Summer Butanol Evaluation Report

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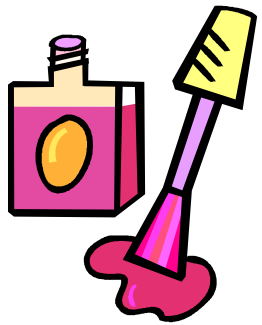
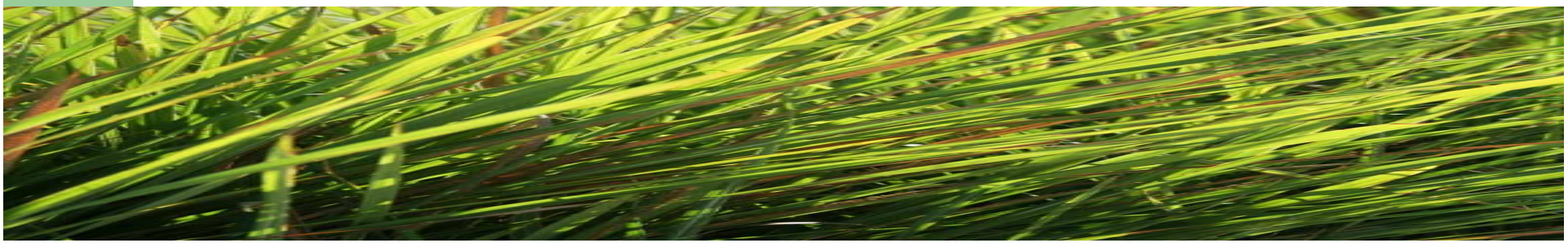
What is Butanol?

- A four carbon alcohol (C_4H_9OH), colorless, neutral liquid of medium volatility with a characteristic banana-like odor.
- Traditionally petrochemical derived - Generally used to make other chemicals, or used as a solvent or an ingredient in formulated products such as cosmetics.



How is Butanol Made?

- Can be biologically derived from biomass in a fermentation process using microorganisms – Biobutanol
- Biobutanol fermentation differs from bioethanol mainly in the use of bacteria.
- An existing ethanol plant can be converted to make butanol



Butanol Properties:

- Butanol 99,800 BTU/gallon
- Gasoline 116,000 BTU/gallon
- **Approximately 86% of the energy content of gasoline**
- Ethanol 76,300 BTU/gallon (68% of the energy content of gasoline)

Butanol Properties:

- Phase Separation
  - As water enters a boat fuel system containing ethanol-extended fuels, phase separation may occur creating an ethanol/water fuel mixture.
  - Butanol does not phase-separate as shown in the cylinder on the right

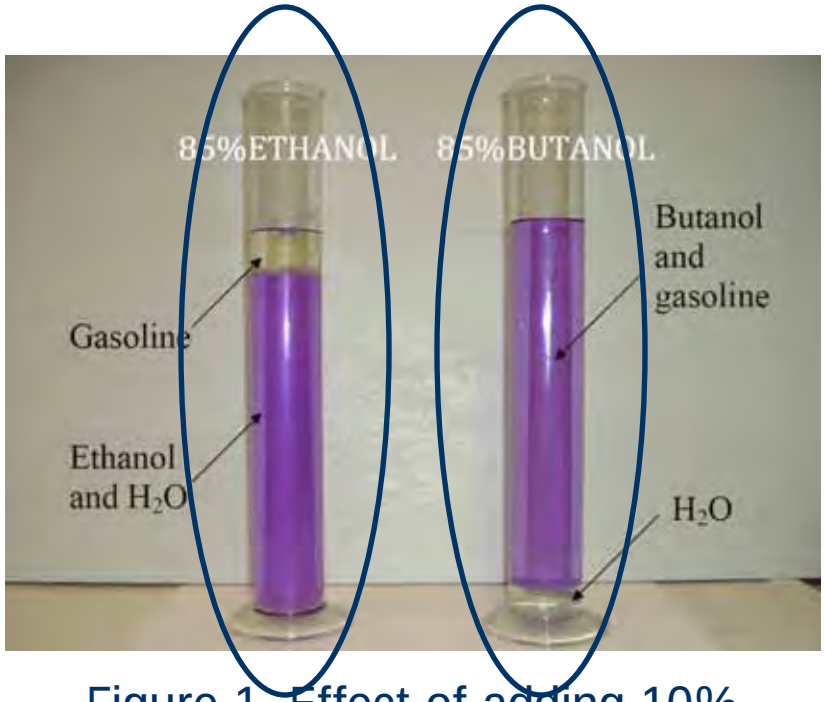


Figure 1. Effect of adding 10% water by volume to 85% ethanol and 10% water by volume to 85% butanol

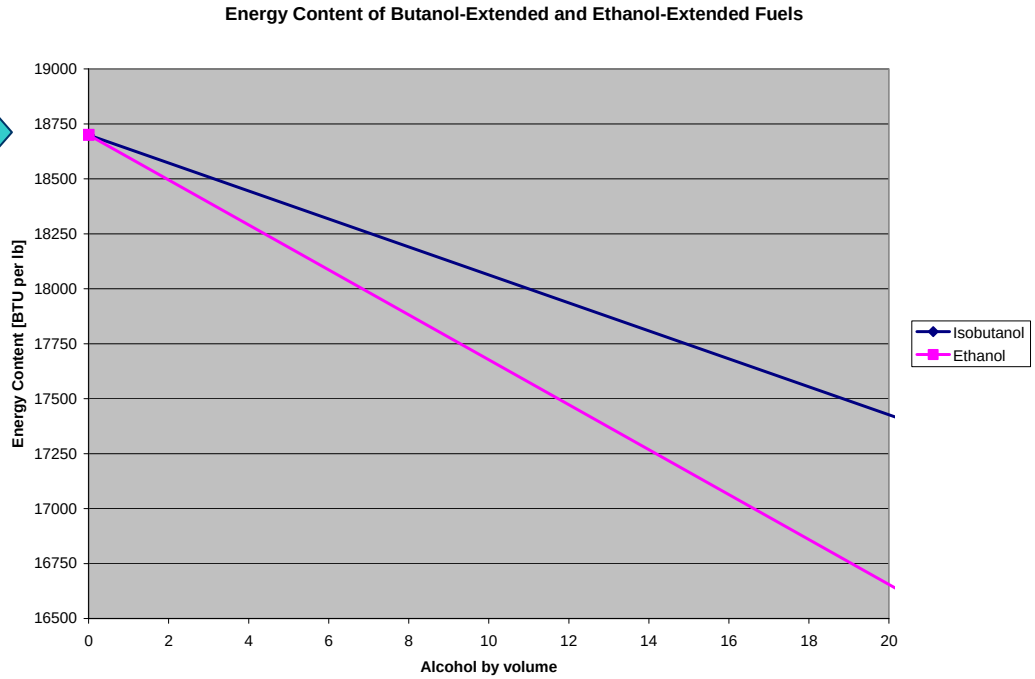
Butanol Introduction:

- Less susceptible to phase separation means butanol could be successfully delivered in existing pipelines
- Eliminates need for splash-blending
- Least corrosive of alcohols
- Higher energy content – can be blended into gasoline at higher percentages than ethanol

Energy Content:

- 16.1% butanol by volume is equivalent to 10% ethanol by volume
- ~3% O_2

Gasoline



Why is the nation focused on ethanol?

- Historically, ethanol fermentation processes resulted in the highest yields
- Recent advancements in microbial fermentation processes have increased the yields of butanol

Purpose of Testing:

- To evaluate the effect of butanol-extended fuels in a harsh marine environment and to see if there is a better alternative to ethanol-extended fuels

Test Set-up:

- On-water emissions testing using the Marine Portable Bag Sampling (MPSS) unit developed for the EPA/NMMA green house gas study.

The Capture

The Boats & Crew

The Boats & Crew

There was a lot of this….

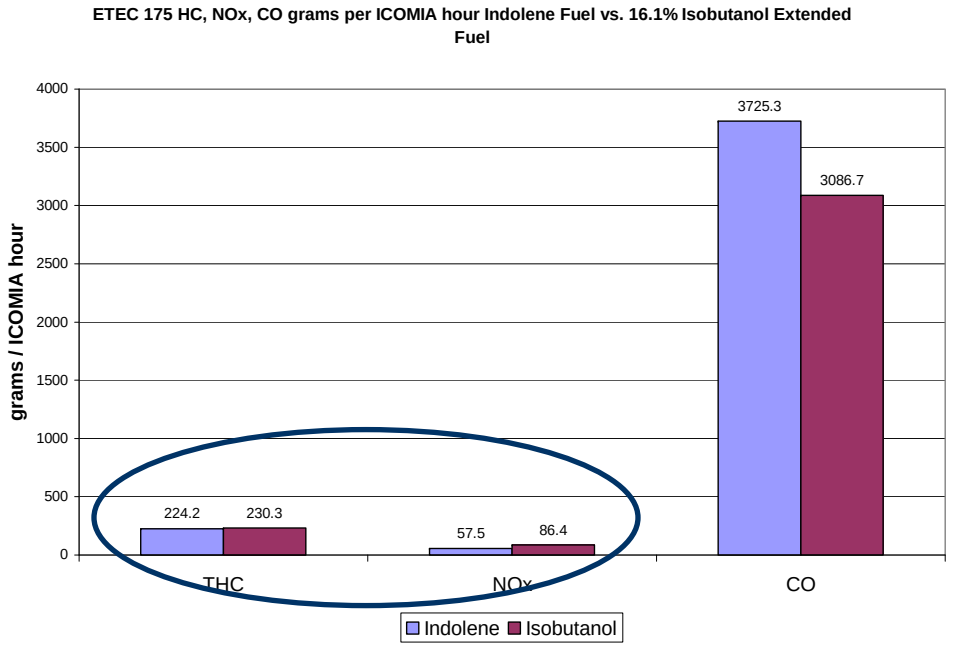
And This…..

Tests Conducted:

- On-water emissions testing
- Emissions data reported using EPA certification fuel (non-oxygenated) and 16.1% isobutanol-extended fuel.
- Values reported in grams per ICOMIA hour:
  - Total Hydrocarbons
  - Nitrogen Oxides
  - Carbon Monoxide

Test Results:

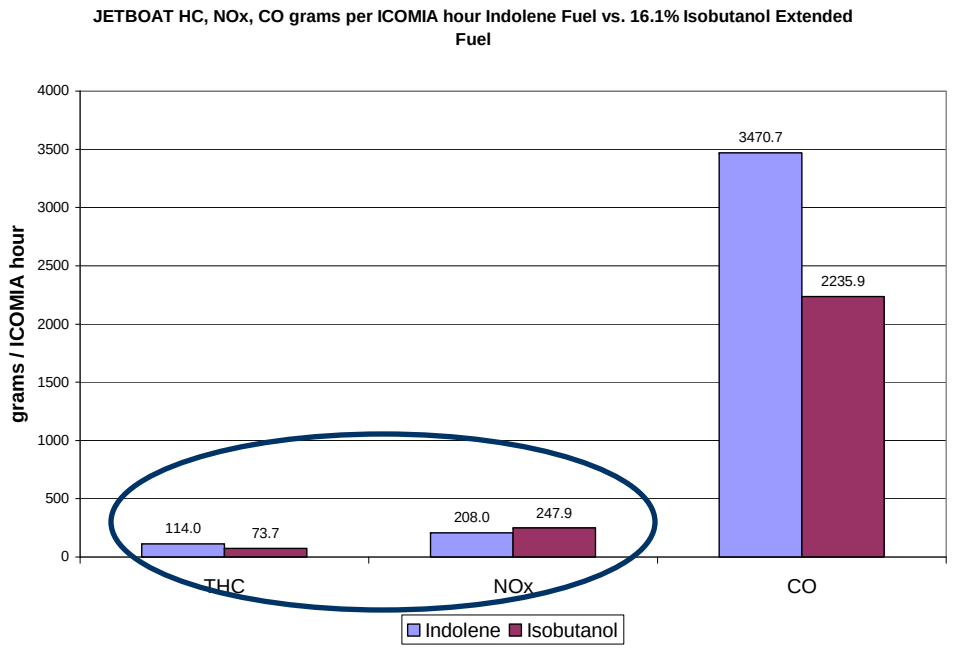
HC + NOx emissions are virtually the same between the two fuels. CO is reduced using isobutanol (as expected)



Evinrude E-TEC 175 Stratified Charged Direct Fuel Injection Two-Stroke on water emissions evaluation [HC, NOx, CO] – 18' Mako Boat. Comparison between Indolene fuel and 16.1% isobutanol extended fuel. Values in grams per ICOMIA hour average of two tests per fuel type

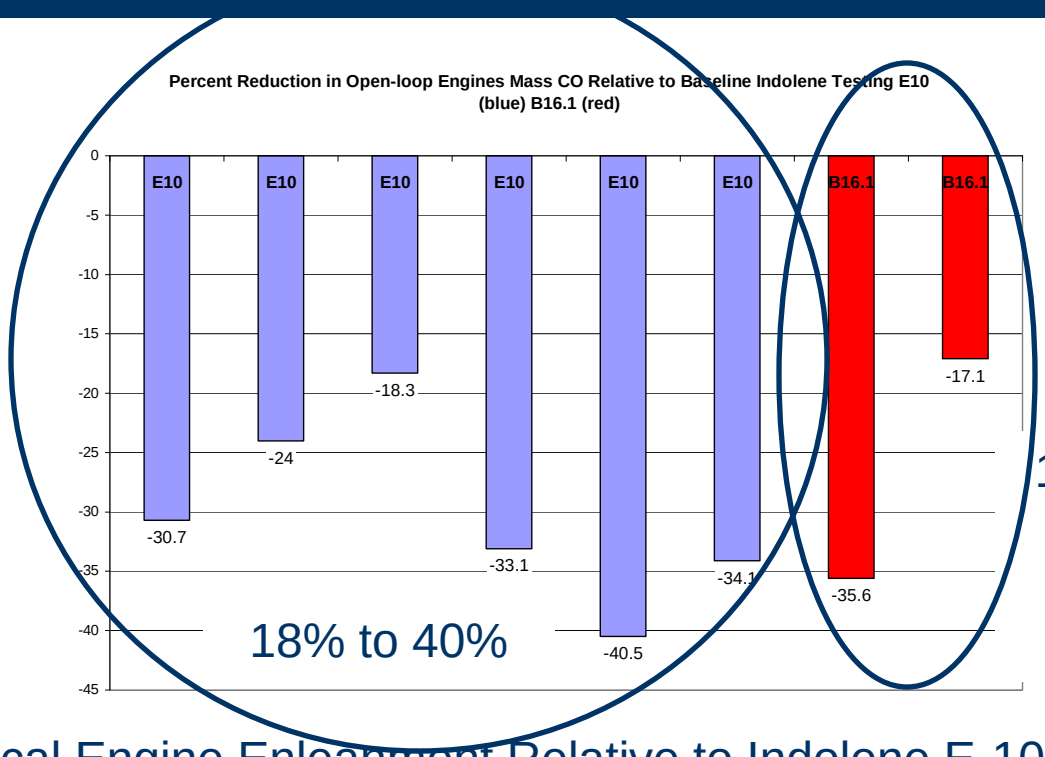
Test Results:

HC decreased slightly and NOx increased slightly using isobutanol…but the total HC+NOx was virtually the same between the two fuels. CO is reduced using isobutanol (as expected)



Jet-boat on water emissions evaluation [HC, NOx, CO] – Rotax 1503 Supercharged Four-stroke engine. Comparison between Indolene fuel and 16.1% isobutanol extended fuel. Values in grams per ICOMIA hour average of two tests per test fuel.

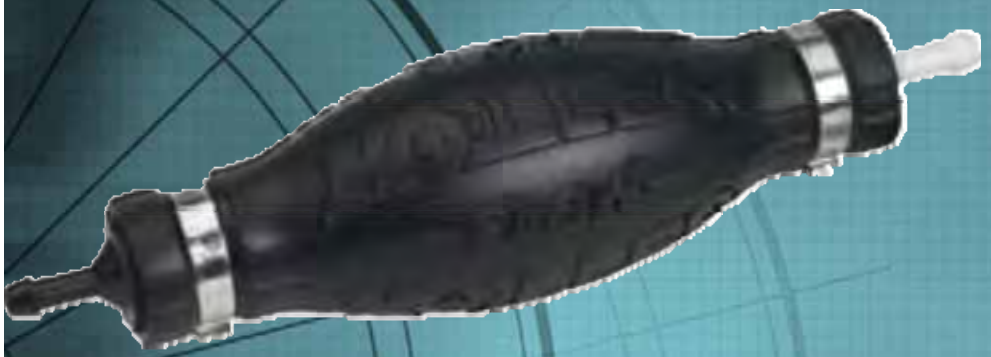
Typical Enleanment of E10 relative to non-oxygenated fuel



16.1% isobutanol similar engine enleanment as 10% ethanol

Typical Engine Enleanment Relative to Indolene E-10 vs. B16. E10 engine CO data as reported by DOE (Knoll et al.)

Product Testing



Vintage Tank Testing…..

Coupon testing

Questions?

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