4th Public Workshop to Discuss Development of Regulations for Ocean-going Ship Main Engines and Auxiliary Boilers

OGV Voluntary and Test Programs

March 5, 2008
Sacramento, CA
Marine Voluntary and Test Programs

- Detailed data from Maersk’s Voluntary Fuel Switch Initiative
- Test Programs
  - lubricity and fuel property testing
  - fuel pump bench testing with low viscosity and/or low lubricity distillate fuel
  - evaluation of long-term impacts on main engines from frequent fuel switching
Maersk Voluntary Fuel Switch Initiative
-Information Requested

♦ Voluntary program initiated by Maersk
♦ Started with Sine Maersk on March 31, 2006
♦ All ships calling in California switch to clean fuel in main and auxiliary engines
  – main Engines: within 24 nm from arrival port
  – auxiliary engines: within 24 nm from California baseline
♦ Cleaner fuel $\leq 0.2\%$ sulfur MGO
♦ ARB has requested and is receiving detailed information from Maersk
Maersk Voluntary Fuel Switch Initiative
-Information Requested

Vessels

♦ Number of vessels and California ports visited under the project
♦ Engine makes and models covered under the project
♦ Fuel delivery systems on participating vessels
Maersk Voluntary Fuel Switch Initiative
-Information Requested

Cleaner Fuels

- Why was 0.2% sulfur fuel selected (as opposed to 0.1% sulfur)
- Primary locations/port/broker of distillate fuel purchases
- Actual sulfur content and fuel properties of the 0.2% sulfur distillate fuels
  - viscosity
  - density
  - flashpoint
Maersk Voluntary Fuel Switch Initiative - Information Requested

Operational Factors

♦ Distillate fuel temperature at the primary fuel pump that may impact fuel viscosity
♦ Time (hrs.) on distillate per visit, typical or ship specific total hours per month or year on distillate.
♦ Fuel switching procedures
♦ Range of engine loads/maximum load during switching and while on distillate?
♦ Cylinder lubricants used
♦ Any fuel additives used
Maersk Voluntary Fuel Switch Initiative
-Information Requested

Performance and Long Term Impacts

♦ Maintenance and inspection data showing any changes in engine wear or performance that can be attributed to fuel switching,

♦ Have there been any problems with main engine associated with fuel switching or using distillate?
Test Programs

- Test programs underway and planned
  1. Lubricity and fuel property testing
  2. Fuel pump bench testing with low viscosity and/or low lubricity distillate fuels
  3. Evaluation of long-term impacts on main engines from frequent fuel switching
Lubricity and Fuel Property Testing

- Testing in-use distillate samples from auxiliary engine enforcement activity
- Total of 20 MGO and 4 MDO samples
- Lubricity testing using High-Frequency Reciprocating Rig (HFRR).
  - ASTM D6079/ISO 12156-1 HFRR
  - 25, 40 and 60 deg C
Lubricity and Fuel Property Testing

♦ Other fuel properties
  - Cetane Index
  - Density at 15°C
  - Distillation (T10/T50/T90 distillation recovery temps)
  - Flash point (°C)
  - Sulfur content (% mass)
  - Viscosity at 40 °C (cSt)
Lubricity and Fuel Property Testing

♦ Target sulfur content ranges for MGO and MDO samples
  – 0 to 0.1% (0 to 1000 ppm)
  – 0.1% to 0.2% (1000 to 2000 ppm)
  – 0.2% to 0.5% (2000 to 5000 ppm)
  – Greater than 0.5% (>5000 ppm)

♦ Distillate from bunkering locations around the world
Lubricity and Fuel Property Testing-Samples Analyzed to Date (8)

Preliminary HFRR wear scar data

![Graph showing wear scar diameter vs percent sulfur at different temperatures.](image-url)
Lubricity and Fuel Property Testing-Samples Analyzed to Date (8)

<table>
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<tr>
<th>Bunker Location City/Port</th>
<th>Bunker Country</th>
<th>Fuel Sulfur Percent</th>
<th>Fuel Type</th>
<th>WS diameter @40C</th>
<th>Viscosity @40C cSt</th>
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Fuel Pump Bench Testing

The goal of this program is to determine the lower limits of fuel lubricity and viscosity for typical fuel injection pumps used on large two-stroke, slow-speed main engines.

Program Description:
- working in partnership with engine manufacturers
- bench testing on a simulated OGV “fuel injection pump rig test”
- injection pump typical of a large two-stroke, slow-speed engine
- operating on selected low sulfur marine distillate fuels
- fuel circulated through the pump for a specified period of time
- pump would be disassembled and inspected for wear
Long-term impacts on main engines from frequent fuel switching

The goal of this program is to evaluate any long term impacts on large two-stroke, slow-speed main engines using engine monitoring, maintenance and inspection Data

Program Description:
- partnering with shipping companies
- working with engine makers
- evaluate the long term impacts from frequent fuel switching
- any changes in engine component wear from baseline (HFO operation)
Long-term impacts on main engines from frequent fuel switching

Evaluation will include:

♦ Changes in the piston, rings, and cylinder liner as viewed through scavenging port

♦ Any Increases in the following components
  • cylinder liner wear beyond the normal baseline level
  • cylinder lubricant metal content as determined from “scrape down” program;
  • fuel injection pump leakage beyond the normal level
  • wear/scuffing in fuel injection pump plunger and barrel
  • leaks/seal replacement anywhere in the fuel system
    - types of seals failed
    - types of seals used as replacement
Next Steps

- Review data from Maersk’s Voluntary Fuel Switch Initiative
- Continue to investigate the impacts of changing fuels
  - lubricity study and fuel properties
  - fuel pump bench testing
  - long term study on engine Impacts