Diesel Fuel Comparison Study Workshop

October 14, 2008

California Environmental Protection Agency
Air Resources Board
Agenda

Background
• AB679 (Calderon)
• Legislative Intent
• Project Schedule
• Revisions to the draft Test Plan
  • Objective & Scope
  • Proposed Test Engine/Cycle Selection
  • Proposed Test Vehicle/Cycle Selection
• Diesel Fuel Properties
  • CARB ULSD
  • Federal ULSD
• Future Discussion Topics
• Next Meeting
• Assembly Bill 679 (Calderon)
  – Requires ARB to convene a panel of interested parties to develop a test protocol
  – Test program shall measure the emissions benefits of CARB diesel fuel
  – Conduct test program
  – Report the results to the Senate Committee on Environmental Quality, the Senate Committee on Transportation and Housing, and the Assembly Committee on Transportation
• Legislative Intent
  – Federal ultralow diesel may produce emissions benefits close to those of CARB diesel
  – Thought to be especially significant for HD diesel engines employing new technology (e.g. EGR)
  – Higher cost of CARB diesel is a competitive disadvantage for CA trucking industry
  – Develop and implement test plan to measure differences in NOx & PM emissions between CARB diesel and Federal ultralow diesel
Project Schedule

• Contract suspended due to budget issues
• Revised draft test plan available for review and comment
  http://www.arb.ca.gov/fuels/diesel/dieselcomp/dieselcomp.htm
• Continuing to review fuel properties, soliciting comments
• Emissions Testing – scheduled to begin in late 2008
  • Coordinating schedules with Biodiesel Research Program
Revised Draft Test Plan

• Assessment of the Emissions from the Use of California Air Resources Board Qualified Diesel Fuel in Comparison with Federal Diesel Fuels – Overview

Dr. Thomas D. Durbin
University of California, Riverside
CE-CERT
Objective & Scope

• Design & implement test program to define the emissions benefits of CARB diesel fuel versus several different Federal diesel fuel blends
  – Proposed scope:
    • Engine dyno – Test 3 (4 if 2010 engine is available) engines, two test cycles
    • Chassis dyno – 9 test vehicles, 1 test cycle, ARB HHDDT cruise, multiple test repetitions per fuel
    • Fuels – 1 ‘representative’ CARB diesel, 2 Federal diesel ‘blends’
    • Emissions measurements – THC, CO, CO2, NOx, NO, PM
Test Engine Selection - Engine Dynamometer Testing

- Test Engine 1 – Selection Confirmed
  - 2006 Cummins ISM 370, 10.8 liter, EGR
  - EFN: 6CEXH0661MAT

- Test Engine 2 – Selection Confirmed
  - 2007 DDC MBE4000, 12.8 liter
  - EFN: 7DDXH12.8DJA
  - EGR+OC+PTOX

- Test Engine 3 – Selection Confirmed
  - 1991 DDC Series 60, 11.1 liter
  - EFN: MDD11.1FZAZ
Test Engine Selection - 2010 Compliant Engine

• Currently working with the Engine Manufacturers Association
  – Seeking a 2010 compliant engine for inclusion in the engine dynamometer test matrix
  – Would include NOx after treatment
  – We would likely test a pre-production or prototype engine
Test Cycle Selection – Engine Dynamometer

• Two test cycles selected

  – First Cycle: Heavy Duty Federal Test Procedure (FTP) Transient Cycle
    • Currently used for emission testing of HDD on-road engines

  – Second Cycle: ARB Heavy Heavy-Duty Diesel Truck (HHDDT) cruise cycle
    • 2083 second cycle with 40 mph average speed
    • Translated cycle, can be used on engine or chassis dynamometers
    • Engine dyno results could be confirmed by chassis testing of in-use HDD fleet
Engine Dynamometer Test Matrix

- 6 test replicates per test day, 3 morning & 3 afternoon
- 2 fuels per test day
- 2 test cycles, 36 tests per engine

<table>
<thead>
<tr>
<th>Test Day</th>
<th>Morning Schedule (3 replicates)</th>
<th>Afternoon Schedule (3 replicates)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>CCC</td>
<td>AAA</td>
</tr>
<tr>
<td>Day 2</td>
<td>AAA</td>
<td>BBB</td>
</tr>
<tr>
<td>Day 3</td>
<td>BBB</td>
<td>CCC</td>
</tr>
<tr>
<td>Repeat</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C=CARB diesel fuel, A=Federal A diesel fuel, B=Federal B diesel fuel
Proposed Test Vehicle Selection - Chassis Dynamometer Testing

- Propose testing a matrix of 9 vehicles
  - Matrix should be based on CA’s in-use HD on-road fleet
  - Should incorporate a range of technologies if possible
  - Engine dynamometer test results will help shape final matrix

- Vehicle acquisition
  - Advertisement
  - Rental / lease
  - Private owners

- Resources available for vehicle recruitment
Test Cycle Selection – Chassis Dynamometer

• ARB HHDDT cruise cycle selected
  – One test cycle selected to increase the number of test replicates per fuel type
  – Test cycle directly tied to engine dynamometer test results
  – 12 test replicates per fuel type
## Chassis Dynamometer Test Matrix

- 6 test days per vehicle
- 12 tests per fuel, 36 tests per vehicle

### Test Day
<table>
<thead>
<tr>
<th>Morning Schedule (3 test replicates)</th>
<th>Afternoon Schedule (3 test replicates)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARB HHDDT Cruise Test Cycle</strong></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>CCC</td>
</tr>
<tr>
<td>Day 2</td>
<td>AAA</td>
</tr>
<tr>
<td>Day 3</td>
<td>BBB</td>
</tr>
<tr>
<td>Repeat once</td>
<td></td>
</tr>
</tbody>
</table>

C=CARB diesel fuel, A=Federal A diesel fuel, B=Federal B diesel fuel
Diesel Fuel Selection

• Propose using three test fuels:
  – Representative or ‘Average’ CARB ULSD
  – Representative or ‘Average’ Federal ULSD
  – Federal ULSD with fuel properties that represent the upper/lower boundaries, affecting emissions characteristics
## CARB Diesel Fuel Properties
### Average Pool Properties\(^1\): Summer 2006\(^2\)

<table>
<thead>
<tr>
<th>Property</th>
<th>CARB ULSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>38.5</td>
</tr>
<tr>
<td>Rel Density (60/60°F)</td>
<td>0.8324</td>
</tr>
<tr>
<td>T50 (°F)</td>
<td>479.3</td>
</tr>
<tr>
<td>Aromatics (v/v)</td>
<td>17.6</td>
</tr>
<tr>
<td>Cetane Number (additized)</td>
<td>51.3</td>
</tr>
<tr>
<td>Cetane Number (clear)</td>
<td>49.1</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>4.4</td>
</tr>
</tbody>
</table>

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\(^1\) All data represent volume weighted averages.

\(^2\) Summer 2006: Refers to the period from June 1 through September 20, 2006.
CARB Diesel Fuel Properties

Average Properties¹: Summer 2007²

<table>
<thead>
<tr>
<th>Property</th>
<th>CARB ULSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>37.0</td>
</tr>
<tr>
<td>Rel Density (60/60°F)</td>
<td>0.8398</td>
</tr>
<tr>
<td>T50 (°F)</td>
<td>490.5</td>
</tr>
<tr>
<td>Aromatics (v/v)</td>
<td>15.9</td>
</tr>
<tr>
<td>Cetane Number (additized)</td>
<td>51.6</td>
</tr>
<tr>
<td>Cetane Number (clear)</td>
<td>-</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>3.1</td>
</tr>
</tbody>
</table>

¹ Data average of 12 - 50 samples taken from CA refineries, not volume weighted.
² Summer 2007: Refers to the period from May 21 through August 16, 2007.
### ‘Average’ CARB ULSD Properties

Proposed Ranges for Test Fuel Selection

Revised October 2008

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>38 - 39</td>
</tr>
<tr>
<td>T50 (°F)</td>
<td>470 – 490</td>
</tr>
<tr>
<td>Aromatics (v/v)</td>
<td>16 - 20</td>
</tr>
<tr>
<td>Cetane Number (additized)</td>
<td>50 - 54</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>&lt;5</td>
</tr>
</tbody>
</table>
‘Average’ Federal ULSD Properties Proposed Ranges for Test Fuel Selection (Federal – A)

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>35 - 37</td>
</tr>
<tr>
<td>T50 (°F)</td>
<td>490 – 510</td>
</tr>
<tr>
<td>Aromatics (v/v)</td>
<td>27 - 33</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>44 - 46</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>&lt;15</td>
</tr>
</tbody>
</table>

CARB vs Federal Diesel Fuel Study
‘Boundary’ Federal ULSD Properties
Proposed Ranges for Test Fuel Selection
(Federal – B)

<table>
<thead>
<tr>
<th>Property</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>API Gravity</td>
<td>33 - 34</td>
</tr>
<tr>
<td>T50 (°F)</td>
<td>-</td>
</tr>
<tr>
<td>Aromatics (v/v)</td>
<td>35 - 40</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>40 - 42</td>
</tr>
<tr>
<td>Sulfur (ppm)</td>
<td>&lt;15</td>
</tr>
</tbody>
</table>
Future Discussion Topics

• Soliciting comments regarding range of fuel properties for study test fuels
• Continuing to seek a 2010 compliant engine for inclusion in the fuel comparison study
• Continued schedule coordination with Biodiesel research project
Next Meeting

• Tentatively scheduled for December 2008

• Visit our web site
  – http://www.arb.ca.gov/fuels/diesel/dieselcomp/dieselcomp.htm
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