

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

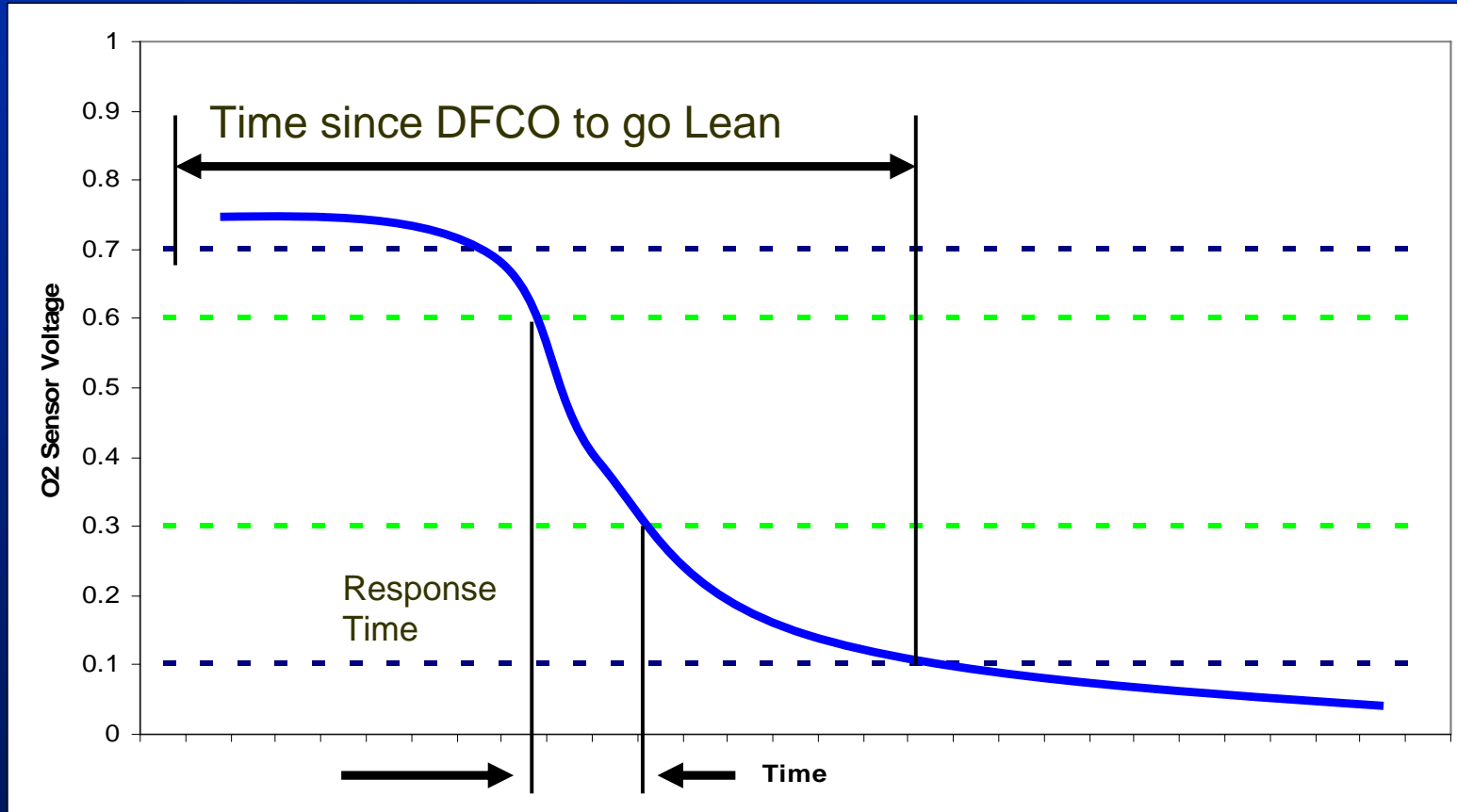
Rear Oxygen Sensor Concerns (cont)

- 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



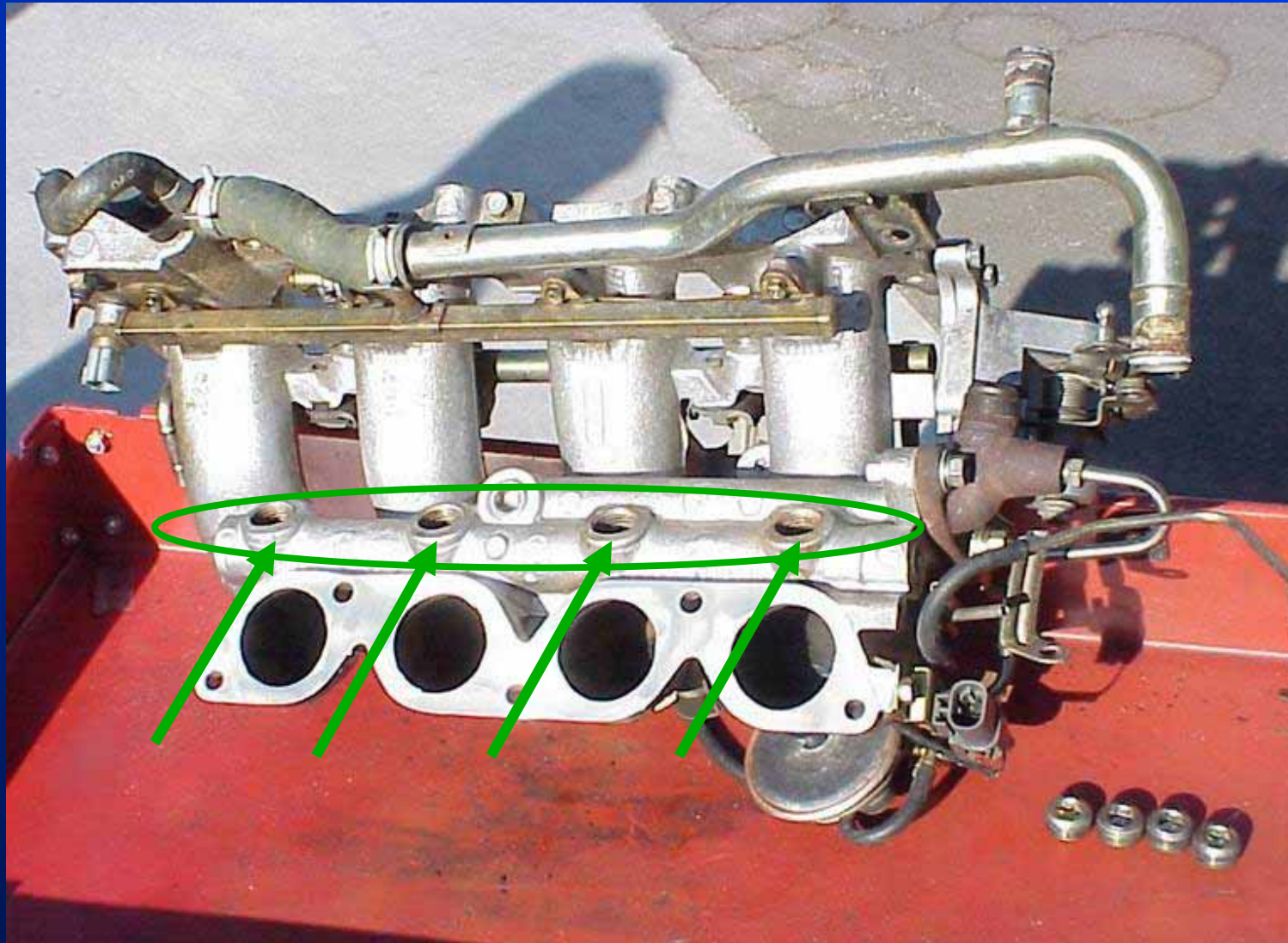
Further Rear O2 Investigation

- 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



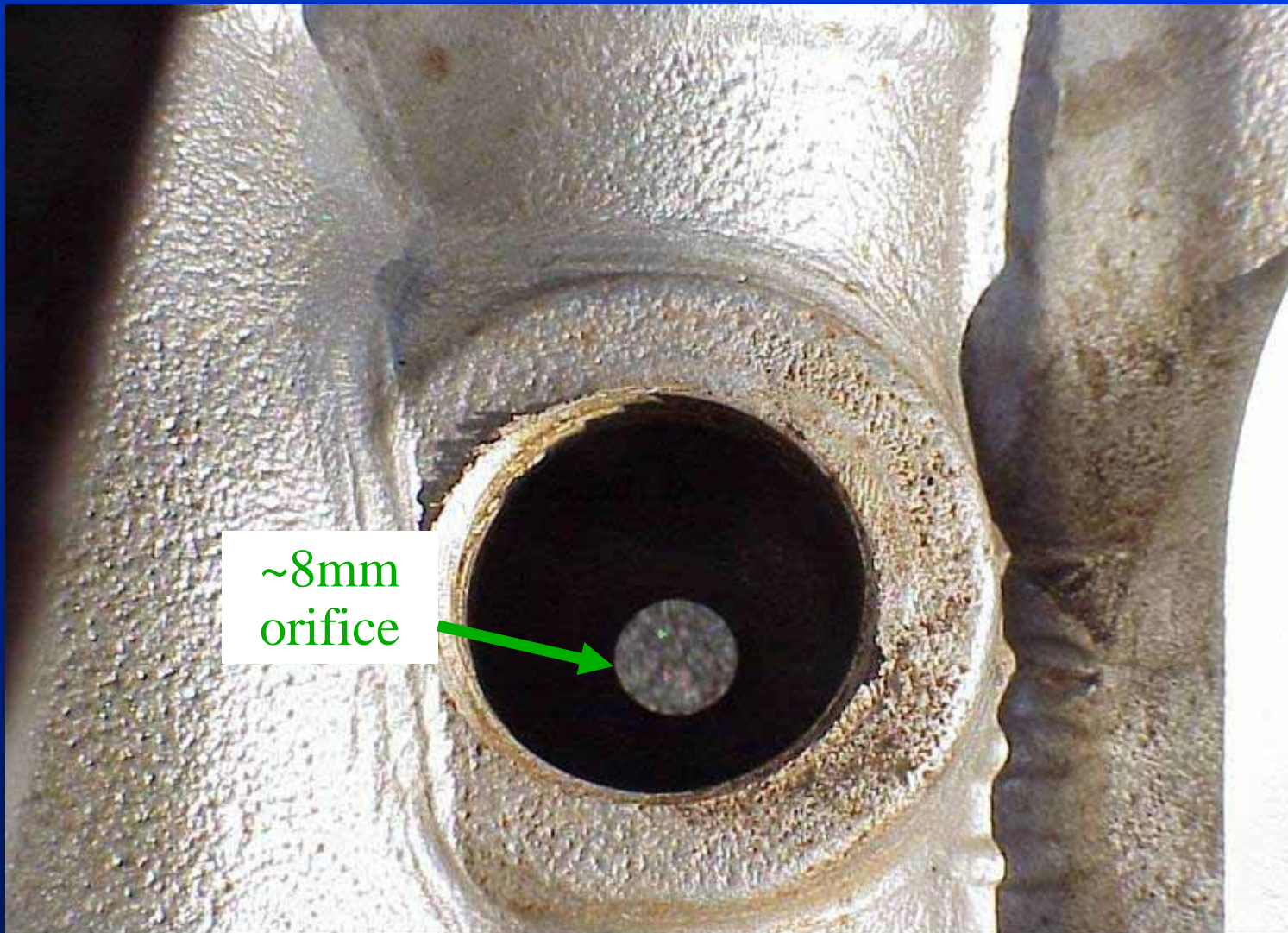
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Zooming in on a plugged EGR orifice



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Same EGR orifice after cleaning



~8mm
orifice

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Cylinder A/F Imbalance

- Result of imbalance can be very high emissions
 - NO_x 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

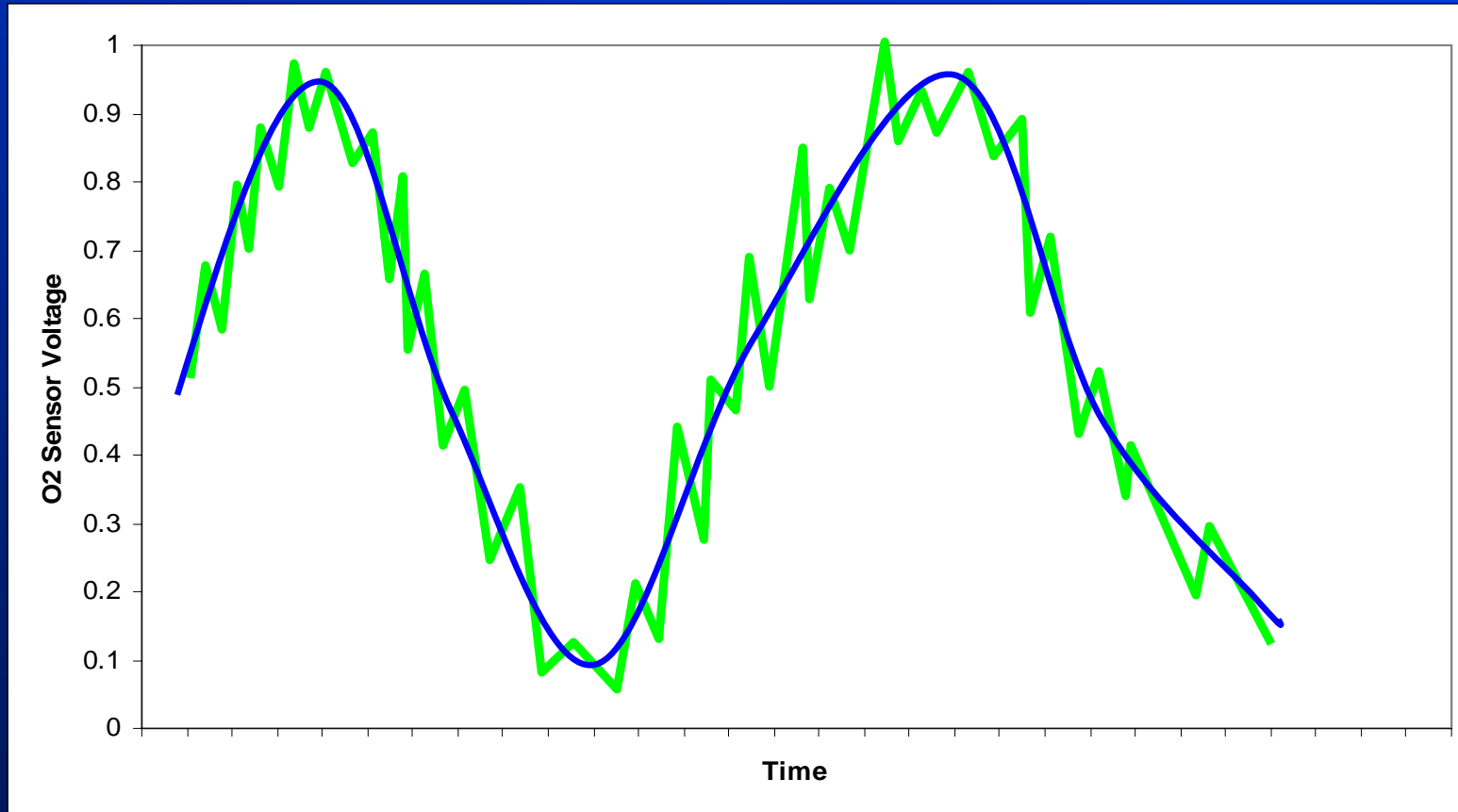
Proposed Monitoring Requirements

- 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”



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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 every 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

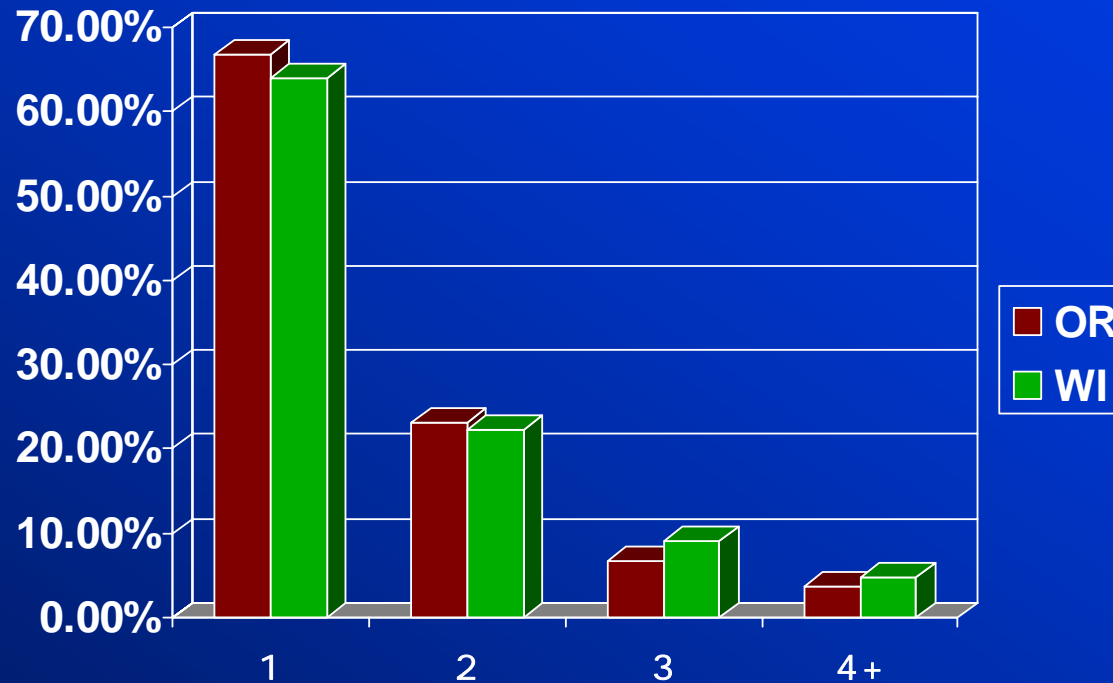
- Proposal will require permanent DTCs identical to requirement for HD OBD
- Feedback from I/M programs showing increased usage of readiness loopholes
 - Up to two monitors can be incomplete at time of inspection
- Permanent DTCs compromise between running all monitors and those previously commanding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

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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

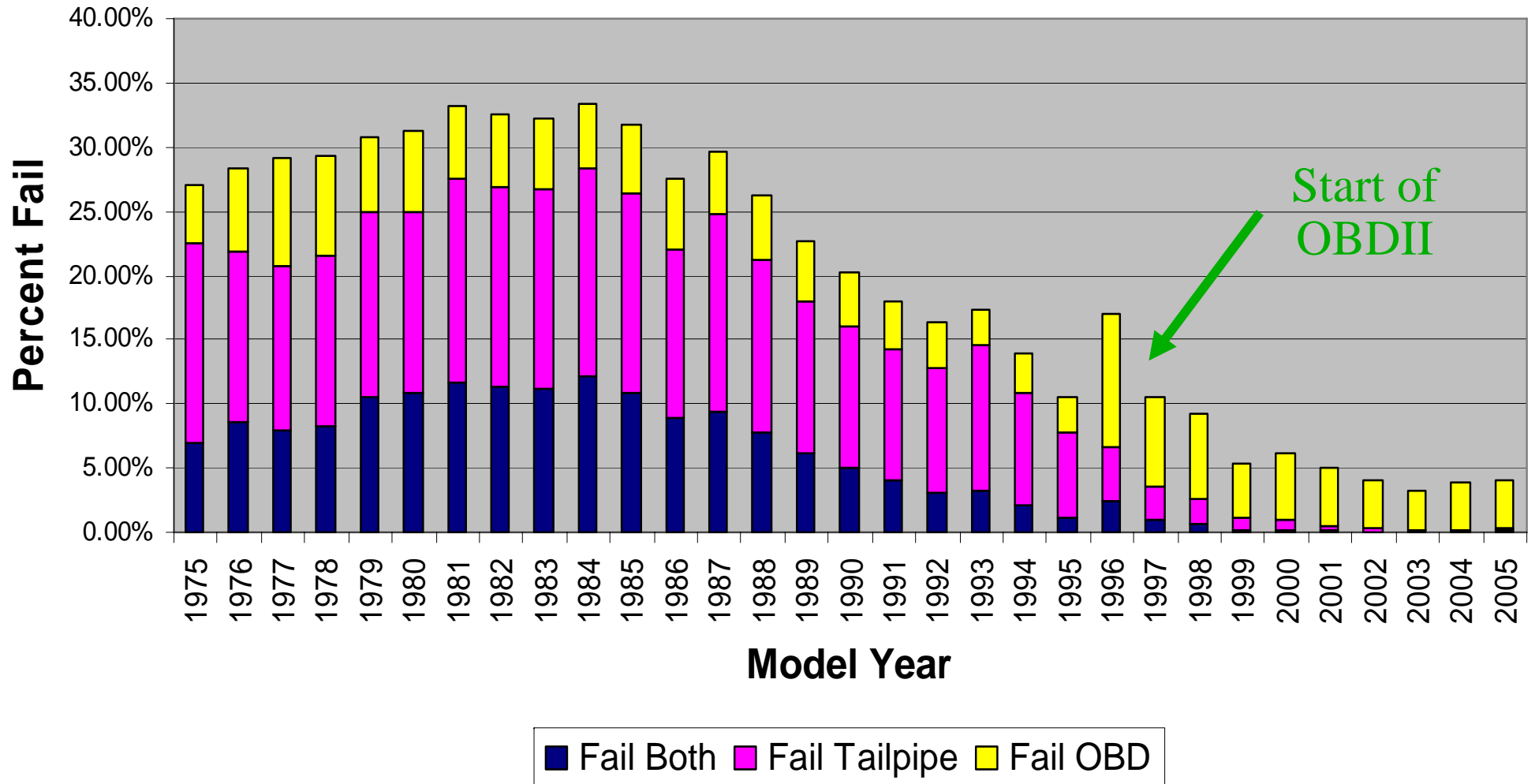
CA Smog Check Statistics

- ~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

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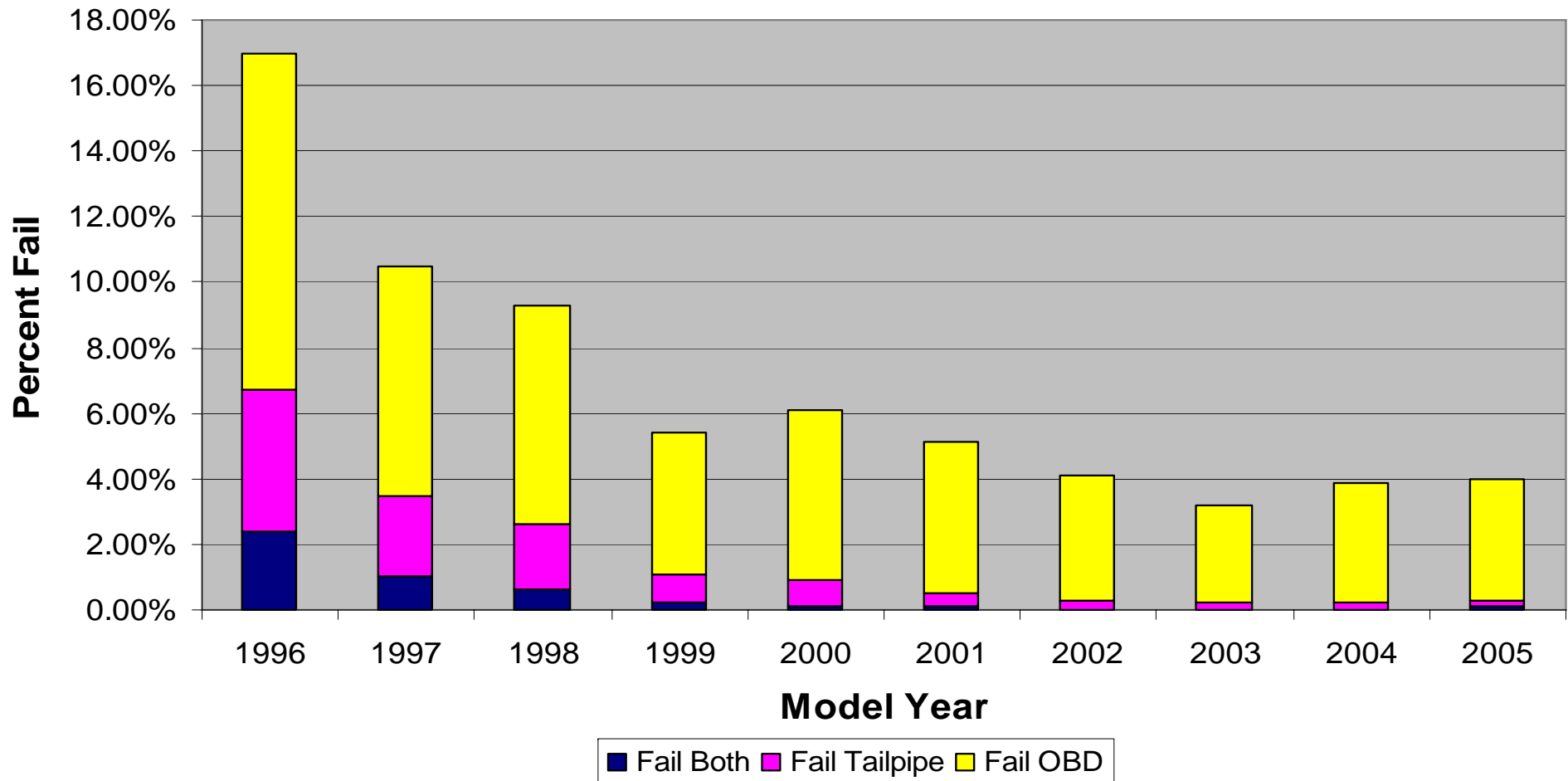
CA Smog Check fail rates



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

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Looking at just OBDII vehicles...



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

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

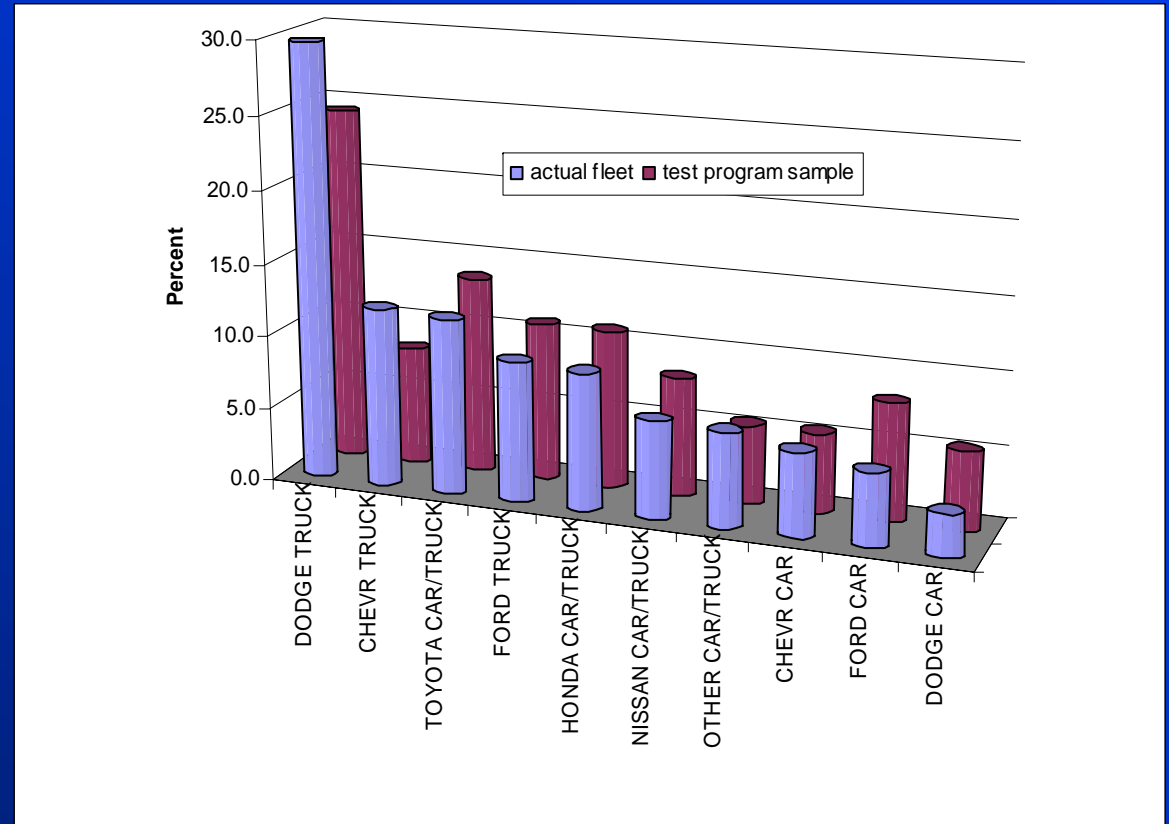
DTC	Percent	Definition
P0420/430	25.82%	Catalyst
P0171/174	14.47%	Fuel System Lean
P0401	13.93%	EGR Flow
P0133/153	13.56%	O2 Response
P0xxx	~10%	Other O2/heater
P0xxx	~10%	Evap
P0300	6.57%	Misfire

Background

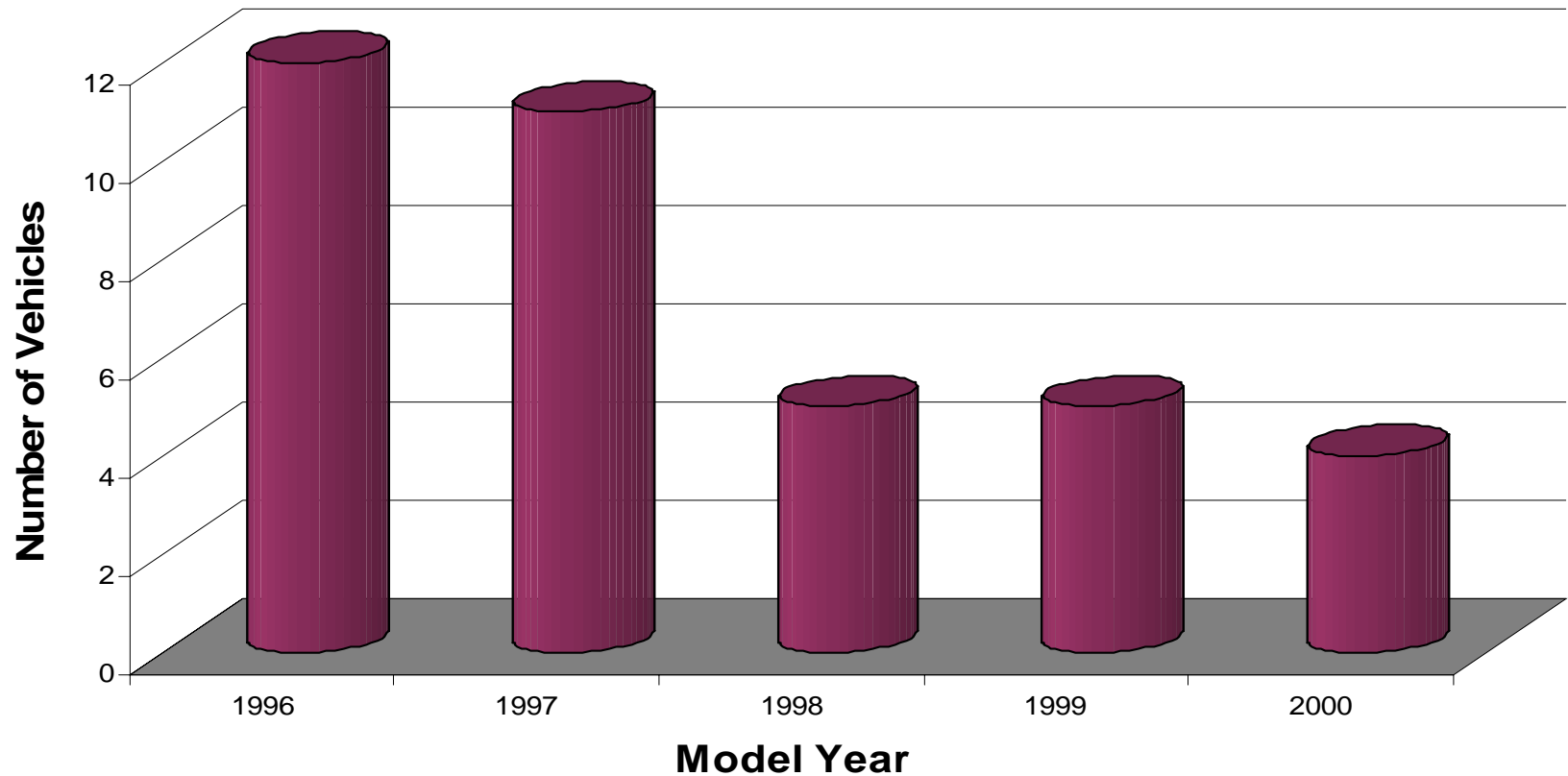
- A small percentage of vehicles (<0.1%) in the fleet pass an EPA OBD only inspection but fail the ASM test at gross polluter (GP) levels
- ARB has been recruiting vehicles that meet this criterion and testing them to understand what's going on

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%



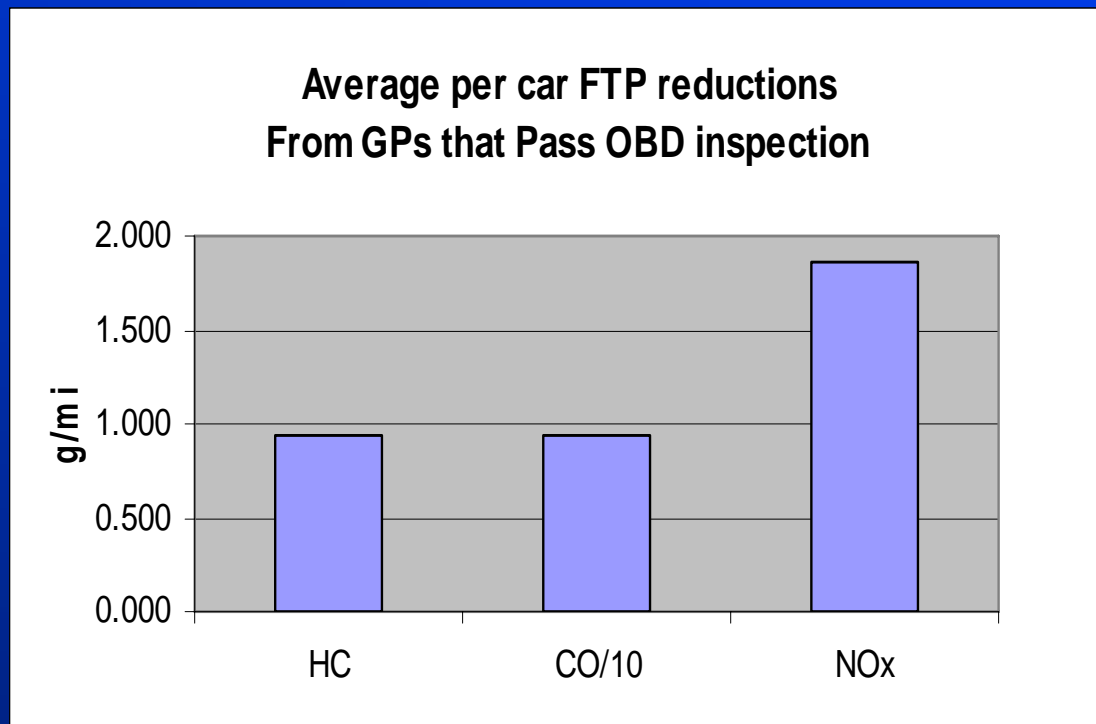
Make-up of the test sample (by model year)



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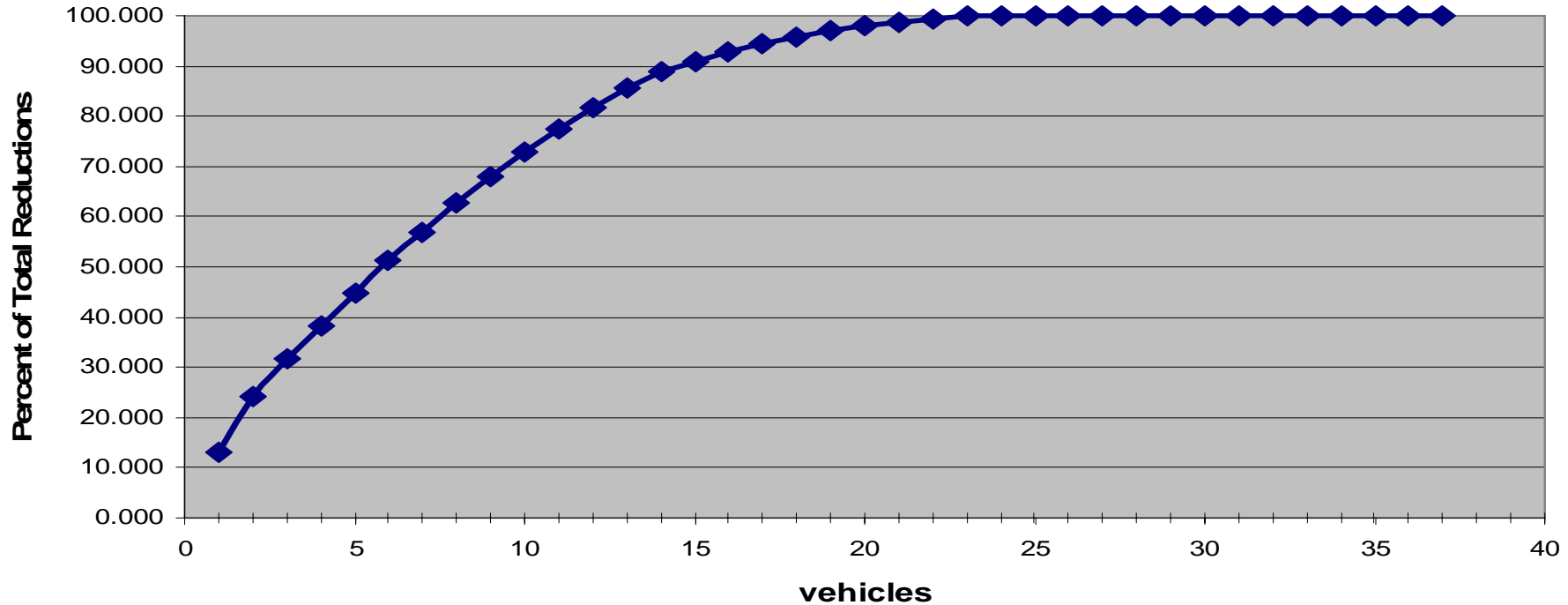
Emission reductions

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



Distribution of Emission Reductions

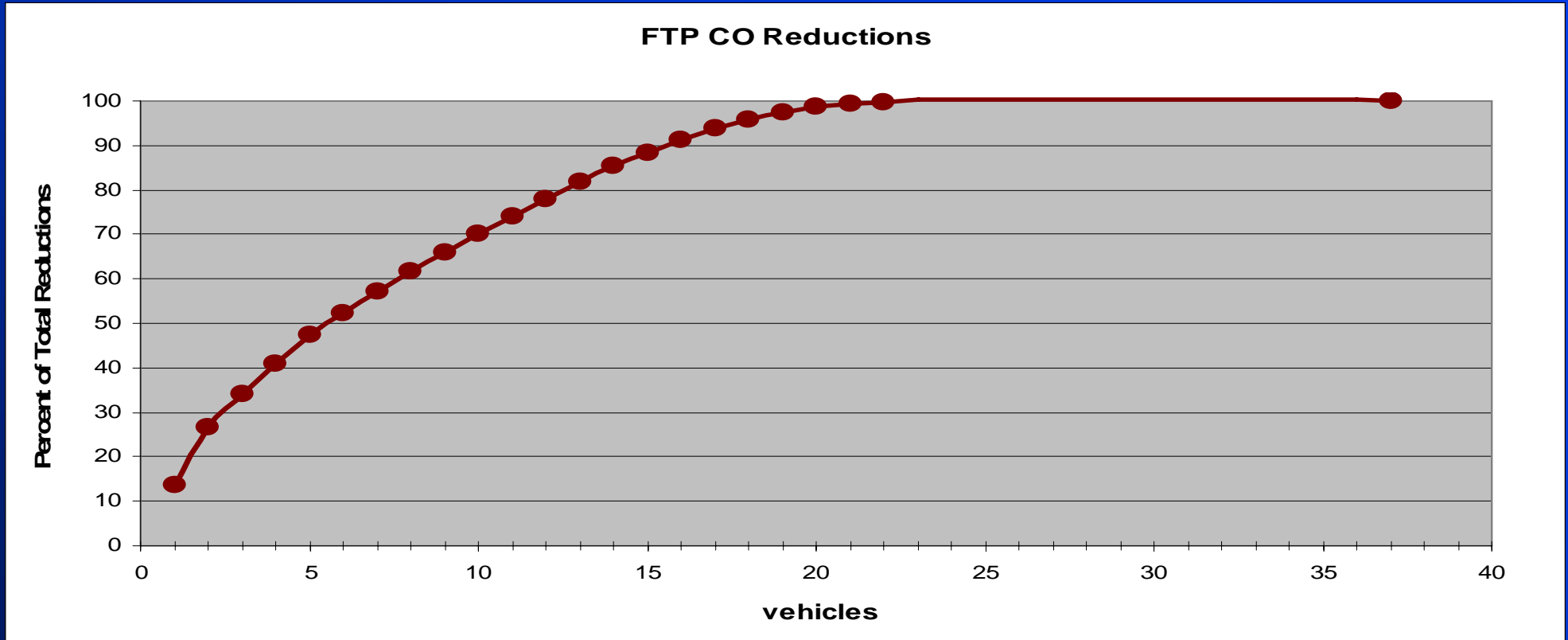
FTP HC Reductions



- 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 catalyts on 96-99 Dodge/Jeep trucks
- 31% from replacing illegal (non-OBDII approved) aftermarket catalyts

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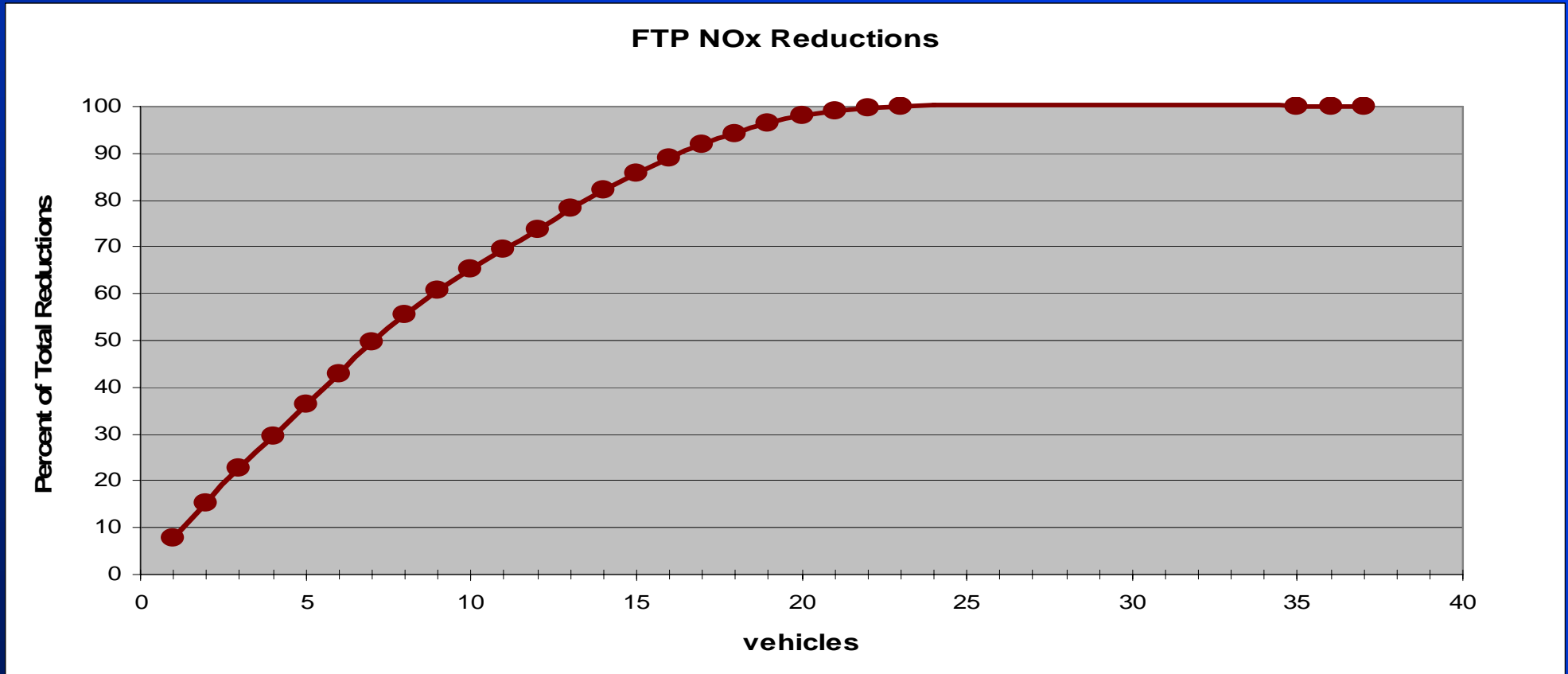
Similar for CO benefits



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

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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

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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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