2021 Truck and Engine Manufacturers Association
Compliance Workshop: Off-Road Breakout Session

April 28, 2021
Outline

• Off-Road In Use Compliance Update
• Off-Road Tier 5 Update
• EMA Q+A
Off-Road In-Use Compliance Program

Nonroad/Marine/Locomotive/Stationary Breakout Session - 04/28/2021
Off-Road HDIUC Status

• Similar to HD on-road program, the Heavy-Duty In-Use Compliance (HDIUC) section is developing an in-use compliance program for off-road equipment.

• Objective is to ensure manufactured vehicle/equipment is in all material respects as certified (AECD, inducements, etc.) and maintains emission compliance throughout useful life.

• Title 13 CCR 2139, 40 CFR 1039, etc. provide the authority for CARB to conduct in-use testing of HD off-road engines and require corrective action in case of nonconformity.
CHAPTER 9. OFF-ROAD VEHICLES AND ENGINES POLLUTION CONTROL DEVICES

- ARTICLE 1. SMALL OFF-ROAD ENGINES
  (Current Regulation: Sections 2400 – 2409)

- ARTICLE 3. OFF-HIGHWAY RECREATIONAL VEHICLES AND ENGINES
  (Current Regulation: Sections 2410 – 2415)

- ARTICLE 4. OFF-ROAD COMPRESSION-IGNITION ENGINES AND EQUIPMENT
  (Current Regulation: Sections 2420 – 2427)

- ARTICLE 4.5. OFF-ROAD LARGE SPARK-IGNITION ENGINES
  (Current Regulation: Sections 2430 – 2439)

- ARTICLE 4.7 SPARK-IGNITION MARINE ENGINES
  (Current Regulation: Sections 2440 – 2448)
Recap of 2020 HDIUC Activities

• A pilot program was initiated to assist with the development of the official IUC program
• Pilot program elements
  • Data logging
  • PEMS testing
• Manufacturers’ support was needed for on data logging due to off-road engines’ non-standardized communication
Pilot Program

- Performed data logging completed using generic and proprietary tools
  - 11 engines
  - 4 different engine manufacturers

- Next steps:
  - PEMS testing
  - Inducement testing
  - Develop an OFCI IUC standard operating procedure (SOP)

- Objectives:
  - Begin the first official off-road ICU program
  - Inform the proposed Tier 5 off-road regulation
CARB’s Request to Manufacturers

- Support for **data logging equipment**
  - Provide support to read, record, and interpret all the information broadcast by an engine’s onboard computers and electronic control units (1039.205 (t) & 13 CCR § 2421 (a)(4)(B))
  - Collect any parameters similar to the targeted list*, even if they are not supported by SAE J1939
  - The CAN bus communications: through both private or/and public networks
  - **Data logging method**: non-invasive method

- On-going **engineering support** on torque curves, warranty history, and responding to other questions

- **Provide diagnostic tool(s):** to ensure equipment is operating as intended

*For reference, CARB has compiled a list of desired target parameters where available SPN was included to be used as reference. List available upon request.*
Conclusion

• CARB’s Off-road IUC program will be developed for CI
  • In the near future: IUC programs for SI, and SI marine engines
• CARB made progress and will continue with the development of the Off-Road IUC program
• CARB requests manufacturer support with data logging, engineering support, and diagnostic tools
• Off-road OEM support is essential and required
• This program will support the development of the Tier 5 off-road regulation
Possible Elements of the Proposed Amendments to the Off-Road Diesel Engine Emission Standards
(Tier 5 criteria pollutant and CO$_2$ standards)
Major NOx and PM$_{2.5}$ Emission Reductions Needed

- California has the worst air quality in the nation
- Key challenges
  - San Joaquin Valley – PM2.5
  - South Coast - ozone
- Off-road equipment are one of the largest contributors
- Action beyond current programs needed to meet air quality goals in various regions

California Ozone and PM2.5 Non-Attainment Areas

Ozone: 0.75 ppb 8-hour Standard (2008)
PM2.5: 12.0 µg/m$^3$ Annual Standard (2012)
Growing Importance of Off-Road

Statewide Mobile Source NOx Emissions

On-Road Vehicles

Off-Road Equipment

Vessels/Ships/Boats (<24nm)

Locomotives

Aircraft

Ref: CEPAM 2019 Summer
## Summary: Off-Road Tier 4 Standards

<table>
<thead>
<tr>
<th>Power Category</th>
<th>Application</th>
<th>PM</th>
<th>NOx</th>
<th>NMHC</th>
<th>NOx+NMHC</th>
<th>CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 19 kW (&lt; 25 HP)</td>
<td>All</td>
<td>0.40</td>
<td>7.5</td>
<td>6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 ≤ kW &lt; 56 (25 ≤ HP &lt; 75)</td>
<td>All</td>
<td>0.03</td>
<td>4.7</td>
<td>5.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 ≤ kW &lt; 130 (75 ≤ HP &lt; 175)</td>
<td>All</td>
<td>0.02</td>
<td>0.40</td>
<td>0.19</td>
<td></td>
<td>5.0</td>
</tr>
<tr>
<td>130 ≤ kW ≤ 560 (175 ≤ HP ≤ 750)</td>
<td>All</td>
<td>0.02</td>
<td>0.40</td>
<td>0.19</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td>&gt; 560 kW (&gt; 750 HP)</td>
<td>Gen Sets</td>
<td>0.03</td>
<td>0.67</td>
<td>0.19</td>
<td></td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Mobile Machines</td>
<td>0.04</td>
<td>3.5</td>
<td>0.19</td>
<td></td>
<td>3.5</td>
</tr>
</tbody>
</table>

Tier 4 Final Exhaust Emission Standards after 2014 Model Year (g/kW-hr)
## Summary: Off-Road Tier 4 Useful Life

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Maximum Power</th>
<th>Rated Engine Speed</th>
<th>Useful Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable or Constant Speed</td>
<td>&lt; 19 kW (&lt; 25 HP)</td>
<td>Any</td>
<td>3,000 hrs or 5 yrs</td>
</tr>
<tr>
<td>Constant Speed</td>
<td>19 ≤ kW &lt; 37 (25 ≤ HP &lt; 50)</td>
<td>≥ 3,000 rpm</td>
<td>3,000 hrs or 5 yrs</td>
</tr>
<tr>
<td>Constant Speed</td>
<td>19 ≤ kW &lt; 37 (25 ≤ HP &lt; 50)</td>
<td>&lt; 3,000 rpm</td>
<td>5,000 hrs or 7 yrs</td>
</tr>
<tr>
<td>Variable Speed</td>
<td>19 ≤ kW &lt; 37 (25 ≤ HP &lt; 50)</td>
<td>Any</td>
<td>5,000 hrs or 7 yrs</td>
</tr>
<tr>
<td>Variable or Constant Speed</td>
<td>&gt; 37 kW (&gt; 50 HP)</td>
<td>Any</td>
<td>8,000 hrs or 10 yrs</td>
</tr>
</tbody>
</table>
Proposed Elements of the Off-Road Diesel Regulatory Amendments

• Upcoming Tier 5:
  • Staff will be amending the off-road diesel regulation
    • Considering proposing significantly more stringent NOx standards that are up to 90% lower than current Tier 4 standards
    • Considering proposing PM standards up to 75% more stringent than current Tier 4 standards to drive deployment of DPFs and get maximum feasible toxic diesel PM reductions
    • Considering proposing CO$_2$ standards to reduce engine GHG emissions from 5 to 10 % below current levels
  • Regulations were last updated in 2004
Possible Elements of Tier 5 Continued

- Low-load and low-temperature NOx emissions
- Work-based in-use compliance procedures
- First-time off-road diesel OBD requirements
- Test procedure modifications to include measurement protocols for off-road diesel CO$_2$ emissions
- Proposing to go to the Board in 2024 with implementation beginning in 2028
Southwest Research Institute (SwRI)
Off-Road Demonstration Program: 19RD025

- Optimize a Deere 6068 engine for low-NOx performance
- Reduce NOx emissions by 90% to 0.04 g/kW-hr
- Reduce PM Emissions by 75% to 0.005 g/kW-hr
- Supplemental demonstration tasks include:
  - Reducing CO$_2$ emissions by 5-10% below current levels in support of a first ever CO$_2$ exhaust standard for off-road diesel engines
  - Full useful-life aging (DAAAC) for emissions aftertreatment components
  - Demonstrating an off-road idle reduction system
  - Demonstrating emissions performance over 12,000-hour useful life
Question on the Off-Road LLAC

• Q: The Nonroad Low Load Application Cycle (LLAC) is a composite cycle made up of low load operations from four different machine applications – what four types of nonroad CI equipment were in the test?

• A: LLAC was constructed by SwRI from real-world data provided by John Deere to demonstrate NOx performance during extended low load operation. The equipment types that produced the data for the LLAC were a Construction Grader, two Mid-sized Tractors, and a Large Tractor. LLAC is not intended as a certification cycle, but as a tool for SwRI to demonstrate NOx control during low load operating conditions.
LLAC Composition Cycles

Construction Grader - Transport
- Speed - Torque

Large Tractor - Dirt Spreader

Mid-Size Tractor - Silage, Transport
- Silage, Spreading, Compacting

Mid-Size Tractor - Silage.

Speed
- 120%
- 100%
- 80%
- 60%
- 40%
- 20%
- 0%

Torque
- 100%
- 80%
- 60%
- 40%
- 20%
- 0%
- -20%

Time, sec

0 500 1000 1500 2000 2500 3000 3500 4000 4500

AR CARB
Question on NTE and the Off-Road LLAC

• Q: Does normal NTE usually capture these [LLAC] low load points?

• A:
  • No. Out of the 4,339 seconds of the LLAC, 630 seconds (14.5%) are within the NTE zone, however the vast majority do not last longer than 30 seconds at a time and are not valid NTE events.
  • There are 3 potential NTE events that occur during the LLAC (one in a mid-size tractor and two in the large tractor). Durations are 57 secs, 39 secs, and 39 secs, respectively.
  • All of these potential short events are disqualified by the aftertreatment (AT) outlet temperature being less than 250ºC.
NTE Events on the Off-Road LLAC Cycle
Why is the LLAC Necessary

• Q: What is the "driver" for potentially utilizing LLAC regarding nonroad CI engines?
• A:
  • SCR requires exhaust temperature to remain above a threshold (≈ 250 °C) to function properly and reduce NOx.
  • Extended low load operation can reduce exhaust temperature to the point that NOx emissions aren’t adequately controlled.
  • LLAC provides SwRI a platform for designing off-road aftertreatment configurations that continue to control NOx during extended low load operation.
  • CARB staff does not intend to propose the LLAC as certification test cycle.
EMA Q+A

• Q: Does CARB regulate underground mining equipment? If so, do they need a waiver from the U.S. Mine Safety and Health Administration (MSHA)? If not, does underground mining equipment fall into the scope of the off-road fleet rule?

• A: There is no exemption for underground mining equipment. If this equipment uses off-road engines, it must be CARB certified prior to being introduced into commerce in CA. MSHA may have additional requirements.
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Questions