Preliminary Results of Sensor Based Onboard Sensing Analysis And Reporting from Fleets During a Two Month Timeframe

13th Annual International OSAR Conference

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Grace Johnson

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CE-CERT

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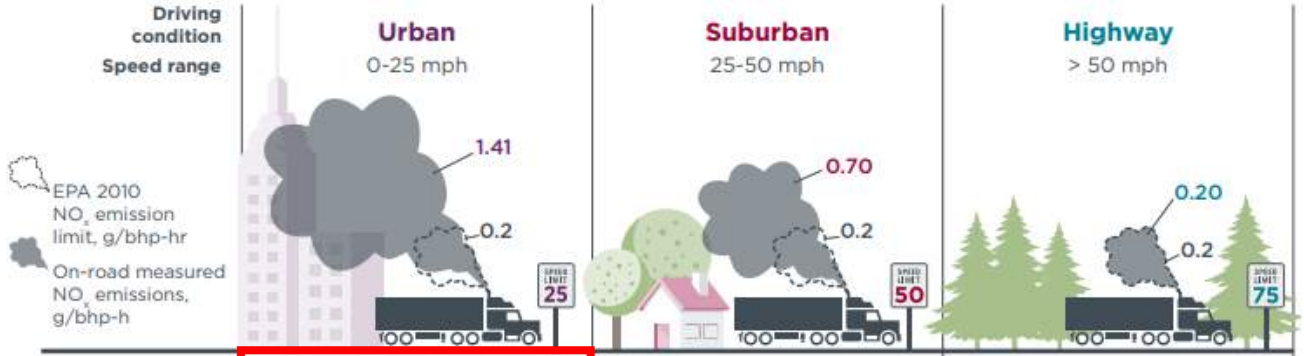
In Use Emissions Vary with Vehicle Operation



Driving condition / Speed range	Urban 0-25 mph	Suburban 25-50 mph	Highway > 50 mph
Average time spent at this condition	43%	11%	46%
Average share NO_x mass	40%	23%	37%
Brake specific NO_x emissions, g/bhp-hr	1.41*	0.70	0.20
Conformity Factor - CF	7.1*	3.5	1.0
Distance-specific NO_x emissions, g/mile	7.0*	2.4	0.6

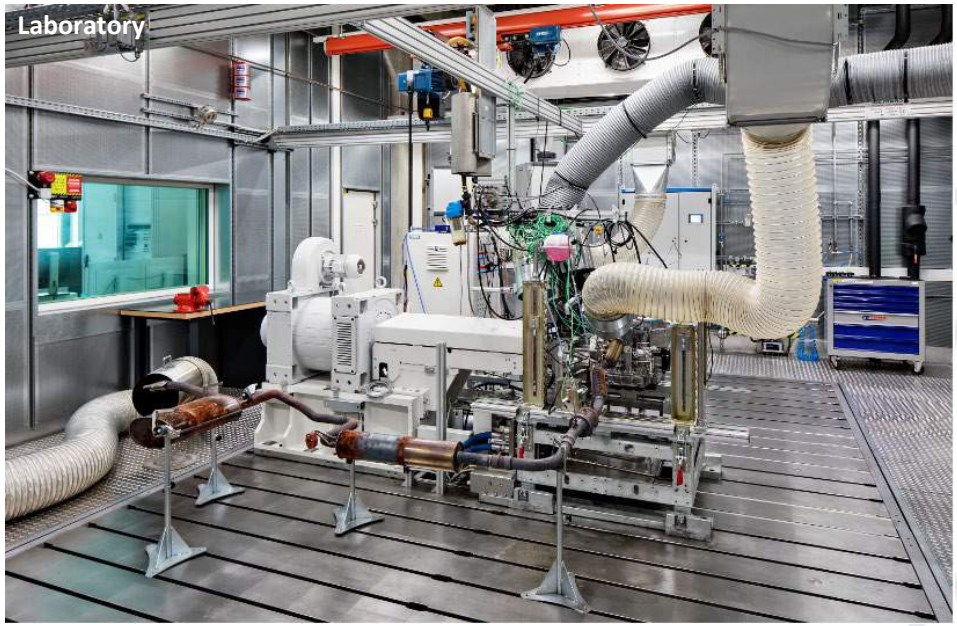
** Brake and distance specific NOx emissions for Urban bin do not include Idle operation, only 1-25 mph operation is included*

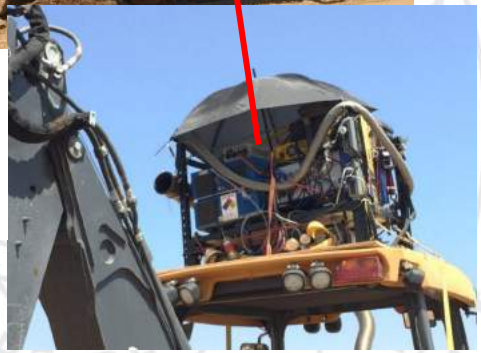
- 189 tests between 2010 and 2019
- Model Year (MY) 2010-2016 with SCR Technology
- **43%** of the activity is between 0-25 mph
- This represents **40%** of the NOx mass

Source: ICCT white paper Nov 2019

Laboratory, In-Use Measurement, and On-Board Sensing

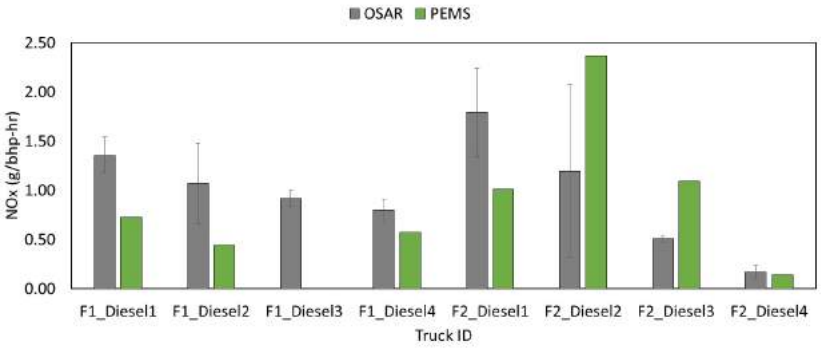
- Laboratory 2% accuracy (1 day of data takes weeks/months to set up)
- In-use measurement 5% (1 day of data takes 4-6 hrs to set up)
- On-board sensing 10% (1 **year** of data takes <1 hr to set up)

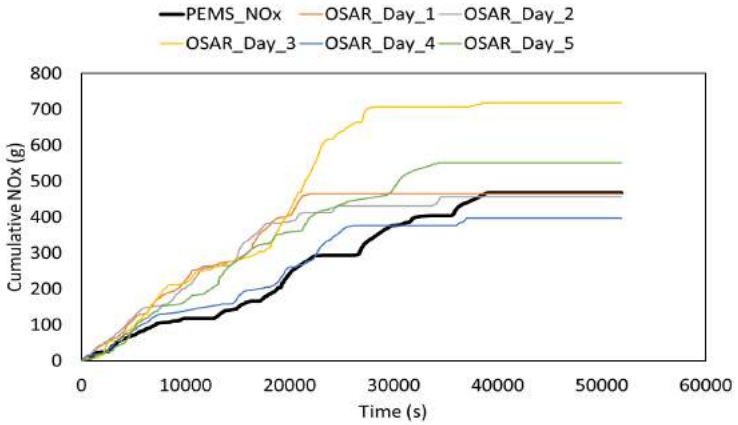




Montes, T., 2018 SAE OBD Symposium Indianapolis, Diesel OBD Programs ECARD Division presentation.
Tan, Y., Collins, J., Yoon, S., Herner, J., Henderick, P., Montes, T., Ham, W., Howard, C., Hu, S., Johnson, K., Scora, G., Sandez, D., Durbin, T., 2018. NOx Emission Estimates from the Activity Data of On-Road Heavy-Duty Diesel Vehicles. Presentation at 28th CRC Real World Emissions Workshop, Garden Grove, CA, March.
Yang, J., Durbin, T.D., Jiang, Y., Tange, T., Karavalakis, G., Cocker III, D.R., Johnson, K.C., 2018. A comparison of a mini-PEMS and a 1065 compliant PEMS for on-road gaseous and particulate emissions from a light duty diesel truck, Science of the Total Environment, vol. 640-641, 368-376.

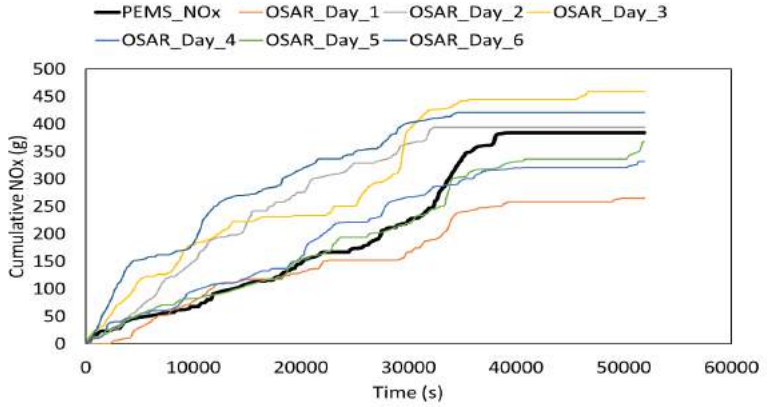
One Day of PEMS Testing Is Not Representative





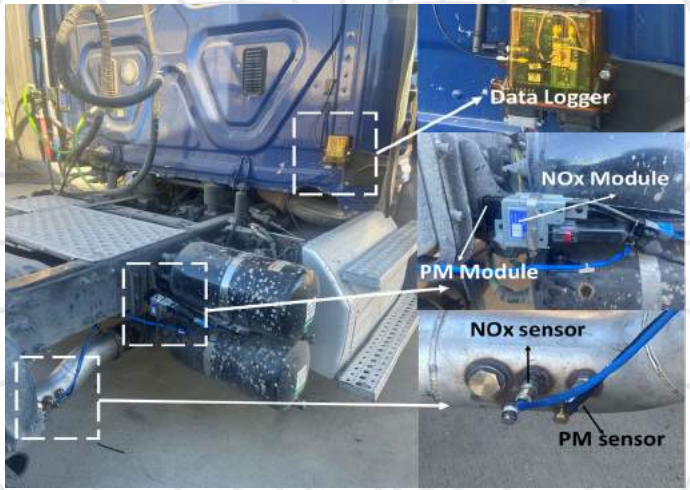
Source ARB funded ZANZEFF project Lights and AQMD Phase 1

- Emissions change between days on the same vehicle
- PEMS data presented emissions measured on one day
- OSAR data showed several days of continuous monitoring results



Introducing OSAR

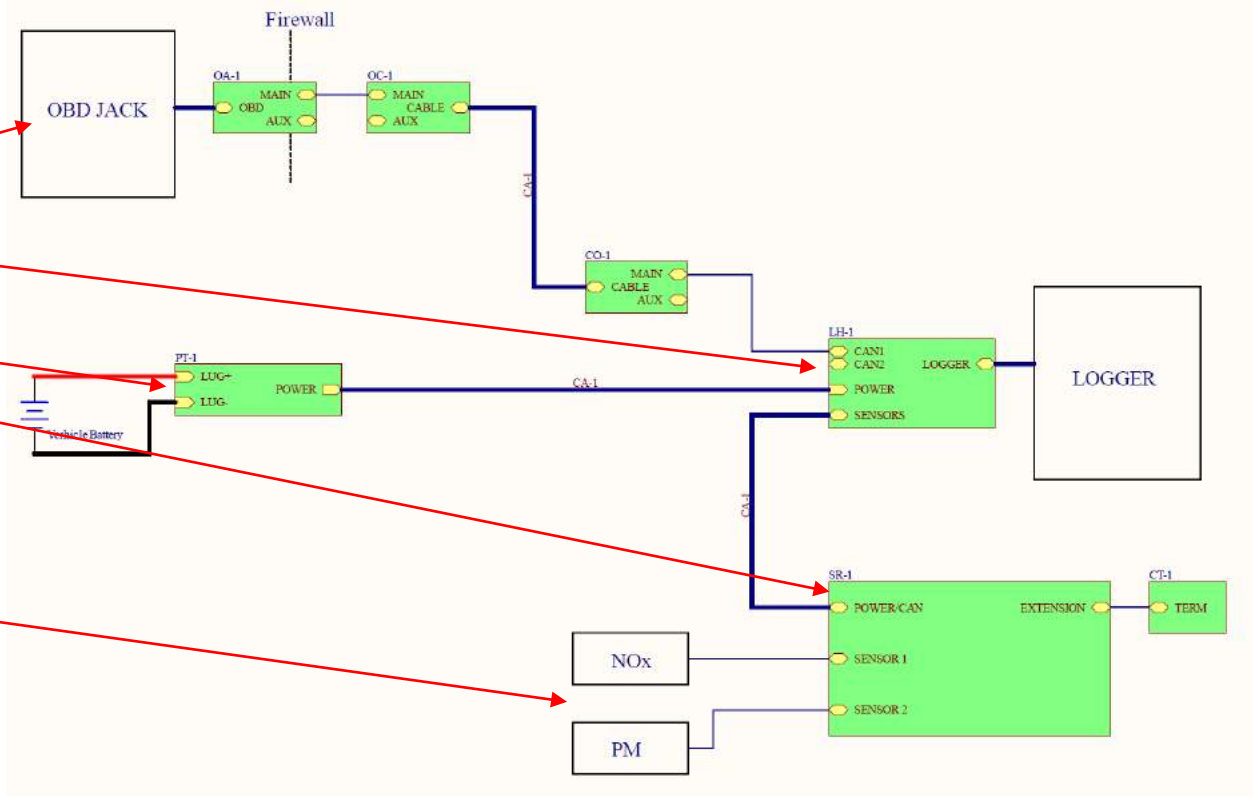
- The Onboard Sensing Analysis and Reporting (OSAR) system was developed for continuous monitoring of diesel and natural gas technologies on an annual basis
- OSAR started out as a consortium lead research initiative, but has now grown to over nine funded programs
- OSAR includes
  - NOx, PM, GPS, CAN, and other sensors
  - Auto starting and shutdown to capture cold starts and all truck operation



Technical Overview

Main components:

- OBD jack: OA-1
- OSAR Logger: Emtrac-6, LH-1
- Power supply: PT-1
- Sensor connections: SR-1, CT-1
- NOx Sensor
- NH_3 Sensor
- CO_2 Sensor
- PM Sensor
- Extension Cables: CA-1



OSAR Systems Are Ready-To-Go

Just add the bungs to the exhaust, install sensors, and wire harness. No on-site calibration needed. Installation and data is good for a year or more.

Full system fits in this box including wire harness and bungs

We have about 40 systems ready for installation

In partnership with

EmiSense

For more information on EmTrac: pt@emisense.com

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Installation of OBD Jack

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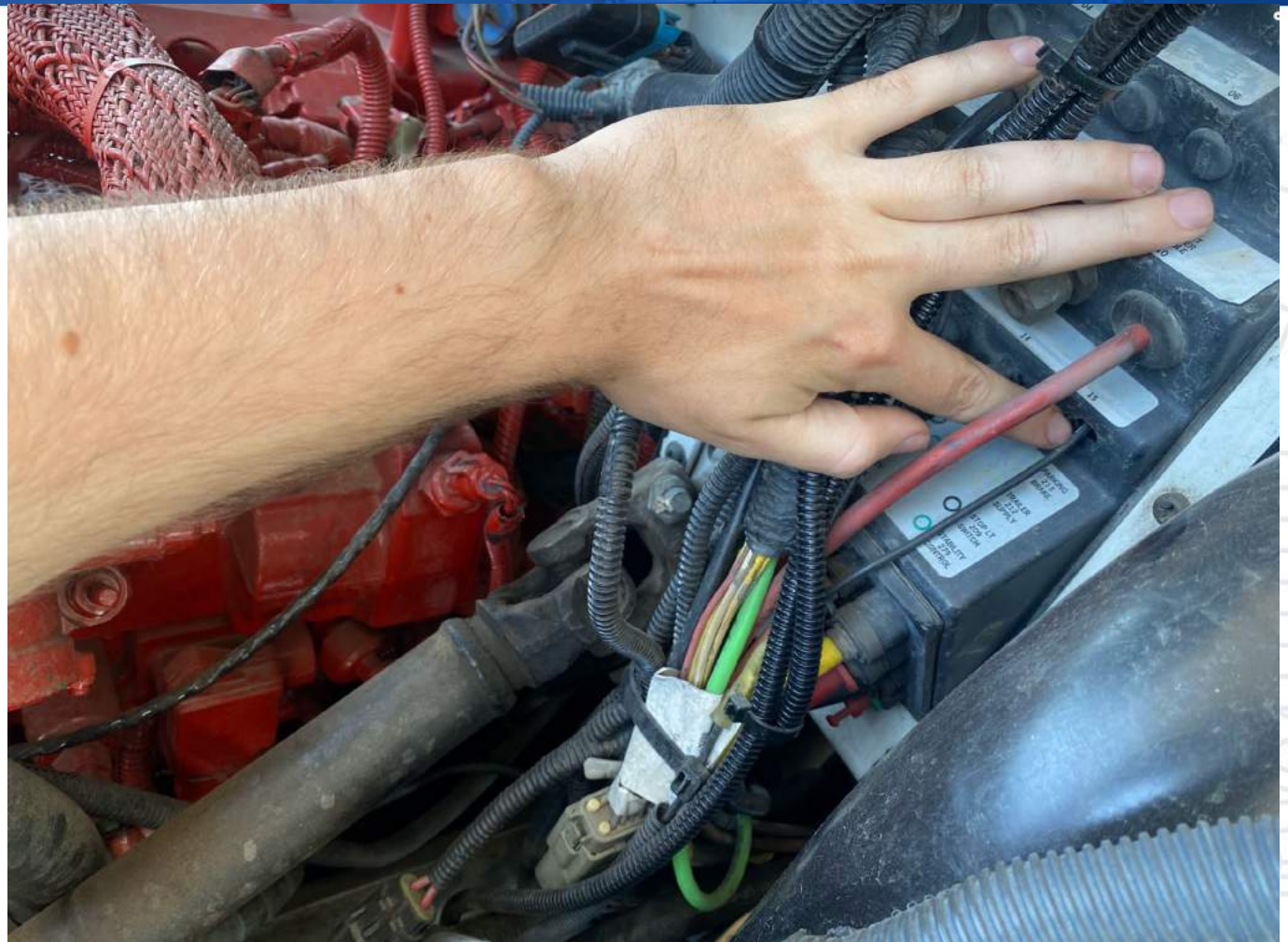

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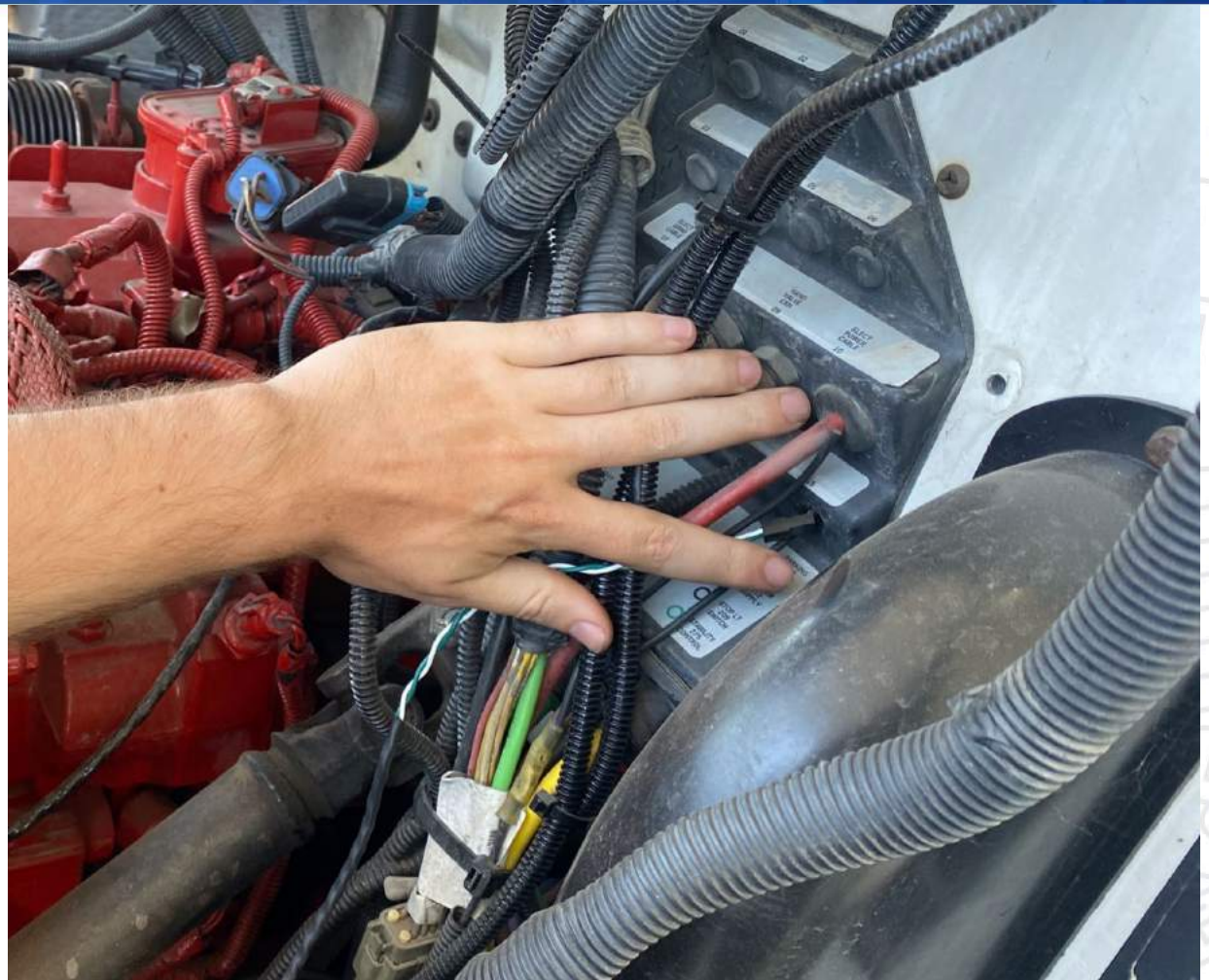

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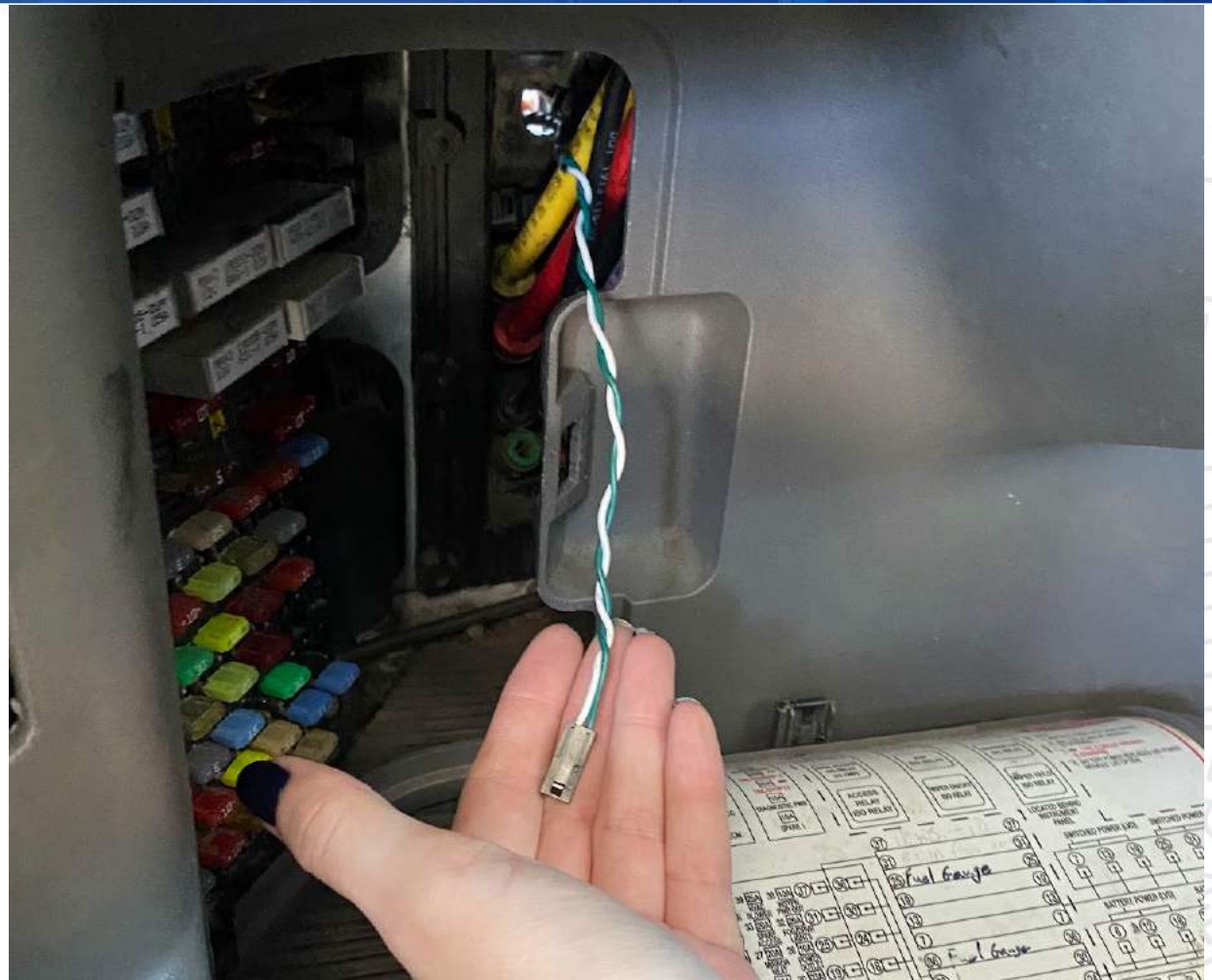

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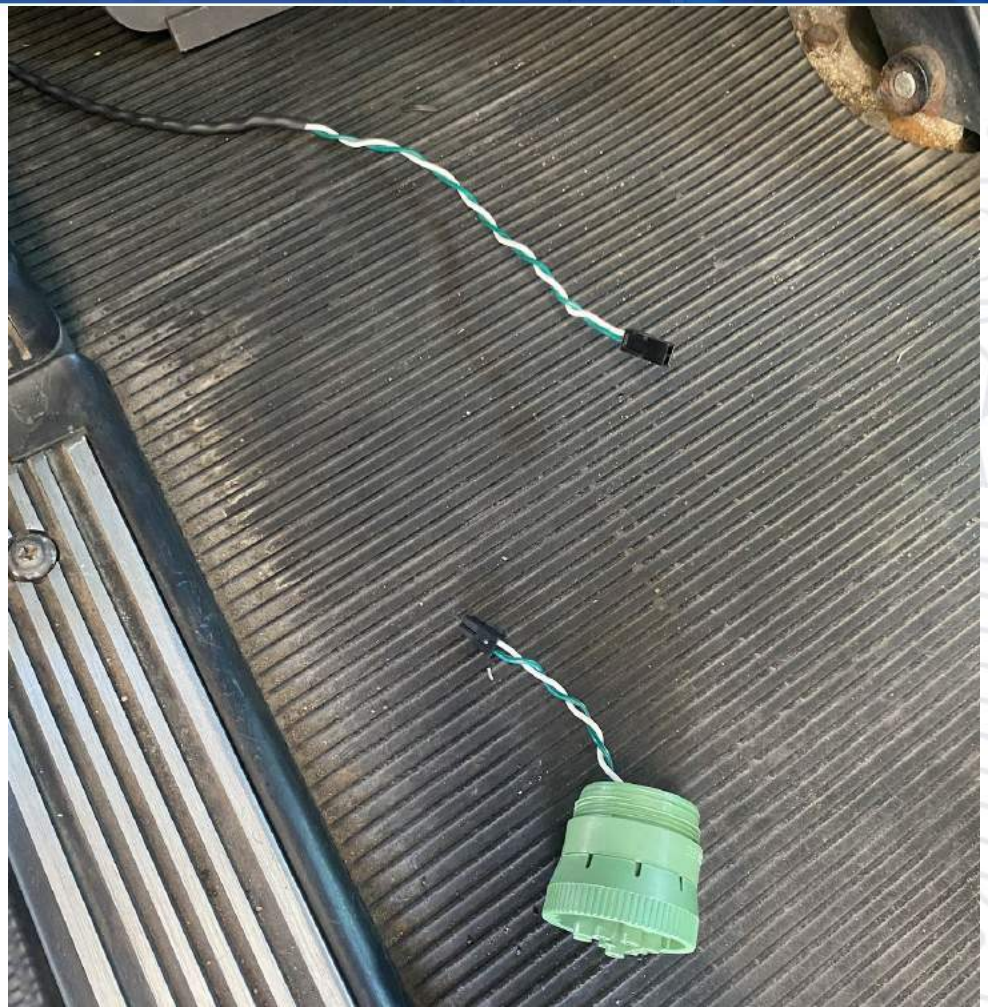

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Installation of OBD Jack Extension Cable

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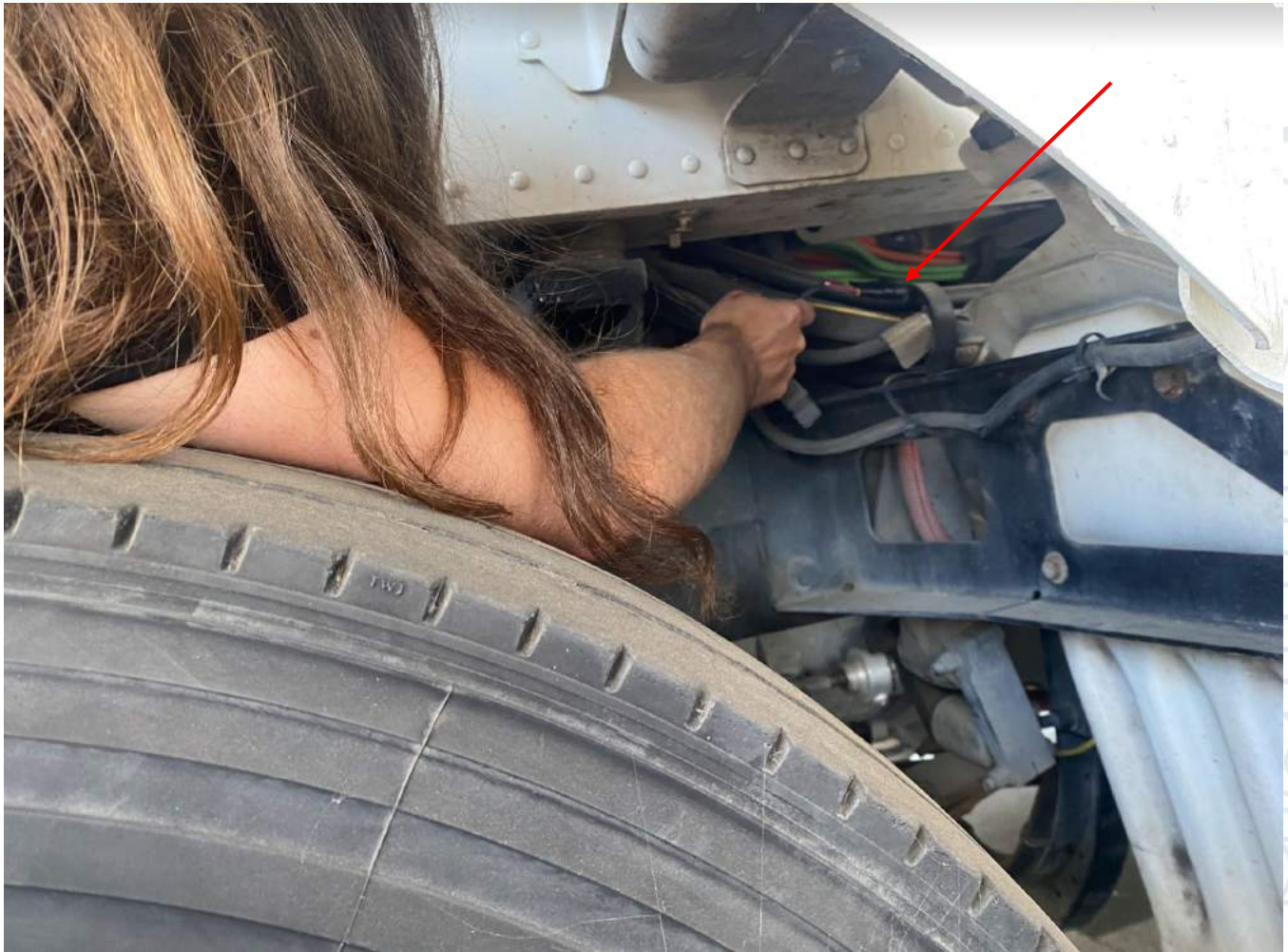

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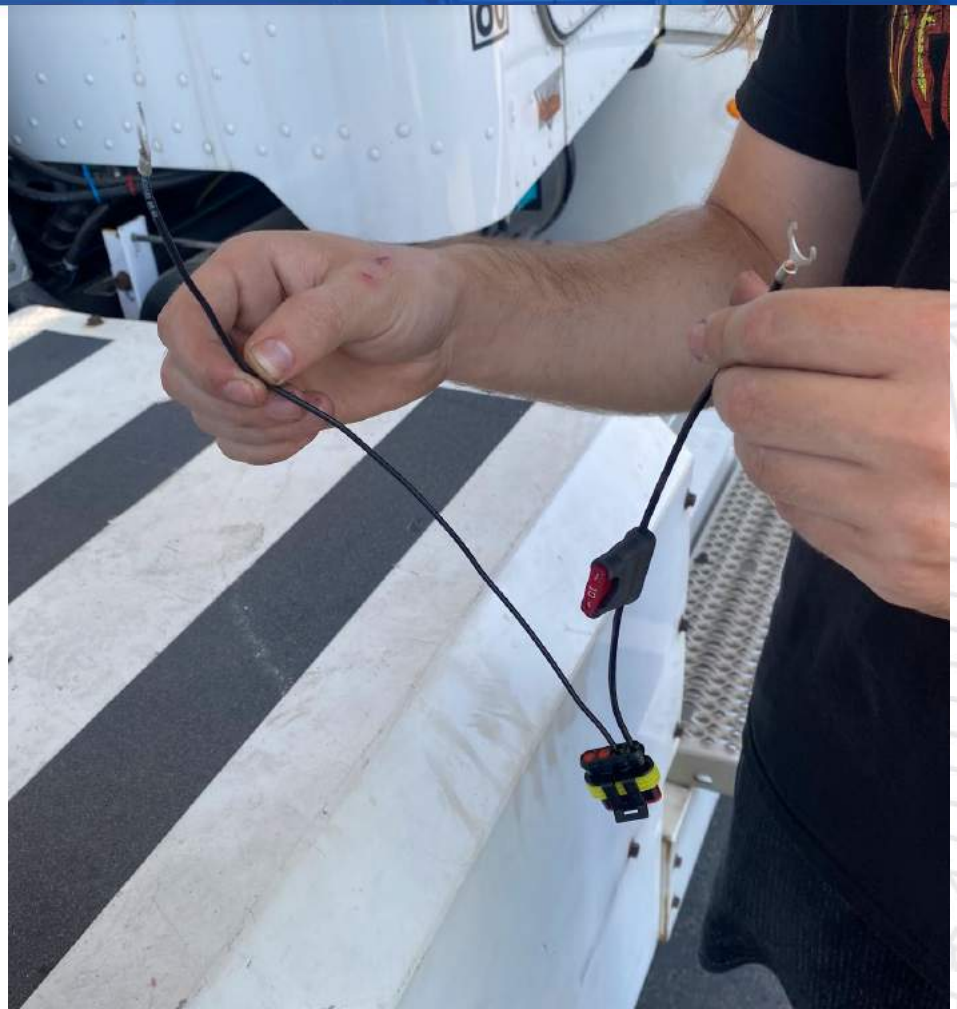
Installation of Power Tail



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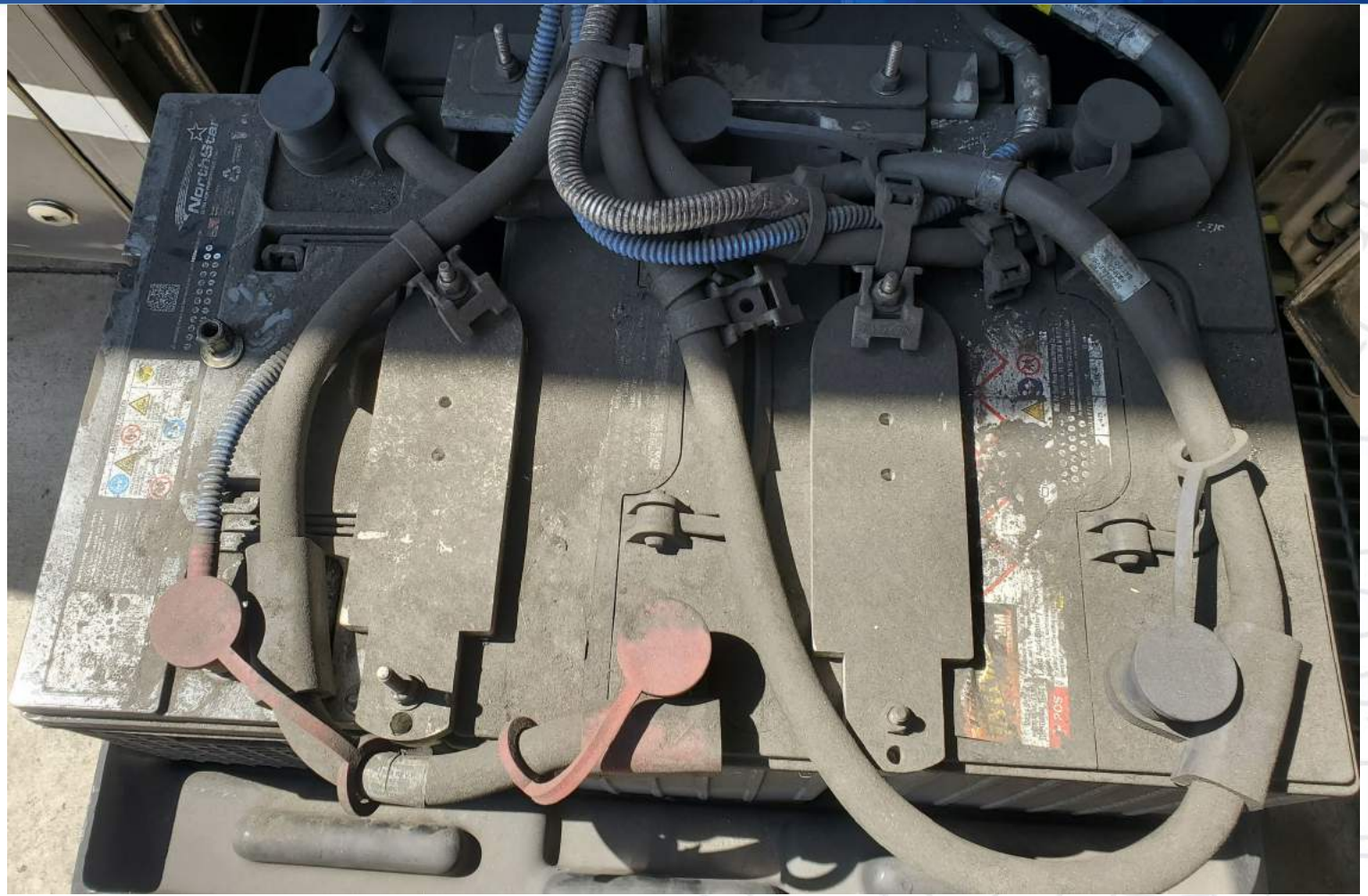

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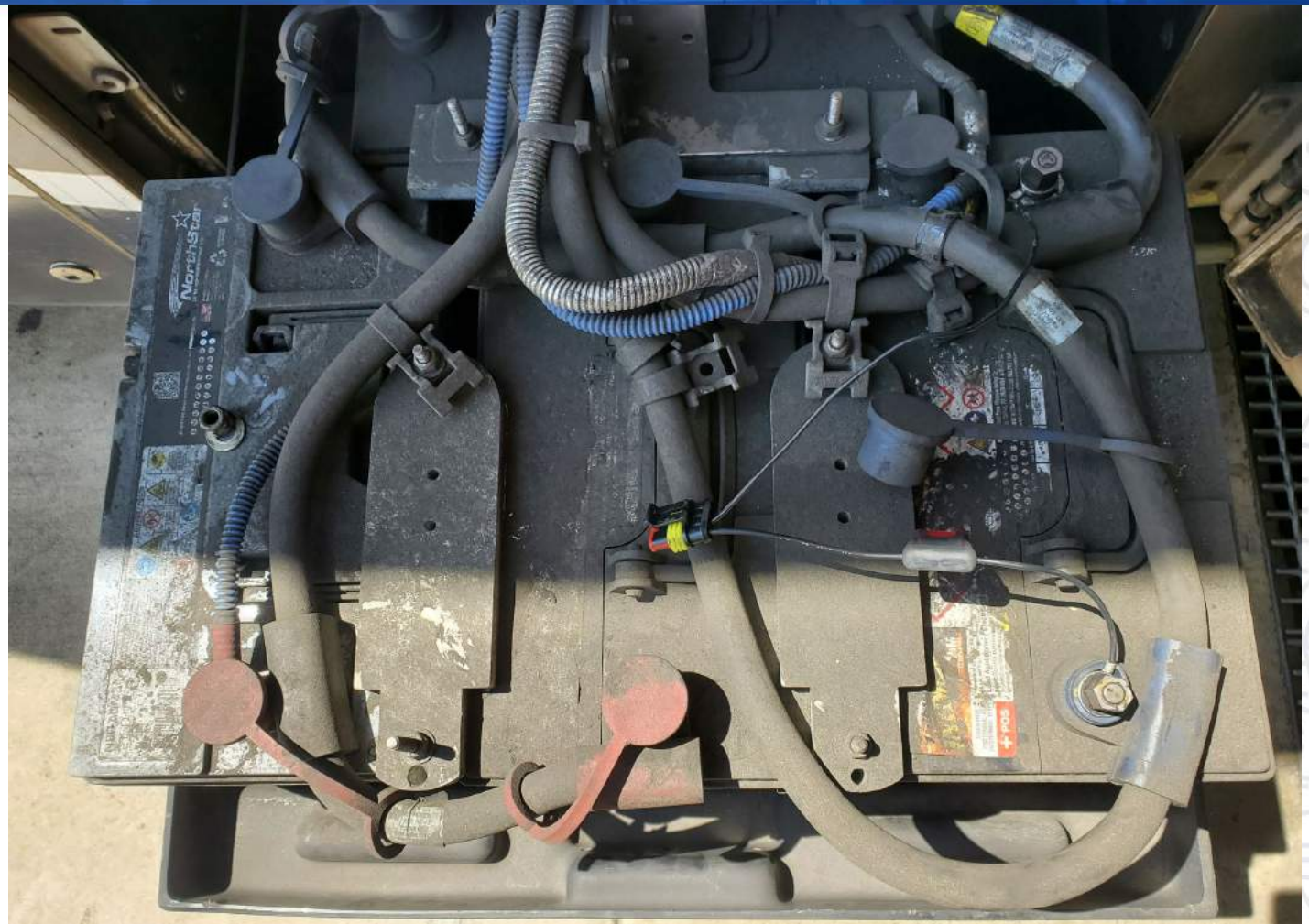

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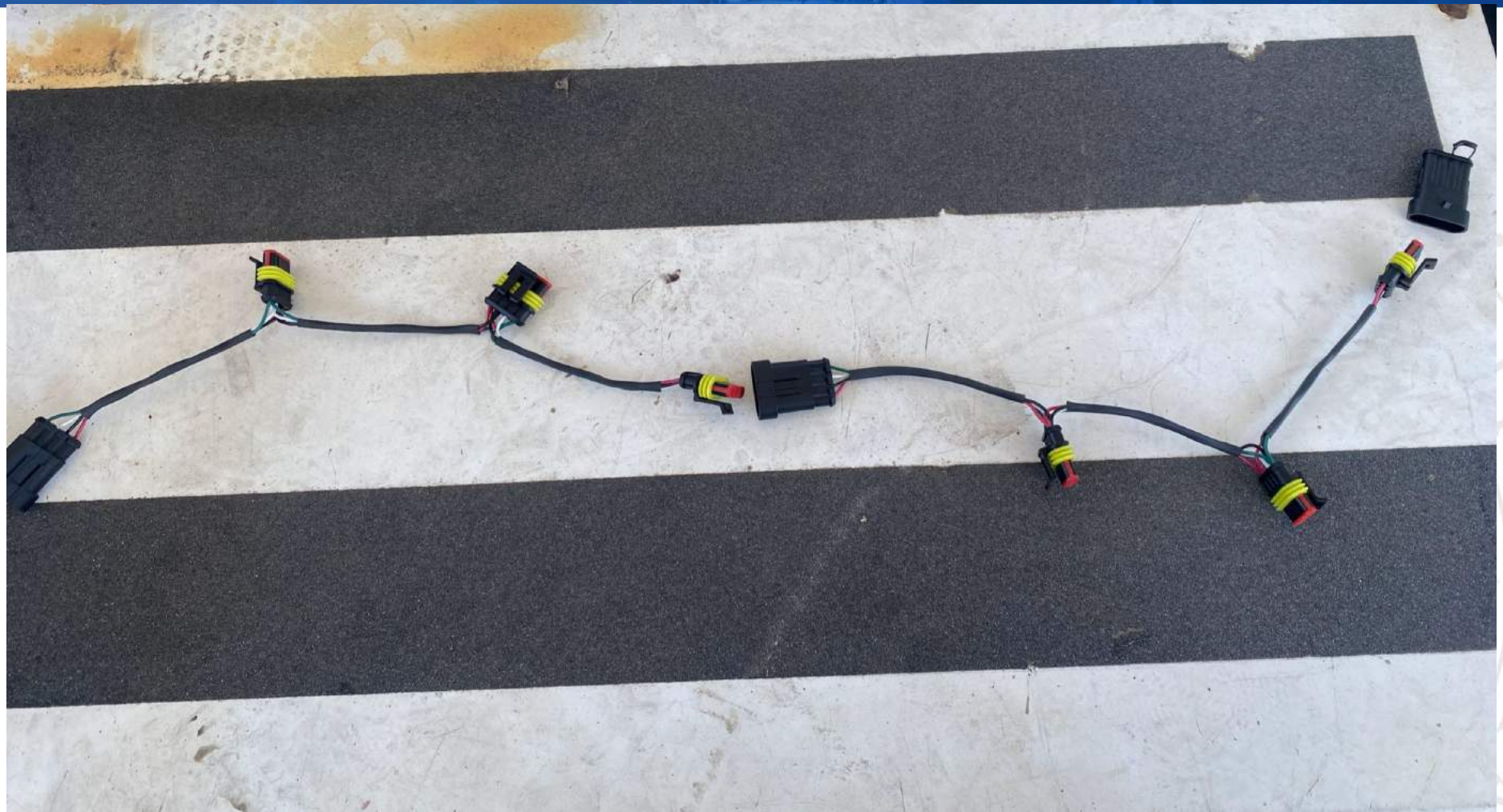
Installation of Sensors



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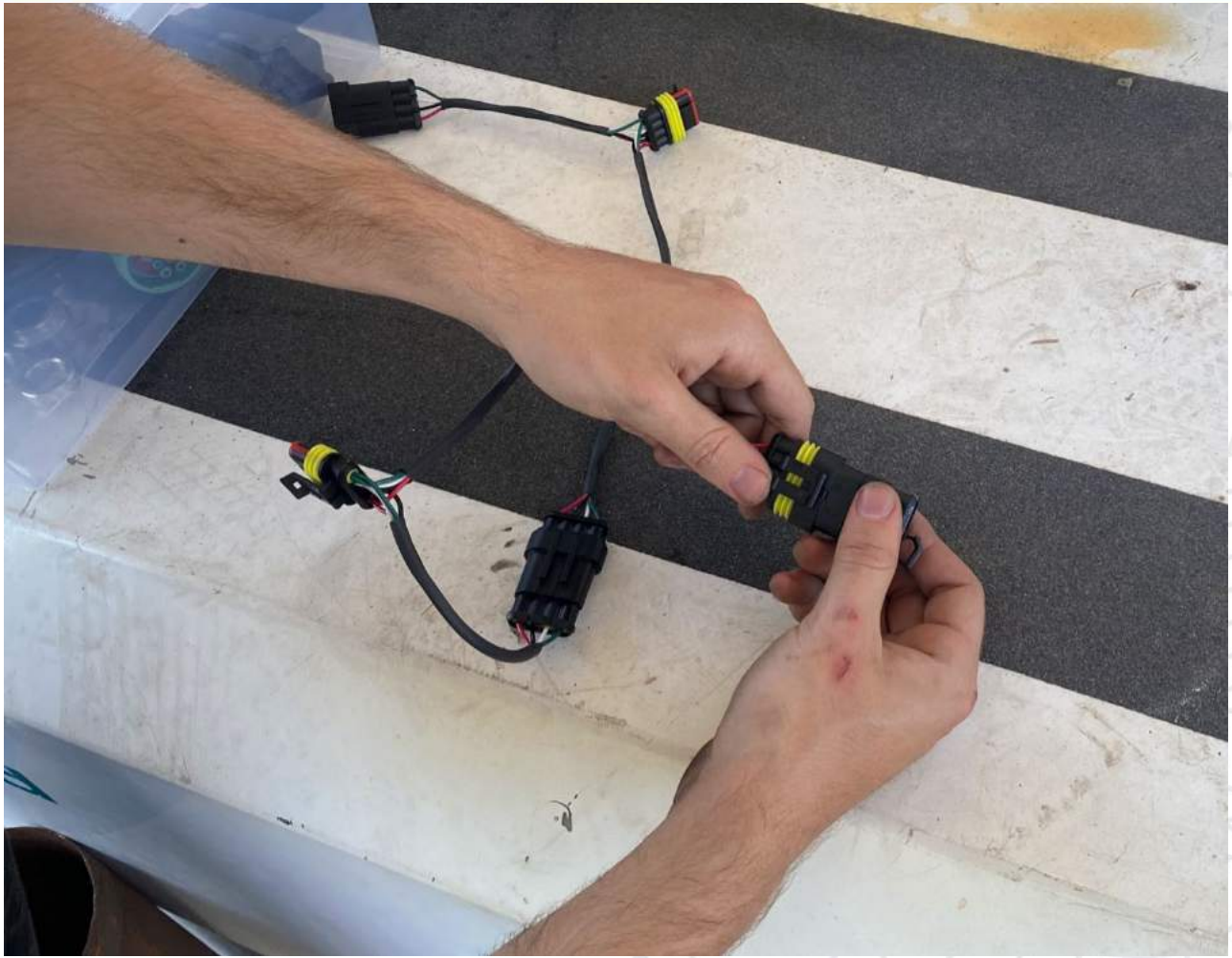

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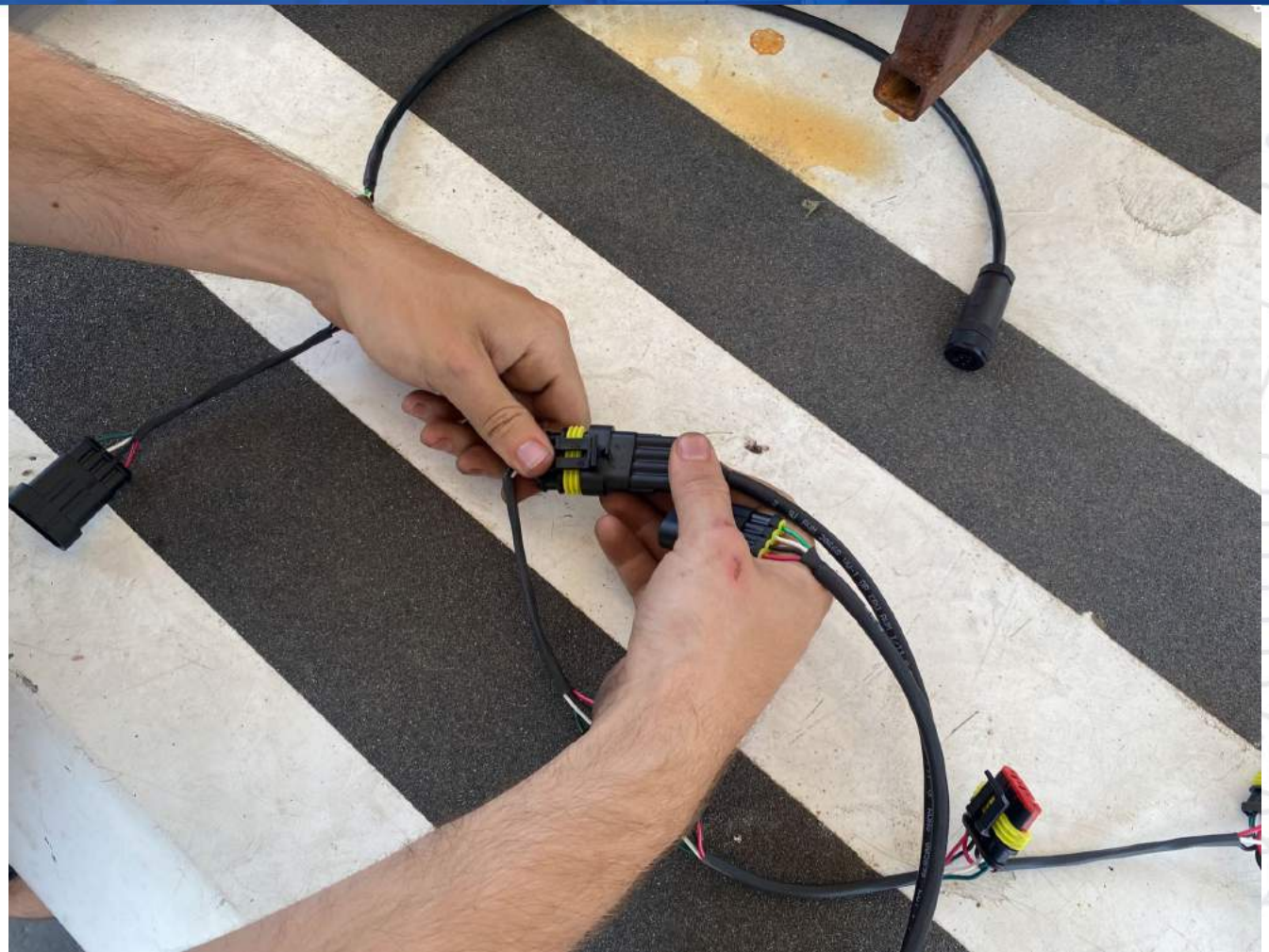

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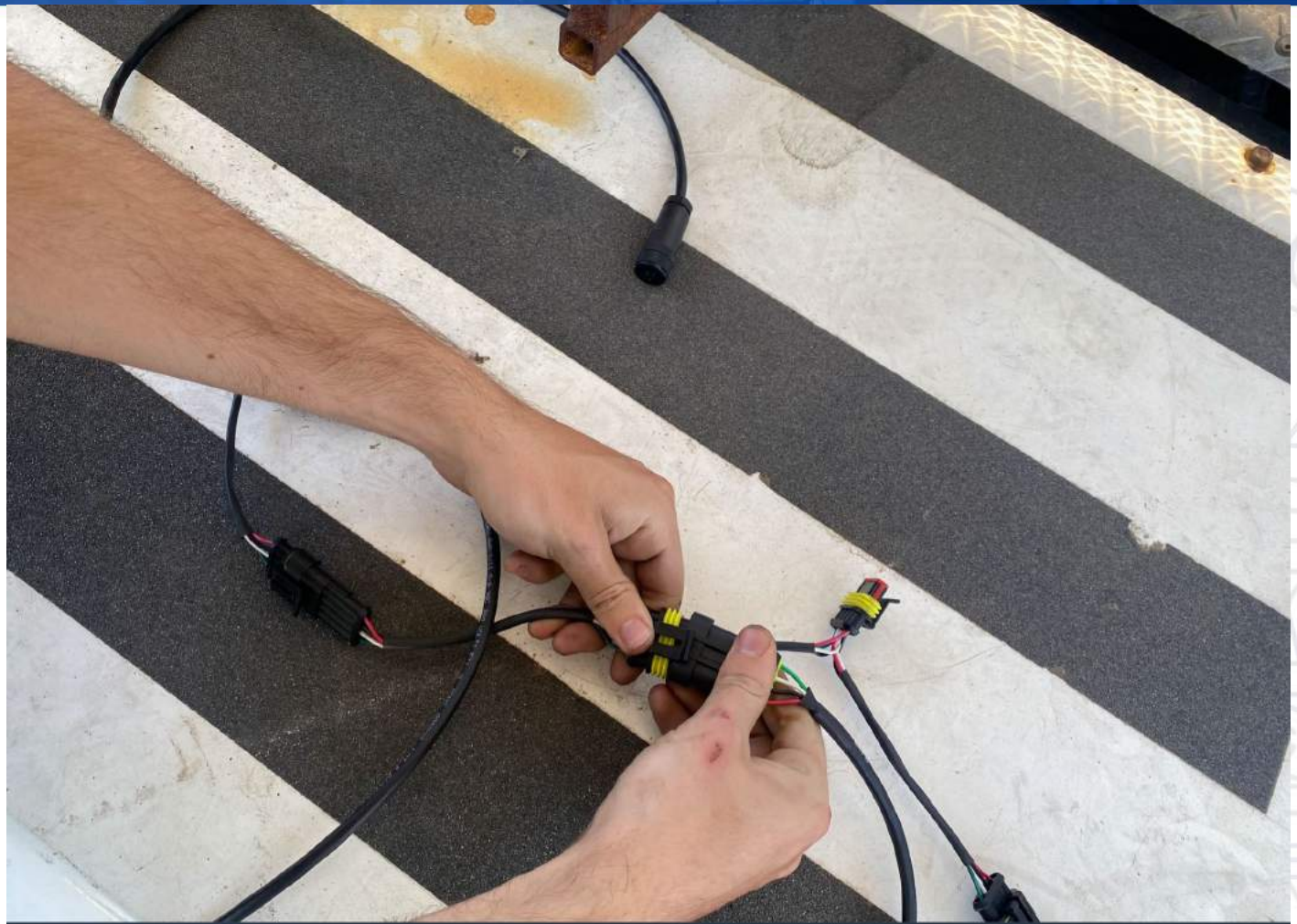

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Installation of Sensors

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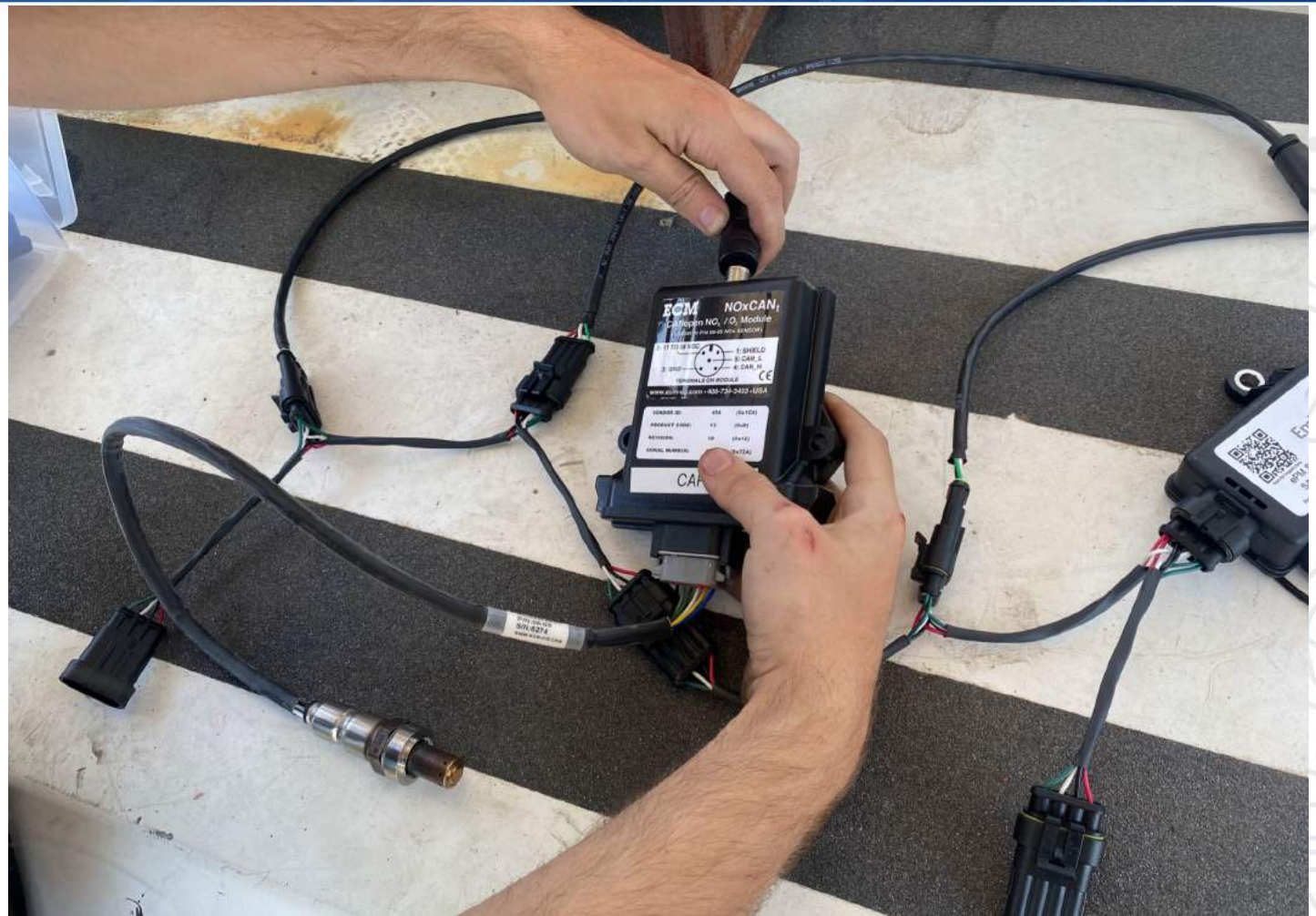

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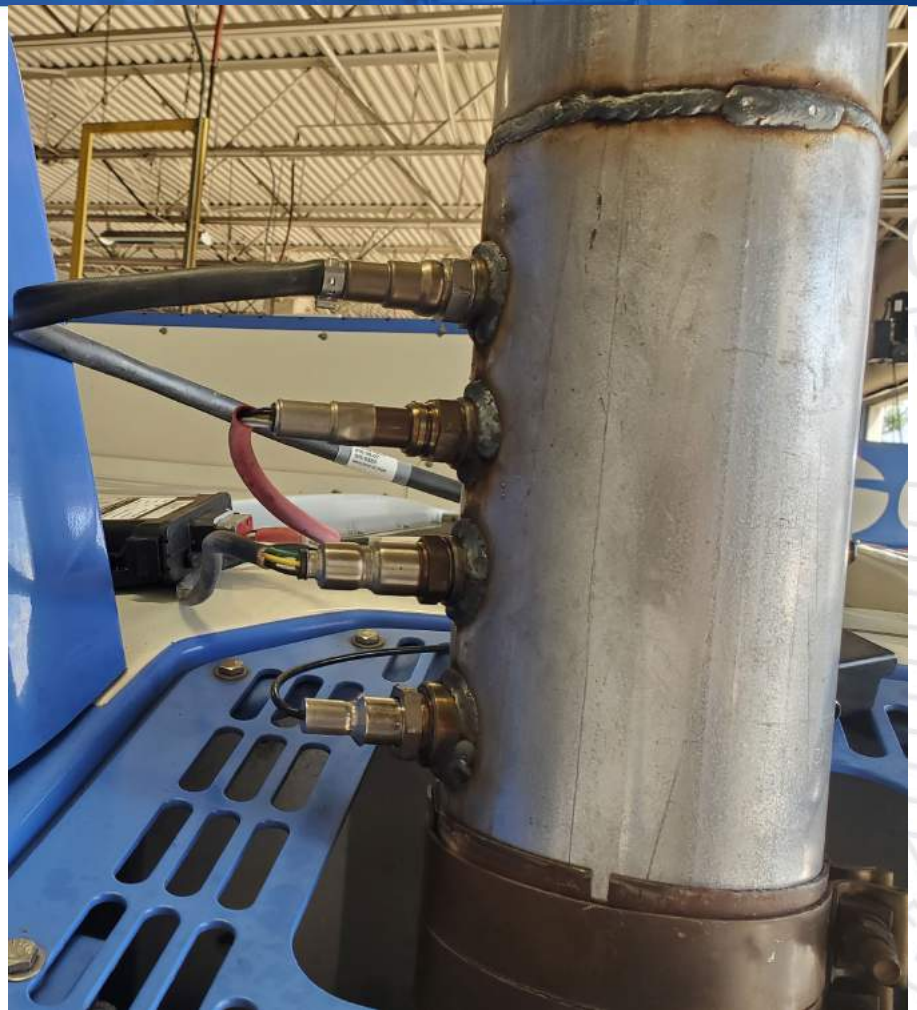

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Installation of Sensors

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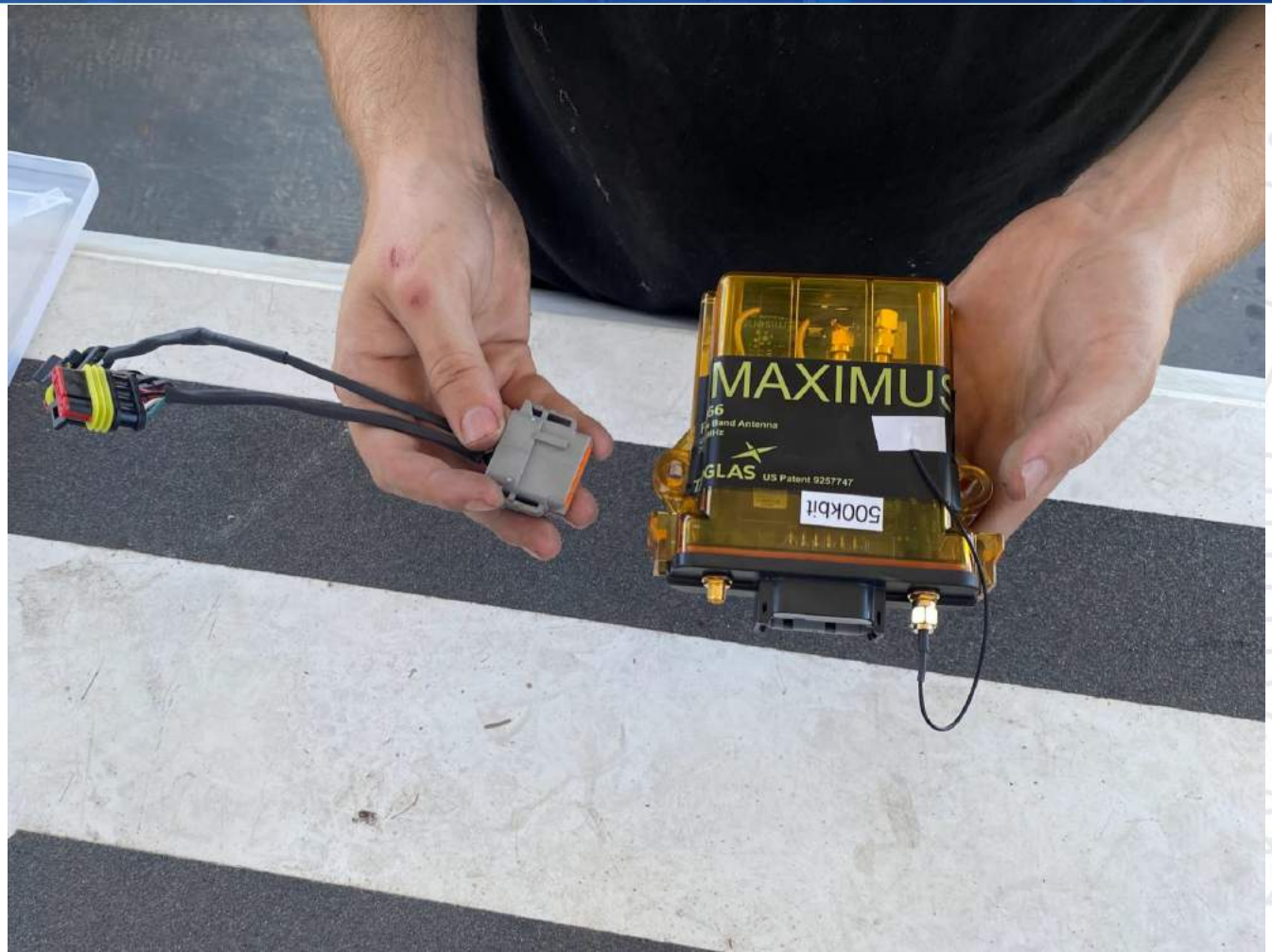
Installation of OSAR Unit



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Installation of OSAR Unit

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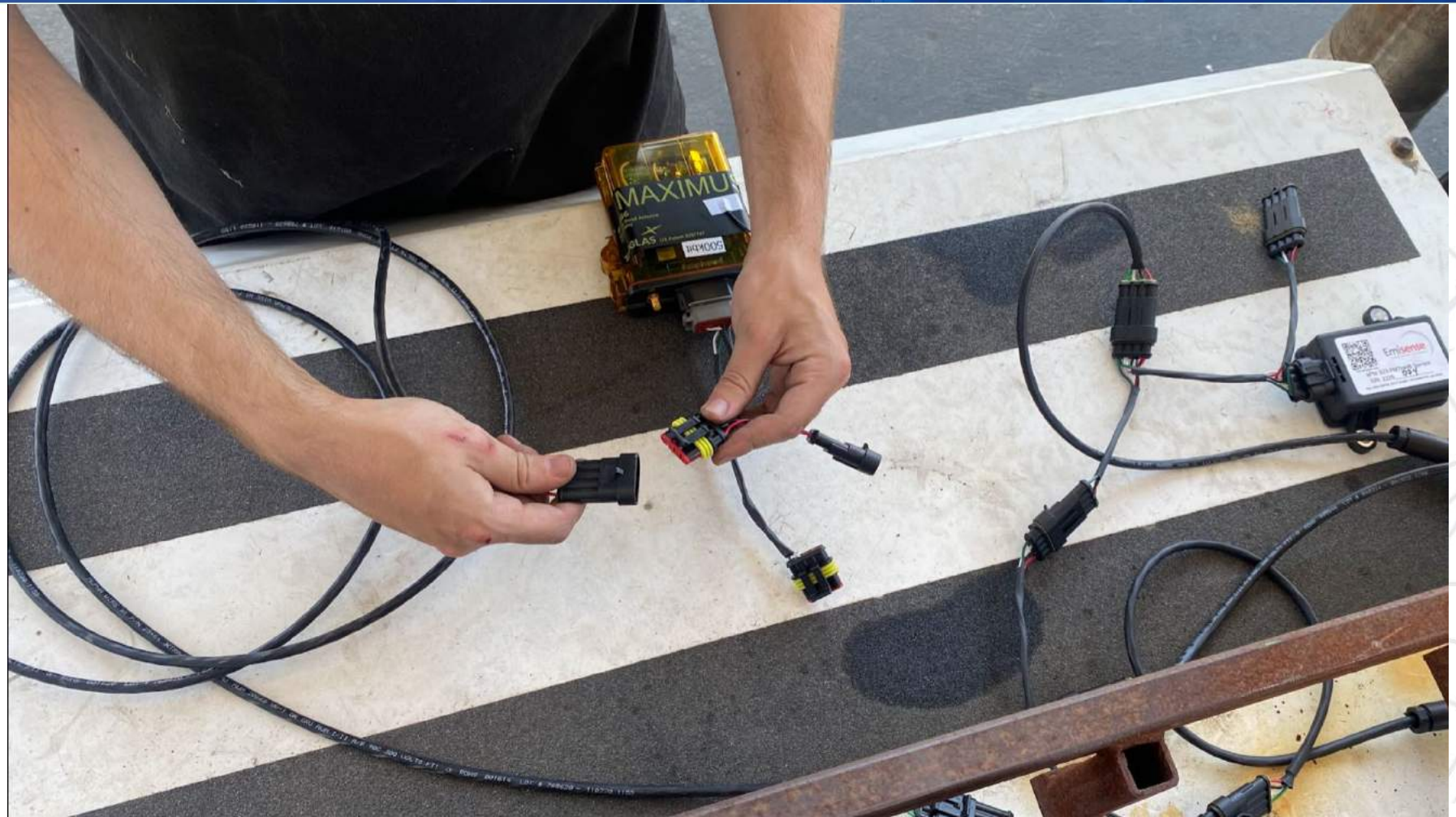
Connection of Sensors to OSAR Unit



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Connecting Sensors to OSAR Unit

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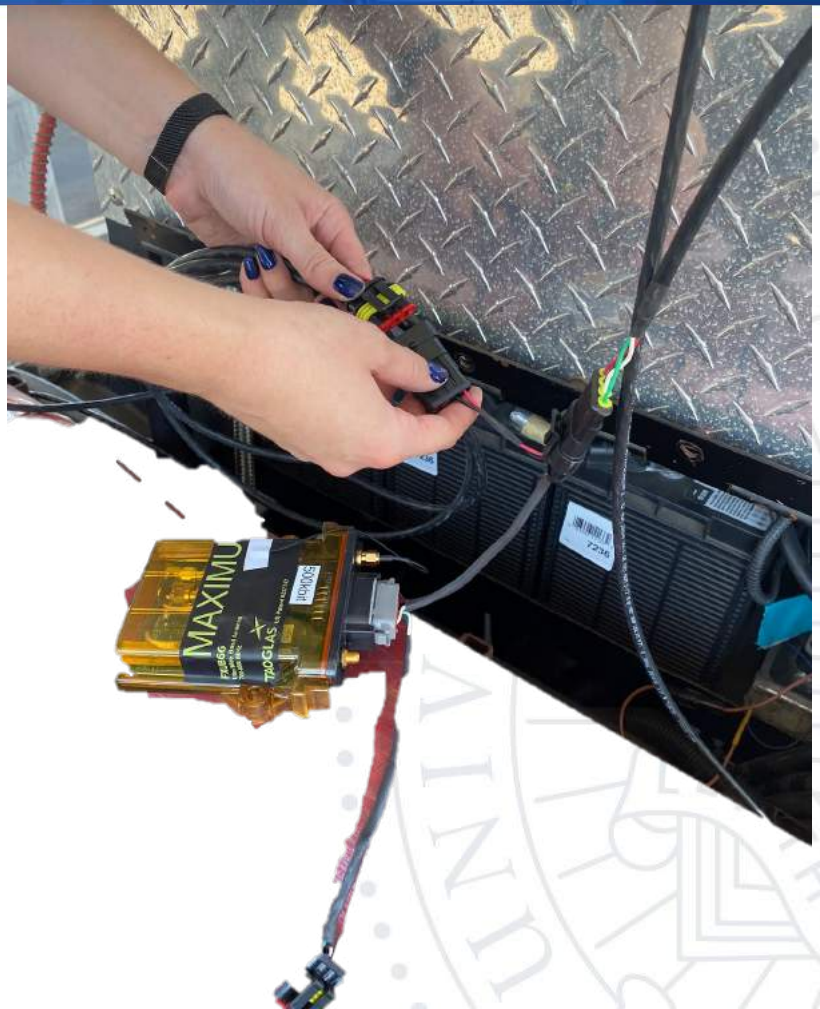
Connection of Power tail to OSAR Unit



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Connection of Power tail to OSAR Unit

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Connection of OBD Jack to OSAR Unit

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Connection of OBD Jack to OSAR Unit

Connection of GPS Antenna to OSAR Unit

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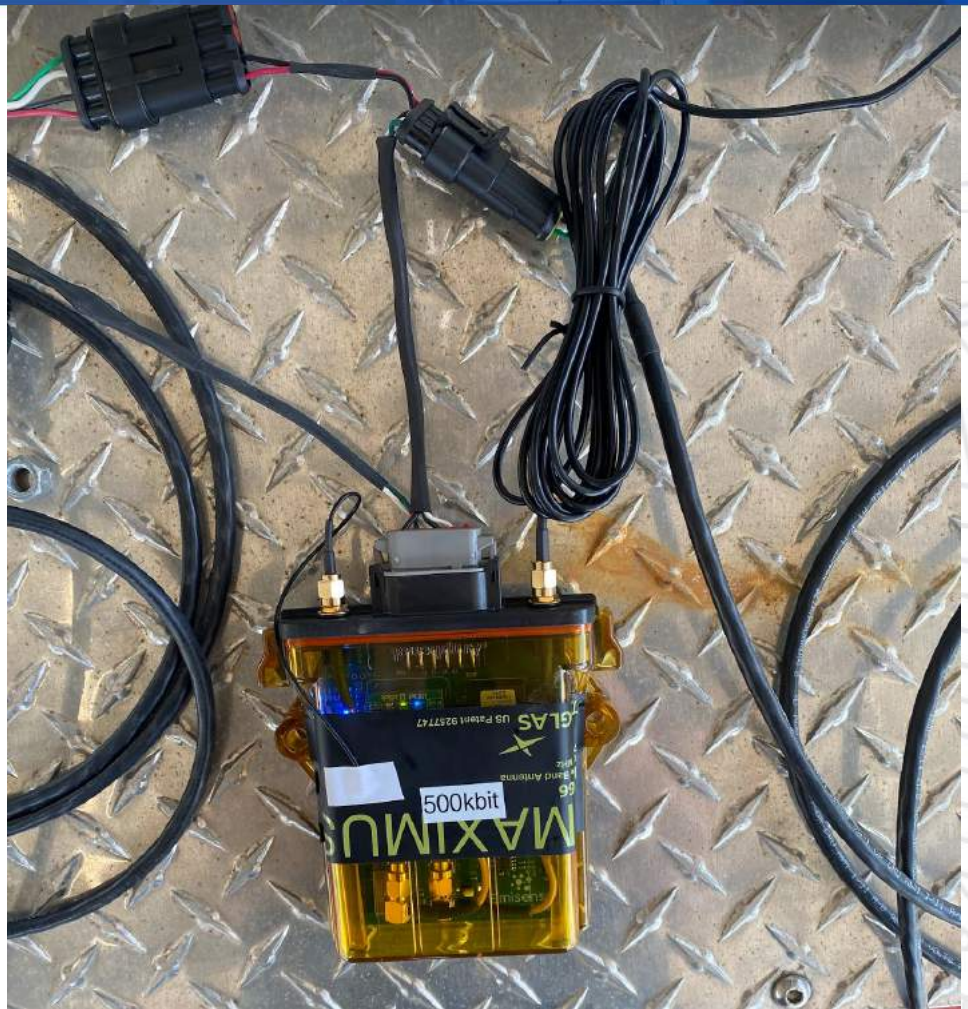

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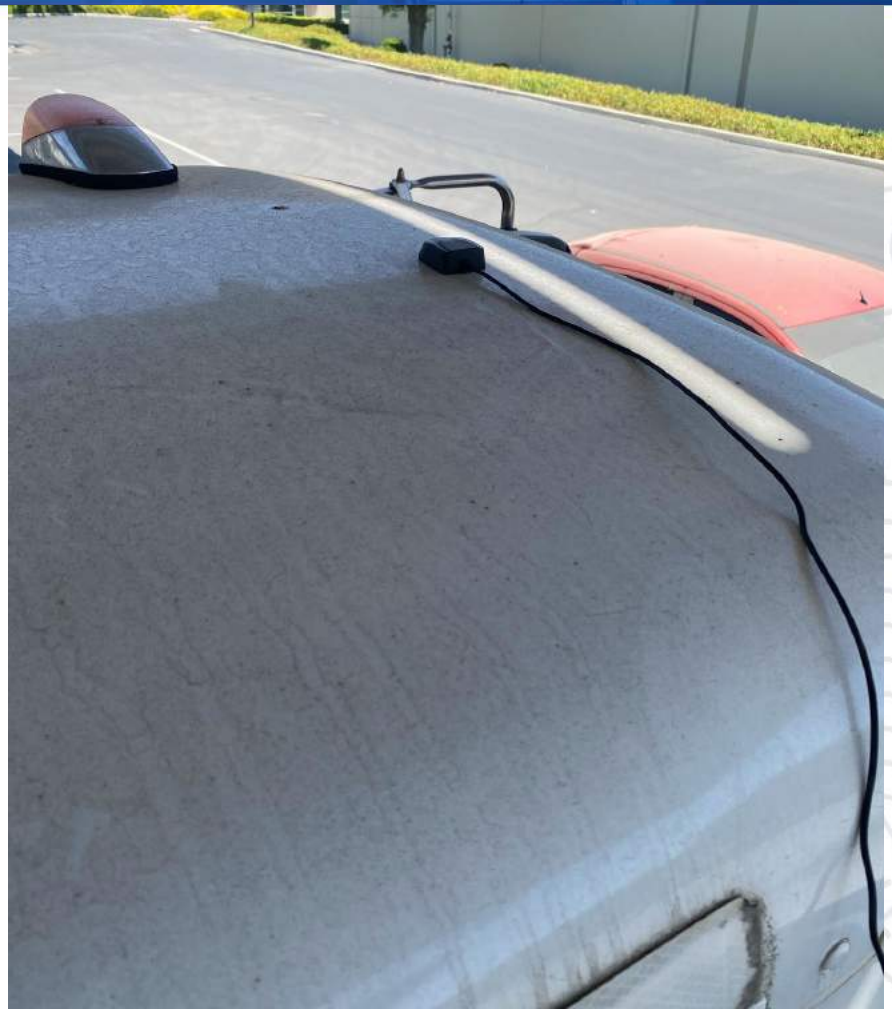
Connection of GPS Antenna to OSAR Unit



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Verifying OSAR Unit Connectivity

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Verifying OSAR Unit Connectivity

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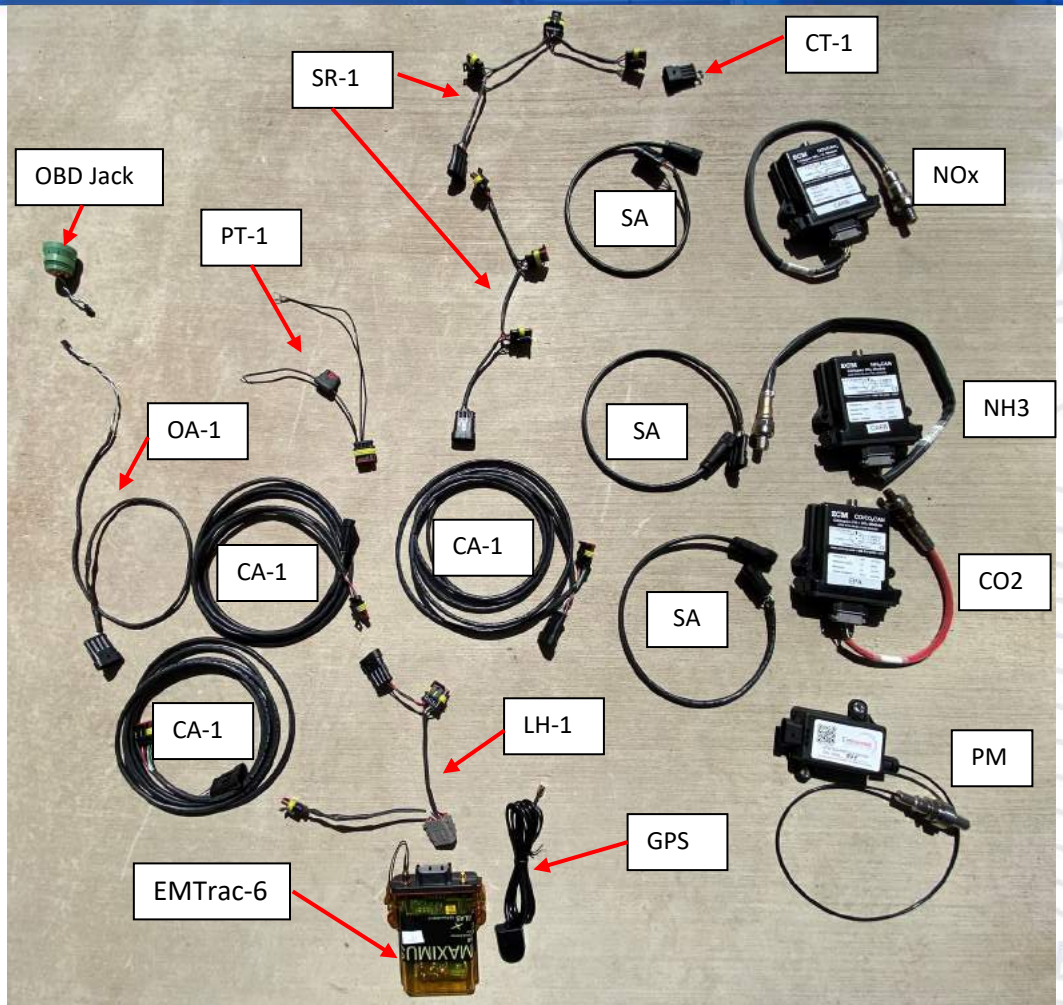
Actual Components



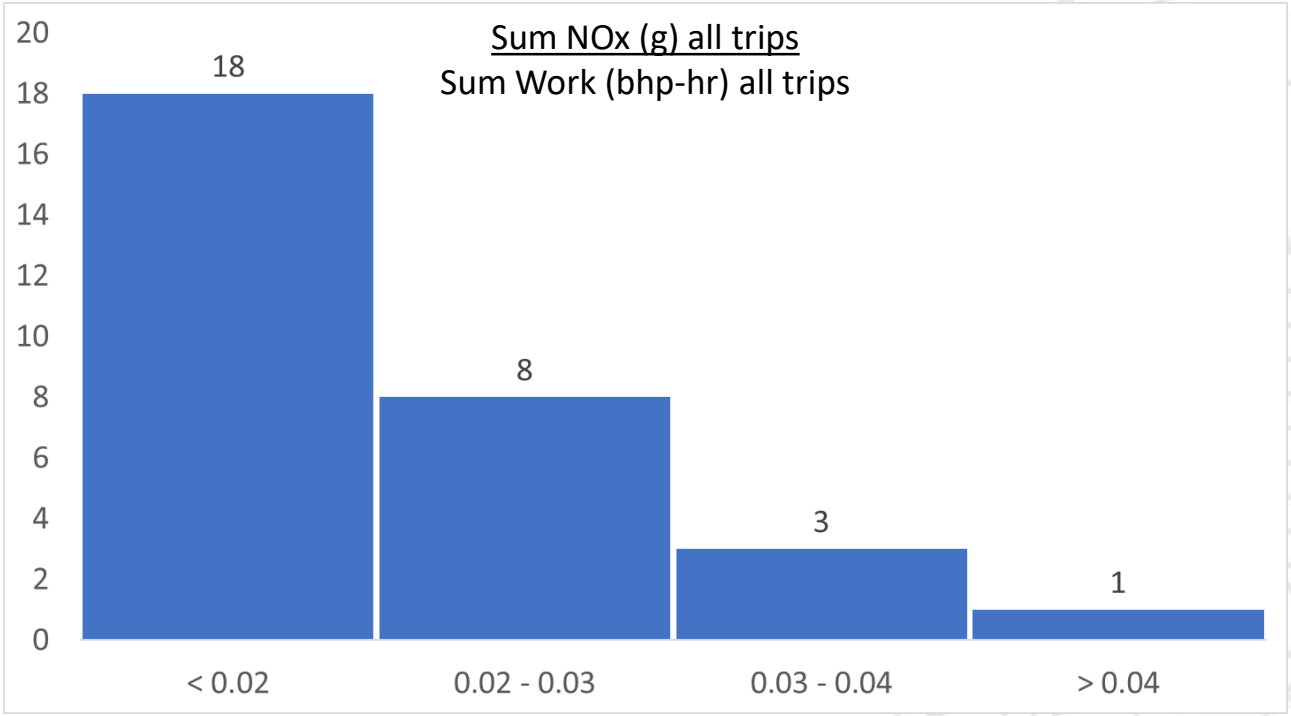
Summary of Data and Analysis

- 4 Heavy Duty Natural Gas Fleets Utilized (MYs 2016 – 2022)
  - Refuse Hauler Fleet (x1)
  - Goods Movement Fleet (x1)
  - Transit Bus Fleet (x2)
- ~10 Vehicles per Natural Gas Fleet
  - OSAR recorded data for approximately 2 months per vehicle
- Filtered out SAE Max and Min ECU and Sensor Values
  - Avoiding Sensor Drop Out
- All figures show data that meets specified criteria
  - 20 min < and 23 bhp-hr <
- Future filtration approaches
  - PM Filtering <100 ^{o}C exhaust gas temperature (EGT)

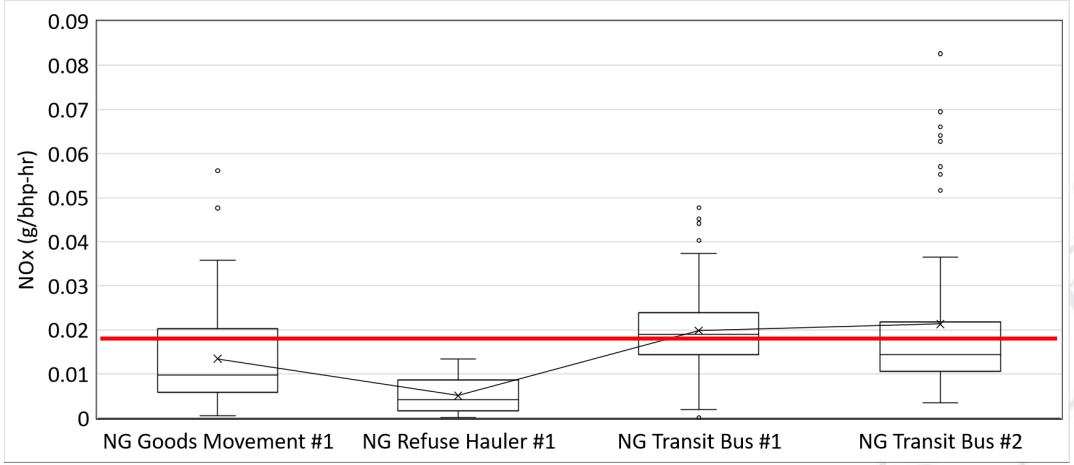
Vehicle Emissions Factor Histogram

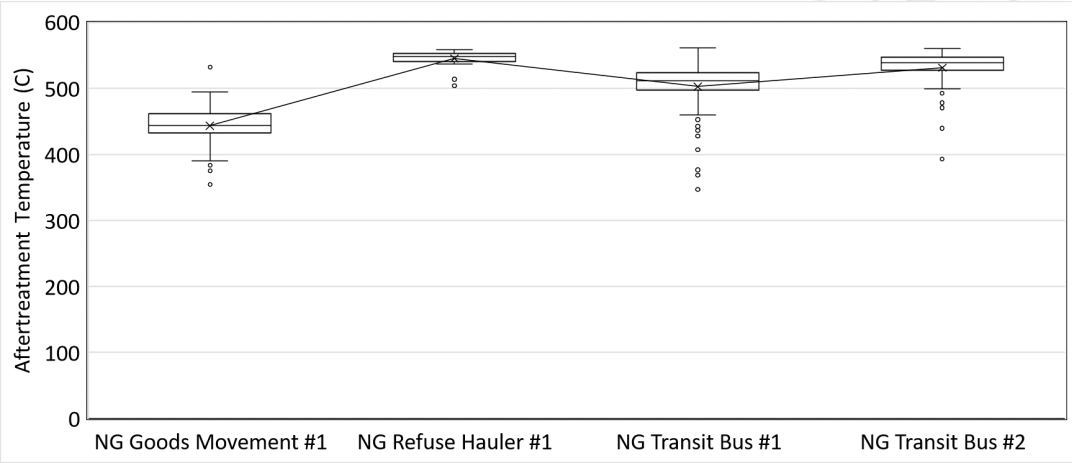
Total Vehicles: 30			
< 0.02	0.02 – 0.03	0.03 – 0.04	0.04 <
18	8	3	1

- Criteria filter not applied data



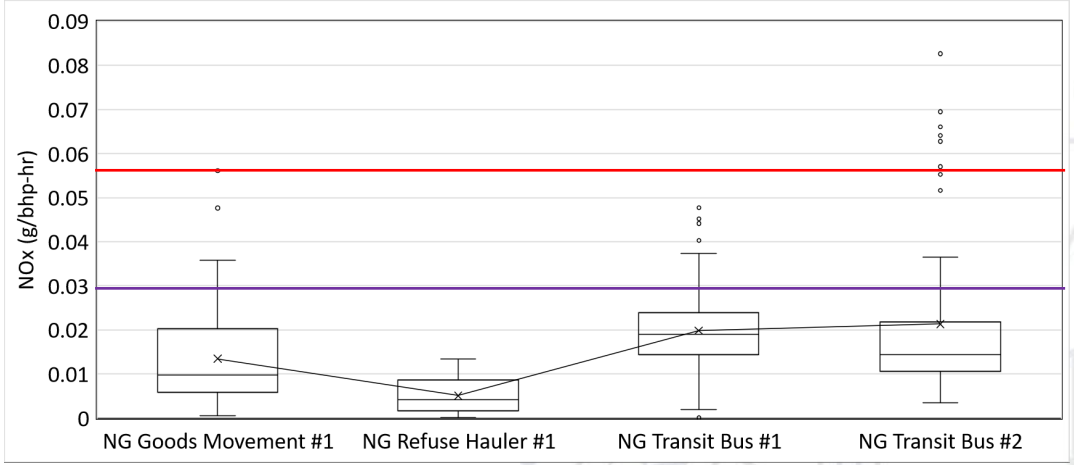
Fleet Comparison – NOx Emissions

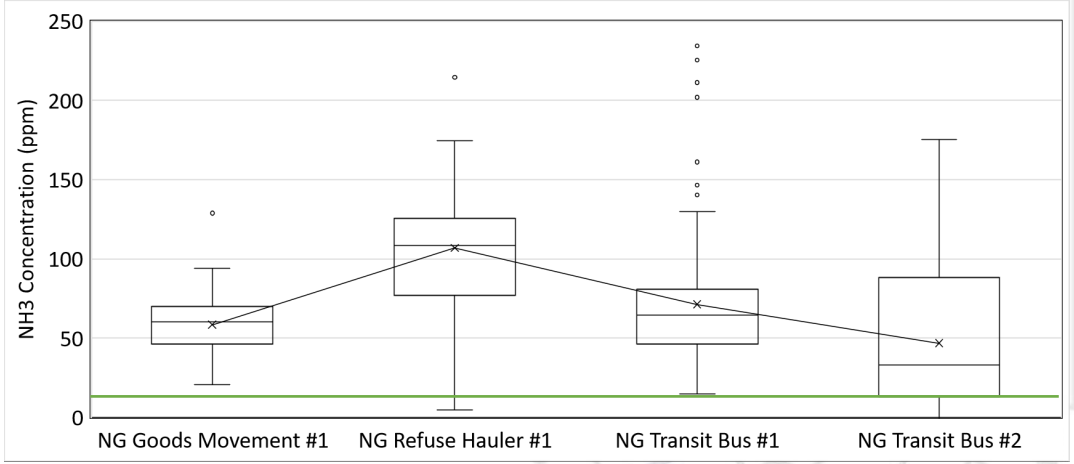




- These four fleets showed an average of 0.019 g/bhp-hr with the sum over sum calculation
- Close to the average seen in these whisker plots comparing all fleet data on a daily basis

Fleet Comparison – NH3 Concentration





0.058 g/bhp-hr Bin 2 Federal Off-Cycle Standard (2035)

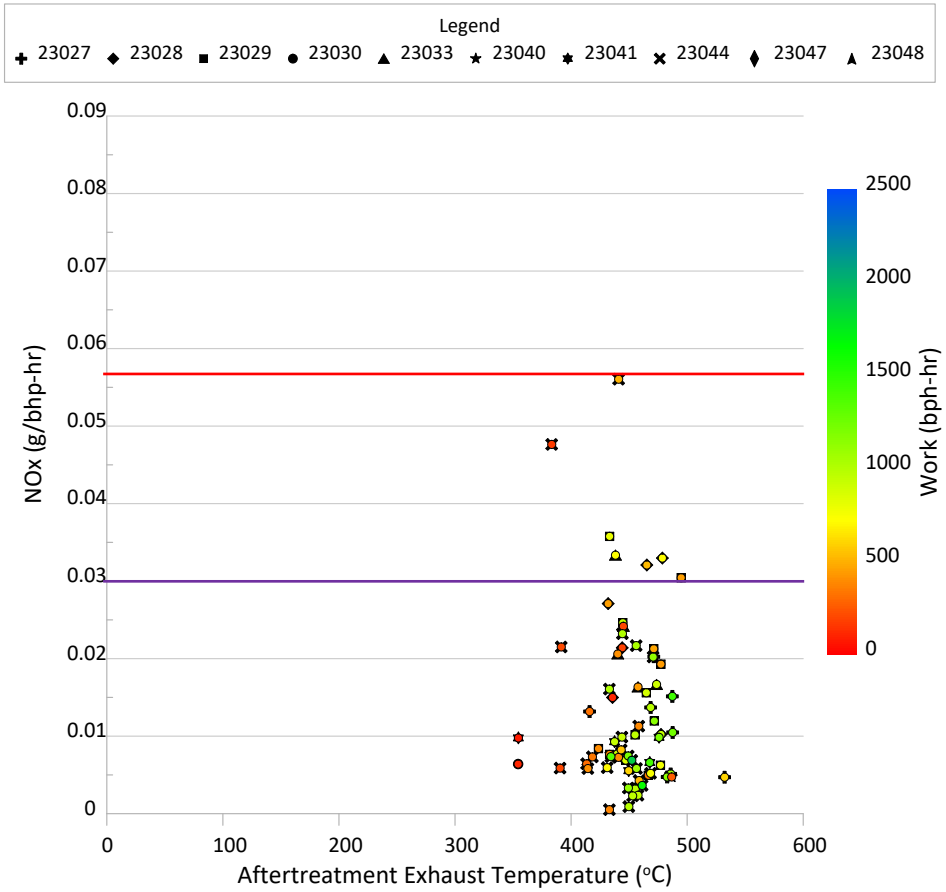
1.5x 0.02 g/bhp-hr Optional Low NOx Standard (0.03 g/bhp-hr) (2018)

Summary of Scatter Plots

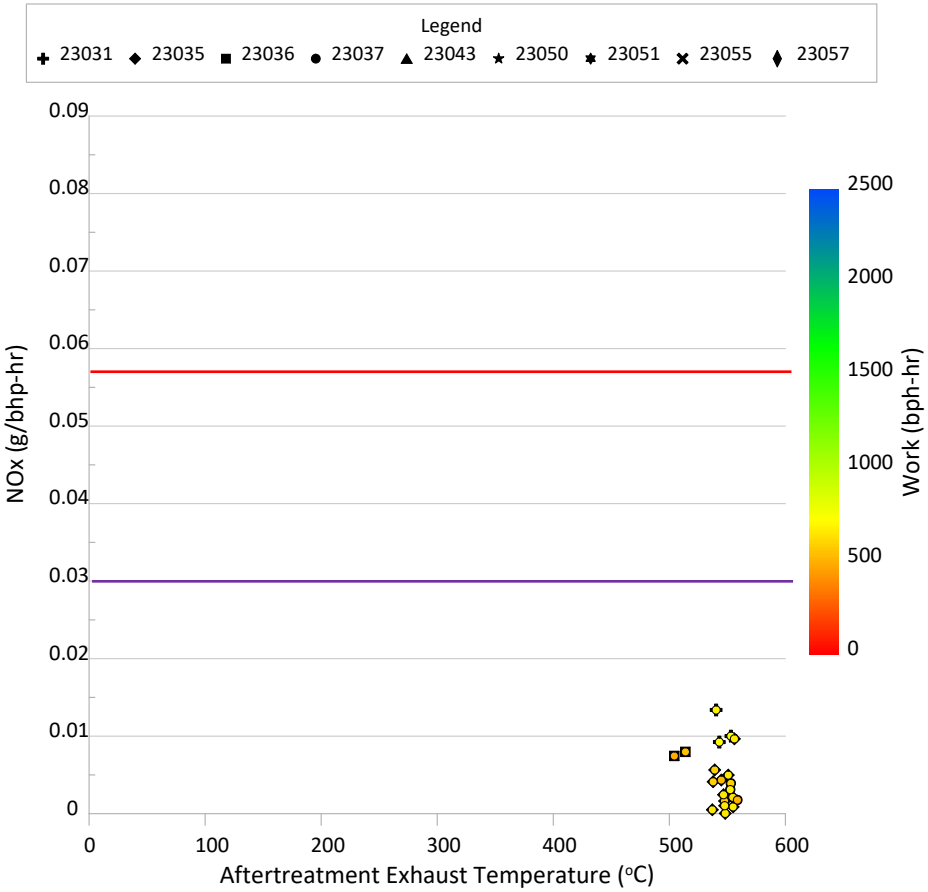
- Each datapoint represents a day of data
- NOx in g/bhp-hr on Y-Axis
- Aftertreatment Temperature in ^{o}C on X-Axis
- Work (bhp-hr) gradient applied
  - Blue indicates highest work values across all fleets
  - Green indicates more frequent work values across all fleets
  - Yellow indicates lower but not uncommon work values across all fleets
  - Red indicates significantly low work values across all fleets

Daily Variability

NG Goods Movement #1

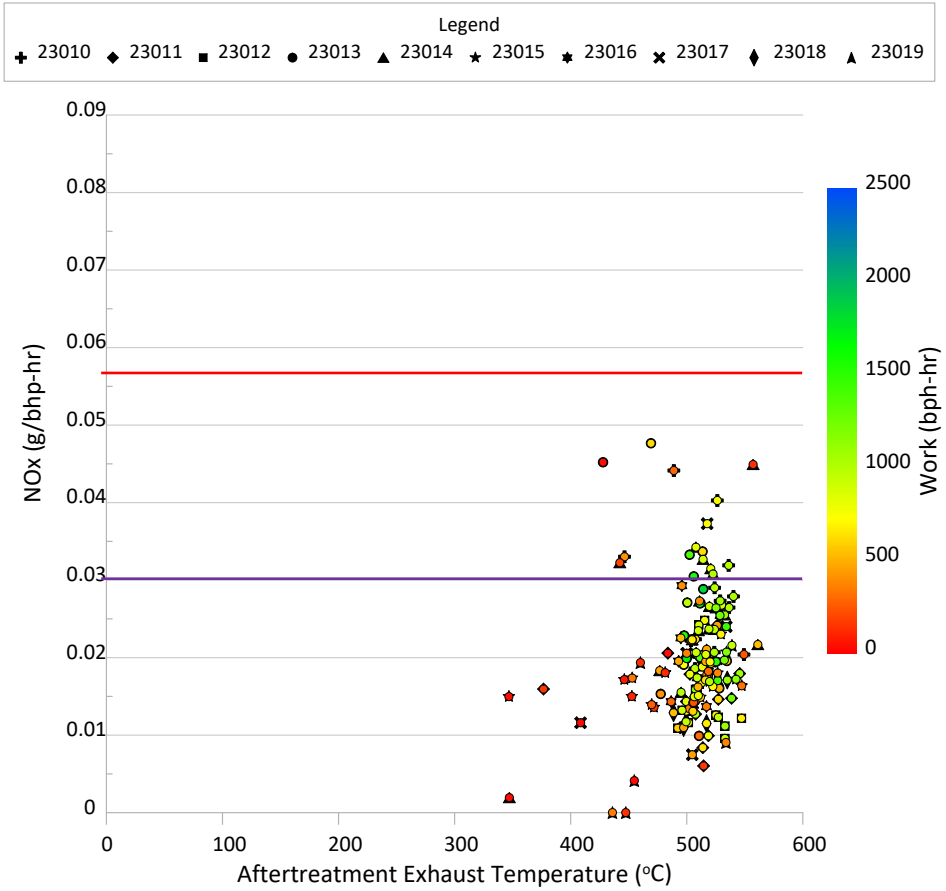


NG Refuse Hauler #1

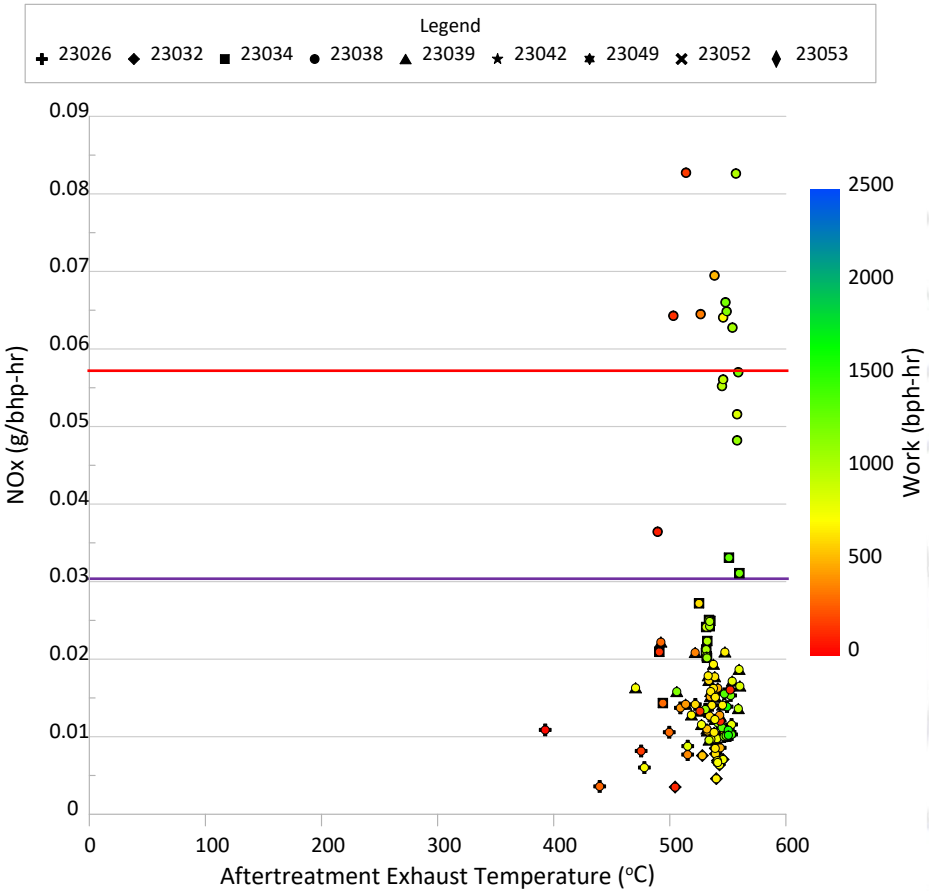


Daily Variability

NG Transit Bus #1

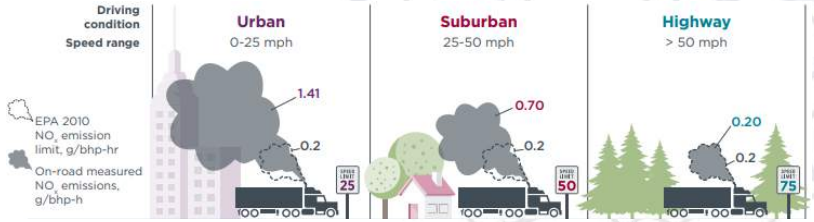


NG Transit Bus #2



Summary

- Natural gas engines can reduce NOx ozone inventory today
- Natural gas engines do emit ammonia which through secondary formations can form ammonia nitrate particles which could affect particulate matter output
- In-use conditions have large variability in loads, distances, and other conditions that can significantly affect emissions control systems with multiple types of variable control
- Even with the in-use conditions, the natural gas vehicles we tested fall on average under the current 1.5x 0.02 g/bhp-hr Optional Low NOx Standard and the to-be-implemented 0.058 g/bhp-hr Bin 2 Federal Off-Cycle Standard




Questions?
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