Biodiesel and Renewable Diesel Emissions Study (Regulated Emissions)

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Objectives

To look at the impact of blend levels, feed stocks, and driving cycles on regulated emissions and a global warming gas.

- **Blend Levels** (20%, 50%, 100%)
- **Feed Stocks**
  - Soy-based biodiesel
  - Animal fat biodiesel
  - Renewable diesel
- **Driving Cycles** (UDDS, Cruise)
- **Regulated Emissions**
  - PM, NOx, CO, THC
- **Global Warming Gas**
  - CO₂
Emission Testing
Vehicles Tested

Veh. #1: 2000 Freightliner C15 Caterpillar  
Veh. #2: 2006 International ISM 370  
Veh. #3: 2008 Freightliner Mercedes Benz MBE 4000
## Description on vehicles and fuels tested

<table>
<thead>
<tr>
<th>Make/model/year</th>
<th>Emission Control Devices</th>
<th>Odometer (miles)</th>
<th>Inertia weight (lbm)</th>
<th>Engine Displacement (liter)</th>
<th>Horse power/ Torque</th>
<th>Test fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 Freightliner C15 Caterpillar</td>
<td>EGR</td>
<td>34,000</td>
<td>Cruise: 58,744</td>
<td></td>
<td>550 at 1800 rpm</td>
<td>CARB diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100), Renewable diesel (R20, R50, R100)</td>
</tr>
<tr>
<td>2006 International ISM 370</td>
<td>EGR</td>
<td>93,000</td>
<td>Cruise: 61,189</td>
<td></td>
<td>370 at 2100 rpm</td>
<td>CARB diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100), Renewable diesel (R20, R50, R100)</td>
</tr>
<tr>
<td>2008 Freightliner Mercedes Benz MBE 4000</td>
<td>EGR, DOC, DPF</td>
<td>8,000</td>
<td>Cruise: 57,490</td>
<td></td>
<td>450 at 1900 rpm</td>
<td>CARB diesel, Soy-based biodiesel (S20, S50, S100), Animal-based (A20, A50, A100), Renewable diesel (R20, R50, R100)</td>
</tr>
</tbody>
</table>
Driving Cycles Tested

I. Urban Dynamometer Driving Schedule (UDDS): low load cycle

II. 50 mph Highway Cruise: High load cycle
Emission Data Measured

Regulated components

- Oxides of Nitrogen (NO$_x$)
- Particulate Matter (PM)
- Total Hydrocarbons (THC)
- Carbon Monoxide (CO)
- NO$_2$ fractions in NO$_x$

Non-regulated components

- Carbon Dioxide (CO$_2$)
- Nitrous Oxide (N$_2$O)
Constant Volume Sampling (CVS) Dilution Tunnel and PM sampling Conditions

Horiba full flow dilution tunnel

Horiba PM filter unit

- Dilution air temp.: 25±5 °C
- Heated filter temp.: 47±5 °C
- Filter face velocity: 100±10 cm/s
PM and Gas Analysis

PM: Mettler Toledo UMX2 Micro Balance

Gases: Horiba MEXA 7200D Exhaust Gas Analyzer

Detector for Gas Analysis

- CO, CO₂: NDIR (Non-dispersive infrared)
- THC: FID (flame ionization detector)
- NOx: CLD (Chemi-luminescence detector)

Readability: 0.1 µg
Test Results
Drift of NO$_x$ Emission for 2000 Vehicle

![Graph showing drift of NO$_x$ emissions for different vehicle types and fuel blends from testing dates 11-28-08 to 2-16-09. The graph compares emissions across UDDS and Cruise cycles.](image-url)
PM Emissions

Emission rate for PM

(g/mi)

Soy base
Animal base
Renewable

Double UDDS

50 MPH Highway Cruise

2000
2006
2008

CARB
S20
S50
S100
A20
A50
A100
R20
R50
R100
CARB
B20
B50
B100
A20
A50
A100
R20
R50
R100
CO Emissions

Emission rate for CO (g/mi)

Double UDDS

50 MPH Highway Cruise

Soy base
Animal base
Renewable

2000 2006 2008

CARB S20 S50 S100 A20 A50 A100 R20 R50 R100

B20 B50 B100 A20 A50 A100 R20 R50 R100

Soy base Animal base Renewable
THC and CO Emissions
Before and After the DOC is Warmed up
(2008 model year vehicle, CARB diesel, double UDDS cycle)
THC Emissions

Emission rate for THC (g/mi)

Soy base
Animal base
Renewable

Double UDDS
50 MPH Highway Cruise

2000 2006 2008
CO₂ Emissions

Emission rate for CO₂ (g/mi)

Double UDDS

50 MPH Highway Cruise

CARB, S20, S50, S100, A20, A50, A100, R20, R50, R100

Soy base, Animal base, Renewable

NO$_2$ Fractions in total NO$_x$ emissions

[Bar chart showing NO$_2$ fractions in total NO$_x$ emissions for different years (2000, 2006, 2008) and for different fuel types: Soy base, Animal base, Renewable. The chart compares Double UDDS and 50 MPH Highway Cruise conditions.]
Summary

• Average PM, THC and CO emission rates decreased with increasing blend level of biodiesel regardless of the driving cycles and the vehicle model year.

• For the 2008 vehicle, THC and CO emissions sharply dropped when the DOC is warmed up and were not affected by biodiesel concentration. PM emissions were close to or below detection limit. In other words, the use of biodiesel did not show any benefits in the reduction of THC, CO and PM emissions when used with DOC/DPF.

• The 2008 vehicle equipped with DOC and DPF showed the lowest regulated pollutant emissions among the vehicles tested. However, this vehicle was not effective at reducing CO$_2$ emissions.
Summary (Contd)

• NO\textsubscript{x} significantly increased for 50% and higher biodiesel blends regardless of the driving cycles and the vehicle model year. Increase in NO\textsubscript{x} emission was most noticeable for the 2008 vehicle.

• For renewable diesel, NO\textsubscript{x} shows a decreasing trend with increasing blend level for both driving cycles. However, its significant increase was observed for pure renewable diesel.

• For the 2000 vehicle with no NO\textsubscript{x} control device (EGR), more NO\textsubscript{x} was emitted for the highway cruise cycle (having high load) than the UDDS cycle (with lower load). However, this emission pattern was opposite for vehicles equipped with EGR, showing a better NO\textsubscript{x} reduction efficiency under higher load driving cycle.
• CO₂ emissions were not significantly impacted by biodiesel blend levels for different vehicle model year except for renewable diesel blend levels higher than 50% which significantly decreased CO₂ emissions for both driving cycles.

• No significant impact of biodiesel was found on NO₂ fractions for all vehicles tested. The NO₂ fractions were the highest for the 2008 vehicle equipped with a DOC. The 2006 vehicle equipped with EGR showed a higher NO₂ fraction than the 2000 vehicle with no EGR.
Thank you for your attention !!!