Development of a Dimethyl Ether (DME)-
Fueled Shuttle Bus

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Ed Heydorn
Air Products and Chemicals, Inc.
DME-Fueled Shuttle Bus Partners

- Air Products and Chemicals, Inc.
- US Department of Energy, National Energy Technology Laboratory
- Pennsylvania Department of Environmental Protection
- Navistar International
- Champion Motorcoach
- DuPont Flourochemicals
- DuPont Dow
- Caterpillar, Inc.
- Parker Racor
- Clean Air Technologies, Int’l
Objectives

- Demonstrate DME-Diesel Fueling in a Campus Shuttle and Operate the Shuttle on DME-Diesel
- Through Laboratory and Field Studies, Determine How to Maximize the Amount of DME in the Blend without Sacrificing Fuel System Integrity
Laboratory DME-Diesel Fueling System

- Fuel return line pressure @ 120 psi
- Diesel-DME blend
- Heat Exchanger
- Engine cylinder head
- Pump
- Fuel filter
- Water separator
- Pressure Relief valve
- Line pressure 120 psi

Back pressure regulator
Navistar T444E V-8 Turbodiesel
After DME-Diesel Conversion
Particulate Matter Results per unit fuel consumed, g/kg fuel

- Baseline
- 5% oxygen by DME
- 10% oxygen by DME
NOx Results per unit fuel consumed, g/kg fuel

- Baseline
- 5% oxygen by DME
- 10% oxygen by DME

Mode

- NOx Results per unit fuel consumed, g/kg fuel

1 2 3 4 5 6 7 8

Mode
CO Results per unit fuel consumed, g/kg fuel

Graph showing CO results per unit fuel consumed for different modes and oxygen concentrations.

- Baseline
- 5% oxygen by DME
- 10% oxygen by DME
HC Results per unit fuel consumed, g/kg fuel

- Baseline, 49 state fuel
- 5% oxygen by DME
- 10% oxygen by DME

Mode

Hydrocarbon emissions, g/kg fuel
HEUI Fuel Injector

- Electronic Signal from Engine Control
- Volume of fuel is delivered per:
  - Injection Timing
  - Injection Pressure
Fuel Injection Timing
(Degrees Before Top Dead Center)

- Baseline
- 5% Oxygen
- 10% Oxygen
High Pressure Viscometer
Viscosity of DME-Diesel Blends at Pressures from 500 to 2500 psi
Blend Response of Viscosity to DME Addition at Various Pressures

![Graph showing the blend response of viscosity to DME addition at various pressures. The graph plots DME content in Blend, Wt. % on the x-axis and Viscosity, cSt on the y-axis. Three lines represent different pressures: 500 psig, 1500 psig, and 1000 psig. As the DME content increases, the viscosity decreases at all pressures.](image-url)
1. Fill Diesel Tank
2. Transfer Diesel to Mixture Tank while Venting Helium and Leftover DME
3. Transfer DME into Mixture Tank
4. Pressurize Mixture Tank with Helium to 90 – 120 psi
5. Start Engine and then Start Circulation Pump, which Keeps the Rail at 250 psi
Shuttle Bus DME-Diesel Fueling System

Fuel Coolers

Circulation Pump

DME Fueling Door

Mixture Tank:
40 gallon Recreation Vehicle Tank for LPG
Staff Shuttle

Monday through Friday 7:20 am to 6:00 pm
Specifications: Service: every 20 minutes;
Vehicle: (1) 20 passenger Van/Bus with wheelchair lift

Effective 11/1/01 DSS2859wh

Staff Shuttle Time Table—Minutes Past the Hour

<table>
<thead>
<tr>
<th>Stops</th>
<th>00</th>
<th>20</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Plant</td>
<td>00</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>I.M. Building</td>
<td>02</td>
<td>22</td>
<td>42</td>
</tr>
<tr>
<td>Computer Bldg</td>
<td>03</td>
<td>23</td>
<td>43</td>
</tr>
<tr>
<td>Pollock/Bigler</td>
<td>04</td>
<td>24</td>
<td>44</td>
</tr>
<tr>
<td>Classroom Bldg</td>
<td>05</td>
<td>25</td>
<td>45</td>
</tr>
<tr>
<td>Osmond Building</td>
<td>06</td>
<td>26</td>
<td>46</td>
</tr>
<tr>
<td>Old Main</td>
<td>07</td>
<td>27</td>
<td>47</td>
</tr>
<tr>
<td>Hosler Building</td>
<td>08</td>
<td>28</td>
<td>48</td>
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<tr>
<td>Rec Hall</td>
<td>09</td>
<td>29</td>
<td>49</td>
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<tr>
<td>Pattee Library</td>
<td>10</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Weaver Building</td>
<td>11</td>
<td>31</td>
<td>51</td>
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<tr>
<td>Creamery</td>
<td>12</td>
<td>32</td>
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<tr>
<td>Mitchell Building</td>
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<td>33</td>
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<tr>
<td>Flower Garden</td>
<td>15</td>
<td>35</td>
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<tr>
<td>Business Services</td>
<td>15</td>
<td>35</td>
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<tr>
<td>Procurement Services</td>
<td>15</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Support Bldg I &amp; II</td>
<td>16</td>
<td>36</td>
<td>56</td>
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<tr>
<td>Dairy Barns</td>
<td>19</td>
<td>39</td>
<td>59</td>
</tr>
</tbody>
</table>
DME-Fueled Shuttle Bus
Faculty/Staff Shuttle Route
Emissions Testing at PTI Track

Exhaust Sampling Line

CATI Portable Emissions Analyzer
Manhattan cycle on 14 volume % DME balance diesel

Manhattan cycle on 25 volume % DME balance diesel
Manhattan cycle - PM [mg/test]

Manhattan cycle - NO

Manhattan cycle - HC [g/test]

Manhattan cycle - CO [g/test]
Transient PM Emissions During Manhattan Cycle

PM (g/sec)

Time (seconds)

0%
14%
25%
Observations and Current Status

- **Shuttle Bus Deployed on Campus on June 5, 2002**
  - Fuel Circulation Pump is a Weak Link in the System; Damaged Pump Replaced in Late June Solved Problems
  - Some Operational Issues Observed – Mostly Due to Heating of the Fuel in the Rail when Shifting from Heavy Load Operation to Idle; Hot Re-Start is Sometimes Difficult; Pull-Out into Traffic More Difficult at 25 wt.% DME

- **Fueling Procedures Working Smoothly and Fueling “Station” is Functioning Well**
  - Hand-Off of Fueling Responsibilities to Penn State’s Fleet Operations is Unlikely

- **Target for Shuttle Operation Remains 25 wt.% DME-Diesel Blend, but Best Observed Operation is at 8-12 wt.%**

- **PM Emissions Decrease 80% with 25 vol.% DME-Diesel Blend in the Shuttle Bus Tests with Clean Air Technologies Analyzer**

- **The Shuttle Bus will Operate until September 30, 2002 on DME-Diesel Blends, mostly on 12 wt.% DME**