NMMA National Marine Manufacturers Association

April 10, 2018

EPA-HQ-OAR-2018-0131

U.S. Environmental Protection Agency
EPA Docket Center
1200 Pennsylvania Ave., NW
Washington, DC 20460

RE: Registration of Isobutanol as a Gasoline Additive (EPA-HQ-OAR-2018-0131).
Comments Submitted Electronically

Dear Administrator Pruitt:

The National Marine Manufacturers Association (NMMA) is pleased to provide the U.S. Environmental Protection Agency (EPA) with the following comments regarding the Registration of Isobutanol as a Gasoline Additive (EPA-HQ-OAR-2018-0131).

NMMA is the leading recreational marine industry trade association in North America, representing 1,500 boat, engine, and accessory manufacturers. NMMA members collectively produce more than 80 percent of the recreational marine products sold in the United States. Recreational boating is a significant driver of the US economy, employing 650,000 people across more than 34,800 boating businesses, while contributing $121.5 billion in economic activity.

The NMMA and the American Boat and Yacht Council (ABYC) conducted a five-year study with the US Department of Energy (DOE) and Argonne National Laboratory to evaluate the effects of 16.1 volume percent isobutanol on the operation of marine engines. This comprehensive study which has been clearly documented in both published reports and peer reviewed studies identifies isobutanol as a superior gasoline additive. Both a summary and the results of these studies will be described in these comments with the reports attached to be part of the record. NMMA strongly urges the EPA to approve the registration of isobutanol for on highway use. Collectively, all marine engine manufacturers have approved the use of isobutanol for marine use.

Isobutanol as a Second-Generation Biofuel

Isobutanol contains nearly 90% of the energy content of gasoline compared to 67% for ethanol. Both Bu16 and E10 contain the same oxygen by weight, and both raise octane when blended into gasoline.   Isobutanol is particularly interesting to the marine industry and boating consumer as it is significantly more resistant to phase separation than ethanol. It is also less corrosive to fuel system component materials such as fuel tanks, fuel hoses, primer bulbs, gaskets and o-rings compared to ethanol[1]. Lack of phase separation and low solvency means that isobutanol could be transported in the existing pipeline distribution infrastructure, minimizing the need for truck and rail transportation, which is required for ethanol[2]. When added to gasoline, isobutanol lowers the Reid Vapor Pressure (RVP) of the finished gasoline blend which results in lower evaporative emissions and allows for a less costly gasoline blend stock.

As a drop-in gasoline blend stock:

- Isobutanol can be made from a variety of feed stocks; helping to support the rural economy. In the near term, isobutanol is being produced by converting existing corn starch ethanol plants to isobutanol. The technology can use cellulosic sugars as and when they become available in a cost-effective manner

- Isobutanol does not cause stress corrosion cracking[i] and can be blended into gasoline at EPA defined "substantially similar" levels. The key to using the existing fuel pipeline distribution infrastructure is to have a renewable material that meets the integrity, quality, and operational needs of the network (butanol products have shipped in pipelines before), and may offer opportunities to use both the NGL pipeline systems (could bring isobutanol from the Midwest to refining centers) or finished product pipeline systems (take finished products to markets)[ii]

- Isobutanol gasoline blending properties provide opportunities; for example:

    a) Its low RVP blend value of 5 psi (+- 1PSI for aromaticity) allows butane, pentane, and other low-cost blend stocks to be used[iii,iv,v] all the while maintaining low evaporative emissions
    b) Its 30% higher energy content, relative to ethanol, allows an EISA equivalence value of 1.3, thereby generating a greater Renewable Identification Number (RIN) generation rate (relative to the EISA renewable volume obligation). A 16.1 vol% isobutanol fuel has a RIN value of 20, twice that of a 10 vol% ethanol fuel and 30% more than E15 (RIN value of 15)
    c) Its low water solubility keeps it in the gasoline phase in the presence of water. This is of interest to the marine engine environment as the majority of boats use open-vented fuel systems in which water can more easily enter the fuel system.
    d) Its lower oxygen content allows larger volumes to be used; (relative to ethanol) hence the EISA targets can more readily be attained with a fuel that can be used in all gasoline engines

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[1] Kass, M., Theiss, T., Janke, C., Pawel, S., et al "Compatibility Study for Plastic, Elastomeric, and Metallic Fueling Infrastructure Materials Exposed to Aggressive Formulations of Isobutanol-blended Gasoline" Oak Ridge National Laboratory, 2014

[2] Wasil, J., McKnight, J., Kolb, R., Munz, D. et al., "In-Use Performance Testing of Butanol-Extended Fuel in Recreational Marine Engines and Vessels," SAE Technical Paper 2012-32-0011, 2012, doi:10.4271/2012-32-0011

Background and Motivation for NMMA Bio-isobutanol Research

Boaters first began to see the negative effects of ethanol being added to gasoline in the late 1990s when ethanol was first used as a replacement for methyl tertiary butyl ether (MTBE), the oxygenate and initial fuel additive of choice required by the Clean Air Act Amendments of 1990. The availability of ethanol increased when concerns associated with MTBE use became apparent and the Energy Independence and Security Act (EISA) of 2007 was passed leading to the Renewable Fuel Standard (RFS). At the same time, multiple incentives were issued for the expansion of ethanol plants including subsidies for every gallon of ethanol produced and low interest loans for ethanol plant construction projects. It was shortly after 2007 that marine engine manufacturers were inundated with warranty claims ranging from reports of clogged fuel filters, damaged engines due to water in the fuel, gasoline fuel leaks due to cracked hoses and the breakdown of the polymer in fiberglass marine fuel tanks due to ethanol fuels. As engine and fuel system component manufacturers worked to resolve the issues with ethanol in gasoline and boaters suffered, the NMMA began researching alternatives to ethanol.

NMMA first approached the DOE in 2010 recognizing that the EISA not only promoted and incentivized the use of ethanol in gasoline, but also required that the US fuel supply contain 36 billion gallons of renewable biofuel by 2022. NMMA worked with the DOE National Renewable Energy Laboratory (NREL) and marine engine manufacturers Volvo Penta and Mercury Marine to commission a study of the impact that E15 would have on marine engines[3],[4]. These two studies clearly identify the damage that increased levels of ethanol have on marine engines.

Rather than take a limited negative position on biofuels based on the NREL studies and boater experience, the NMMA began researching butanol, a promising second-generation biofuel. In our first year of testing NMMA and ABYC worked with a limited grant from the U.S. Coast Guard Office of Boating Safety. This was supplemented by marine engine and vessel manufacturer support and a lot of sweat equity. The results of this first year of isobutanol tests indicated that this biofuel functioned more closely to gasoline with a significantly higher energy content when compared to ethanol. Furthermore, isobutanol does not exhibit the negative aspects of ethanol which include corrosivity, water and fuel phase separation and an elevated Reid Vapor

[3] Zoubul, G., Cahoon, M., Kolb, R., *Volvo Penta 4.3 GL E15 Emissions and Durability Test* NREL/SR-5400-52577 October 2011

[4] Hilbert, D. *A Study of the Effects of Running Gasoline with 15% Ethanol Concentration in Current Production Outboard Four-Stroke Engines and Conventional Two-Stroke Outboard Marine Engines* NREL/SR-5400-52909 October 2011

Pressure (RVP) when added to gasoline.

Based on the information in our first-year study, the staff at the DOE Office of Energy Efficiency and Renewable Energy's Vehicle Technologies Program (VTP) included funding for continued research into the effect of isobutanol on marine engines and vessels. Over the next four years we exhausted every possible impact that isobutanol can have on vessel operation through evaluations such as fuel system compatibility, oil tribology, emissions compliance and engine durability among others. NMMA took a proactive approach into biofuels research to help bring forward a meaningful biofuel solution for boating consumers.

Marine Industry Biobutanol Testing Summary

The National Marine Manufacturers Association (NMMA) and the American Boat and Yacht Council (ABYC) under the direction and guidance of the U.S. Department of Energy and Argonne National Laboratory engaged in a multi-year program to evaluate the performance of recreational marine engines and vessels operated on biologically produced isobutanol fuel[5]. With known issues associated with ethanol fuels and the ongoing push toward higher quantities of ethanol such as E15, the marine industry came together to evaluate an advanced biofuel with properties better suited for the marine environment than ethanol.

Thousands of hours of engine and vessel testing performed through years-long collaborative industry efforts have confirmed the compatibility of isobutanol fuel blends with marine engines and vessels. The major tests performed during this comprehensive biobutanol testing program and conclusions are highlighted below:

Tests Performed

- Gaseous and particulate engine exhaust emissions (regulated and non-regulated)
- Greenhouse gas emissions (GHG)
- Combustion analysis
- Cold start
- Power and performance
- Runability
- Winter storage
- Oil tribology and lubricity
- Exhaust gas temperature
- Stoichiometric air/fuel ratio (Lambda)
- Field engine and vessel performance

[5] DOE Annual Progress Reports - Emissions and Operability of Gasoline, Ethanol, and Butanol Blends in Recreational Marine Applications – 253p research book http://marinebiobutanol.net

- Full useful life endurance/durability
- Engine tear down and component inspection

Types of Fuels Tested

- E10 (10 vol% ethanol – control fuel)
- iB16 (16 vol% isobutanol)
- Tri-fuel blend (8 vol% isobutanol, 5 vol% ethanol and 87 vol% gasoline)
- Indolene (non-oxygenated certification fuel)

Engine Technologies Tested

- Electronic fuel injection four-stroke outboards
- Carbureted four-stroke outboards
- Open-loop (CARB 3-star) SD/I and PWC engine
- Closed-loop (CARB 4-star) SD/I engines
- Conventional carbureted two-stroke outboard
- Direct fuel injection two-stroke outboards

Engine Brands Tested

- BRP – Evinrude and SeaDoo
- Mercury
- Volvo-Penta
- Yamaha
- Tohatsu
- Honda
- Indmar
- OMC – Johnson

In addition to the aforementioned tests, marine manufacturers participated in cooperative research and development agreements (CRADA) with the U.S. Coast Guard to evaluate engine and vessel performance on 25' Response Boats – Small (RB-S) operating out of USCG Training Center Yorktown, VA. Test data consisted of environmental data, engine/fuel system data, fuel chemistry, and crew observations[vi,vii].

Summary of Major Testing Results

- Laboratory, endurance, and field testing results on boats and engines indicate no discernable difference in power, performance, runability, emissions or durability between E10 and biobutanol test fuels (Bu16/Trifuel blends)

- All test engines remained below U.S. EPA and California emissions standards for HC+NOx and CO. Exhaust emissions comparisons between E10 and biobutanol test fuels were virtually the same on all engines tested. No significant emissions differences between E10 and biobutanol test fuels were found regardless of engine technology.

- Full useful life engine tear-down and inspection on pistons, cylinder heads, cylinder bores, intake/exhaust valves, intake/exhaust ports, connecting rods and rod bearings indicate similar wear between the E10 control engines and Bu16 test engines. No unusual wear, carbon build-up or durability issues were observed with either fuel during equivalent 10-year useful life testing.

- No engine runability, engine durability, or engine/boat performance issues were experienced during the test program. All engines and boats performed well throughout the test program.

- Engine start ability performed at two different temperatures indicates similar seconds to start and pulls to start at 75°F between E10 and Bu16 test fuels. At 30°F, data indicates a slight advantage in start ability for biobutanol fuels.

- No effect on maintenance between E10 or Bu16 use was found. In addition, after testing for materials compatibility, and visually examining engine components following bench testing, no difference between the effects of E10 and Bu16 was found.

- Friction, wear and scuffing tests performed on engine oils indicate no major differences between the load carrying capacity of the oil with either E10 or Bu16 fuels.

Marine Biobutanol Availability

Following isobutanol approval for marine engines and vessels, a limited number of marinas have been successfully offering biobutanol fuel blends to boating consumers. Availability includes Lake Havasu, several locations across Texas and multiple locations in Missouri. Furthermore, Gulf Fuels is offering marine and off-road isobutanol performance fuels.

The majority of recreational boats are trailerable boats which are fueled at automotive gas stations. Expansion of isobutanol fuels into on-road markets will increase the availability of this proven second-generation biofuel for boating consumers.

Conclusion

The recreational marine environment and product usage profiles represent a worst-case evaluation platform to which second generation biofuels can be evaluated. All test engines operated on 16.1 vol% bio-isobutanol and tri-fuel blends (ethanol/isobutanol/gasoline) remained below EPA and CARB emissions standards for HC+NOx and CO. Exhaust emissions comparisons between E10 and butanol test fuels were virtually the same on all engines tested. No significant emissions differences between E10 and butanol test fuels were found regardless of engine technology. Bio-isobutanol was found to behave more similarly to gasoline throughout the years-long industry research program.

Full useful life engine tear-down and inspection on pistons, cylinder heads, cylinder bores, intake/exhaust valves, intake/exhaust ports, connecting rods and rod bearings indicate similar wear between the E10 control engines and iB16 test engines. No unusual wear, carbon build-up or durability issues were observed with either fuel during the 350-hour (equivalent 10-year useful life) testing for each engine tested.

Finding no major concerns with respect to engine and vessel operation throughout this comprehensive marine industry testing program, engine and boat manufacturers have unanimously approved the use of bio-isobutanol up to 16.1 vol%. NMMA strongly urges the EPA to approve the registration of isobutanol for on highway use.

Thank you for the opportunity to provide comments. If you have any questions about our priorities or would like more information, please do not hesitate to contact me at jmcknight@nmma.org, 202.737.9757 or Jeff Wasil (BRP Engineering Manager, Emissions Certification & Regulatory Development) at jeff.wasil@brp.com, 262.884.5322.

Sincerely,

John McKnight

John McKnight
Senior Vice President of Government Relations
National Marine Manufacturers

Attachments:

Emissions and Operability of Gasoline, Ethanol, and Butanol Blends in Recreational Marine Applications – 253p final project report June 2015 http://marinebiobutanol.net

cc:

Paul Machiele - US EPA National Vehicle and Fuel Emissions Laboratory
Cleophas Jackson - US EPA National Vehicle and Fuel Emissions Laboratory

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[i] Ryan, C., Munz, D., Bevers, G., 'Isobutanol – A Renewable Solution for the Transpiration Fuels Value Chain' Pipeline stress corrosion cracking (SCC) and elastomeric compatibility. http://www.biofuelstp.eu/downloads/wp-isob-gevo.pdf
[ii] Gui, N. Sridhar, M. Peters, *Compatibility of Carbon Steel with Isobutanol*, 2011 NACE Corrosion International PaperNumber 11139 F. DNV Dublin, OH
[iii] Bata, R., Elrod, A., "Butanol as a Blending Agent with

Gasoline for I. C. Engines", Clemson University, Clemson, SC SAE 890434
[iv] ‘An alternative fuel for spark ignition engines’, A. Hull, Institute for Surface Chemistry, Stockholm, Sweden, I.Golubkov, Swedish Biofuels AB, Stockholm, Sweden, B. Kronberg, T Marandzheva, Tuchkov Most, Sankt-Peterburg, Russia and J. van Stam, Department of Physical Chemistry, Karlstads University, Karlstad, Sweden
[v] Serras-Pereira, J., Wallace, S., Aleiferis, P.G., *Characteristics of Ethanol, Butanol, Iso-Octane, and Gasoline* Sprays and Combustion from a Multi-Hole Injector in a DISI Engine SAE paper 2008-01-1591
[vi] M.Wiggins et al. ‘Butanol Honda CRADA Report’ United States Coast Guard Research & Development Center New London, CT 06320 Report number CG-D-10-15 February 2015
[vii] M.Wiggins et al. ‘Butanol Mercury CRADA Report’ United States Coast Guard Research & Development Center New London, CT 06320 Report number CG-D-11-15 February 2015