CALIFORNIA
AIR RESOURCES BOARD

Tier 5 Rulemaking Workshop

Draft Potential Off-Road On-Board Diagnostics (OR OBD) Regulation

February 27, 2026

CARB

The text is draft, for purposes of discussion, and may be revised and/or reorganized in the future.

Acronyms

- 2B-MAW: 2-bin moving average window
- 3B-MAW: 3-bin moving average window
- CA: California
- CO: carbon monoxide
- CO_2: carbon dioxide
- DEC ECU: diagnostic or emission critical electronic control unit
- DEF: diesel exhaust fluid
- DLC: diagnostic link connector
- DPF: diesel particulate filter
- DTC: diagnostic trouble code
- ECU: electronic control unit

Acronyms (cont'd)

- EGR: exhaust gas recirculation
- FUL: full useful life
- g/kW-hr: grams per kilowatt-hour
- ISO: International Organization for Standardization
- kW: kilowatts
- MAD: monitor activity data
- MIL: malfunction indicator light
- MY: model year
- NOx: oxides of nitrogen
- NMHC: non-methane hydrocarbon
- NRTC: nonroad transient test cycle
- O_2: oxygen

Acronyms (cont'd)

- OBMD: on-board monitoring and diagnostics
- OR OBD: off-road on-board diagnostics
- OR-REAL: off-road real emissions assessment logging
- PEVE: production engine/vehicle evaluation
- PM: particulate matter
- ppm: parts-per-million
- RMC: ramped-modal cycle
- SAE: SAE International
- SCR: selective catalytic reduction
- SwRI: Southwest Research Institute

Updates to Proposal

- Draft potential OR OBD regulation language describes the details of the proposal
  - Provided on Tier 5 workshop website
- Staff revised some proposals that were presented in the draft regulations and presentations provided as part of the Tier 5 workshops in October 2023 and October 2024
- Major revisions will be covered in today's workshop

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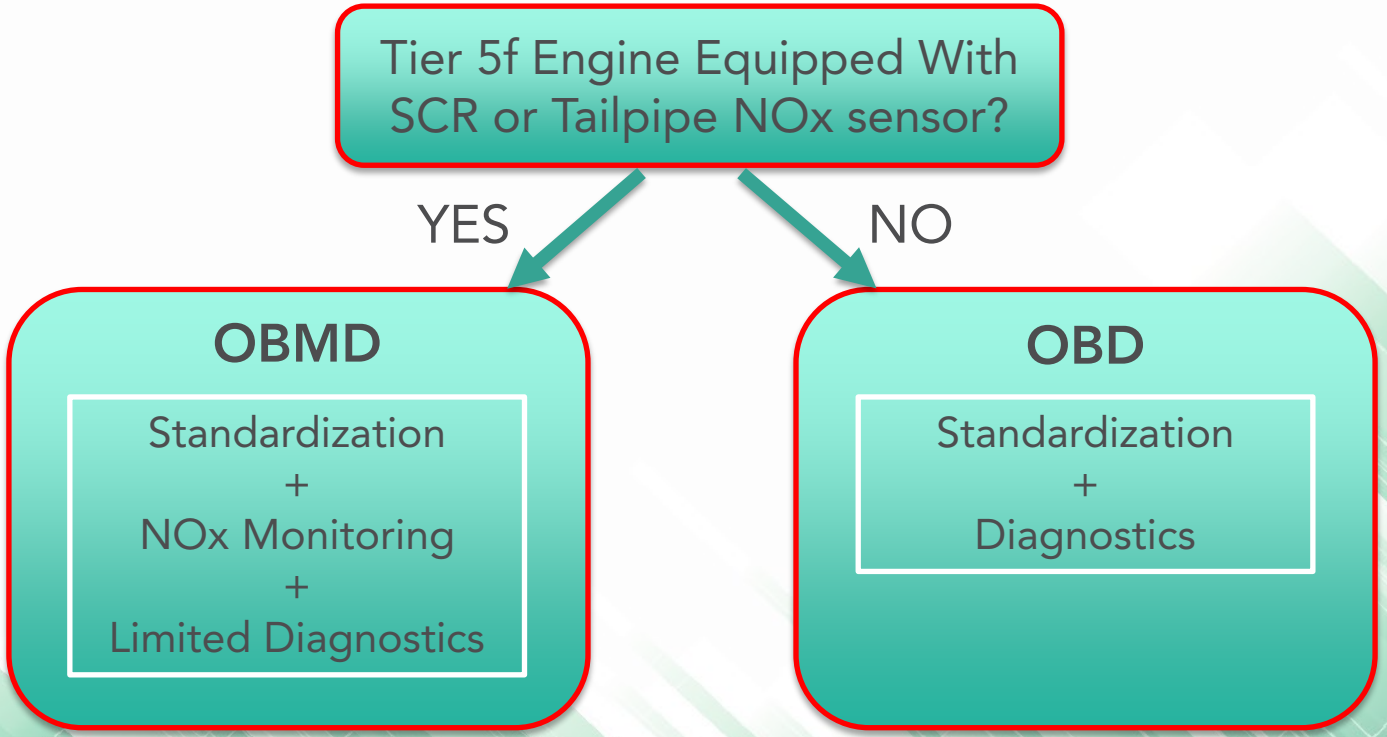
Applicability

- Original Proposal: Electronically-controlled off-road diesel engines certified to Tier 5 standards
- Revised Proposal: Off-road engines that meet all the following conditions:
  - Certified to Tier 5 final standards
  - Equipped with an ECU that controls fueling (e.g., fuel injection timing or quantity) **AND**
  - Equipped with an ECU that controls any of the following: intake air flow, EGR flow, turbocharger boost level, DEF injection quantity, regeneration events, aftertreatment thermal management strategies, or catalyst operating conditions (e.g., air-fuel ratio)

Applicability



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Implementation Schedule

- Revised OR OBD Implementation Framework:
  - Eliminated "Phase 1, Phase 2" terminology
  - Retain the two Stages:

Stage 1	Stage 2

• Standardization requirements:
  ○ Communication protocol
  ○ DLC
  ○ Data stream signals
  ○ OR-REAL data (NOx sensor)
  ○ CALID and CVN
• **No diagnostic requirements**
• Demonstration testing: NOx mass accuracy testing only
• No post-certification verification requirements
	• Additional standardization requirements:
	  ○ Fault codes, MIL, freeze frame
	  ○ Monitor test results
	  ○ Additional data stream signals
	  ○ Monitor activity data (MAD)
	  ○ PM filter fault history tracking
	• Diagnostic requirements (OBMD, OBD)
	• Diagnostic demonstration testing
	• Post-certification verification requirements

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Implementation Schedule

- Original Proposal:

OR OBD Parent Ratings

Power Category	Stage 1	Stage 2
130≤kW≤560	2029-2032 MY	2033+ MY
>560 kW	2030-2033 MY	2034+ MY
Other categories	2031-2033 MY	2034+ MY

OR OBD Child Ratings

Power Category	Stage 1	Stage 2
130≤kW≤560	2029-2035 MY	2036+ MY
>560 kW	2030-2036 MY	2037+ MY
Other categories	2031-2036 MY	2037+ MY

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Implementation Schedule (cont'd)

- Revised Proposal:

Power Category	Stage 1	Stage 2
All	2036-2038 MY	2039+ MY

  - Aligned with Tier 5 final implementation schedule
  - No OR OBD parent/child rating distinctions
  - All power categories have same implementation schedule

Standardization Requirements

- Communication Protocol
  - Original Proposal:
    - Oct. 2023 Workshop: Allow either SAE J1939 or ISO 15765-4 (SAE J1979-2)
    - Oct. 2024 Workshop: Allow only SAE J1939
  - Revised Proposal: ISO 15765-4 (SAE J1979-2) is back by popular demand!
    - **Both** protocols allowed once again

Implementation Schedule (cont'd)

- Revised Proposal:

Power Category	Stage 1	Stage 2
All	2036-2038 MY	2039+ MY

  - Aligned with Tier 5 final implementation schedule
  - No OR OBD parent/child rating distinctions
  - All power categories have same implementation schedule

Standardization Requirements

- Data Stream Signals
  - Revised Proposal:
    - Move signals below from certification-critical list to "so equipped" list:
      - Engine percent load at current speed
      - Ambient air temperature
      - Barometric pressure
      - SCR outlet temperature
    - Add "Throttle position (for engines so equipped)" to certification-critical list consistent with in-use testing datalogging requirements

Standardization Requirements

- OR-REAL Data Tracking
  - Revised Proposal: Switch from 3B-MAW bins to 2B-MAW bins

	Bin 1 Total	SCR Outlet Temperature (deg C)			
		≤ 200	> 200 & ≤ 250	> 250 & ≤ 400	>400
Power (% of rated)	≤ 25%	Bin 2	Bin 3	Bin 4	Bin 5
	> 25% & ≤ 50%	Bin 6	Bin 7	Bin 8	Bin 9
	> 50%	Bin 10	Bin 11	Bin 12	Bin 13

DPF Regen	Bin 14
MIL-on	Bin 15

NOx Screening 3B - MAW		
Bin A	Bin B	Bin C

PM Screening
Fault Code History Tracker

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Standardization Requirements

- OR-REAL Data Tracking (cont'd)
  - Proposed changes to array structure:

Parameter	Active 50 Hour Array[1] (Bins)		Stored 50 Hour Array[1] (Bins)		Lifetime Array[1] (Bins)		Lifetime Engine Activity Array[2] (Bins)	
NOx mass – engine out (g)	1-15	-	1-15	-	1-15	-	-	-
NOx mass – tailpipe (g)	1-15	A, B~~, C~~	1-15	A, B~~, C~~	1-15	A, B~~, C~~	-	-
Engine output energy (kWh)	1-15	B~~, C~~	1-15	B~~, C~~	1-15	B~~, C~~	1-15	~~B, C~~
Engine Run time (hours)	1-15	A, B~~, C~~	1-15	A, B~~, C~~	1-15	A, B~~, C~~	1-15	~~A, B, C~~
Total fuel consumption (liters)	1-15	A,B	1-15	A,B	1-15	A,B	1-15	-

1. Tracks data only when NOx sensors are on.
2. Tracks data over all engine activity (can thus determine amount of activity with no NOx data).

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Standardization Requirements

- OR-REAL Data Tracking (cont'd)
  - Original proposal: MAW data sorted into bins based on **average power** of each 300-second window
    - Calculated using torque and speed from engine ECU
  - Revised proposal: Use "**normalized CO_2 emission mass**" for MAW binning
    - Harmonizes with U.S. EPA on-road 2B-MAW binning
    - Bin A = normalized $CO_2 \leq 8\%$
    - Bin B = normalized $CO_2 > 8\%$

Standardization Requirements

- OR-REAL Data Tracking (cont'd)
  - $Normalized\ CO_2\ emission\ mass = \frac{Window\ CO_2\ mass}{e_{CO2} * P_{max} * t_{window}}$
    - Window CO_2 mass = sum of estimated CO_2 emitted by the engine over the 300-sec window
    - e_{CO2} = CO_2 emission rate from certification test data of the emission-data engine over the NRTC (or steady-state cycle for constant speed engines)
    - P_{max} = highest value of rated power in the engine family
    - t_{window} = 0.083 hours (300 seconds)

Standardization Requirements

- OR-REAL Data Tracking (cont'd)
  - Proposed method for estimating CO_2 mass emissions uses NOx sensor O_2 signal:
    - $CO_2\ mass = \frac{\%CO_2}{100} * \frac{CO_2\ molar\ mass}{Air\ molar\ mass} * Exhaust\ mass$
    - $Where:\ \ \%CO_2 = \frac{(20.95\% - \%O_2)}{(1+\frac{1.8}{4})}$
  - Manufacturer may propose alternative method, which will be approved if:
    - At least as accurate as O_2 signal method, **OR**
    - Within +/- 15 percent of test facility result

Standardization Requirements

- NOx Mass Accuracy Requirement
  - Original Proposal: OR OBD system engine-out and tailpipe NOx mass estimates must have a ***TBD*** level of accuracy relative to lab results over the certification test cycle
  - Revised Proposal: Error relative to lab results must not exceed **+/- 15%**, or alternatively at the manufacturer's discretion, **+/- 0.08 g/kW-hr**

Standardization Requirements

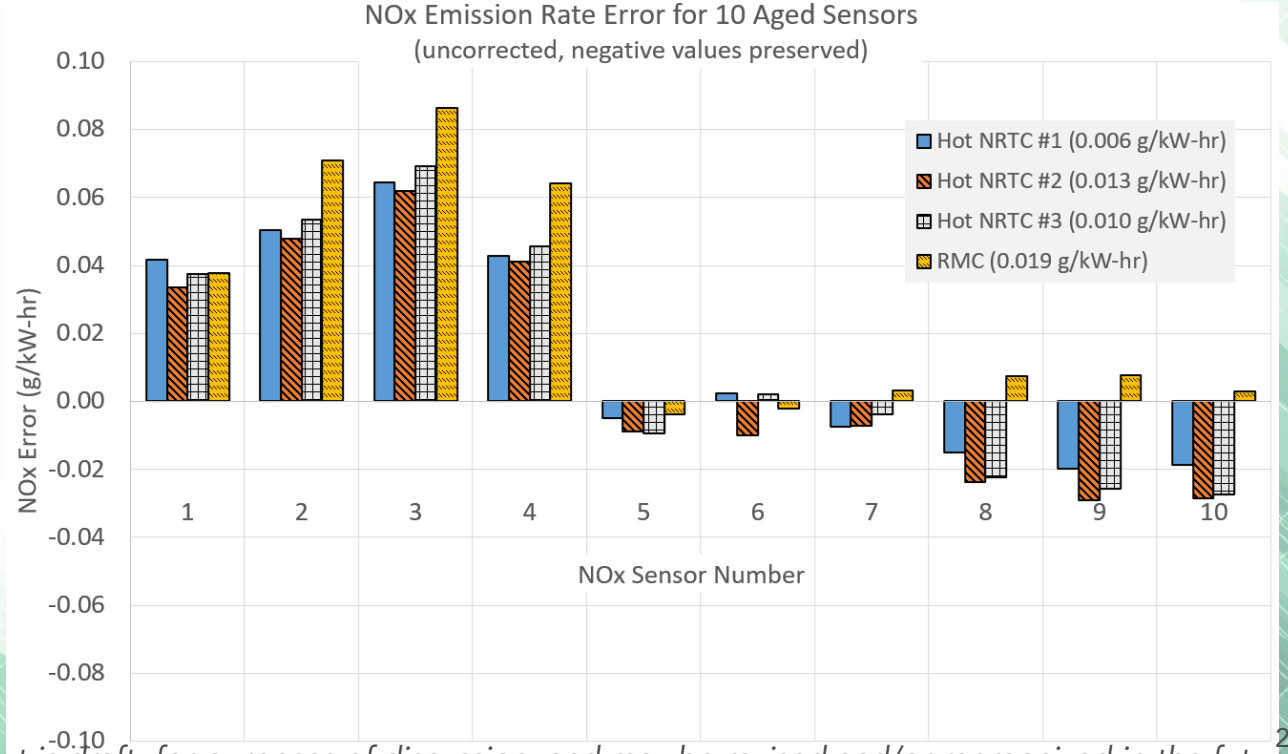
- NOx Mass Accuracy Requirement (cont'd)
  - Proposal based on results from the SwRI NOx sensor project funded by CARB, specifically the uncorrected NOx sensor data
  - Will explore accuracy improvements from NOx sensor correction methods in the future

Standardization Requirements

- NOx Mass Accuracy Requirement (cont'd)

Graph shows **tailpipe** results from SwRI Low-NOx Off-road Engine

(Also, **engine-out** NOx mass error never exceeds 6%)



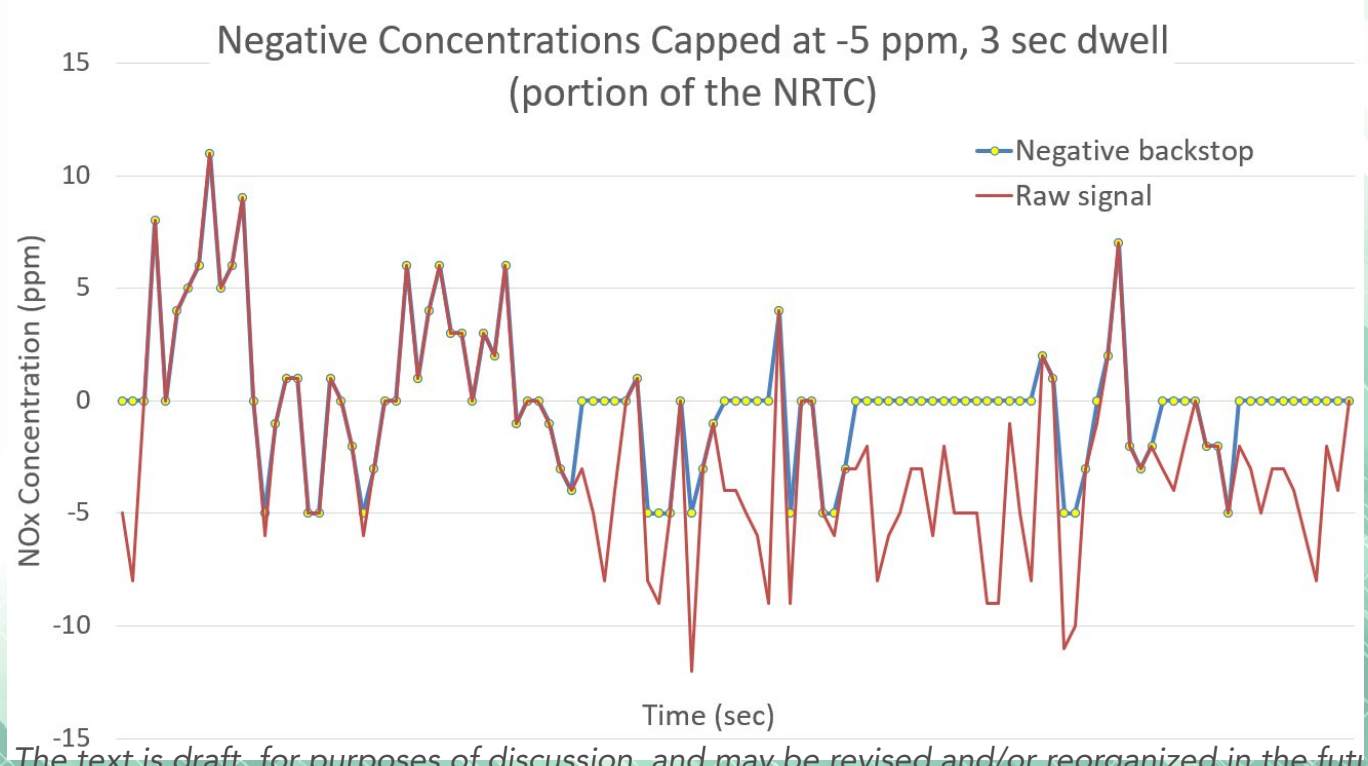
Standardization Requirements

- NOx Mass Accuracy Requirement (cont'd)
  - Original Proposal: All negative NOx concentration readings must be set to zero
  - Revised Proposal: Implement a "backstop" on negative concentrations:
    - **Most negative value allowed: – 5 ppm**
      - Consistent with SAE J3349 recommendation
    - **Negative dwell capped at 3 seconds**
      - Subsequent negative values set to zero

Standardization Requirements

- NOx Mass Accuracy Requirement (cont'd)

Illustration of negative NOx backstop



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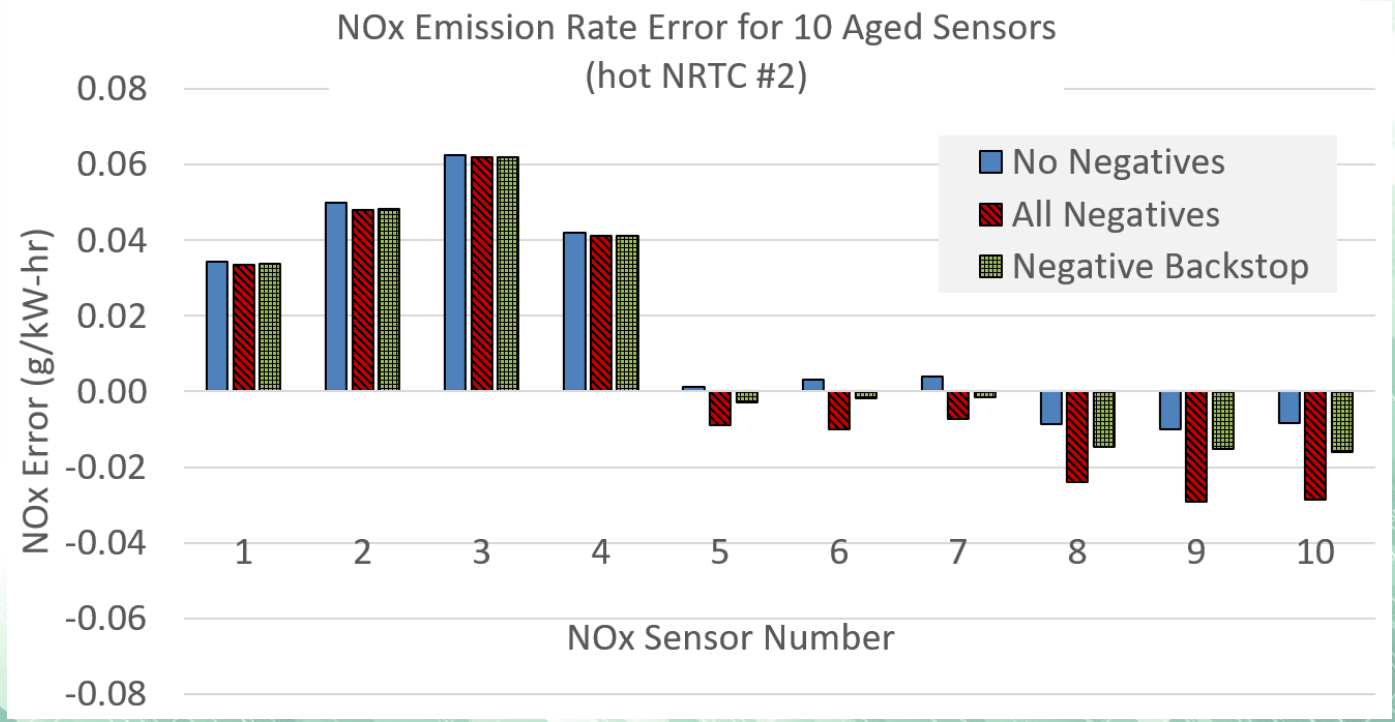
Standardization Requirements

- NOx Mass Accuracy Requirement (cont'd)

Impact of negative NOx backstop



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Standardization Requirements

- Monitor Activity Data
  - Tracks how often each diagnostic runs
  - Revised proposal provides more detail on when to pause tracking:
    - If a fault code pauses the general denominator incrementation, tracking in all DEC ECUs must pause
    - If the fault code does **not** pause the general denominator, pause tracking only in the DEC ECU that stored the fault code

Standardization Requirements

- Monitor Activity Data (cont'd)
  - Original Proposal: the OR OBD system shall track and report a mini-denominator *for each DEC ECU that is capable of storing a fault code*
  - Revised proposal adds a criterion: *…and that tracks and reports mini-numerator data*
    - Reflects network architectures in which a DEC ECU may be able to store fault codes but tracking of mini-numerator data is centralized in a different DEC ECU

Diagnostic Requirements

- OBM NOx Emission Threshold Monitor
  - Original Proposal: OBM NOx monitor makes decisions based on data stored in OR-REAL MAW bins
  - Issue: No monitoring when MAW bins are paused due to a malfunction
    - Purpose of OR-REAL MAW bins is to track performance when the engine is free of malfunctions (consistent with official in-use testing)
    - Purpose of OBM is different: to identify high NOx emissions caused by any malfunction

Diagnostic Requirements

- OBM NOx Emission Threshold Monitor (cont'd)
  - Revised Proposal: OBM NOx emission threshold monitor uses data that are independent of OR-REAL MAW bins
    - Different pause conditions that are better suited to detection of high emissions caused by a malfunction (key differences highlighted next slide)

Diagnostic Requirements

Condition (not comprehensive)	OR-REAL 2B-MAW	OBM NOx Monitor	Comments
MIL on (general case)	Paused	Active	Includes MIL for engine-out NOx sensor and SCR outlet temperature.
MIL on for Tailpipe NOx sensor	Paused	Paused	Aligned, but for OBM, all accumulated windows since last monitoring decision are reset (not just the current window).
Engine-out NOx sensor not reporting valid data	Paused	Active	Not necessarily a fault condition (e.g., momentarily not reporting valid data).
Frozen DEF tank	Active	Paused	Avoid OBM monitoring decisions based on periods where NOx sensor active but DEF still frozen.

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Diagnostic Requirements

- OBM NOx Emission Threshold Monitor (cont'd)
  - Revised Proposal: OBM NOx emission threshold monitor may use a lower-memory approach to formation of windows
    - Not necessary to perfectly mimic the official in-use testing methodology
    - Allow option for 300-second windows composed of 30 intervals, 10 seconds each

Diagnostic Requirements

- Revised Proposal: Add "Other Emission Control Component or System" diagnostic requirements for OBD engines (engines without NOx sensors)
  - Intended to cover emission controls on non-diesel Tier 5 final engines (e.g., hydrogen-fueled internal combustion engines)
  - If equipped, requires monitoring of:
    - Catalyst that is not a DOC
    - Air-fuel ratio sensor, and
    - Oxygen sensor

Diagnostic Requirements (cont'd)

- OBD Emission Thresholds (non-OBMD engines)
  - Original Proposal:
    - **EGR** and **Fuel System** Diagnostics:

Power Category	NOx Threshold	PM Threshold	NHMC Threshold	CO Threshold
19≤kW<56	2.0x	0.040 g/kW-hr	2.0x	2.0x
All others	2.0x	2.0x	2.0x	2.0x

Diagnostic Requirements (cont'd)

- OBD Emission Thresholds (non-OBMD engines)
  - Revised Proposal: **EGR**, **Fuel System**, **Other Emission Control** Diagnostics

Power Category	NOx Threshold	PM Threshold	NHMC Threshold	CO Threshold
<19 kW	1.5x	2.0x	N/A	2.0x
19≤kW<56	1.5x	0.040 g/kW-hr	2.0x	2.0x
56≤kW≤560	0.60 g/kW-hr	0.040 g/kW-hr	0.38 g/kW-hr	2.0x
>560 kW Gen sets	1.2 g/kW-hr	0.040 g/kW-hr	0.38 g/kW-hr	2.0x
>560 kW Mobile	1.5x	2.0x	2.0x	2.0x

Demonstration Testing

- Test Engine Selection Criteria for Tailpipe NOx Mass Accuracy Testing (for engines equipped with a NOx sensor)
  - Original Proposal:
    - Test 1-3 engines based on number of engine families certified in a given MY
  - Revised Proposal:
    - Test the representative engine from each OR OBD certification documentation group in an application for certification

Demonstration Testing (cont'd)

- Testing Requirements – Test Engine Aging
  - Original Proposal:
    - Stage 2 OBMD engines: low-hour engine with FUL aged tailpipe NOx sensor
    - Stage 2 OBD engines and Stage 1 engines equipped with a tailpipe NOx sensor: emission durability test engine aged in accordance with draft potential Tier 5 engine aging requirements
  - Revised Proposal:
    - For Stage 1 engines equipped with a tailpipe NOx sensor, allow use of a low-hour engine with FUL aged tailpipe NOx sensor

Demonstration Testing (cont'd)

- Testing requirements – FUL aged NOx Sensor
  - Original Proposal:
    - Definition of FUL aged NOx sensor was TBD
  - Revised Proposal:
    - FUL aged NOx sensor means a NOx sensor that has been aged together with an engine in accordance with draft potential Tier 5 engine aging requirements

Certification Documentation

- Representative engine for "OR OBD certification documentation group"
  - Original Proposal: Representative engine required to meet the following conditions:
    - Cover all emission control devices and monitors/diagnostics for all engines in the group
    - Certified to most stringent emission standard in the group
  - Revised Proposal: Representative engine required to meet the following condition:
    - From engine family with highest projected CA sales number in group and from engine rating with highest projected CA sales number in engine family

Certification Documentation (cont'd)

- DLC Information
  - Original Proposal: Provide information in the OR OBD application (before OR OBD system certification) about DLC description and locations on every equipment type covered by the application
  - Revised Proposal: Provide the DLC information as part of the post-certification verification requirements (after OR OBD system certification)
    - No later than 12 months after start of engine production

Deficiencies

- Original Proposal: Fines apply as follows:

Power Category	OR OBD parent rating engines	OR OBD child rating engines
130≤kW≤560	2036+ MY	2037+ MY
All other power categories	2037+ MY	2038+ MY

- Revised Proposal: Fines apply to **2039+ MY** for all power categories (Stage 2 engines only)

Deficiencies (cont'd)

- Original Proposal: Fines apply to the 3rd and subsequent deficiencies
- Revised Proposal: Fines apply as follows:

Model Year	Number of Deficiencies
2039-2042	5th and subsequent
2043+	3rd and subsequent

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