CALIFORNIA
AIR RESOURCES BOARD

Tier 5 Workgroup: In-Use Program Concepts

May 2, 2022

CARB

Outline

- Current California Air Resources Board (CARB) Off-Road In-Use Compliance (ORIUC) Program
- Proposed Changes to CARB ORIUC Program
- Background re: Heavy-Duty In-Use Testing (HDIUT)
- Manufacturer run Off-Road In-Use Testing (ORIUT) Program Concept
  - Proposed Reporting
  - Proposed Pass/Fail Criteria
- Portable Emissions Measurement System (PEMS) Testing Challenges and Solutions
- Feedback Requested

Current CARB ORIUC Program

- CARB staff currently has the authority to conduct in-use testing on off-road engines *13 CCR 2139(g)*
- Off-road engines are evaluated with test procedures used at certification:
  - Transient, steady state, and not-to-exceed
- Off-road engines may be tested up to 75% of Useful Life (UL)

Proposed Changes to CARB's ORIUC Program

- Clean up language for ORIUC
- Off-Cycle Test Procedures with PEMS
- Updating emissions calculation and evaluation methods
- Considering changes to expand the UL limits for ORIUC test engines

Manufacturer-run ORIUT

- In-Use Testing background
- ORIUT Concept
  - Phase 1: Engine Control Unit (ECU)/sensors data submission and screening
  - Phase 2: Triggered PEMS testing
  - Phase 3: Corrective action and long-term PEMS testing, if needed

Background: In-Use Testing

- Manufacturer run in-use testing programs
  - On-Road Heavy Duty Diesel Engines
    - Heavy-duty diesel engines non-compliance was discovered
    - Settlement/consent decrees
    - 40 CFR 86 Subpart T
  - Large Nonroad Spark Ignition Engines
    - 40 CFR Part 1048
    - Additionally has production line testing and selective enforcement audits
- Currently, manufacturer run in-use program does not exist for:
  - On-road Otto engines
  - Off-road compression ignition engines
    - Selective Enforcement Audits (13 CCR 2427 & 40 CFR 1068 Subpart E)

ORIUT Program Concept

- Minimize cost while ensuring accurate emissions data
- A multiphase approach would allow us to screen large volumes of sold engines with ECU/sensors data at a lower cost compared to PEMS testing
- More accurate PEMS methods would be used for real world emissions assessment if triggered by screening results
- Manufacturer run ORIUT with PEMS would be conducted for engine families not passing screening
- Targeting ≥56 kW engines which at minimum would require Selective Catalytic Reduction (SCR) to comply

Concept for Manufacturer-Run ORIUT Program

- Manufacturers submit annual summary report of sensors/ECU/ Off-Road Real Emissions Assessment Logging (OR-REAL) data per engine
- Borrows elements implemented in the In-Use Vehicle Emissions reporting from the extended durability program for on-road
- Data collection would be conducted with telematics

Flow Chart of ORIUT Concept

Step 1: ECU / Sensors data screening

- Manufacturers would annually submit data for 75% of engine sales per engine family (EF)
- Emissions data would be binned into idle, low load, or high load bins
- CARB staff would review reports for high emitters by bin
- If data for an EF raises no alerts, then the in-use testing requirements for the EF would be fulfilled

Step 2: Off-cycle testing with PEMS

- An EF flagged from screening would be required to conduct in-use testing like the on-road manufacturer requirements (5 to 10 engine tests with PEMS)
- If compliance is determined, then the in-use testing requirements would be fulfilled

Step 3: Corrective Action (if needed)

- If PEMS testing shows an EF is not compliant, then the manufacturer must take steps to correct the non-compliance

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Concept for Manufacturer-Run ORIUT Program

- Manufacturers would submit data for a minimum of 75% of CA certified engines sold for each EF in California.
- Manufacturer must submit all collected data
- Data reports are not required for engines exceeding their useful life
- Staff would use this information to screen for engine families with binned emissions greater than twice the emission standards for Low Load and Nonroad Transient Cycle (NRTC).
  - Currently evaluating how to handle idle.

What Reporting Would be Included ?

- EF name
- CA sales volume for EF
- Rated engine power (kilowatt)
- Engine Serial number
- Engine run time (hours)
- Date of data collection
- Tracking parameters in OR-REAL details to be determined
  - Tables 1 and 2 show hypothetical examples of OR-REAL tracking arrays and bin structure

Table 1. NOx Tracking Arrays and Parameters

Parameter	Active 100 Hour Array	Stored 100 Hour Array	Lifetime Array	Lifetime Engine Activity Array[5]
NOx mass - engine out[1](g)	x	x	x	n/a
NOx mass – tailpipe[2] (g)	x	x	x	n/a
Engine output engergy[3] (kWh)	x	x	x	x
Distance Traveled (km)	x	x	x	x
Engine runtime (hour)	x	x	x	x
Vehicle fuel consumption[4] (liters)	x	x	x	x

1. Mass of NOx emitted by the engine upstream of the NOx emission control system.
2. Mass of NOx emitted by the engine which enters the atmosphere (downstream of the NOx emission control system)
3. Brake work output of the engine.
4. The amount of fuel consumed by the engine summed with the amount of fuel injected directly into the aftertreatment system.
5. Engine activity data are recorded regardless of NOx senor status.

Table 2. Bin Structure for Each parameter in Each Array

	Vehicle Speed (km/h)						
% of Rated Power	> 0 ≤64	0	> 0 ≤16	> 16 ≤40	> 40 ≤64	> 64	
≤ 25%	bin 1	bin 2	bin 3	bin 4	bin 5	bin 6	
>25 % ≤50%			bin 7	bin 8	bin 9	bin10	NTE Bin Bin 15
>50 %			bin 11	bin 12	bin 13	bin 14	Regen Bin Bin 16

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When Would Manufacturer Off-Road PEMS Testing Be Required?

- For each EF selected, for each report, CARB would evaluate emissions vs the nitrogen oxides (NOx) emission standards for each of the bins (Low Load and NRTC)
- If 20% or more of the reports for an EF have events in any bin with emissions greater than 2 times the emission standard, then the engine manufacturer would be required to conduct ORIUT with PEMS (Step 2)

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Proposed Pass and Fail criteria

- Similar structure to the on-road program (40 CFR 86 subpart T)
- Emissions evaluation method: in development
  - Looking into using binned moving average window emissions evaluation methodology
- Start with 5 engines and if 5 pass, then EF passes
  - 5/6 pass tests → EF pass
  - If 2/6 fail → 4 more engines tested (total 10)
  - Less than 8 engines passing would be considered EF failure
- If an EF fails, then corrective action would be required
- Additionally, failing EFs would require ORIUT with PEMS every 2 to 4 years

PEMS Testing Challenges and Solutions

- Standardized connection and data stream protocols
- Location for mounting on off-road equipment and safety considerations
  - Creative mounting solutions for mounting (ex. roof)
  - Special harnesses or bolt down options
  - CARB staff and European Union have conducted testing on some equipment with PEMS mounted to following golf cart
- Some PEMS is approximately the size of the equipment
  - Consideration of compact PEMS for such applications
- Vibration and impact resistance
  - Require more data on forces from real world scenarios

Feedback Requested

- Alternative manufacturer-run concepts
- Power category and equipment type applicability
- Is a sensors-based program attractive to industry?
- Defining bins for sensors reporting
- Standardization of ECU communication
- OBD OR-REAL program for off-road applications
- In-use emissions data evaluation methods
- Off-road off-cycle emissions testing with PEMS
- Other comments