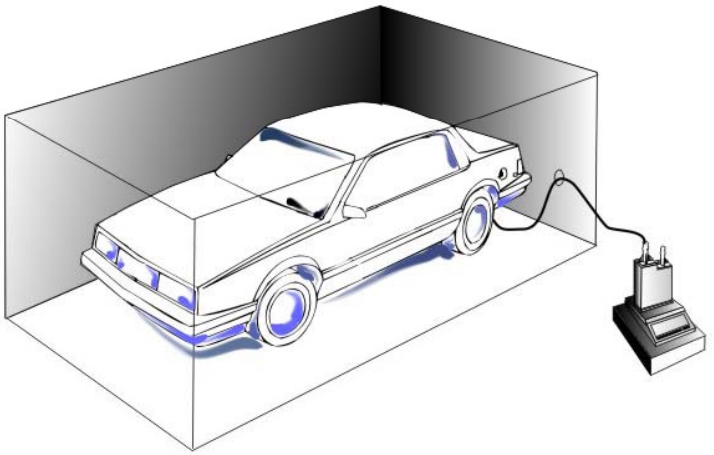
Evaluation of Evaporative Leaks using RSD and Inventory Implications

David Hawkins[1], Constance Hart[1], Carl Fulper[1], David Brzezinski[1], James Warila[1], James Sidebottom[2], James Kemper[2], Sandeep Kishan[3], Timothy H. DeFries[3],

1 U.S. Environmental Protection Agency, Office of Transportation and Air Quality, 2000 Traverwood Drive, Ann Arbor, MI 48105

2 Colorado Department of Public Health and Environment (CDHPE), 4300 Cherry Creek Drive South, Denver, Colorado 80246

3 Eastern Research Group (ERG), 3508 Far West Blvd, Suite 210, Austin,TX 78731



Background

- MOVES evaporative rates in need of update
  - New Fuels
  - New Control Systems
- CRC E-77 suite of programs has addressed the need for lab data on aging enhanced-evap emission vehicles with different fuels and implanted leaks
- Missing piece is how many “high” evap vehicles exist in the fleet

Project Goals

- Develop cost-effective, non-intrusive, reliable measurement tools for large volume of vehicles in field
  - RSD as screening method
  - Portable SHED (PSHED)
  - Identify leak source(s)?
- Better characterize the evaporative emissions inventory
  - Fraction of “High-Evap” in LD fleet
  - Liquid vs. Vapor Leaks
  - Application to other RSD datasets
  - Update MOVES

Found a Partner with Same Mission

- Discovered Colorado Department of Public Health and Environment (CDPHE) was already working on same issues with RSD's evap detection
- Developed Cooperative Research And Development Agreement (CRADA) to partner together in project development

Project Design

- RSD Screening Development
  - How to recruit?
- RSD Measurement Development
  - Pretesting at known speeds, leak rates, and exhaust HC emissions
- Testing Methodology

RSD Screening Development

- Statistical sampling
  - Sampling is biased towards recruiting vehicles identified in higher RSD bins
- Evaporative Index 23 (EI23)
  - Algorithm developed for recruitment
  - “Work in progress”
- Evap Bins (1-8)
  - 1 = lowest, 8=highest

Pretesting: RSD Measurement development

Detecting Propane from Fuel Fill Door: /20 Trials(Audit Truck)

	Evap (scfh propane)	15	4.5	1.5	0.45	0.15
	(~ g propane / 15min)	185	55	19	6	2
	Exhaust HC					
12 mph	0 ppmC3	19	20	12	3	3
12 mph	1100 ppmC3	20	20	17	8	4
12 mph	6015 ppmC3	11	16	3	4	1
34 mph	0 ppmC3	20	15	6	2	1
34 mph	1100 ppmC3	20	15	8	1	2
34 mph	6015 ppmC3	20	6	9	4	3

“High” Evap Testing Methodology

- Testing in Denver, CO
  - Lipan IM station, 2008
  - Ken Caryl IM station, 2009

- Participating vehicles receive:
  - Additional “Hot” RSD readings
  - Modified CA method leak check
    - Handheld HC “Sniffer” Check
  - PSHED for 15 min hot soak

RSD Testing in I/M Lane

PSHED Recovery/Retention

Average Recovery	97.6%
Recovery Std. Dev.	3.3%
Average Retention	95.7%
Retention Std. Dev.	2.3%

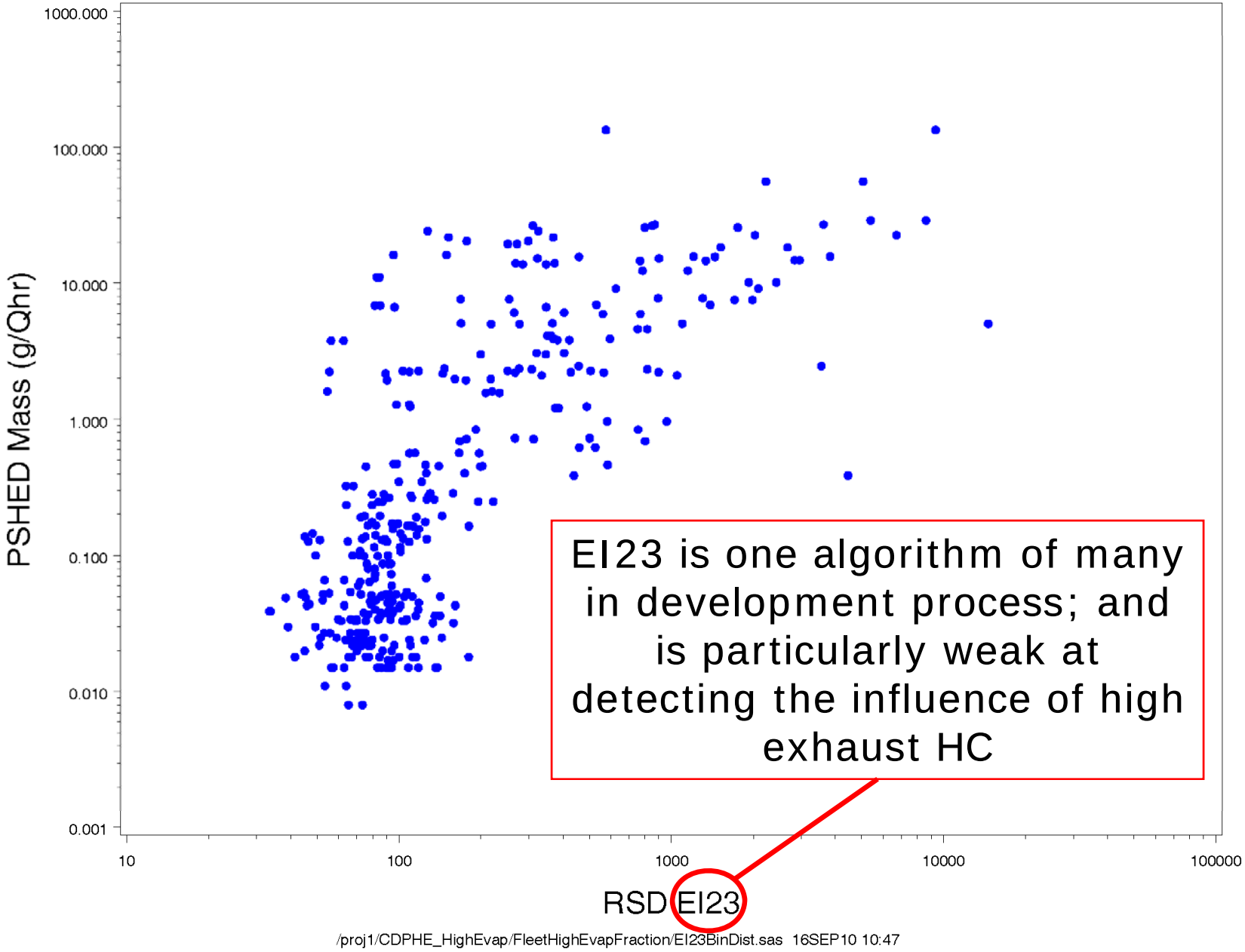
Participation Results at Denver IM Lanes

	Lipan 2008	Ken Caryl 2009
Length of Testing	4 weeks	8 weeks
RSD Data Points (vehicle throughput)	7,011	13,027
Recruited Vehicles	196	558
Participants with PSHED evaluation	87	175
Acceptance Rate	44%	31%

Field Testing Analysis Parameters

- Ultimate goal is to relate RSD scores to evap leaks
- Initially classified .3g/15min PSHED as a “high” evap vehicle
  - Evap standard = 2g = Hot Soak + Diurnal
    - Assume 20% (.4g) attributed to Hot Soak
    - Assume 75% of that (.3g) is in first 15 min
- RSD scores stratified into 8 bins to describe emissions spread

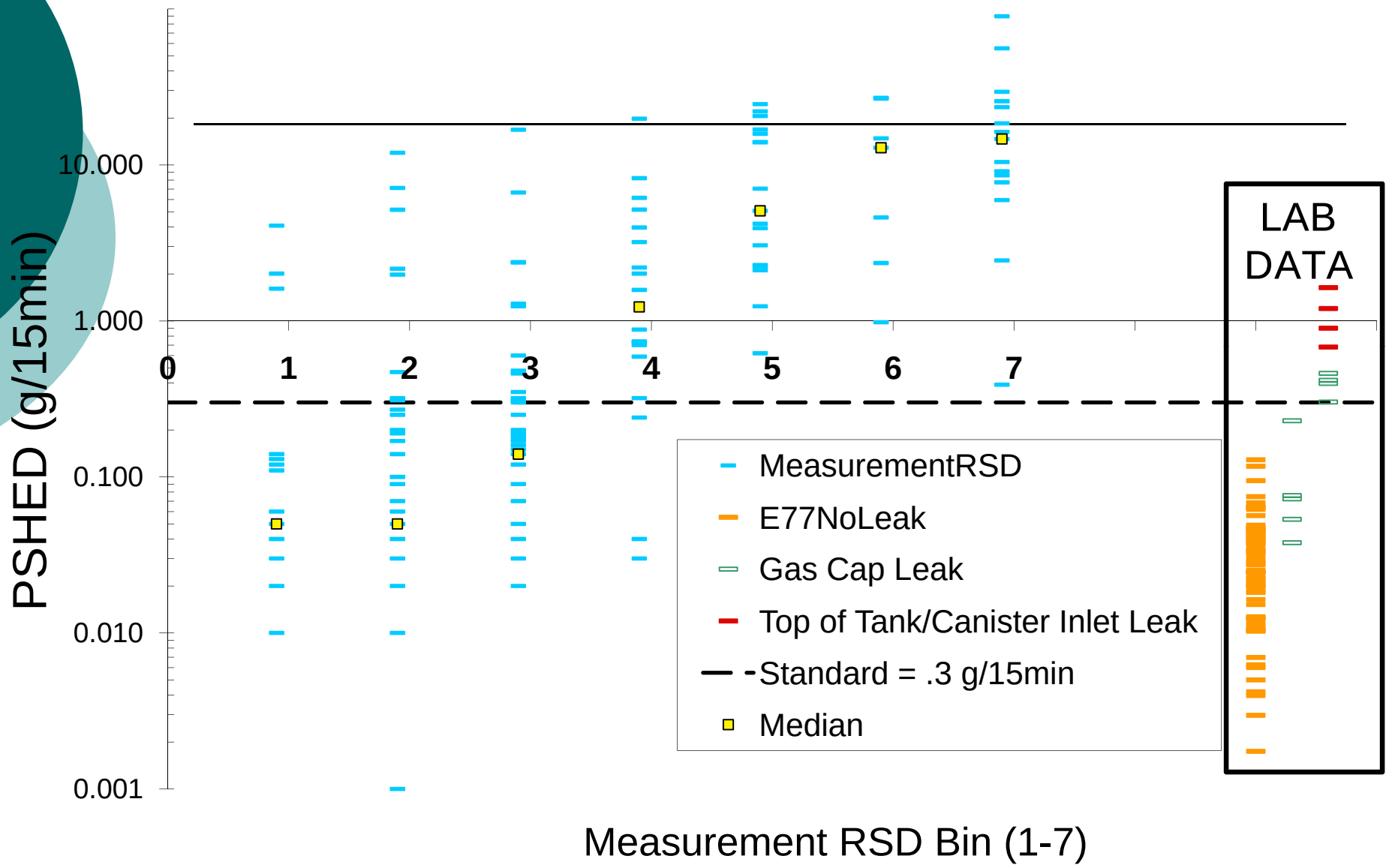
PSHED vs. EI23 for the Stratified Set



Known Issues with RSD

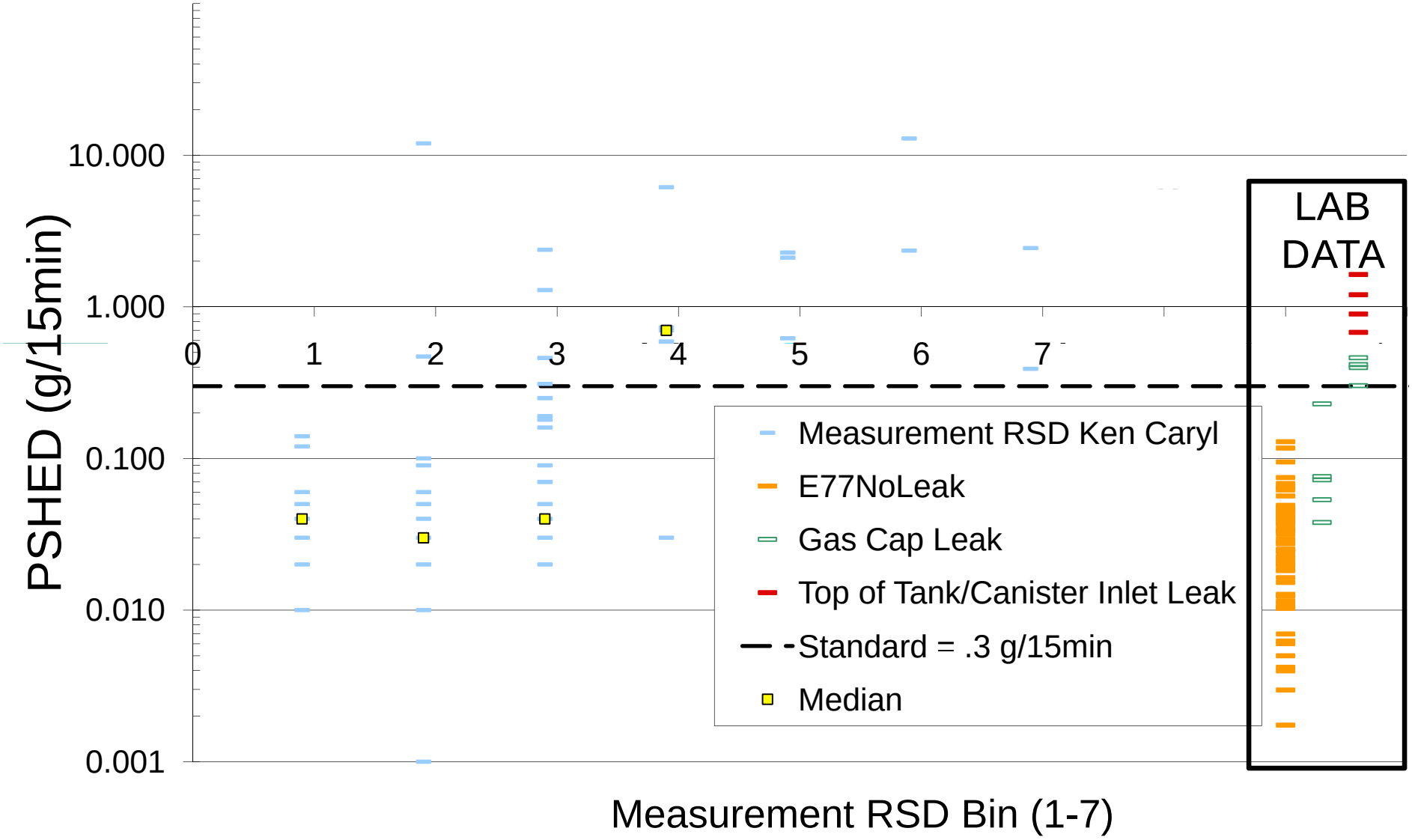
- Confounding factors
  - Noise (variability)
  - Exhaust HC
  - Vehicle Speed
  - Environment

PSHED vs E-77 (Lab Hot Soak)



Note: Vehicle condition not reconciled with data shown (ie not checked against surveys on recent refueling, oil changes, fluid fills, or source of leaks).

PSHED vs E-77 (Hot Soak) 1996 & later



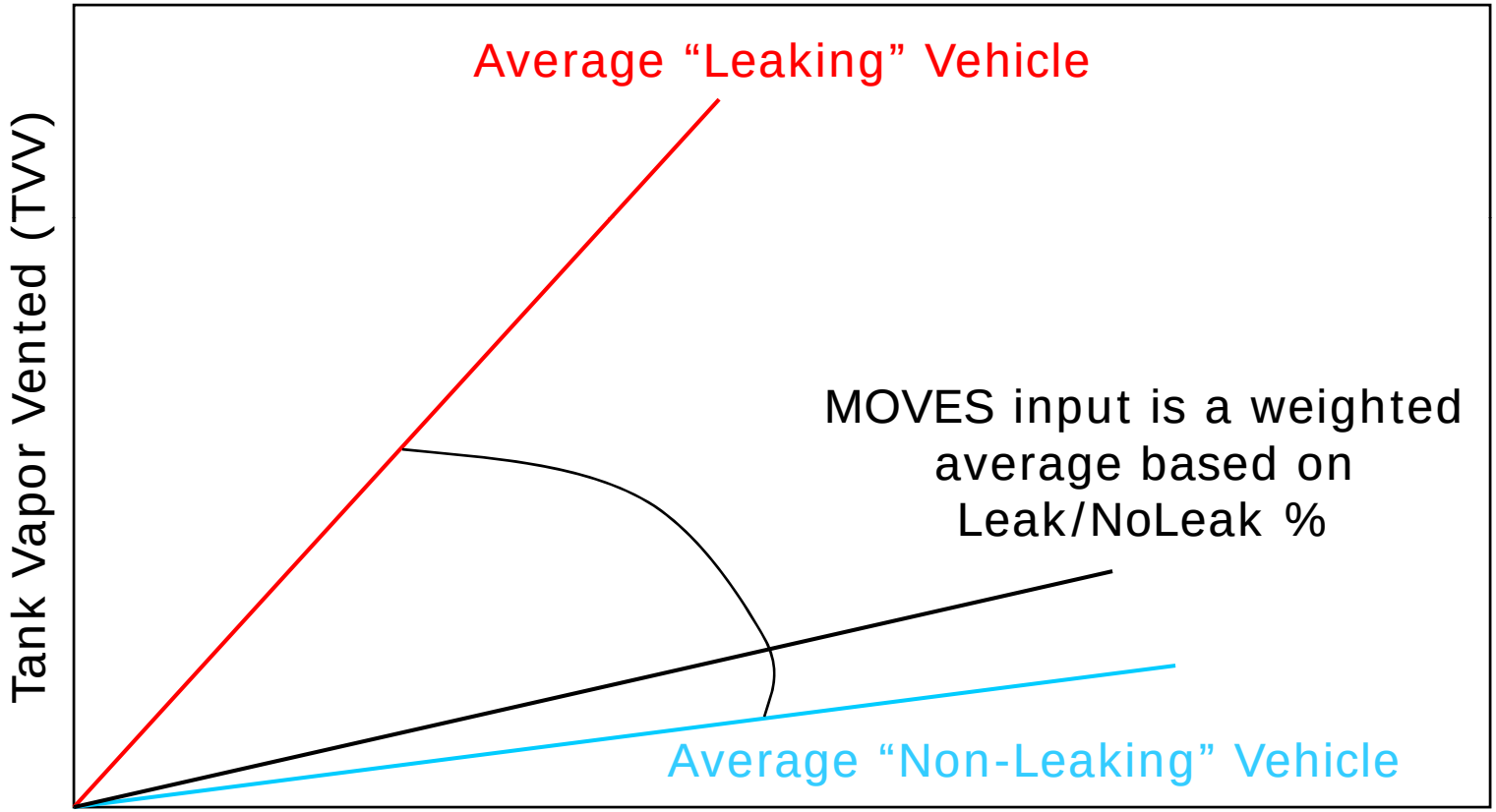
Note: Vehicle condition not reconciled with data shown (ie not checked against surveys on recent refueling, oil changes, fluid fills, or source of leaks).

Pilot Analysis & Comparison to MOVES

- DraftMOVES
  - Rates for leaking/non-leaking
    - Historical CRC diurnal testing
  - % of leaking/non-leaking in fleet
    - Historical IM database OBD failure codes

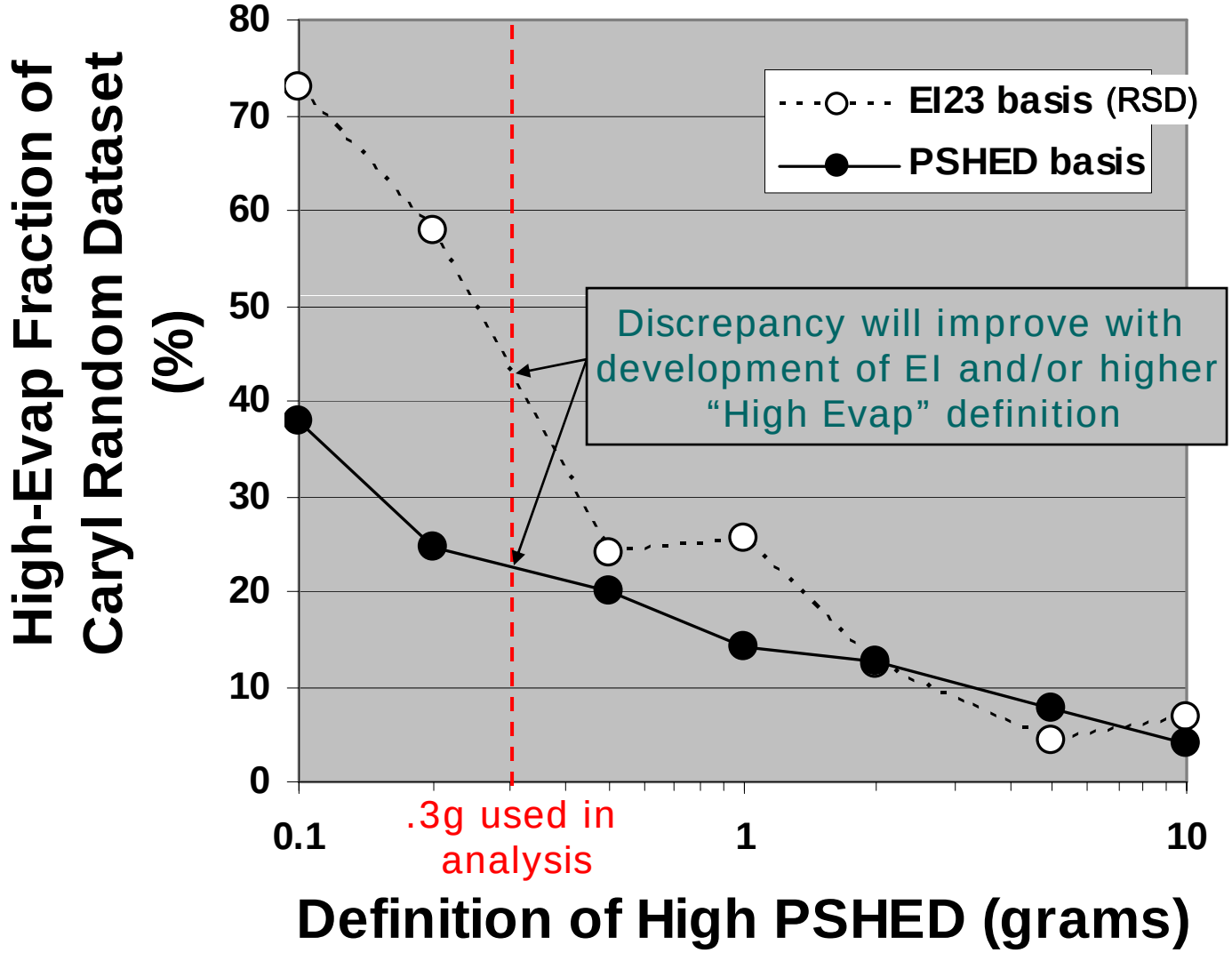
- Preliminary comparison of E-77 to DraftMOVES
  - Rates for leaking/non-leaking
    - E-77-2 programs diurnal testing
  - % of leaking/non-leaking in fleet
    - Preliminary analysis of Colorado Program
      - Reconstructed population from PSHED participants
      - Real population of fleet driving by RSD (EI23)

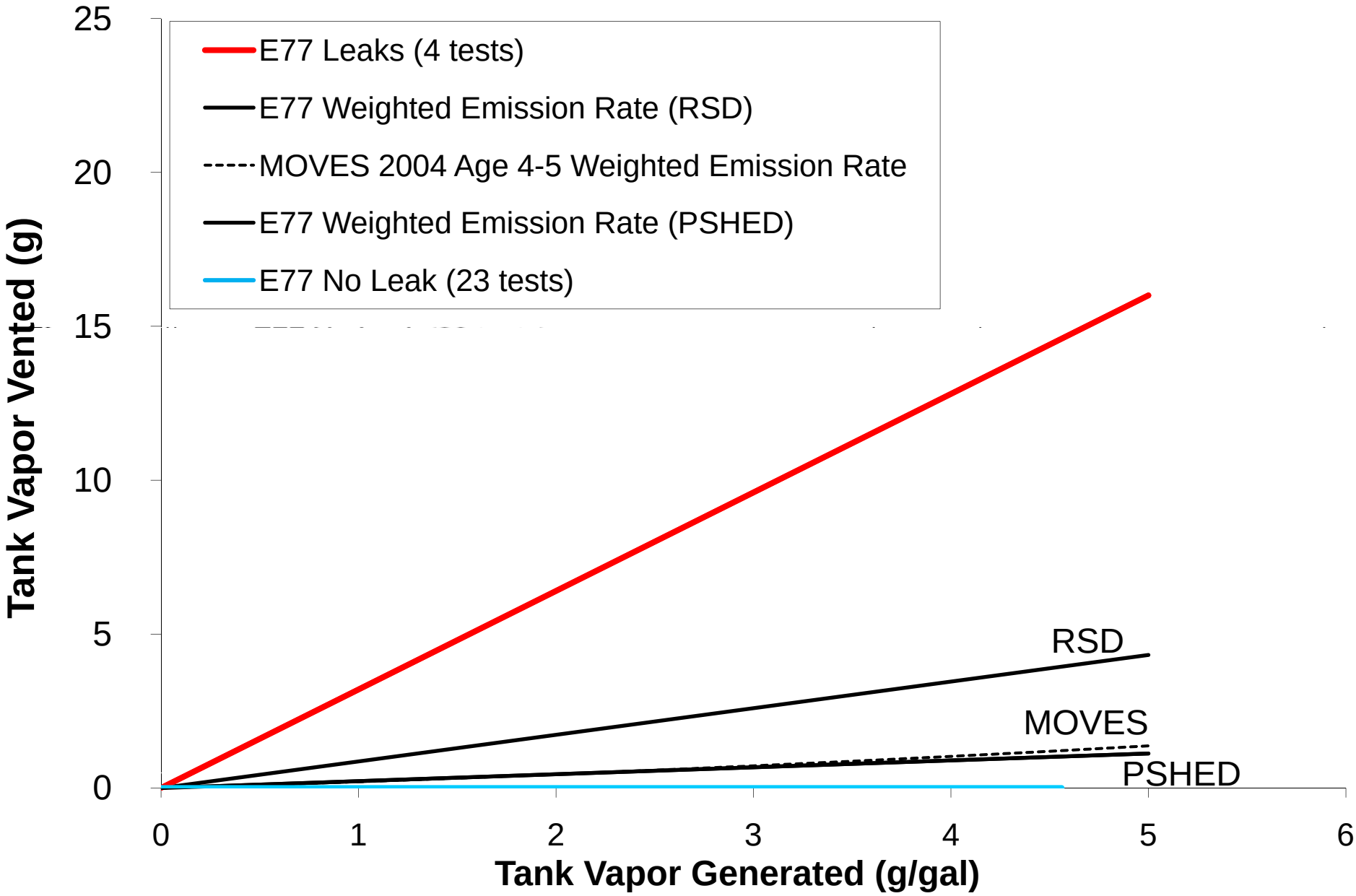
How Vapor Leaks are modeled in MOVES

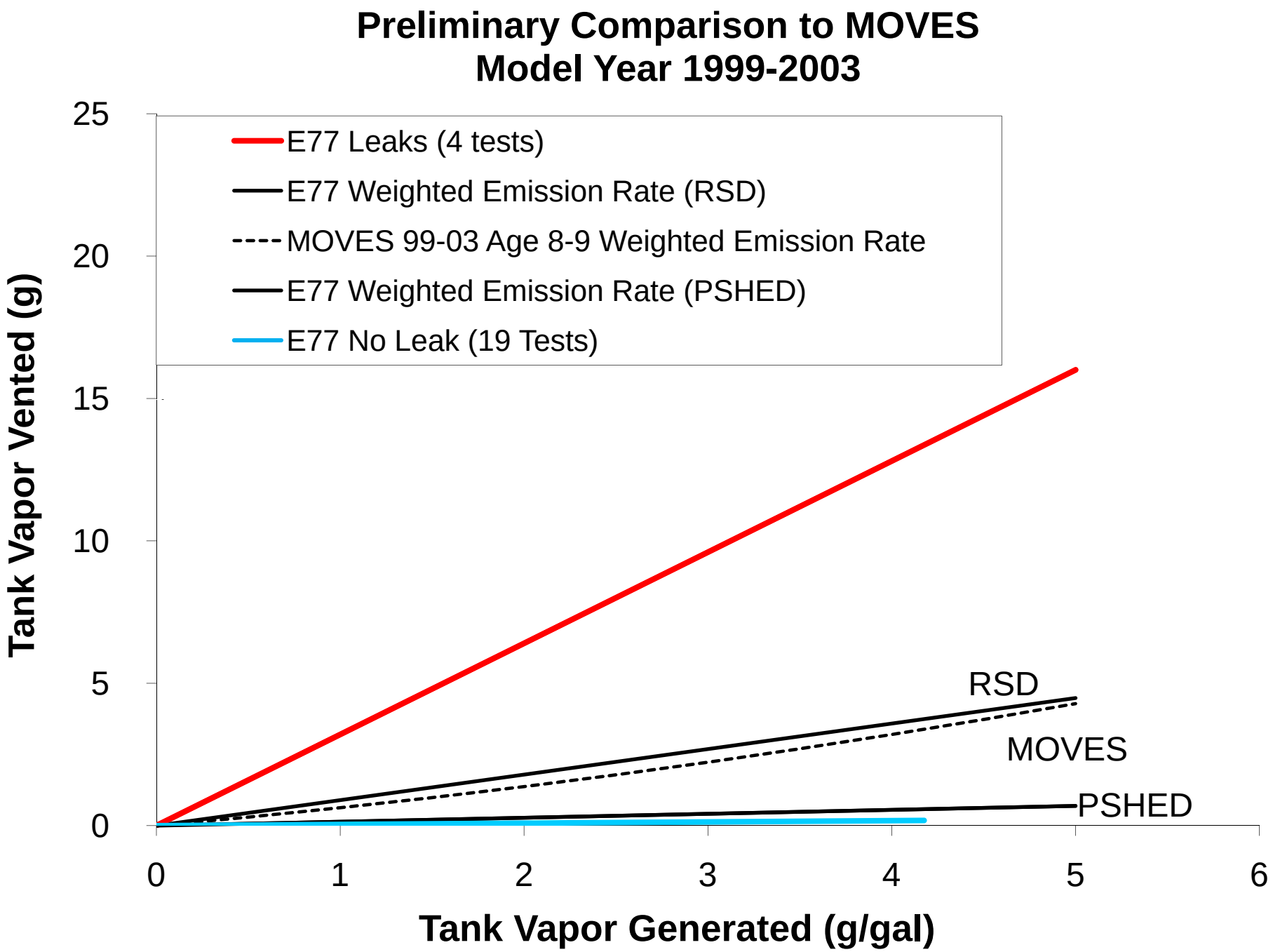


Function of Fuel RVP and Temperature

Probability of "HighEvap" Summer2009 Ken Caryl IMStation RSD to PSHED model




Preliminary Comparison to MOVES
Model Years 2004+
E77 Leaks (4 tests)
E77 Weighted Emission Rate (RSD)
MOVES 2004 Age 4-5 Weighted Emission Rate
E77 Weighted Emission Rate (PSHED)
E77 No Leak (23 tests)
Tank Vapor Vented (g)
Tank Vapor Generated (g/gal)
RSD
MOVES
PSHED
0
5
10
15
20
25
0
1
2
3
4
5
6


Preliminary Comparison to MOVES
Model Year 1999-2003
E77 Leaks (4 tests)
E77 Weighted Emission Rate (RSD)
MOVES 99-03 Age 8-9 Weighted Emission Rate
E77 Weighted Emission Rate (PSHED)
E77 No Leak (19 Tests)
Tank Vapor Vented (g)
25
20
15
10
5
0
RSD
MOVES
PSHED
0
1
2
3
4
5
6
Tank Vapor Generated (g/gal)

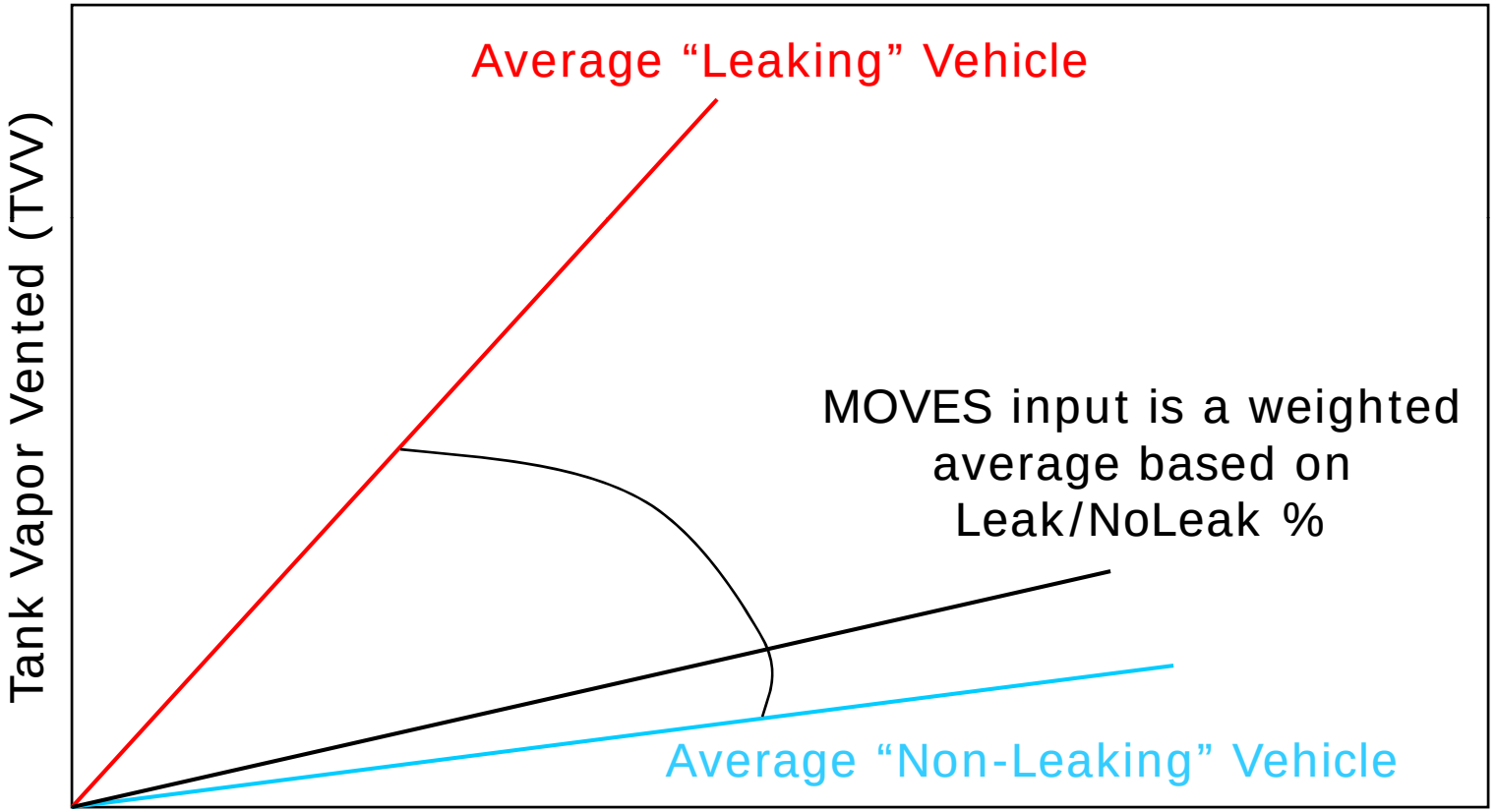
Colorado Summer 2010

- Development of z-score index
  - Vehicles have multiple RSD readings
  - **Can use** RSDs taken at high speeds!
    - But, lower speed RSDs have more influence
- Vehicle Testing
  - PSHED at tech center
  - LSHED/6-hour Diurnal at Aurora Lab
    - Measure real world leak behavior in diurnal!

MOVES Summary

- MOVES is being developed along with RSD methodology
- MOVES inputs
  - Curve for “non-leaking” vehicles
    - Calculated from Diurnal test data
  - Curve for “leaking” vehicles
    - Calculated from Diurnal test data
  - Fraction of “leaking” vehicles
    - Will be used to weigh both curves together
    - As RSD indices improve, this fraction can be measured with RSD data

How Vapor Leaks are modeled in MOVES



Function of Fuel RVP and Temperature

Next Steps

- Predictive Analysis Tools, Further Analysis:
  - Use RSD data sets to predict fraction of high evap in a metropolitan area
  - Do candidate RSD data sets exist within the limitations of the measurement capabilities?
  - How do the PSHED results relate to OBD evap codes and can we make a link between RSD and OBD from this?
- CDPHE Summer 2010 High Evap Testing
  - Develop z-score RSD index
  - Analyze PSHED/LSHED data for use in MOVES

Questions?