Design, Performance, and Measurements Taken in a Heavy Duty Diesel Ambient Dilution Wind Tunnel during DPF Regeneration

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Objectives

1. Real world emission testing of a Parked Regeneration of Diesel Particulate, DPF, Filter. Testing involves both 2007 and 2010 certified DPFs.
2. Design and construct an ambient wind tunnel capable of measuring particulate and gaseous emissions from the regenerations with relatively
3. high dilution ratios.
4. Design a PM sampling system to measure particle size distribution and
5. total particle mass.
6. Analyze the particulate and gaseous emissions emitted during regeneration testing.

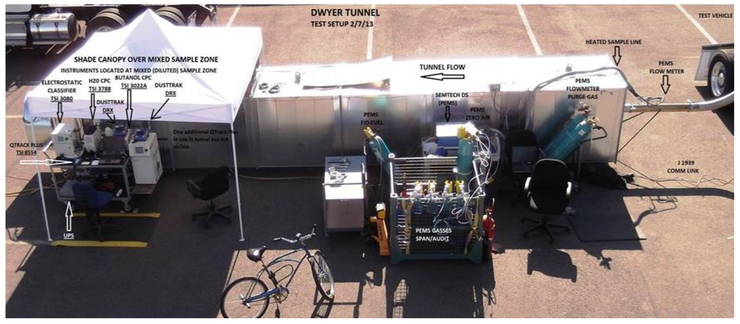


Figure 1. Total view of the experimental testing for a Parked Regeneration.

Materials and Methods

1. Facility – The tunnel was constructed at CARB's Depot Park facility in Sacramento.
2. The ambient flow rate and tunnel temperature and velocity distribution were measured.
3. Two HDDTs were tested with 2007 and 2010 certified emissions systems.
4. The following instrumentation was used, see also Figure 2: SEMTECH-DS PEMS; TSI EEPS 3090; TSI SMPS; DustTrak DRX; DMM 230-A; and Gravimetric Filter media.

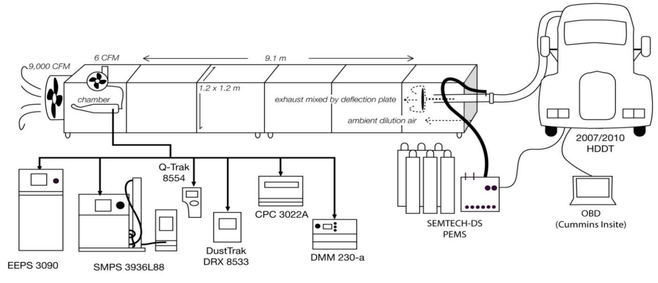


Figure 2. Setup of the parked HDDT, ambient dilution tunnel, and instrumentation.

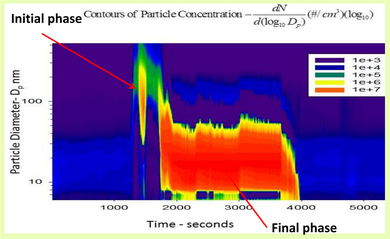
Results

Ambient Wind Tunnel

- The flow quality in the tunnel was very good and delivered a flow rate of 9000 cfm which yielded a dilution ratio of approximately 30/1.
- The sampling tube delivered 160 liters per minute without significant loss of ultrafine particles to the walls of the sampling system.
- The ambient wind tunnel can be expanded to higher flow rates and a longer length for future experimental research.

Particle Size Distribution 2007

- All parked regenerations of the 2007 DPF yielded large amounts of PM.
- The initial and shorter phase of the regeneration yielded large numbers of particles one micron and larger, while the final phase yielded very large numbers of ultra-fine particles. See Figure 3.



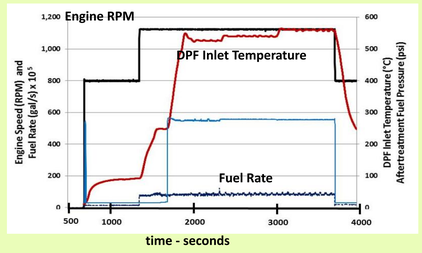
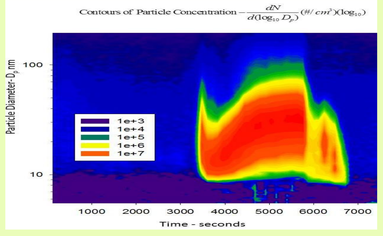


Figure 3. Left. EEPS particle size distribution during a parked regeneration of the 2007 DPF. Right. Some engine and DPF properties during regeneration of the 2007 DPF.

Particle Size Distribution 2010

- All parked regenerations of the 2010 DPF yielded significantly smaller amounts of PM than the 2007 DPF.
- The initial and shorter phase of the regeneration yielded particles one micron and larger, while the final phase yielded very large numbers of
- ultra-fine particles. See Figure 4.



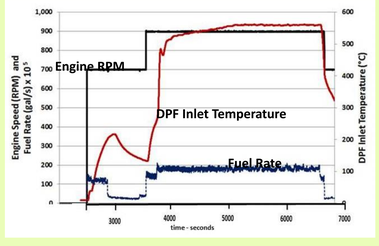


Figure 4. Left. SMPS particle size distribution during a parked regeneration of the 2010 DPF. Right. Some engine and DPF properties during regeneration of the 2010 DPF.

Emission Rates and PM Mass during Regenerations

- Estimates of mass emission rates and PM mass were made for all instrumentation and compared with filter weights.
- All of the instrumentation had PSD deficiencies due to the very wide particle size distributions exhibited during the parked regenerations. However, the use of all instruments gave significant insight into the particles released during regeneration.
- Although the DustTrak DRX did not measure the very large number of ultra-fine particles emitted, it clearly showed that large particles are emitted during the DPF regeneration.
- Figure 5 shows the very large mass emission rates measure during a regeneration of the 2007 DPF.

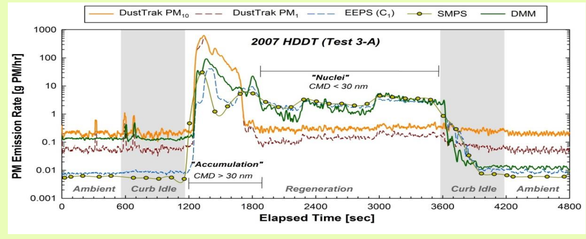


Figure 5 Tunnel emission rates during a parked regeneration of the 2007 DPF

Regulated Emissions during DPF Regeneration

The primary regulated emissions for both the 2007 and 2010 DPFs were PM, NOx , THCs, and Particle Number, PN. In general the largest values occurred at the start of DPF regeneration and decreased during the later phase of the regeneration except for PN. For a reference the total values of these emissions are compared to average values for FTP emissions during ACEs 1 and 2.

Test	Time - sec	PM Total– mg	Total Particle #	NO_x - g
FTP (2007) ACEs	1200	36	$1.17 \cdot 10^{14}$	32.3
16 hr ACEs	57,600	2,275	$5.79 \cdot 10^{16}$	2,610
Test 1 (2007)	3036	12,950	$1.77 \cdot 10^{17}$	396
Test 2 (2007)	1512	1,800	$1.07 \cdot 10^{17}$	232
Test 3 (2007)	2415	8,340	$2.2 \cdot 10^{17}$	292
FTP(2010) ACEs	1200	24	$6.9 \cdot 10^{13}$	2.4
16 hr ACEs	57,600	1,050	$1.75 \cdot 10^{16}$	131
Test 4 (2010)	2730	1,790	$2.12 \cdot 10^{17}$	35.8
Test 5 (2010)	1000	240	$0.92 \cdot 10^{17}$	23

Table 1 Total Parked Regeneration Emission Measurements with a Reference to ACES 1 and 2 Emission Measurements

Acknowledgments – Staff of the Depot Park Facility

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