Update on Light Duty OBD II

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SAE OBD TOPTEC
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Discussion Points

- Background
- Monitoring Issues
- Production Vehicle Testing
- Other issues
- Regulatory Schedule
- I/M Summary

Background

- OBD II is CARB regulation originally adopted in 1989
- Usually updated every two years
- Most recent revisions adopted April 2002
- Next round of revisions starting now

Reasons for Changes

- Keep pace with technology
- I/M and technician feedback and experience
- Certification staff experience
- Review previous round of adopted requirements

Where we are today

- Over 120 million cars on the road in the U.S. with OBD II systems
  - More than 50% of the in-use fleet
  - Over 6 trillion miles accumulated in-use
- 25 states in the U.S. using OBD II for I/M
  - Nearly 13,000 OBDII inspections a day just in CA

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Diesel Monitoring Requirements

- Significant amount of added specification for diesel monitoring
- In general terms, align MDV requirements with HDV as per HD OBD requirements
  - TBD on exact thresholds and timing
- In general, keep PC/LDT requirements "equivalent" to gasoline requirements
  - Diesel must be equivalent in all aspects to any gasoline vehicle it displaces

Added Diesel Specification

- Catalyst monitoring
  - For both oxidation and NOx catalysts
- NOx Adsorber monitoring
  - Add specific requirements
- Misfire monitoring
  - Likely add full-range for engines with HCCI-like operation

Added Diesel Specification (cont.)

- Fuel system monitoring
  - Added specification for pressure control, injection quantity, and injection timing
- EGR monitoring
  - Added language for high/low flow, proper cooler performance
- PM trap monitoring
  - Added language for types of monitoring required

Rear Oxygen Sensor Monitoring

- Current requirement includes:
  - To the extent feasible, detect a fault when the rear sensor is no longer sufficient for catalyst monitoring
- Proper catalyst monitoring is a key concern
  - In-use vehicles confirm suspicion that deteriorated rear sensors affect catalyst monitor

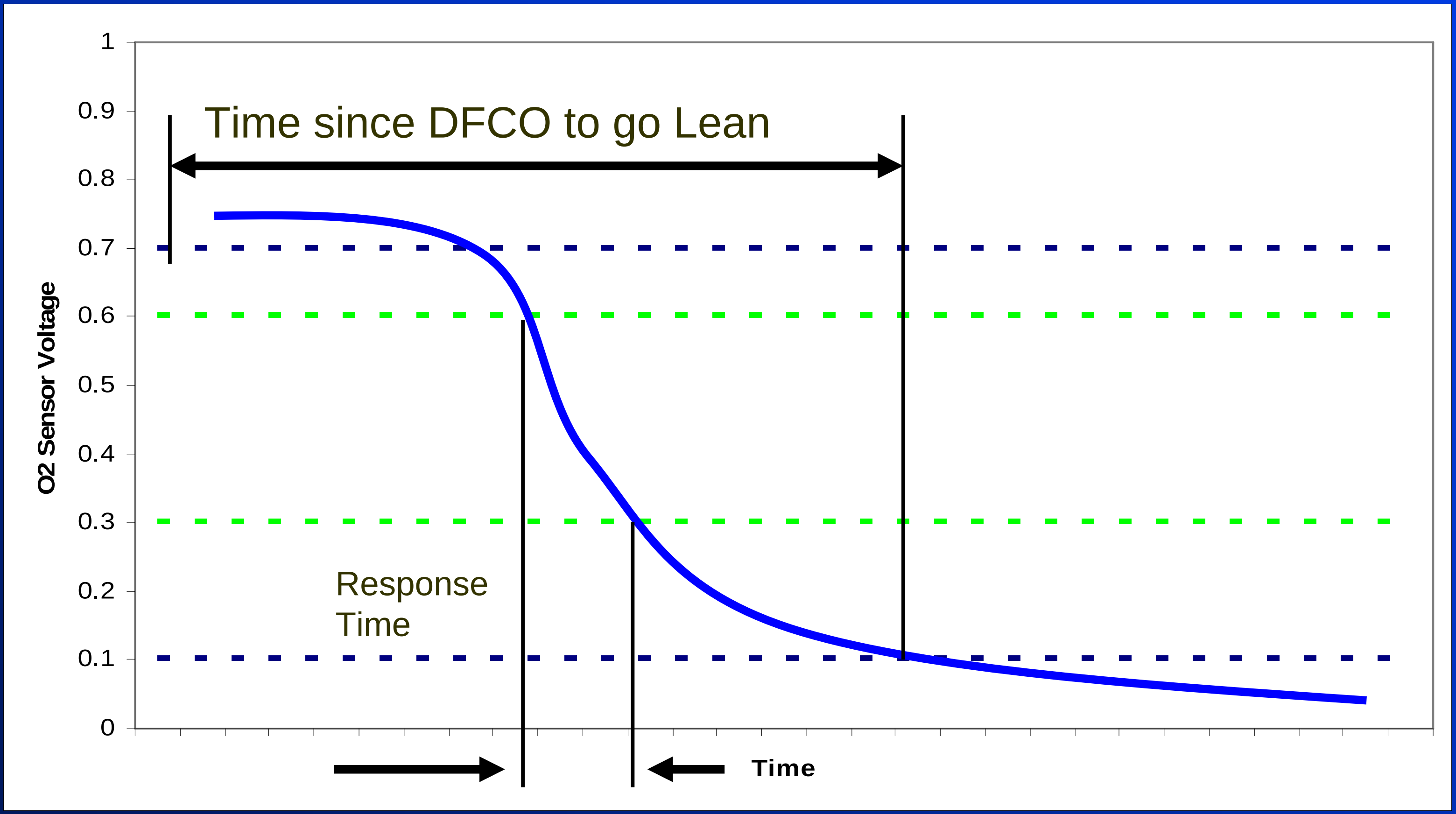
Rear Oxygen Sensor Concerns (cont)

- Ideal situation is that rear sensor is either:
  - Good enough to detect a “threshold” catalyst; or
  - Detected as faulty rear sensor and turns on MIL
- Very few manufacturers meet this ideal situation
  - Even so, catalyst DTCs represent over 25% of failures on cars >75,000 miles in Smog Check

Regulation Changes

- Add specification as to minimum acceptable monitor:
  - Use experience from what manufacturers have been doing
  - Demonstration that ideal situation is met eliminates need for further improvement
- Require "two-prong" rich-to-lean monitoring
  - Verify sensor goes lean enough, fast enough during mandatory, intrusive DFCO
  - Isolate sensor response from catalyst effects and transport time as much as possible

Rear Oxygen Sensor Monitoring



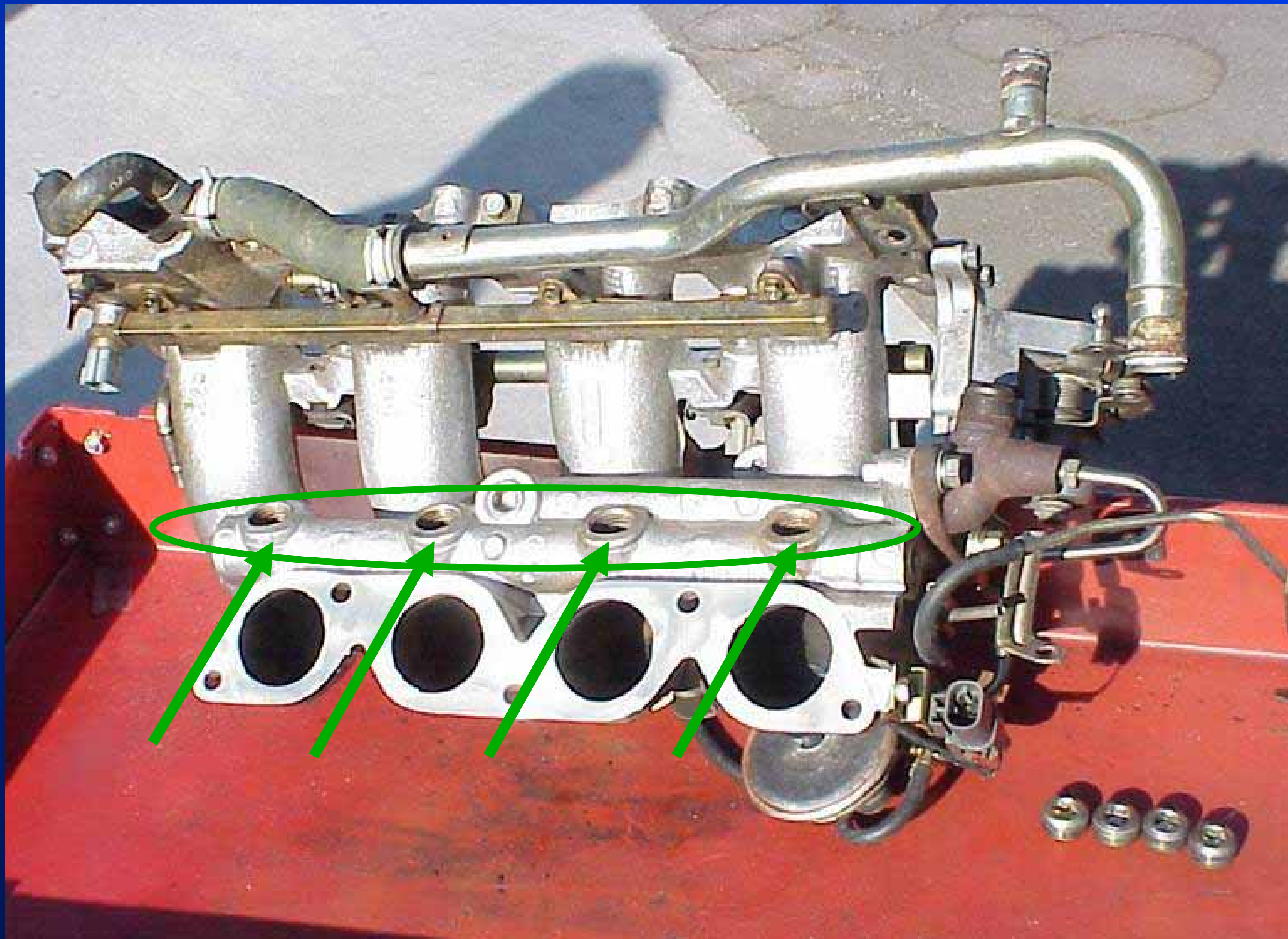
Further Rear O2 Investigation

- Still investigating feasible (and least intrusive) methods for lean-to-rich monitoring
  - Current strategies include enrichment or immediately following re-fueling after DFCO
- Alternate approach to this problem:
  - Deny approval of any combination of catalyst monitor and rear O2 sensor monitor that has a "gap" in detection
  - Likely will force significant catalyst monitor changes

Cylinder A/F Imbalance

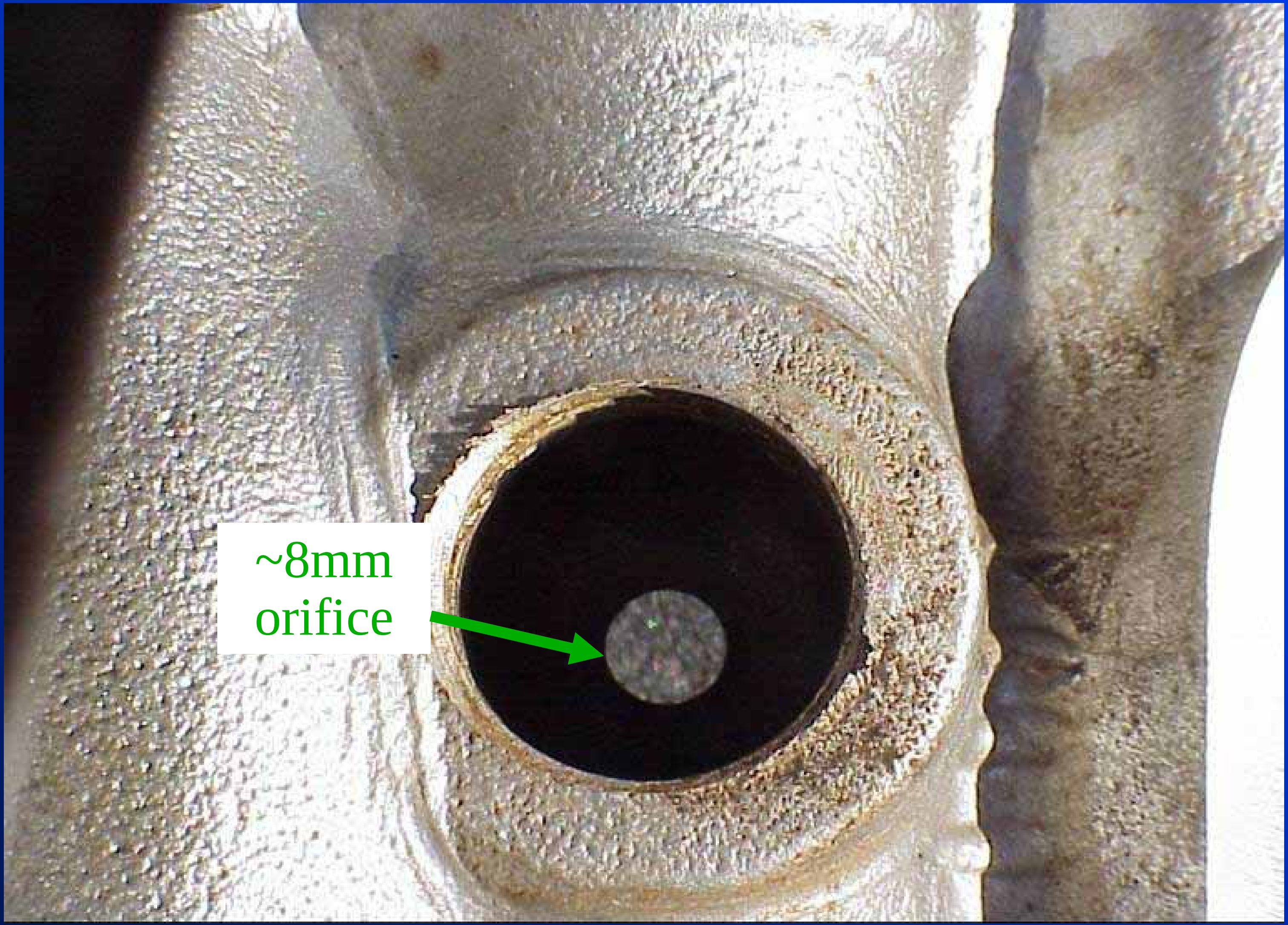
- Field testing has revealed a failure mode OBDII generally does not comprehend
  - Proposing an additional monitoring requirement to cover this
- Problem appears to be cylinder to cylinder differences in air/fuel ratio that are improperly corrected by fuel control
  - Can be caused by fuel injector variation, intake air delivery variation, or uneven EGR distribution

1997 Nissan Altima Intake Manifold



Zooming in on a plugged EGR orifice

Same EGR orifice after cleaning



Cylinder A/F Imbalance

- Result of imbalance can be very high emissions
  - NOx emissions on Altima:
    - 160k cat: 3.0x std before EGR cleaning, 2.4x std after
    - 0k cat: 1.1x std before EGR cleaning, 0.5x std after
  - Data from another manufacturer with varied fuel injection quantity
    - FTP emission impact from 0 to >5x std (depending on which cylinder) with ~25% quantity shift
- Many times front O2 sensor does not see all cylinders equally
  - Location of sensor in manifold collector
  - Oversensitive or "blind" to specific cylinders
  - Causes improper fuel system correction

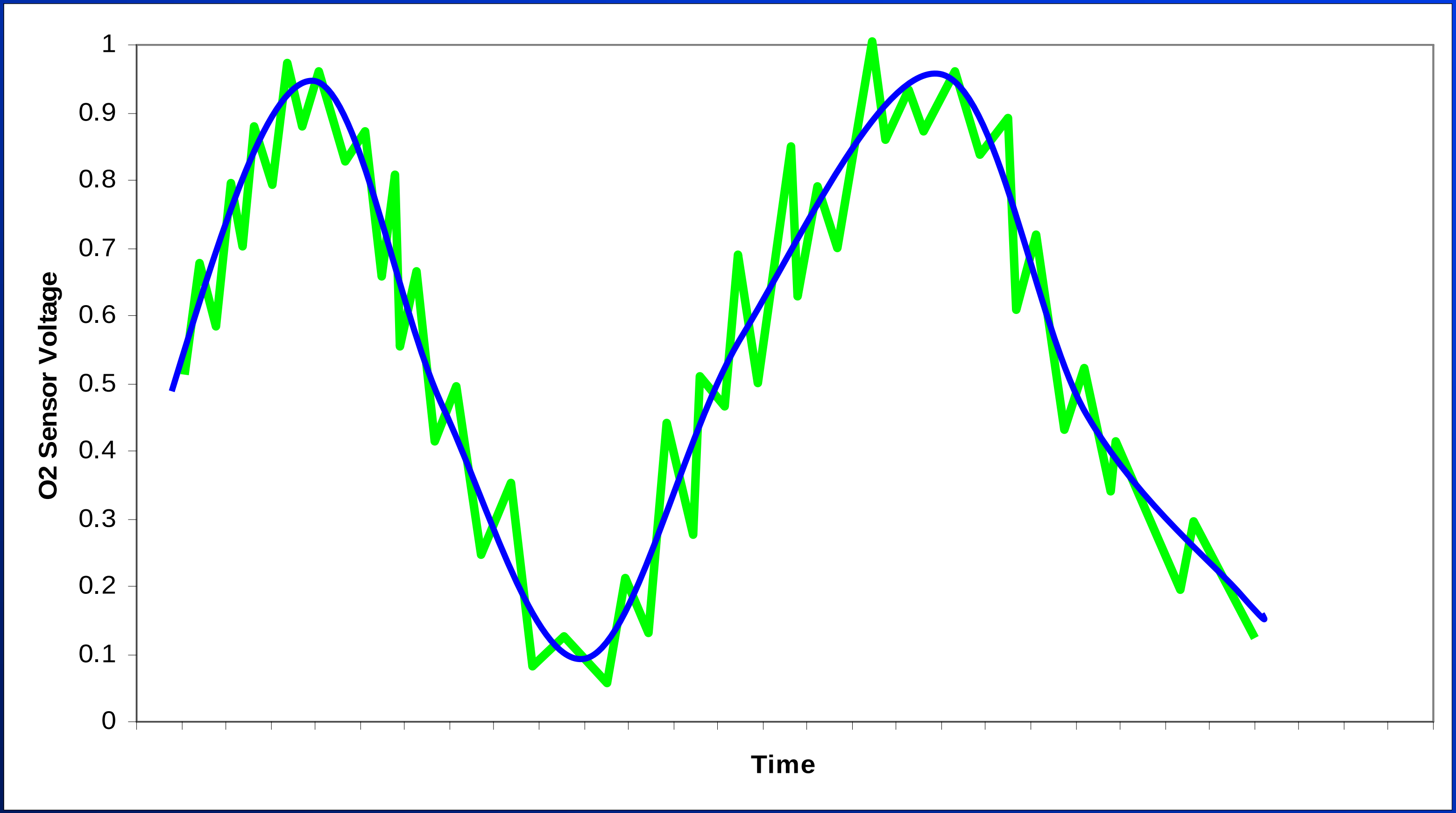
Proposed Monitoring Requirements

- Likely will be added as subpart to fuel system monitor
  - May also need additional subpart in EGR system for systems with individual cylinder EGR delivery tubes
- Intent is to target detection of malfunctions at 1.5x standard

Possible Monitoring Strategies

- Problem first observed on a Geo Metro (Suzuki) with intake valve deposits
  - Caused cylinder A/F variations from internal EGR
- Investigation by Suzuki revealed front O2 sensor overcompensating for one cylinder
  - Close look at front O2 data by Suzuki showed “noise”
- Investigation by another manufacturer also showed some potential in front sensor signal analysis

Front Oxygen Sensor "Noise"



Possible Monitoring Strategies (cont)

- Rear O2 sensor signal often shows signs of cylinder imbalance as well
  - Geo Metro did not have rear O2 fuel control and rear sensor output was consistently lean (non-stoich)
- Rear sensor analysis alone might not be sufficient
  - Depending on catalyst and sensor configuration, rear sensor might not provide sufficient data
- Monitoring of rear O2 fuel control adaptive values not likely sufficient to cover all cases
  - This will remain a separate monitoring requirement

Cold Start Strategy Monitoring

- Current requirement:
  - Monitor key parameters and detect a malfunction of the individual components associated with the strategy before emissions >1.5x std
  - Functional check for components that can't cause 1.5x std
- Most manufacturers fall into functional check category
  - Spark retard, increased idle speed/air flow, sometimes specific VVT position

Monitoring Approaches

- Two common approaches:
  - Individual component monitors
  - Overall system monitor
- Both approaches have pros and cons
  - Still trying to weigh the benefits of each to see where the requirements are best satisfied

Individual Component Approach

- Perform functional check of each component
  - Verify some level of spark retard was commanded
  - Verify some level of increased idle speed/air flow was achieved
- Pros include:
  - Better pinpointing of malfunctions
  - Verify some of each element is working as current regs specify
- Cons include:
  - Generally looks at commanded final spark, not actual delivered
  - Difficult to verify final commanded spark represents retard

System Approach

- Perform functional check of entire system
  - Verify air mass/modeled exhaust temp indicates some amount of cold start strategy applied
- Pros include:
  - Better characterization of overall impact of strategy
  - Takes into account actual delivered spark
- Cons include:
  - Can be difficult/impossible to calibrate to catch loss of complete function from one of the two components (e.g., complete loss of spark retard might not show up)

Relative Stringency

- Some have argued that functional monitor imposes more stringent requirements than threshold monitor
  - Assume both have non-cold start idle speed of 600rpm
  - Ex: Aggressive strategy of 1500rpm target engine speed and a fault threshold of -500rpm (absolute of 1000rpm) to reach 1.5x standards
  - Ex: Mild strategy of 750rpm target engine speed and a functional monitor threshold of some level of increased rpm
- Argument: Functional monitor “more stringent” to detect a fault at ~150rpm below target than threshold monitor at ~500rpm below target
  - But, in threshold example, system has to increase 400rpm over non-cold start to pass while functional example has to increase a few rpm to pass

Cold Start Strategy Proposal

- Hoping to get meaningful feedback from industry on two approaches
- Primary concern behind monitor was to protect emission benefit from these strategies as cars age
  - Supportive of cheap ways to get emission benefit IF they really happen in-use and we can maintain them

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PVE Testing (j)(1)

- Requires all 2005+ vehicles to be tested for conformance with ISO/SAE standards
  - Focus on verifying vehicle will work in an I/M test
  - Also to minimize “exceptions” or “work-arounds” for scan tools
- Will be updating regs to require use of SAE J1699-3 plus a J2534 device

PVE Testing (j)(1) Results

- Nearly every manufacturer has failed one or more elements
  - Incorrect message response length/format
  - Incorrect VIN padding/message count/end of line programming
  - Non-response to required functions (especially CAL ID and CVN)
  - Illegal negative response codes
  - Improper initialization (wrong protocol, multiple protocols, wrong non-emission module waking up)
  - Missing Mode $06 results
  - Data collisions causing time-outs
- Hoping number of non-compliances decreases over time
  - Until then, still severely limiting grouping of different applications into a single (j)(1) test group

PVE Testing (j)(2)

- Requires manufacturers to individually verify <u>every</u> fault path for proper MIL illumination on 2-6 production vehicles
  - Testing takes 2-4 weeks to complete
  - Only diagnostics exempted from testing are those that cause permanent damage, excessive tear-up to production vehicle, or have been previously done during the DDV testing.

PVE Testing (j)(2) Results

- Most manufacturers have also caught mistakes in this testing
  - Diagnostics that set pending codes and disable themselves
  - Enable conditions that can’t be satisfied (e.g., engine off voltage criteria that could not be satisfied)
  - Non-MIL diagnostics disabling MIL diagnostics
  - Wrong DTCs being stored
  - Calibration mistakes prevented detection at the correct level
- Some manufacturers have asked for a reduction in the number of vehicles tested per year
  - Considering reducing the number on intermediate manufacturers but reluctant given success to date

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Permanent Fault Codes

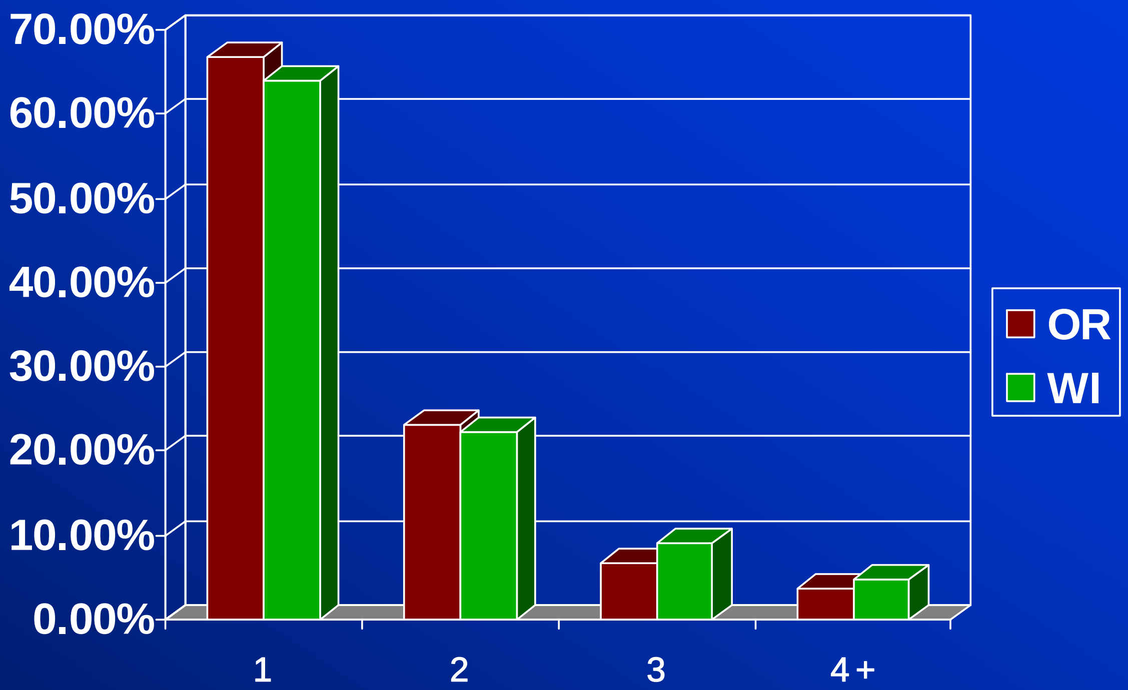
- Proposal will require permanent DTCs identical to requirement for HD OBD
- Feedback from I/M programs showing increased usage of readiness loopholes
  - Up to two monitors can be incomplete at time of inspection
- Permanent DTCs compromise between running all monitors and those previously commanding the MIL on

Structure of Permanent DTCs

- Any DTC that is commanding MIL on must be logged as a permanent fault code
    - Must be stored in memory that survives battery disconnect and all scan tool clear commands (clear DTCs, reset KAM, etc.)
- Permanent DTC can only be erased by the vehicle's OBD II system
    - If fault is healed and MIL goes off, permanent DTC erased
    - If fault is cleared (e.g., scan tool), permanent DTC not erased until that specific monitor has run and determined no fault present
- Still TBD on format for SAE J1979 (e.g., new Mode, subpart of Mode $09, etc.)

Number of stored DTCs in I/M

Proposal: Capable of storing 4 permanent DTCs at one time



*Data from Rob Klausmeier, dKC presentation at 2003 Colorado Clean Air Conference

Emission Warranty

- CARB is planning on updating emission warranty regulations
  - Probably will be done with OBDII update
- Current requirements include outdated references
  - Uses an emission parts list from 1985
- Hope to simplify requirements

Current Emission Warranty

- Performance Warranty of 3 years/50,000 miles
  - Designed and built to meet CA standards
  - Will pass an I/M test
  - Title 13, CCR section 2038
- Defects Warranty of 3 years/50,000 miles
  - Free from defects that cause a failure of an emission-related part
  - Cause the MIL to illuminate
  - Title 13, CCR section 2037
- Defects Warranty of 7 years/70,000 miles
  - Free from defects that cause a failure of an emission-related part that is:
    - On the Emission Warranty Parts list; and
    - Exceeds an inflation adjusted repair cost (currently $480)

Proposed Emission Warranty

- Warranty of 3 years/50,000 miles
  - Free from defects that cause a failure of an emission-related part; or
  - Cause the MIL to illuminate
- Warranty of 7 years/70,000 miles
  - Anything covered above that also exceeds an inflation adjusted repair cost (same cost formula as today)
- Warranty of 8 years/80,000 miles
  - Catalyst and emission-related on-board computers
    - Harmonize with EPA requirement

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Biennial Review Schedule

- Workshop Notice
  - 30 days before workshop
  - Will include draft regulatory language
- Workshop in early November
- Board Hearing Notice
  - 45 days before Board Hearing
  - Will include staff report and proposed regulatory language
- Board Hearing in early 2006 (Feb-Mar?)

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CA Smog Check Background

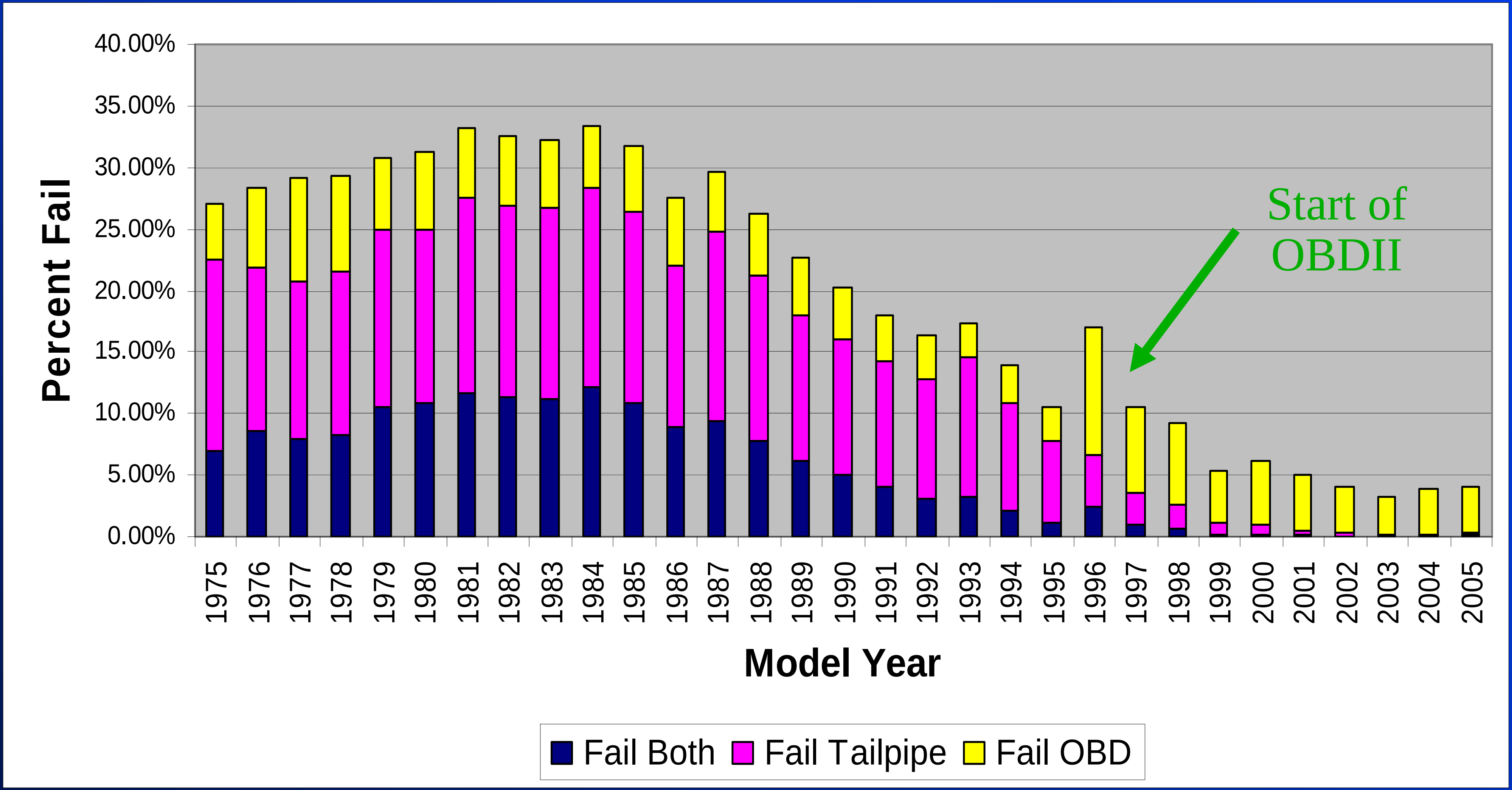
- Biennial test plus change of ownership
  - New vehicles exempt for first six years
- Test includes
  - Acceleration Simulation Mode (ASM) dyno tailpipe test at 15 and 25mph
  - OBD II inspection (MIL status plus >2 monitors with incomplete readiness)
  - Visual inspection
  - Gas cap leak check
- Tailpipe test cutpoints essentially the same for 1993-2005 model year
  - Target vehicles at significantly > 2-3x FTP standards
  - Even in 1997, 70% of the fleet was Tier1

CA Smog Check Statistics

- ~400,000 OBD II vehicle inspections per month
  - Even with exemption of cars for first 6 years
- ~450,000 pre-OBD II vehicle inspections per month
  - 75% of the failures are in this population
- Over 1,000 OBDII vehicles fail per month
  - 80-95% of these fail because of OBDII (MIL on or not ready)

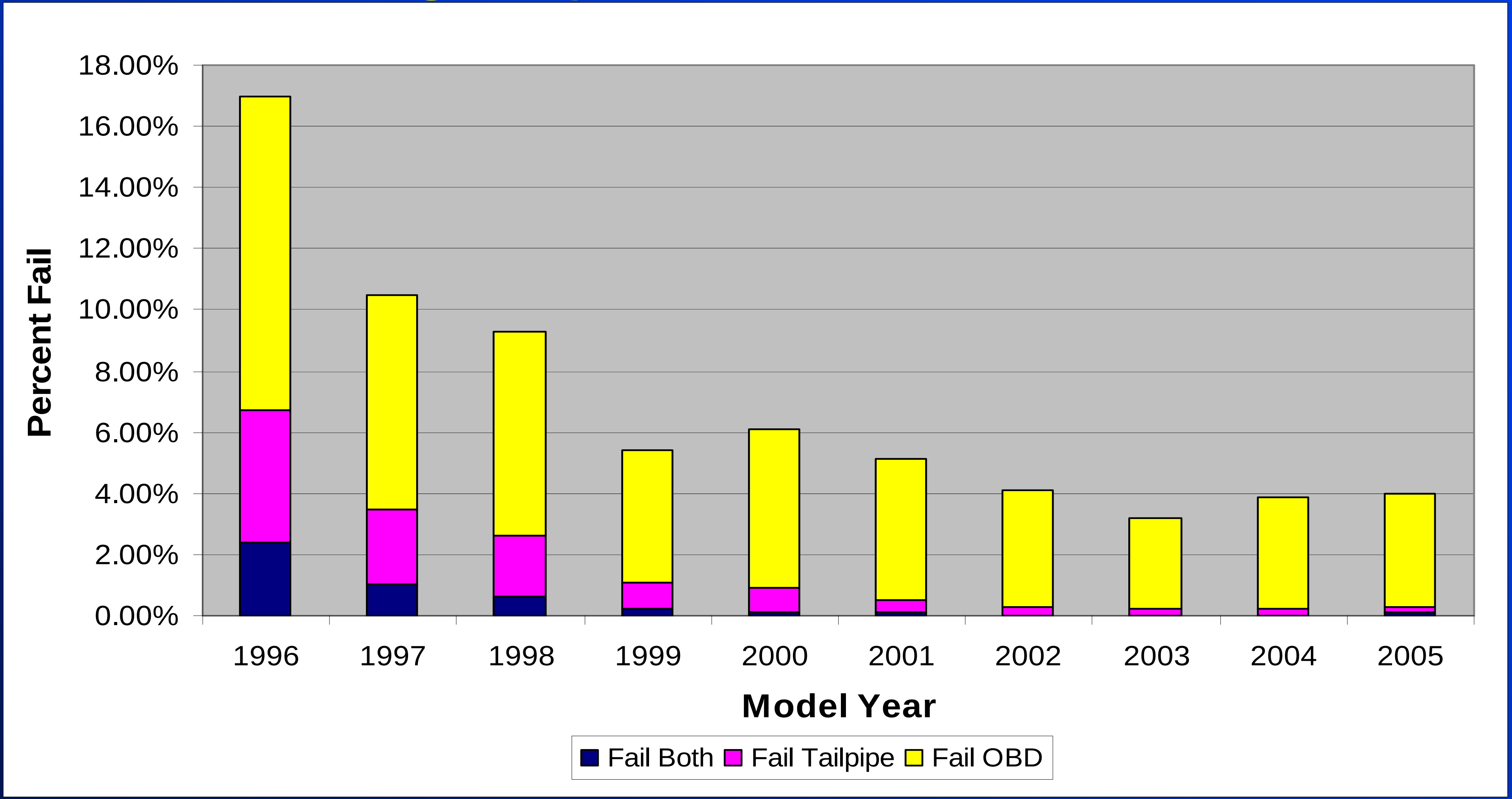
Data from BAR Executive Summary, Statewide, August 2005

CA Smog Check fail rates



Data from BAR Executive Summary, Statewide, second quarter 2005, over 2.4 million cars tested

Looking at just OBDII vehicles…



Data from BAR Executive Summary, Statewide, second quarter 2005, over 1.1 million cars tested

Most Common I/M DTCs for Vehicles >75,000 miles

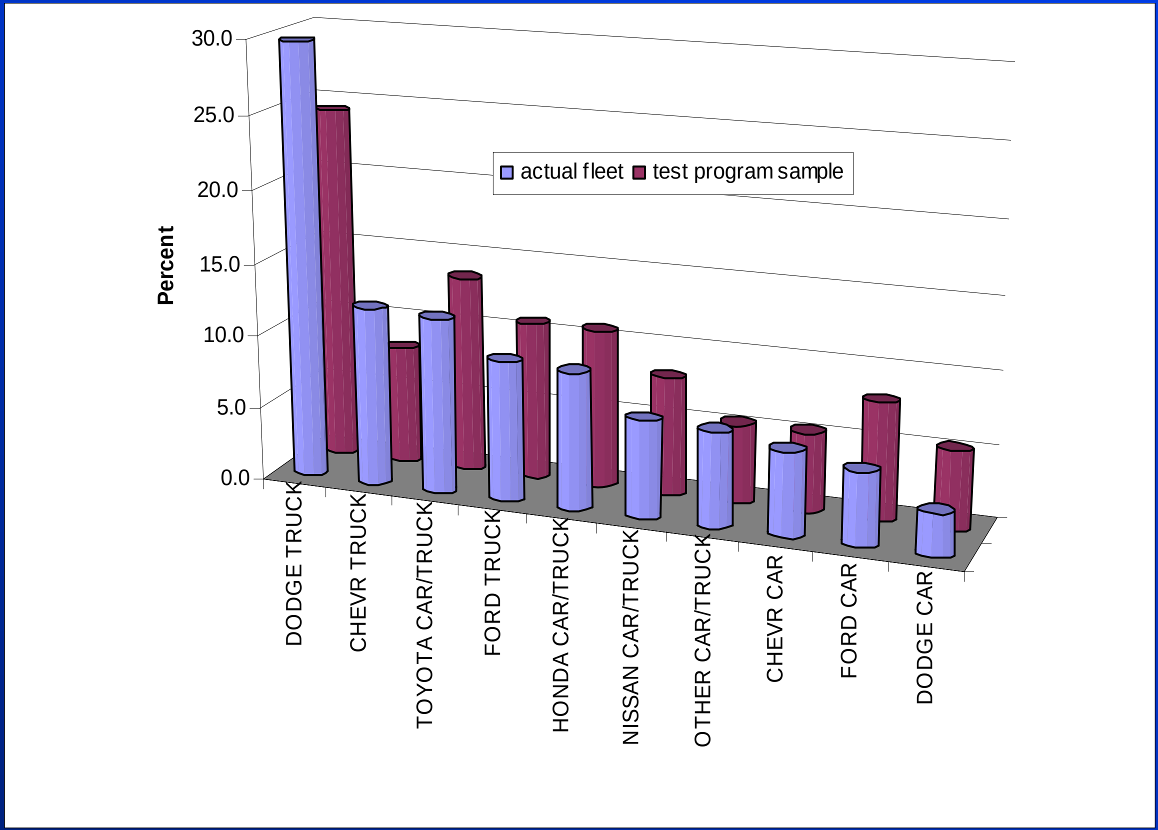
DTC	Percent	Definition
P0420/430	25.82%	Catalyst
P0171/174	14.47%	Fuel System Lean
P0401	13.93%	EGR Flow
P0133/153	13.56%	O2 Response
P0xxx	~10%	Other O2/heater
P0xxx	~10%	Evap
P0300	6.57%	Misfire

Background

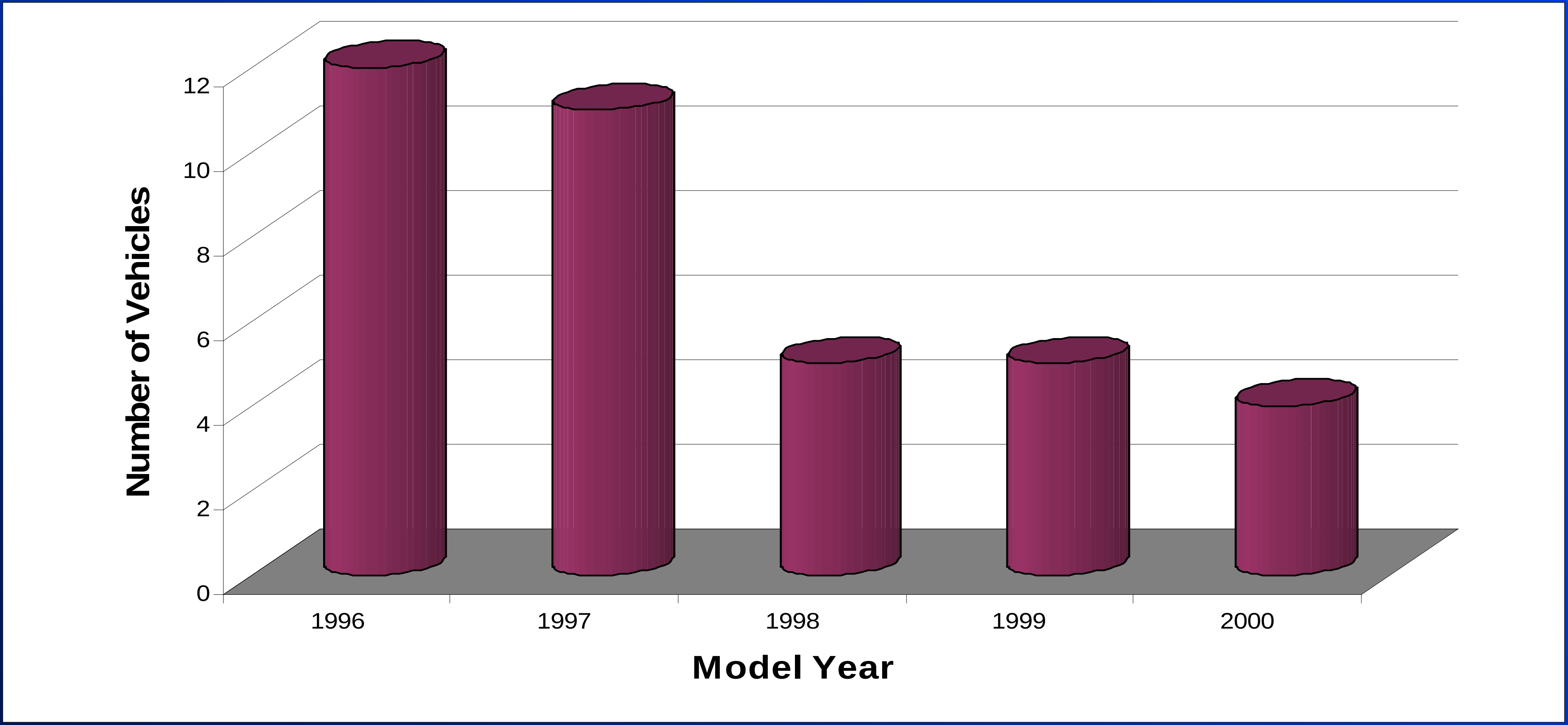
- A small percentage of vehicles (<0.1%) in the fleet pass an EPA OBD only inspection but fail the ASM test at gross polluter (GP) levels
- ARB has been recruiting vehicles that meet this criterion and testing them to understand what's going on

Make-up of the fleet
(that are GPs and pass OBD inspection)

- Ideally, distribution of vehicles in our sample (dark, back row) would match distribution of vehicles in the actual fleet (light, front row).
  - Our sample is close
- Some vehicles represent substantially more of this fleet than their sales market share
  - Dodge/Jeep trucks at 30%

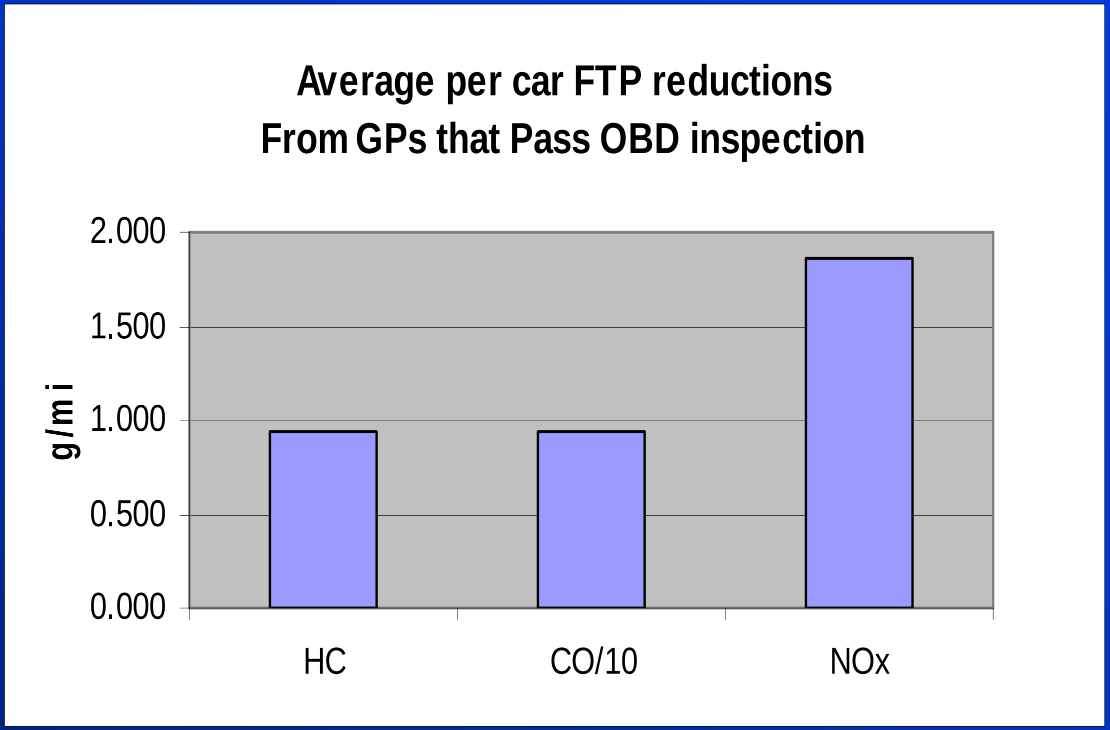


Make-up of the test sample
(by model year)

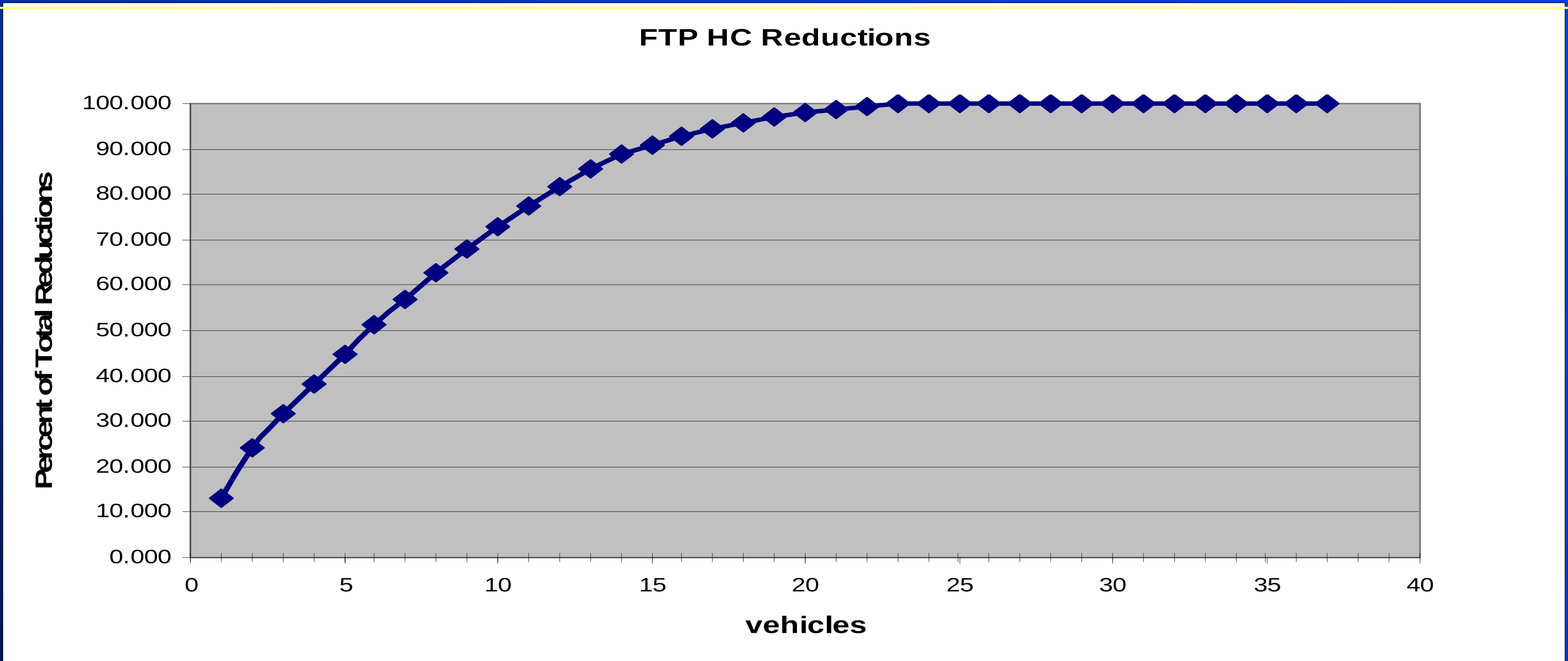


Emission reductions

- Average vehicle emission reductions is significant
  - Most of the tested vehicles are Tier1 (0.31 HC, 4.2 CO, 0.6 NOx)
- Study has not yet factored in the number of these vehicles in the fleet or cost-effectiveness to find them

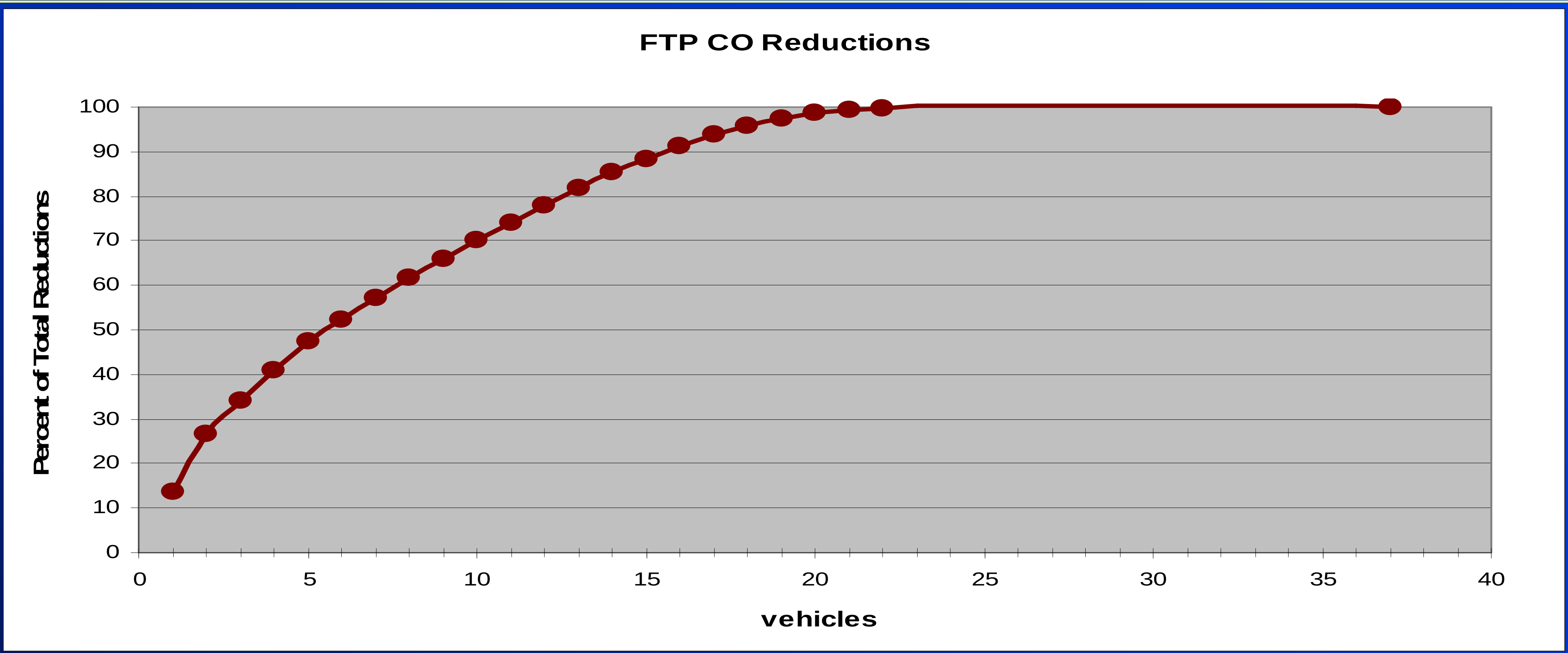


Distribution of Emission Reductions



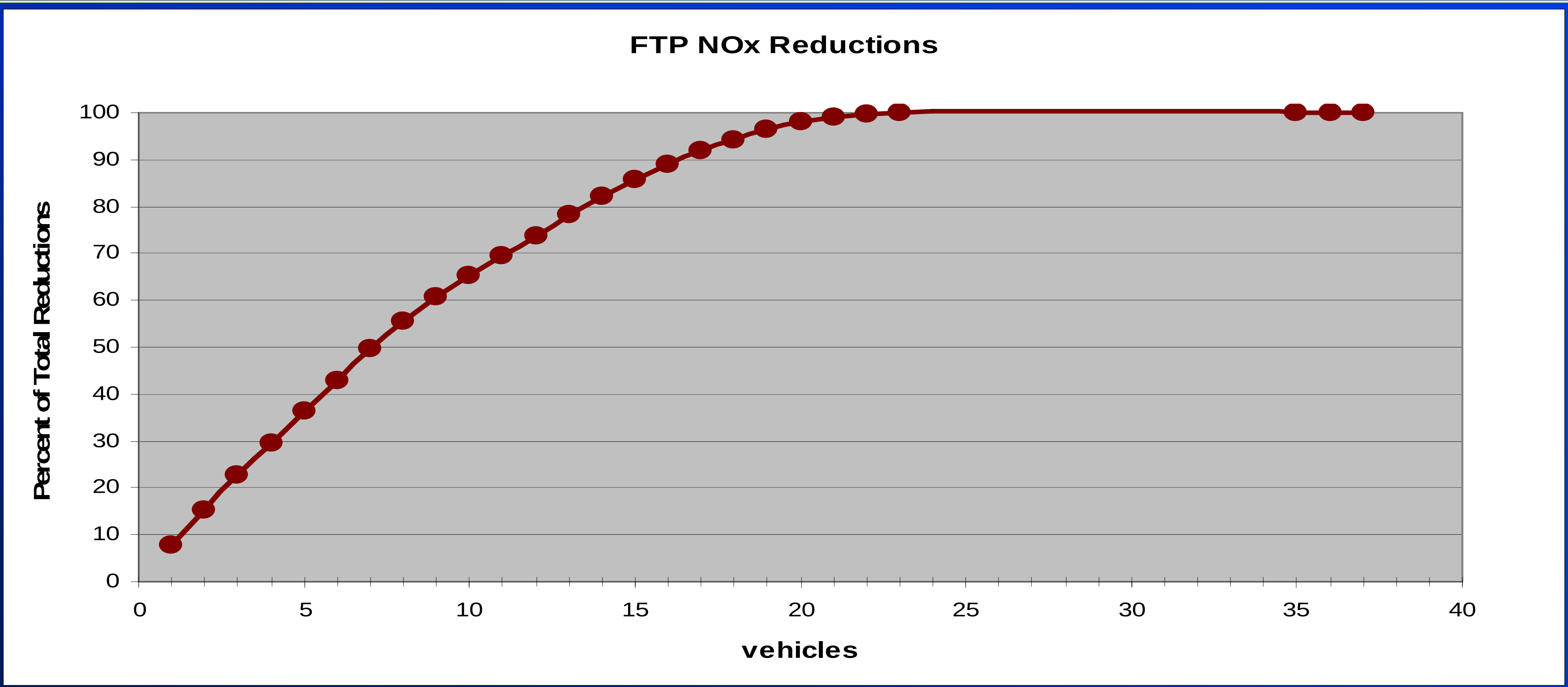
- Just over 50% of emission benefit from only 6 of the 37 cars
- 0% from 14 (37%) of the cars
- 43% from replacing rattling/missing catalysts on 96-99 Dodge/Jeep trucks
- 31% from replacing illegal (non-OBDII approved) aftermarket catalysts

Similar for CO benefits



- 50% of emission benefit from only 6 of the 37 cars
- 0% from 12 (32%) of the cars
- 38% from replacing rattling/missing catalysts on Dodge/Jeep trucks
- 21% from replacing illegal (non-OBDII approved) aftermarket catalysts

And for NOx benefits



- Just over 50% of emission benefit from 7 of the 37 cars
- 0% from 14 (38%) of the cars
- 45% from replacing rattling/missing catalysts on Dodge/Jeep trucks
- 28% from replacing illegal (non-OBDII approved) aftermarket catalysts

Which of these emission failures will likely go undetected in future OBD-only inspections?

- Analysis of the 37 vehicles
  - Root cause, reason it passed EPA OBD inspection, improvements in OBD systems all considered
- 11 vehicles had no repairable emission benefit
  - Problem too intermittent, false ASM fail with no vehicle problem, improper test method, etc.
- 6 vehicles had intermittent O2 sensor problems that are detected consistently on newer model year vehicles
  - MIL came on during testing
  - O2 monitor frequency and fault coverage continually improved from 1997-2001 model year

Which of these emission failures will likely go undetected in future OBD-only inspections? (cont.)

- 6 vehicles were 96-99 Dodge/Jeep trucks with known catalyst and catalyst monitor problem
  - Enforcement case almost settled
- 1 other vehicle had empty catalyst can and no detection
- 7 vehicles had an illegal aftermarket cat
  - Changes to/enforcement of illegal catalyst installations would catch it
  - 3 of the 7 did detect the cat as bad when cat monitor ran

Which of these emission failures will likely go undetected in future OBD-only inspections? (cont.)

- 5 vehicles used readiness loophole to get through
  - 1-2 incomplete monitors that turned the MIL on during testing
  - Permanent DTCs would catch these
- 2 vehicles had malfunctions that OBD will not detect
  - Uneven distribution of EGR to all cylinders
  - Proposal for cylinder imbalance monitor would likely detect this
- 2 vehicles were tampered and OBD would not detect
  - One had a tampered catalyst system
  - One had an illegal exhaust header (should have been failed by visual)

Summary

- OBD II, as a whole, is doing the job it was designed to do
- Gasoline diagnostics should remain fairly stable
- I/M continues to play an increasing role as to how the system is performing

Questions….?

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