Isobutanol in Marine Gasoline

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1B: Drivers for Emergence of Biofuels for Maritime Industry
Gevo’s Current Business System

Gevo Production Facilities

Isobutanol Production – Side-by-Side with Ethanol
Luverne, MN
15 MGPY ETOH
1.5 MGPY IBA*

Hydrocarbon Biorefinery
South Hampton Resources
Silsbee, TX

Core Near Term Markets

Drop-in Markets - Isobutanol
Specialty Chemicals & Solvents
Specialty Gasoline Blendstock (Marine/Off-Road)

Drop-in Markets - Hydrocarbons
Jet Fuel
Isooctane (gasoline)
Isobutanol Properties

- Gasoline with 10% Water
- Isobutanol blended Gasoline with 10% Water
- Ethanol blended Gasoline with 10% Water
### Gasoline blending value

<table>
<thead>
<tr>
<th></th>
<th>Gasoline</th>
<th>Ethanol</th>
<th>Isobutanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>RON</td>
<td>95</td>
<td>109</td>
<td>105</td>
</tr>
<tr>
<td>MON</td>
<td>85</td>
<td>90</td>
<td>91</td>
</tr>
<tr>
<td>Anti-knock Index</td>
<td>90</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td>RVP (psi)</td>
<td>7-15</td>
<td>19</td>
<td>5.2</td>
</tr>
<tr>
<td>Density 20C [kg/m3]</td>
<td>720-775</td>
<td>794</td>
<td>801</td>
</tr>
<tr>
<td>Boiling Point (C)</td>
<td>32.2</td>
<td>21.1</td>
<td>26.6</td>
</tr>
<tr>
<td>% Heating Value of Gasoline</td>
<td>100</td>
<td>66</td>
<td>84</td>
</tr>
<tr>
<td>Oxygen (%w/w)</td>
<td>&lt;2.7%</td>
<td>34.7</td>
<td>21.6</td>
</tr>
</tbody>
</table>

Isobutanol has low RVP, enabling refiners to blend incremental volumes of butanes and pentanes.
Marine Research Overview

Marine Engine Tested – BRP Envinrude and SeaDoo, Mercury, Volvo-Penta, Yamaha, Tohatsu, Indmar, OMC-Johnson, Honda.
- Impact of Blending Gasoline with Isobutanol Compared to Ethanol on Efficiency, Performance and Emissions of a Recreational Marine 4-Stroke Engine
- Gaseous and Particulate Emissions Using Isobutanol-Extended Fuel in Recreational Marine Two-Stroke and Four-Stroke Engines
- In-Use Performance Testing of Butanol-Extended Fuel in Recreational Marine Engines and Vessels
- Effect of Fuel Contamination of Lubrication with Marine Engine Oil
- Isobutanol Testing Update – International Boat Builders Exposition 2014
- Effect of Fuel Weathering on RVP, Distillation and Oxygen Content of Ethanol and iso-Butanol Blends
- Compatibility Study for Plastic, Elastomeric, and Metallic Fueling Infrastructure Materials Exposed to Aggressive Formulations of Isobutanol-Blended Gasoline
- Butanol Mercury Marine CRADA Report - US Coast Guard
- Butanol Honda CRADA Report - US Coast Guard

https://sites.google.com/site/marinebiobutanolfuel/research
NMMA Board approved an Engine Manufacturer Division (EMD) resolution to support encourage the use of isobutanol 16% as the preferred renewable fuel for recreational marine engines and boats

NMMA EMD Membership-

AB Volvo Penta
American Honda Motor Co Inc
BRP U.S. Inc.
BRP U.S. Inc.
BRP/Evinrude
Caterpillar Inc. Global Marine Division
Caterpillar Marine Division
Caudwell Marine (Pty) Ltd.
Clean eMarine Americas LLC
Crusader Engines Pleasurecraft Engine Group
Cummins Inc.
Cummins MerCruiser Diesel
Elco Motor Yachts, LLC
Flagship Marine Engine Co., Inc.
FPT Powertrain Technologies
GM Powertrain, General Motors
Honda Canada, Inc.
Honda Marine American Honda Motor Co.
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Teague Custom Marine, Inc.
Textron Motors
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Tohatsu America Corp.
Torqeedo Inc.
Volvo Group/Volvo Penta
Volvo Penta Canada, Inc.
Volvo Penta of the Americas
Westerbeke Corp.
Yamaha Marine Group
Yamaha Motor Canada Ltd.
Yamaha Motor Corporation, U.S.A
Yamaha Motor Corporation
Yanmar Marine International B.V.
Thank you

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