Heavy-Duty Gasoline Truck Evaporative Emissions Testing for Emissions Inventory

Air Resources Board Contract #98-303

Dennis McClement

Automotive Testing Laboratories, Inc.
August 7, 2002

Goal

"To collect evaporative emissions test data under real-world conditions to improve the accuracy of California's on-road heavy-duty truck emissions inventories."

Emissions Inventory

- Concept simple - ledger (or computer program) listing relative contributions of different sources to total emissions picture.
- The inventory is used in decision making process to select “best” changes to achieve an emissions goal. Model needs to forecast future inventory and permit evaluation of different alternatives
- Mobile Source emission models, such as California’s EMFAC 2001, are primarily populated with laboratory data using procedures based on new vehicle certification. (Includes cars, trucks, and motorcycles).

Heavy Duty Truck Definition

- Typical trucks defined as “Light” and “Medium” duty, including SUV’s. Very largest “Heavy-Duty”, usually dual drive wheels, heaviest trailer towing package and up.
  - Light Heavy-Duty 8,501 - 14,000 #s GVWR
  - Medium Heavy-Duty 14,001 - 33,000
  - Heavy Heavy-Duty more than 33,001
- Diesel powered vehicles not considered significant contributors to evaporative inventory because of basic fuel properties - gasoline powered only in this program.
- HHDGT, less than 1% of population, not tested.

Evaporative Emissions

- Running Loss - Generated by vehicle when engine is running.
- Hot Soak - Generated shortly after key is turned off, primarily driven by residual heat from operating engine.
- Diurnal - Created by temperature changes through the passage of a day. Major source would be saturated fuel vapor from fuel tank which is displaced by expansion as ambient temperature rises.
- Resting Loss - Non temperature driven, generally constant emissions throughout the day even when vehicle not used. (permeation - passage through hoses/plastics etc.)

"Real-World" & Certification Test Protocol Changes

- Initially used carbon canister trap to capture Hot Soak and Diurnal emissions. Diurnal simulated with one hour fuel heating.
- Improved in late 1970's to whole vehicle enclosure (SHED) to capture Hot Soak and Diurnal Emissions. Continued one hour diurnal
- Further Improved in 1996 to include Running Loss emissions and Variable Temperature/24 hour diurnal test.

Why Now?

- Previously extrapolated from light and medium duty test results. Assumed adjustments for fuel tank size and vehicle usage patterns sufficient.
- Cost of testing larger vehicles a significant factor.
- In-use fraction of 8,501# and greater gasoline-powered vehicles substantially increased in the 80's and 90's. Now they are a very significant inventory element.
- "Easy" pickings are gone, hard choices being made to achieve clean air goals.

Test Program Design

- Vehicles
  - California certified HDGT.
  - Range of model years, makes, sizes
- Fuel
  - California commercial summer grade Phase II fuel
- Temperatures
  - Selected 95ºF driving, 72 to 96 ºF diurnal
- Driving Cycles
  - Used repeated city test cycles

Vehicles

- California certified - vehicles designed to pass emission tests for Model Year they were produced.
- Stratified design - small sample size tested in this program requires inclusion of samples from specified classes. Other programs test enough vehicles to include samples from small classes (oldest vehicles, lower sales volumes).
- Test Plan included 7 LHDGT and 3 HHDGT, ranging from 1972 model year to current, with requirements for carburetor and/or fuel injection appropriate for model year tested.

Fuel

- California commercial fuel was purchased in California, transferred to drums at wholesaler.
- Sealed drums were shipped to ATL's Mesa laboratory and stored at 50ºF throughout duration of program.
- Independent and ARB analysis performed on fuel before and after testing portion of program. Met requirements for commercial California Phase II fuel.
- Reid Vapor Pressure (RVP) 7.0 psi nominal.

Temperatures

- Gasoline very sensitive to fuel temperature applied during vehicle operation
- California certification performed at “extreme” temperature, not “average” temperature.
- Direction to use more typical temperatures received. These include vehicle operation (running loss and hot soak) at 95ºF and diurnal temperature range from 72 to 96 back to 72ºF during 24 hour period.
- Correction factors for higher and lower temperatures available from other testing programs.

Driving Cycles

- Driving patterns important in generation of evaporative emissions
  - amount of heat generated
  - amount of canister purge
- Selected (3) UDDS cycles, 20 minute shutdown, final UDDS cycle. Urban Dynamometer Driving Cycle basis for City driving test. Running Loss certification uses UDDS and very low speed/high idle New York City Cycle.

Test Sequence

- LHDGT vehicles received Dynamometer Running Loss Test. MHDGT received road operation to warm up
- All vehicles received 3 hour Hot Soak test following engine shut down
- All vehicles received 24 hour Diurnal test.
- Inspection followed successful completion of baseline test.
- Four repeat tests performed - one replicate, one replicate except Running Loss and Hot Soak performed at 75ºF, and two vehicles repaired and retested.

Running Loss Testing

- Vehicles operated on dynamometer (treadmill) in sealed enclosure (SHED).
- Air provided from outside of enclosure to engine intake, exhaust gases from tailpipe directed to outside.
- Hydrocarbon levels in SHED monitored continuously to permit modelers to compute running losses after different lengths of operating time.
- Fuel temperature controlled during operation to match temperatures observed during outdoor operation using same test cycle.

Hot Soak Testing

- Following dynamometer or road operation, vehicle placed in SHED.
- Hydrocarbon levels monitored continuously for modelers.
- Three hours after engine shut down recorded (One hour used for new vehicle certification).

Diurnal Testing

- Variable Temperature (VT) SHED used to accommodate volume changes that result from temperature changes.
- 72 to 96ºF change results in approximate 4.5% change in volume - would damage fixed volume SHED.
- Old diurnal tests were one hour duration, with artificial fuel heating.
- New 24 hour test much more representative of “real world”
  - reflects true storage processes in carbon canister
  - measures low rate permeation/resting losses not detected in one hour test.

Post Test Inspection

- Initial inspection performed to verify vehicle met procurement criteria (model year, California certified) and safe operation. This inspection was limited to avoid any change in vehicles before testing was performed.
- Comprehensive after test inspection documented all evaporative related components, including relative position and relation to heat sources.

Data

- Track fuel tank temperature profile
- Electronic data submission
  - Minute by Minute Running Loss emissions
  - Minute by Minute Hot Soak emissions
  - Minute by Minute Diurnal emissions
- Comprehensive vehicle inspection, sketches and mechanic's observations
- Some Interesting Photographs

Results

- 1972 - 1985 Carbureted LHDGT

#	MY	Make	Odo	RL	HS	Diur
07	1974	Ford	240K	3.70	14.5	38.8
08	1984	Chev	160K	1.83	14.1	43.4
09	1984	Chry	126K	0.78	1.8	15.8

- All MHDGT

06	1974	GMC	161?		48.3	54.5
05	1990	Ford	87K		2.4	39.4

Results

- 1986 -1999 Fuel Injected LHDGT

#	MY	Make	Odo	RL	HS	Diur
01	1989	Ford	190K	0.29	1.02	9.05
02	1990	Ford	119K	1.02	0.41	19.49
03	1997	Chry	48K	0.09	0.93	5.65
04	1999	Chev	19K	0.01	0.09	0.92

Results

- Span the range of “pass light duty passenger standards” to extremely high.
- Similar to lighter vehicle results
  - age and odometer strongly related to emissions
  - older vehicles carbureted, newer fuel injected, but suspect fuel injection lower than carbureted
  - as seen in other programs, liquid leaks overwhelm vapor emissions.
- Stratified sample emphasized effect of age in this program
- Fuel tank capacities yield high emissions

Comparison with Other Programs

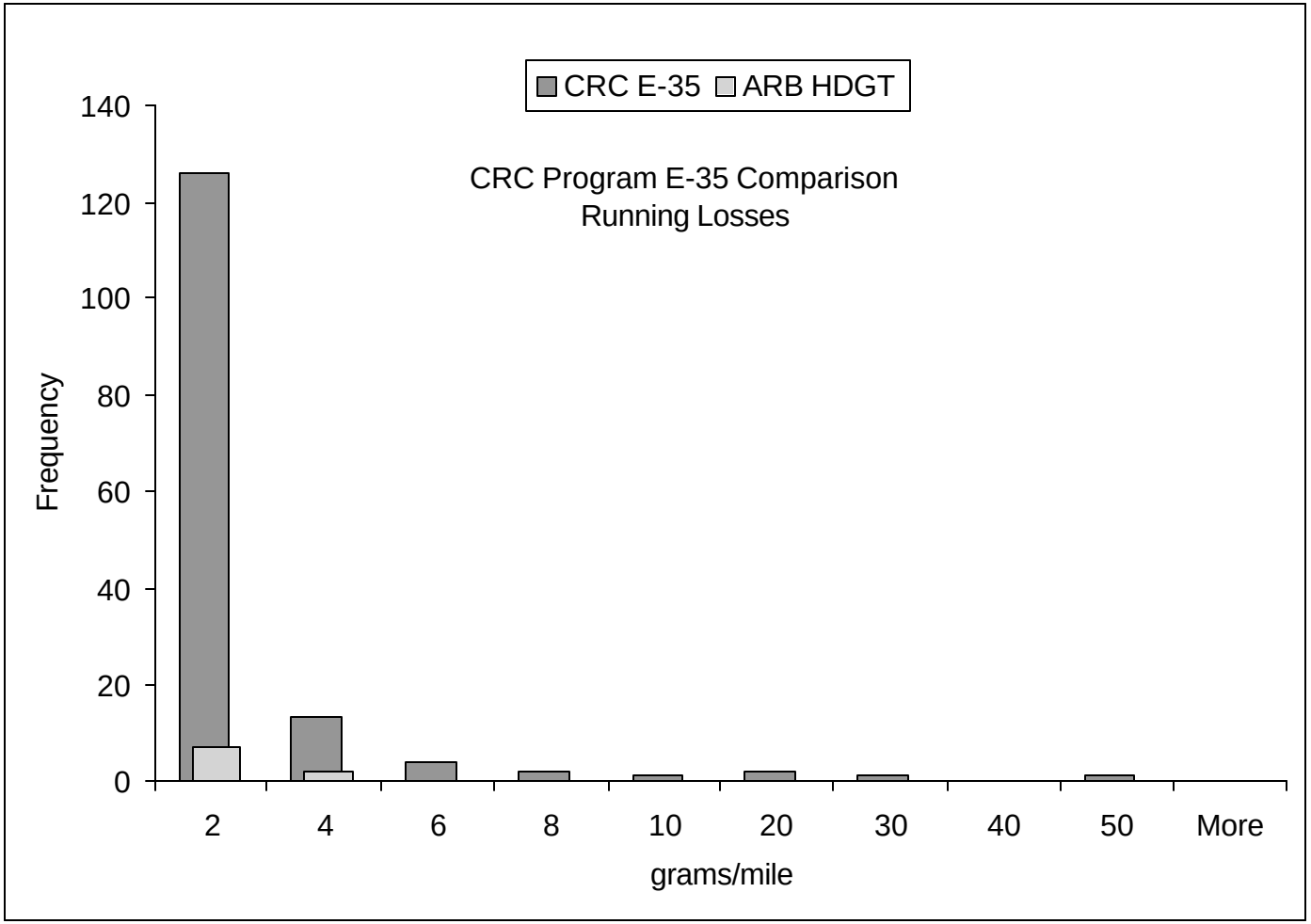
- No perfectly comparable program
- Series of Auto/Oil and CRC programs interesting
  - Auto/Oil 300 vehicle Hot Soak Program
  - CRC E-9 150 vehicle Diurnal Program
  - CRC E-35 150 vehicle Running Loss Program

This Program

- Limited - 9 vehicle samples
- “Stratified” sample
  - Technology/Model Year groups
- Any source
- Some repairs after baseline test.

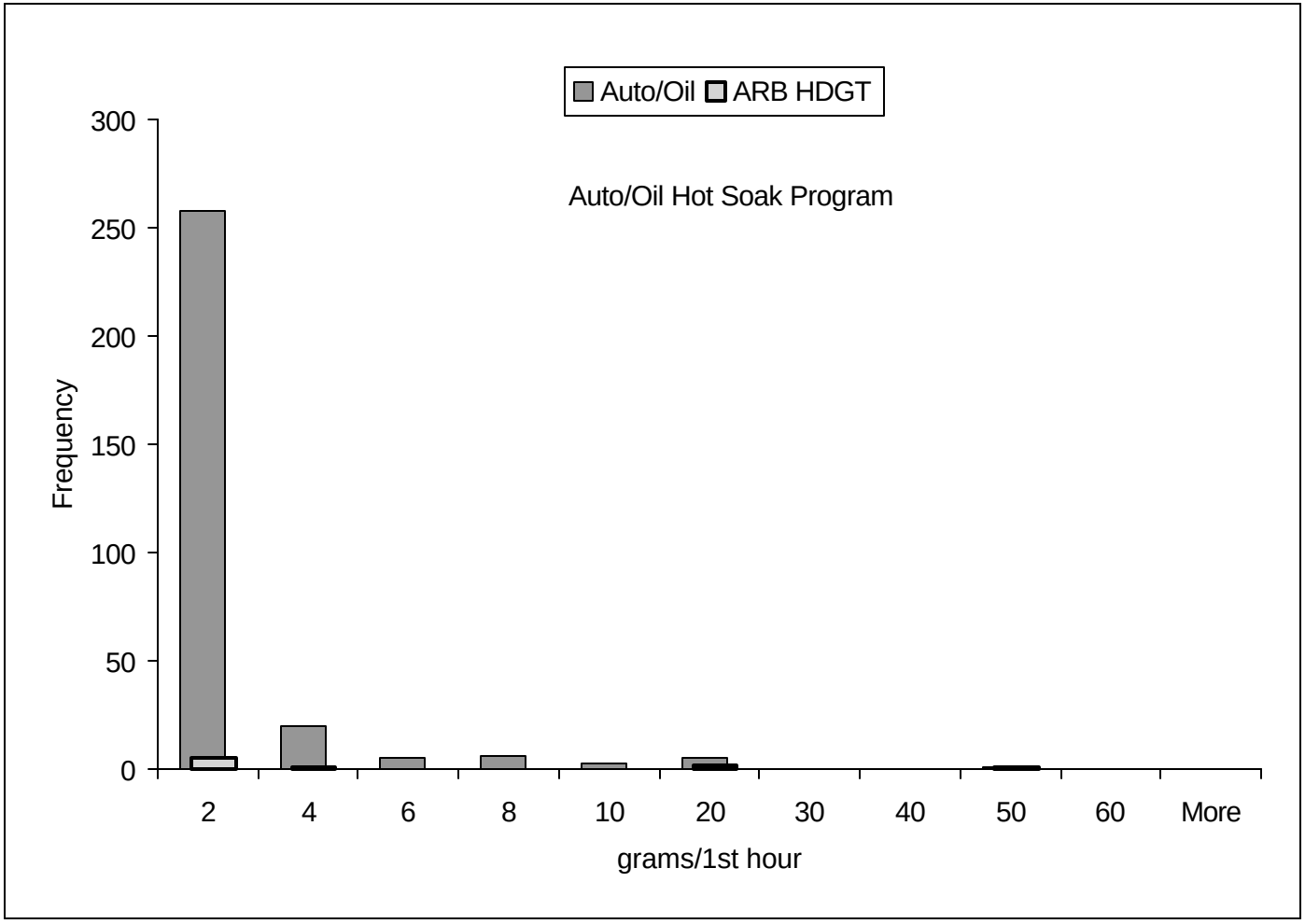
CRC E-35 Running Losses

- 150 randomly procured in-use light duty cars and trucks
  - 1/3 1971 - 1977
  - 1/3 1980 - 1985
  - 1/3 1986 - 1991
- High fraction carbureted (66%)
- Many instances of higher running losses in CRC program than this program


CRC E-35
ARB HDGT
CRC Program E-35 Comparison
Running Losses
Frequency
140
120
100
80
60
40
20
0
2
4
6
8
10
20
30
40
50
More
grams/mile

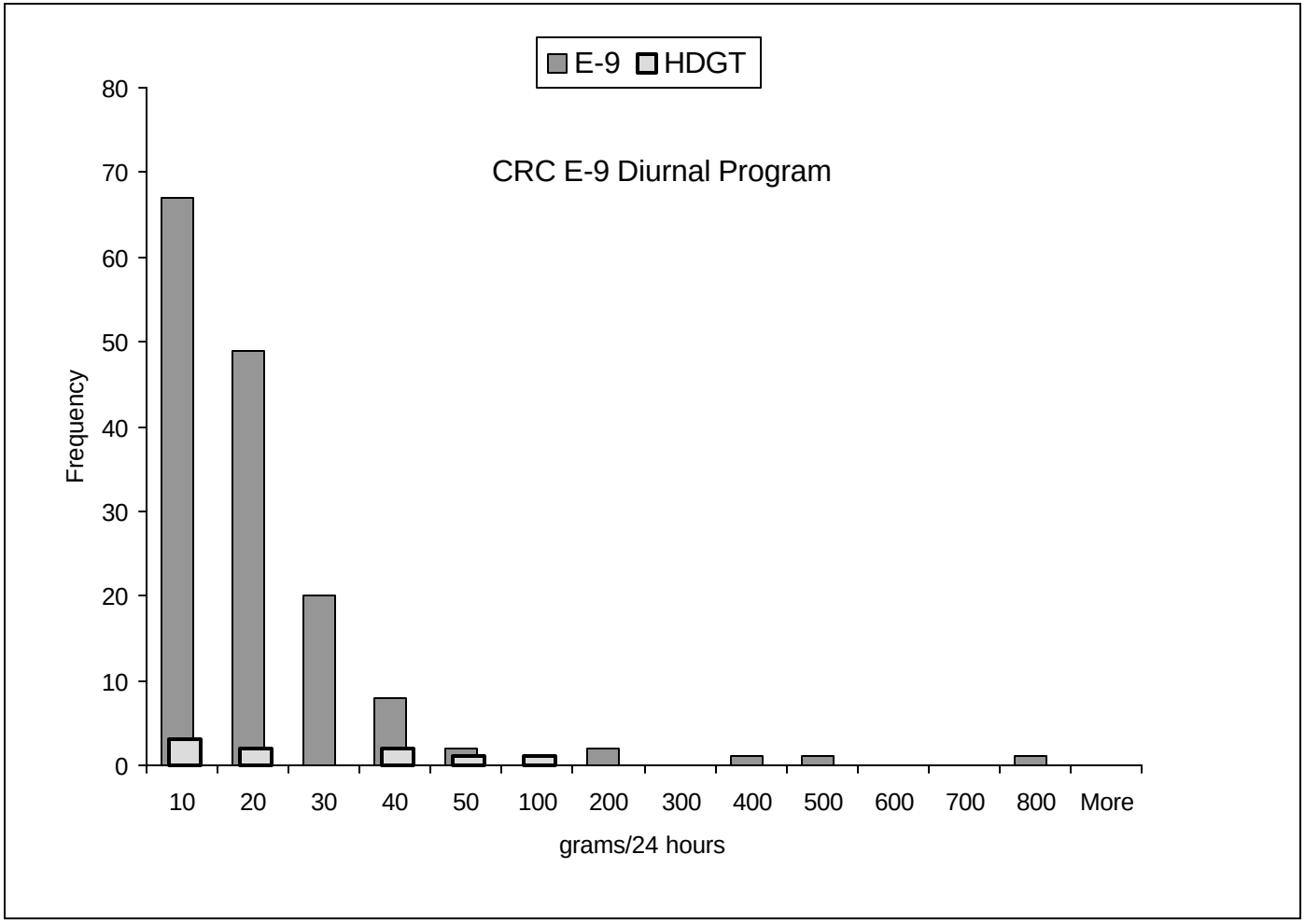
Auto/Oil Hot Soak Program

- 300 randomly procured in-use light duty cars and trucks.
- 1983 - 1993 model years
- 25% Trucks
- 22% Carbureted/78% Fuel Injected
- Comparable results considering age, technology. Older vehicles in CRC running loss program gave higher results, newer vehicles in Auto/Oil program gave lower results, when compared to HDGT program.


Auto/Oil
ARB HDGT
Auto/Oil Hot Soak Program
Frequency
300
250
200
150
100
50
0
2
4
6
8
10
20
30
40
50
60
More
grams/1st hour

CRC E-9 Diurnal Emissions

- 150 randomly procured in-use light duty cars and trucks. Like E-35:
  - 1/3 1971 - 1977 - carbureted
  - 1/3 1980 - 1985 - natural carb/fuel injection mix
  - 1/3 1986 - 1991 - fuel injected only
- High fraction carbureted (68%)
- Some very high results in CRC program
- Trend resulting from much larger fuel tanks in this program


E-9
HDGT
CRC E-9 Diurnal Program
Frequency
80
70
60
50
40
30
20
10
0
10
20
30
40
50
100
200
300
400
500
600
700
800
More
grams/24 hours

Conclusions

- Past practice of extrapolating light duty evaporative results to heavy duty trucks is reasonable.
- Observations
  - Expensive heavy-duty trucks kept in service longer
  - Larger fuel tanks drive higher diurnal emissions
  - Lower fuel temperatures observed result in lower running loss emissions
  - Liquid leaks in vehicles > 10 years old consistent with other programs, largest source of gross evaporative emissions