Modeling vapor emissions during Hot Soak operation from leaking vehicles

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Background

- Hot Soak operation is defined as time between turning off engine and engine reaching ambient temperature
- Vapor leaks are not explicitly included in MOVES2010b Hot Soak rates
- Vapor leak emissions are very high compared to non-leak emissions

Data Available

Program	Location	Test Length	Fuel RVP	Altitude (ft)	# Obs.
High Evap Field Study	Lipan IM station, CO	15 min	In-use	5130	~100
	Ken Caryl IM station, CO	15min	In-use	5130	~175
	Denver IM station, CO	15min, 1 hour	In-use	5130	~100
E-77-2	Mesa, AZ	1 hour	7, 9, 10	1243	~100

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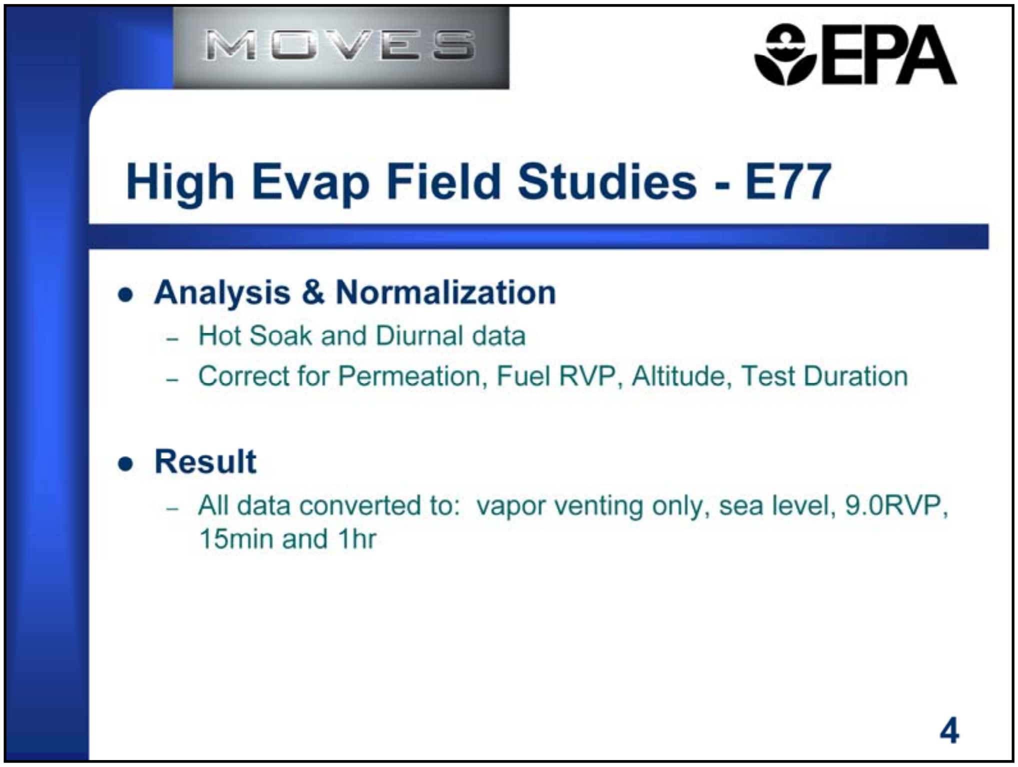
We have leaking vehicle data for all these procedures



Fuel correction uses Wade-Reddy to calculate vapor at testRVP and 9.0RVP and use that ratio
For altitude correction, use the Wade-Reddy equation to calculate the low Altitude RVP that generates the same vapor at High Alt.
For duration correction, use average 60min/15min ratio for all tests that had both lengths and apply to tests with only one duration.

Each leaking test must have a 15 min emission quantity to determine which leak-size bin it belongs in.
Each test must have a 1hr emission quantity to be used as a MOVES emission rate.

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Assumptions for Normalization

- **Subtracting MOVES2010-modeled permeation from SHED measurement leaves Hot Soak Vapor Venting**
- **Vapor leak emissions will increase/decrease proportionally to vapor generation.**
  - *A vehicle with a vapor leak at low & high elevation with the same fuel will have higher emissions at the higher elevation*
  - *A vehicle tested at the same elevation with have higher emissions with a higher RVP fuel*

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Normalize Hot Soak Data

1) Linearly interpolate Sea Level to Denver to determine vapor generation at Mesa, AZ

$$TVG_{Mesa} = TVG_L + \left((TVG_H - TVG_L) * \frac{Elevation_{Mesa}}{Elevation_{Denver}}\right)$$

2) Calculate the equivalent RVP at sea level

$$RVP_{SeaLevel} = \left(\frac{1}{B_{low}}\right) * ln\left(\frac{TVG_{high}}{A_{low} * \left(e^{C_{low}*T_1} - e^{C_{low}*T_0}\right)}\right)$$

3) Convert the emissions measurement to 9 RVP

$$TVG_{measRVP} = A_{low} e^{B_{low}*RVP_{meas}} \left(e^{C_{low}*T_1} - e^{C_{low}*T_0}\right)$$

$$TVG_{MOVES} = A_{high} e^{B_{high}*9.0} \left(e^{C_{high}*T_1} - e^{C_{high}*T_0}\right)$$

$$HS_{MOVES} = HS_{Measured} * \left(\frac{TVG_{measRVP}}{TVG_{MOVES}}\right)$$

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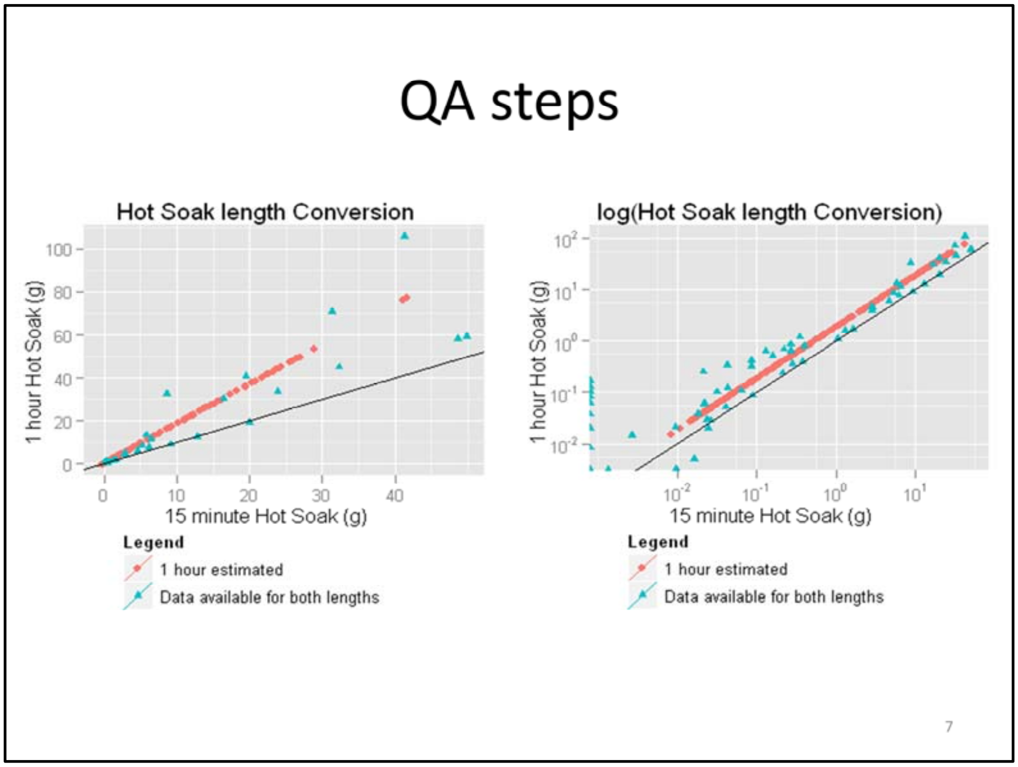
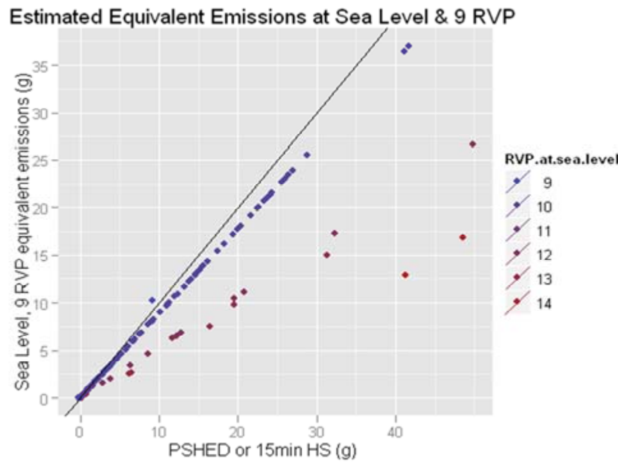
E-77 program was performed at Mesa, AZ (1,243 ft) [Source: wikipedia.org]

The convention is to input MOVES emission rates in the emission rate database at sea level, 9 RVP, grams per hour. This is a requirement as fuel and elevation adjustment calculators perform on this assumption.



Leak prevalence rates were developed using PSHED 15-minute data. In order for an hour leak measurement to be assigned to a certain leak severity bin, we must know its emissions at 15-minutes. However, MOVES emission rates are input in grams per hour rates. In order for the 15-minute leak measurements to be represented in the average emission rate, we must calculate their 1-hour equivalent. For some tests where by-minute data is available, we know the measurements at both 15 minutes and 60 minutes (blue triangles). The 15m to 60m ratio from these tests was applied to other tests where only one measurement exists (pink circles). The graphic on the right is the log scale of the graphic on the left. This is a more inclusive graphic due to the nature of leak measurements covering many orders of magnitude.

QA steps



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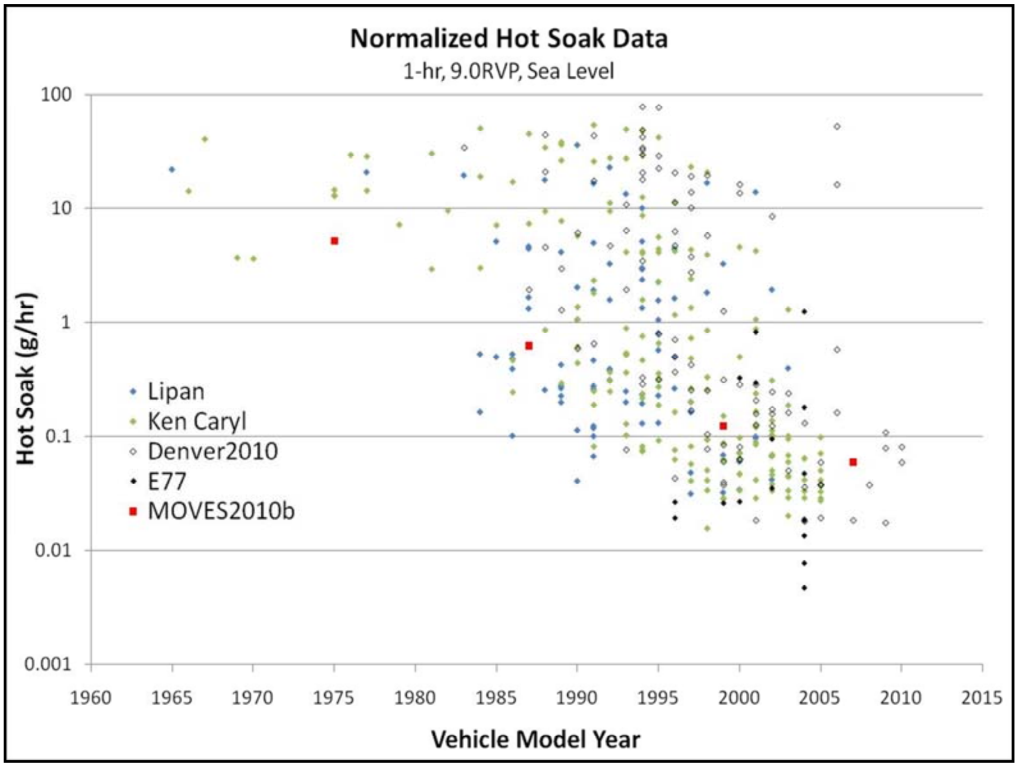
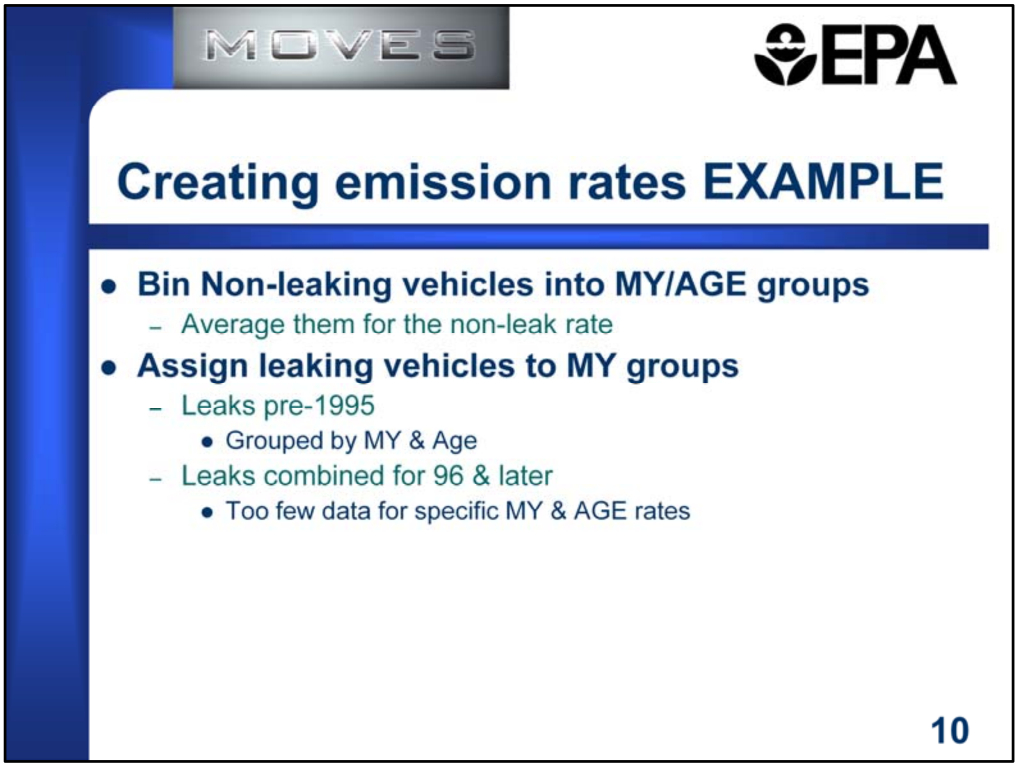
This graphic plots the conversion of emissions at higher RVPS to 9RVP. The highest RVP fuels have the highest emissions. Therefore they are the most severely corrected when converted to equivalent emissions had they been 9RVP fuel. The “line” of points is a result of controlled test program where many tests were performed with the same fuel.



The data, as pictured, is not representative of the fleet. Our sampling strategy was designed to recruit high RSD vehicles in the Colorado programs. E-77 vehicles were tested multiple times.



Leaks are combined into various severity bins because our data includes the occurrence of different sizes of leaks.
The result is a weighted leak rate that is more representative of existing leaks. For example, younger vehicles have predominately small leaks. Older vehicle vapor leaks have either stayed the same, grown, or been repaired. All of which can alter the size distribution.

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Creating MOVES emission rates

- **For each MYG / Age, calculate the average rate:**

*Non-leak Rate * (1 – Leak Prevalence)*
*+ Leak Rate * Leak Prevalence*

= Hot Soak Rate

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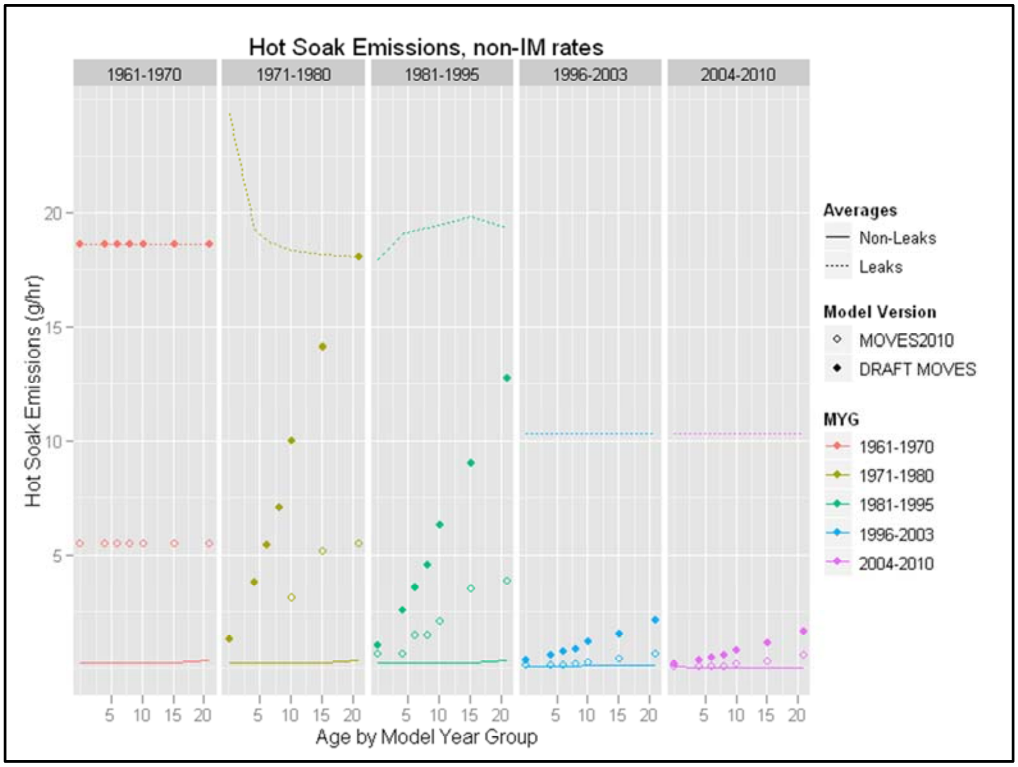

The hollow dots are the emission rates from MOVES2010 that do not include any vapor leak emissions. The solid dots are the proposed emission rates which include vapor leaks. The leak prevalences that are used for Hot Soak process are the same as those used for Cold Soak process. However, in the MOVES emission rate database, the leak and non-leak emission rates are not separate entities for Hot Soak. They are for Cold Soak.

Summary

- Vapor leaks dominate Hot Soak emission rates, and cause them to be higher than MOVES2010b rates
- Emissions from vehicles without vapor leaks are minimal.
- Vapor leak prevalence rates are very influential

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Questions?

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Appendix

Wade – Reddy Vapor Generation Eqn.

$$TVG = A\, e^{B*RVP} \left(e^{CT1} - e^{CT0} \right)$$

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