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Measurement of emissions from independent bus heaters

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Background:

Independent bus heaters heat the engine coolant, which heats both the engine and the cabin. They operate when the bus is started and also when there is insufficient waste heat from the engine. With more efficient powertrains, there will be less heat.

The engine exhaust emissions are subject to strict regulations. The heaters are not. There is little data on emissions from independent heaters. So who knows whether an electric bus with a diesel heater produces less emissions than a diesel bus with a DPF?

Goal:

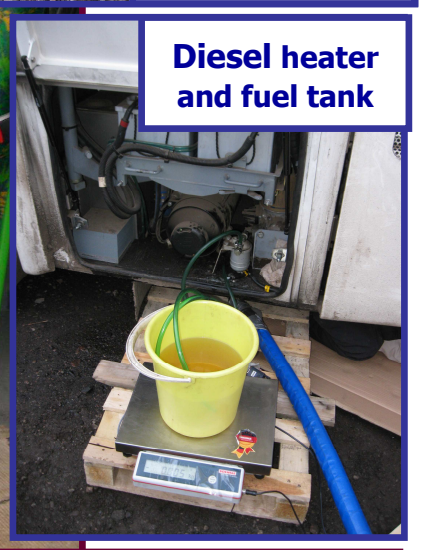
Evaluation of emissions of independent CNG and diesel bus heaters on production buses.

Approach:

- Two recent production city buses (SOR Libchavy, Czech Republic) used: CNG bus with a CNG heater and diesel bus with a diesel heater
- Buses left outside overnight at ~ 2 °C
- Heater started in the morning and let run for approximately one hour until "stabilized cycling" reached (engine off, cabin heaters on, bus doors open)
- Portable on-board emissions monitoring system (PEMS) used to measure composition of heater exhaust
- Heater fed from a separate fuel tank placed on electronic scale to monitor real-time fuel consumption
- Heater exhaust flow calculated from fuel consumption and measured air-fuel ratio

Results & Discussion:

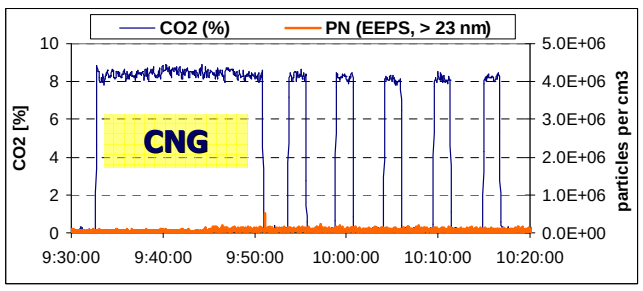
- Heater runs at one power level, switches off when desired coolant temperature reached, switched on when coolant temperature drops
- Fuel consumption steady
  - diesel fuel 2.42 kg/h or 102 MJ/h at 42 MJ/kg
  - CNG 2.35 kg/h or 110 MJ/h at 47 MJ/kg
- Concentrations of selected pollutants shown in graphs
- Particle, HC, CO emissions dominated by spikes during startup, NO and NO_2 emissions steady
- Average values expressed per kg of fuel, per MJ, and using "average heater consumption" of 25 km/liter (diesel, CNG calculated on energy equivalent basis), per km driven (see table)
- Rough comparison per kg of fuel basis with Euro 6 limits (see table), however, these do not apply to temperatures at which heaters are used
- Particle emissions relatively low
- CNG heater had much lower particle emissions
- Gaseous emissions are not negligible
- Measurement using PEMS successful & feasible

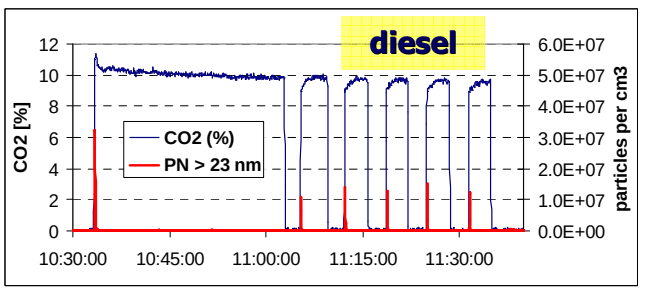


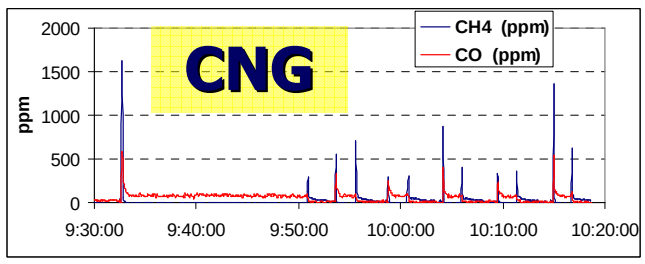
Portable emissions monitoring system (PEMS)

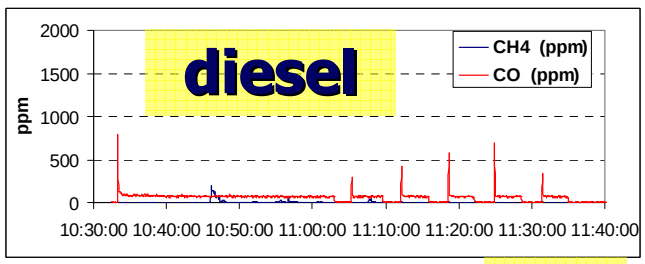
Particle size distributions: EEPS model 3090 & Rotating disc microdiluter 150°C heated sampling line

Gaseous compounds: FTIR (Fourier transform infra-red) spectrometer, 6 m path length, 121°C, ~ 25 kg, 0.5 cm^{-1} resolution, 2-3 s response time









Gaseous compounds Measured with FTIR, NMHC data only qualitative	max. measured concentration (ppm)		mean emissions g per kg of fuel		g / MJ (CNG 47 MJ/kg diesel 42 MJ/kg)		g / km (0.04 liters of diesel per km)		*Euro 6 "equivalent" WHSC/WHTC at 250 g/kWh, 25 C g per kf guel*
	CNG	diesel	CNG	diesel	CNG	diesel	CNG	diesel	
Methane	1657	200	18.6	0.40	0.40	0.01	0.55	0.01	*Methane: 2.0*
Ethane	15	5	0.42	0.13	0.01	0.00	0.01	0.00	
n-alkanes	20	16	0.10	1.05	0.00	0.02	0.00	0.03	
aromatics	15	10	0.04	0.40	0.00	0.01	0.00	0.01	*THC (diesel),*
Formaldehyde (HCHO)	34	<DL	0.54	<DL	0.01	<DL	0.02	<DL	*NMHC (CNG):*
Sum of resolved HC (NMHC for CNG)	1872	315	1.09	1.98	0.02	0.05	0.03	0.07	*0.64/1.60*
Carbon monoxide (CO)	571	771	2.10	3.44	0.04	0.08	0.06	0.11	*CO: 1.5/4.0*
Nitrogen oxide (NO)	37	151	0.64	3.60	0.01	0.09	0.02	0.12	
Nitrogen dioxide (NO2)	55	51	0.97	0.90	0.02	0.02	0.03	0.03	
Nitrogen oxides (NOx)			1.60	4.49	0.03	0.11	0.05	0.15	*NOx: 1.60/1.84*
Nitrous oxide (N2O)	1.3	4.1	<DL	<DL	<DL	<DL	<DL	<DL	
Ammonnia (NH3)	0.8	0.6	<DL	<DL	<DL	<DL	<DL	<DL	
Particles > 23 nm	(#/cm3)		# / kg fuel		# / MJ		# / km		***particles / kg fuel***
from EEPS distribution	CNG	diesel	CNG	diesel	CNG	diesel	CNG	diesel	***PMP methodology***
24-560 nm including volatiles	2.1E+05	3.2E+07	1.9E+10	1.7E+12	4.1E+08	4.0E+10	5.7E+08	5.5E+10	*2.4/3.0E+12*

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