The Use of Biodiesel Blends in Marine Vessels

Daniel N. Pope, Ph.D.
Assistant Professor
University of Minnesota Duluth

Sponsor: GLMRI
Motivation

• Reduced Dependence on Foreign Oil
• Reduce Emissions
• Respond to Current Mandates
  – State
  – Federal
    • Energy Policy Act (EPACT)
• Proactively Identify Potential Problems and Solutions
  – Mandated Biodiesel Content will Likely Increase
Project Goals/Topics

• Identify potential issues involved with the shipboard use of biodiesel blends
  – Specific to shipboard equipment
  – Biodiesel (B100)
    • Acts as a solvent
    • Gels at a higher temperature than #2 diesel

• Develop long-term cold storage test for biodiesel blends
  – Testing of biodiesel blends
Diesel-Powered Ship Systems

• General Observations
  – Proper functioning can be difference between life and death
  – Systems vary from ship to ship
  – Some systems exposed to external environment
    • Deck/Hatch Crane
  – Fuel turnover is rapid during shipping season
  – Two-month winter lay up
    • Long-term fuel storage concern
Diesel-Powered Ship Systems

• Typical Systems
  – Diesel Generator Sets
    • Supplied by storage and service tanks
    • Located in environmentally controlled spaces
  – Main Engine
    • Heavy fuel oil (IF 280) or #2 diesel
    • Supplied by fuel bunkers via heated day tank
  – Boilers
    • Steam for heating ship and fuel oil
Diesel Generator Set

Caterpillar D399 – 4 DG Sets

M/V Mesabi Miner – Interlake Steamship
Diesel-Powered Ship Systems

• Typical Systems
  – Emergency Diesel Generator
    • Low fuel turnover rate
    • Located in environmentally controlled space
  – Hatch/Deck Crane
    • Exposed to environment
    • Low fuel turnover rate during winter lay up
  – Lifeboat Power Pack
    • Exposed to environment
    • Low fuel turnover rate
Diesel-Powered Ship Systems

• External Environment
Cold Storage Test

• Time at temperature
  – 1 month total
    • Winter lay up is 2 months
    • No change in the test results between 2 and 4 weeks
  – Storage tank test
  – Small sample test

• Storage tank test
  – Top/Bottom sampling of tank
  – Bi-weekly sampling
  – Hydrometer test for density variation
  – Does blend separate → gelling of biodiesel component

• Small sample test
  – Visual inspection for crystallization

• Blends tested
  – B5, B10, B20, B50
Cold Storage Test Apparatus

• Freezer with external temperature control
  – Freezer internal control range: -10°F to 10°F

• External temperature control
  – Automation Direct TC33-2010-AC temperature controller
    • On/Off control with 2°F hysteresis
    • Type J thermocouple
Cold Storage Test
Tanks and Sample Preparation

- 6+ gallon (23.2 L) self-venting gas can
- Sample Size – 22 L
  - Volume Measurements - 1000 ±10 ml graduated cylinder

<table>
<thead>
<tr>
<th>Sample</th>
<th>Vol. B100 (L)</th>
<th>Vol. #2 Diesel (L)</th>
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</thead>
<tbody>
<tr>
<td>B5</td>
<td>1.1</td>
<td>20.9</td>
</tr>
<tr>
<td>B10</td>
<td>2.2</td>
<td>19.8</td>
</tr>
<tr>
<td>B20</td>
<td>4.4</td>
<td>17.6</td>
</tr>
<tr>
<td>B50</td>
<td>11.0</td>
<td>11.0</td>
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</table>
Cold Storage Test
Bi-Weekly Tank Samples

- 16 oz. glass sample bottles
- Sample Size – 400 to 450 ml
- Top and Bottom Samples
  - Stainless Steel Drum Pump
Cold Storage Test
Hydrometer Test

• Performed on
  – Initial Mixture
  – Bi-Weekly Samples

• Measure Fluid Temperature

• Specific Gravity Hydrometer
  – SG 60/60°F
  – Range: 0.800 → 0.910

• Correct Hydrometer Reading to 60°F
Cold Storage Test
Small Sample Test

- 16 oz. glass sample bottles
- Sample Size – 400 to 450 ml
- Visual Inspection for Crystallization
Cold Storage Test

• Blends
  – B5, B10, B20, B50

• Temperatures
  – First test: 23 – 25°F
    • Conservative temperature above cloud point of B50
    • Cloud point of B100 is 32 to 40°F
  – Second test: 30 – 32°F
    • Fuel bunker in contact with water

• Additional Tests
  – Kinematic Viscosity and Flash Point
    • Small Samples from First Test
Cold Storage Test
Results

• **Storage Tank Tests**
  – First test: 23 – 25°F
    • Particulate matter in B50 bottom sample
    • No density variation between top and bottom samples
  – Second test: 30 – 32°F
    • Same results as first test
  – **Summary**
    • No stratification of biodiesel component
    • Particulate formation and settling for B50
Cold Storage Test Results

• Small Sample Tests
  – First test: 23 – 25°F
    • Visible crystallization (cloudiness) in B10, B20, and B50 samples
    • Cloudiness disappears as samples approach room temperature and are manually agitated
    • Particulate matter in B50 sample
  – Second test: 30 – 32°F
    • Crystallization in B20 and B50 samples
    • Particulate matter in B50 sample
  – Particulate formation in B50 verified
Viscosity and Flash Point
(After 4 weeks @ 23 – 25°F)

- **B100 Specs**
  - Kinematic Viscosity (40°C)
    - 1.9 – 6.0 mm²/s
  - Flash Point
    - 130°C (minimum)

- **#2 Diesel Specs**
  - Kinematic Viscosity (40°C)
    - 1.9 – 4.1 mm²/s
  - Flash Point
    - 52°C (minimum)

<table>
<thead>
<tr>
<th>Sample</th>
<th>Viscosity (mm²/s)</th>
<th>Flash Point (°C)</th>
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<tbody>
<tr>
<td>B100</td>
<td>4.031</td>
<td>138</td>
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<tr>
<td>B50</td>
<td>2.927</td>
<td>78</td>
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<tr>
<td>B20</td>
<td>2.425</td>
<td>72</td>
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<tr>
<td>B10</td>
<td>2.264</td>
<td>73</td>
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<tr>
<td>B5</td>
<td>2.200</td>
<td>68</td>
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<tr>
<td>#2 Diesel</td>
<td>2.132</td>
<td>65</td>
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Testing performed by personnel at the Superior Refinery of Murphy Oil USA, Inc.
Additional Tests Underway

• Effect of Cold Flow Additive
  – Sample Bottles (450 ml)
  – Samples with and without Additive
    • B100, B50, B20, B10, B5, #2 Diesel
  – Start at 45°F
  – Decrease Temperature 3°F Per Day
  – Visually Inspect for Crystallization

• Filtration Test
  – Run Cold Storage Test Samples through Fuel Filter Material
  – Collect and Classify Filtered Particulates
Conclusions

• Reviewed typical diesel-powered ship systems
  – Identified potential problems

• Long-term cold storage test developed
  – Test results
    • No stratification of biodiesel component
    • Particulate formation and settling in B50 sample
    • Good cold storage characteristics for blends up to B20

• Additional tests underway