On-Board Diagnostics (OBD) Program Overview

California Air Resources Board

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Presentation Outline

- OBD History and Background
- OBD Requirements
- OBD Certification
- OBD Enforcement
- OBD and Smog Check

OBD II Regulation - History

- Adopted by Air Resources Board in 1989
  - Implementation began in 1994
  - Full Implementation achieved in 1996
  - Over 150 million OBD II-equipped vehicles operating in the United States today
- Vehicle Applications (< 14,000 pounds)
  - Passenger cars
  - Light-duty trucks
  - Medium-duty vehicles and engines
- OBD requirements adopted for heavy-duty vehicles in 2005 (HD OBD, > 14,000 pounds)
  - Full implementation in 2013

Keeping In-use Cars and Trucks Clean

- Low emission vehicles depend on numerous and complex emission controls to clean up a dirty combustion process
  - Emission solutions are increasingly complex
- Malfunctions can increase emissions to many times the certification standards
  - Deterioration
  - Improper maintenance
  - Manufacturing defects
  - Tampering

On-Board Computer

- Modern vehicles use on-board computers
  - Control fuel metering (fuel injection)
  - Actuate EGR and purge valves, etc.
  - Regulate anti-lock braking
  - Control transmission

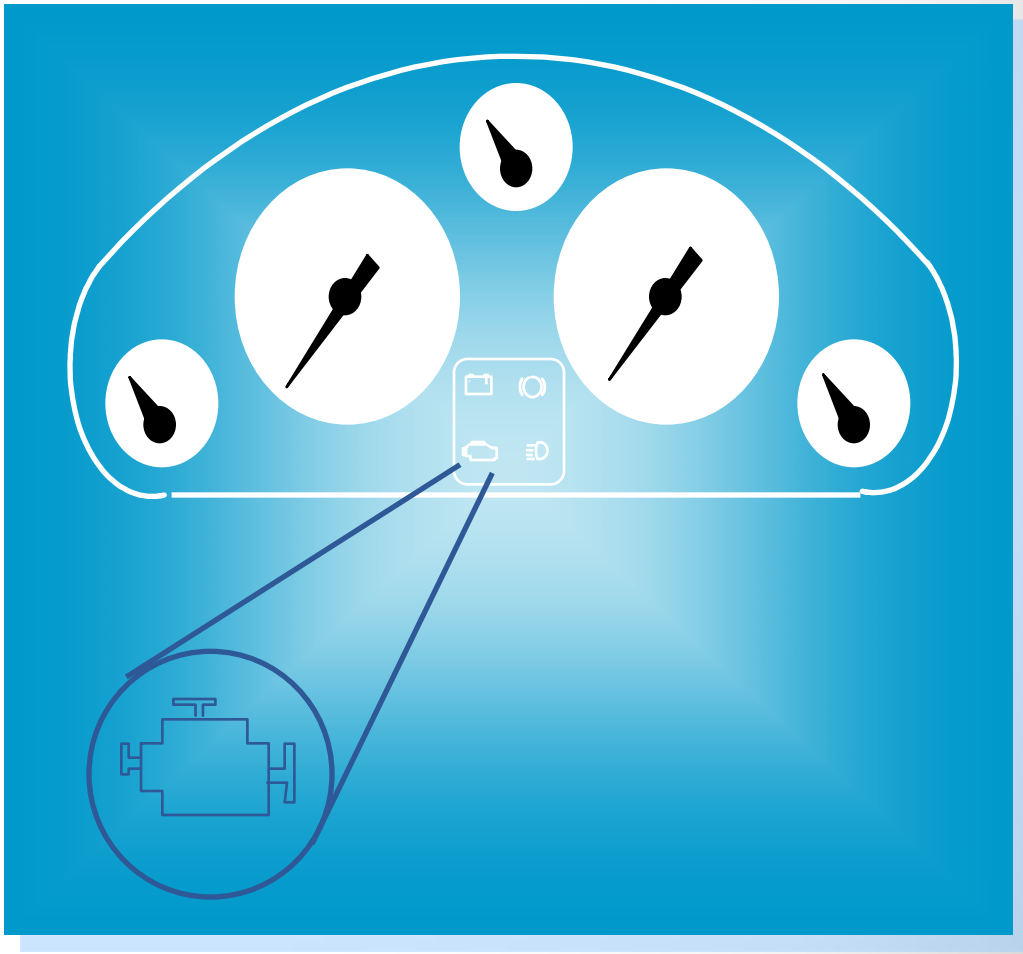
- OBD II is an extension of the computer

What is On-Board Diagnostics?

- A system in the engine's on-board computer that monitors the performance of almost every emission-related components for malfunctions
- Uses information from sensors to judge performance of emission controls
  - Sensors do not directly measure emissions
- Mostly software that runs diagnostics in the background

Malfunction Indicator Light (MIL)

- A warning light will appear on the vehicle's instrument panel to alert the driver if a malfunction is detected



OBD Monitoring Scope

- Virtually every source of excessive vehicle emissions is monitored

Monitoring Categories		
Catalyst Efficiency	Misfire Detection	Evaporative System
Secondary Air	Fuel System	Exhaust Gas Sensors
Exhaust Gas Recirc.	Crankcase Ventilation	Engine Cooling System
Cold Start Strategies	Variable Valve Timing	Direct Ozone Reduction
Air Metering System	Transmission controls	Forced air systems
Hybrid System	Engine speed/angle	

Standardized Information

- When a malfunction is detected, information about the malfunctioning component is stored
- Technicians can download the information with a “scan tool” to help fix vehicle
- Information also used by Smog Check inspectors
- Information is communicated in a standardized format so one tool works with all vehicles (SAE and ISO standards)

Why Is OBD Needed?

- Maintain Emission Control Systems In-Use
  - Deterioration with age
  - Oldest 20% of vehicles cause 60% of pollution
- Help Technicians Properly Diagnose and Repair Complex Problems

Other Benefits of OBD

- Encourages design of durable and robust emission control systems
- Helps keep emissions low by identifying emission controls in need of repair
- Provides for effective/inexpensive emission inspections
- Works for life of the vehicle

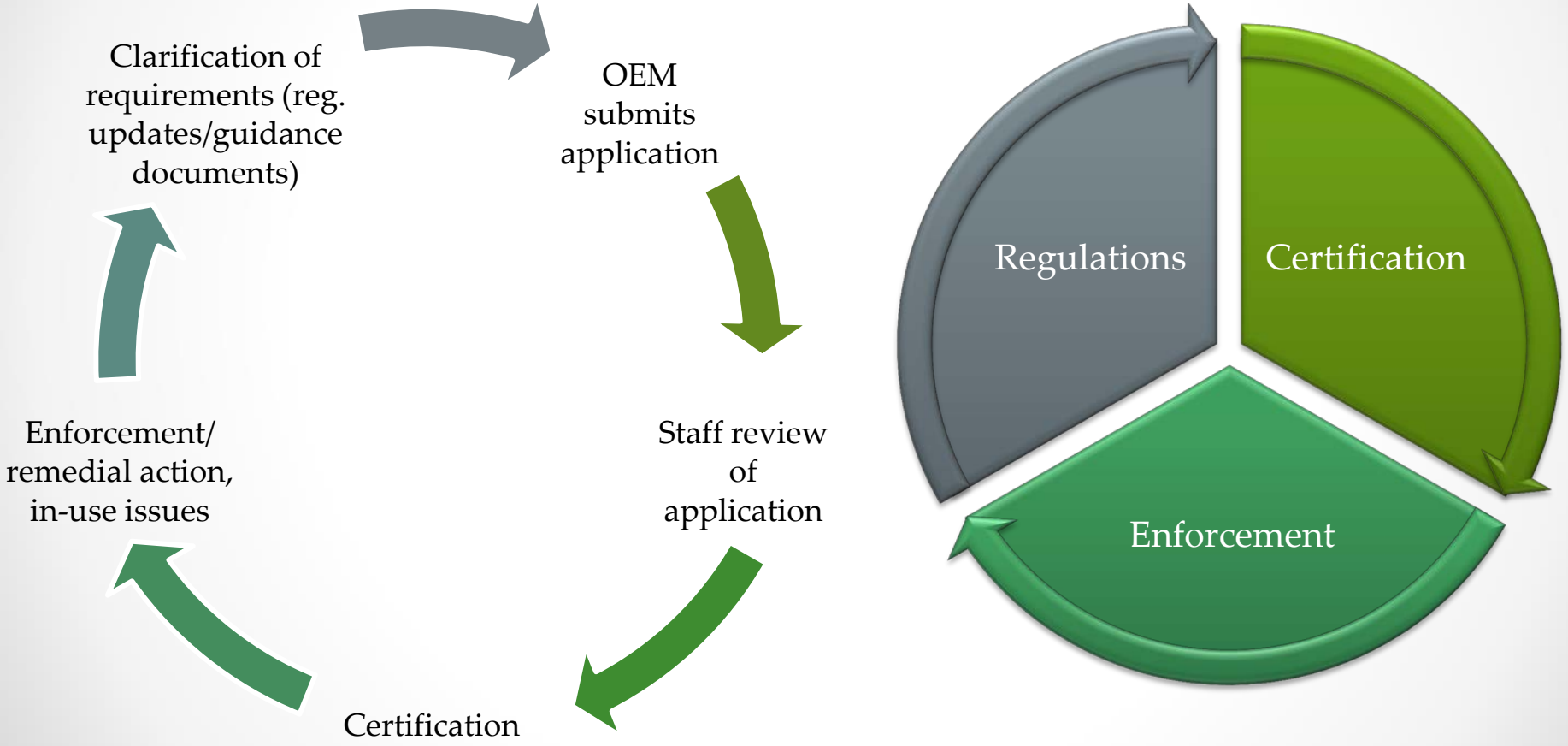
Durable Components

- Cause of MIL Subject to Emissions Warranty
  - 3 Year / 50,000 miles (EGR, O2, etc.)
  - 7 Year / 70,000 miles (catalyst, computer)
  - 15 Year / 150,000 miles for PZEV
- Durability Less Expensive than Replacement

Consumer Cost Benefits

- Early Detection of Malfunctions
  - Prevent secondary malfunctions (e.g., detect misfire before catalyst damaged)
  - Marginal components replaced during warranty
- Eliminates Unnecessary Repairs
  - Fault codes and other scan tool data give information about area of malfunction or the specific component
  - Contrast: tailpipe test simply identifies high emissions, but not fault information, repairs are often trial and error

Aspects of an Effective OBD Program



Amendments

- The regulation has often been amended to improve effectiveness and to accommodate new vehicle technologies

- Adopted 1989
- Amended in 1991, 1994, 1996, 2002, 2006, 2015
- Other minor amendments through other rulemakings
- Rulemakings Available on the ARB OBD website:
  http://www.arb.ca.gov/msprog/obdprog/obdregs.htm

OBD Requirement Concepts

- Emission threshold monitoring
  - Malfunction Indicator Light on when emissions increase X%
  - Usually based on 1.5 x standards
  - 8-20 per vehicle
- Non- emission threshold monitoring
  - Comprehensive components
  - Functional, rational, electrical
  - 75-200 diagnostics per vehicle
- Standardization Requirements
  - Information OBD system required to store
- OBD testing and validation
  - Pre- and post-production; by vehicle manufacturer

Basic OBD Diagnostic Procedure

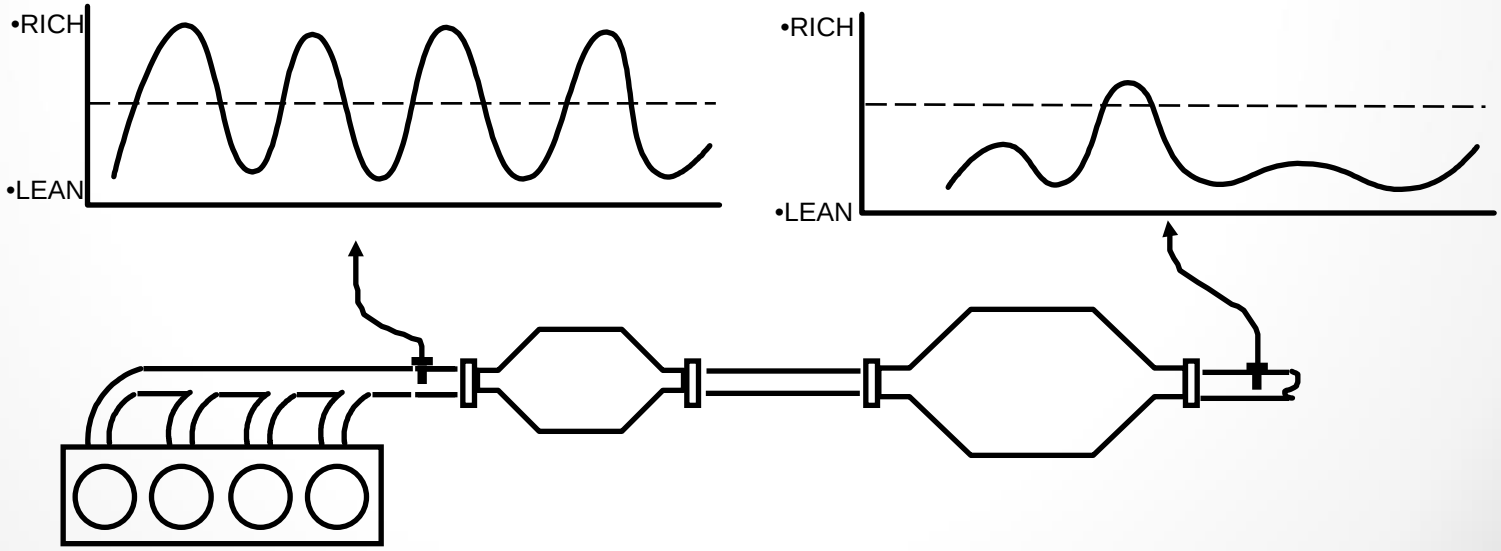
- System waits for right monitoring conditions
- Observes Signals Entering the Computer
  - Directly from the component/system, or
  - Related to performance of component/system
- Verifies Peformance /Functionality / Rationality
  - Malfunction criteria
- Notifies Driver of Fault
  - MIL illumination
  - Unique fault code storage
  - Freeze frame information

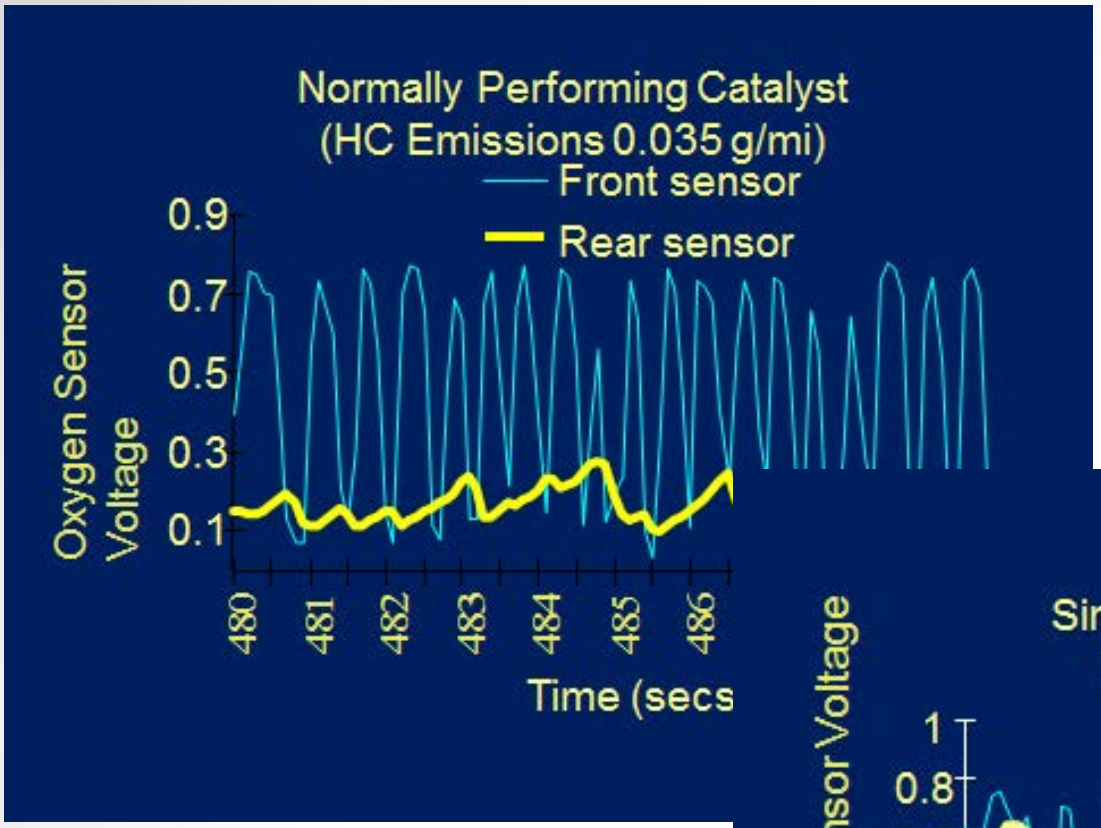
Example of how OBD works: Catalyst Monitoring

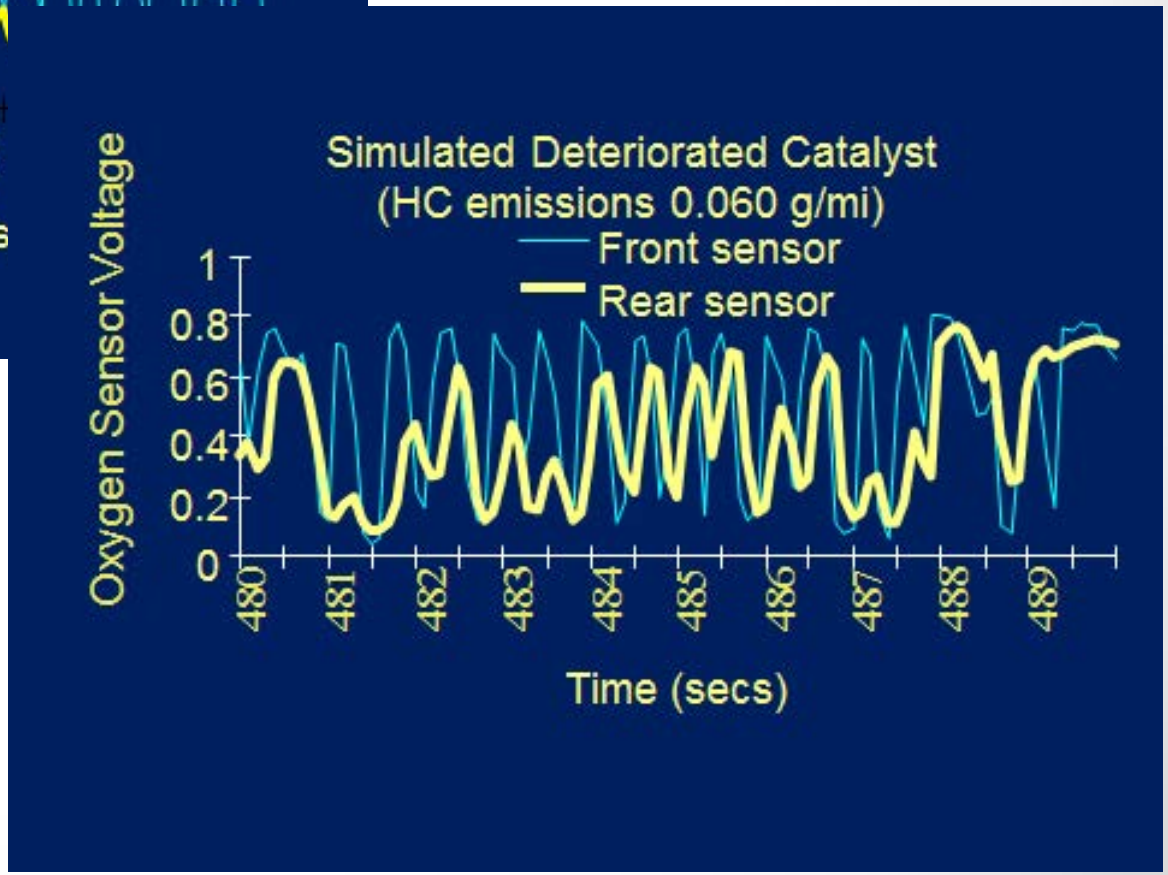
- Oxygen sensor data used to evaluate catalyst conversion performance
- Manufacturer correlates tailpipe emissions with catalyst system performance based on oxygen sensor data.
- OBD system is calibrated to turn on MIL and store fault information for the catalyst when performance drops to the point where emissions exceed malfunction threshold (1.75 X HC or NOx standard)

Catalyst Monitoring Technology

- Monitoring Method: Oxygen sensors before and after the catalyst(s)
- Oxygen storage used to infer HC conversion efficiency

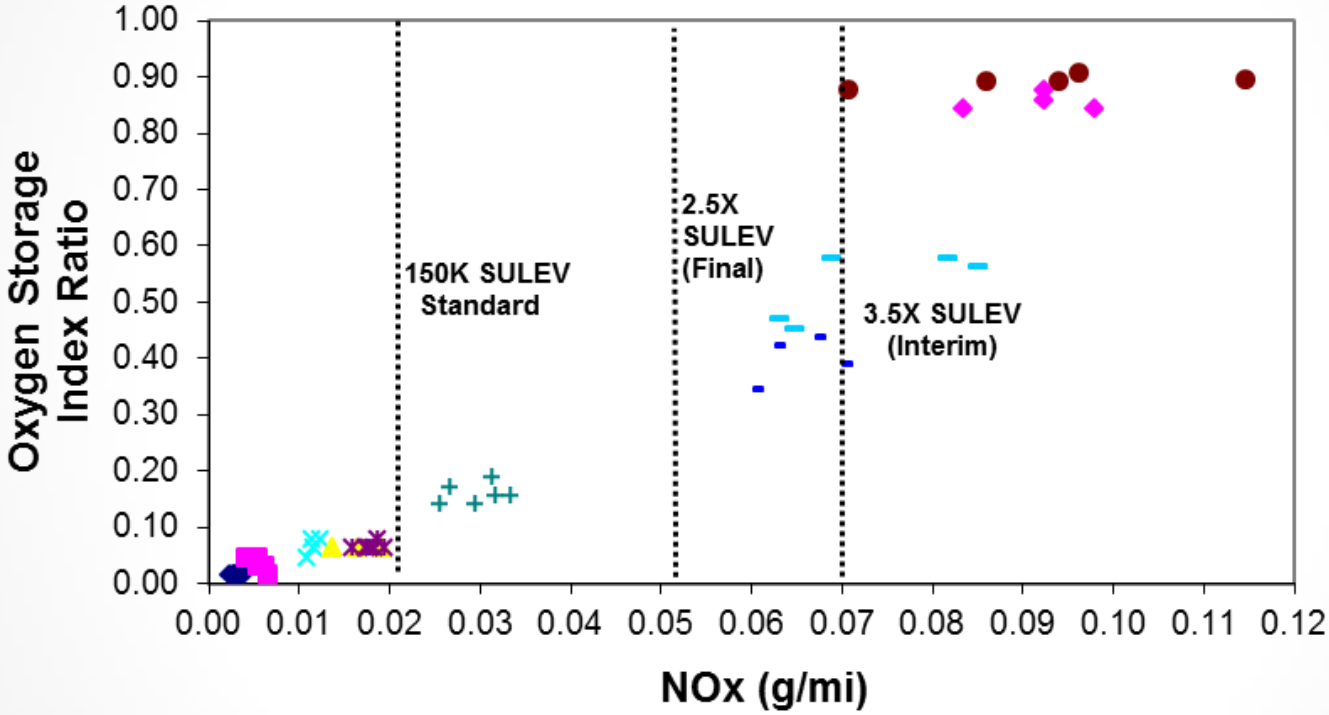



Normally Performing Catalyst
(HC Emissions 0.035 g/mi)
Front sensor
Rear sensor
Oxygen Sensor Voltage
0.9
0.7
0.5
0.3
0.1
480
481
482
483
484
485
486
Time (secs


Simulated Deteriorated Catalyst
(HC emissions 0.060 g/mi)
Front sensor
Rear sensor
Oxygen Sensor Voltage
1
0.8
0.6
0.4
0.2
0
480
481
482
483
484
485
486
487
488
489
Time (secs)

§1968.2(e)(1)

Catalyst Monitor Emissions Correlation



§1968.2(e)(1)

Certification

- Vehicle manufacturer required to submit certification application for review and approval. Application includes:
  - Detailed specifications for all monitors in format prescribed in regulation
  - Demonstration emission test data
  - Any other information/diagrams/data used to support OBD system

- ARB Mail-Out #06-23

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

Certification

- Require detailed disclosure of strategies at the time of certification
- Careful review of trained engineers to understand and look for loopholes/shortcomings
  - OBD certification engineers need to understand OBD system nearly as well as the manufacturer engineers
  - Needed for effective certification and enforcement
- Ability to still get certified and sell with shortcomings but require correction for future model years
  - Deficiencies are important part of successful program
- Reasonable amount of data included to support compliance of system (e.g., demonstration data)

Summary Table (sample portion)

Component/ System (example)	Fault Code	Monitor Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameters	Enable Conditions	Time Required	MIL illum.
Catalyst	P0420	oxygen storage	rear oxygen sensor	> .75	engine speed	1000<rpm<4000	20 seconds	two trips
			period vs. front oxygen		engine load	>20%	once per trip	
			sensor period		ECT	>70C		
					MAP	> 25 kPa		
					fuel system status	closed loop		
				disable				
				conditions:	MIL not illuminated			
					for DTCs:	P0139		
						P0105		
						P0133		
EGR System	P0401	difference in MAP	delta MAP	< 10 kPa	vehicle speed	> 35 mph	3 seconds	two trips
		readings			ECT	> 70C		
					fuel system status	fuel-cut		
					battery voltage	> 11.0 volts		
				disable				
				conditions:	MIL not illuminated			
					for DTCs:	P0105		
Manifold Absolute Pressure (MAP) Sensor:								
MAP High	P0108	Out of Range High	MAP Voltage	> 4.0 V (110 kPa)	Engine Speed	> 300 rpm	Continuous	one trip
MAP Low	P0107	Out of Range Low	MAP Voltage	< 0.15 V (15 kPa)	Engine Speed	> 300 rpm	Continuous	one trip
MAP Rationality	P0106	Comparison of	High Rationality					two trips
		modeled MAP to	MAP Voltage:	< 3.1 (65 kPa)	Engine Speed	1000 to 5000	2 seconds	
		actual MAP signal			Vehicle Speed	> 10 mph		
					calculated load	> 50%	Monitor runs	
							whenever enable	
			Low Rationality	> 1.0 (25 kPa)	Engine Speed	> 1500	conditions are	
			MAP Voltage:		Vehicle Speed	> 10 mph	met	
					Fuel System Status	Fuel Cut		

In-Use Compliance

- Key to ensuring as-built cars actually match design/certification.
- Does OBD system work as described by manufacturer? If not, find out why.
- Combination of manufacturer self-testing and agency testing
- Divided into distinct regions to focus on areas where problems have previously been found

Compliance Testing:

Manufacturer Self-Testing

- Demonstration Testing
  - Shows that malfunctions are detected before emissions exceed thresholds (e.g., 1.5 X emission standards)
- Communication standardization via J1699
  - Makes sure that production vehicles properly handle/communicate required information through datalink
- Diagnostic function
  - Manufacturers have to implant faults and verify detection on production vehicles
- IUMPR - In-use Monitor Performance Ratios
  - Tracks how frequently monitors really run on the road. Data reported to ARB for review.

Compliance Testing

Agency Enforcement Testing

- Confirmatory testing of demonstration vehicles
  - ARB duplicates testing to verify that malfunctions are detected before emissions exceed threshold levels (e.g., 1.5 x standards)
- Actual in-use vehicle testing by engineers with implanted faults, dyno and on-road driving, data logging.
  - Do the monitors run when they are supposed to?
  - Do they detect malfunctions that are implanted?
  - Is the right data stored when a malfunction is detected?
  - .. And so on.

Enforcement: Remedial Action

- Criteria to determine appropriate remedial action in enforcement regulations
- Remedial action varies from nothing up to recall and fines
  - Field fix software
  - Service bulletin
  - Notification to OBD clearinghouse: http://obdclearinghouse.com/
- Mandatory recall if a major monitor is non-functional, or if defect prevents I/M testing

Background: OBD II and I/M

- OBD II designed from the beginning as an I/M Tool
  - Comprehensive monitoring requirements
  - Fault thresholds based on emission standards
- Readiness Indicators

OBD Based I/M Procedure

1. Does the MIL work? (Key on engine off)
2. Is the vehicle ready for an inspection?
   - No recent code clearing
3. Is the MIL commanded off?

◉ If YES to all 3: PASS

◉ If NO, remedy as necessary:

- Fix MIL lamp or wiring
- Conduct more in-use driving and return for re-inspection
- Fix detected fault and return for re-inspection

Benefits over Tailpipe I/M

- More comprehensive fault detection
  - All emission-related components individually monitored
  - Cold start problems detected
  - Evaporative emission problems detected
  - Broad in-use testing conditions
  - OBD failure rates 2.5X ASM failure rates
- Convenience
  - Faster (less than 5 minutes)
  - No surprises (MIL off = pass, unless recently serviced)
  - Less expensive

Pre-Inspection Benefits

- Most detected faults are addressed before Inspection
- Failure rates / Benefits much higher than Smog Check database would indicate
- Data indicates that benefits may be 3 times as high as indicated by Smog Check failure rate.

Time/Cost Savings

- OBD II Inspections can be completed in a matter of few minutes
- Cost savings could be $15 to $35 per test

Calendar Year	Cost Savings Range ($/year)
2015	$107M - $305M
2020	$139M - $356M

- Continued tailpipe testing along with OBD inspections not cost effective:
  - $300K to $900K per ton HC+NOx

•http://www.arb.ca.gov/msprog/smogcheck/march09/transitioning_to_obd_only_im.pdf

Fraud Detection

- A given vehicle should have specific values.
- Most should not change from one inspection to the next

- VIN
  - Vehicle specific
  - Should not change
- Readiness Profile
  - A given make/model/year should have a specific readiness profile
  - Possible to change (running change), but usually rare
- ECU Address
  - A given make/model/year should have specific value that won't change

More "Fingerprinting" Data

- Cal ID / CVN
  - Combinations are make/model/year specific.
  - May change (field fixes), but still make/model/year specific
- Communication Protocol
  - Shouldn't change
  - Mostly useful for older vehicles
    - (all newer vehicles use same protocol)
- Supported Parameter IDs (PID Count)
  - Calculated value based on the types of data the vehicle supports
  - Careful implementation necessary to ensure calculations are consistent

Readiness Indicators

- Show whether or not major monitors have run since computer memory was last clear.
- When the indicators are “ready”, it means that the OBD system is ready for inspection
- When too many indicators are “not ready”, faults could exist that haven’t been detected yet by the OBD system
- If the emission control is not on the vehicle (e.g., secondary air), the readiness indicator status will be “unsupported”, which is functionally equivalent to “ready”

Readiness Profile (Gasoline)

- Misfire
- Fuel System
- Comprehensive Components
- Catalyst
- Catalyst Heater
- Evaporative System
- Secondary Air
- Air Conditioning
- Oxygen Sensor
- Oxygen Sensor Heater
- EGR

A profile that has changed from one inspection to the next , is inconsistent with similar vehicles , or is faulty may indicate fraud.

Black = Always supported (1998 +)

Green = Always supported/complete

Red = Always unsupported

Orange = May / May Not be Supported

Detecting Fraud "Clean Scanning"

•2005 Chevy 3.8 liter tested instead of 2000 Chevy 2.2 liter

VIN	PCM Vin	MY	Make	Eng Size	misfire	fuel	CCM	Cat	HCAT	EVAP	Sec Air	AC	O2	O2 H	EGR	Protocol	NCA_CAL_ID
1G1JC1249Y7140173	1G1JC1249Y7140173	2000	CHEV	2200	1	1	1	1	0	1	0	0	1	1	0	V	12221143
1G1JC1249Y7143042	1G1JC1249Y7143042	2000	CHEV	2200	1	1	1	1	0	2	0	0	2	2	0	V	12221083
1G1JC1249Y7145308	2G1WH52K459178966	2000	CHEV	2200	1	1	1	1	0	1	0	0	1	1	1	V	12594513
1G1JC1249Y7145924	1G1JC1249Y7145924	2000	CHEV	2200	1	1	1	1	0	1	0	0	1	1	0	V	12221143
1G1JC1249Y7150198	1G1JC1249Y7150198	2000	CHEV	2200	1	1	1	2	0	1	0	0	2	1	0	V	12221143
1G1JC1249Y7150945	1G1JC1249Y7150945	2000	CHEV	2200	1	1	1	1	0	1	0	0	1	1	0	V	12221143
1G1JC1249Y7151268	1G1JC1249Y7151268	2000	CHEV	2200	1	1	1	1	0	2	0	0	2	1	0	V	12206343
1G1JC1249Y7151710	1G1JC1249Y7151710	2000	CHEV	2200	1	1	1	1	0	1	0	0	1	1	0	V	12221163

0=unsupported

1=supported/complete

2=supported/incomplete

Fraud Detection - ECU Tampered

VIN	PCM Vin	MY	Make	Eng Size	misfire	fuel	CCM	Cat	HCAT	EVAP	Sec Air	AC	O2	O2 H	EGR	Protocol	NCA_CAL_ID
JA3AH86DX5U011933	JA3AH86DX5U011933	2005	MITS	2000	1	1	1	1	0	1	0	0	1	1	1	I	1860A118AA
JA3AH86D85U049791	JA3AH86D85U049791	2005	MITS	2000	1	1	1	0	0	1	1	1	0	1	0	I	1860A118AA
JA3AH36D15U048114	JA3AH36D15U048114	2005	MITS	2000	1	1	1	1	0	1	0	0	1	1	2	I	1860A118AA

•2005 Mitsubishi Lancer Evolution

Continuous Testing

- Also known as “OBD III” or “Remote OBD”
- Vehicle OBD system status is periodically/continuously transmitted and recorded
- Vehicles without problems don’t have to be inspected
- If a vehicle has a malfunction, the owner addresses it within a reasonable period of time.

Remote OBD Technologies

- Cellular
- Short Range
  - Wifi
  - FM
  - Bluetooth
- OEM Telematics
  - On-star

Continuous Testing Benefits

- More emission benefits
  - o shortens time between detection and repair
  - o directly addresses code clearing
- Better year round compliance
- Added convenience for passing vehicles

Increased Benefits over Biennial Testing (Oregon CY 2015)	
HC	25.8%
NOx	22.1%

- FACA Transitioning I/M report http://obdclearinghouse.com/index.php?body=get_file&id=1269

Continuous Testing Status

- Some pilot programs have taken place, but no widespread implementation yet
- Program start up costs
- Privacy issues