In-Use Emissions Testing and Fuel Usage Profile of On-Road Heavy-Duty Vehicles

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Background

- Air quality is a critical factor in human health, and achieving air quality goals remains a challenge in many California areas.
- Heavy-duty diesel vehicles (HDDVs) and heavy-duty diesel engines (HDDEs) are the largest sources of NOx emissions, which is one of the most critical pollutants in terms of meeting air quality standards.
  1. Selective Catalytic Reduction (SCR) aftertreatment that became widely implemented in 2010 for on-highway HDDVs.
  2. Advanced near-zero emission natural gas engines and other alternative fuels.
  3. Electric, hybrid, and fuel cell technologies are being more widely implemented in heavy-duty applications.
- Considerable progress has been made in reducing NOx emissions from heavy-duty vehicles (HDVs).
- To understand the benefits that these advanced technology vehicles have on reducing emissions, it is important to evaluate their emissions under in-use operating conditions, as past in-use testing of HDVs has shown that engine certification tests don't necessarily represent real world emissions due to differences in vocations/duty cycles.

OBJECTIVES

- This study is one of the most extensive studies of heavy-duty vehicle emissions and performance to date, incorporating 200 heavy-duty vehicles.
- Activity measurements with portable activity measurement systems (PAMS)
- Emissions measurements using portable emissions measurement systems (PEMS)
- Chassis dynamometer emissions measurements
- Real-world emissions measurements
- Testing is split evenly between University of California at Riverside (UCR) and West Virginia University (WVU)
- Information from this study will be of value in identifying technology benefits/shortfalls, feeding into fuel CEC R&D opportunities and the development of CARB regulations, and improving emissions inventory estimates.

Portable Activity Measurement Systems (PAMS)

Vocation	Transit	School Bus	Refuse	Delivery	Goods Movement
Number of PAMS Vehicles	20	20	25	45	90
CNG 0.20g	8	8	17	15	20
CNG 0.02g	2	2	6	0	16
Diesel 0.20g	2	5	2	16	40
Diesel (No SCR)	0	1	0	1	2
Other Alt Fuels					
LNG/Diesel HPDI (0.20g)	0	0	0	0	4
Diesel-Electric Hybrid	2	0	0	4	0
Electric	4	1	0	4	6
Fuel Cell	2	0	0	0	0
CNG Hybrid	0	0	0	0	0
Propane	0	2	0	4	0
RD 0.20g	0	1	0	1	2
RD (No SCR)	0	0	0	0	0

Table 1 Allocation of PAMS Tests

- UCR CE-CERT is employing HEM data loggers to log all vehicle activity data.
- The vehicle activity collection is based on the data publicly available on the CAN bus, as read by the HEM data logger. Up to 200 engine parameters or more can be collected
- A summary of ECU activity collected during the data logging is provided in Table 2

Figure 1 J1939 ECM port (left) and HEM logger (right)

Vehicle and Engine Information	ECU Data	GPS Data
Vehicle ownership	Vehicle speed	Speed
Vehicle type and vocational use	Engine horsepower	Latitude
Vehicle odometer reading	Engine revolutions per minute	Longitude
Vehicle maintenance history	Exhaust and SCR temperatures	Altitude
Axle configuration	Engine percent load	Date and time
Vehicle model year	Engine percent torque	
Vehicle identification number	Reference engine torque	
Vehicle GVWR	Engine intake manifold temperature	
Engine make, model, and family	Engine turbo boost pressure	
Engine model year	Engine coolant temperature	
Engine operating hours		
Engine technology and displacement		
Engine maximum rated power		

Table 2 A subset of Test Vehicles Activity Data

Portable Emission Measurement Systems (PEMS)

Vocation	Transit	School Bus	Refuse	Delivery	Goods Movement
Number of PEMS Vehicles	10	10	15	20	45
CNG 0.20g	4	3	10	4	12
CNG 0.02g	2	2	3	0	11
Diesel 0.20g	2	2	2	9	16
Diesel (No SCR)	0	1	0	1	2
Other Alt Fuels					
LNG/Diesel HPDI (0.20g)	0	0	0	0	2
Diesel-Electric Hybrid	2	0	0	4	0
Electric	0	0	0	0	0
Fuel Cell	0	0	0	0	0
CNG Hybrid	0	0	0	0	0
Propane	0	2	0	2	0
RD 0.20g	0	0	0	0	2
RD (No SCR)	0	0	0	0	0

Table 3 Allocation of PEMS Tests

- The units continuously measure in-use emissions from the exhaust of test vehicles for a typical day of operation. The PEMS were removed at the end of the day of operation.
- The PEMS used for this study were SEMTECH-DS gas-phase analyzers. This system is 1065 compliant and measures carbon monoxide (CO) and carbon dioxide (CO_2) using a non-dispersive infrared (NDIR) analyzer, total hydrocarbons (THC) using a heated flame ionization detector (HFID), and total NOx emissions using a non-dispersive ultraviolet (NDUV) analyzer.
- A 40 CFR 1065 capable flow meter manufactured by Sensors, Inc. was used for the exhaust flow measurements. This flow meter is compatible with a wide range of PEMS systems. The flow meter is housed in a 3", 4", or 5" diameter pipe that is placed in line with the engine tailpipe exhaust for the equipment being tested.

Figure 2. Exhaust Flow Meter (left) and SEMTECH-DS unit (right)

Chassis Dynamometer Tests

Vocation	Transit	School Bus	Refuse	Delivery	Goods Movement
Number of Chassis Dyno Vehicles	10	6	12	12	20
CNG 0.20g	2	1	6	2	2
CNG 0.02g	2	1	2	0	2
Diesel 0.20g	2	1	2	2	6
Diesel (No SCR)	0	1	0	1	2
Other Alt Fuels					
LNG/Diesel HPDI (0.20g)	0	0	0	0	2
Diesel-Electric Hybrid	1	0	0	2	0
Electric	1	1	0	2	2
Fuel Cell	1	0	0	0	0
CNG Hybrid	0	0	0	0	0
Propane	0	0	0	1	0
RD 0.20g	1	0	2	1	2
RD (No SCR)	0	1	0	1	2

Table 4 Allocation of Chassis Dynamometer Tests

- Chassis dynamometer emissions measurements with UCRs mobile emission laboratory (MEL) will be conducted over test cycles representative of real-world operation.
- Emissions measurements will include regulated emissions, toxics (BTEX & carbonyls), PM mass, size, and number, and NH_3 and N_2O
- Includes both tailpipe and engine out emissions

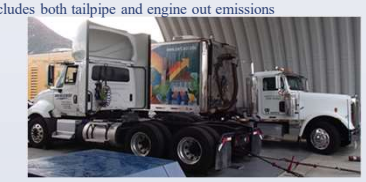

Figure 3. UCR-CECERT chassis dynamometer

Test Cycle	Vocation				
	Transit	School Bus	Refuse	Delivery	Goods Movement
UDDS	X	X	X	X	X
CARB HHDDT				X	X
Modified SCAQMD Refuse Cycle			X		
Port Drayage Cycle (Markov)					X
CBD	X				
OCTA	X				
South Coast School Bus (Markov)		X			
Delivery (Markov)				X	

Table 5 Test Cycles by Vocation

UDDS: Urban Dynamometer Driving Schedule (UDDS), HHDDT: Heavy-Heavy-Duty Diesel Truck Cruise Cycle, CBD: Central Business District cycle, OCTA: Orange County Transit Authority bus cycle

Figure 4a HD-UDDS cycle
Speed: Ave - 18.86 mph, Max 58 mph

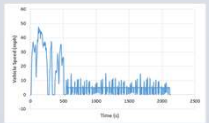

Figure 4b AQMD RTC cycle
Speed: Ave – 9.57 mph, Max 47.6mph

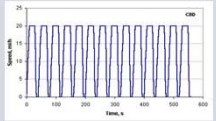

Figure 4c CBD cycle
Speed: Ave-12.6 mph, Max 20 mph

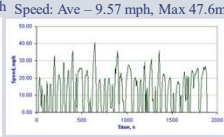

Figure 4d OCTA cycle
Speed: Ave- 12.4 mph, Max 40.6 mph

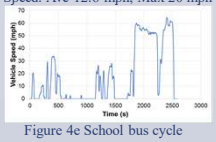

Figure 4e School bus cycle
Speed: Ave- 12.3 mph, Max- 45 mph

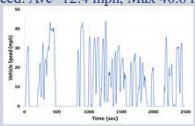

Figure 4f Delivery cycle
Speed: Ave-17.4 mph, Max-64 mph

Real-World Testing

Vocation	Transit	School Bus	Refuse	Delivery	Goods Movement
Number of In-Use Vehicles	0	0	0	0	10
CNG 0.20g	0	0	0	0	2
CNG 0.02g	0	0	0	0	1
Diesel 0.20g	0	0	0	0	4(1)*
Diesel (No SCR)	0	0	0	0	2
Other Alt Fuels					
LNG/Diesel HPDI (0.20g)	0	0	0	0	1
Diesel-Electric Hybrid	0	0	0	0	0
Electric	0	0	0	0	0
Fuel Cell	0	0	0	0	0
CNG Hybrid	0	0	0	0	0
Propane	0	0	0	0	0
RD 0.20g	0	0	0	0	0
RD (No SCR)	0	0	0	0	0

Table 6 Allocation of Real-World Tests

Figure 5 UCR-CECERT Mobile Emission Laboratory

- The routes developed from vehicle activity in the these areas: grocery distribution (goods movement), port drayage (goods movement), parcel delivery (delivery) and waste disposal (goods movement).
- Emissions measured with UCRs MEL, include all the tailpipe emissions measured for the chassis dyno testing, but no engine out emissions.

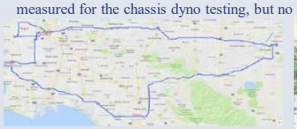

Figure 6a The Grocery Distribution route

Figure 6b The goods movement with elevation change AKA "UPS route"

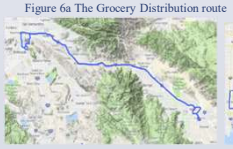

Figure 6c The Highway Goods Movement route

Figure 6d The port-drayage route

STATUS

- ❑ Vehicle recruitment is essentially completed
- ❑ PAMS and PEMS portion of the study is nearly finished.
- ❑ Chassis dynamometer and real-world trailer testing in progress.
- ❑ Completion of the study is expected in the summer or fall.

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CALIFORNIA AIR RESOURCES BOARD

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