Evaluation of Passive and Active Soot Filters for Removal of Particulate Emissions from Diesel Engines

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Outline

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  – catalyzed soot filter
  – electrically regenerated soot filter

• Emissions Sampling Techniques and Testing
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Purpose of Program

- Demonstrate catalyzed soot filters and active soot filters for reducing particulate matter (PM) emissions
- Demonstrate CO and hydrocarbon reduction with catalyzed soot filters
- Survey DoD diesel engine operating characteristics to establish the range of catalyzed soot filter applicability
- Conduct 8 month field test of eight low precious metal catalyzed soot filters on non-tactical buses and trucks at Camp Pendleton and Fort Irwin
- Conduct 4 month field test of two electrically regenerated soot filters on mobile generator-sets at Edwards Air Force Base
- Measure chassis dynamometer emissions with the University of Utah and the California Air Resources Board
Catalyzed Soot Filter

- The engine exhaust enters the filter where it is forced to flow through a porous wall

- Soot collects in wall and also forms a layer on the catalyst washcoat
Soot Filter Operation—Electrically Regenerated Soot Filter

• uncatalyzed sintered metal fibers act as both the filtration media and the resistive element for electrical regeneration

• the media is assembled into several cartridges, that are regenerated sequentially when required

• electrical power is supplied by gen-set output for power generating applications or by second or larger alternator for mobile applications
Emissions Sampling Techniques-U of Utah

- PM reduction was determined by tests with and without filters installed
- Tests were conducted at beginning and end of field tests to measure any change in filtration capability
- Near real-time measurements were made of:
  - particle distributions (14.6 nm-661 nm) by scanning mobility particle sizer
  - total particle count (< 10 µm) by optical particle counter
  - carbon mass by photoacoustic analyzer
  - PAH by photoelectric aerosol sensor
Emissions Sampling Techniques-CARB

- Chassis dynamometer with constant volume sampling (CVS) system
- Gravimetric analysis to determine filtration efficiency

original exhaust system

CSF installed
## Soot Filters Tested

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Year</th>
<th>Engine</th>
<th>Technology</th>
<th>Emissions Tests Run</th>
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</thead>
<tbody>
<tr>
<td><strong>Camp Pendleton</strong></td>
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<tr>
<td>Thomas Bus-00582</td>
<td>1999</td>
<td>CAT 3126, 330HP</td>
<td>catalyzed soot filter 11.25&quot; x 12&quot; 5 g/ft³ PM</td>
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<td>Bluebird Bus-294509</td>
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<tr>
<td><strong>Ft. Irwin</strong></td>
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<td>Thomas Bus-00172</td>
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<td><strong>Edwards AFB</strong></td>
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<td>1998</td>
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</table>
U of Utah Test Findings-Degreening of Filter

- When the filter is new, filtration ability increases with increased soot loading
University of Utah Results-Camp Pendleton

**Filtration efficiency remains > 90% after 7 month field evaluation**

**Thomas Bus 00583- Prior to Field Test**

**Thomas Bus 00583-Following 7 Month Field Test**

*Engine Load/Speed [rpm]*

*% Reduction*

- PAH
- Carbon
- > 300 nm (LASAIR)
- 14.6 nm-661 nm

- < 10 um (DustTrak)
- 14.6 nm-661 nm
CARB Transient Test Using Camp Pendleton Bus

- Thomas Bus 00583 was tested at CARB's emissions testing facility in L.A.
- Three transient cycles were run on chassis dynamometer: Central Business District (CBD), New York Bus Cycle (NYBC), and Urban Dynamometer Driving Schedule (UDDS)
CARB Test-U of Utah's results

- The University of Utah sampled simultaneously to CARB

- Utah's results for particulate reduction are within 2.5% of CARB's (by $PM_{10}$ vs. gravimetric)
Electrically Regenerated Soot Filter Testing-Edwards AFB

- Installation of systems on two 72 kW generator-sets at Edwards Air Force Base, used for ground maintenance of aircraft
- Engines were Cummins B5.9-185 HP
- Field test duration was 4 months
- 3 steady-state test points were chosen for Utah emissions measurements:
  - high idle
  - 40% load
  - 75% load
Electrically Regenerated Soot Filter Testing-Edwards AFB

Average particle (<10 µm) reductions were 62%
Electrically Regenerated Soot Filter-Post Test Inspection

- Low filtration efficiencies attributed to gasket leaks between the cartridges and a failed cartridge on DX-02
- On DX-04 unit, 30% of gaskets had leaked
- Overly aggressive regeneration strategy may have resulted in low efficiencies due to lack of soot layer build-up
- Improved design will be tested at Cummins
Conclusions

• Results met project objectives for emissions reduction
• The catalyzed soot filters demonstrated 95% to 98% filtration efficiency in removing total particulate matter, and 72% to 89% THC and 49% to 92% CO reductions during various transient tests
• On average, the electrically regenerated soot traps filtered 62% of the particulates smaller than 10 µm. Lower than expected filtration efficiency is attributed to gasket leakage and a failed cartridge. An improved design will be tested at Cummins
• Particulate measurement devices used by the U of Utah, such as particle counters, are more mobile than typical CVS systems, and can perform near real-time measurements. Particulate reduction numbers show good agreement with CVS measurements
• Filters should be degreened before testing to allow stable measurements to be made
Acknowledgements

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