Workshop for 2012 Biennial Heavy-Duty OBD and Medium-Duty OBDII Updates

Advanced Engineering Section
Mobile Source Control Division
California Air Resources Board

CARB Workshop
March 28, 2012
El Monte, CA

Background

- Since their inception, the OBD II and HD OBD regulations have been subject to biennial reviews
  - Report back to the Board on manufacturers' progress in meeting the requirements and propose changes, as needed
- Discuss main issues and proposed changes today
  - Board Hearing scheduled for July 2012
  - Feedback from today will be used to develop final staff proposal for Board Hearing

Background (cont)

- Discussion today will not include proposed changes to OBD II and HD OBD enforcement regulations
  - Such changes won't be available until proposed changes to HD OBD and OBD II regulations finalized.
- Format for today's discussion
  - Staff presentation on issues and proposed changes within each discussion point followed by discussion of those items

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

Gasoline Monitors

- Minor changes proposed for heavy-duty gasoline monitors
  - Misfire monitoring clarification for engines that have shutoff strategies (e.g., hybrids):
    - currently required to enable/re-enable monitor no later than the end of the 2nd crankshaft revolution after "engine start" or "engine restart"
    - change "engine start/restart" to "engine fueling beings/resumes"
  - Secondary air system monitoring: added functional monitoring/backstop requirement for faults that cause an increase in air flow
  - Engine cooling system monitoring: clarified enablement requirement for thermostat monitor based on a few still misinterpreting the language

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

Diesel Misfire Monitor

- HD OBD currently requires monitoring for misfire only during idle and for faults that cause one or more cylinders to be continuously misfiring
  - 2013+ MY engines with combustion/combustion quality sensors required to continuously monitor for misfire before emissions exceed specific thresholds
- Misfires found in field that occur during specific speed/load regions that would not be detected by idle-only/complete cylinder out monitor
- Staff Proposal: for all 2016+ MY diesel engines, require continuous misfire monitoring before emissions exceed specific thresholds
  - Expect most engines will use crankshaft acceleration methods and others will use combustion quality/in-cylinder pressure sensors.

Diesel EGR System Monitor

- HD OBD currently requires monitoring of EGR catalysts on all 2013+ MY
- Industry argued that failures of EGR catalyst do not have a direct impact on emissions
  - Indirect impact because it leads to more aggressive deterioration of other EGR components (e.g., fouling of EGR cooler)
  - Also indicated difficulty in pinpointing EGR catalyst faults
- Staff proposal: Exempt from monitoring if EGR catalyst failure will not cause a direct measurable emission impact on criteria pollutants during any reasonable driving condition

Diesel NMHC Catalyst Monitor

- Current Requirement: Threshold of 2.0 x NMHC std for 2013+ MY
- Industry proposal: Increase to threshold of 4.0 x std
  - Only feasible to detect completely-failed catalyst
  - Would ensure functional monitoring for most engines
- Staff Proposal: no change to thresholds
  - Monitoring at that level is feasible
  - Engines moving towards higher engine-out NOx emission levels (i.e., lower engine-out NMHC levels) to maximize efficiency
  - Improvements in lowering emissions during regen and longer regen intervals help make IRAF less a factor in determining threshold catalyst

NOx Catalyst/NOx Sensor Monitors

- Current thresholds for HD and MD NOx conversion efficiency, SCR reductant delivery system, and NOx sensor monitors:
  - 2010-2012MY: NOx std + 0.4 g/bhp-hr
  - 2013+ MY: NOx std + 0.2 g/bhp-hr
- Industry Proposal:
  - 2013+ MY: NOx std + 0.4 g/bhp-hr
  - NOx sensor accuracy not sufficient to meet current threshold
  - SCR catalyst failing at current threshold is still highly functional

NOx Catalyst/NOx Sensor Monitors

- ARB's Proposal:
  - Provide relief for 2013-2015MY
    - Addresses industry's concerns by providing near-term compliance relief
    - Not as much as industry requested

NOx Catalyst/NOx Sensor Monitors

Heavy-Duty NOx Thresholds					
	2013MY	2014MY	2015MY	2016MY	2017+ MY
Current	NOx std + 0.2 g/bhp-hr				
Proposal	NOx std + 0.4 g/bhp-hr	**≥ 20%** of HD CA diesels: NOx std + **0.3** g/bhp-hr All other engines: NOx std + 0.4 g/bhp-hr	**≥ 50%** of HD CA diesels: NOx std + 0.3 g/bhp-hr All other engines: NOx std + 0.4 g/bhp-hr	Carry-overs from 2014 or 2015: NOx std + 0.3 g/bhp-hr All other engines: NOx std + **0.2** g/bhp-hr	All engines: NOx std + 0.2 g/bhp-hr

NOx Catalyst/NOx Sensor Monitors

Medium-Duty NOx Thresholds					
	2010-2012MY	2013MY	2014MY	2015MY	2016+ MY
Current	NOx std + 0.4 g/bhp-hr	NOx std + 0.2 g/bhp-hr			
Proposal	NOx std + 0.4 g/bhp-hr	NOx std + **0.3** g/bhp-hr			NOx std + **0.2** g/bhp-hr

NOx Catalyst Monitors

- Technical Feasibility of Proposal for NOx Catalyst Monitor:
  - Several MD manufacturers are already capable of detecting faults at final threshold levels.
  - NOx sensors do not appear to be limiting factor in achieving final thresholds
  - Likely paths to the final thresholds include:
    - Further refinement of enable conditions
      - Better accounting for transients, temperature changes, and NH_3 storage/release
      - Improved statistical filtering of results
    - Correlating ammonia storage ability to catalyst conversion efficiency
      - Some using ammonia sensors
      - May include intrusive monitors that alter engine out NOx or saturate and/or deplete ammonia storage
    - Better base control strategies to prevent high variability in monitoring results
      - Includes adaptive algorithms

NOx Sensor Monitors

- Technical Feasibility of Proposal for NOx Sensor Monitor:
  - Proposing identical thresholds (to SCR catalyst) for upstream and downstream sensors
  - Upstream sensors easier to meet threshold or better (some already there)
    - Most manufacturers compare sensor to expected/modeled engine-out emission levels during controlled or intrusive condition
    - Location sees higher NOx levels making sensor accuracy at low levels less critical and less influenced by aftertreament
  - Downstream sensors more difficult to discern from SCR catalyst condition so same threshold as SCR catalyst is appropriate

PM Filter Monitor

- Current PM thresholds for HD:
  - 2010-2012MY: 0.07 g/bhp-hr (or std + 0.06)
  - Most 2013-2015MY: 0.05 g/bhp-hr (or std + 0.04)
  - All 2016+MY and original OBD phase-in engine family for 2013-2015MY: 0.03 g/bhp-hr (or std + 0.02)
  - Failure mode exemption allowance applies indefinitely
    - Allows EO to approve non-detection of some failure modes if that is the best technology can do
- Industry proposal for HD:
  - 2010-2015MY: 0.07 g/bhp-hr
  - 2016+MY: 0.05 g/bhp-hr
  - Indicated that PM sensors needed to meet current thresholds and not available for 2013MY timeframe

PM Filter Monitor

- ARB's Proposal:
  - Agree that PM sensors not available for wide-scale implementation in 2013
  - Provide relief for 2013-2015MY
    - Addresses industry's concerns by providing near-term compliance relief
    - Not as much as industry requested
  - Would end indefinite application of failure mode exemption allowance

PM Filter Monitor

Current Heavy-Duty PM thresholds			
2013MY	2014MY	2015MY	2016MY+
One engine family: 0.03 g/bhp-hr All other engines: 0.05 g/bhp-hr			All engines: 0.03 g/bhp-hr

PM Filter Monitor

Proposed Heavy-Duty PM thresholds					
2013MY		2014MY	2015MY	2016MY	2017+ MY
All engines: 0.05 g/bhp-hr w/ failure mode exemption (FME) possible	Option 1	**≥ 20%** of HD CA diesels: 0.05 **w/o FME** All other engines: 0.05 w/ FME	Same as 2014	Carry-overs from 2014 or 2015: 0.05 w/o FME All other engines: **0.03 w/o FME**	All engines: 0.03 w/o FME
	Option 2	All engines: 0.05 w/ FME (same as 2013)	**≥ 50%** of HD CA diesels: **0.03 w/o FME** All other engines: 0.05 w/FME	All engines: **0.03 w/o FME**	

PM Filter Monitor

Current Medium-Duty PM thresholds			
2013MY	2014MY	2015MY	2016+MY
All engines: 0.03 g/bhp-hr w/ FME	All engines: 0.03 g/bhp-hr w/o FME		
FME: Failure mode exemption			

PM Filter Monitor

Proposed Medium-Duty PM thresholds				
2013MY		2014MY	2015MY	2016+MY
All engines: 0.03 g/bhp-hr w/ FME	Option 1	**≥ 20%** of MD CA diesels: 0.03 **w/o FME** All other engines: 0.03 w/ FME	Same as 2014	All engines: 0.03 g/bhp-hr **w/o FME**
	Option 2	All engines: 0.03 w/ FME (same as 2013)	**≥ 50%** of MD CA diesels: 0.03 **w/o FME** All other engines: 0.03 w/FME	

PM Filter Monitor

- Technical Feasibility of Proposal
  - Virtually all HD on track to phase-in PM sensors beginning in 2014 or 2015MY
    - Data show PM sensors able to detect faults at final PM threshold level of 0.03 g/bhp-hr
  - MDVs are capable of detecting PM filter performance deterioration at the current levels right now without PM sensors
  - Further reduction of engine-out PM expected making it easier to achieve 0.05 without a PM sensor

PM Filter Monitor

- Propose additional monitoring requirement for proper feedgas generation of catalyzed PM filter
  - Start date 2016MY
  - Broadens existing requirement to monitor NMHC catalysts for proper feedgas to also apply to catalyzed PM filters.
    - In some aftertreatment configurations, the catalyzed PM filter is used in lieu of an NMHC catalyst to help create (or preserve) NO_2 in feedgas

Other Diesel Monitors

- ARB proposal: delay start dates from 2013MY to 2015MY for following monitors:
  - NMHC catalyst ability to generate proper feedgas for SCR
  - Catalyzed PM filter NMHC conversion performance
  - Fuel control system component tolerance compensation
- Additional lead time addresses manufacturers' concerns
- Aligns with recent changes to MD OBD II regulation

MD OBD II Diesels

- While engine dyno thresholds are defined, chassis-dyno thresholds are not.
  - Manufacturers required to propose equivalent thresholds
  - Chassis-certified MDVs now becoming more common
  - Manufacturers and ARB have gained more experience with respect to emission-based thresholds
- Staff proposal: 2016+MY chassis-certified diesel MDVs use the same thresholds as diesel LDVs.
  - Nominally 1.5x and 1.75x stds.
  - Most chassis MDVs already meet this criteria for the majority of monitors

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

In-Use Monitor Performance
Background

- Track number of times monitors run in-use (numerator)
- Track a counter that represents vehicle activity (denominator)
- Ratio of these two (numerator/denominator) provides an indicator of in-use monitoring frequency
- Design monitors to meet a minimum ratio of 0.100 on 2013+ MY

In-Use Monitor Performance
Background

- Purpose of denominator is to measure vehicle activity
  - Not a drive cycle that must run all monitors
- Robust and compliant monitors might never run on the denominator drive cycle and still have adequate monitoring frequency

In-Use Monitor Performance
Staff Proposal

- Proposed changes to denominator incrementing criteria
  - PM filter active/intrusive monitor: currently increment denominator when regeneration event 'is commanded for 10 or more seconds'
    - Intrusive injection not necessarily used in every regeneration or within first 10 secs
    - Propose to increment denominator when intrusive injection is commanded for ≥10 seconds
  - PM sensor monitoring capability monitor: currently use general denominator criteria
    - PM sensor monitoring strategies to verify sensor is capable of being used still uncertain as to likely monitoring conditions
    - Propose to have manufacturer get EO approval of alternate criteria to increment denominator until more experience gained
  - PM sensor heater monitor: currently use general denominator criteria
    - PM sensor heater may be used infrequently in-use
    - Propose to increment denominator when heater commanded to function for ≥10 seconds

In-Use Monitor Performance
Staff Proposal

- Proposed changes to tracking and reporting requirements
  - List of diesel components/systems to report amended to align with requirements in SAE J1979/J1939
  - NOx/PM sensor monitoring capability monitor now required to be tracked and reported

In-Use Monitor Performance
Staff Proposal

- Minimum in-use monitor ratios
  - Currently 0.100 for all monitors starting in 2013MY
    - 0.100 is interim ratio until enough experience exists to propose more appropriate ratios
  - Started analysis of in-use data to determine appropriate final ratios
    - Still looking for more in-use data on drive cycles
    - High variability in trips/day and miles/day observed
    - Inconclusive at this point how much higher ratios need to be
  - PM filter monitor frequency is the one exception

In-Use Monitor Performance
PM Filter Monitor

- Currently uses 0.100 and special denominator
  - Increment once every 800 mins (formerly ~500 miles)
  - Rationale was best chance of passive monitoring would be relative to a regen occurring/during a certain filter loading range
  - Issue all along has been that PM filter is needed every second of every drive cycle, not once every 500 miles
  - As expected, regen intervals starting to get much longer (~10x)
- PM sensor based monitors not dependent on regen/loading
  - Accordingly, technology for 2016 would be capable of achieving 'comparable' monitoring frequency to other major emission component
- Proposal for 2016+ MY:
  - 0.100 based on the general denominator (e.g., just like SCR catalyst, etc.)

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

Updates to SAE/ISO References

- SAE and ISO documents referenced in HD OBD regulation have been updated with most recent versions
- Further updates may be made prior to the 2012 Hearing to publication dates for a few documents currently still being revised/balloted

DLC/Communication Protocol

- Changes needed due to addition of protocol variants (e.g, 500 kbps) in SAE J1939
  - Diagnostic Connector: J1939 specification originally adopted only had one connector while new version has two connectors. Clarify that "Type 1" (original) connector is the only one allowed.
  - Communication Protocol: Same issue. Clarify that 250kbps baud rate (original) version is the only one allowed.
- For diagnostic connectors, also propose to prohibit manufacturers from putting an additional identical non-OBD connector in same area as the standardized OBD connector
  - To avoid confusion among technicians/inspectors

Readiness Status

- Readiness status for each monitored system reports "complete" or "incomplete" based on whether associated monitors have run or not
  - However, current language not definitive about which monitors should be associated with each system readiness status
- Proposal would identify the specific monitors required to be included in determining each readiness status bit

Erasure of Emission-Related Information

- Specific events that cause key information to be changed or erased require a corresponding special erasure of certain information:
  - If permanent fault codes are lost during reprogramming, readiness status from all OBD ECUs must be reset
  - If VIN or engine serial number are reprogrammed, all diagnostic info from all OBD ECUs must be erased
- Called 'coordinated' clearing by some and requires specific software and architecture to achieve
- Proposal: Simplify requirement while maintaining protection for fraud
  - Require event to trigger erasure/readiness reset only to OBD ECUs that support a readiness bit other than comprehensive components
  - Will avoid having to coordinate erasure of some secondary ECUs
  - Still meets need to provide obvious telltales and force vehicle operation subsequent to the event and prior to inspection.

CVN

- Historically, some have taken an extended time to respond to a CVN request from a scan tool
  - ECUs respond with response indicating they need more time to provide the response
  - SAE protocol deferred to regulation as to when such responses were allowed
  - Regulation provided some guidance but not as clear as it could be and some took liberty to additionally use it elsewhere
- Proposed language change clarifies exactly when it is allowed:
  - Only for CVN requests received: Within first 60 secs of operation after a reprogramming event or NVRAM clear or within first 30 secs after a battery disconnect or volatile memory clear

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

Heavy-Duty Alternate-Fueled Engines

- Currently allows alternate-fueled engines to delay "full" OBD implementation until 2020MY
  - Assumed very small market share and similar conversions as light-duty
  - Recently learned assumptions incorrect/no longer valid
    - Could see significant volume
    - Types of conversions very different
- Staff Proposal: move up start date from 2020MY to 2016MY

Heavy-Duty Alternate-Fueled Engines

- Propose definition for "alternate-fueled engine"
  - Specifically identify configurations that would be considered alternate-fueled engines
  - Address confusion about engines that use more than one type of fuel (e.g., bi-fuel and dual-fuel engines)
    - Engines that can operate solely on gasoline or diesel not considered "alternate-fueled" during those operating conditions
  - Would require manufacturers to ask for approval of monitoring plan - EO approval based on appropriateness of plan to components/systems on engine

Heavy-Duty Alternate-Fueled Engines

- Currently exempt from evaporative system monitoring if engine is 'not required to be equipped with evaporative emission systems'
  - Language doesn't align with actual requirements
  - Vehicles either are or are not subject to evaporative emission standards as opposed to required to be equipped with certain components
- Staff Proposal: tie monitoring exemption to engines not subject to evaporative emission standards
  - Monitoring would be required on alternate-fueled engines subject to standards (e.g., liquid propane gas (LPG) engines).

Discussion Points

- Background
- Heavy-Duty Gasoline Monitors
- Heavy-Duty and Medium-Duty Diesel Monitors
- Heavy-Duty In-Use Monitor Performance Requirements
- Heavy-Duty Standardization Requirements
- Heavy-Duty Alternate-Fueled Engines
- Heavy-Duty Hybrid Vehicles

Hybrid Vehicles

- Minor changes to align with recent changes to OBD II regulation
  - Add definitions of hybrid vehicles, fueled engine operation, and propulsion system active
    - Definition of "hybrid vehicle" slightly modified from OBD II definition for even more clarity
  - Changes to permanent fault code erasure protocol and rate-based denominator incrementing criteria to clarify how they should be handled on hybrids.

Hybrid Vehicles

- Current requirements:
  - All 2013+ MY engines will have HD OBD systems
  - 2013+ MY engines mated with hybrid systems have to stay in compliance with HD OBD
    - E.g., Engine monitors still have to run with adequate frequency and robustly detect faults at the required levels
  - Many hybrid components themselves subject to comprehensive component monitoring requirements
    - E.g., electronic powertrain input and outputs that can cause a measureable emission increase during any driving condition
- Industry issues:
  - Hybrids are small volume so resource intensive
  - Hybrid system manufacturers have limited interaction with engine manufacturers
  - Hybrid manufacturers have not made much progress towards OBD compliant systems

Hybrid Vehicles

- Goals: Transition a large portion of the HD fleet to hybrids in the next 15-20 years
  - But, relies on hybrids being very efficient and compliant with all emission requirements
  - And cost effective without HVIP incentives
- Requires heavy integration with engine
  - Ability to alter engine operation; run accessories; maximize regen, idle off, and electric only launch without safety risks; etc.
  - Likely will take engines calibrated differently to optimize certain operating conditions/take full advantage of hybrid
  - Architecture will likely be different depending on usage of truck (e.g., different vocations, etc.)

Hybrid Vehicles

- Proposal for 2013 MY:
  - Provide path for hybrids to not comply with HD OBD
  - Means hybrid components will not have to be monitored in accordance with OBD
  - Means engines that are mated to hybrids will no longer be liable for OBD compliance
  - Will require abbreviated certification process with OBD staff
- Will be optional to certify to HD OBD in 2013 MY
  - Advantage would be increased incentive funding through the HVIP program

Hybrid Vehicles

- Proposal for 2014+ MY:
  - Certification to HD OBD required
    - One entity has to take responsibility for whole package
    - Integrated design approach only realistic way of meeting requirements
  - Hybrid components
    - Monitored in accordance with HD OBD
  - Engine diagnostics
    - Demonstrate still compliant (thresholds, rate-based, etc.)
  - Deficiencies available
    - Same as the provisions exist today