21,035
Connecticut	1,482	1,375	1,187	1,229	264	1,160	6,697	7,142	2,863	3,351	4,152	1,565	2,274	21,347
Delaware	0	1,468	324	615	81	466	2,954	1,235	98	1,223	715	464	826	4,561
Dist. of Columbia	0	0	0	0	0	0	0	474	401	912	912	328	438	3,465
Florida	9,682	10,981	4,385	2,378	1,406	3,579	32,411	15,238	6,227	27,316	15,707	11,602	19,308	95,398
Georgia	8,866	6,324	7,081	6,362	2,102	4,827	35,562	14,091	2,314	10,790	9,975	4,573	8,079	49,822
Hawaii	0	655	780	323	33	307	2,098	1,557	614	1,324	683	872	797	5,847
Idaho	1,834	1,787	874	1,263	226	2,257	8,241	805	0	1,142	1,057	474	577	4,055
Illinois	9,131	4,475	5,061	5,142	422	3,484	27,715	16,747	940	18,172	15,191	7,724	7,700	66,474
Indiana	7,472	5,551	4,345	10,877	2,067	2,775	33,087	7,044	1,084	9,760	6,709	2,147	4,721	31,465
Iowa	3,846	4,671	2,578	3,146	788	1,519	16,548	1,767	0	2,746	2,625	741	1,560	9,439
Kansas	2,878	3,805	2,156	2,932	270	1,572	13,613	2,510	1,036	2,900	2,475	849	1,770	11,540
Kentucky	5,088	5,282	2,157	5,146	2,349	2,884	22,906	4,996	726	4,242	3,942	1,706	2,577	18,189
Louisiana	5,113	2,985	2,555	6,302	1,755	2,232	20,942	4,528	645	5,513	4,380	1,325	1,314	17,705
Maine	1,812	1,716	1,742	2,164	741	1,083	9,258	496	131	928	872	626	278	3,331
Maryland	3,074	3,323	2,445	2,197	802	1,530	13,371	10,189	3,545	7,757	5,359	2,576	2,085	31,511
Massachusetts	2,162	1,804	1,366	1,433	230	871	7,866	11,397	3,559	9,876	7,856	2,704	4,795	40,187
Michigan	6,177	7,273	5,916	8,079	1,276	2,422	31,143	12,556	3,923	16,251	12,241	3,794	5,795	54,560
Minnesota	3,637	5,866	4,203	3,537	1,138	2,635	21,016	6,282	2,382	3,152	6,361	2,048	2,831	23,056
Mississippi	3,536	4,236	3,712	4,152	398	3,959	19,993	1,664	200	3,273	1,500	1,018	1,911	9,566
Missouri	5,979	7,475	3,320	6,416	459	2,855	26,504	9,849	2,820	6,969	4,707	1,961	6,537	32,843
Montana	2,066	2,079	1,022	994	319	695	7,175	219	0	819	436	307	484	2,265
Nebraska	2,187	2,617	2,043	1,406	262	1,161	9,676	785	172	2,445	1,443	545	741	6,131
Nevada	1,714	1,353	468	578	416	902	5,431	1,889	559	1,855	2,402	711	1,127	8,543
New Hampshire	1,402	1,542	1,014	1,220	448	567	6,193	823	531	912	1,384	415	385	4,450
New Jersey	2,123	3,734	1,525	2,072	761	1,280	11,495	9,040	7,432	11,695	9,369	3,491	8,490	49,517
New Mexico	4,111	2,622	1,313	1,792	508	2,844	13,190	1,541	1	3,288	1,010	785	1,332	7,957
New York	5,782	5,379	5,255	4,986	6,341	3,208	30,951	15,102	15,605	17,009	17,897	9,611	8,916	84,140
North Carolina	6,767	7,762	6,220	9,181	3,473	4,309	37,712	6,977	2,801	8,917	7,173	2,140	10,333	38,341
North Dakota	1,102	1,421	566	823	0	949	4,861	207	0	567	423	183	304	1,684
Ohio	8,771	6,711	4,722	9,562	2,054	6,343	38,163	18,127	3,935	12,356	12,029	4,789	11,389	62,625
Oklahoma	4,318	4,145	2,520	4,758	157	2,487	18,385	3,767	1,730	4,241	4,475	1,008	4,883	20,104
Oregon	3,864	4,673	1,828	2,569	727	1,980	15,641	3,549	1,075	3,546	2,714	1,501	2,008	14,393
Pennsylvania	8,109	9,409	8,008	5,835	2,659	6,358	40,378	9,531	5,511	15,334	11,385	6,380	6,001	54,142
Rhode Island	295	204	155	169	51	24	898	1,557	666	1,823	699	420	833	5,998
South Carolina	6,818	3,990	5,604	4,792	625	2,210	24,039	2,869	587	4,862	3,818	1,701	848	14,685
South Dakota	1,637	1,562	952	1,063	137	535	5,886	300	20	488	577	196	202	1,783
Tennessee	7,658	4,594	5,236	3,328	2,722	1,713	25,251	7,474	1,173	9,446	7,007	2,281	3,582	30,963
Texas	13,363	15,118	10,411	12,766	2,291	2,319	56,268	27,401	18,052	26,701	20,539	10,931	21,204	124,828
Utah	2,771	1,441	944	1,027	241	538	6,962	3,974	104	2,266	2,478	1,061	1,936	11,819
Vermont	1,042	725	884	1,123	159	449	4,382	320	74	438	353	208	431	1,824
Virginia	8,315	6,319	5,723	6,179	568	3,293	30,397	10,901	3,168	9,444	7,113	2,496	6,292	39,414
Washington	4,143	4,126	2,121	3,695	959	1,132	16,176	9,057	4,080	6,821	6,437	3,041	3,638	33,074
West Virginia	3,331	2,512	2,053	3,227	420	965	12,508	1,304	55	1,257	1,415	420	462	4,913
Wisconsin	4,829	8,152	5,167	4,145	765	4,070	27,128	3,167	2,152	7,169	4,930	1,174	5,676	24,268
Wyoming	1,976	1,135	685	508	361	700	5,365	285	8	611	245	343	187	1,679
U.S. Total	223,382	215,567	153,028	186,212	49,936	105,164	933,289	341,528	151,560	370,338	293,272	126,929	205,907	1,489,534
Puerto Rico	1,053	374	796	692	453	662	4,030	3,074	817	2,657	2,083	1,433	1,454	11,518
Grand Total	224,435	215,941	153,824	186,904	50,389	105,826	937,319	344,602	152,377	372,995	295,355	128,362	207,361	1,501,052
Percent - Area	23.9	23.0	16.4	19.9	5.4	11.3	100.0	23.0	10.2	24.8	19.7	8.6	13.8	100.0

Speed by HPMS Classification

- VMT is collected by the following facility types:

  Urban - Interstates
  Other freeways and expressways
  Other principal arterials
  Minor collectors
  Collectors
  Local

  Rural - Interstates
  Other principal arterials
  Minor arterials
  Major collectors
  Minor collectors
  Local

- Within each subset, speed is weighted by VMT to calculate an average speed (and emission factor)

- Accuracy is improved by dividing the day into separate periods so that congested and free-flow speeds are not mixed

Speed Estimates Applied to VMT fromTraffic Count Data

(Based on M6.SPD.003)

- Generally, two methods are used to estimate speeds:
  - Procedures from the Highway Capacity Manual (HCM)
  - Volume/capacity relationships from the Bureau of Public Roads (BPR) curves
- The accuracy of both methods fails when applied to arterials due to signalization

Speed Estimates – Highway Capacity Manual

- HCM method requires more facility-specific information than is likely to be readily available

- As a result, BPR method is often used for regional analyses

- HCM data needs (interrupted flow facilities):

  - hourly volumes
  - number of lanes
  - free-flow speed
  - arterial class
  - density of signals per mile
  - peak hour factor
  - percentage turning traffic from exclusive lanes
  - medians
  - exclusive turn lanes
  - green time per cycle
  - cycle length
  - quality of signal progression
  - signal controller type

Speed Estimates – BPR Method

- BPR method is not data intensive
- Standard BPR equation is:

$$s = s_f / (1 + a(v/c)^b)$$

where:

s = predicted mean speed
s_f = free flow speed
v = volume
c = practical capacity
a = 0.05 for signalized facility types (arterial)
a = 0.20 for unsignalized facility types (fwy)
b = 10

- Practical capacity is 80% of maximum capacity
- Default tables of capacity by functional class are available

HPMS National Average Speeds
(From Volume IV)

- If no network model is available (and in marginal nonattainment areas), the following can be used

- Rural Areas (mph)

	LDVs	HDVs
Interstates	57.3	43.6
Other principal arterials	45.4	36.0
Major arterials	39.9	33.3
Major collectors	35.1	29.8
Minor collectors	30.5	24.4

- Urban Areas (mph)

	LDVs	HDVs
Interstates	46.3	39.0
Other fwys/expressways	43.3	36.5
Other principal arterials	18.9	16.0
Minor arterials	19.6	19.6
Collectors	19.6	16.4

Mapping HPMS Classifications to MOBILE6

- Urban

HPMS	MOBILE6
Interstates	Freeway
Other fwys/expressways	Freeway
Other principal arterials	Arterial
Minor collectors	Arterial
Collectors	Arterial
Local	Local

- Rural

HPMS	MOBILE6
Interstates	Freeway
Other principal arterials	Arterial
Minor arterials	Arterial
Major collectors	Arterial
Minor collectors	Arterial
Local	Local

- In the absence of local data, assume that Ramp VMT accounts for 8% of total MOBILE6 freeway VMT

Example 13

Development of a Rural Inventory VMT Estimates

Fremont County in Wyoming had a 1995 population of 35,000, and the statewide population was 475,000.

Use these data to estimate daily VMT in Fremont County in 1995; forecast to 2005 based on a 1.5% annual growth rate. Assign appropriate facility types and speeds to the overall VMT estimates.

Example 14

Development of a Rural Inventory Emissions Estimates

Using the VMT and speed estimates from Example 13, generate a summertime VOC and NOx emissions inventory for Fremont County in 2005

Temperature: 68 to 88°F
RVP: 8.7 psi
Sulfur: Western conventional
Evaluation month: July

Travel Demand Network Models (TDMs)

- Network models often provide more detailed information than HPMS, including

  - Speed
  - Operating conditions
  - Trip starts
  - Trip ends
  - Trips per day per vehicle
  - Vehicle mix
  - Time-of-day activity

- Network models can be used to spatially and temporally allocate VMT (and therefore emissions) within a nonattainment area

- However, VMT estimates of total travel should be made consistent with HPMS estimates

TDMs – Background

- Basic requirement of transportation planning is an understanding of:
  - Where travel occurs
  - What factors stimulate it
  - How demand is satisfied
- FHWA and FTA developed a series of models to help communities with this requirement
- Historically, the most frequently used model was the Urban Transportation Planning System (UTPS)
- MPOs and state transportation agencies typically implement and operate transportation planning models

Overview of Network Models

Primary steps include:

- Representation of roadway/transit system
- Estimation of number of current/future drivers and transit riders; number of trips taken in a day; trip origin and destination
- Assign trips to appropriate roads and transit routes (usually minimizing travel time)
- Prepare maps, tables, and graphs to display results and compare transportation alternatives

Network Development

- Development of the Zone System

  - Zones are geographic areas dividing the study area into homogenous areas of land-use, land activity, and aggregate travel demand

  - Zones represent the origin and destination of travel activity within the study area

  - Zone centroids reflect the center of activity

- Selection of Links

  - Links represent facilities that comprise the highway system

  - Two nodes that mark a link’s endpoints define the link in the transportation network

  - Nodes are locations where vehicles are able to change direction of travel (intersections, interchanges, etc.)

TDM VMT Estimates

- "Trip Tables" identify the number of trips between each pair of zones (i.e., origin-destination pairs)
- Assignment of travel in TDMs uses calculated speeds to minimize travel time on roadway segments or links (i.e., alternate routes could be selected, depending on estimated travel time)
- To the extent that all trips are captured, TDMs provide comprehensive regional VMT estimates
- Additionally, uncertainty associated with extrapolation of traffic volumes from count data at selected locations is avoided
- However, it is difficult to achieve accurate route assignments and accurate speeds in TDMs, so speeds are often calculated external to the model

Uncertainties in TDM VMT Estimates

- Trips not assigned to the network are not captured
  - "Intrazonal" trips (i.e., origin and destination within the same zone)
  - Local roads typically not part of the TDM network
- These must be separately addressed
  - Intrazonal – based on assumptions regarding intrazonal trip lengths, sizes of zones, local roadway speeds
  - Locals – based on count data
- TDMs focus primarily on travel by individuals rather than goods movement; HDV activity usually based on simple adjustment factors

Freeway Ramps

- Often not accounted for in network models
- Default MOBILE6 ramp VMT based on a study done by the Charlotte Department of Transportation (CDOT)
- CODT estimated:
  - 19.4% of freeway VMT in the central business district
  - 8.7% of freeway VMT in commercial areas
  - 2.4% of freeway VMT in residential areas
- MOBILE6 uses 8.7% as its default (i.e., 8% of total freeway + ramp VMT)

VMT Summary for Chicago (AM Peak)
(From M6.SPD.003)

Speed Range	Vehicle Miles Freeway	Highway	Arterial	Collector	Local	Total
0.0 - 2.5	0	0	0	0	0	0
2.5 - 7.5	3362	856	4970	7607	6416	23211
7.5 - 12.5	0	17769	29132	25812	3652	76365
12.5 - 17.5	105660	66463	137749	123324	10492	443688
17.5 - 22.5	182753	201406	530801	340752	51658	1307370
22.5 - 27.5	181568	327280	929526	409209	115174	1962757
27.5 - 32.5	156724	348149	804607	224273	72144	1605897
32.5 - 37.5	251344	240993	538417	161452	44870	1237076
37.5 - 42.5	198653	160016	222657	152032	102912	836270
42.5 - 47.5	133224	117340	116133	101917	61213	529827
47.5 - 52.5	517441	57882	22251	35996	34334	667904
52.5 - 57.5	309012	18407	1153	881	1131	330584
57.5 - 62.5	107232	0	0	0	0	107232
62.5 - 67.5	135870	0	0	0	0	135870
67.5 - 72.5	0	0	0	0	0	0
Total	2282844	1556560	3337395	1583256	503996	9264051

VMT Distribution for Chicago (AM Peak)
(From M6.SPD.003)

	Fraction of Total VMT					
Speed Range	Freeway	Highway	Arterial	Collector	Local	Total
0.0 - 2.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2.5 - 7.5	0.0004	0.0001	0.0005	0.0008	0.0007	0.0025
7.5 - 12.5	0.0000	0.0019	0.0031	0.0028	0.0004	0.0082
12.5 - 17.5	0.0114	0.0072	0.0149	0.0133	0.0011	0.0479
17.5 - 22.5	0.0197	0.0217	0.0573	0.0368	0.0056	0.1411
22.5 - 27.5	0.0196	0.0353	0.1003	0.0442	0.0124	0.2119
27.5 - 32.5	0.0169	0.0376	0.0869	0.0242	0.0078	0.1733
32.5 - 37.5	0.0271	0.0260	0.0581	0.0174	0.0048	0.1335
37.5 - 42.5	0.0214	0.0173	0.0240	0.0164	0.0111	0.0903
42.5 - 47.5	0.0144	0.0127	0.0125	0.0110	0.0066	0.0572
47.5 - 52.5	0.0559	0.0062	0.0024	0.0039	0.0037	0.0721
52.5 - 57.5	0.0334	0.0020	0.0001	0.0001	0.0001	0.0357
57.5 - 62.5	0.0116	0.0000	0.0000	0.0000	0.0000	0.0116
62.5 - 67.5	0.0147	0.0000	0.0000	0.0000	0.0000	0.0147
67.5 - 72.5	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Total	0.2464	0.1680	0.3603	0.1709	0.0544	1.0000

Speed by Facility File from MOBILE6 (SVMT.DEF)

```
SPEED VMT
1 1  0.0083 0.0272 0.0210 0.0224 0.0217 0.0381 0.0344 0.0536 0.0614 0.0700 0.2507 0.1150 0.2550 0.0212
1 2  0.0260 0.0066 0.0076 0.0156 0.0282 0.0326 0.0344 0.0361 0.0360 0.0435 0.2453 0.1729 0.3023 0.0129
1 3  0.0259 0.0033 0.0064 0.0057 0.0126 0.0281 0.0342 0.0349 0.0407 0.0369 0.2181 0.1066 0.4399 0.0127
1 4  0.0145 0.0096 0.0021 0.0022 0.0041 0.0166 0.0232 0.0373 0.0418 0.0449 0.2248 0.1190 0.4422 0.0177
  .
  .
1 24 0.0031 0.0003 0.0000 0.0010 0.0001 0.0011 0.0134 0.0124 0.0240 0.0267 0.2404 0.1226 0.5271 0.0278
2 1  0.0004 0.0052 0.0061 0.0053 0.0158 0.0854 0.3210 0.1382 0.2804 0.0595 0.0628 0.0103 0.0095 0.0001
2 2  0.0036 0.0029 0.0059 0.0234 0.0735 0.1114 0.2842 0.0950 0.2633 0.0396 0.0698 0.0107 0.0169 0.0000
2 3  0.0033 0.0021 0.0032 0.0085 0.0436 0.1130 0.2914 0.1076 0.2835 0.0424 0.0719 0.0091 0.0204 0.0000
  .
  .
2 24 0.0000 0.0000 0.0000 0.0000 0.0085 0.0502 0.3271 0.1054 0.3324 0.0699 0.0752 0.0100 0.0211 0.0002
*
* Comments are not allowed before the end of the data!
*
* Fraction of vehicle miles traveled within an hour within an average speed bins by hour of the day.
* The first hour is 6 a.m.
*
* Freeways
* Hr   2.5    5.0   10.0   15.0   20.0   25.0   30.0   35.0   40.0   45.0   50.0   55.0   60.0   65.0+
*
* Arterial and Collector Roadways
* Hr   2.5    5.0   10.0   15.0   20.0   25.0   30.0   35.0   40.0   45.0   50.0   55.0   60.0   65.0+
```