CALIFORNIA
AIR RESOURCES BOARD

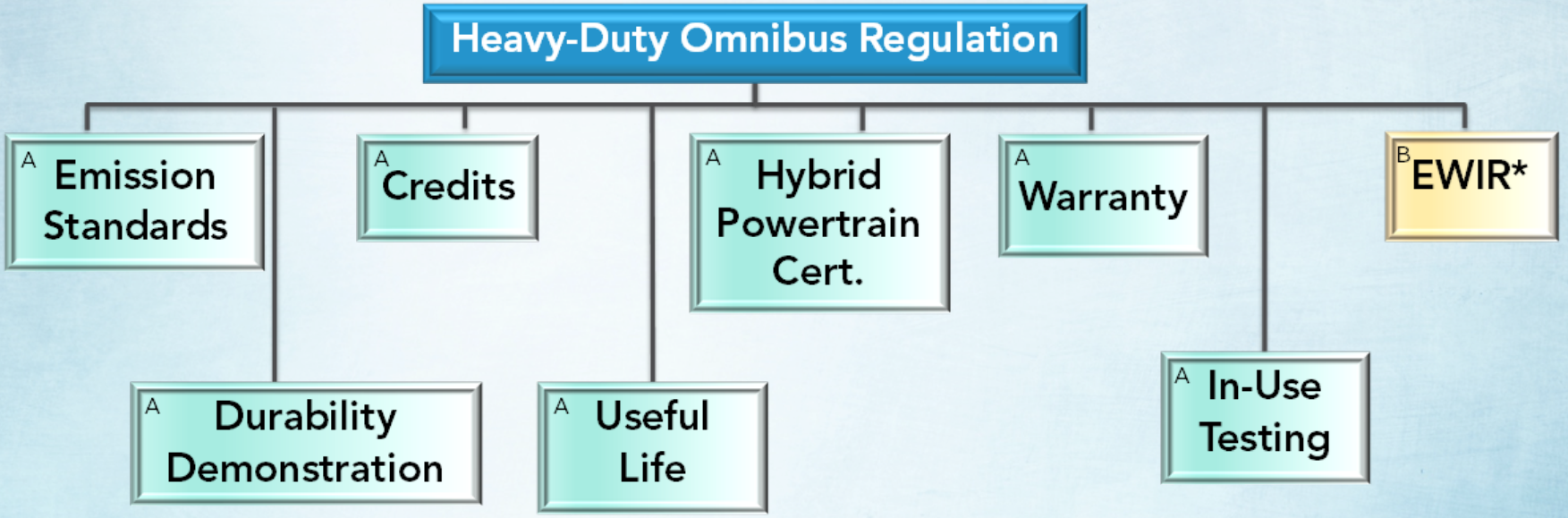
Workshop: Comparison of the Omnibus Regulation and the Clean Trucks Plan (CTP) Oxides of Nitrogen (NOx) Rule

March 3, 2023

Outline

- Program elements
- Comparison of standards
- Key differences
- Emission benefit losses if CARB harmonizes with CTP NOx
- NOx compliance allowance for in-use testing
- Temperature adjustment to Off-Cycle NOx Standards
- Phase 3 Greenhouse Gas (GHG) Regulation

Program Elements



* CTP-NOx rule does not include new amendments for the Emission Warranty Information Reporting (EWIR) program. EWIR is a CA-only program.

CTP-NOx & Omnibus A

Omnibus Only B

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Comparison of Standards

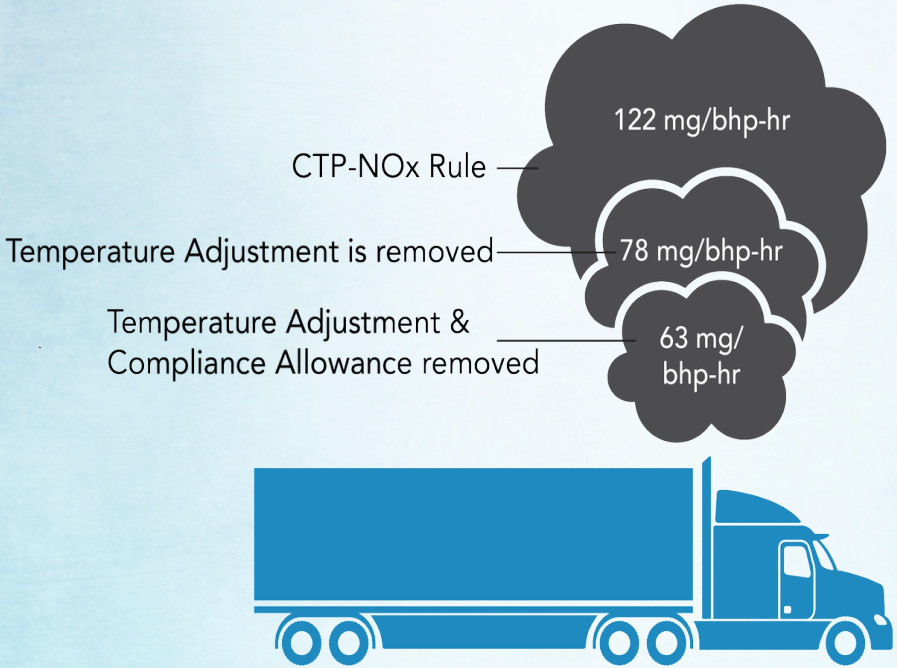
- For 2027 and subsequent model years, the Omnibus regulation progressively increases the stringency of the heavy-duty emissions standards in two phases:
  - 2027-2030 model year transitional period, and
  - Final standards for 2031+ model years (MY).

- The Environmental Protection Agency's (EPA) CTP NOx rule includes one set of standards for 2027 and subsequent MYs

Key Differences

- Interim NOx compliance allowance for in-use testing – 40 CFR §1036.150(y)
  - Introduced as an interim measure for heavy heavy-duty engines (HHDE) in the proposed rule with a MY 2033 sunset date
  - Finalized as a provision for medium heavy-duty engines (MHDE) and HHDEs in the final rule as "interim" provision with no sunset date
- Temperature adjustment to off-cycle NOx standards – 40 CFR §1036.104(a)(3)
  - Introduced in the final rule without seeking public comment

CTP-NOx Off-Cycle Standard and Allowances

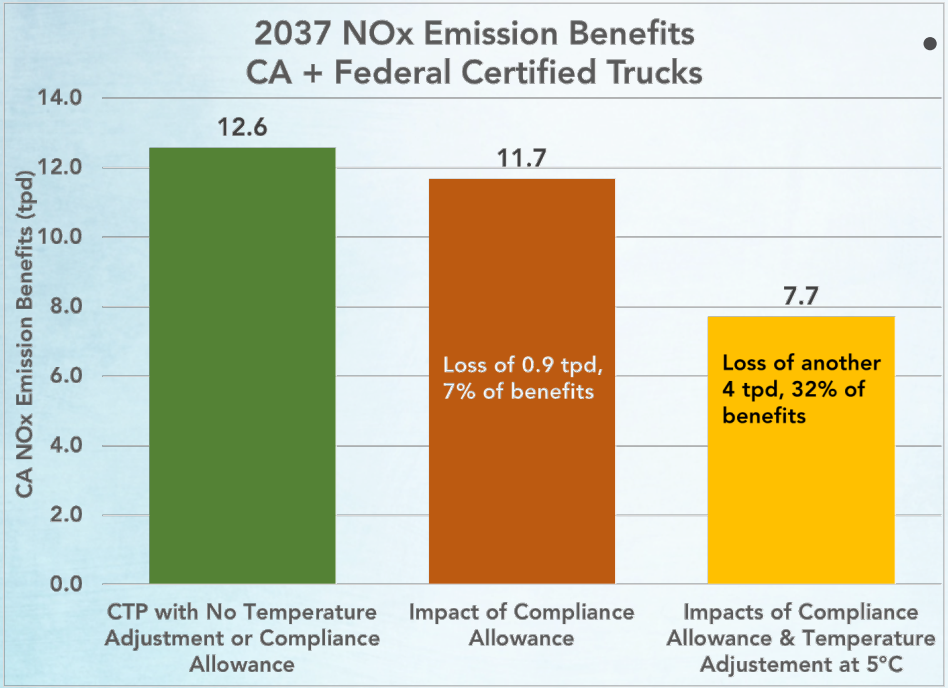


- Off-cycle Bin-2 NOx standard (mg/hp-hr):
  - 1.5x conformity factor: **58**
  - Plus "accuracy margin": **63**
  - Plus "compliance allowance": **78**
  - Plus "temperature adjustment": linear between 25 °C and 5° C
    - At 25 °C: **78**
    - At 5° C : **122**

California & Federal Requirements: History of Harmonization

- For the heavy-duty sector, the federal and CA emission standards have been harmonized since 1991 MY
- Manufacturers offer the same truck platform for sale nationwide
- Manufacturers, dealers, and fleets would prefer to see the same products being offered at the national level (i.e., continued harmonization between federal and CA requirements)

Impacts of Harmonization



- Compliance allowance and temperature adjustment would reduce NOx emission benefits up to 4.9 tpd in 2037
  - Losses are greater than benefits expected from some rulemakings in the State Implementation Plan (motorcycle standards, ZE forklift, etc.)

Compliance Allowance

- Applicable to MHDEs & HHDEs
  - Additive 15 mg/hp-hr to the in-use FTP/SET/LLC & bin-2 off-cycle NOx standards (88 FR 4502; 40 CFR § 1036.150(y))
- U.S. EPA concluded Compliance Allowance[1] needed due to:
  - Sulfation
  - Fuels (short-term impacts)
  - Sensors
  - Production Variability
  - Field Aging (discussed further on next few slides)

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[1] - (Regulatory Impact Analysis (RIA) pp. 124-126)

Field Aging

- RIA (pp. 125-126)
- Long-term impact of a more severe duty cycle (that might require more diesel particulate filter (DPF) regenerations)
- Impact of fuel impurities
- Impact of other engine related issues (such as an exhaust gas recirculation cooler leak that was too small to detect, or the impact of a short-term high temperature excursion results from a turbocharger failure prior to fault detection, etc.)

Field Aging: Severe Duty Cycle/DPF Regenerations

- For MHDEs, the NOx standards were derived from emissions data at 650,000 miles (vs 350,000-mile useful life (UL))
  - Justification: MHDEs encounter more severe duty cycle/DPF regenerations (RIA 3.1.1.2)
- For HHDEs, laboratory aging to 750,000 miles (650,000-mile UL) is required to provide a cushion for additional deterioration from field aging (88 FR 4307)
- Severe duty cycle already accounted in development of the 35 and 50 mg/hp-hr FTP/RMC and LLC NOx standards, respectively
- Adding field aging component for in-use compliance allowance is double counting
- Heavy-Duty In-Use Testing (HDIUT) program allows for screening out of vehicles with atypical operations (severe duty cycle). 40 CFR §1036.410(c)

40 CFR § 1036.410 Selecting and Screening Vehicles and Engines for Testing

…

(b) Select vehicles and engines for testing that meet the following criteria:

(1) The vehicles come from at least two independent sources.

(2) Powertrain, drivetrain, emission controls, and other key vehicle and engine systems have been **properly maintained and used**. See § 1036.125.

(3) The engines **have not been tampered with, rebuilt, or undergone major repair that could be expected to affect emissions** .

(4) The engines **have not been misfueled** . Do not consider engines misfueled if they have used fuel meeting the specifications of § 1036.415(c).

…

(c) You must notify us before disqualifying any vehicle based on illuminated MIL or stored OBD trouble codes as described in § 1036.415(b)(2), or for any other reasons not specified in paragraph (b) of this section. For example, notify us if you disqualify any vehicle because the engine does not represent the engine family or the **vehicle's usage is atypical for the particular application** . You do not need to notify us in advance if the owner declines to participate in the test program.

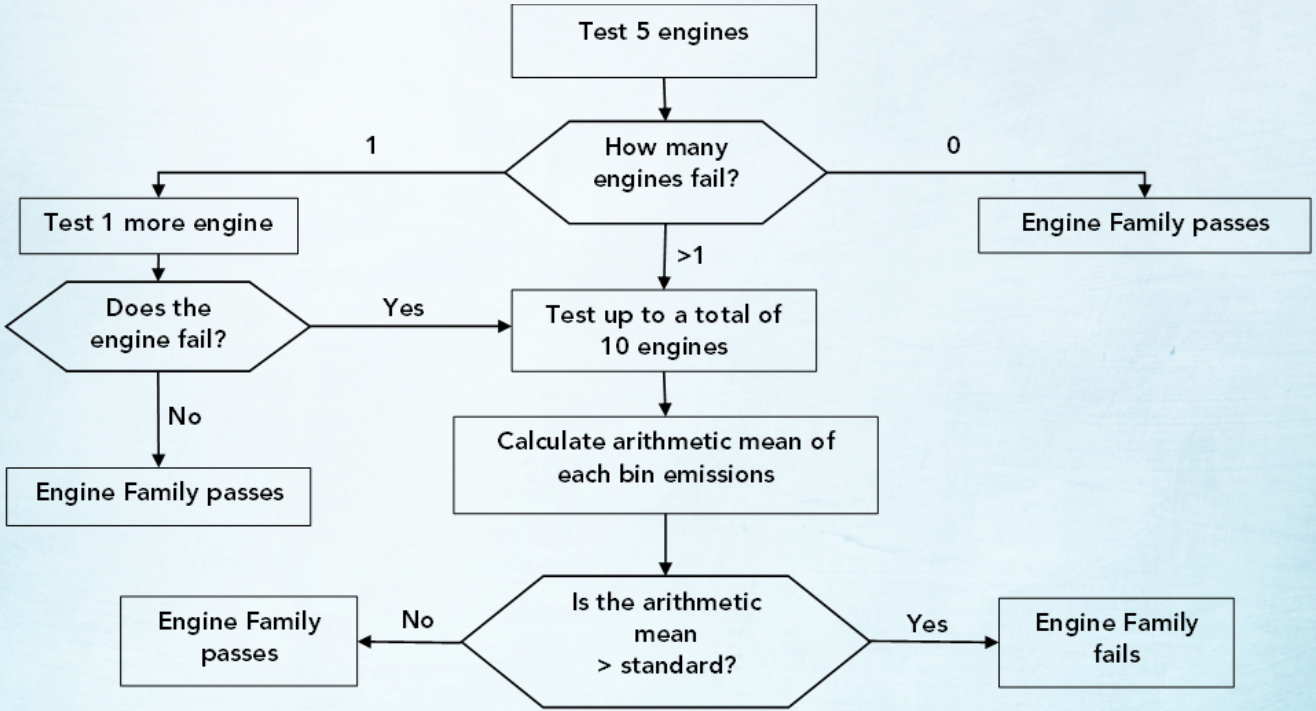
Field Aging:
Fuel Impurities & Hardware Failures

- Fuel Impurities - HDIUT screen out vehicle criteria for misfuelling 40 CFR §1036.410(b)(4)
- Hardware Failures
  - Unclear why additional allowance is needed for hardware failure scenarios. All emission related component must be durable to full UL. Potential failure due to poor design or bad components should not be used as a justification to relax the standards via a compliance allowance
  - Screen out criteria for poorly maintained vehicles 40 CFR §1036.410(b)(2)

Compliance Allowance Statistical Analysis

- Each Compliance Allowance input (sulfation, fuels, etc.) contributes via a variance term that was calculated based on a single engine test
  - The final Compliance Allowance of 15 mg/hp-hr was based on results for a single engine test
- HDIUT pass/fail criteria – Fail criteria only determined after averaging results from 10 engine tests per engine family. A single engine failure would not make an engine family non-compliant
  - Compliance Allowance needs to consider a sample size of 10 engines since that is the only failure mode
  - Allowance calculated with sample size of 10 engines would be much smaller
- A larger sample size of engine tests reduces the variance of the test results

HDIUT Pass/Fail Criteria (40 CFR §1036.425)*



*Applies to 2027 and Subsequent MY Engines
Additional flexibility to pass is provided for 2027 and 2028 MYs

Compliance Allowance - Summary

- Calling a provision "interim" implies there is a Sunset date
- Considering failure scenario and accounting for a sample size of 10 engine tests would reduce the calculated allowance
- Original equipment manufacturers (OEMs) already can screen out mal-maintained/misfueled vehicles from HDIUT program, already accounting for the issues used to justify the field aging component

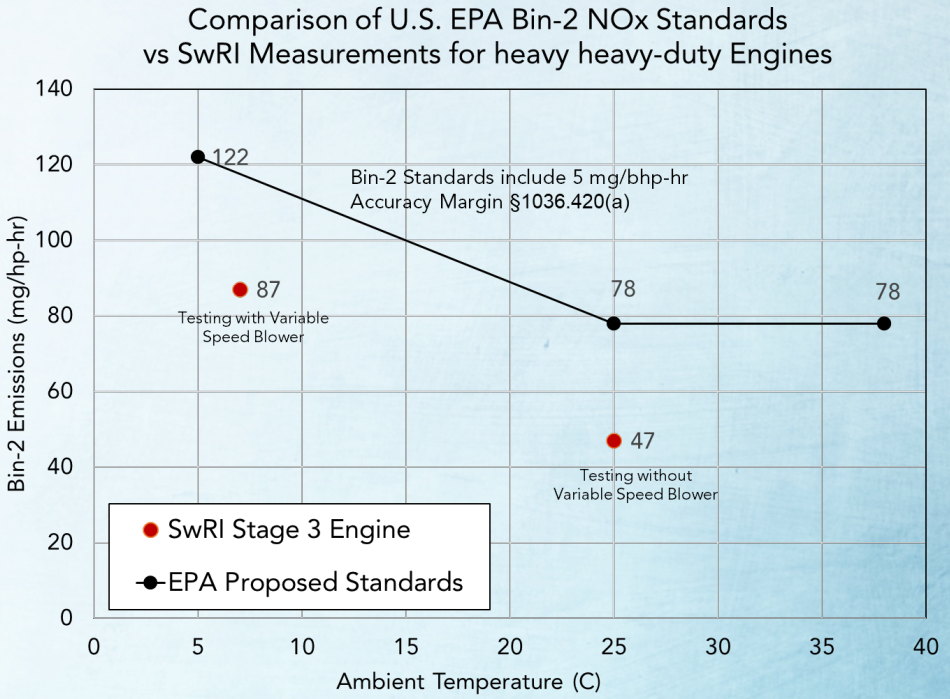
Temperature Adjustment

- EPA introduced the adjustment to off-cycle NOx standards based on Engine Manufacturers Association sponsored testing at Southwest Research Institute (SwRI) – Low Ambient Temperature Testing with Wind Simulation
- Objective was to simulate actual truck operations on-the-road in cold ambient conditions
- Lab temperature was reduced to ≈ 2-9 °C
- Variable speed blower was used to blow cold lab air over the aftertreatment system (ATS)

Air speed over ATS = C% x vehicle speed

Temperature Adjustment

- Cooling of exhaust gas temperature led to loss of catalytic efficiency; thereby, increased tailpipe NOx emissions
- Based on simulation, EPA introduced the temperature adjustment function
  - Standard at 5 °C raised by 44 mg/hp-hr (56%)

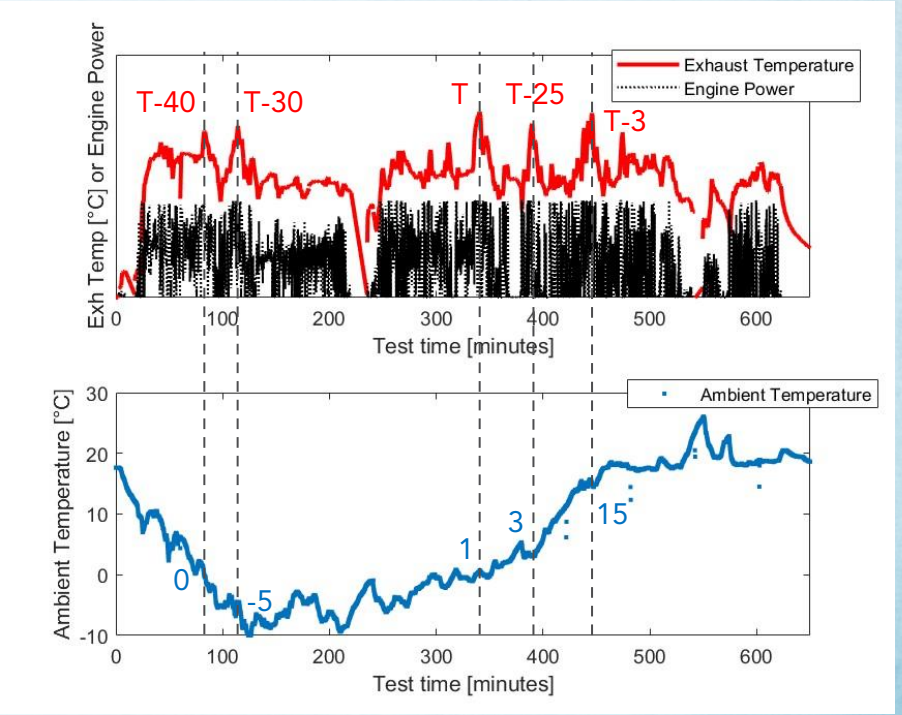


Relevant Facts re: the Temperature Adjustment

- Countermeasures can be taken with the Stage 3 engine to correct for ambient temperature fluctuations – EMA project scope did not include investigation of these measures
- HDIUT data from actual truck operations (by several manufacturers) on-the-road do not show exhaust temperature cooling in cold days
  - For 16 years, CARB has been analyzing in-use test data from real-world trucks and testing trucks in-house
- FTP/RMC/LLC standards do not have a temperature adjustment function (ambient test temp 20-30 °C)
- Current NTE protocols do not include a temperature adjustment
- EU in-use test protocols do not include a temperature adjustment

Heavy-Duty In-Use Test Results (1 of 2)

- The temperature adjustment assumes lower exhaust temperatures at colder ambient temperatures
- However, exhaust temperatures do not track the ambient temperature
- Instead, exhaust temperatures closely track the engine power



Exhaust temperature (Exh Temp) and engine power values are removed to protect OEM confidentiality.

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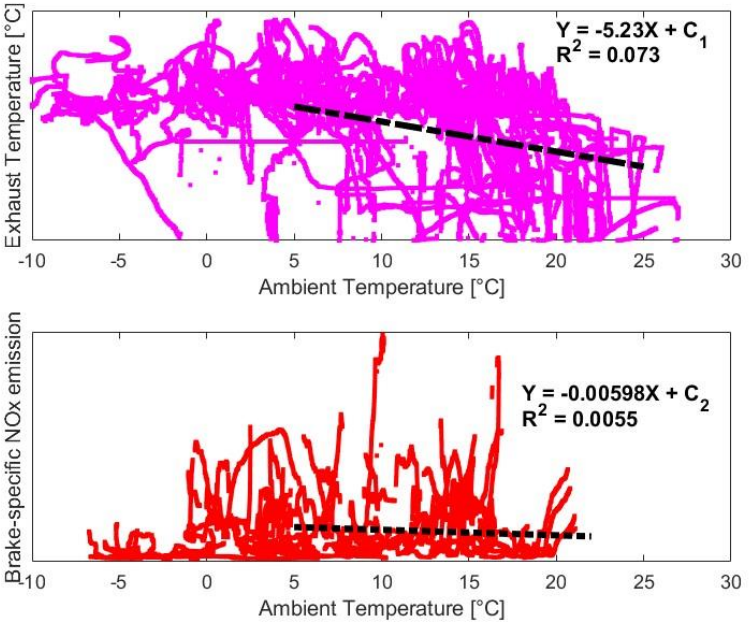
Heavy-Duty In-Use Test Results (2 of 2)

- The temperature adjustment assumes 30-50 °C reduction in selective catalytic reduction temperature at 2-9 °C ambient temperature compared to ~25 °C
- That means a slope of around +1.5 to +2.5 in exhaust temperature versus ambient temperature
- The observed trends are not consistent with the assumption
- NOx emission did not increase at lower ambient temperatures



- Results from five tests from the same engine family are combined into one.
- Exh Temp and NOx values (in medium/high load operations) are removed to protect OEM confidentiality.
- C_1 and C_2 are constants.

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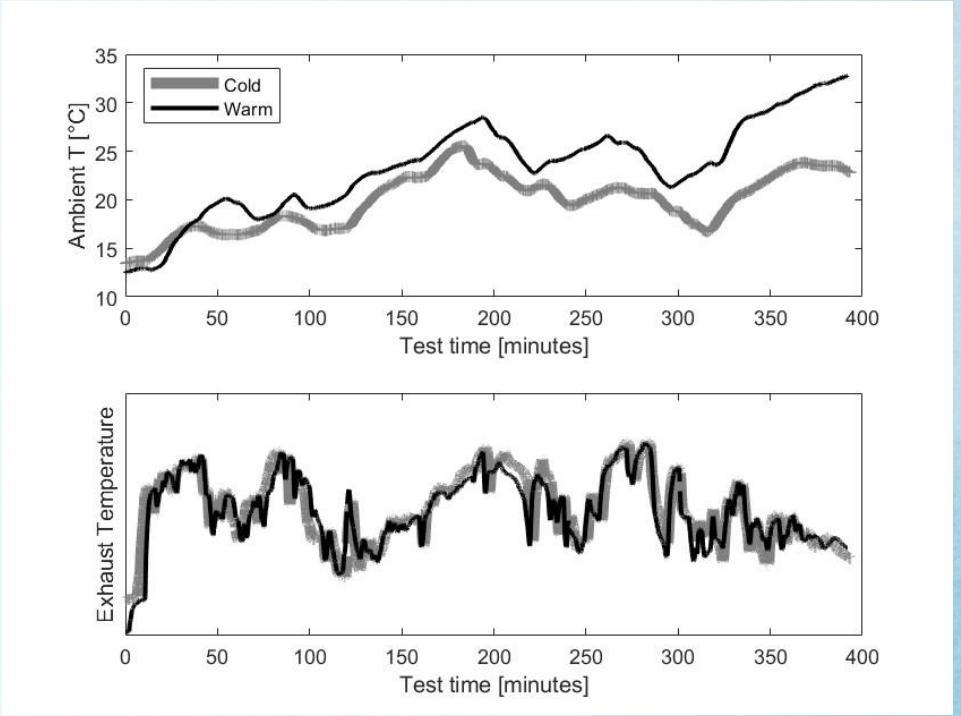
Heavy-Duty In-Use Compliance Test Results

- In this test, the same vehicle was tested on the same route at different ambient temperatures.
- The colder test did not result in consistently lower exhaust temperatures throughout the test
- Again, in-use data is not consistent with the assumption of the temperature adjustment
- In real world , the aftertreatment does **not** cool off any faster in lower ambient temperatures within 5-25 °C
  - Contradicts premise of temperature adjustment



- Exh Temp values are removed to protect OEM confidentiality

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California's GHG Goals

- Climate change targets
  - 40% below 1990 levels by 2030
  - 80% below 1990 levels by 2050
  - 2045 Carbon Neutrality
- Clean electricity
  - 60% renewable by 2030
  - Zero-carbon by 2045

Governor's Goal:
100% zero-emission transportation by 2045 where feasible

HD GHG Rulemaking Timeline

2016 — U.S. EPA/NHTSA adopted the second phase of GHG standards (Phase 2)

2018 — CARB largely harmonized with federal Phase 2

2023 — U.S. EPA plans to release the Phase 3 notice of rulemaking (March)

U.S. EPA plans to release the Phase 3 final rule (December)

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Nationwide Highlights from 2022…

Inflation Reduction Act (IRA) Aug. 2022

- Offers potential tax rebates up to $40,000 per HD ZEV
- Builds on Bipartisan Infrastructure Law investments

COP 27 Nov. 2022

- U.S. signed international agreement to work to:
- 2030: 30 percent zero-emission of new sales of commercial delivery vehicles, buses and trucks
- 2040: 100 percent zero emission sales of such new vehicles

…Nationwide Highlights from 2022

Multinational Original Equipment Manufacturers (OEM)

- OEMs projecting significant sales fractions
- 2030 ZEVs & 2040 Decarbonization

50%	100%	Navistar
60%	100%	Daimler
70%	100%	Volvo
	100%	PACCAR

Independent studies

- IRA forecasted to drive large nationwide shifts to HD ZEVs
  - 2030 HD ZEV sales to increase significantly: 10 percent 'business-as-usual' → ~25 percent of sales with IRA*

*Source: International Council on Clean Transportation and Energy Innovation

Conclusions

- Alignment with the CTP-NOx rule would lead to ~1-5 tons per day of NOx benefit losses in 2037 for CA because of the compliance allowance and temperature adjustment
- In order to offset those losses, would need to see very high nationwide zero-emission (ZE) penetration (e.g., sleeper cabs sales around 30% in 2027, ramping up to 70% in 2037)

Acronyms & Abbreviations

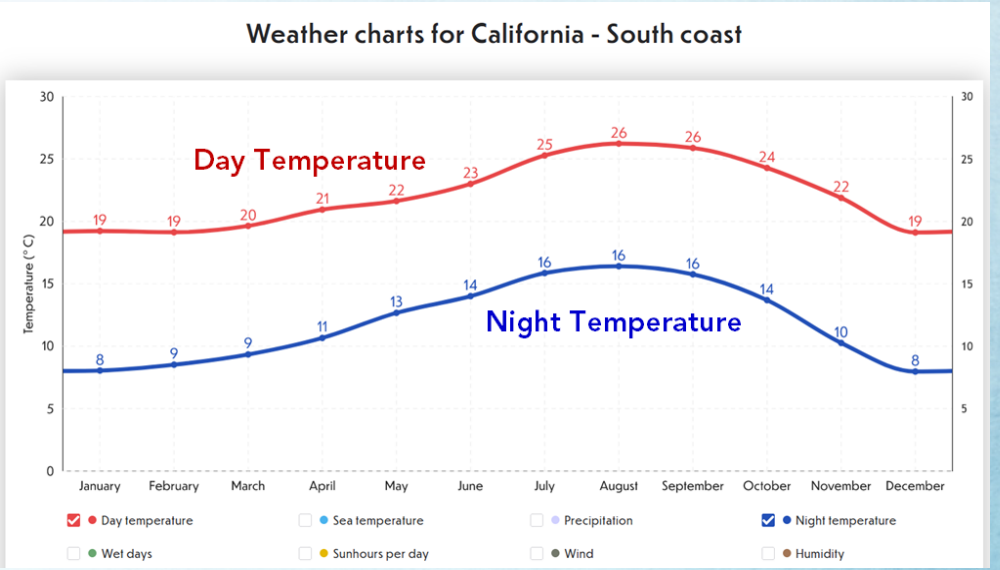
- FTP: Federal Test Procedure
- SET: Supplemental Emission Test
- LLC: Low Load Cycle
- mg/hp-hr: milligrams per brake horsepower-hour
- MY: Model Year
- UL: useful life
- LHDE: light heavy-duty engine used in a vehicle that is between 14,001 to 19,500 pounds GVWR
- MHDE: medium heavy-duty engine used in a vehicle that is between 19,501 to 33,000 pounds GVWR
- HHDE: heavy heavy-duty engine used in a vehicle that exceeds 33,000 pounds GVWR
- MAW: Moving Average Window test
- HD: Heavy-duty

Backup Slides

Relevance of Low Ambient Temperature in South Coast

- Typical 10 °C differential between morning and evening temperatures (monthly average) throughout the year
- Monthly average evening temperatures are below 25 °C even during summer months
- Approximately 37% of heavy-duty vehicle miles traveled (HD-VMT) in the South Coast Air Basin (SCAB) occurs between 8 pm to 8 am

Monthly Average Temperatures



https://www.sunheron.com/north-america/united-states-of-america/california-south-coast-weather-climate/

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Light Heavy-Duty Engines

	Least Stringent → Most Stringent		
Idle NOx Standard(g/hr)	10[3]		5[1] 5[2]
In-Use* FTP/SET NOx Standard (mg/bhp-hr)	35[3]		20[1] 20[2]
In-Use* LLC NOx Standard (mg/bhp-hr)			50[1] 50[2] 50[3]
In-Use Off-Cycle bin-2/bin-3 NOx Standards (mg/bhp-hr)	63-107/no bin-3[3]	100/40 (55 for 2-bin)[1]	75/30 (41 for 2-bin)[2]
Warranty Period (miles)	150,000[1]		210,000[2] 210,000[3]
Useful Life (miles)	190,000[1]		270,000[2] 270,000[3]

(1) Omnibus 2027-2030 Model Year

(2) Omnibus 2031+ Model Year

(3) Clean Trucks Plan

* In-Use FTP/SET/LLC standards are calculated by adding the applicable NOx compliance allowance for in-use testing to the emissions standard as described in §1036.150 (y). For example, the in-use FTP-NOx standard for a heavy heavy-duty engine is calculated by taking the applicable standard of 35 mg/bhp-hr (§1036.104 (a)(1)) and then adding the applicable 15 mg/bhp-hr NOx compliance allowance for in-use testing as specified in §1036.150 (y).

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Medium Heavy-Duty Engines

	Least Stringent → Most Stringent		
Idle NOx Standard(g/hr)	10[3]		5[1] 5[2]
In-Use* FTP/SET NOx Standard (mg/bhp-hr)	50[3]		20[1] 20[2]
In-Use* LLC NOx Standard (mg/bhp-hr)	65[3]		50[1] 50[2]
In-Use Off-Cycle bin-2/bin-3 NOx Standards (mg/bhp-hr)	78-122/no bin-3[3]	100/40 (55 for 2-bin)[1]	75/30 (41 for 2-bin)[2]
Warranty Period (miles)	220,000[1]		280,000[2] 280,000[3]
Useful Life (miles)	270,000[1]		350,000[2] 350,000[3]

(1) Omnibus 2027-2030 Model Year

(2) Omnibus 2031+ Model Year

(3) Clean Trucks Plan

* In-Use FTP/SET/LLC standards are calculated by adding the applicable NOx compliance allowance for in-use testing to the emissions standard as described in §1036.150 (y). For example, the in-use FTP-NOx standard for a heavy heavy-duty engine is calculated by taking the applicable standard of 35 mg/bhp-hr (§1036.104 (a)(1)) and then adding the applicable 15 mg/bhp-hr NOx compliance allowance for in-use testing as specified in §1036.150 (y).

Heavy Heavy-Duty Engines

	Least Stringent → Most Stringent		
Idle NOx Standard(g/hr)	10[3]		5[1] 5[2]
In-Use* FTP/SET NOx Standard (mg/bhp-hr)	50[3]		35[1] 40[2]
In-Use* LLC NOx Standard (mg/bhp-hr)	90[1] 100[2]		65[3]
In-Use Off-Cycle bin-2/bin-3 NOx Standards (mg/bhp-hr)	78-122/no bin-3[3]	180/70 (98 for 2-bin)[1]	150/60 (83 for 2-bin)[2]
Warranty Period (miles)	450,000[1] 450,000[3]		600,000[2]
Useful Life (miles)	600,000[1]	650,000[3]	800,000[2]

(1) Omnibus 2027-2030 Model Year

(3) Clean Trucks Plan

(2) Omnibus 2031+ Model Year

* In-Use FTP/SET/LLC standards are calculated by adding the applicable NOx compliance allowance for in-use testing to the emissions standard as described in §1036.150 (y). For example, the in-use FTP-NOx standard for a heavy heavy-duty engine is calculated by taking the applicable standard of 35 mg/bhp-hr (§1036.104 (a)(1)) and then adding the applicable 15 mg/bhp-hr NOx compliance allowance for in-use testing as specified in §1036.150 (y).

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