HEAVY DUTY OBD UPDATE

Thomas Montes
Manager, Diesel OBD
Emissions Compliance, Automotive Regulations & Science
California Air Resources Board

SAE 2015 On-Board Diagnostic Symposium

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SAE INTERNATIONAL

California Environmental Protection Agency
Air Resources Board

HD OBD - Agenda

- Standardization: New Datastream Parameters
- Manufacturer Self-Testing
- PM Filter Monitoring Requirements
- J1939-84 Progress
- Case Study on Monitoring Robustness vs. Monitoring Frequency…continued
- Reducing In-use NOx Emissions from HD vehicles
  - What role can HD OBD play?
- Innovative Technology Regulation Background/Introduction

HD OBD - Agenda

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HD OBD - Standardization Requirements

New Datastream Parameters

- Engine Reference torque (PID $63/SPN 544)
- Friction Losses (PID $8E/SPN 514)
- Parasitic losses (PID $?/SPN 2978)
- Actual Engine Percent torque (PID $62/SPN 513)…*already in regulation*
- DEF dosing *% Duty Cycle* (PID/SPN ?)
- DEF dosing rate in ml/sec (PID/SPN ?)
- Cylinder fuel rate in mg/stroke (PID A2/SPN ?)
- Engine fuel rate in g/s (PID 9D/SPN ?)
- Vehicle fuel rate in g/s (PID 9D/SPN ?)
- NOx sensor correction in ppm (PID A1/SPN ?)

Proposal to add requirement to verify that net brake torque measured on engine dyno is equivalent to net brake torque calculated using scan tool output during DDE testing

HD OBD - Standardization Requirements

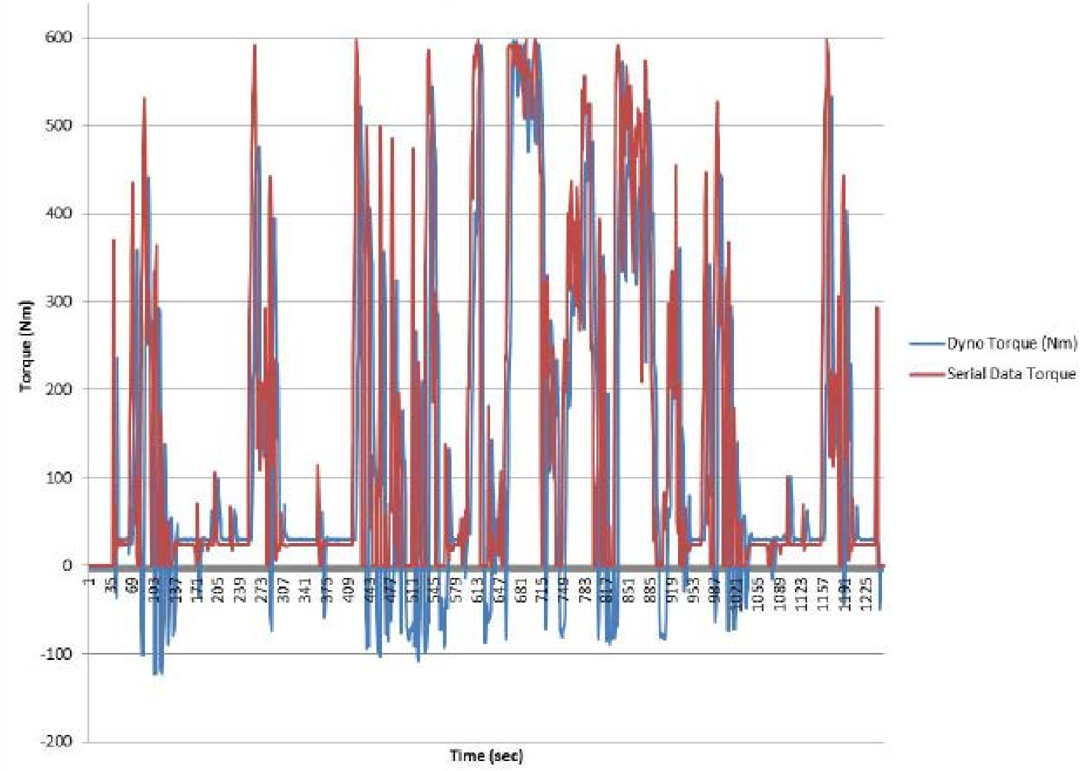
Engine Dyno/Scan Tool Torque Comparison over FTP & SET

Engine Dyno Cycles FTP/SET:

Plot Net Brake Torque as measured by engine dyno, and

Plot Scan Tool Torque Output; where, Net Brake Torque = $63 * ($62 - $8E)

Objective: verify that these data agree and that parasitic losses are *not* included in friction losses to support valid torque data for PEMs emission testing.



HD OBD - Standardization Requirements

Engine Dyno/Scan Tool Torque Comparison over FTP & SET (cont.)

Parasitic losses should *not* be included in torque output used for PEMS emission measurements

WRONG: Net Brake Torque = $63 * ($62 - $8E - parasitic) ….biased-HIGH PEMs emissions

WRONG: Net Brake Torque = $63 * ($62) ….biased-low PEMs emissions

CORRECT: Net Brake Torque = $63 * ($62 - $8E) ….valid PEMs emissions ✓

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HD OBD - Manufacturer Self-Testing

Background

- Section 1971.5 (c)
- Manufacturers are required to procure high mileage vehicles (70 to 80% FUL) and verify MIL illuminates for all monitors in sections (e) through (g) before emissions exceed the malfunction criteria (e.g., fuel system, misfire, EGR,…)

Current Requirement

- For 2013 model year and subsequent, testing required each model year
  - Test one engine rating: if certifying one to five engine families
  - Test two engine ratings: if certifying six to ten…
  - Test three engine ratings: if certifying eleven or more…

HD OBD - Manufacturer Self-Testing cont.

Timeline for submission of data

- Testing shall be complete within three calendar years after the model year of the engine
- For the 2013 model year and subsequent, manufacturers shall complete testing and submit report complete by end of 2016 calendar year; 2014 model year complete by 2017 calendar year,…
- Report of results shall be submitted 30 days after completing testing

Manufacturers should present their 2013/14/15 MY engine ratings to staff for selection as soon as possible (21 months left until 2013 MY deadline)

ARB Staff plan to be present to witness testing

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HD OBD - PM Filter Monitoring Requirements

HD OBD Regulation removes the failure mode exemption (FME) for the 2016 and subsequent model years

- All failure modes required to be detected before exceeding OBD threshold
- Empty can demonstration is not always worst case for emissions
- Partial melting/partial cracking has shown higher emissions
  - Emissions data required for this failure mode from manufacturers not planning to implement a PM sensor
- Thresholds for 2016 MY: 0.03 g/bph-hr or +0.02 g/bhp-hr PM emission standard

HD Regulation removes 800-minute (500-mile) denominator for the 2016 MY for PM filter monitoring

- Manufacturers required to use general denominator and meet 0.1 in-use monitoring frequency ratio

HD OBD - PM Filter Monitoring Requirements

ARB prohibited from granting deficiencies and certifying engines that meet the mandatory recall criteria in section 1971.5

- Emissions greater than 3 x OBD threshold
- Rate-based data less than 33% of the 0.1 ratio
- Section 1971.5 (d)(3)(A)(vi)(b) …failure to detect any malfunction of the PM filter (e.g., partial melting/partial cracking) that causes PM emissions to be equal to or greater than the emission level of the engine with the PM filter completely removed
- Deficiency Provision: Deficiencies are issued based on good-faith effort to meet the requirements of the regulation. Part of meeting the good-faith effort means the manufacturer use the best available monitoring technology to meet the requirements of the regulation. In essence, this means using a PM sensor to detect all possible DPF failure modes before emissions exceed the OBD threshold or, if using a delta-pressure sensor, demonstrating that PM emissions are less than the OBD threshold for all possible failure modes of the DPF, including partial melting/partial cracking.

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HD OBD - J1939-84 Compliance Testing

Still seeing many failures in log files

- timing errors
- mapping of DM30 scaled test results not correct
- OBD modules reporting that they are non-OBD modules
- message requests timed out with no response
- Permanent DTCs in DM 28 do not match DTCs in DM 12

OBD Staff directed to review -84 logfiles and work with manufacturers to come into compliance as soon as possible

- Deficiencies issued for manufacturer non-compliance with J1939 specification

New version 2.0 of J1939-84 just released on sourceforge.net

- All future submissions should be conducting using this latest version

HD OBD - J1939-84 Compliance Testing

Manufacturers should submit supporting report to explain all failures of J1939-84 testing

- **Report should include**
  - Year/make/model of vehicle tested
  - Table with headings:
    - Identification of failure
    - Root cause of failure
    - Relevant OBD regulation/section
    - Manufacturer System Compliance: yes/no
    - Detailed explanation of the issue:
      - J1939-84 implementation or manufacturer issue
    - How will the issue be resolved
    - When will the issue be resolved

Based on J1939-84 compliance to date, still much work to be done before staff can start grouping/reducing test requirements

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HD OBD - Case Study: Monitor Robustness vs Frequency

What must to be considered in monitor design?

1) **Make good decisions**
   - (d)(3.1) '…define monitoring conditions that are technically necessary to ensure robust detection of malfunctions'
2) **Meet in-use monitoring frequency**
   - (d)(3.2) '…define monitoring conditions that yield an in-use performance ratio that meets or exceeds the minimum required ratio,' (e.g., 0.336) *and* should only increment when monitor is capable of detecting a failure

Both of the above need to hold true simultaneously

HD OBD - Case Study: Monitor Robustness vs Frequency

- Demo testing observations (red flags)
  - Monitor does not consistently fail during demonstration testing
  - Test results do not show consistent failing values with failed part installed
  - Numerator increment when falsely passing
- Confirmatory testing observations
  - Fail on demo cycle, pass off cycle (e.g., on road)

HD OBD - Case Study: Monitor Robustness vs Frequency

- Application: exhaust gas sensor slow response
  - Based on enable conditions and thresholds listed in summary table, monitor should run under all reasonable in-use driving conditions.
    - Summary table specifically indicated that the min/max speed-load criteria were calibrated to enable monitor at road load in multiple gears
- Confirmatory Testing Verification:
  - Staff conducted on-road verification testing
    - After code clear, sensor monitor made passing decision for the first drive cycle; failed after that.
    - Driving conditions when pending code was recorded were 3-4th gear, 35-40 mph
    - Staff questioned manufacturer as to whether there was some filtering or averaging being done.
    - Manufacturer Response: Failure threshold was calibrated to prohibit failing the monitor in real world driving conditions; i.e., the monitor was “calibrated-out” during in-use driving conditions
  - <u>The monitor was deemed non compliant</u>

HD OBD - Case Study: Monitor Robustness vs Frequency

Malfunction criteria table: possible to calibrate entire engine map

		Engine Speed								
		1000	1500	2000	2500	3000	3500	4000	4500	5000
Engine Load	20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
	25	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	30	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	35	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	40	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	45	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	50	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	55	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
	60	n/a	n/a	0.5	0.7	0.7	0.7	0.7	0.7	n/a
	65	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
	70	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
	80	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
	90	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
	100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

HD OBD - Case Study: Monitor Robustness vs Frequency

Monitor enable range is a subset of entire speed load map

Engine Load	Engine Speed								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
30	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
35	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
40	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
45	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
50	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
55	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
60	n/a	n/a	0.5	0.7	0.7	0.7	0.7	0.7	n/a
65	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
70	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
80	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
90	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

HD OBD - Case Study: Monitor Robustness vs Frequency

Demonstration on certification cycle occurs in limited range

Engine Load	Engine Speed								
	1000	1500	2000	2500	3000	3500	4000	4500	5000
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
30	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
35	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
40	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
45	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
50	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
55	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
60	n/a	n/a	0.5	0.7	0.7	0.7	0.7	0.7	n/a
65	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
70	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
80	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
90	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

HD OBD - Case Study: Monitor Robustness vs Frequency

Same failed part was demonstrated on the road and resulted in a false-pass since on-road conditions led to different malfunction criteria

	Engine Speed								
Engine Load	1000	1500	2000	2500	3000	3500	4000	4500	5000
20	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
25	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
30	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
35	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
40	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
45	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
50	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
55	n/a	n/a	0.5	0.5	0.5	0.5	0.7	0.7	n/a
60	n/a	n/a	0.5	0.7	0.7	0.7	0.7	0.7	n/a
65	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
70	n/a	n/a	0.5	0.7	3.0	3.0	3.0	3.0	n/a
80	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
90	n/a	n/a	0.7	0.7	3.0	3.0	3.0	3.0	n/a
100	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

HD OBD - Case Study: Monitor Robustness vs Frequency

- Look for the application red flags
  - If monitor is not robust across entire enable range, the monitor is not compliant
- As a supplier, don’t sell monitoring solutions like this
- As a calibrator, don’t sign off on a calibration that behaves this way
- As a manufacturer seeking certification
  - Identify this before certification
  - Be ready to provide an explanation for a monitor that is calibrated this way in support of a deficiency request
  - Non-compliances such as this that are not assigned a deficiency are handled through enforcement action

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ARB needs to significantly reduce in-use NOx emissions

Vision Targets

Goal	Year	Percent Reductions from 2010	
O3 Standard (ppb)	Target	NOx	CO_2
84	2023	80%	
75	2032	90%	
65*	2050	95%	
GHG	2050		85%

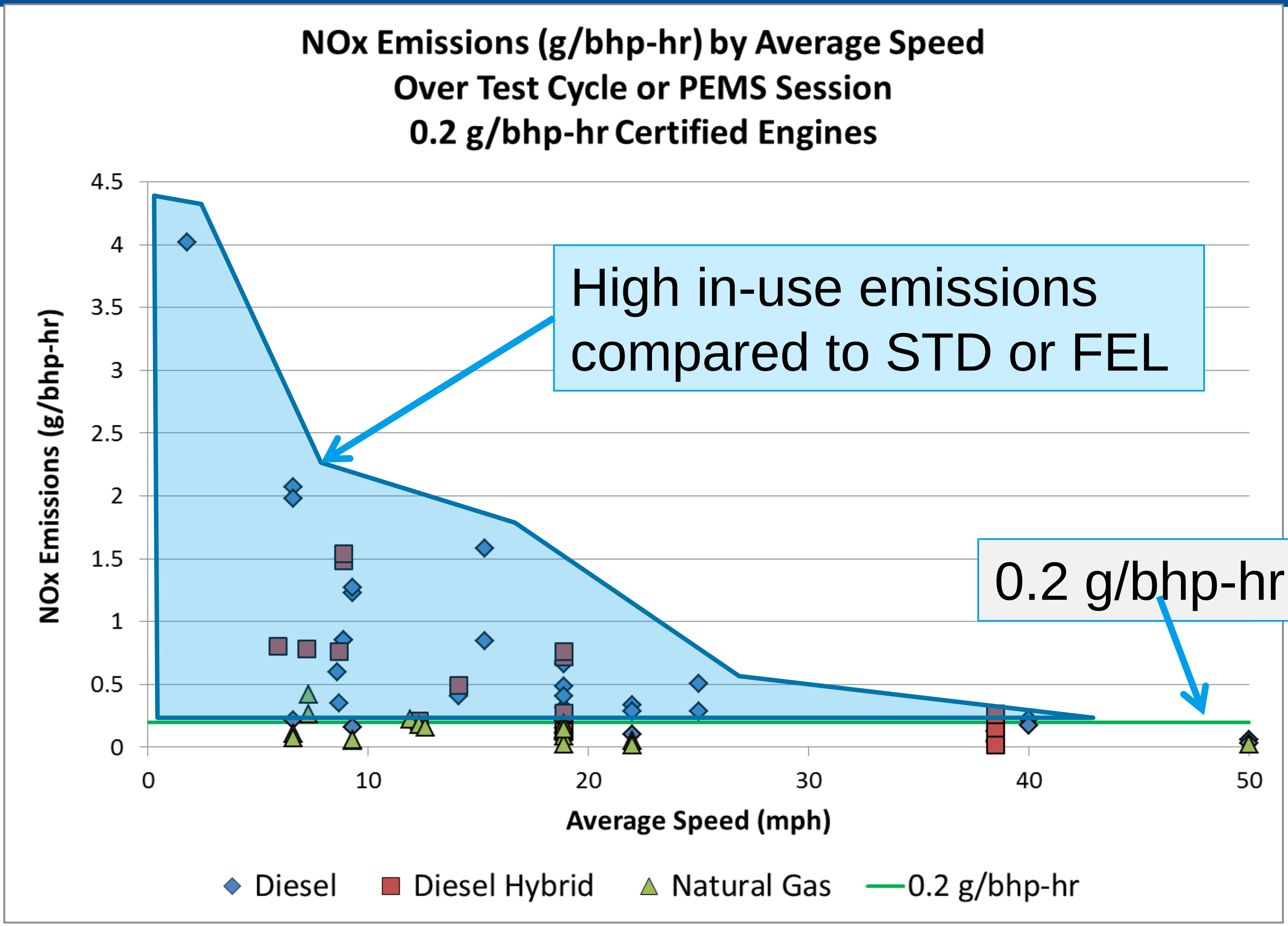
* Assumption based on Clean Air Act Scientific Review Panel Recommendation of a 0.060 to 0.070 range for the 2008 Ozone standard.

HD OBD - High In-use NOx Emissions From HD Vehicles

ARB analyzing high in-use NOx emissions using PEMs data

- Reasons for high NOx emissions range from:
  - Low SCR temperatures at low load driving
  - Robust NOx control during test cycle is not representative of off-cycle control
  - Engine dyno test cycle may not account for all variables that affect in-use emissions
    - Engines do not operate in their ‘optimal’ NOx control region during in-use operation
  - NOx sensors with significant delays before ready *and* sensors dropping out during low load driving
    - Staff noticing NOx sensors require extensive time to come online even after dew point temperature reached (e.g., 15+ minutes after engine start)

HD OBD - High In-use NOx Emissions From HD Vehicles



HD OBD - High In-use NOx Emissions From HD Vehicles

Possible HD OBD Ideas - Necessary Data Stream Parameters

- Engine-out NOx in g/second
- Pre- and Post SCR NOx concentration
- Real-time SCR Conversion Efficiency
- SCR temperature
- Modeled Exhaust Flow in g/second
- Total engine runtime
- Vehicle speed

Different ways to bin SCR conversion efficiency data

- Vehicle speed: 1 to 25 mph, 25 to 50 mph, …
- Vehicle load/rpm or positive kinetic energy (PKE)
- Ambient Temperature: less than/greater than 50° F
- Cumulative time in each bin

How might we use this data?

- May provide support/experience for better in-use NOx control
- May provide input for development of new test cycle
- May provide input to revise and update NOx emissions inventory
  - Compare test cycle SCR conversion efficiency to in-use SCR conversion efficiency
- Help to identify vehicle applications that do not operate in their optimal NOx control region

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HD OBD – Innovative Technology Regulation

Purpose: Provide certification/OBD and aftermarket part approval flexibility to facilitate market launch of needed truck and bus technologies, while maintaining ability to ensure anticipated air quality benefits

HD OBD – Innovative Technology Regulation

Conceptual Framework

Certification or aftermarket approval flexibility provided to each manufacturer per technology within sales tiers

- Tier 1: Low volume market launch enables fleet evaluation of new technology
- Tier 2: OBD and other requirements ramp up
- Sales volumes beyond Tier 2: Full certification or aftermarket approval requirements apply

Maximum sales volumes per tier tbd

- Volumes would be cumulative across model years
- Staff welcomes stakeholder comment regarding most impactful allowable volumes per tier

HD OBD – Innovative Technology Regulation

Possible Technology Applicability[1] - *New Engine or Vehicle Certification*

Vehicle Type	Hybrid w/ Significant Zero-Emission Operation	Hybrid w/ Low/No Zero-Emission Operation	>20% GHG Benefits (Non-Hybrid)	Alt NOx Std – ↓50%	Alt NOx Std – ↓75%	Alt NOx Std – ↓90%
Class 2b/3	√	√	TBD	TBD	TBD	TBD
Vocational Truck/Bus	√	√	TBD	TBD	TBD	TBD
Class 7/8 Tractor	√	√	√	√	√	√

Each vehicle type and technology combination (i.e. each green cell) in the graph above represents a discrete ‘innovative technology.’ Manufacturers would be eligible for certification/OBD flexibility for a defined sales volume for each ‘innovative technology.’

1 - Other technologies could apply to be defined as innovative based upon their providing a technology pathway/bridge to zero-emission truck and bus technology.

HD OBD – Innovative Technology Regulation

Innovative Technology Regulation

- Upcoming workshop March 9, 2015 in El Monte, CA
- Webpage
  - www.arb.ca.gov/msprog/itr/itr.htm

Contact info:
Joe Calavita, Lead Staff
Tel. 916-445-4586
jcalavit@arb.ca.gov

HD OBD – The End

Official ARB documents available from

- www.arb.ca.gov

Direct link to OBD page

- http://www.arb.ca.gov/msprog/obdprog/obdprog.htm

Contact info:

Thomas Montes: Manager, Diesel OBD Section

tmontes@arb.ca.gov

626-575-6777