Real World Brake Activity of Heavy-Duty Vehicles

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Real World Brake Activity of Heavy-Duty Vehicles

Project Motivation

Non-tailpipe PM emissions become the primary focus as tailpipe emissions are reduced through implemented regulation.

Brake wear emissions depend on brake pad material, vehicle category, and driving patterns.

Background

The California Air Resources Board EMission FACtors model (EMFAC) assess emissions from on-road vehicles using both laboratory testing and near road environments.

In this study:

A heavy-duty vehicle brake activity is assessed based on vehicle vocation by using both chassis dynamometer testing and on-road testing.

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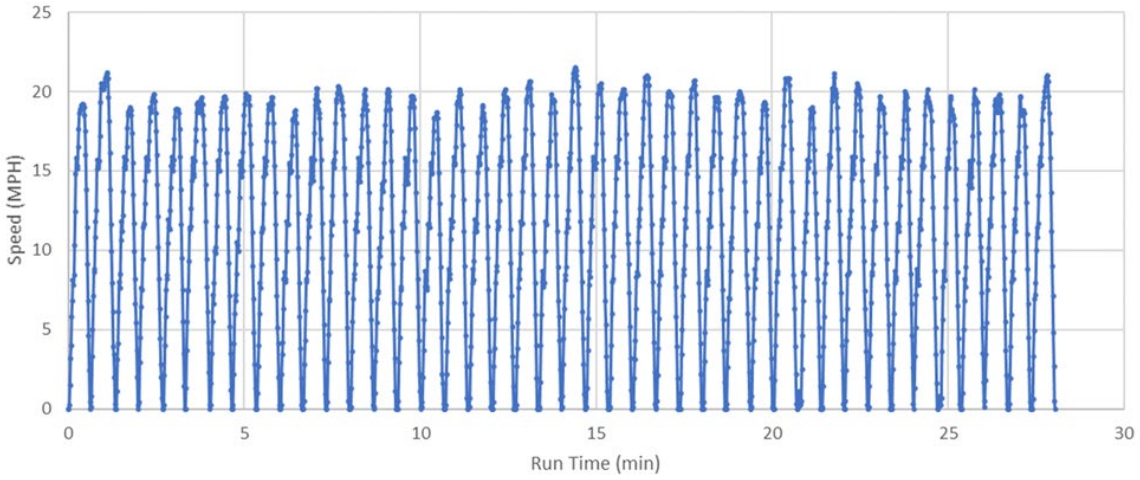
Project Overview

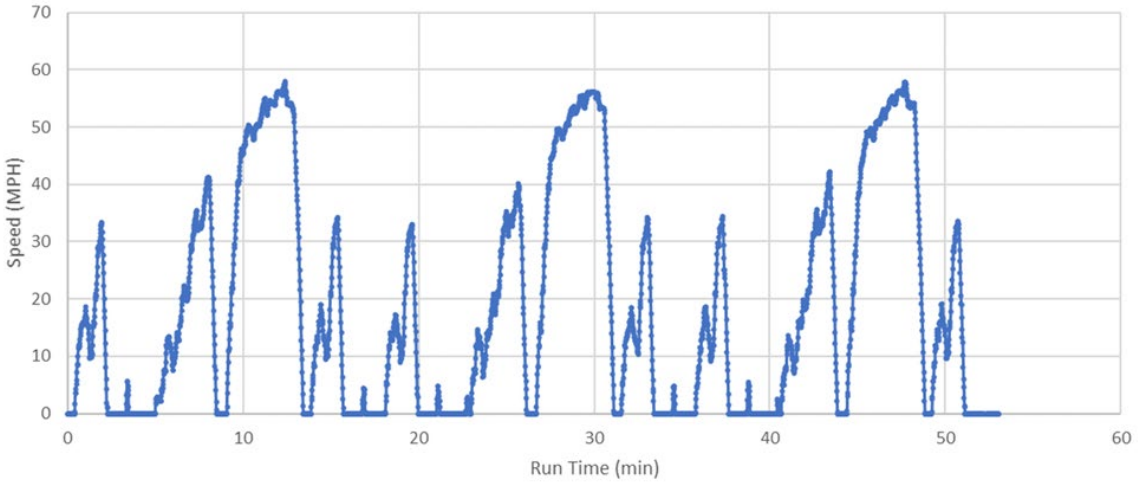
Chassis Dyno Tests

The brake activity quantified: brake temperature, brake fluid pressure, vehicle speed, vehicle position and elevation, and ambient conditions.

Central Business District (CBD) cycle
representative of a city bus or transportation vehicle driving patterns.



Urban Dynamometer Driving Schedule (UDDS) Cycle
Representative of heavy-duty vehicle urban driving conditions



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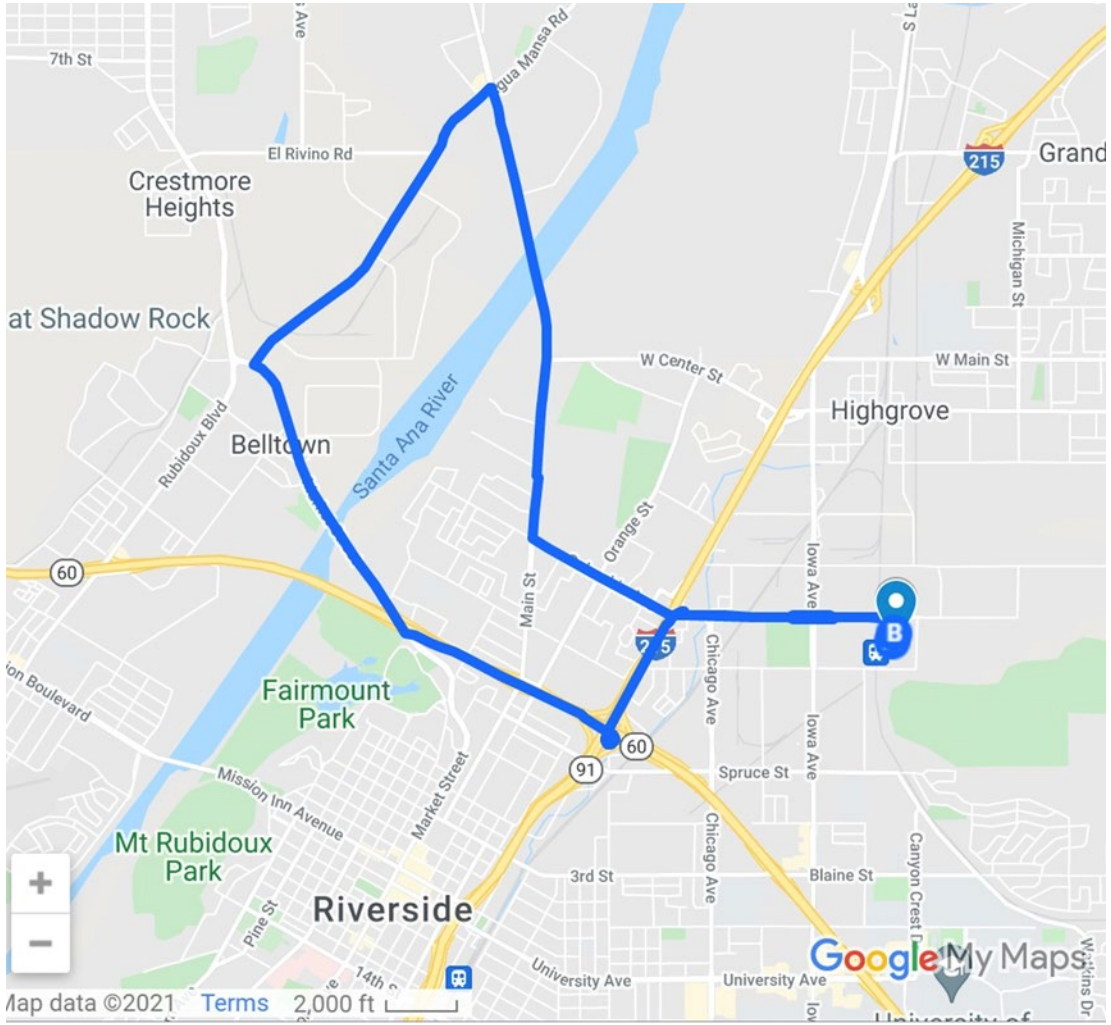
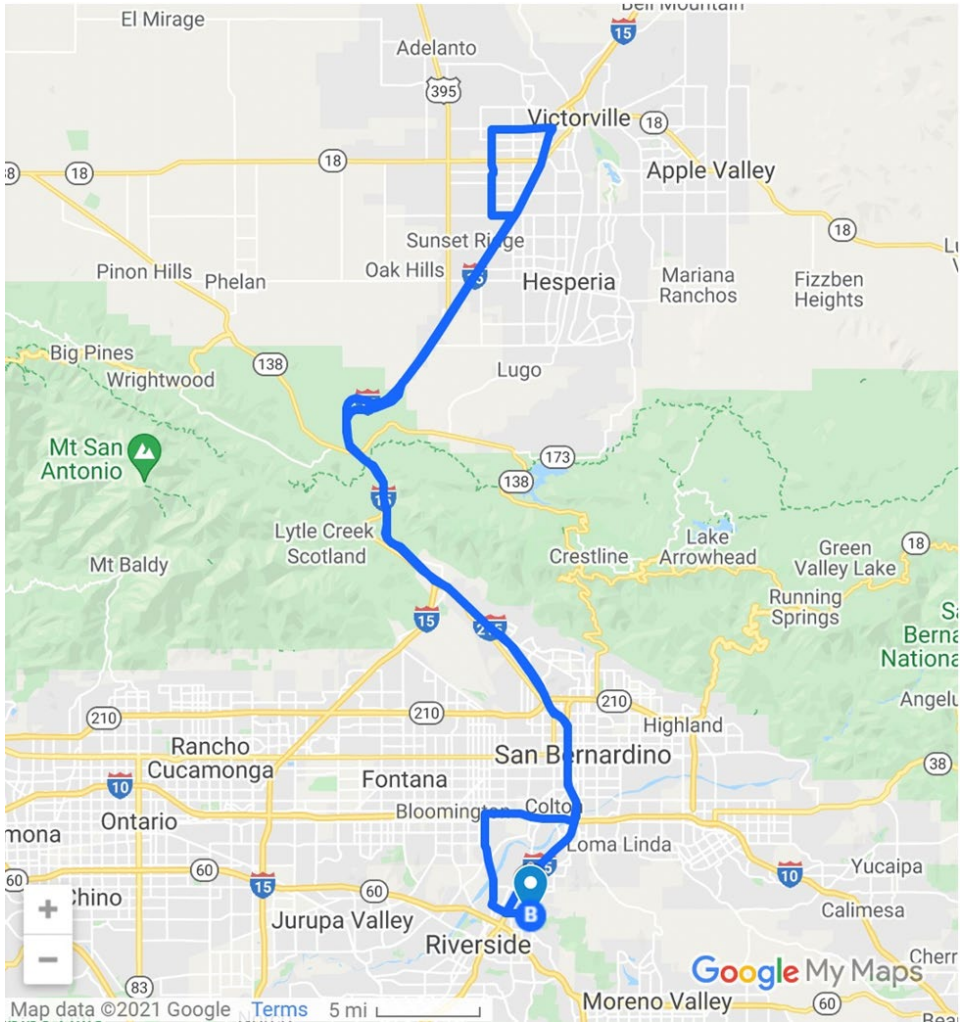
Project Overview

On-Road Tests



Local Riverside City Route



Long Distance Highway Route

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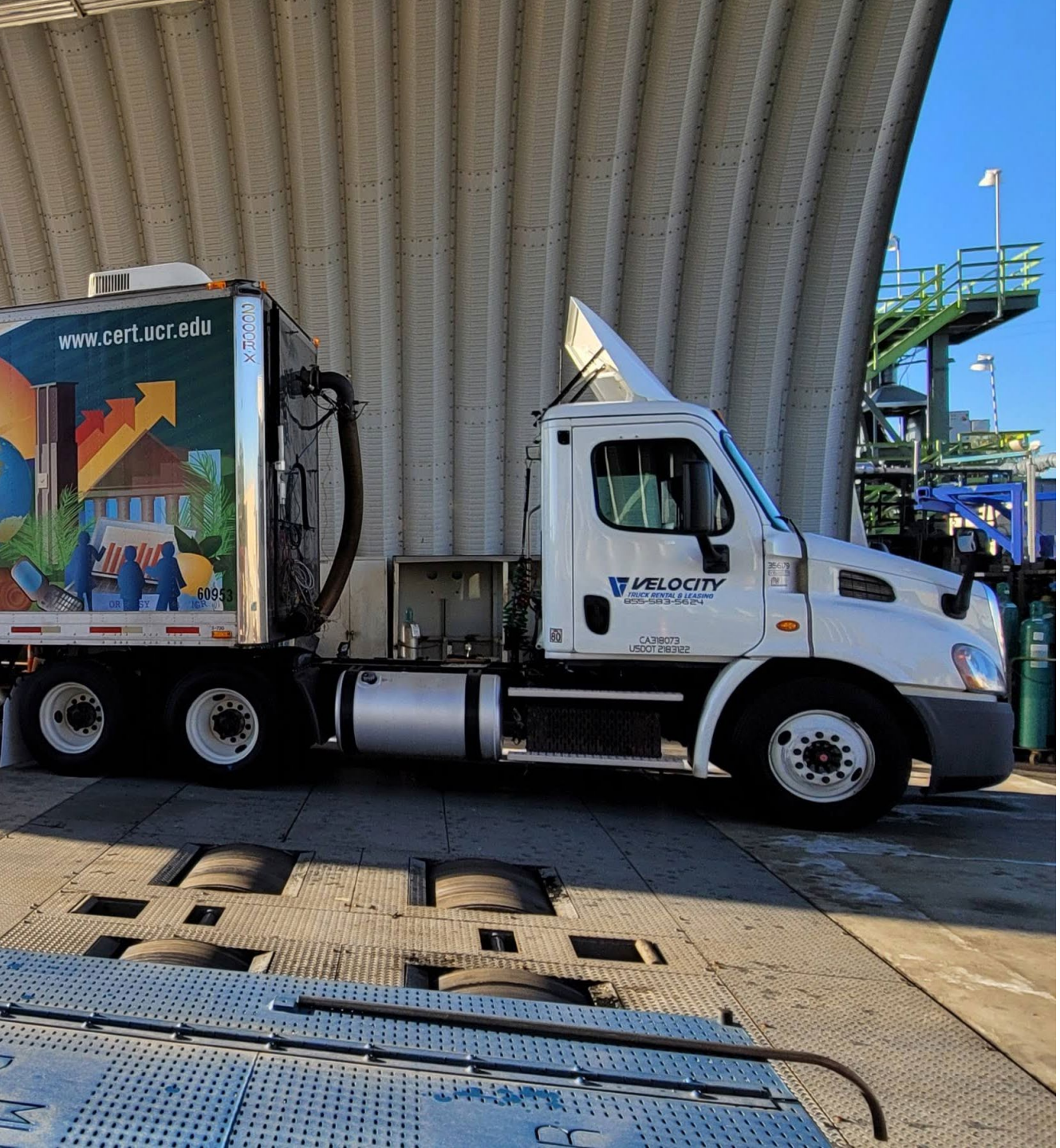

Test Vehicle

- HDV: Freightliner Cascadia 2015
  - 12.8 L Detroit Diesel engine with air brake system
  - Curb weight: 15,892 lb.
  - Total vehicle weight (tractor + trailer): 65,000 lb.

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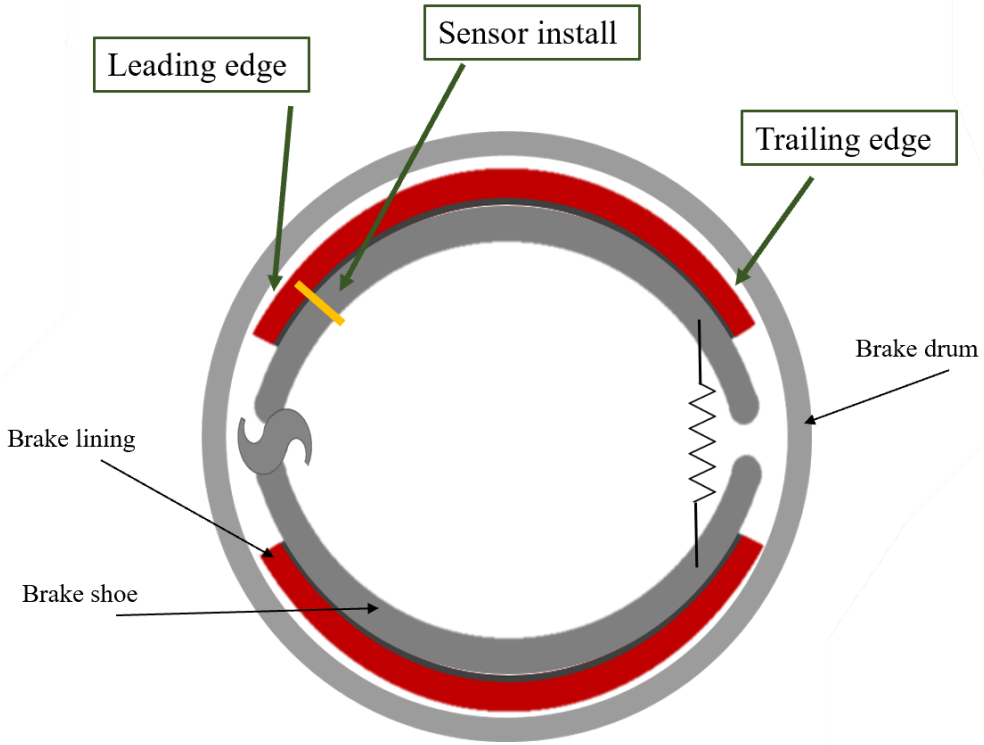
Temperature Installation



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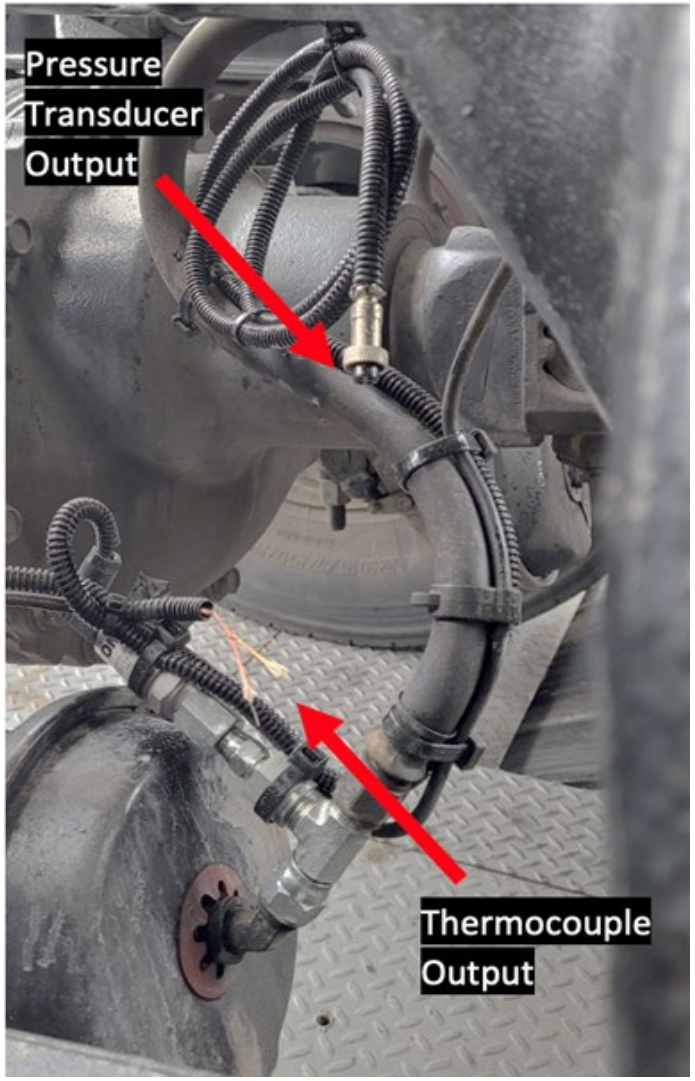
Data Collection

- K-type thermocouple
  - 1/8 copper tube encasing
  - 2 mm below brake pad material
- Pressure transducer
  - Brake fluid line to the rear right brake canister.
- Brake datalogger
  - 1 Hz data sampling
- OBD2 HEM logger
  - GPS, vehicle speed, altitude
  - 1 Hz data sampling
- Ambient conditions
  - local weather stations managed by the California Irrigation Management Information System (CIMIS)



Brake datalogger

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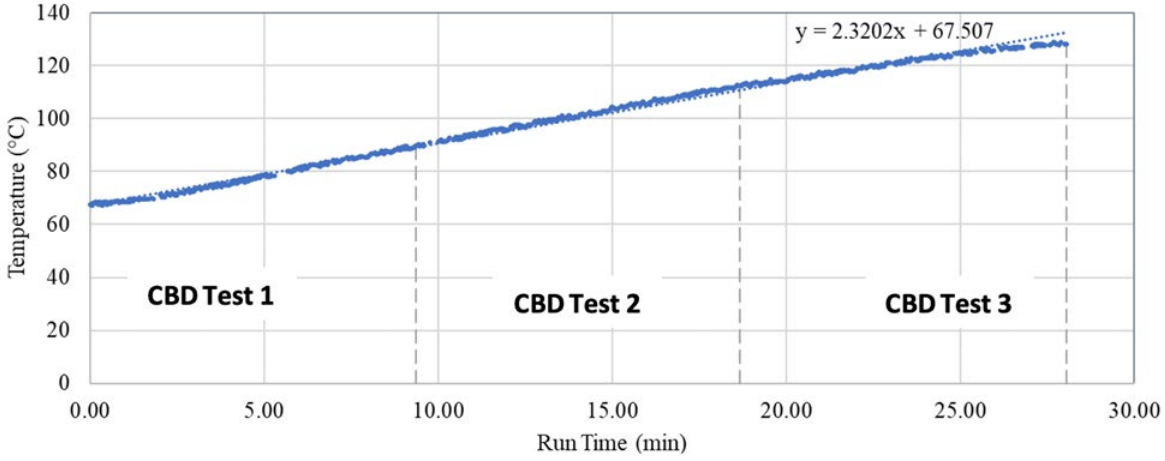
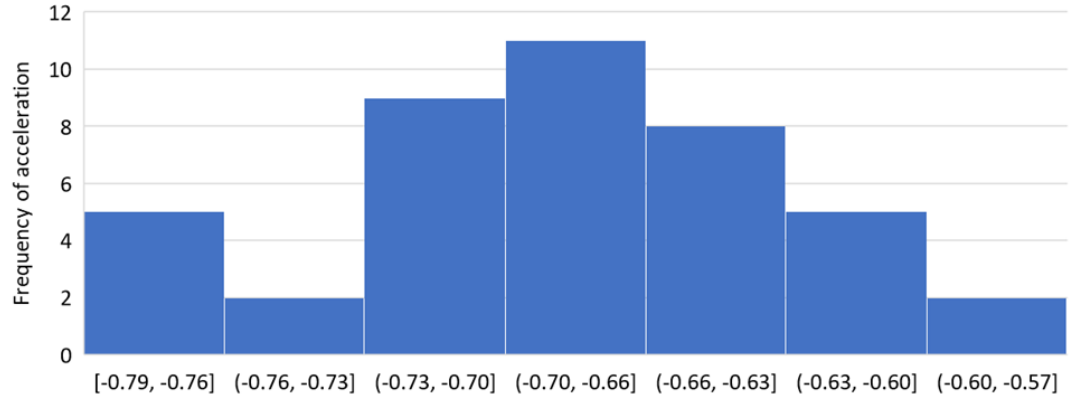
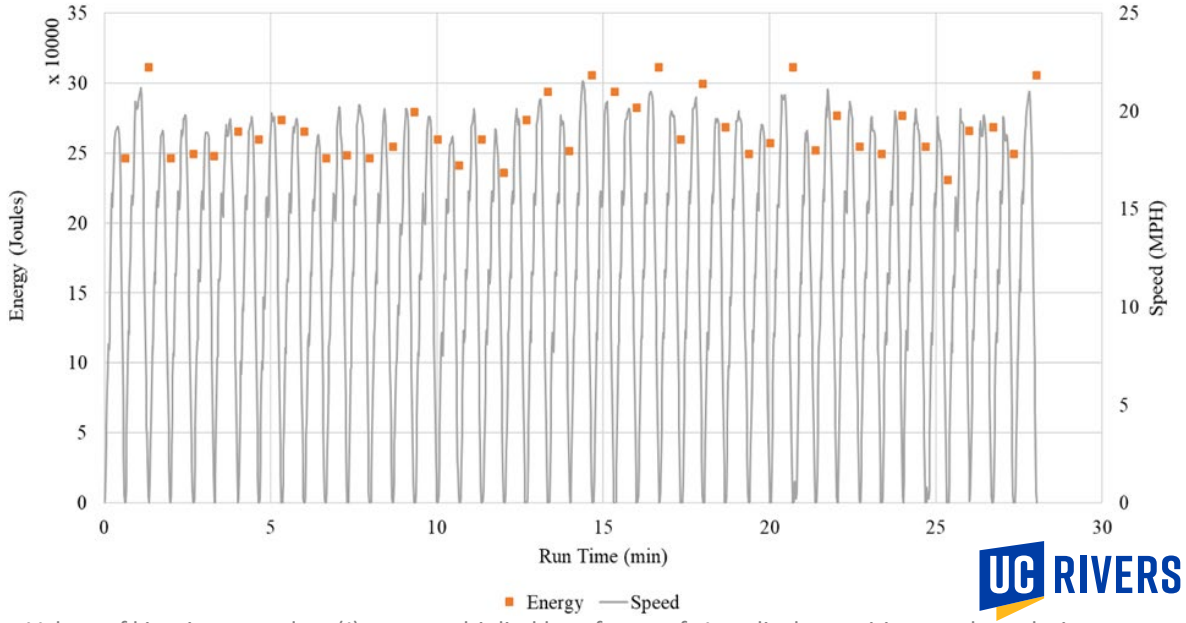
CBD Cycle: Brake Temperature, Acceleration & Kinetic Energy Lost



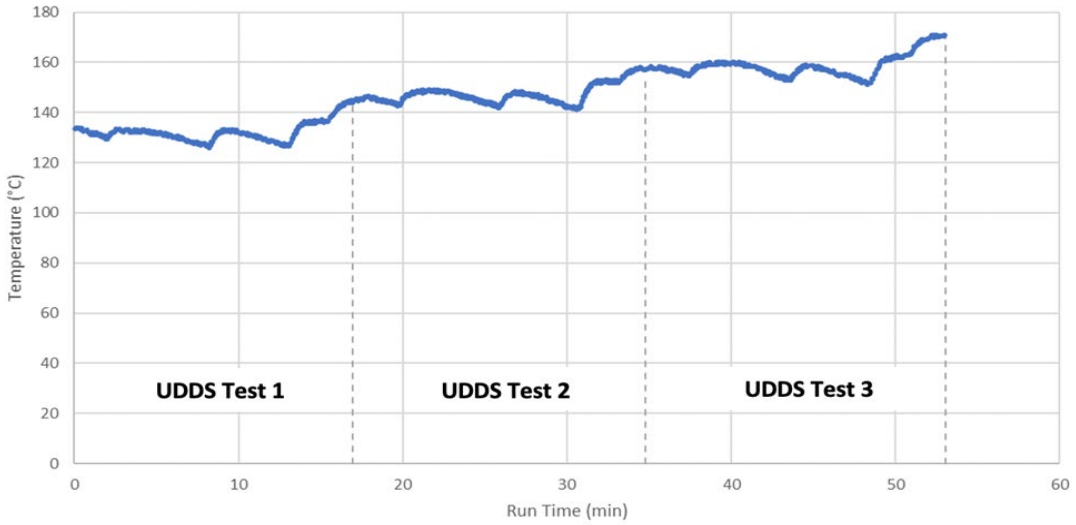


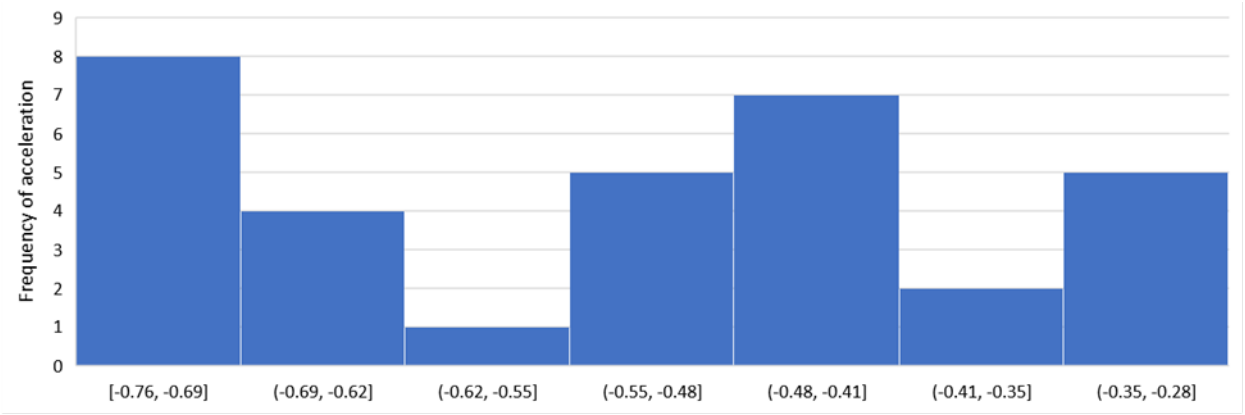
- Negative acceleration values were approximately linear.
- the brake pressure varied from 20 psi to about 30 psi with one spike up to 38 psi
- Average kinetic energy lost compared to temperature slope within each CBD cycle, divided by number of brakes:
  - 2.4E-5 °C/J, 2.3E-5 °C/J, and 2.3E-5 °C/J



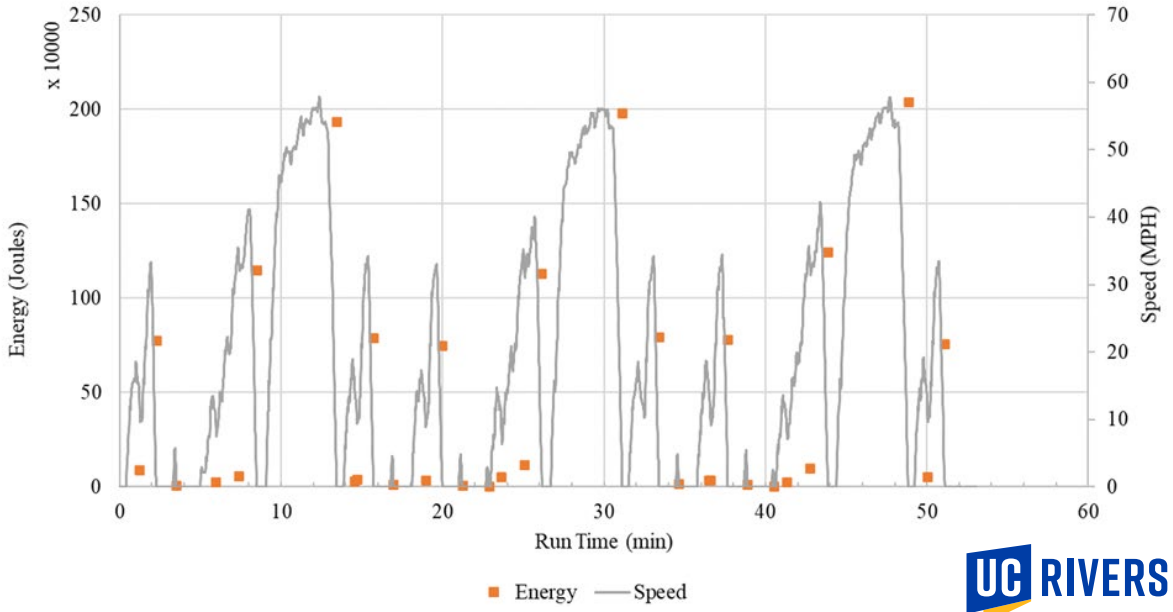
Values of kinetic energy lost (J) were multiplied by a factor of -1 to display positive numbers during deceleration events

UDDS Cycle: Brake Temperature, Acceleration & Kinetic Energy Lost



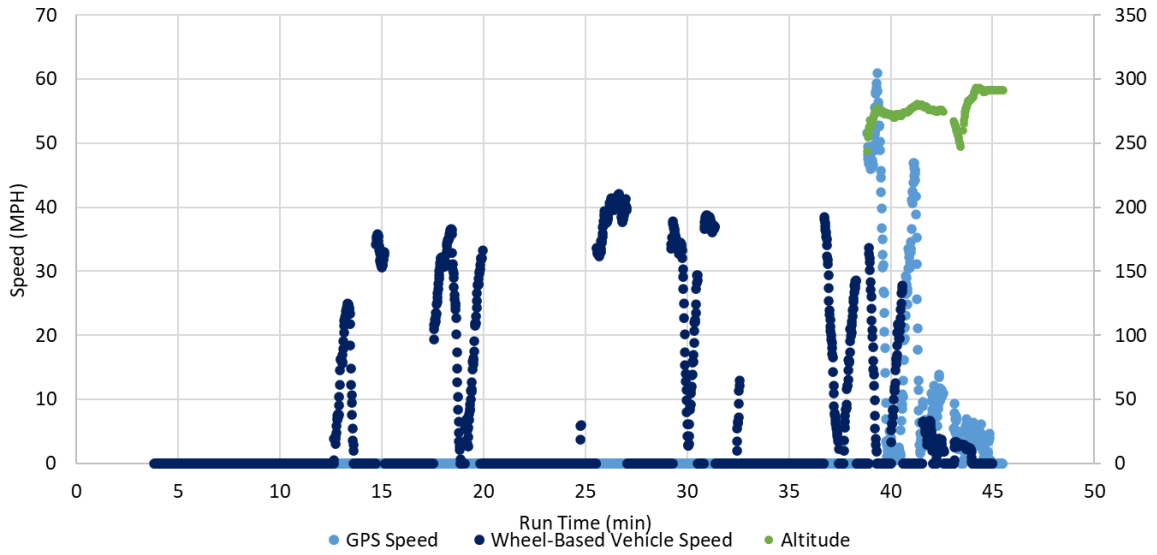


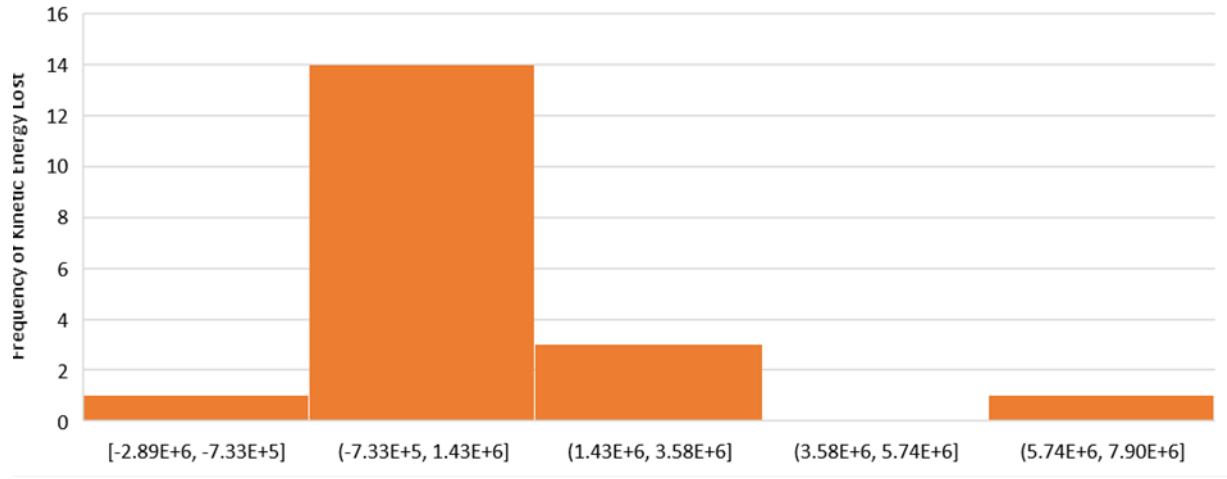
- 20-minute delay between the CBD and UDDS tests
- brake pressure varied from 10 psi to about 30 psi with one spike up to 45 psi
- Average kinetic energy lost for each cycle:
  - 2.6E5 J, 2.7E5 J, and 2.6E5 J



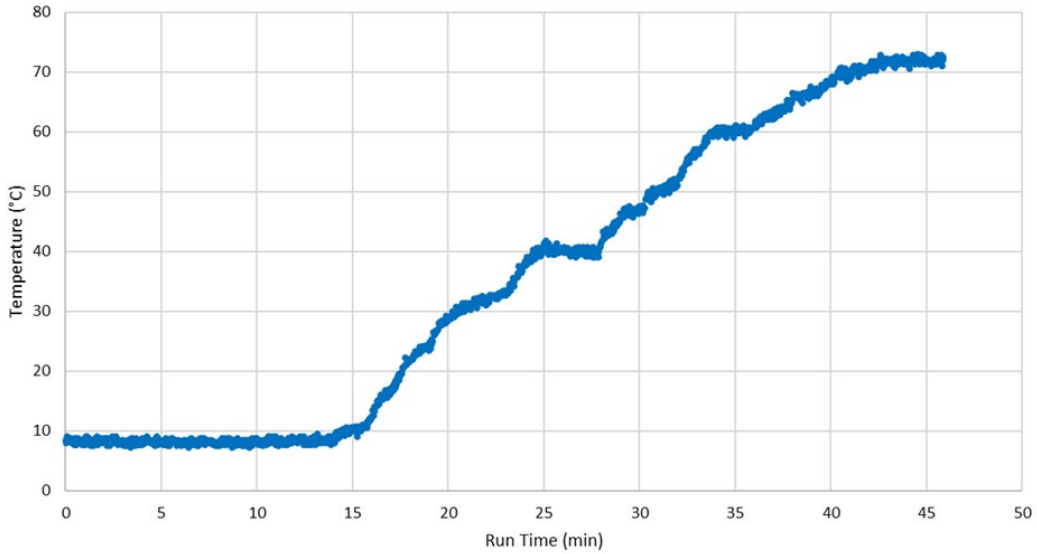
Values of kinetic energy lost (J) were multiplied by a factor of -1 to display positive numbers during deceleration events

On-Road Test: Riverside City





Values of kinetic energy lost (J) were multiplied by a factor of -1 to display positive numbers during deceleration events



- Average acceleration ranged from -4.43E-1 to -2.56E-2 m/s^2
- The pressure ranged from 10 psi to 20 psi with a few spikes as high as 33 psi.
- Braking energy lost suggests a higher frequency in the -7.33E5 to 1.43E6 Joule bin compared to the chassis testing.

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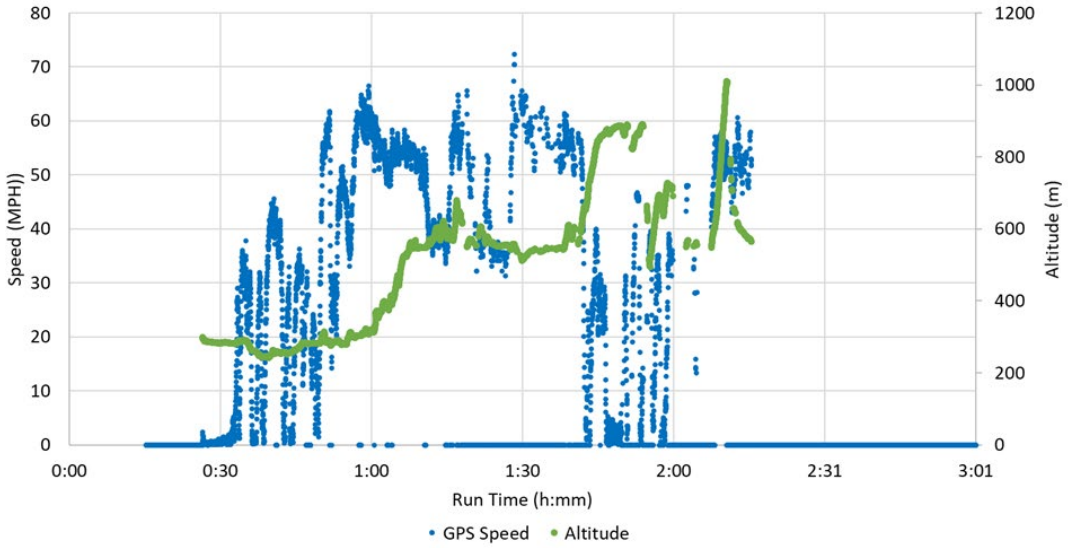
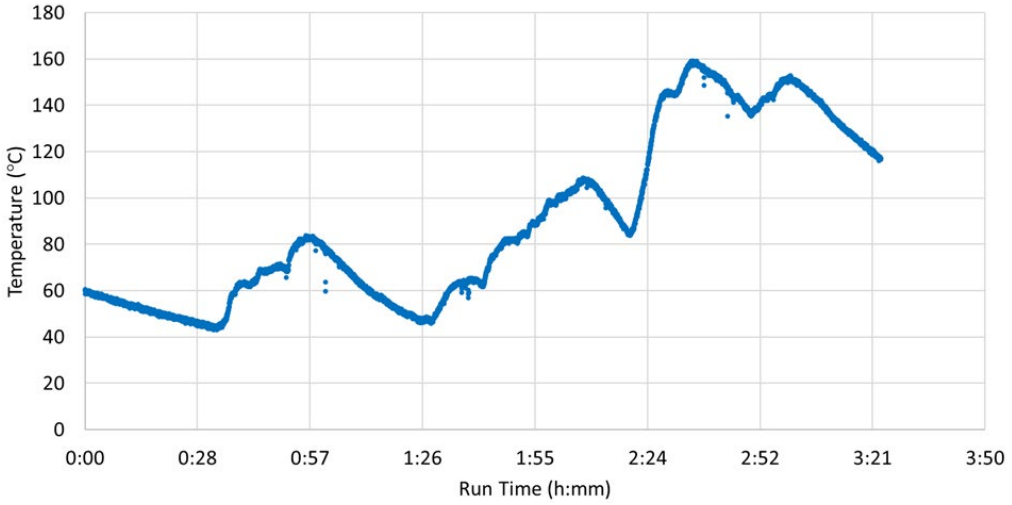
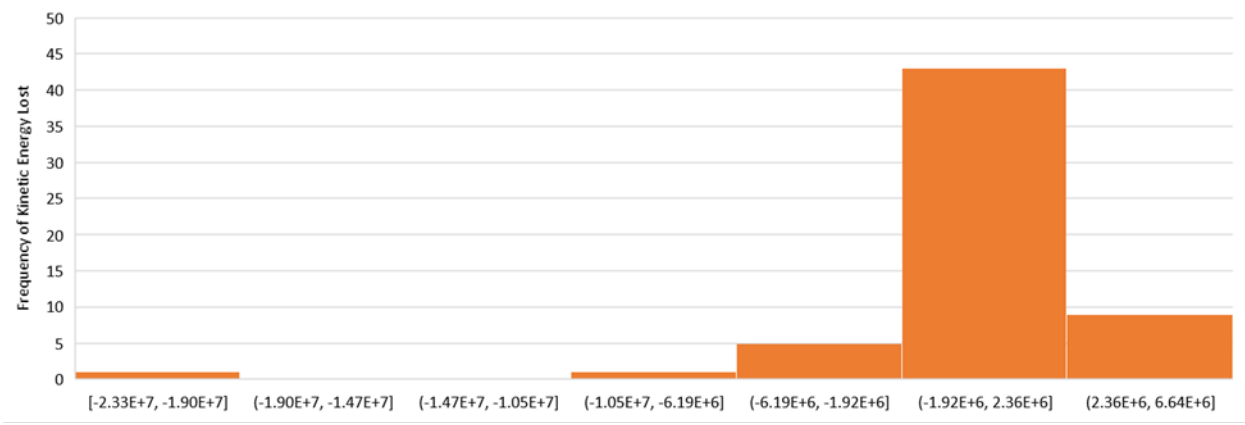
On-Road Test: Highway







Values of kinetic energy lost (J) were multiplied by a factor of -1 to display positive numbers during deceleration events

- Brake pressure was around 20 psi with several spikes over 30 psi and one up to 39 psi.
- Kinetic energy lost contains negative values attributed to road elevation and travelling downhill.
- KE 2-3 times larger than chassis tests.

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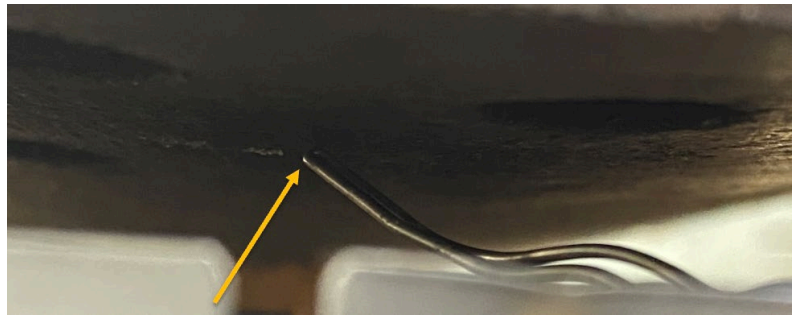
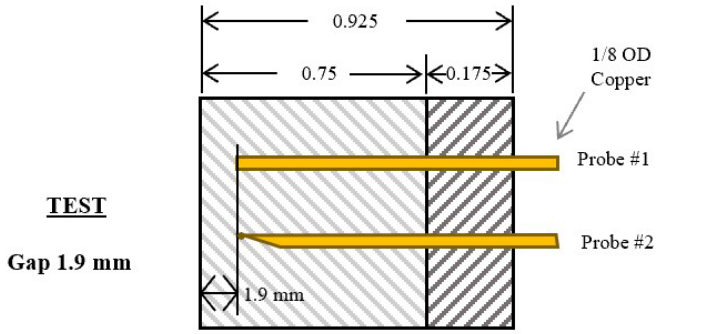
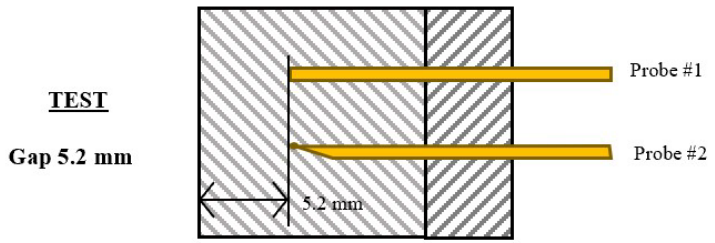
Bench Top Laboratory Testing

- A lab experiment was setup to evaluate the temperature probe in the “as-found” condition.
- Butane camping stove was setup to produce a 3” diameter blue flame ~1” from the surface.
- Data was logged with a CR10x data logger.



Probe tips: brake test probe (bottom) used in the study and exposed tip (top).





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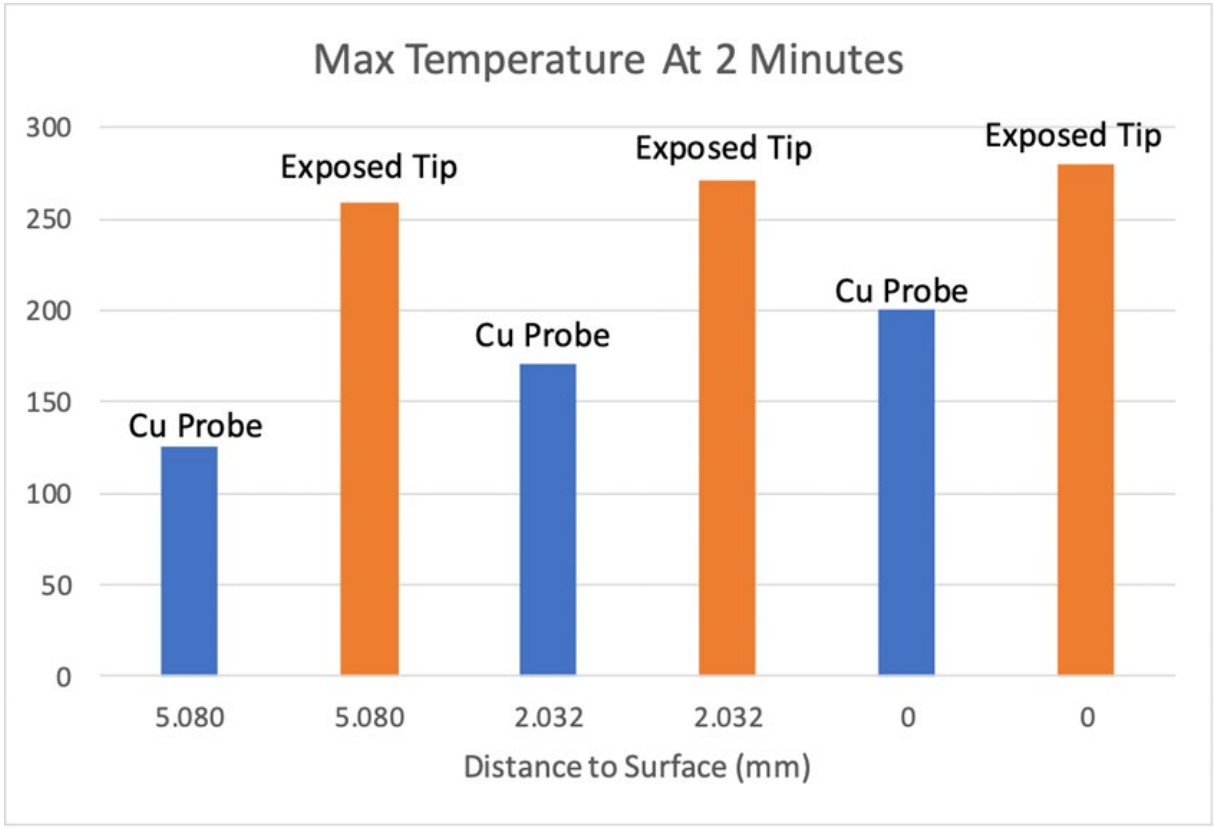
Bench Top Laboratory Testing Cont…

- Overview of the maximum temperature reached after 2 minutes.
- Difference between the exposed tip and Cu probe was about 100 °C to 150 °C.
- The 0 mm was estimated from the 5 and 2 mm depts tests and was not measured.
- Suggest braking temperatures may be low by around 100 C.



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Key Findings

- The brake activity widely varied between laboratory cycles and on-road test.
- It should be noted brake activity from the same vehicle can vary as a function of hauling load.
- Brake pressures ranged from 20 psi typically up to a maximum of 45 psi.
- Brake temperatures ranged from 60C to 160C where it is possible the maximum temperature could be over 260C if the correct temperature probe were utilized.

Future Work

- Utilizing an exposed tip thermocouple to measure brake pad temperature at the targeted depth of 2 mm.
- Simultaneous measure the brake particle emissions along with brake activity to find relationship between brake activity and brake particle emissions.
- Measure brake activity for vehicles with different vocations such as sweeper vehicle, buses, trucks as well as other applications.

Acknowledgements

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Thank You

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