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SYMPOSIUM
April 7–8, 2019 | Detroit, MI

MODERNIZING HD IN-USE TEST PROCEDURES TO ACHIEVE REAL WORLD EMISSION REDUCTIONS

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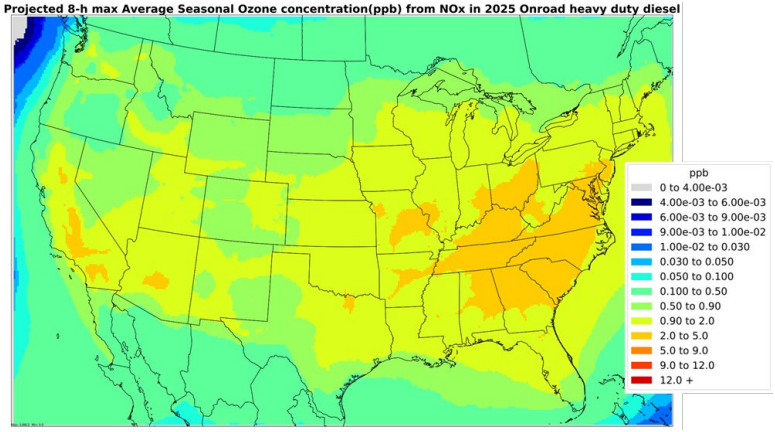
Overview

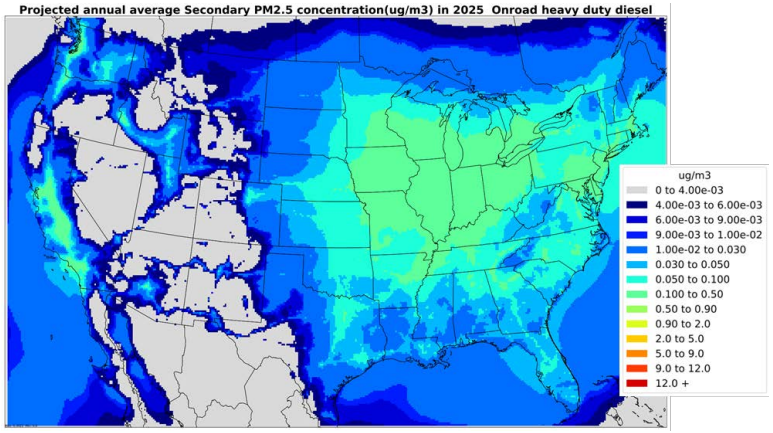
- Impact of emissions from heavy-duty vehicles
- Highway HD compliance process
- History of EPA heavy-duty in use testing requirements
- EPA's *Cleaner Trucks Initiative*
- Targeted updates to in-use testing requirements

Impact of NOx Emissions from Heavy-Duty Diesel Vehicles*

NOx Contribution to Ozone in 2025



NOx Contribution to Ambient PM2.5 in 2025



* Zawacki, et al. https://doi.org/10.1016/j.atmosenv.2018.04.057

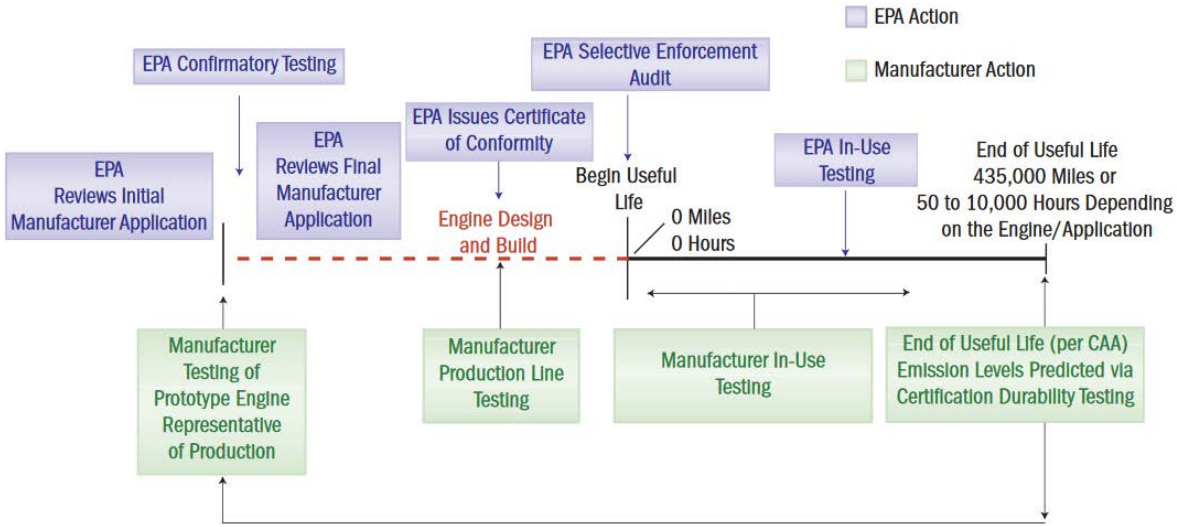
Heavy-Duty Compliance Process

Certification Requirements:

- Emissions standards on pre-production engines/vehicles
- Performance evaluated on laboratory test cycles
- Tests also evaluate:
  - Engine durability
  - Excess emissions during emission controls regeneration
  - On-board diagnostic systems

In-use Requirements:

- Emissions standards applied to engines/vehicles operating in real world



History of Heavy-Duty In-use Test (HDIUT) Program

Designed to address manufactures changing engine operation under sustained high load to improve fuel efficiency, that resulted in elevated NOx emissions

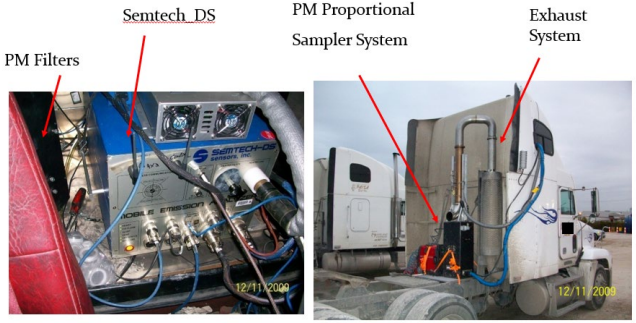
- **1998: Consent decree**
- **2001: In-use standards finalized**
- **2005: Manufacturer run in-use test program requirements finalized**
- **2006: CARB adopts HDIUT and national HDIUT pilot year**
- **2007: 1st year of HDIUT gaseous criteria pollutant enforcement**
- **2008: Gaseous measurement allowance values finalized**
- **2010: PM measurement allowance value finalized**
- **2011: 1st year of HDIUT PM criteria pollutant enforcement**

Current Heavy-Duty In-Use Testing (HDIUT) Requirements for HD On-Highway Engines

- **Section 207(c) of the CAA states: EPA shall order a recall if the "Administrator determines that a substantial number of any class or category of vehicles or engines, although properly maintained and used, do not conform to the regulations prescribed under section 7521 of this title, when in actual use throughout their useful life . . ."**
- **Both EPA and manufacturers test a small number of engines used on vehicles operating in the real world Compliance is based on a Not-to-Exceed (NTE) standard**

Pollutant	NTE Emission Standard
NOx	0.3 g/hp-hr (1.5x FTP)
PM	0.015 g/hp-hr (1.5x FTP)
Non-methane hydrocarbon (NMHC)	0.21 g/hp-hr (1.5x FTP)
CO	19.375 g/hp-hr (1.25x FTP)

Current in-use requirements allow manufacturers to exclude parts of the engine's operating range from the NTE standard



Portable Emissions Measurement System (PEMS)

Criteria for Valid NTE Events

1. **Inside NTE control area**

> 30% max power

> 30% max torque

> 15% SET Cycle speed (rpm)

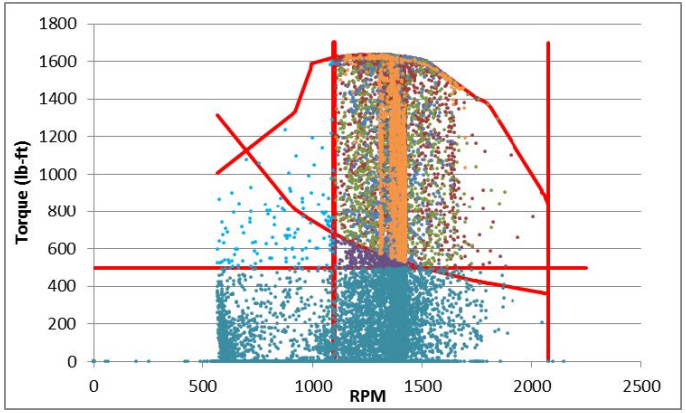
2. **Temperature conditions**

> 250°C (for SCR aftertreatment)

Meet minimum intake manifold/engine coolant temperatures

3. **At least 30 consecutive seconds meeting above criteria**

Emissions value: work-specific average of 1 Hz data within each NTE event



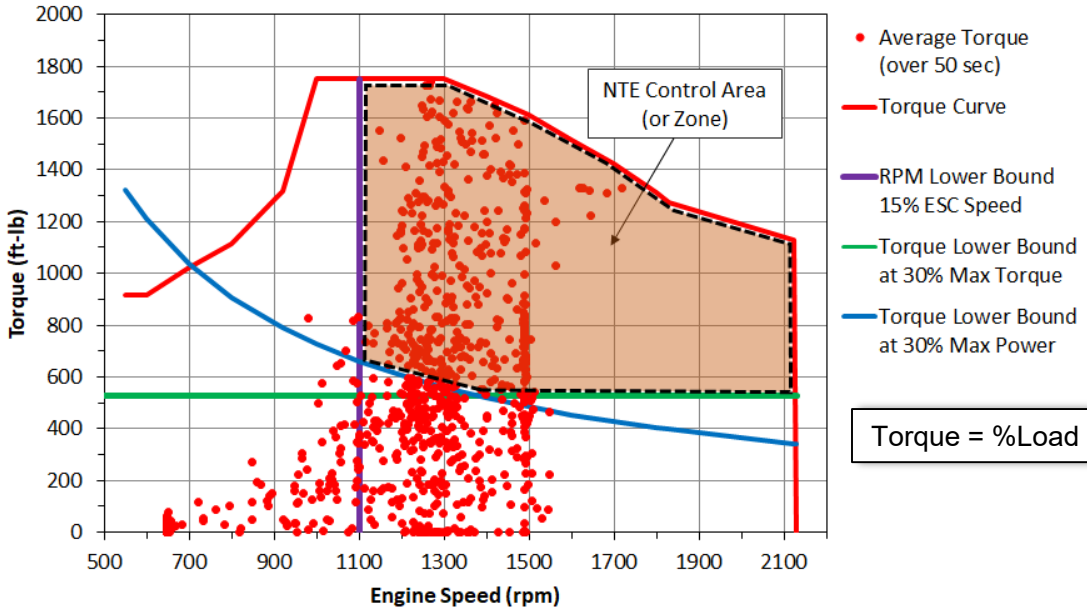
Points excluded by reason:

- Intake Manifold Temperature
- Aftertreatment Out Temperature
- Power
- Torque
- RPM
- Duration
- NTE Event

From November 3, 2016 CARB Public Workshop

In-use Results – Vocational Vehicle Test Case

NTE Control Area - Engine Family Name: EMFR1-HDEFN3, Vocational Truck



Valid NTE event duration is at least 30 seconds of vehicle continuous operation in the NTE zone with all exclusions in the current regulation applied

Torque = %Load * Max Torque

In-use Results – Vocational Vehicle Test Case cont.

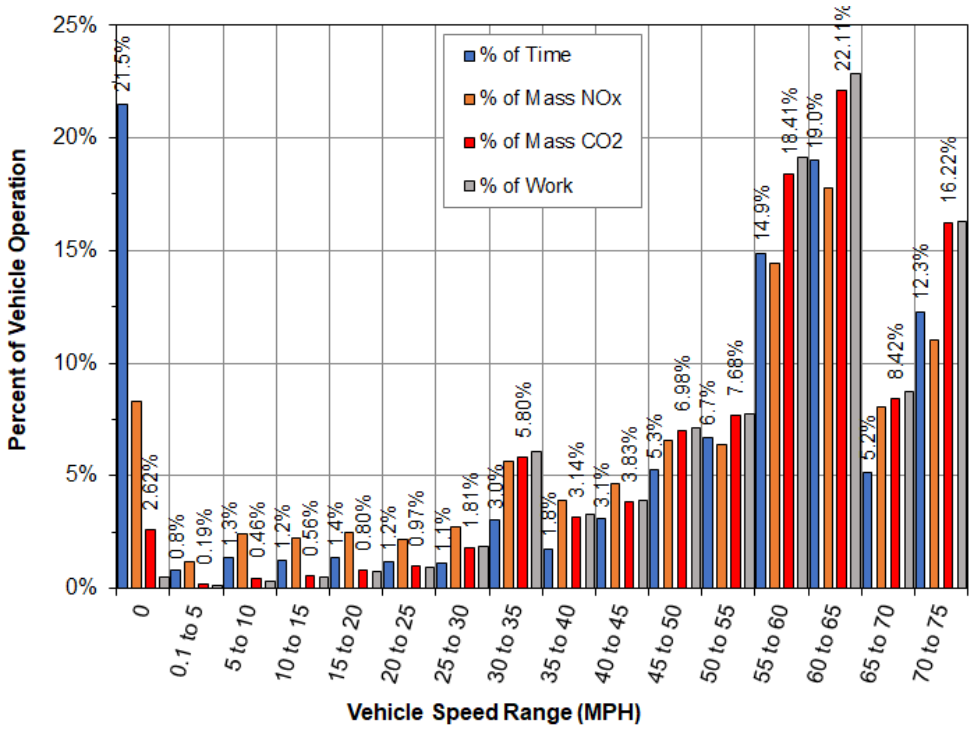
Each Vehicle has a Distinctive Operation Profile

Engine Family Name: EMFR1-HDEFN3, Vocational Truck

- Test Time = 13 hr.
- Mass NO_X = 340 g
- Mass of CO_2 = 873917 g
- Diesel Fuel = 85.85 gallons
- Work = 1727 hp-hr

For 0 - 50 MPH:

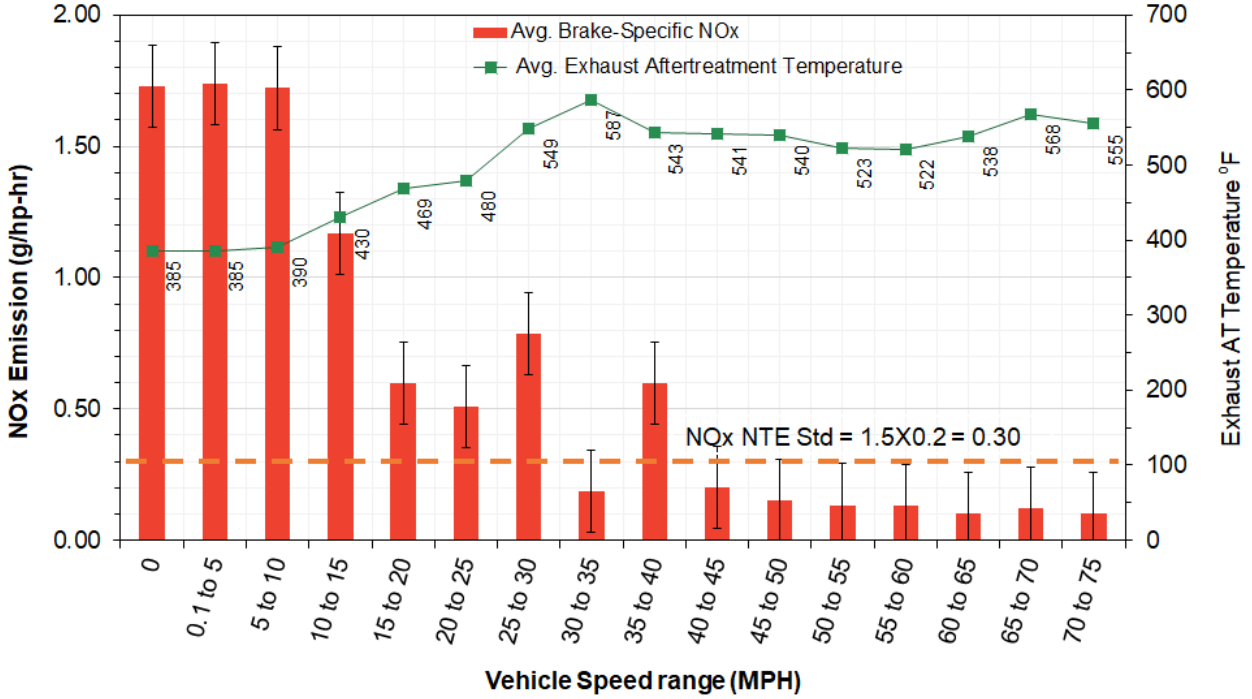
- Mass of NO_X is about 42%
- Mass of CO_2 is about 27%
- Work is about 25%



In-use Results – Vocational Vehicle Test Case cont.

Engine Family Name: EMFR1-HDEFN3, Vocational Truck

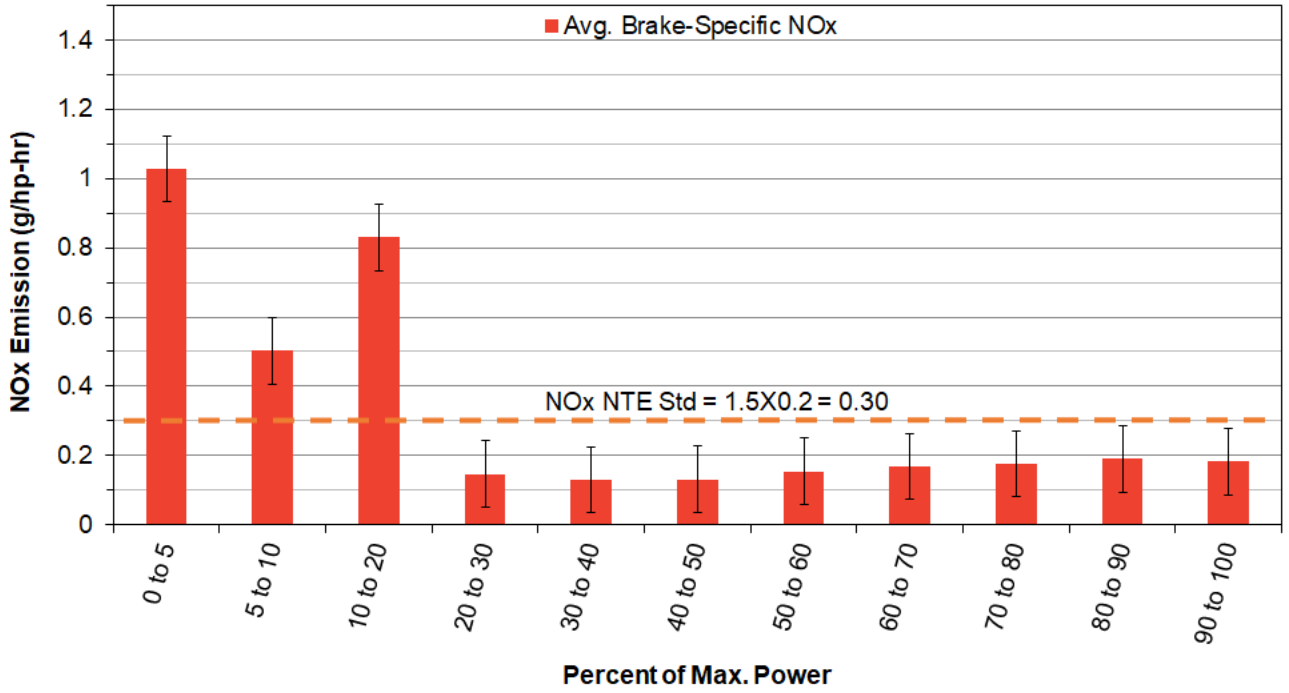
Urban Brake-Specific NOx Emissions are About 3-5 X NTE Standard



In-use Results – Vocational Vehicle Test Case cont.

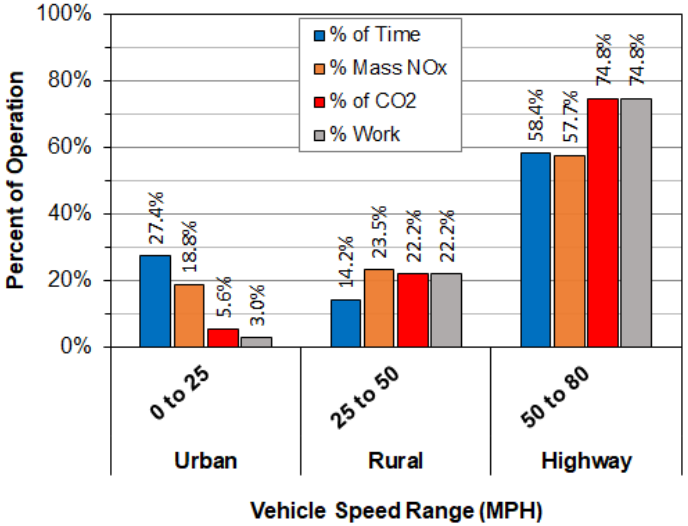
Engine Family Name: EMFR1-HDEFN3, Vocational Truck

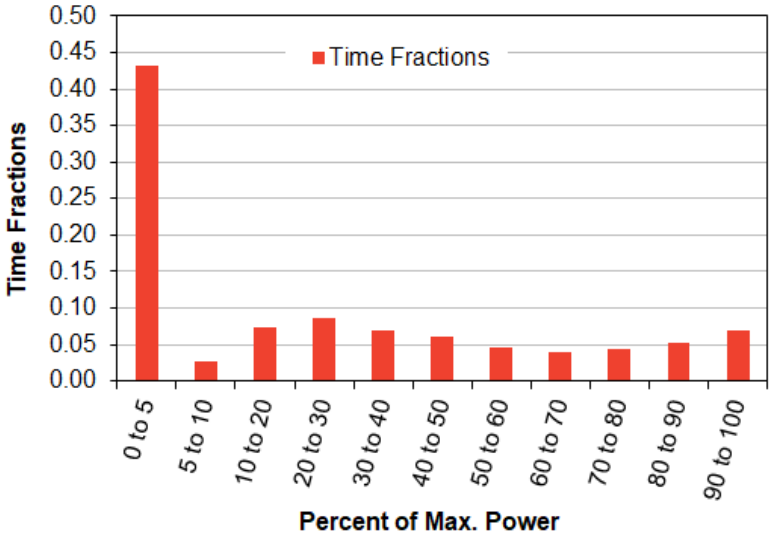
Average brake-specific NOx emissions increase at lower power, especially below 30% of max power



In-use Results – Vocational Vehicle Test Case cont.

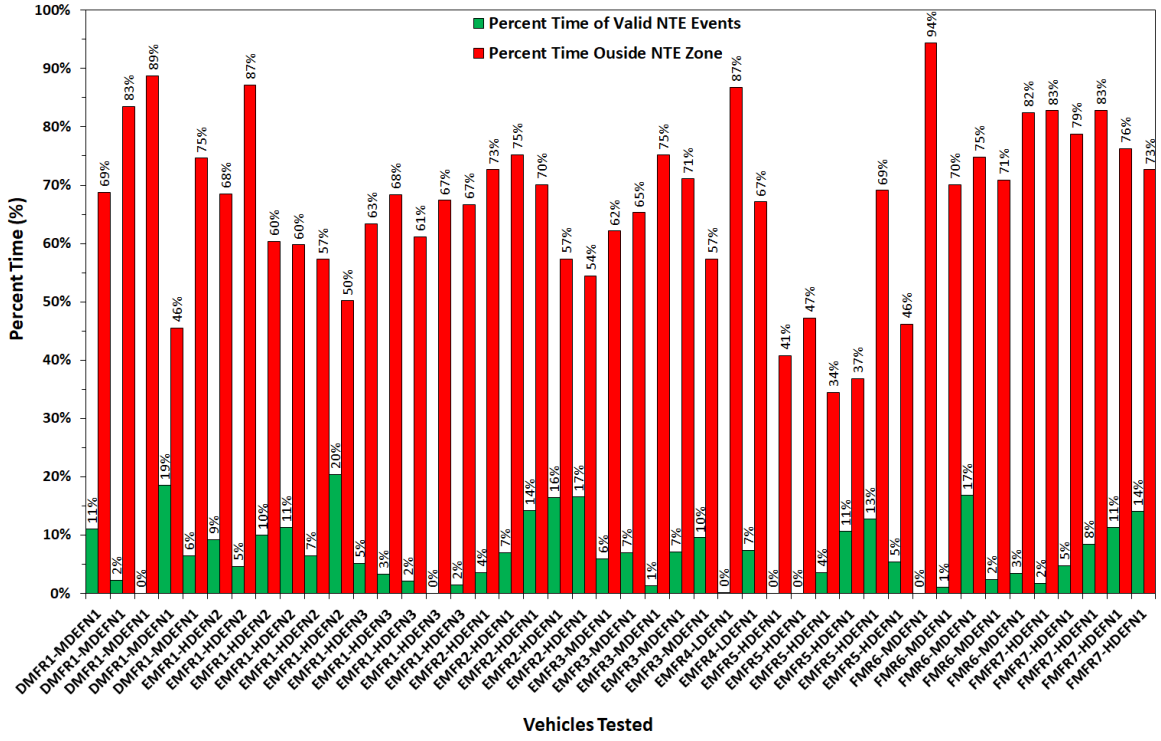
Percent of Time Spent in Urban Driving and Idling - Engine Family Name: EMFR1-HDEFN3, Vocational Truck



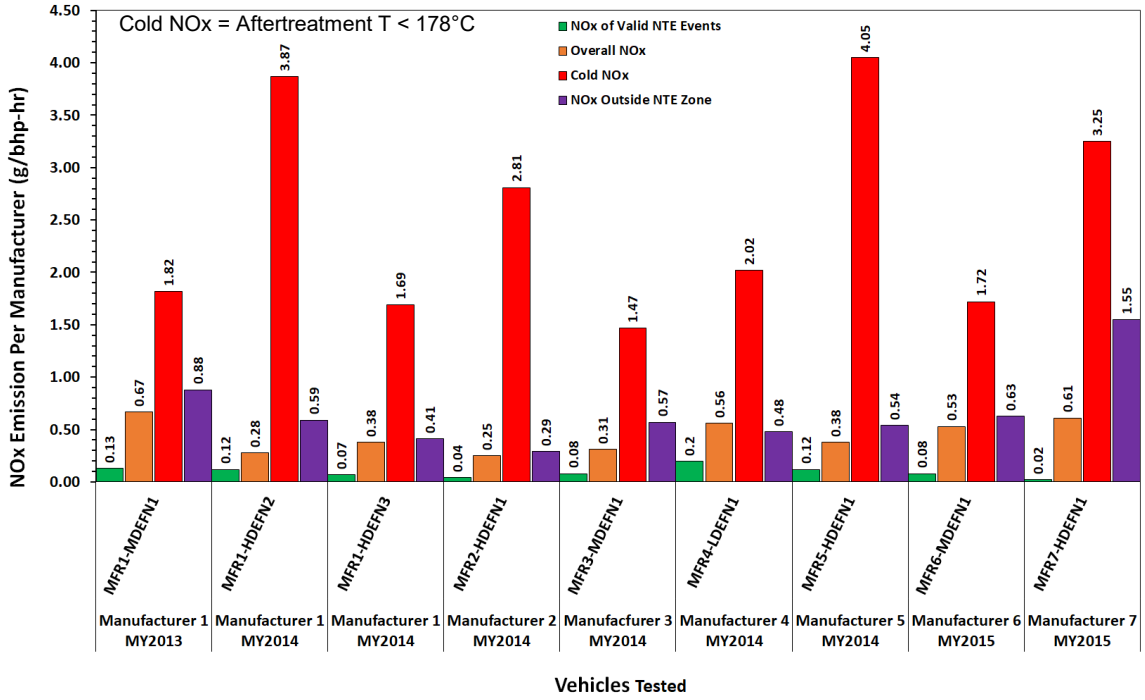


- Urban + rural driving represent over 40% of the HD NOx emissions time from vehicles
- In real driving low speed and idling are major part of the duty cycles even for line haul and delivery vehicles

In-use Results – Percent Time of In-Use Testing in the Valid NTE Zone vs. Outside NTE Zone



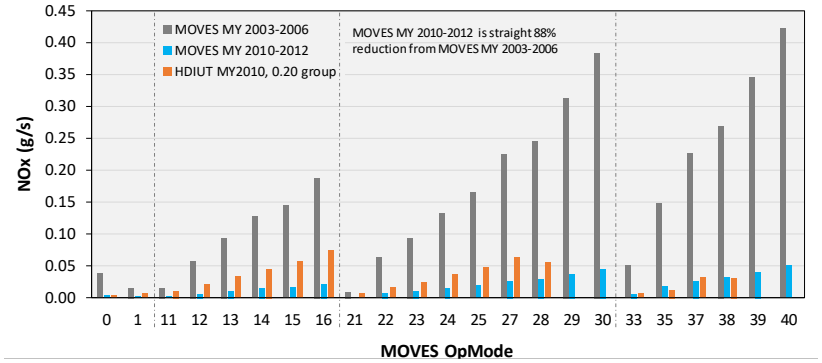
In-use Results – Average Brake-Specific NOx Emissions per Engine Family

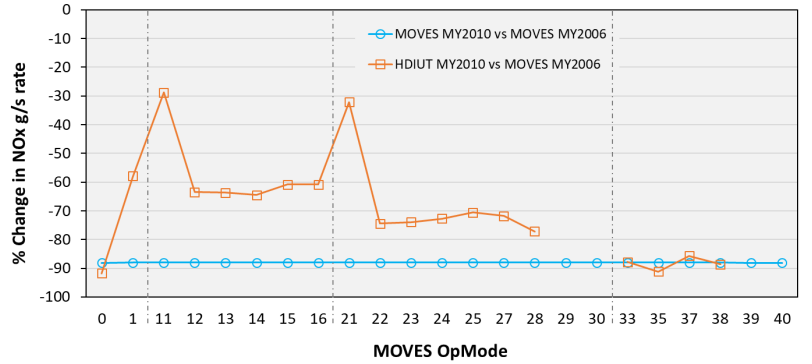


Further Insight from HDUIT Data – MOVES vs. HDIUT

- **Comparison of expected vs. actual reductions in HHD diesel emissions**
  - Pre- and Post-2010 MOVES NOx Rates for HHD Diesel Engines
  - Actual rates from manufacturer run HDIUT
  - Actual reductions vary by OpMode (binned vehicle speed and power)*

*Comparisons unavailable in OpModes 29, 30, 39, 40 due to change in modeling approach for high-powered OpModes.





In-use Results – Summary of Data Submitted for 2012 – 2016 Test Orders

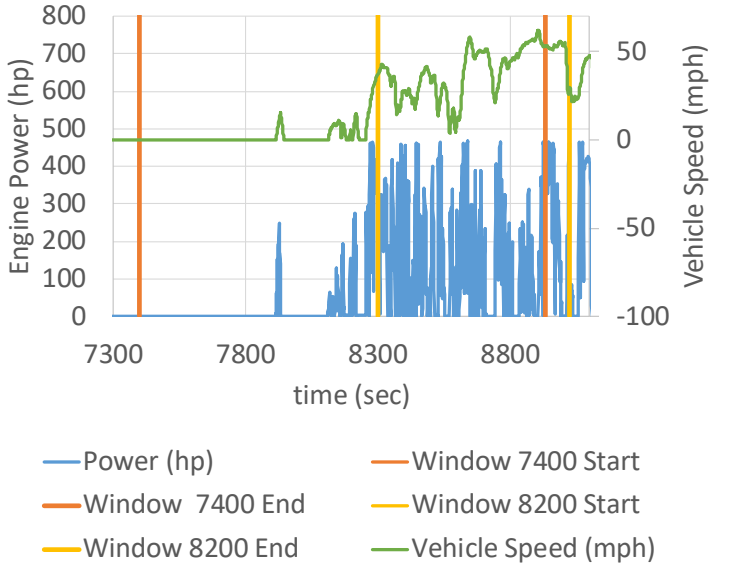
- Overall average vehicle pass ratios submitted since 2012
  - NOx = 0.97
  - PM = 0.99
  - CO = 1.0
- Percentage of tests meeting or exceeding the 0.90 vehicle-pass ratio threshold since 2012
  - NO_x = 94%
  - PM = 100%
  - CO = 100%
- Estimated total mileage covered is greater than 200,000 miles

The *Cleaner Trucks Initiative*

- **On November 13, 2018, EPA Administrator Andrew Wheeler announced the Cleaner Trucks Initiative (CTI) to address emissions from new heavy-duty trucks and engines**
- **Our objective is to achieve lower NOx emissions nationwide—**
  - Ensure real-world emissions reductions in all conditions throughout the workday
  - Investigate options for improving current certification and in-use testing requirements
  - Pursue a national, harmonized program (California already working on a low NOx program)
- **Focus on NOx, but take a broad look at other heavy-duty engine emissions**
- **Identify cost-effective means of ensuring real-world compliance and explore opportunities to streamline existing requirements**

Overview of Moving Average Window (MAW) Method

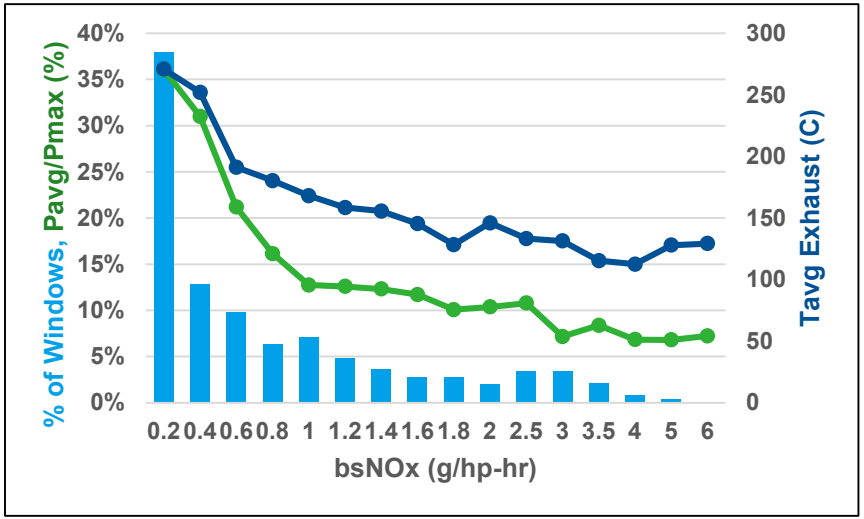
- **Implemented in Euro VI regulations**
- **Emissions mass calculated for subsets ("windows") of total dataset**
  - Length of windows based on the reference work or CO_2 measured over the transient certification cycle
  - Windows start every second of the data set given that there is enough following data to complete a window length
  - 1Hz NO_x emissions are averaged over a window
  - Window emissions are reduced to single point Window Averages.
  - Average engine power for a window must be ≥ 15-20% of engine maximum power (reducing to 10% for MY 2019)
- **Brake specific averaged window emissions are ordered and the 90th percentile window is compared with the emission standard**
- **The ratio of the 90th percentile emission to the emissions standard must not be greater than the conformity factor, 1.5**

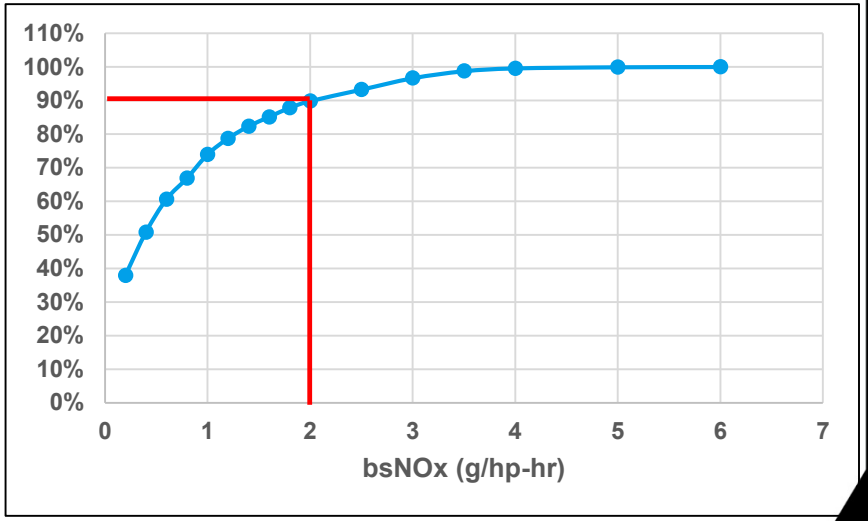


Window Average Power/Engine Max Power
Window # 7400: 15%
Window # 8200: 33%

WBW Results from HDUIT Data

- Plots made with data from 44 HHD Vehicles with an FEL of 0.2 g/hp-hr for NO_x
- For these tests the brake-specific NO_x emission at the 90th cumulative percentile of the window is ~2 g/hp-hr





Benefits of MAW to NTE

- **Longer averaging window from MAW method increases accuracy**
  - Removal of the measurement allowance for criteria emissions
  - Currently manufacturers well under MA allowance for compliant NTEs
- **In-use operation is not excluded due to short periods of operation that don't meet the criteria (30 sec minimum window size, lower power, lower temperature, etc.)**
- **More operation covered by method**
  - Current HDUIT data from the Heavy-Heavy engines have less than 17% of the time covered by NTE
  - MAW could be designed to cover more than 90% of operation

Potential Changes for EPA/ARB to MAW Method

- **EPA will likely propose moving average window procedure for HDIUT in CTI rulemaking and is considering the following changes:**
  - Lower average power threshold for valid windows (5%)
  - Normalize by CO_2 or fuel consumption to enable lowering of the average power threshold (emissions exponentially increase at low power operation)
  - Test route determined by actual in-use operation over the shift-day, not a prescribed route
  - Include cold-start operation, weight 1/7th
  - Actual vehicle payload used
  - Compare percentile higher than 90th to the standard (95th)
  - Eliminate conformity factor and compare against an actual in-use standard

Summary

- In-use emissions testing can positively influencing air quality by ensuring that manufacturers implement emissions control technologies to achieve emissions reduction under real driving conditions including low speeds and loads.
- There is a disconnect between laboratory certified emission levels and actual in-use emission levels.
- Exclusion of some modes of operation can significantly affect achievable in-use emission reductions.
- Cold-start and idle NOx emissions, almost without exception exceed the NTE emission limits.
- A redesign of the in-use compliance program is needed to achieve emission control to the current FTP and RMC limits or any newly promulgated limits.