Diesel Engine Major Monitors

- Fuel System
- Misfire
- EGR System
- Boost Pressure Control System

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Fuel System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
  - fuel system pressure control
  - fuel injection quantity
  - fuel injection timing
- Additional requirement: Detect fault if closed loop system:
  - Fails to enter closed loop
  - Defaults out of closed loop
  - Control authority reaches limits

Fuel System Monitoring Approach

- Fuel Pressure Control
  - Compare target and actual pressure using pressure sensor
- Fuel Injection Quantity
  - Calculate crankshaft speed fluctuations caused by pilot injection during overrun conditions or other cylinder balance type strategy
- Fuel Injection Timing
  - Compare measured crank angle where fluctuation above occurs with command or use injector inductive signature/"flyback" signal

Misfire Monitoring

- Requirement for 2010-2012 MY:
  - Must detect misfire occurring continuously in one or more cylinders during idle
- Requirement for 2013+ MY:
  - Monitor for misfire that causes emissions to exceed 1.5 x standards
  - Monitor during entire speed and load range

Misfire Monitoring (cont'd)

- Full-range, intermittent misfire monitoring necessary
  - Aggressive use of EGR and other concepts such as HCCI cause engine to operate near combustion limits at various speeds and loads
- Misfire Monitoring Approach
  - Measure crankshaft speed fluctuation with crankshaft speed sensor

EGR System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
  - EGR Flow Rate
  - EGR Response Rate
  - EGR Cooling System Performance
- Additional requirement: Detect fault if closed loop EGR system:
  - Fails to enter closed loop
  - Defaults out of closed loop
  - Control authority reaches limits

EGR System Monitoring Approach

- Flow Rate and Response Rate
  - Compare target and actual flow rate using MAF sensor
  - Measure time to reach target flow rate using same sensor
- EGR Cooling System
  - Monitor cooling effectiveness using EGR temperature sensor(s) or IMT sensor(s)

Boost Pressure Control Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
  - Under and over boost malfunctions
  - Slow response (VGT systems only)
  - Charge air undercooling
- Additional requirement: Detect fault if closed loop system:
  - Fails to enter closed loop
  - Defaults out of closed loop
  - Control authority reaches limits

Boost Pressure Control Monitoring Approach

- Under and over boost malfunctions
  - Compare target and actual boost pressure using boost pressure sensor
- Slow response (VGT systems only)
  - Measure time to reach target boost pressure using boost pressure sensor and/or turbine speed sensor
- Charge air undercooling
  - Monitor cooling effectiveness using IMT sensor(s)

Diesel Engine Aftertreatment Monitors

- NMHC Catalyst
- NOx Catalyst (Lean NOx and SCR)
- NOx Adsorber
- PM Filter

NMHC Catalyst Monitoring

- Requirement for 2010-2012 MY:
  - Detect conversion efficiency fault before NMHC emissions exceed 2.0 x standards
  - Functional monitor to detect fault if:
    - Insufficient exotherm to achieve PM filter regen
    - Insufficient NO_2 feedgas generation for SCR
    - No NMHC conversion on clean-up/guard catalysts
- Requirement for 2013+ MY:
  - Same as above except detect fault before NMHC emissions exceed 1.5 x standards

NMHC Catalyst Monitoring Approach

- NMHC emission conversion
  - Exhaust temperature sensors to correlate exotherm to conversion efficiency during intrusive post-combustion fueling event
- Functional monitors
  - Exhaust temp sensor for sufficient exotherm for PM filter regeneration and NMHC conversion on clean-up catalysts
  - NOx sensor for insufficient NO_2 feedgas for SCR

NOx Catalyst Monitoring (Lean NOx and SCR)

- Requirement for 2010-2012 MY:
  - Detect following faults before NOx emissions exceed the standards by 0.3 g/bhp-hr:
    - NOx conversion efficiency
    - SCR reductant delivery
- Requirement for 2013+ MY:
  - Same as above except detect faults before NOx emissions exceed the standards by 0.2 g/bhp-hr

NOx Catalyst Monitoring (Lean NOx and SCR) (cont'd)

- Additional requirements for 2010+ MY: Detect a fault if:
  - Separate reductant tank empty or filled with non-reductant
  - Feedback control of reductant:
    - Fails to enter closed loop
    - Defaults out of closed loop
    - Control authority at limits

NOx Catalyst Monitoring Approach

- NOx emission conversion
  - NOx sensor(s) for higher conversion efficiency systems
  - Exhaust temperature sensor(s) for low conversion efficiency systems (functional type check)
- Reductant delivery/injection
  - Confirm delivery/metering of reductant with NOx sensor (or possibly temperature sensor for open loop/low-efficiency systems)

NOx Catalyst Monitoring Approach (cont)

- Reductant tank/quality
  - NOx sensor to identify empty tank or non-reductant
  - Alternate approach: tank level sensor and reductant quality sensor (in tank or in exhaust)
- Feedback control
  - Control limits of reductant injection system are reached

NOx Adsorber Monitoring

- Requirement for 2010-2012 MY:
  - Detect NOx adsorber capability fault before NOx emissions exceed the standards by 0.3 g/bhp-hr
- Requirement for 2013+ MY:
  - Same as above except detect faults before NOx emissions exceed the standards by 0.2 g/bhp-hr

NOx Adsorber Monitoring (cont'd)

- Additional requirements for 2010+ MY: Detect a fault if:
  - Insufficient active/intrusive injection to achieve desorption of NOx adsorber
  - Feedback control of NOx adsorber or active/intrusive injection system:
    - Fails to enter closed loop
    - Defaults out of closed loop
    - Control authority reaches limits

NOx Adsorber Monitoring Approach

- NOx adsorber capability performance
  - A/F sensors before and after to correlate desorption time with performance
  - NOx sensors could also be used
- Active/intrusive injection
  - A/F sensors before and after to verify rich exhaust condition achieved
  - NOx sensor(s) could also be used

PM Filter Monitoring

- Requirement for 2010-2012 MY:
  - Require following faults to be detected before PM emissions exceed 0.05 g/bhp-hr:
    - Filtering Performance
    - Infrequent Regeneration
- Requirement for 2013+ MY:
  - Same as above except detect fault before PM emissions exceed 0.025 g/bhp-hr

PM Filter Monitoring (cont'd)

- Additional requirements for 2010+ MY:
  - Detect: (before NMHC emissions exceed 2.0x std)
    - too frequent regeneration
    - catalyzed filter NMHC conversion efficiency
  - Functional monitor for:
    - Incomplete regeneration
    - Missing substrate
    - Insufficient injection for active PM filter regeneration
  - Detect a closed loop regeneration system fault:
    - Fails to enter closed loop
    - Defaults out of closed loop
    - Control authority reaches limits

PM Filter Monitoring Approach

- Filtering Performance
  - Differential pressure sensor, inlet temperature sensors, and PM loading model to correlate to filtering performance
- Infrequent Regeneration
  - Comparison of regeneration triggers (differential pressure sensor, PM loading model, time/distance) to identify improper PM loading

PM Filter Monitoring Approach

- Catalyzed NMHC Conversion
  - Temperature sensors to measure performance during active regeneration
- Too Frequent/Incomplete Regeneration
  - Comparison of regeneration triggers (differential pressure sensor, PM loading model, time/distance) to identify improper PM loading
- Missing Substrate
  - Differential pressure sensor and exhaust flow rate to identify unacceptably low backpressure

Diesel Engine Additional Monitors

- Exhaust Gas Sensors

Exhaust Gas Sensor Monitoring

- A/F sensors:
  - For upstream sensors,
    - Detect fault before any emissions exceed 1.5 x standards
  - For downstream sensors in 2010-2012:
    - Detect fault before aftertreatment thresholds exceeded (NMHC 1.5 x standard, NOx standard plus 0.3 g/bhp-hr, or PM 0.05 g/bhp-hr)
  - For downstream sensors in 2013+
    - Same as above but with final aftertreatment thresholds (NMHC 1.5 x standard, NOx standard plus 0.2 g/bhp-hr, or PM 0.025 g/bhp-hr)

Exhaust Gas Sensor Monitoring (cont'd)

- NOx sensors:
  - 2010-2012 MY: Detect fault before aftertreatment thresholds exceeded
    - NMHC 1.5 x standard, NOx standard plus 0.3 g/bhp-hr, or PM 0.05 g/bhp-hr
  - 2013+ MY: Same as above except detect fault before final aftertreatment thresholds
    - NMHC 1.5 x standard, NOx standard plus 0.2 g/bhp-hr, or PM 0.025 g/bhp-hr

Exhaust Gas Sensor Monitoring (cont'd)

- Additional requirements for 2010+ MY: Detect the following faults for all sensors:
  - Circuit/out-of-range faults
  - Feedback faults that cause an emission control system to default out of closed loop
  - Insufficient performance of the sensor for use for other OBD monitors
  - Heater performance and circuit faults

Exhaust Gas Sensor Monitoring Approach

- Upstream/downstream A/F and NOx sensors
  - Analyze sensor output and response during known exhaust conditions
  - e.g., overrun, idle, steady cruise, with or without EGR, during active injection for PM filter regeneration or NOx adsorber desorption

Gasoline Engine Monitors

- Same as light-duty OBD II monitoring requirements (section 1968.2)
  - Emission thresholds tied to 1.5 or 1.75 x standards for major monitors
  - Evap leak check for 0.030” instead of 0.020”
    - Phase-in of 0.090” for 2010-2012
    - Final size of 0.030” for 2013+

Gasoline Engine Monitors (cont'd)

- Alternate-fueled engines
  - Subject to requirements for gasoline engines (even if they are derived from a diesel engine)
  - 2010-2016MY: May request relief/exemption from monitoring requirements
    - For any monitor where monitoring may be unreliable with respect to the alternate fuel

Diesel and Gasoline Engine Monitors

- VVT System
- Cooling System
- PCV System
- Comprehensive Components
- Other Emission Systems

VVT System Monitoring

- Requirement: Detect following faults before emissions exceed 1.5 x standards:
  - target error
  - slow response
- Monitoring Approach:
  - Compare target (commanded) and actual (sensed) valve timing and/or lift

Cooling System Monitoring

- Requirement: Monitor cooling system (e.g., thermostat, ECT sensor) for proper performance:
  - must reach minimum temperature necessary to enable other OBD monitors or any emission control strategy within a reasonable time
  - must reach near thermostat-regulating temperature within a reasonable time

Cooling System Monitoring (cont'd)

- Will likely require engine manufacturers to set upper and lower bounds on amount of heat that coach builders may take out of system during warm-up
  - e.g., max heat removed from the engine side of the thermostat during warm-up
- Monitoring approach:
  - Compare actual temperature with warm-up model (based on start-up temp, ambient, driving conditions, etc.)

PCV System Monitoring

- Gasoline requirement: Detect disconnection of the system between:
  - the crankcase and PCV valve, or
  - the PCV valve and the intake manifold.
  - Or, design the systems to avoid disconnection
- Diesel requirement: Submit plan for review:
  - Combination of detection and, more likely, design of the system to avoid disconnection

Comprehensive Component Monitoring

- Required to monitor electronic components that are used/inputs to the engine controller and that:
  - can cause a measurable emissions increase during any reasonable driving condition, OR
  - affect any other OBD monitors
- Requirement: Detect following faults:
  - circuit and rationality faults for input components
  - functional faults for output components
- Monitors not tied to emission thresholds

Comprehensive Component Monitoring (cont'd)

- Components "outside" of the engine
  - Required to monitor: Transmission/other powertrain components used by the engine controller for enabling, disabling, or malfunction determination (e.g., VSS or park/neutral switch used to disable monitors)

Comprehensive Component Monitoring (cont'd)

- Components "outside" of the engine
  - Not required to monitor: transmission components that aren't used by the engine controller (even if they could fail and cause the trans to operate in a manner that won't run one of the engine monitors)
    - e.g., shift solenoid that results in the engine not shifting to all gears and that results in reduced engine speed range

Other Emission Control System Monitoring

- Required to monitor other emission control systems that are:
  - not identified under the other monitoring sections, OR
  - identified as a comprehensive component, but not corrected or compensated for by an adaptive control system
- Manufacturers required to submit a plan detailing monitoring strategy and malfunction criteria for ARB approval