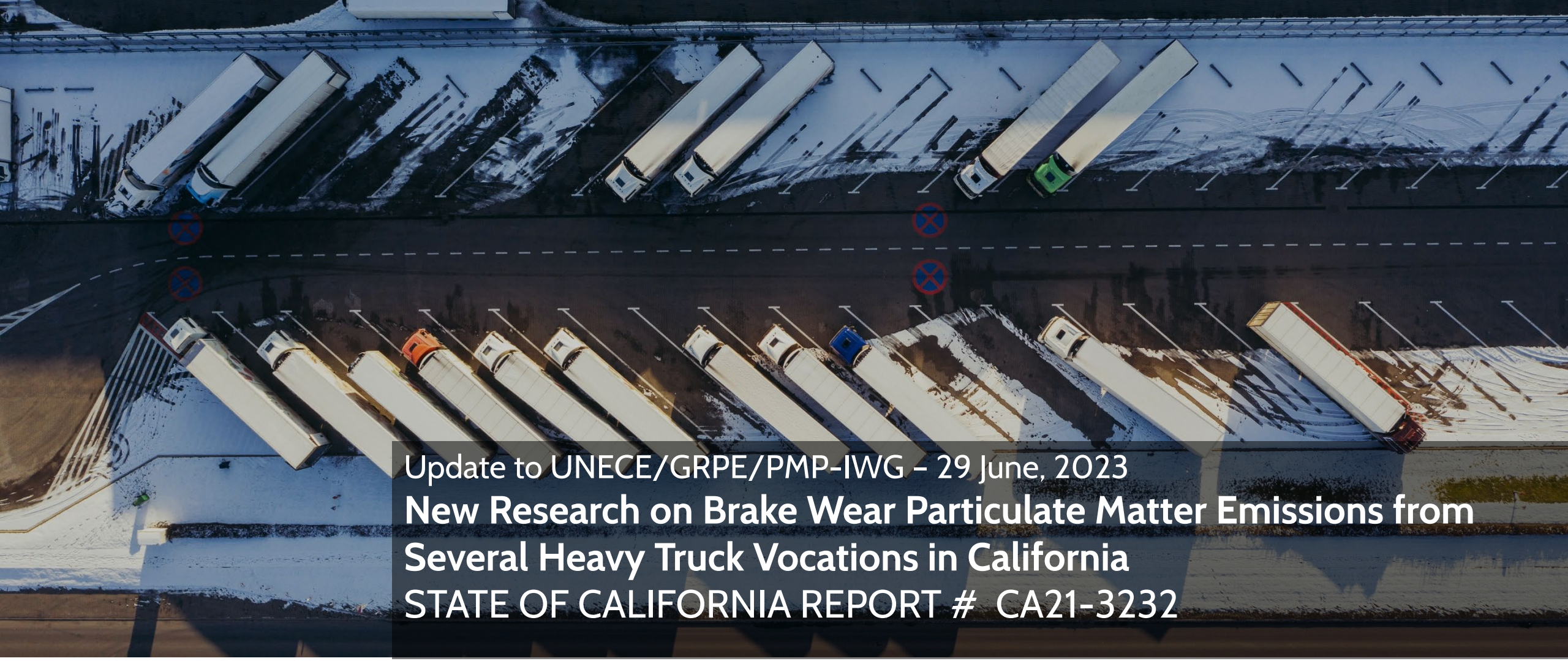


Update to UNECE/GRPE/PMP-IWG – 29 June, 2023

New Research on Brake Wear Particulate Matter Emissions from Several Heavy Truck Vocations in California

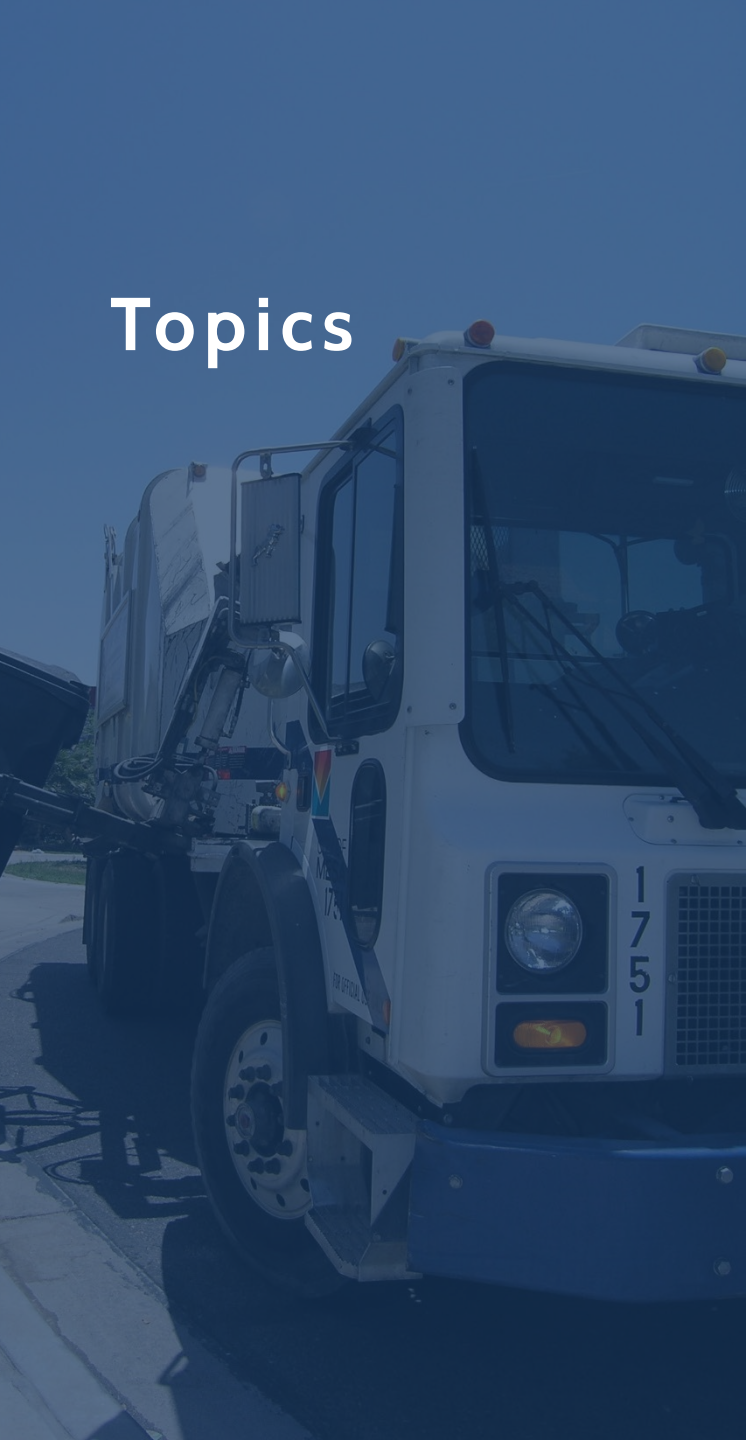
STATE OF CALIFORNIA REPORT # CA21-3232

Simon Bisrat

John Koupal*, Yuke Zhao, Allison DenBleyker, Sandeep Kishan

Carlos Agudelo, Ravi Teja Vedula

Topics



Objectives
Driving cycles
Test setup
Emissions factors

...the rest of the team

ERG: Alan Stanard, Timothy DeFries

EPA: *Chad Bailey, Bob Gianelli*

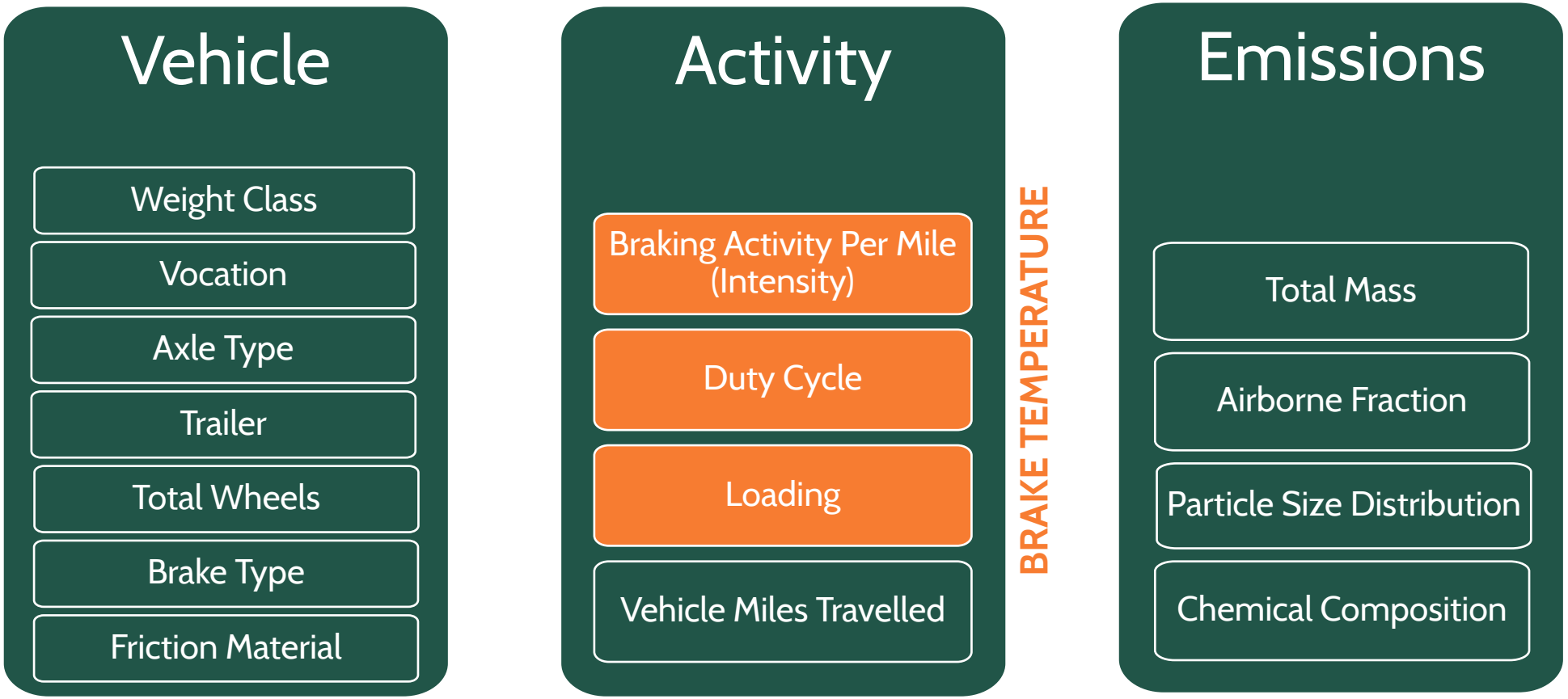
LINK: Quinn O'Hare, Jerry Lawruk, Mark Hunt, Brian Nycek, Josh Bautell, Trent Fagrell, Aaron Voisard

CARB: Sonya Collier, Seungju Yoon, Jeff Long, Sara Forestieri, Qi Yao, Inna Dzhema, Oliver Chang

Brake suppliers: Federal Mogul, ArvinMeritor, Bendix

Factors to Account for in Emissions Inventories for HD Truck Brakes

Three-step assessment

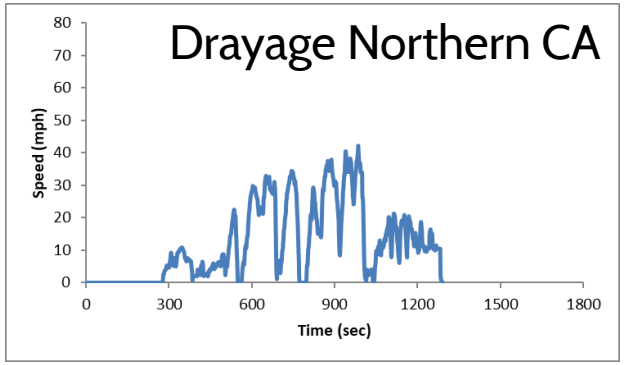


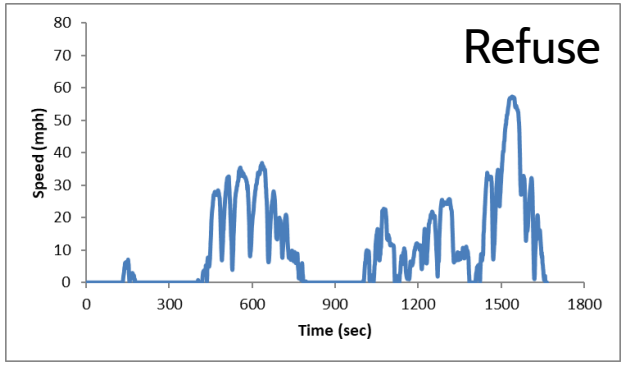
Brake Temperature Evaluation

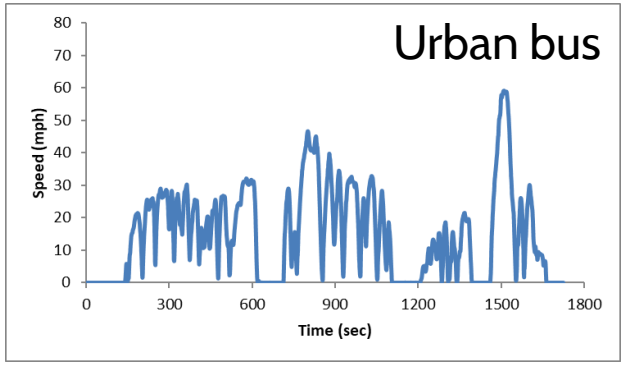
Vehicle	Load	Vocation					
		Dryage	Delivery	Long haul	Towing	Refuse	U.Bus
Class 8 - Air Disc Brake 	Full	•	•	•			
	Unloaded	•					
Class 8 - Drum 	Full	•	•				
	Uloaded	•	•				
Class 6 hydraulic 	26k lbs		•		•		
Refuse 	Full					•	
Bus 	37.5k lbs						•

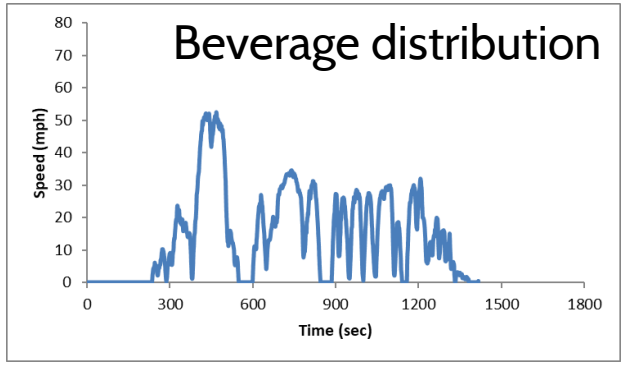
Drive cycles

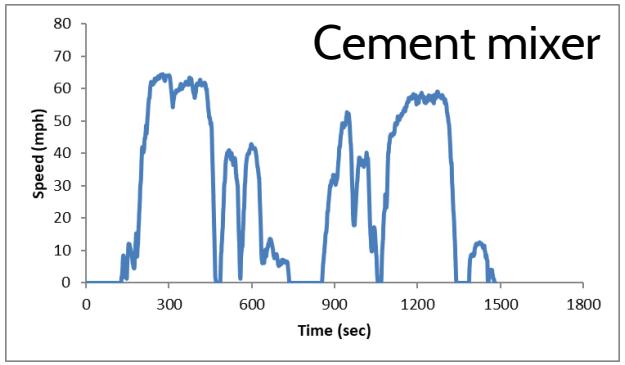
Using 2021 field study from University of California – Riverside (UC-CERT)

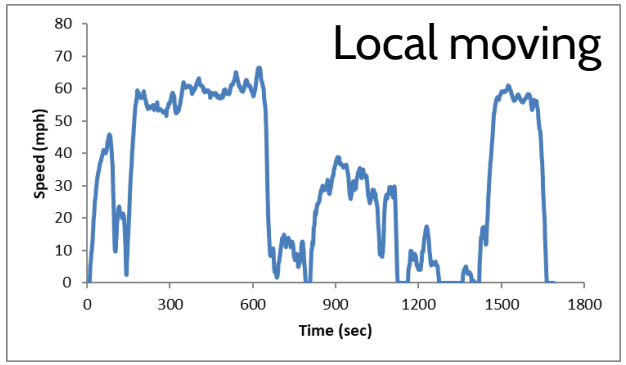


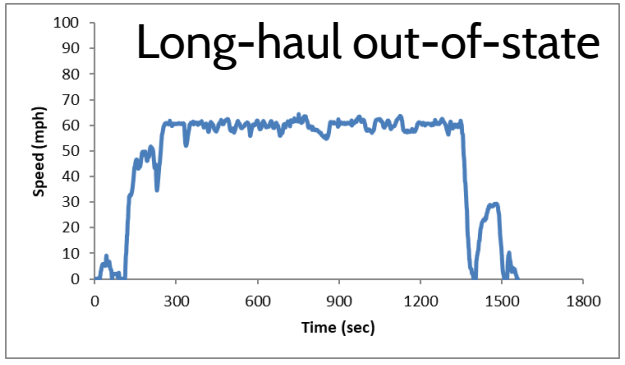












Emissions Test Matrix

Combining vehicles, brake types, cycles, loading, and repeatability tests

Vehicle	Brake/axle	Cycle 1	Cycle 2	Cycle 3	Load	Repeat	EMFAC class
Class 8	drum steer	Drayage N*	Cement	LH OOS**	1		T7
	drum drive	Drayage N	Cement	LH OOS	2	Yes	
	ADB steer	Drayage N	Cement	LH OOS	2	Yes	
	ADB drive	Drayage N	Cement	LH OOS	1		
Refuse	ADB steer	Refuse			2		Refuse
	ADB drive	Refuse			1		
Urban bus	ADB steer	Urban bus			1		Bus
	ADB drive	Urban bus			1		
Service	Hyd. Disc steer	Beverage	Delivery		1		T6
	Hyd. Disc drive	Beverage	Delivery		1	yes	

*Northern CA Drayage ** Long-Haul Out-of-State

Brake Temperature Modeling

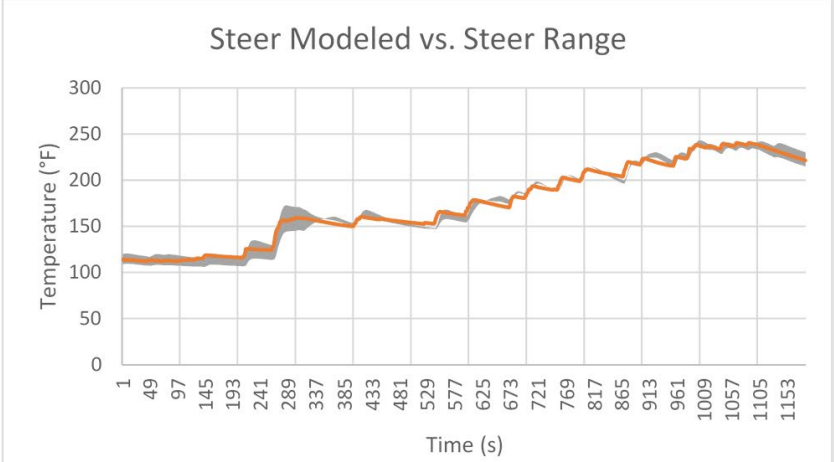
Updated UMTRI model with track data

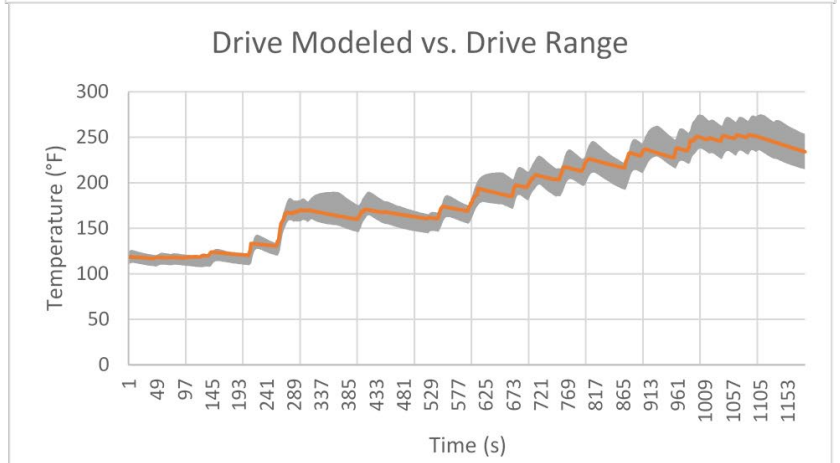
$$T = T_i \cdot e^{-t/\tau} + \left[(HP_B/h(v) + T_a) \cdot \left(1 - e^{-t/\tau}\right)\right]$$

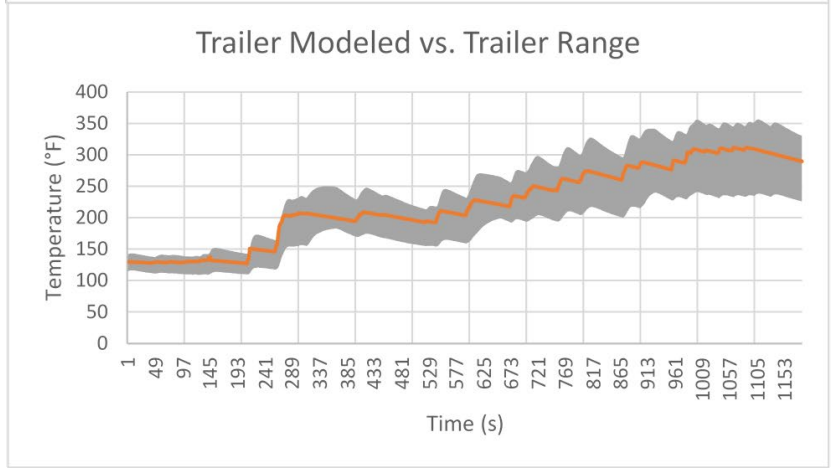
- Ambient temperature
- Cooling coefficient 2
- Braking horsepower
- Heating/cooling constant
- Time
- Initial temperature
- Temperature

Adaptations:
- Braking events v. coastdowns
- Estimation of braking power

Target temperatures for emissions tests

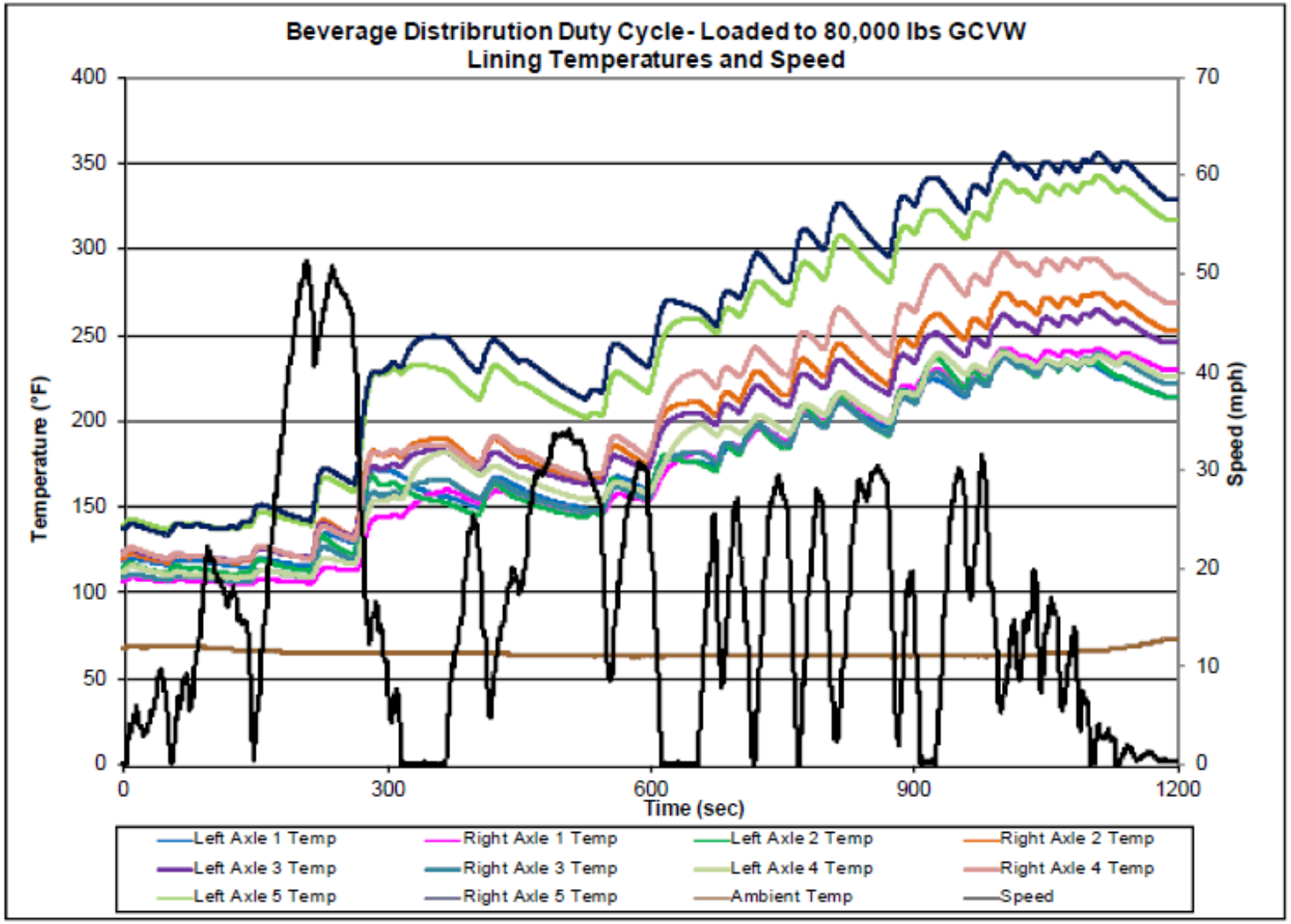


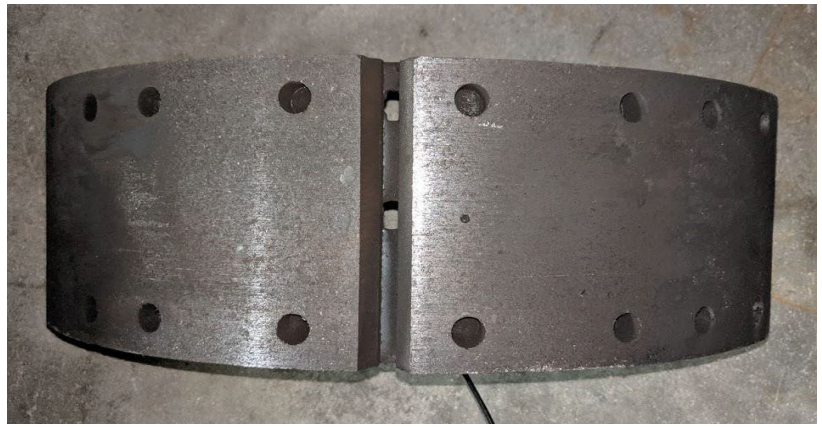




Example Brake Temp Results

e.g., Test track measurement on Class 8 drum brake on beverage delivery cycle

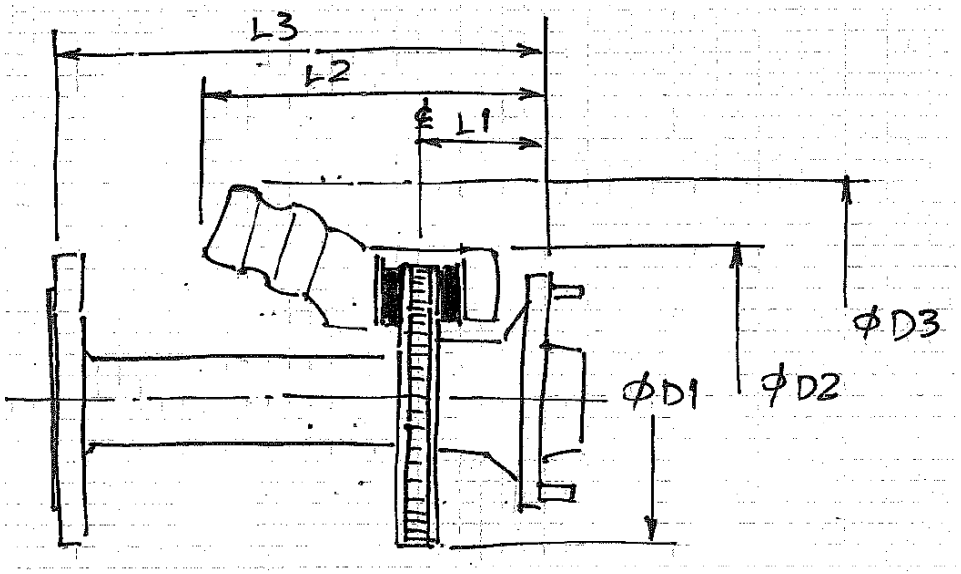




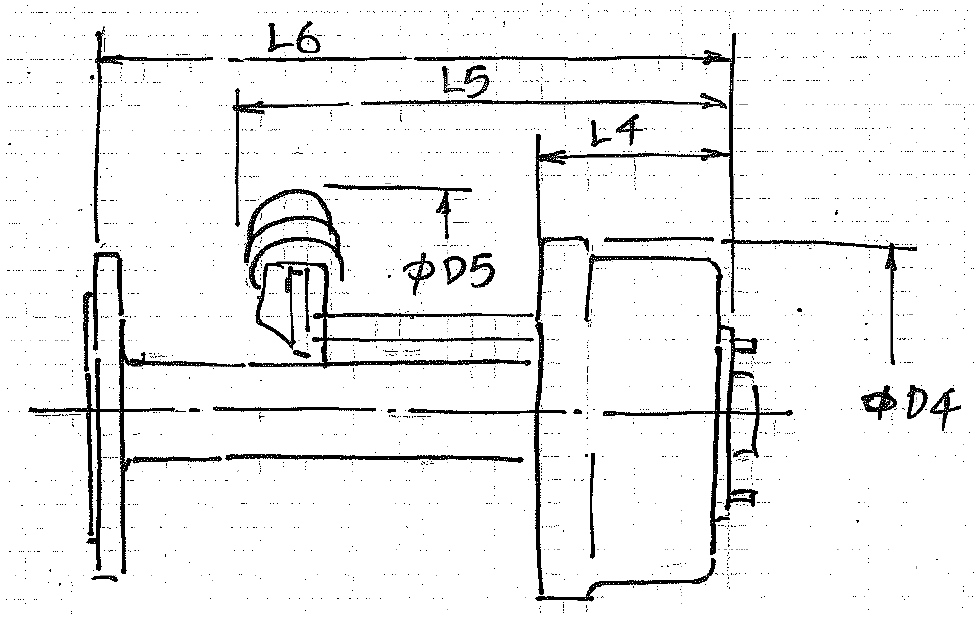
Thermocouples in primary brake shoes of all wheel ends per FMVSS 121

Brake configurations

Envelope dimensions significantly larger than ligh-duty vehicles



Air-disc brakes
L2 [450…650 mm], D2 [450…600 mm]



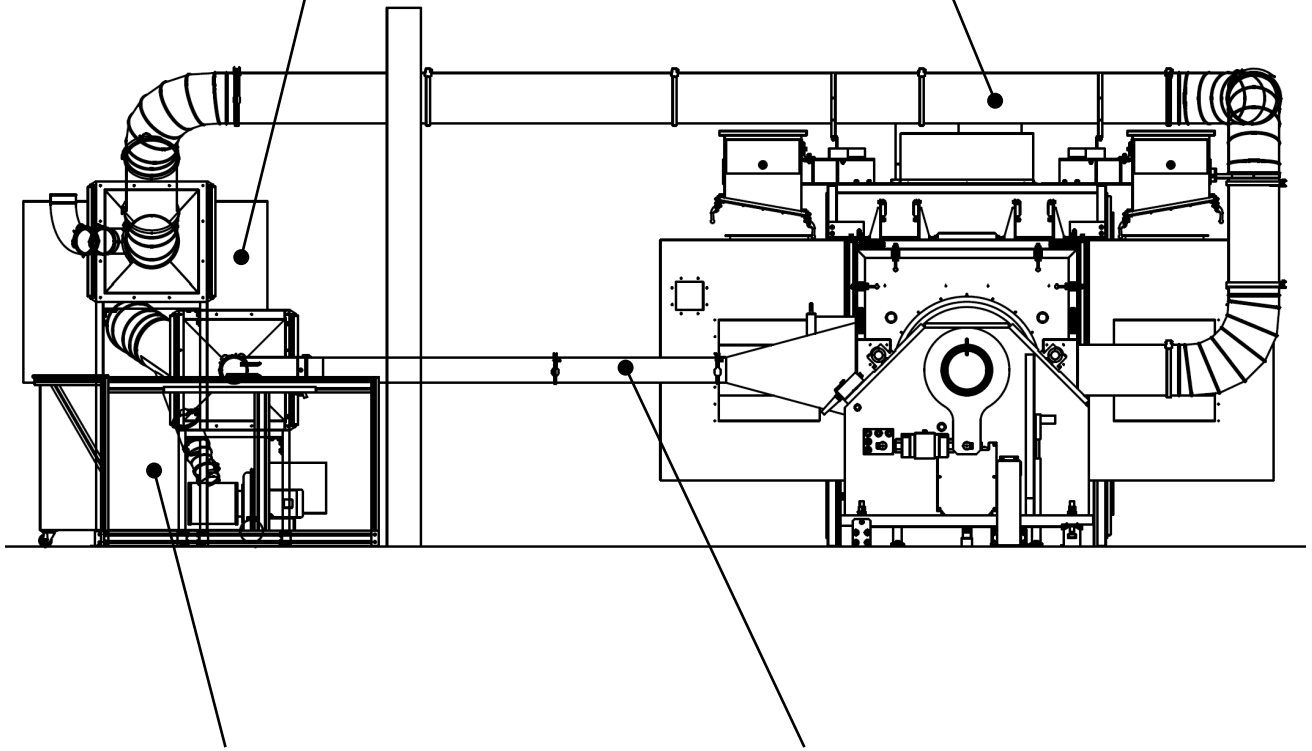
Air-drum brakes
L5 [550…850 mm], D4 [380…520 mm]

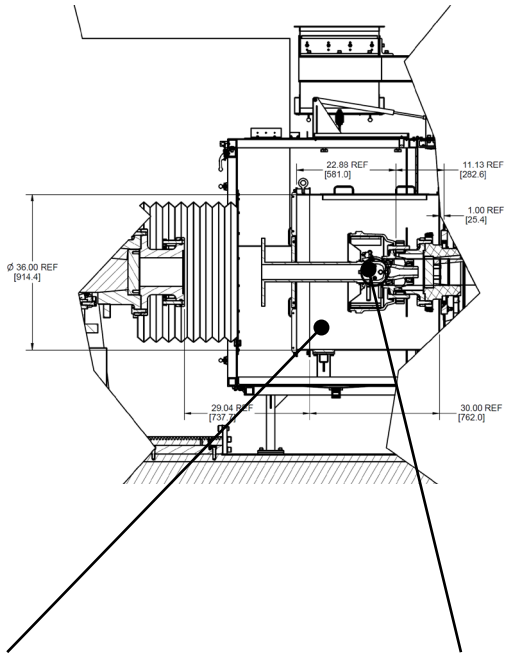
Brake Dynamometer Test Setup

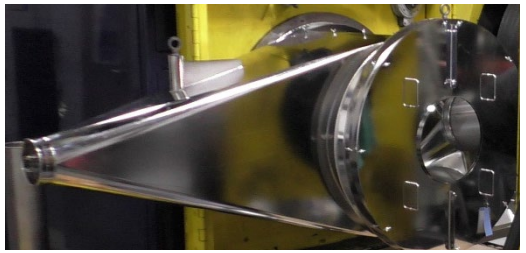
Caltrans setup with setup aligned with PMP sampling (pre-GTR)

climatic unit + HEPA filters

inlet ducting







PM + PN systems

+ EEPS + APS + QCM

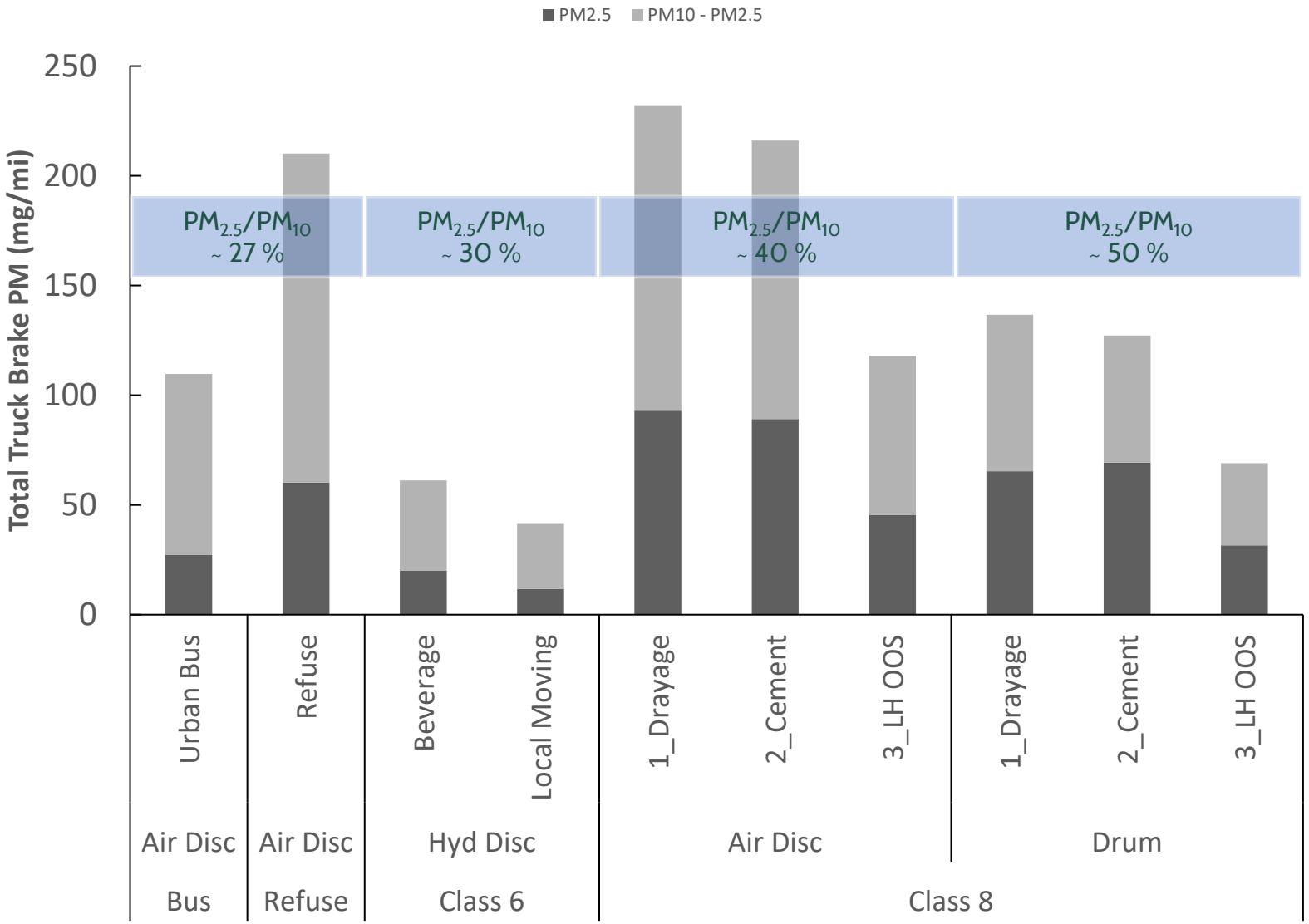
sampling tunnel

brake enclosure

brake assembly

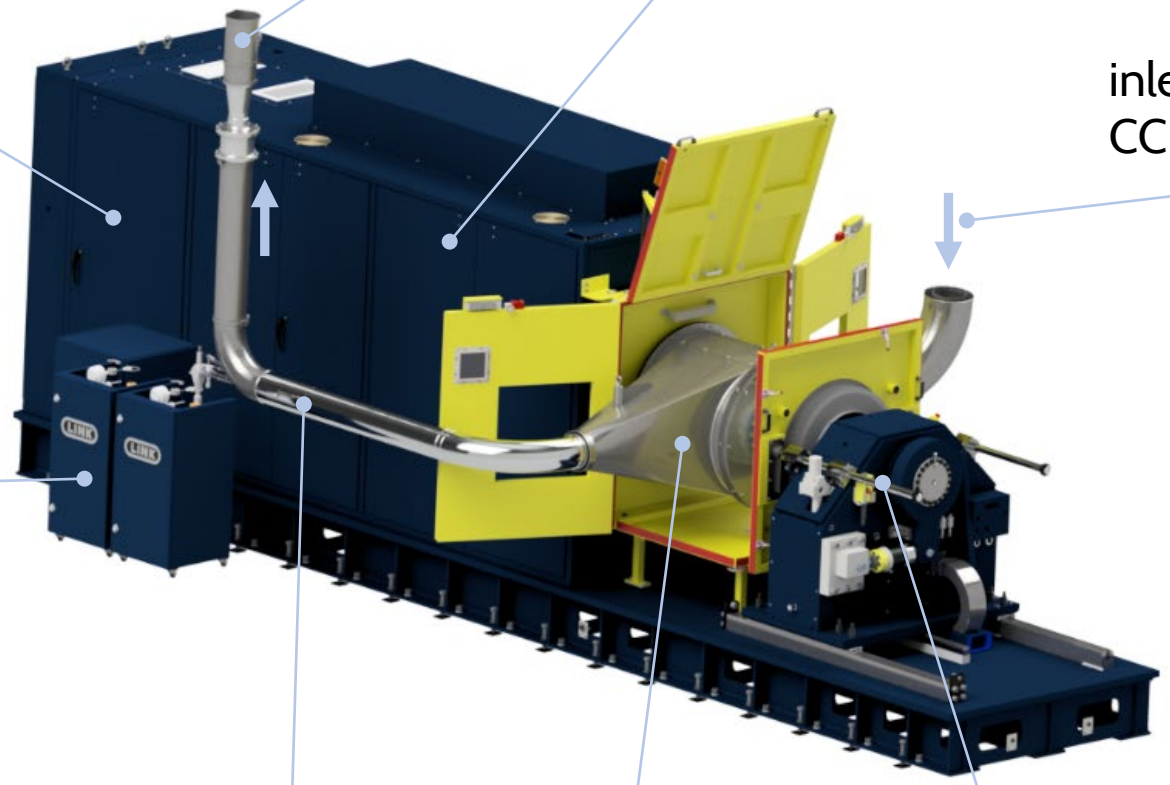
Total Truck PM_{10}

The $PM_{2.5}/PM_{10}$ fraction exhibited differences accross brake types



Brake dynamometer for commercial vehicle applications

Adapting the PMP GRPE-87-40 system setup



Brake dynamometer for commercial vehicle applications

Adapting the light-duty method GRPE-87-40 + CV applications

- Cimatic conditioning
- Sampling system
- Emissions measurements



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