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NH_3 Cross-Sensitivity of a NO_X sensor and NH_3 Measurements of Newer-Model Gasoline Light-Duty Vehicles

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Introduction

- A screening project revealed unexpectedly high on-road NO_X emissions from gasoline LDVs measured by a mini-PEMS NO_X sensor.
- The NO_X sensor's cross-sensitivity to NH_3 was evaluated in a bench study.
- Dynamometer testing was conducted on gasoline LDVs to confirm NH_3 emissions.

Objectives

1. To evaluate the cross-sensitivity of a NO_X sensor to NH_3
2. Collect NO_X and NH_3 for gasoline LDVs on the dynamometer

Bench Study

Set-up:

- Adequate calibration of the NO_X sensor was verified using low and high concentrations of NO reference gases
- The NO_X sensor was fed NH_3 reference gases of concentrations ranging from 20 parts per million (ppm) to about 900 ppm
- Sampling chamber was purged with zero air between readings for at least 120 seconds
- Sampling chamber was heated by NO_X sensor heating (minimum sensor operating temperature is 190° C); however, gas temperature in chamber was not measured
- Gas flowrate was not measured

Bench Study

Reference gases

	Concentrations (ppm)	Balance gas
NO	9.274	N_2
	285	
NH_3	20.31	
	100.0	
	480.0	
	898.0	

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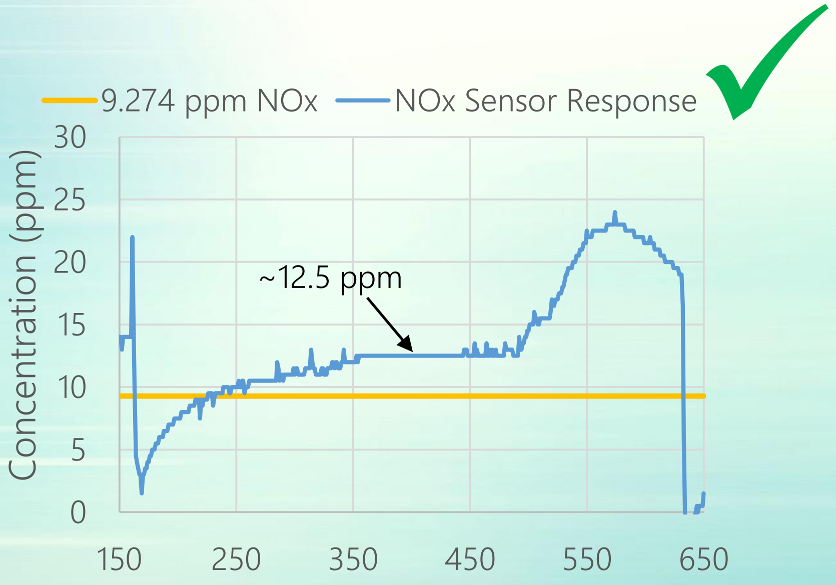
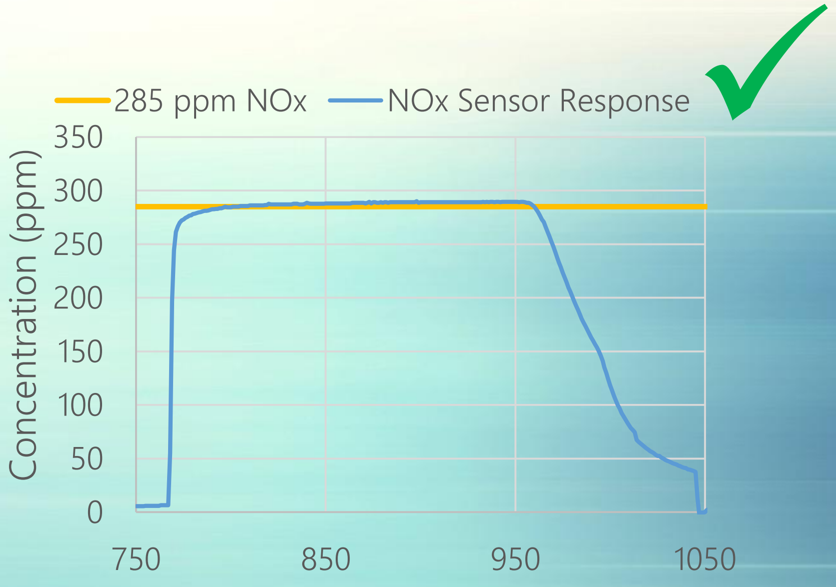
Bench Study

NO$_X$ sensor calibration check

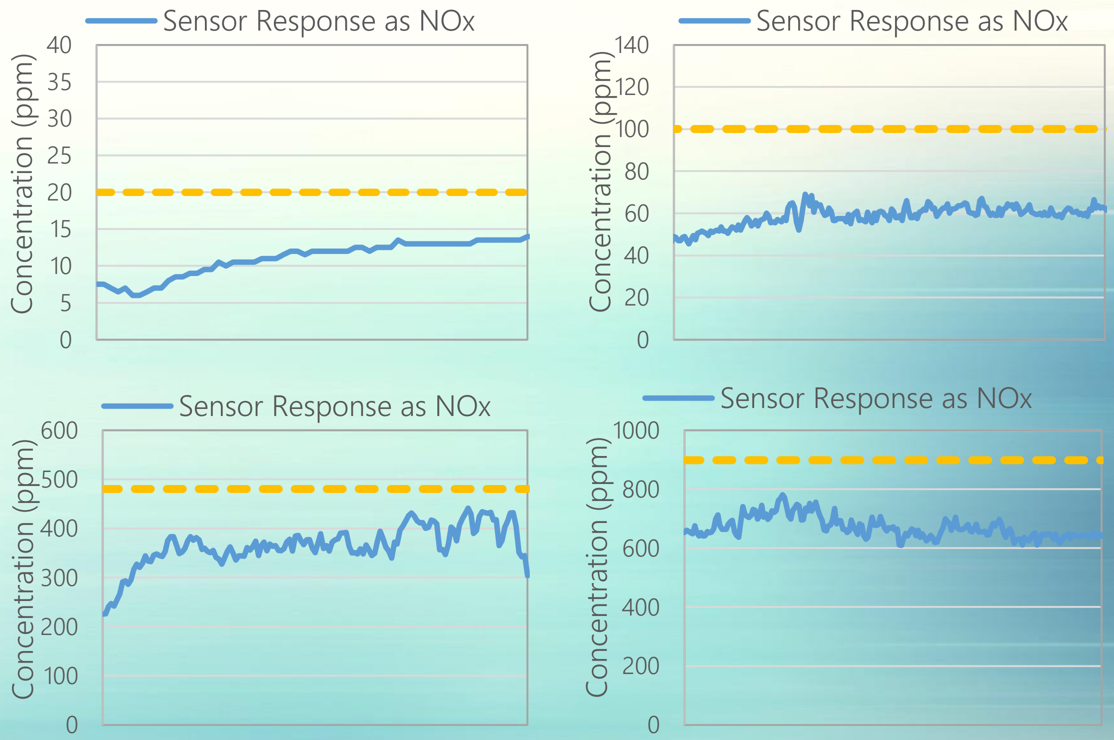




Bench Study

Results

Results shown here are stabilized portions of the sensor readings. Sensor response concentrations are reported as NO_X by the mini-PEMS.



Bench Study

Results

Average NO_X sensor readings were taken from the most stabilized portions of the test – 40 seconds for the 20 ppm NH_3 test, to 140 seconds for the 100 ppm NH_3 test.

The NO_X sensor's cross-sensitivity to NH_3 appears to be significant.

NOx Sensor NH3 Cross-sensitivity		
NH3 reference gas (ppm)	Average Reading (ppm)	Percent Reading
20	12	62%
100	61	61%
480	362	75%
898	643	72%

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NH3 From Gasoline Vehicles

- NH_3 from gasoline vehicles produced during reduction reactions of NO in the TWC.[1]
- $2NO + 2CO + 3H_2 \rightarrow 2NH_3 + 2CO_2$
- $2NO + 5H_2 \rightarrow 2NH_3 + 2H_2O$
- NH_3 concentrations were observed to increase during fuel-rich combustion ($\lambda < 1$) when TWC conditions are more reductive and when increased concentrations of CO and H2 are also present.[2]

[1]Harley, R., CARB, 2008. On-road measurements of light-duty gasoline and heavy-duty diesel vehicle emissions. Contract No. 05-309
[2]Suarez-Bertoa, R., et. al., 2014. Ammonia exhaust from spark ignition vehicles over the New European Driving Cycle. Atmospheric Environment, 97, 43-53

Validation in the Dynamometer

Measurement Methods

Emission Component	Test Instrument	Measurement Principle
NO_X	NGK/NTK Compact Emission Meter (NCEM mini-PEMS)	Amperometry
	Horiba MEXA-7200LE CLA-750LE / AVL AMA-4000	Chemiluminescence
NH_3	AVL SESAM FT	Fourier-transform infrared spectroscopy

- Laboratory measurements taken to further assess suitability of NO_X sensor in gasoline LDV applications
- NO_X measured by test cell analyzer
- NO_X sensor used for one vehicle
- NH_3 measured by FTIR

Dynamometer Testing

Testing Notes

Prior to testing, all vehicles were:

- Checked for OBD diagnostic codes
- Drained and filled with commercial phase 3 gasoline
- Driven on a prep cycle

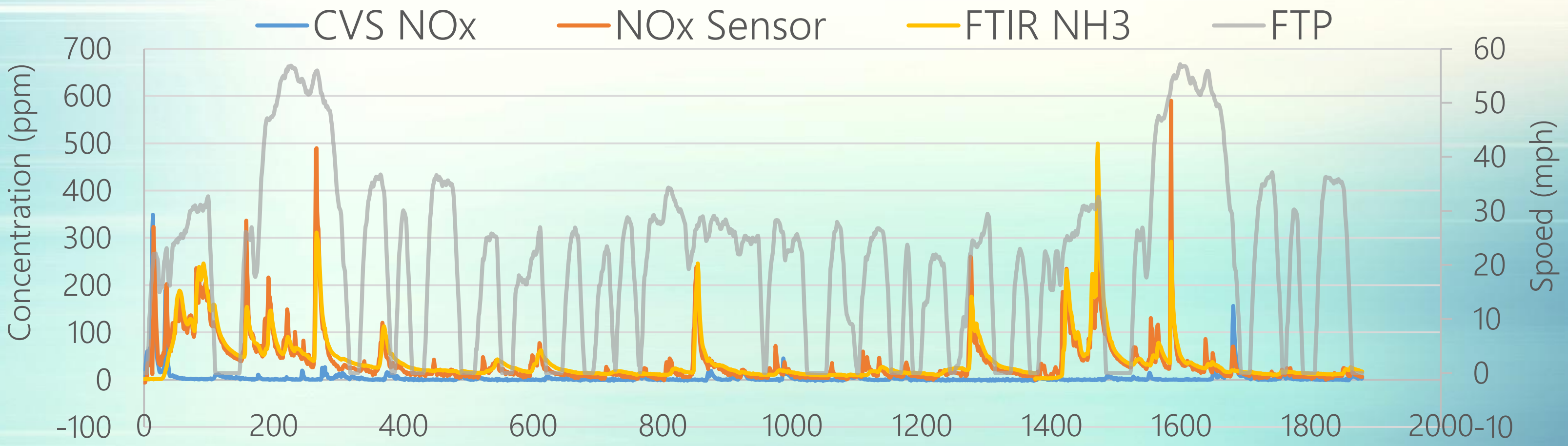
All UC and FTP tests were:

- Cold-start tests
- Conducted in the same dynamometer lab with the same equipment

Test Vehicles

Vehicle	Model year / Vehicle Type	Displace-ment	Emission Standard	Mileage	Technology
1	2018 LDT4	5.3 L	LEV3 ULEV125	17,549	Cylinder deac., GDI
2	2017 PC	2.5 L	LEV2 ULEV	32,948	PFI
3	2016 PC	2.4 L	LEV3 SULEV30	41,260	PFI
4	2018 LDT2	3.6 L	LEV2 ULEV	814	PFI
5	2018 PC	2.0 L	LEV3 SULEV30	16,486	PFI
6	2018 PC	2.5 L	LEV3 SULEV30	11,219	PFI, EGR
7	2017 PC	2.0 L	LEV3 ULEV70	8,600	GDI, TC
8	2017 PC	2.0 L	LEV3 SULEV30	36,768	GDI
9	2018 PC	2.0 L	LEV3 ULEV 70	16,457	GDI, TC
10	2018 PC	2.0 L	LEV3 SULEV30	15,543	GDI, TC

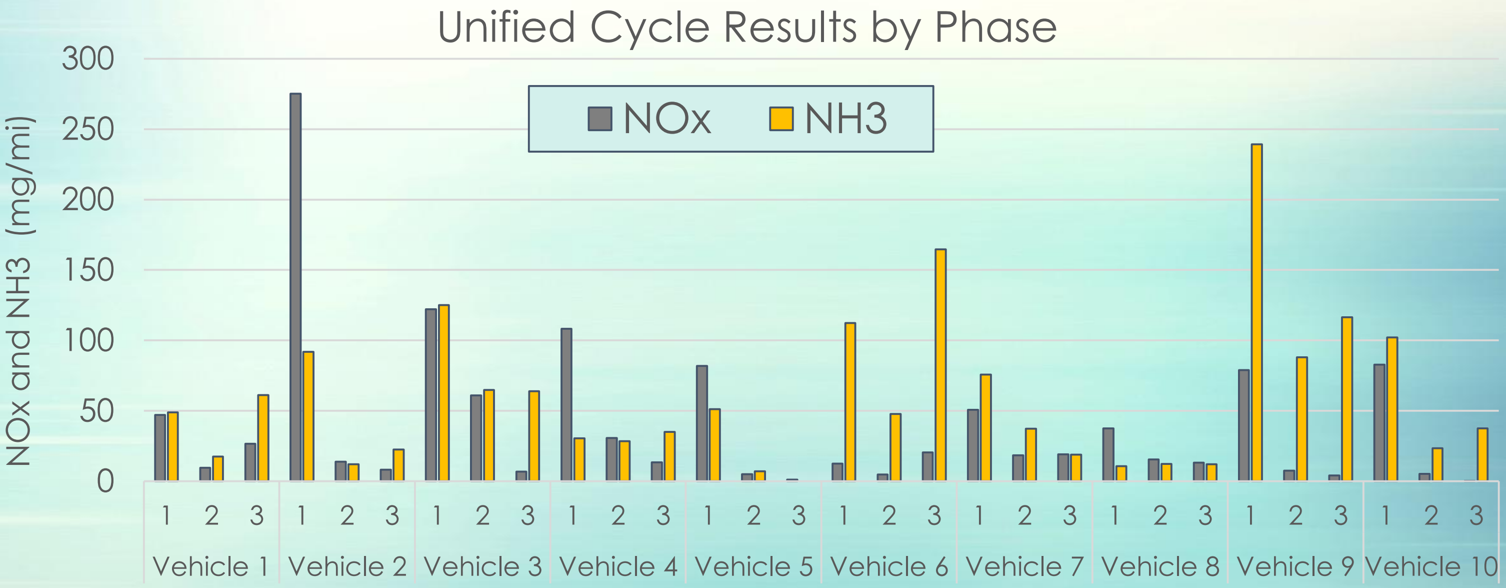
Preliminary Evaluation



FTIR readings in the dyno identify NH_3 emissions previously reported by the sensor as NO_X emissions during on-road screening.

Dynamometer Testing

Results



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Conclusion

Results identified a need for:

1. Addressing the NH_3 cross-sensitivity for NO_X sensors in gasoline exhaust measurement applications in order to support continued improvement of on-road, real-world emissions screening, and
2. Further investigation of NH_3 emissions from gasoline LDVs for the purpose of updating the mobile source NH_3 emissions inventory in California.

THANK YOU

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