



Smog Check Technology Forum & Round Table

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RSD Technical Feasibility

Peter McClintock Ph.D., Applied Analysis
Haj Vescio, General Manager, ESP

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South Coast Air Quality Management District





Presentation Outline



- Smog Check Challenges:
 - High Emitters
 - High Re-fail Rate

- RSD as Part of the Solution:
 - RSD Light Duty Applications
 - Identifying Active High Emitters
 - Sites
 - Cost Effectiveness
 - Influencing Vehicle Owner Behavior
 - HD Applications
 - Developments



High Emitters



- Majority of repairable emissions are found in a few vehicles

- 10% of vehicles have been responsible for three-quarters of excess HC + NO_x:
 - 73% - California roadside 1997-1998 ASM;
 - 75% - Sacramento 1994 Study IM240;
 - 76% - Phoenix I/M 1998 IM240/147.

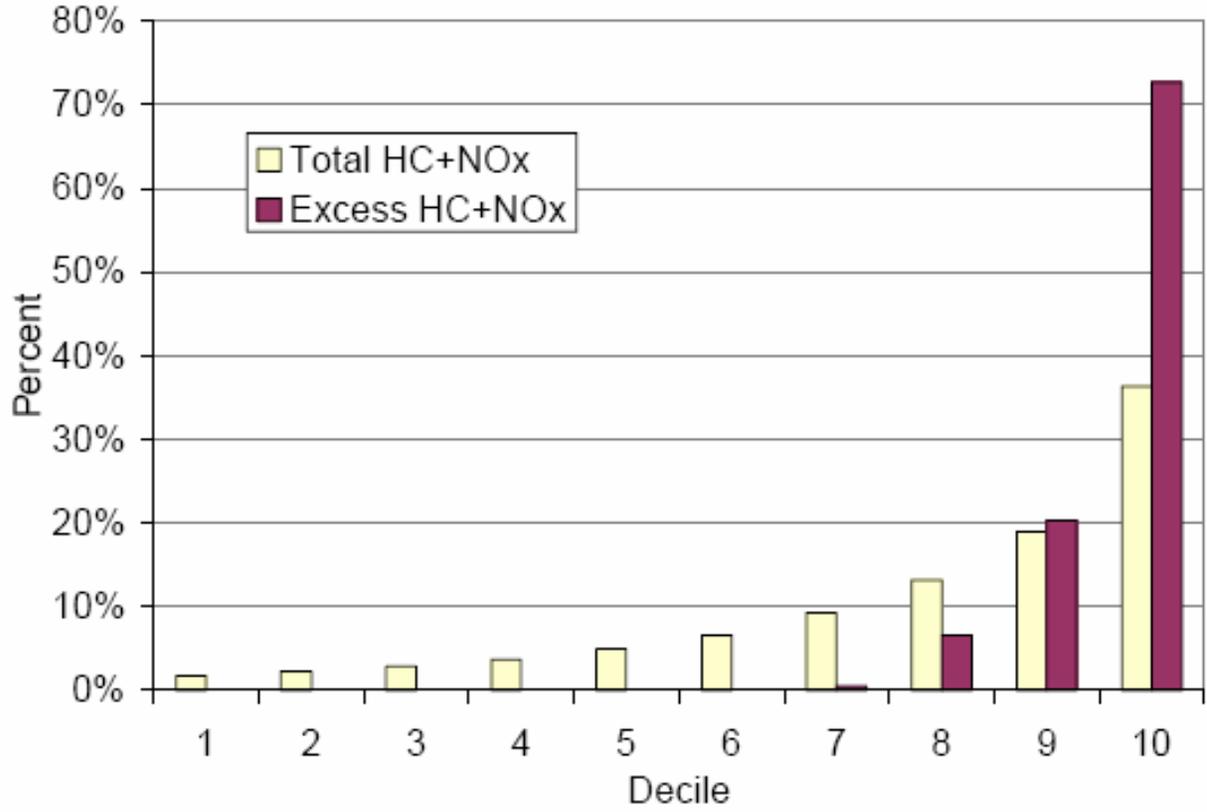


High Emitters

IMRC 2000: California roadside 1997-1998 ASM:



Figure 11. Distribution of Total and Excess HC+NOx Based on Roadside ASM Data Converted to FTP Equivalents





High Re-Fail Rate



- ARB 2004 Evaluation of Smog Check, page 41:
“based on roadside data collected in 2001, 40.4 percent of the repaired vehicles tested failed the subsequent roadside test.”
- October 2006 IMRC Presentation, Phil Heirigs (draft):
40% of Repaired Vehicles Fail Roadside ASM Soon After Smog Check;
18% of Passing Vehicles Fail Roadside ASM Soon After Smog Check;

Potential Smog Check Benefits May be Twice Those Being
Achieved?



High Re-Fail Rate



Speculative Causes of Re-fail Rate:

- Coaxing Vehicles to Pass:
 - Vehicle variability – is it hot enough?
 - Tuning to Pass ASM mode
 - Use of fuel additives
 - Tampering or replacement of parts
- Improper inspections
- Short lived or incomplete repairs:
 - Repair to standard rather than full repair
 - root causes not fixed
 - inferior components



High Re-fail Rate



- Roadside fail rates are high right after Smog Check.
- Mandatory Smog Check fail rates are low – especially for older vehicles.
- Annual inspection of older vehicles may help but will not resolve all the issues.

Additional tools would be helpful.



RSD: Light Duty Applications

Typical RSD Set-up:





RSD: Light Duty Applications

➤ RSD Programs Operating in the US:



Location	Application	First Started	2006 Active Units	2006 Valid Measurements ('M)
Colorado	Clean Screen evolving to High Emitter	2001	8	3.1
Missouri	Clean Screen	2000	4	2.6
Texas	High Emitter	1998	7	6.0
Virginia	High Emitter	2006	2	0.5

- International RSD programs:
- Taiwan – annual high emitter survey and off-cycle testing.
 - Korea – active correlation pilot for 2009 program.
 - Hong Kong – active pilot HEI program for 2008 program.
 - Juarez, Mexico – active HEI enforcement program.
 - Austria – Heavy duty truck HEI (particulates) starting in 2007.



RSD: Light Duty Applications



- Strengths:
 - Independent - measures vehicles on-road, unprepared in normal operation, regardless of registration status
 - Convenient - no interference to vehicle owner
 - Relatively inexpensive

- Challenges:
 - On-road environment, ambient conditions
 - Short test under variable real-world conditions
 - Variability of high emitters themselves
 - Get beyond being compared to a 'bronze' standard (ASM)

- Sites



RSD: Identifying High Emitters

Reliably identifies the worst on-road high emitters in pull-over studies.

1989 Lynwood:

86% of vehicles with RSD >2% CO failed roadside inspection

1996 Orange County SCAQMD/DRI:

95% of vehicles with RSD >4% CO or 1,000 ppm HC failed IM240

2001 BAR:

83-88% of vehicles with RSD >2% CO or 1000ppm HC or 1,500 ppm NOx failed roadside ASM

92% w/ 2 observations with RSD >2% CO or 1000ppm HC or 1,500 ppm NOx failed ASM

2004 ARB/BAR:

“For some vehicles, RSD cutpoints can perfectly predict ASM failure (i.e. approximately the highest 3% of RSD readings). ERG, 2006 CRC

The logo for ESP, consisting of the letters 'e', 's', and 'p' in a stylized, lowercase font, set against a yellow square background.



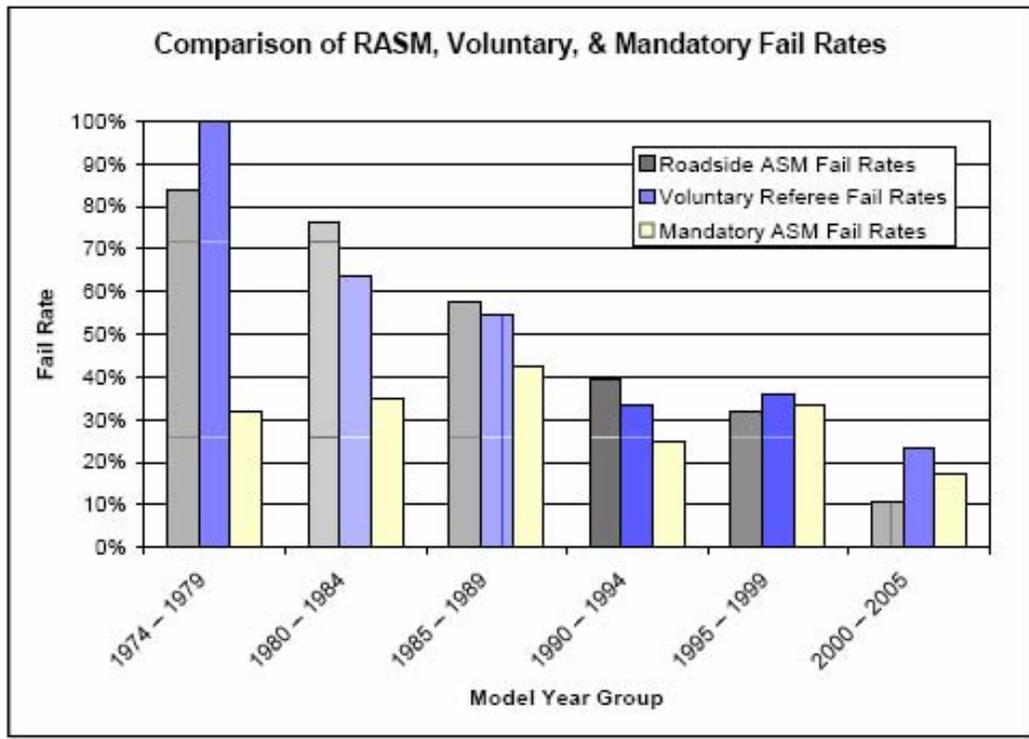
RSD: Identifying High Emitters

Andrew Burnette, ERG 2006 CRC, Impact of VSP Filtering on RSD
Prediction of Roadside ASM Failure:



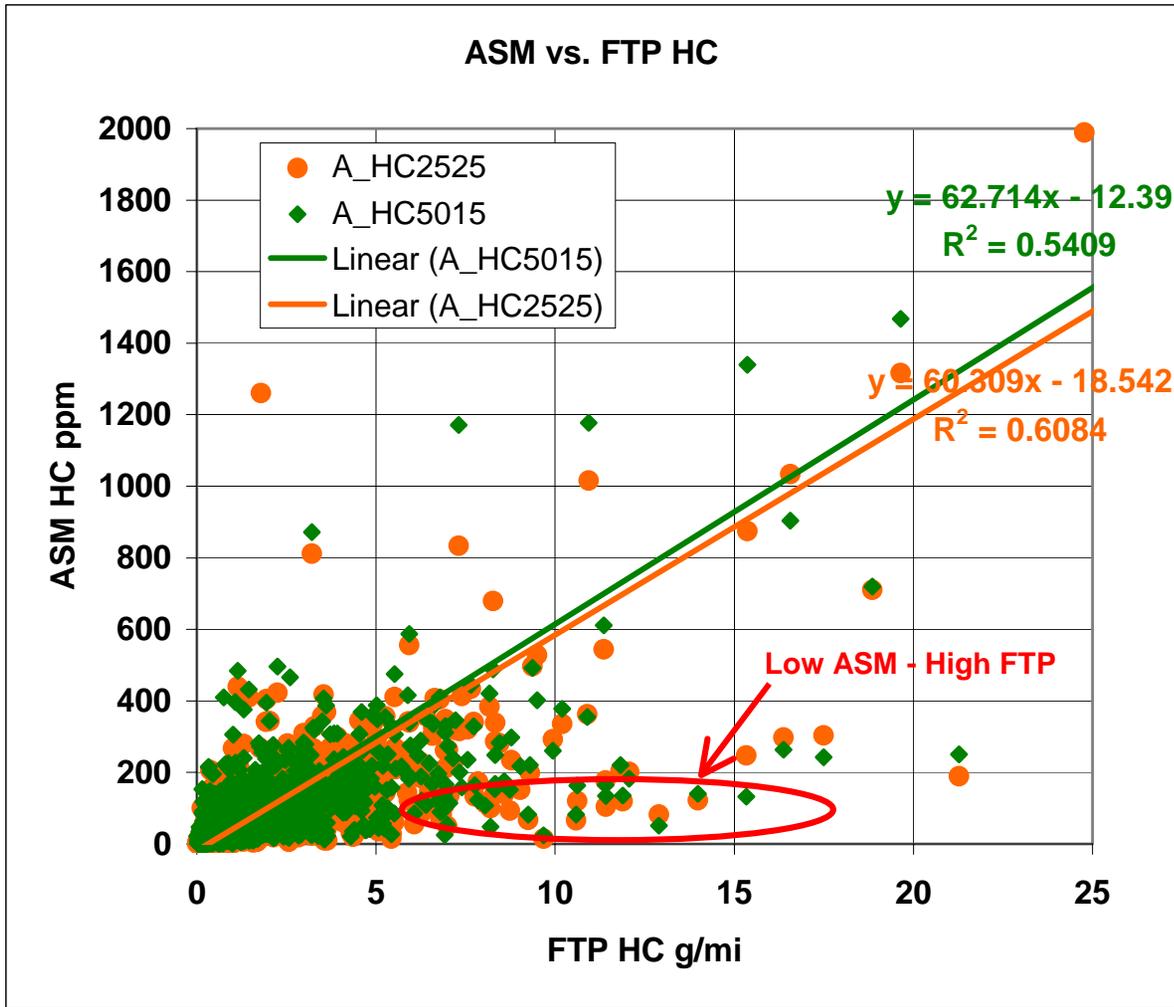
Fail Rate Comparison Graph

RASM and Voluntary results agree with each other, but disagree with Mandatory results for older vehicles.





RSD: Identifying High Emitters



ARB/BAR FTP-ASM Dataset ~ 2,000 Vehicles (some off-chart)

ASM is not a perfect test.

Some high emitters have low HC on ASM



RSD: Identifying High Emitters



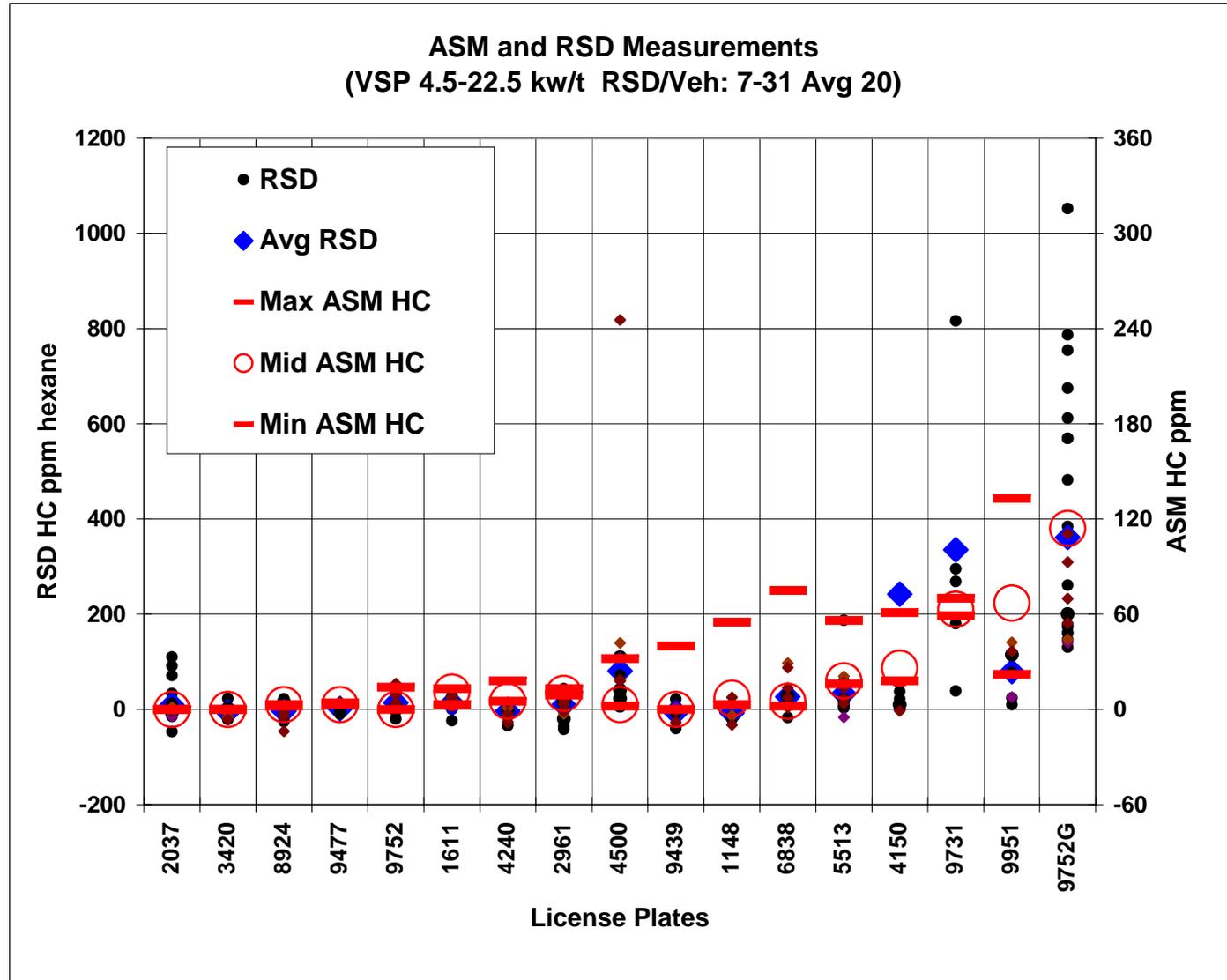
- Following slides show ASM and RSD results for 16 vehicles:
 - Korean vehicles MY 1993-2000
 - 3 ASM tests in succession after 30 minute warm up
 - Multiple RSD measurements: different speeds with and without acceleration
 - Last vehicle has catalytic converter removed

- Clean vehicles are normally clean under virtually all operating modes.

- Marginal vehicles have much more variable emissions.



RSD: Identifying High Emitters HC





RSD: Identifying High Emitters



➤ Observations on HC slide:

- RSD measurements: range of speeds and accelerations
- Variability in ASM and RSD
- Most vehicles clean on ASM and RSD
- First ASM is sometimes higher
- Higher ASM higher RSD
- Vehicle 9951: variable ASM, clean on-road
- Vehicle 9752G without catalytic converter – higher on RSD and ASM



RSD: Identifying High Emitters

Comments on NO_x slide:



- RSD NO_x varies with engine power or VSP
- Clean vehicles: low RSD NO_x across the power range
- Higher ASM NO_x, higher RSD NO_x
- Four vehicles 'passed' ASM right at the standard
- 9752G no cat: consistently high RSD NO_x
- VSP effects less important than catalytic converter



RSD: Identifying High Emitters



- Variable emissions in the normal operating range indicate:
 - Poor fuel/air control, or
 - Inefficient catalytic converter

- ASM results don't provide a very accurate indication of drive-cycle emissions: fast-pass, conditioning of dirty vehicles

- 'False fails' inevitable if RSD compared to 'bronze' ASM:
 - plan accordingly
 - diagnose the vehicle

- Most vehicles with variable, high emissions could benefit from repair even if they can be coaxed into passing ASM



RSD: Sites



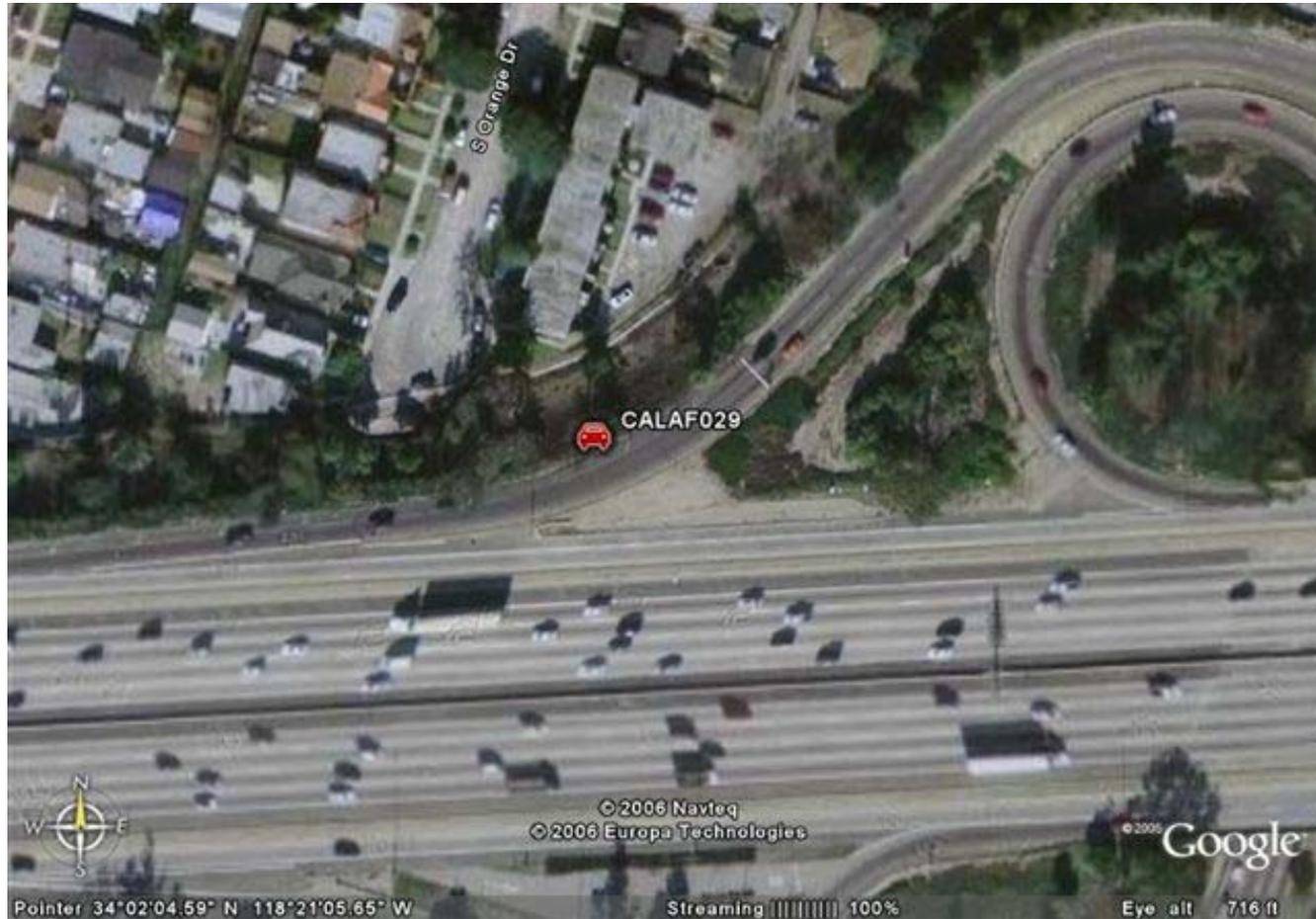
- Mostly highway on-ramps:
 - Vehicles are warmed-up
 - Most vehicles in the correct power range
 - Metered ramps are good after the meter
 - Two lanes often merge to a single lane

- SC AQMD:
 - Preliminary 120 sites identified
 - Traffic counts indicate productivity similar to Texas
 - 2004/5 CalTrans 10am-3pm restrictions being addressed
 - First round of AQMD on-ramp permits approved for full-day operation



RSD: Sites

Typical metered site:





RSD: Cost Effectiveness

Cost to identify & recruit high emitters:



- RSD cost to measure unique vehicles - \$1.00 - \$2,00
 - AQMD project ~ \$1.25
 - Texas ~\$1.60
 - Virginia ~\$2.00

- **\$320** SC AQMD RSD VAVR/VRV **3% Dirtiest**
 - 20% recruitment
 - \$220 - RSD identification (\$1.25/ 3% fail /20%)
 - \$100 - Recruitment, testing, processing

- **\$155** Mandatory RSD High Emitter **3% Dirtiest**
 - 80% Compliance

- **\$337** Smog Check **Average** High Emitter
 - 2005: \$49 fee / 14.5% fail rate



RSD: Cost Effectiveness



- On its face, 3% RSD high emitter program has lower costs and greater emission reductions per vehicle than Smog Check

- Benefits issues:
 - What is 'incremental' with 40% re-fail rate?
 - Mass emissions of very high emitters underestimated by published ASM-FTP equations
 - Vehicles measured on-road have higher VMT than others of same model year



RSD: Cost Effectiveness



- AQMD High Emitter VAVR/VRV:
 - ❑ AQMD estimate:
 - VAVR \$8,000-\$14,000 per ton (HC + NOx)
 - VRV \$12,000 per ton (HC+NOx)

 - ❑ ESP combined estimate \$6,000 - \$12,000

- ValleyCAN Tune-In and Tune-Up
 - Doug Lawson \$8,700-\$14,900 per ton
 - Not including evaporative reduction benefits



RSD: Influencing Owner Behavior



- RSD On-Road High Emitter Program:
 - Deters tampering or replacement of parts for I/M test
 - Deters improper inspections
 - Deters non-compliance
 - Encourages prompt maintenance
 - Encourages complete repairs
 - Encourages correct registration (~3.5% unregistered¹)

- Hidden benefits are likely to exceed measured benefits

Also:

Provides data for fleet monitoring and detailed program evaluation.

¹ Younglove T, et al, "Unregistration Rates for On-road Vehicles in California", Journal of Transportation and Statistics V7, 2004



RSD: Heavy Duty Applications



- Characterize on-road HD fleet performance
 - Cross-border study at Nogales, Arizona
- Fleet Maintenance Monitoring
 - Massachusetts Bay Transportation Authority – bus fleet
- Select vehicles for HD inspection and priority retro-fit
 - Austria - On-road monitoring and pull-over
- HC, CO, NOx and PM
- RSD Smoke Channel:
 - UV wavelength responsive to PM2.5
 - PM mass per unit of fuel (or brake horsepower hour)
 - Easy translation to inventory and cert standards
 - RSD -> 2004 lab correlations at CE-CERT/WVU

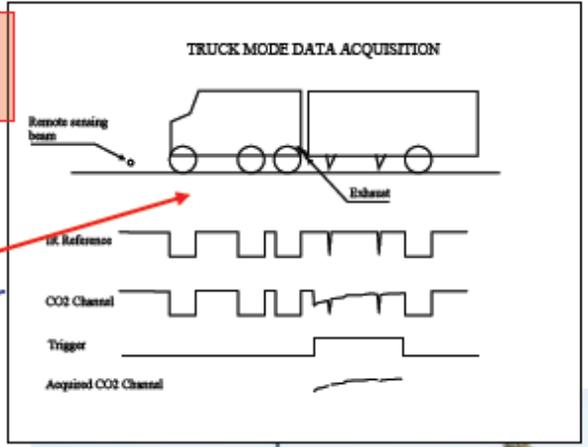


RSD: Heavy Duty Applications



Low Exhaust Pipe Vehicle

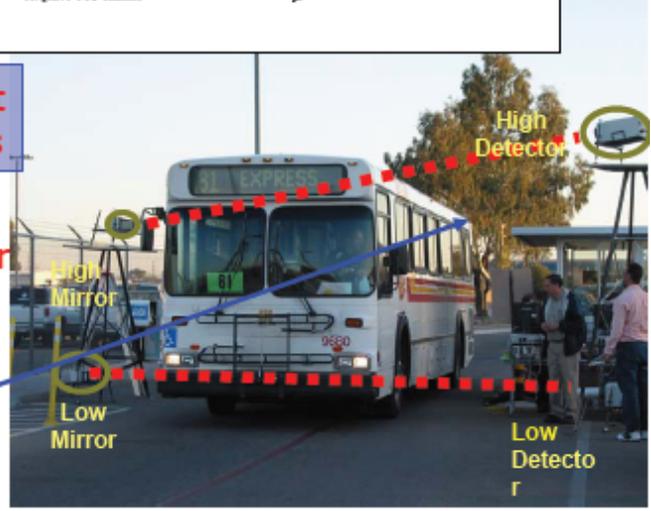
Measure Under Trailer



High Exhaust Pipe Vehicles

Measure Over Trailer

Measure Behind Bus



High Detector

High Mirror

Low Mirror

Low Detector



RSD: Developments

Goal: Lower cost measurements



- RSD 5000
 - Unattended, battery
 - Small footprint (no van)
 - Wireless monitoring

- Two-lane monitoring with vehicle separation detection



Thank You.