Great Lakes Maritime
Research Institute

A University of Wisconsin-Superior and
University of Minnesota Duluth Consortium

The Use of Biodiesel Blends in Marine Vessels

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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

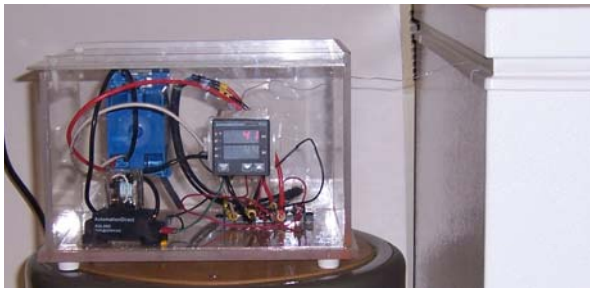
- External Environment

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

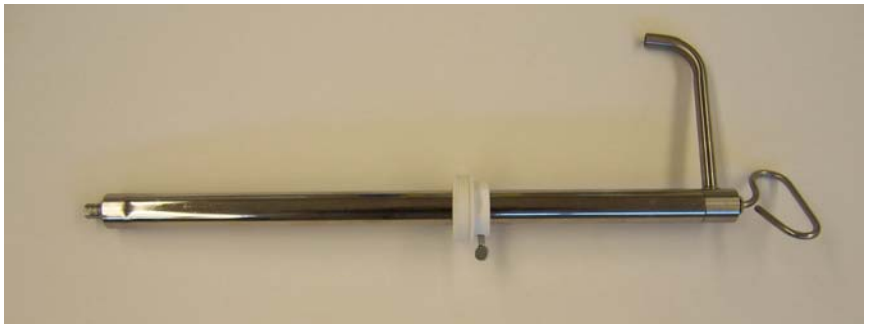
Cold Storage Test
Tanks and Sample Preparation

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

Sample	Vol. B100 (L)	Vol. #2 Diesel (L)
B5	1.1	20.9
B10	2.2	19.8
B20	4.4	17.6
B50	11.0	11.0

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 mm^2/s**
  - Flash Point
    - **130°C (minimum)**
- #2 Diesel Specs
  - Kinematic Viscosity (40°C)
    - **1.9 – 4.1 mm^2/s**
  - Flash Point
    - **52°C (minimum)**

Testing performed by personnel at the Superior Refinery of Murphy Oil USA, Inc.

Sample	Viscosity (mm^2/s)	Flash Point (°C)
B100	4.031	138
B50	2.927	78
B20	2.425	72
B10	2.264	73
B5	2.200	68
#2 Diesel	2.132	65

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

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