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
  o Implementation began in 1994
  o Full Implementation achieved in 1996
  o Over 150 million OBD II-equipped vehicles operating in the United States today

• Vehicle Applications (<14,000 pounds)
  o Passenger cars
  o Light-duty trucks
  o Medium-duty vehicles and engines

• OBD requirements adopted for heavy-duty vehicles in 2005 (HD OBD, >14,000 pounds)
  o 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
  o Emission solutions are increasingly complex

• Malfunctions can increase emissions to many times the certification standards
  o Deterioration
  o Improper maintenance
  o Manufacturing defects
  o 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

<table>
<thead>
<tr>
<th>Monitoring Categories</th>
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<tbody>
<tr>
<td>Catalyst Efficiency</td>
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<tr>
<td>Misfire Detection</td>
</tr>
<tr>
<td>Evaporative System</td>
</tr>
<tr>
<td>Secondary Air</td>
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<td>Fuel System</td>
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<td>Exhaust Gas Sensors</td>
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<td>Exhaust Gas Recirc.</td>
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<td>Crankcase Ventilation</td>
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<td>Engine Cooling System</td>
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<td>Cold Start Strategies</td>
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<td>Variable Valve Timing</td>
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<td>Direct Ozone Reduction</td>
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<tr>
<td>Air Metering System</td>
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<tr>
<td>Transmission controls</td>
</tr>
<tr>
<td>Forced air systems</td>
</tr>
<tr>
<td>Hybrid System</td>
</tr>
<tr>
<td>Engine speed/angle</td>
</tr>
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</table>
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 the vehicle.
- Information is 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
  o Deterioration with age
  o 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

- Clarification of requirements (reg. updates/guidance documents)
- Enforcement/remedial action, in-use issues
- Certification

OEM submits application

Staff review of application

Certification

Regulations

Enforcement
Amendments

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

- Adopted 1989
- 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
  o Malfunction Indicator Light on when emissions increase X%
  o Usually based on 1.5 x standards
  o 8-20 per vehicle

• Non-emission threshold monitoring
  o Comprehensive components
  o Functional, rational, electrical
  o 75-200 diagnostics per vehicle

• Standardization Requirements
  o Information OBD system required to store

• OBD testing and validation
  o 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 Performance / 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
Catalyst Monitor Emissions Correlation

§1968.2(e)(1)
Certification

• Vehicle manufacturer required to submit certification application for review and approval. Application includes:
  o Detailed specifications for all monitors in format prescribed in regulation
  o Demonstration emission test data
  o 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)
<table>
<thead>
<tr>
<th>Component/System (example)</th>
<th>Fault Code</th>
<th>Monitor Strategy Description</th>
<th>Malfunction Criteria</th>
<th>Threshold Value</th>
<th>Secondary Value</th>
<th>Enable</th>
<th>Time Conditions</th>
<th>Required MIL Conditions</th>
<th>Required MIL Parameters</th>
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<td>oxygen storage</td>
<td>rear oxygen sensor period vs. front oxygen sensor period</td>
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<td>engine load</td>
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<td>delta MAP</td>
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<td>MAP High</td>
<td>P0108</td>
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<td>MAP Voltage</td>
<td>&gt; 4.0 V (110 kPa)</td>
<td>Engine Speed</td>
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<tr>
<td>MAP Low</td>
<td>P0107</td>
<td>Out of Range Low</td>
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<td>High Rationality</td>
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<td></td>
<td>Vehicle Speed: &gt; 10 mph</td>
<td>Calculated load</td>
<td>&gt; 50%</td>
<td>Monitor runs whenever enable conditions are met</td>
<td>fuel system status</td>
<td>Fuel Cut</td>
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</tbody>
</table>
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
  o Shows that malfunctions are detected before emissions exceed thresholds (e.g., 1.5 X emission standards)

• Communication standardization via J 1699
  o Makes sure that production vehicles properly handle/communicate required information through data link

• Diagnostic function
  o Manufacturers have to implant faults and verify detection on production vehicles

• IUMPR - In-use Monitor Performance Ratios
  o 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://obdcleaninghouse.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

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Cost Savings Range ($/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>$107M - $305M</td>
</tr>
<tr>
<td>2020</td>
<td>$139M - $356M</td>
</tr>
</tbody>
</table>

• Continued tailpipe testing along with OBD inspections not cost effective:
  o $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

<table>
<thead>
<tr>
<th>VIN</th>
<th>PCM Vin</th>
<th>MY</th>
<th>Make</th>
<th>Eng Size</th>
<th>misfire</th>
<th>fuel</th>
<th>CCM</th>
<th>Cat</th>
<th>HCAT</th>
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0=unsupported
1=supported/complete
2=supported/incomplete
<table>
<thead>
<tr>
<th>VIN</th>
<th>PCM Vin</th>
<th>MY</th>
<th>Make</th>
<th>Eng Size</th>
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• 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
  - shortens time between detection and repair
  - directly addresses code clearing
- Better year round compliance
- Added convenience for passing vehicles

### Increased Benefits over Biennial Testing
(Oregon CY 2015)

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</tr>
</thead>
<tbody>
<tr>
<td>HC</td>
<td>25.8%</td>
</tr>
<tr>
<td>NOx</td>
<td>22.1%</td>
</tr>
</tbody>
</table>

- FACA Transitioning I/M report
Continuous Testing Status

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