In-Use On-Road FTP/SFTP Emissions Testing

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Executive Summary

1. Purpose

- Conduct a pilot testing if in-use on-road FTP/SFTP emissions testing with using PEMS, which would be easier and convenient , is feasible, characterize test results, and compare the collected emissions data to MOVES emission estimates.

2. Methodology

- Modification of a test vehicle for the testing with slave acceleration and brake pedals
- Attempts (test runs) to follow FTP/SFTP drive schedules on a 9mile circular track;
- In-use on-road emissions data collection during the test runs; and, then,
- Analyze the collected data and compare the emissions results with MOVES estimates.

3. Findings

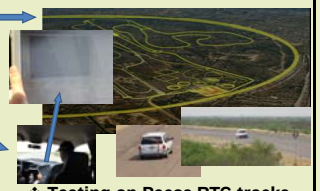
- Two people could maneuver the vehicle to follow drive schedules; one on the slave pedals for speed control and the other on the wheel for driving direction.
- Authors could not perfectly follow the drive schedules, but for most of time (on average, about 90% or more of time) the driven speed profiles were maintained within the tolerance limits. The Drive schedules followed were: FTP (3-phase) and UDDS (urban dynamometer drive schedule), SFTP (US06 and SC03) schedules, and HFET (highway fuel economy test) schedule.
- Measured emissions were compared to MOVES estimates obtained with using the driven speed profiles. In general, measured CO_2 emissions were similar or slightly higher than the MOVES estimates. For other pollutants (CO, NOx, HC, and PM), MOVES estimates were (mostly) much higher than the measured except for CO and THC for US06 (aggressive highway drive schedule).
- Based on the test results, cold-start (i.e., for the first phase of the FTP schedule) increased CO, NOx, and HC emissions significantly and CO_2 emissions slightly.
- Also, operations of air conditioning system (A/C) while following HFET schedule increased NOx and HC emissions significantly, CO emissions modestly, and CO_2 emissions slightly compared to the tests without operating the A/C.

Methodologies

- **Vehicle Modification**
  Slave acceleration and brake pedals on TTI's 1999 Dodge Grand Caravan (in the assistance seat)

❖ **Slave pedals in the test vehicle**

- **Driving with following FTP/SFTP drive schedules**
  - On a 9mile circular test track: Pecos Research and Test Center (RTC)
  - Drive schedules: On the computer screen with using using PEMS software
  - Maneuver by two people: → one on the pedals with following the drive schedules on the screen → the other on the steering wheel



❖ **Testing on Pecos RTC tracks**

- **Emissions Data Collection**
  During the driving, emissions data collected with using 2 portable emissions measurement systems (PEMS):
  - SEMTECH-DS (Sensors, Inc.) for gases
  - Axion (Clean Air Technology Int'l) for PM

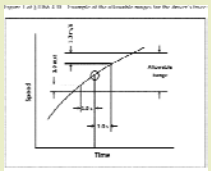
❖ **Two PEMS & other testing equipment including sample probes installed**

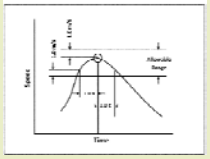
- **Emissions Comparisons**
  Test results vs. MOVES estimates

Results – Speed Profiles

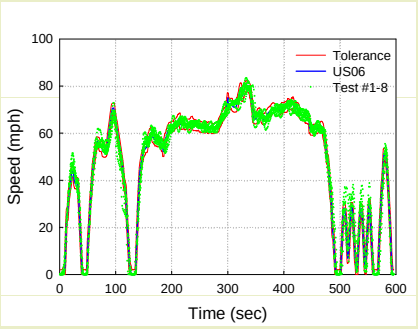
- For each drive schedule, several attempts (test runs) were conducted to follow the drive schedule within the acceptable tolerance set on EPA's 40 CFR 86 & 1066.

Drive schedule	Number of test runs	Frequency within the acceptable tolerance based on average speed profiles
FTP (3-phase)	4	88%
UDDS	9	88%
US06	8	90%
SC03	4	90%
HFET	9	97%





❖ **The acceptable tolerance ranges on 40 CFR 1065**



❖ **Speed profiles for US06 (a SFTP schedule)**

Results – Measured & MOVES Estimates

	Average Emission Rate (g/mi)				
	CO_2	CO	NOx	THC	PM
FTP (3-phase)	626	2.88	0.69	0.35	0.001
UDDS	615	1.17	0.42	0.11	UD*
US06	572	42.95	0.62	0.53	UD*
SC03	701	2.28	0.59	0.07	UD*
HFET	385	0.75	0.20	0.03	UD*

* UD: under the detection limits.

- MOVES emission rate estimates were obtained using the driven speed profiles, temperature, relative humidity, and other inputs (such as geological location and fuel type) based on the test locations and test date.
- Then, the measured emission rates were compared to the MOVES estimates

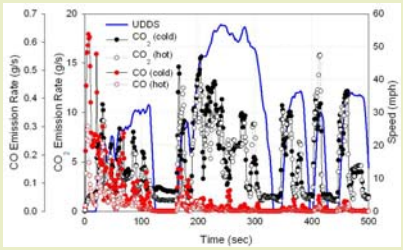
	Ratio (Measure Emission Rates/MOVES Estimates)				
	CO_2	CO	NOx	THC	PM
FTP (3-phase)	116%	29%	40%	72%	23%
UDDS	109%	11%	22%	21%	N/A*
US06	105%	263%	22%	105%	N/A*
SC03	126%	18%	26%	14%	N/A*
HFET	94%	9%	12%	10%	N/A*

* N/A: not applicable (because that the measured PM emission rates were under the detection limits).

Test Results – Cold-Start Effects

	Average Emission Rate (g/mi)				
	CO_2	CO	NOx	THC	PM
UDDS (cold)	652	3.46	0.79	0.48	0.001
UDDS (hot)	615	1.17	0.42	0.11	UD*
	Ratio (UDDS(cold)/UDDS(hot))				
	1.1	3.0	1.9	4.4	N/A**

* UD: under the detection limits.
** N/A: not applicable (because that the measured PM emission rates were under the detection limits).



❖ **Cold-start effects shown for the first phase of UDDS**

Test Results – A/C Effects (for HFET schedule)

- Authors followed HFET drive schedules with and without operating the A/C.

	Average Emission Rate (g/mi)				
	CO_2	CO	NOx	THC	PM
HFET (A/C)	457	1.15	0.47	0.10	UD*
HFET (No A/C)	385	0.75	0.20	0.03	UD*
	Ratio (HFET(A/C)/HFET(No A/C))				
	1.2	1.5	2.4	3.2	N/A**

* UD: under the detection limits.
** N/A: not applicable (because that the measured PM emission rates were under the detection limits).

Conclusions

- With the modified vehicles, authors could follow the drive schedules closely on-road (on a 9-mile circular track at Pecos RTC in Pecos, TX; on average, about 90% or more driven speed profiles were within the tolerance limits.
- During the test runs, using PEMS, emissions data were collected and compared with MOVES estimates obtained with using the driven speed profiles.
  - Generally, measured CO_2 emissions were similar or slightly higher than the MOVES estimates
  - For other pollutants (CO, NOx, HC, and PM), MOVES estimates were mostly higher than the measured with only exception that CO and THC emission rates measured during the US06 test runs. Authors believe that the aggressive driving during the US06 test produced such higher CO and THC emissions.
  - The comparisons between cold-start and hot UDDS test results showed that the cold-start increased emissions of CO, NOx, and HC significantly and CO_2 emissions slightly.
  - The HFET test results showed that the operation of A/C during the tests increased NOx and HC emissions significantly, CO emissions modestly, and CO_2 emissions slightly.
- To expand this project, additional studies are needed in the following areas:
  - Automated driving to follow drive schedules 100% within the tolerance limits
  - Detailed comparisons with MOVES (including Opmode emission rate comparisons)
  - More tests and incorporation of test results into MOVES

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