

California Air Resources Board

Engine Certification Workshop - Durability and Deterioration Factors

March 24, 2010

California Environmental Protection Agency

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Applicable Categories

- On-Road CA-Medium-Duty Engines (MDE)
- On-Road Heavy-Duty Otto-Cycle Engines (HDOE)
- On-Road Heavy-Duty Diesel Engines (HDDE)
- Off-Road Compression-Ignition Engines (OFCl--Tier 4i / Tier 4)
- Others (HD Hybrids & Special Cases)

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Workshop Agenda

- New Emissions Standards
- Use of New Emission Control Technologies
- Engine Durability Program / Generating New DFs
- Certification Issues

New Emissions Standards

New Engine Emissions Standards

- HDOE (CFR Part 86)
 - Otto FTP Transient
- HDDE (CFR Part 86 and Part 1065)
 - Diesel FTP Transient
 - SET (ramp-modal cycle: RMC)
- OFCI (CFR Part 89 and Part 1039)
 - Non-road Transient (NRTC)
 - Steady-State (C1 / D2 / etc.)

New Emission Control Technologies

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New Emission Control Technologies

- Exhaust Gas Recirculation (EGR)
- Diesel Particulate Filter (DPF)
- Selective Catalytic Reduction (SCR)

EGR

- Durability of EGR System
 - Valves
 - By-pass controls
 - Coolers
- Others
- Maintenance Intervals
- Deterioration Effects

DPF

- Infrequent Regeneration and Emissions Adjustment Factors (UAFs/DAFs)
- Ash Cleaning Event
- Operator Commanded Regeneration (OCR) for DPF is allowed under safe harbor provisions
 - See (CHC-2006-007-1)

SCR

- SCR system deterioration:
 - Linear vs. non-linear deterioration
 - Interaction w/ upstream and downstream ATD (OC, DPF, etc) and engine
 - Control sensors durability
- Toxics
 - Copper-based catalyst
 - Vanadium catalyst

Applicable Regulations

On-Road CA-Medium-Duty Engines and Heavy-Duty Otto-Cycle Engines

- Exhaust and Evaporative Emissions Compliance
CCR 1956.8
- 40 CFR Part 86 xxx-026
- Compliance to FUL
- Same as before

Applicable Regulations

On-Road Heavy-Duty Diesel and Off-Road Compression-Ignition Engines

- Exhaust and Evaporative Emissions Compliance
CCR 1956.8
- 40 CFR Part 86xxx-026 and Part 1039-240
- Compliance to FUL

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Certification Requirements

- Engine Durability to Defined Useful Life via service accumulation cycle + hours
- Emissions Compliance to Defined Useful Life via emissions deterioration factors for
 - Exhaust
 - Evaporative, as applicable

Performance and Emissions Demonstration

- Engine Durability Requirements
- Test Protocol and Test Procedures
- Durability Service Accumulation Cycle
- DF Calculations (~100% UL)
- Scheduled Maintenance and Emissions Testing

Service Accumulation Duration

- CA-MDE FUL = 120k miles
- On-Road HDOE FUL = 110k miles
- On-Road HDDE LH/MH/HH 50% FUL
- OFCI 50% of FUL

- Optional DF for HHDDE/OFCI: 35% FUL +

2 DFs to be Generated

One service accumulation cycle producing 2DFs:

- HDDE Category (2007+)
 1. DF1 = FTP Transient Cycle
 2. DF2 = ramp-modal cycle (RMC)
- OFCI Category (Tier4i / Tier4)
 1. DF1 = Non-Road Transient Cycle (NRTC)
 2. DF2 = Steady State

Emissions Test Points / Intervals

- Minimum of three, equally spaced test points, throughout service accumulation period (recommend every 250 hours)
- FTP / NRTC: test sample point = 1 cold start + 3 hot starts
- RMC / C1 / D2: test sample point = 3 hot starts
- Equal sampling at each test sample point

Service Accumulation Cycle

- Service accumulation hours
- Transient segments required
- Real-life or in-use engine cycle
- Emissions testing hours excluded from total cycle
- Recommend agency pre-approval

Deterioration Factors

- Separate Factors for Each Pollutant
- Useful Life Projected Values
- Applied to EDE to Show FUL Compliance

DF Calculation

- Must include all data collected
- Engines with after-treatment: Multiplicative
 - xxHC, NO_x, CO, HCHO
 - PM additive
- Engines with no after-treatment: Additive
- Will consider alternatives

DF Calculation (continued)

- Individual pollutant with separate DF
- DF for composite xxHC+NOx standard
- May use least-square linear regression method
- May propose other calculation methodology

Agency Pre-Approval for Special Cycles / Procedures

- Special pre-conditioning procedures
- Special emission test procedures
- Any deviation from established protocols

Durability Engine

Allowable Maintenance

- On-Road HDD, HDO, and MDE engines
- Applicability: 40CFR Part86xxx-025
- Highly recommend discussing maintenance schedule with agency
- May require before and after emissions tests

Durability Engine

Allowable Maintenance

(continued)

- OFCI for all Tier 4i and Tier 4 engines
- Applicability: 40CFR Part 1039.125
- Highly recommend discussing maintenance schedule with agency
- May require before and after emissions tests

Certification Issues

Certification Issues / Items

- Unscheduled maintenance
- DF engine “failures”
- DPF ash-cleaning event
- DF carryover / carry-across
- Future DF protocol

Durability Engine

Unscheduled Maintenance

Recommend seeking Agency pre-approval,
Example:

- Cleaning, replace, or repair of :
 - EGR (system), injectors, turbocharger, after-coolers, and by-pass controls
- After-treatment device replacement
- Calibration changes

What to do with DF Engine/Part Failure

1. Do NOT replace, repair, clean, or modify the DF engine or engine part(s)
2. Identify and diagnose failure and impact of failed part(s)
3. Contact agency for guidance

What to do with DF Engine/Part Failure (continued)

4. Seek approval from agency for any maintenance of the DF engine
5. Agency will consider appropriate action for the DF engine
6. Must provide engineering report of failure in application

Collection of DPF Ash Cleaning and Resultant Emission Data

- If an ash cleaning is required within the FUL, this event must be demonstrated
- Emissions testing before and after the ash cleaning event
- Emission data will be used to validate the cleaning procedure
- Collected data may be part of the DFs

DFs: Carry-Over & Carry-Across

- Allowed for comparable engines
- Carry-over to a different model year (minor changes w/o emissions impact)
- Carry-across between engine families
 - Worksheet to be completed
 - Worksheet available on ARB website

Sample C/O and C/A Worksheet

| DF Carry-across comparison parameters | | | | | | |
|---------------------------------------|--|---------------|--|--|--|--|
| 1 | Engine Family | Tested Family | | | | |
| 2 | Engine Type | | | | | |
| 3 | Number of Cylinders | | | | | |
| 4 | Cylinder Head Configuration | | | | | |
| 5 | Displacement | | | | | |
| 33 | Reducing agent/fuel consumption ratio (Volumetric) per 1000 Hours of Operation | | | | | |
| 34 | Catalyst surface area/Max. Power | | | | | |
| 35 | Type of Oxygen Sensor | | | | | |
| 36 | Maximum Exposure Temperature on Oxygen Sensor | | | | | |
| 37 | Type of NOx Sensor | | | | | |

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DFs: Carry-Over & Carry-Across (on-road to off-road)

Comparing these follow items:

- Engine hardware/software
- In-use characteristics
- Durability cycle
- Emissions test cycles
- Engine duty-cycle, engine-load and performance, and control calibrations

ARB May Consider Accepting Alternative DF Protocol

- Case by case approval
- Rapid Alternative Durability Process (RADP)
- Real-world, In-use validations
- Engine-out vs. tailpipe-out
- Rapid aging (bench aging protocol)

Other Items of Interest

- AECD sensors table (available on ARB website)
- Engine emissions label durability and alternative protocol to demonstrate label durability
- Provide physical labels for testing

Sample Sensors Table

| Line Number | Sensor Name / Abbreviation | Sensed Parameter Range: High / Low (Units) | Sensor - Actual Value (unit) | Sensor / Actual Value : Low (unit) | Sensor still working? (yes / no) | Failure Detection | Failure Indication | Default Mode / threshold value | Failure Consequence | Impacts on Emissions | AECD Type | AECD Justification | ARB staff comment |
|-------------|----------------------------|--|------------------------------|------------------------------------|----------------------------------|-------------------|--------------------|--------------------------------|---------------------|----------------------|-----------|--------------------|-------------------|
| | | | | | | | | | | | | | |

Other Items of Interest (continued)

- California Warranty
- HD-ZEV and HD-Hybrid rulemaking process
- HD Hybrid DF protocol
- OBD aged-part considerations

Compression-Ignition and Heavy-Duty Certification

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Questions and Answers

Q ??? / A !!!

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