



Ultrafine and Nanoparticle ELPI Number Distribution Emissions from Hybrid-Electric and Conventional Diesel Buses Using Ultra-low Sulfur Diesel

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Introduction

- Ultrafine particles (<100 nm) and nanoparticles (< 50 nm) have been suggested as potential health hazards because their small size allows them to travel deeply into the lung.
- Number size distributions become more important than mass distributions when looking at the actual adverse effects on human health of these particles.
- Heavy-duty vehicles contribute one quarter of PM emissions from mobile sources.(1)
- Using ultra-low sulfur fuel, diesel particle filters and hybrid diesel buses have been suggested as solutions for reducing heavy-duty vehicle emissions.

(1)Environmental Protection Agency (2000)EPA 420-F-0057

Experimental Setup

Vehicle Experimental Conditions

- Buses Tested:**
 - Two conventional diesel buses:
 - 280 HP - Year 2002 – Detroit Diesel Series 40
 - Two hybrid electric-diesel buses:
 - 280 HP - Year 2003 - Cummins ISL
 - Parallel drive
 - Allison Electric Drive Transmission
- On-road Driving Routes:**
 - Steady State Freeway
 - Distance: 33 miles
 - Average speed: 60 mph
 - Stop-and-go:
 - Distance: 10.4 miles
 - Average speed: 30 mph
- Fuel:**
 - Ultra-low sulfur diesel (ULSD)

ELPI Experimental Setup

- Electrical Low Pressure Impactor (ELPI) :
 - Dekati
 - 30 lpm
 - 1-sec resolution
 - Filter stage (F) – lower cut 7 nm
 - Size range focus in this work: 7 – 100 nm
- Single-stage mini-diluter

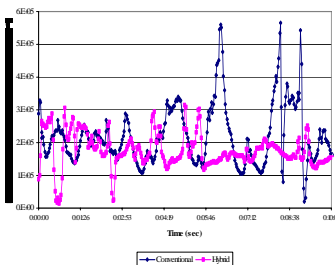


Note: All reported results are uncorrected for dilution ratio

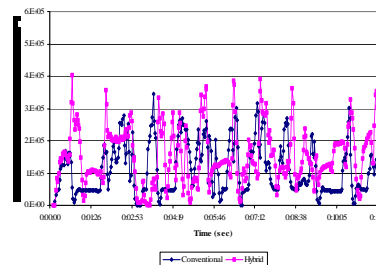
Results

1. Raw data ELPI sec-by-sec emissions on two different routes for Filter Stage (7-29 nm)

1A. Freeway



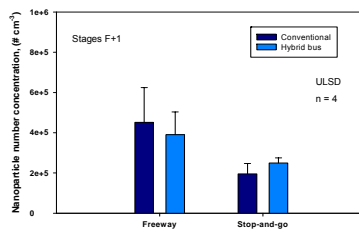
1B. Stop-and-go



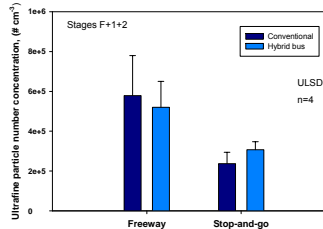
- Variability is higher on stop-and-go route.

2. Mean particle number concentration – all buses, all days

2A. Nanoparticle emissions



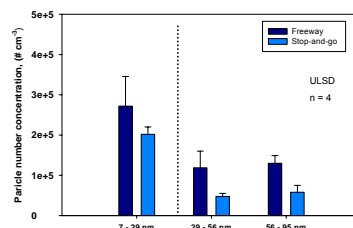
2B. Ultrafine particle emissions



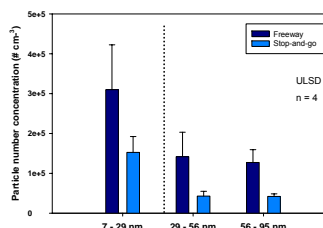
- During highway operation, the hybrid bus had 12% lower nanoparticle emissions and 10% lower ultrafine particle emissions compared to the conventional bus.
- For both buses, freeway emissions were higher than during the stop-and-go route.

3. Importance of measurements with ELPI filter stage (7 - 29 nm):

3A. Hybrid electric-diesel bus



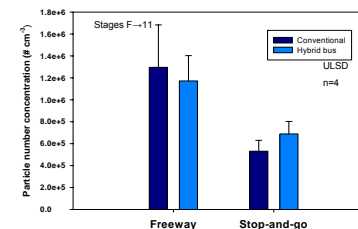
3B. Conventional diesel bus



- Emissions in the smaller size range (7-29nm) for the hybrid bus were similar to those of the conventional bus.
- The difference in mean number emissions between the tested routes was greater for the conventional diesel bus than for the hybrid when analyzing the three ultrafine stages (7-95 nm).
- The filter stage collected 53% of the ultrafine emissions for the highway and 65% for the stop-and-go route.

Results-Continued

4. Average total ELPI number concentration (7 nm – 10 μm)



- During freeway operation, the hybrid had 10% lower mean total particle emissions compared to the conventional bus.
- During stop-and-go operation, the mean particle emissions of the hybrid bus were higher than conventional bus by 29%.

Conclusions

- In real-world driving, the hybrid bus configuration reduced the formation of nanoparticles during freeway driving by 12% when compared to the conventional diesel bus. The standard deviation for freeway conditions was lower for the hybrid bus, suggesting more consistent emission levels.
- The use of the filter stage for the ELPI helps the study of nanoparticles smaller than 29 nm and will become more useful in the continuing effort of defining testing procedures and setting particle number emissions regulations.
- Preliminary tests show that the hybrid bus emissions of ultrafine and nanoparticles were greater than those of the conventional diesel bus during the stop-and-go route.

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