PROPOSED DURABILITY DEMONSTRATION PROGRAM FOR ON-ROAD HEAVY-DUTY DIESEL-CYCLE ENGINES

MOBILE SOURCE CONTROL DIVISION
The objective of the certification DDP is to:
- Demonstrate that each certified engine family meets the applicable emissions standards at the end of its useful life (UL)
- Demonstrate emission related component durability throughout UL (subject to scheduled maintenance intervals)

DDP is a certification requirement

For heavy-duty diesel engines, DDP is currently performed by aging the engine and aftertreatment system (EAS) to a portion of the useful life (≈35-50% UL) on an engine dynamometer

Since EAS is currently aged to a portion of UL, the deteriorated full UL emissions are estimated by linear extrapolation of emissions data from the DDP
The following proposals apply only to engine families that are certified through heavy-duty diesel test procedures.

Engine families certified through heavy-duty Otto-cycle test procedures will continue to use the existing procedures to demonstrate full UL durability demonstration. Adjustments to the useful life period will need to be considered.
PROPOSED DDP PROCESS

- **Goal**
  - Obtaining Deterioration Factor (DF) values that better reflect real world deterioration for EAS at time of certification

- **Method**
  - Standardizing the DDP Process for 2022 and subsequent model year **NEW** heavy-duty diesel engine families (does not apply to 2022 model year carryover engine families)

- **Elements**
  - Regenerations prior to emissions tests
  - Break-in Period
  - Standardized Dynamometer Aging Cycles & Accelerated Aftertreatment Aging option
  - Opportunities for validation of durability via in-use and NOx sensor data in 2026+ MY (Alternate Durability Program Concept)

  Applicable to durability & certification engines
REGENERATIONS BEFORE OFFICIAL EMISSIONS TESTS

- New preconditioning procedures to minimize the impacts of auto and manual regenerations on emissions test results
  - Need to assure that emission levels have stabilized prior to an official emissions test

- Manual regenerations
  - If used, report in the certification application or durability test results
  - No emissions test allowed until 40 hours of service accumulation after each manual regen event

- Auto regenerations (includes: soot cleaning, ammonia de-crystallization, sulfur removal, hydrocarbon removal, etc.)
  - No emissions test allowed until 10 hours of service accumulation after each auto regen event
BREAK-IN PERIOD

- Initial break-in period is required to assure that emissions are stabilized before an official emissions test is conducted
- Survey of on-road heavy-duty diesel-cycle durability data indicate that the current default 125 hours of break-in period is insufficient for achieving stabilized emissions
- Propose to increase the default break-in period to 300 hours
  - Similar to Tier IV off-road compression-ignition engines
- Manufacturers may propose alternate break-in period as described in §86.004-26(c)(4). Must provide actual emission test results at various intervals to verify that FTP, SET and Low Load Cycle (LLC) stabilized emissions have been reached for each engine family
NEED FOR DDP REVISIONS

- Staff believes that current 35-50% of UL method does not fully represent real life component failures and emission deterioration of EAS
- Need to enhance the process for EAS aging
- OBD regulations (adopted Nov. 2018) defined a standardized process for OBD-aging
  - Objective is to obtain similar OBD system response between laboratory aging and real-life in-use aging
- Certification DDP objectives & compliance evaluation process are different:
  - Demonstrate emission related component durability,
  - Estimate expected deterioration of EAS over UL, i.e. develop DFs
Goal is to have a program that represents full UL (FUL) EAS aging

Manufacturers must use standardized DDP process and aging cycles for all certified products

For EAS aging on a dynamometer, we propose two possible pathways:

- Pathway 1 - Use the standardized certification cycles (FTP, SET) for aging
- Pathway 2 - Use Phase 2 GEM model to create engine aging cycle
- Select the pathway which yields the highest cycle-average engine power level (CAPL) based on maximum engine power

An option for using Diesel Aftertreatment Accelerated Aging Cycle (DAAAC*) protocol is proposed for a portion of the durability testing period for HHDD

Other accelerated aftertreatment aging processes under development may also be considered in lieu of DAAAC (subject to CARB pre-approval)

Pathway 1 – Engine Certification Cycles

- t = 0
- Idle for ≈ 2 hours
- FTP
- SET
- Repeat 105 ± 1 hours?
  - Yes
    - LLC ≈ 1.5 hours
    - Idle for ≈ 2 hours
  - No
    - Shut down for cool down**
- t_{run} ≥ durability period
  - No
  - Yes
- end

* t_{run} excludes cool down period
** Scheduled maintenance may be performed during cool down period
Pathway 2 – Phase 2 GEM Drive Cycles

$t = 0$

- Idle for ≈ 2 hours
- Transient HHDDT
- 55 Cruise
- 65 Cruise

Repeat 105 ± 1 hours?

Yes

- LLC ≈ 1.5 hours
- Idle for ≈ 2 hours
- Shut down for cool down**

No

$t_{run} \geq$ durability period

Yes

end

No

- $t_{run}$ excludes cool down period
- ** Scheduled maintenance may be performed during cool down period
Example – Dynamometer Pathway Selection Process (for illustration purpose only)

For each Engine Family

Examine possible vehicle/engine combinations from phase 2 GEM (example):
- Tractor - High Roof, Class 8 Combination, Sleeper Cab (Total Weight = 31,978 kg)
- Vocational - Class 8 Vehicle – Regional (Total Weight = 19,051 kg)

Tractor is the worst case vehicle/engine combination because it has the highest CAPL

Phase 2 GEM cycles (pathway 2) should be used for dynamometer aging because it has the higher CAPL

Calculate FTP/SET engine CAPL (40%)

Run phase 2 GEM model for all tractor vehicle configurations (max phase 2 GEM model engine CAPL = 42%)
## Proposed DDP Service Accumulation Schedules

<table>
<thead>
<tr>
<th>Primary Intended Service Class</th>
<th>Current UL (miles)</th>
<th>DDP Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHDD</td>
<td>110,000</td>
<td>Age EAS on dynamometer to FUL using pathway 1 or 2 cycles ($\approx 2,500^* \text{ hours}$)</td>
</tr>
<tr>
<td>MHDD</td>
<td>185,000</td>
<td>Age EAS on dynamometer to FUL using pathway 1 or 2 cycles ($\approx 4,200^* \text{ hours}$)</td>
</tr>
</tbody>
</table>
| HHDD                          | 435,000            | Two possible options:  
• Age EAS on dynamometer to FUL using pathway 1 or 2 cycles ($\approx 9,800^* \text{ hours}$), or  
• Age EAS on dynamometer for 4,600 hours using pathway 1 or 2 cycles, and then age aftertreatment only using DAAAC for an additional 500-600 hours (equivalent to $\frac{1}{2}$ UL). Age for 300 additional dyno hours ($\approx 5,500^* \text{ hours}$). This option requires NOx sensor data submittal. |

* Service accumulation schedule DOES NOT INCLUDE time required for cool down.  
Assumes 11 MPH average speed and 1.5 hour duration for LLC (subject to change).
Combined Dyno aging + DAAAC Protocol for HHDD (UL = 435,000 miles)

1. Engine After-treatment
2. EAS After Break-in
3. Age EAS to ≈ 4,600 hours using pathway 1 or 2
4. Clean Ash as needed
5. Minimum Required Emission Test Points
6. After-treatment
7. Disassemble engine and aftertreatment
8. Age additional ½ UL using DAAAC (≈600 hrs)
9. FUL EAS
10. Engine After-treatment
11. Age 300 hrs using pathway 1 or 2
12. Engine

Minimum Required Emission Test Points:
- Age EAS to ≈ 4,600 hours using pathway 1 or 2
- Clean Ash as needed
- After-treatment
- Disassemble engine and aftertreatment
- Age additional ½ UL using DAAAC (≈600 hrs)
- FUL EAS
CARB is considering an increase to UL for all HD primary intended service classes beyond current values starting with 2026 MY.

By 2026 MY, CARB anticipates that a combination of in-use test data, lab aging data, and NOx sensor reporting may lead to the development of an alternate durability program that relies on submittal of NOx sensor reports combined with a shortened lab aging program.

Manufacturers with high emission related component failure rates may not be eligible to use the accelerated aftertreatment aging option or alternate durability program.
Timeline – Alternate Durability Program Concept

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 MY</td>
<td>Begin in-use NOx Sensor Data Collection &amp; reporting Program</td>
</tr>
<tr>
<td>2020 MY</td>
<td>Submit NOx Sensor Reports to CARB</td>
</tr>
<tr>
<td>2021 MY</td>
<td>CARB will approve/deny Alternate Durability Plan</td>
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<tr>
<td>2022 MY</td>
<td>New Durability testing Requirements</td>
</tr>
<tr>
<td>2023 MY</td>
<td>Submit request for Alternate Durability procedures</td>
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<tr>
<td>2024 MY</td>
<td>Proposed increase in UL</td>
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<tr>
<td>2025 MY</td>
<td></td>
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<tr>
<td>2026 MY</td>
<td></td>
</tr>
<tr>
<td>2027 MY</td>
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