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Butanol/Gasoline Test Plan

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16. Abstract (MAXIMUM 200 WORDS) This Test Plan was developed to demonstrate the feasibility of using an alternative fuel in USCG gasoline-powered boats. A blend of 16.1 percent biobutanol and gasoline (BU16) was selected as the test fuel and a USCG 25' Response Boat-Small (RB-S) with Honda Marine outboard gasoline engines and a 38' Special Craft-Training Boat (SPC-TB) with Mercury Marine outboard gasoline engines were chosen as the demonstration boats. Testing consists of four phases: materials, bench, field, and operational testing. Materials testing will ensure all components in the engine and fuel system are compatible with BU16. Bench testing will ensure the engines operate satisfactorily on BU16. Field testing will ensure there are no problems with using BU16 on the USCG boats prior to operational testing. Operational testing will ensure there are no problems with using BU16 on the test boats over an extended period that encompasses typical operational and environmental factors. Prior to commencing field testing, the RB-S and SPC-TB engines and fuel systems will be modified in accordance with a Time Compliance Technical Order (TCTO) to ensure compatibility with BU16.					
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EXECUTIVE SUMMARY

The Federal Government is placing an emphasis on environmentally friendly and sustainable energy solutions through national initiatives and Federal Government actions. The two main drivers of the use of alternative fuels are 1) the Energy Independence and Security Act (EISA) of 2007 that has a goal of increasing United States (U.S.) energy security by developing renewable fuel production and by improving vehicle fuel economy and 2) the DHS Sustainability Plan of June 2011, with a 25 percent greenhouse gas (GHG) reduction goal for the CG. Alternative fuels as replacements for the diesel fuel and gasoline in its boat fleet provide the CG with a means to comply with these mandates to reduce the fuel carbon footprint and increase energy independence. The CG Research & Development Center (RDC) contracted with Science Applications International Corporation (SAIC) and Alion Science and Technology (Alion) to develop test plans to demonstrate the feasibility of using alternative fuels in certain CG boats.

A 2010 RDC study (Remley, 17 December 2010) identified the most promising alternative fuels for a demonstration as biodiesel (fatty-acid methyl ester (FAME)), hydrogenation-derived renewable diesel (HDRD), and natural gas for the diesel boats; and biobutanol and natural gas for the gasoline-powered boats. RDC selected a biobutanol/gasoline blend as the fuel of choice for the gasoline-powered boat demonstration. Butanol is a compound that can be made from biomass (biobutanol), and it can also be made from oil (petrobutanol).

The RDC has entered into Cooperative Research and Development Agreements (CRADAs) with Honda Marine and Mercury Marine to conduct the engine materials and bench testing, and solicited the technical support of the only producers of biobutanol, Gevo®, Inc.(Gevo) and Butamax™ Advanced Biofuels LLC (Butamax) for advice on the use of biobutanol. The test plan is structured to demonstrate the feasibility of using the butanol blend on a CG 25' Response Boat - Small (RB-S) with Honda Marine outboard gasoline engines, and a 38' Special Craft - Training Boat (SPC-TB) with Mercury Marine outboard gasoline engines.

The RDC selected CG Training Center (TRACEN) Yorktown, VA as the biobutanol/gasoline demonstration site. TRACEN Yorktown has boats with both the Honda Marine (RB-S) and Mercury Marine (SPC-TB) engines, which present good testing platforms and, as a training center, TRACEN Yorktown does not have the operational demands and restrictions that are present at other units and might conflict with testing.

The RDC determined that a 16.1 percent blend by volume of biobutanol with gasoline (BU16) would be the desired test fuel based on discussions with Oak Ridge National Laboratory (ORNL), Butamax, and Gevo. This blend is scheduled to be commercially available in the near future and is approved for off-road use. Testing will consist of the following four phases.

- **Materials testing** is conducted to determine the compatibility of boat and engine fuel system fuel-wetted parts with BU16. Mercury Marine and Honda Marine will independently conduct material compatibility tests on the fuel-wetted parts of their respective engines using their own methodologies, and will provide the results to the RDC. In addition, Butamax is currently conducting materials testing and will make the results available upon completion.
- **Bench testing** is conducted on the gasoline engines in a stationary test cell environment where engine-operating parameters such as fuel consumption, performance, and emissions are monitored under controlled conditions, with the addition in this project of some on-the-water testing. Honda Marine and Mercury Marine will independently conduct bench testing on their respective engines.

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The goal of this testing is that both manufacturers will certify to the CG that the tested engines will operate satisfactorily on BU16.

- **Field testing** is conducted to develop baseline data, and diagnose and correct problems before the operational testing phase begins. Field testing will be conducted at TRACEN Yorktown using simulated mission operating conditions with test personnel monitoring and recording engine and boat performance data. Operational testing will begin following field testing, provided there are no major issues or safety concerns. Honda Marine and Mercury Marine will participate in field testing.
- **Operational testing** will be conducted at TRACEN Yorktown using dedicated RB-Ss and SPC-TBs over a 12-month period as the final phase in determining the feasibility of using BU16 in CG boats.
- The following summarizes the testing schedule.
 - Materials Compatibility Testing by OEMs
 - Honda Marine: January 2012 - August 2012
 - Mercury Marine: March 2012 - July 2012
 - Bench Testing by OEMs
 - Honda Marine: September 2012 - January 2013
 - Mercury Marine: July 2012 - November 2012
 - Field Testing at TRACEN Yorktown
 - Honda Marine and Mercury Marine: February 2013 - March 2013
 - Operational Testing at TRACEN Yorktown
 - Honda Marine: April 2013 - March 2014

RB-S and SPC-TB Preparation and Modifications

Prior to commencing field and operational testing, the RB-S and SPC-TB engines and fuel systems will be prepared to ensure compatibility with BU16, based on recommendations from Gevo and Butamax and materials testing results from the engine OEMs. The required preparation and modifications will be directed in two Time Compliance Technical Orders (TCTOs); one for the RB-S and one for the SPC-TB. Draft TCTOs are included in this plan and reflect information available at the time of submission. Once materials testing identifies all compatibility issues, the TCTOs will need to be reviewed, updated as necessary, and approved. All required modifications will be accomplished prior to the start of field and operational testing.

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LIST OF ACRONYMS

ABYC	American Boat and Yacht Council
ANT	Aids to Navigation Team
BFCO	Boat Forces & Cutter Operations
BU16	16.1 percent blend of biobutanol with gasoline
BUSL	Buoy Utility Stern Loading
CAN	Controller Area Network
CG	Coast Guard
CO	Carbon monoxide
COG	Course over ground
CRADA	Cooperative Research and Development Agreement
DHS	Department of Homeland Security
DIW	Dead in the water
DOT	Department of Transportation
E0	100% gasoline
E10	10% ethanol in gasoline blend
ECM	Engine Control Module
EISA	Energy Independence and Security Act
EPA	Environmental Protection Agency
FAME	Fatty-acid methyl ester
GAR	Green-Amber-Red
GHG	Greenhouse gas
GPH	Gallons per hour (gauge display)
GPS	Global Positioning System
HAZMAT	Hazardous material
HC	Hydrocarbon
HDRD	Hydrogenation-derived renewable diesel
HGH	Honda Power Products R&D Center (Japan)
HP	Horsepower
ICW	Inter-Coastal Waterway
LAF	Lean air/fuel ratio sensor
LOA	Length overall
MSDS	Material Safety Data Sheet
NDBC	National Data Buoy Center
NFPA	National Fire Protection Association
NM	Nautical mile
NMEA	National Marine Electronics Association
NMMA	National Marine Manufacturers Association
NO	Nitrogen oxide
NOAA	National Oceanic and Atmospheric Administration
NOx	Mono-nitrogen oxide
O2	Oxygen
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory



LIST OF ACRONYMS (CONTINUED)

POC	Point of contact
RB-S	Response Boat - Small
RDC	Research & Development Center
RPM	Revolutions per minute (gauge display)
SAE	Society of Automobile Engineers
SAIC	Science Applications International Corporation
SFLC	Surface Forces Logistics Center
SOG	Speed over ground
SOP	Standard Operating Procedure
SPC-TB	Special Purpose Craft - Training Boat
TCTO	Time Compliance Technical Order
TRACEN	Training Center
U.S.	United States
U/W	Underway
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
WX	Weather



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1 INTRODUCTION

The Federal Government is placing an emphasis on environmentally friendly and sustainable energy solutions for national initiatives and Federal Government operations. Executive Order 13514 (The President, Federal Leadership in Environmental, Energy, and Economic Performance, 5 October 2009) requires Federal agencies to quantify, manage, and reduce greenhouse gas (GHG) emissions. The Energy Independence and Security Act (EISA) of 2007 (Energy Public Law 110 - 140, 2007) aims to increase United States (U.S.) energy security by developing renewable fuel production and improving vehicle fuel economy. EISA requires Federal agencies to reduce facility energy intensity by 30 percent by 2015, relative to 2005 levels. Section 142 of EISA requires Federal agencies to achieve at least a 20 percent reduction in petroleum consumption and a 10 percent increase in alternative fuel consumption by 2015, from the 2005 baseline. For the U.S. Coast Guard (CG), the Department of Homeland Security (DHS) Strategy sets a reduction target for Scopes 1 and 2 GHG emissions of 25 percent relative to the 2008 baseline by 2020 (DHS Strategic Sustainability Performance Plan, June 2011).

The CG, as a protector of the marine environment, intends to be in the forefront of these initiatives by evaluating and adapting solutions that serve to reduce its carbon footprint. One way of complying with the legislative mandates is through the use of alternative fuels as substitutes for currently used gasoline and diesel fuels. Carbon dioxide captured by growing the feedstocks for the alternative fuels reduces overall GHG emissions compared with using similar petroleum-based fuels. A 2010 Research & Development Center (RDC) study (Remley, 17 December 2010) identified the most promising alternative fuels for a demonstration as biodiesel (fatty-acid methyl ester (FAME)), hydrogenation-derived renewable diesel (HDRD), and natural gas for the diesel boats; and biobutanol and natural gas for the gasoline-powered boats. The RDC contracted with Science Applications International Corporation (SAIC) and Alion Science and Technology (Alion) to develop test plans to demonstrate the feasibility of using alternative fuels in certain CG boats based in part on the recommendations of that report.

The RDC selected a biobutanol/gasoline blend as the fuel of choice for the gasoline-powered boat demonstration which is the subject of this test plan. Butanol is a compound that can be made from biomass (biobutanol), and it can also be made from oil (petrobutanol). This study will use the biobutanol-derived form of butanol and blend it with gasoline to a level of 16.1 percent biobutanol by volume (BU16). The gasoline-biobutanol (isobutanol) blended fuel is hereafter referred to as a biobutanol blend, and the 16.1 percent biobutanol blend described above is referred to as BU16. A biobutanol blend with added corrosive contaminants (called an ‘aggressive blend’) will also be used for some of materials testing.

The benefits of using a biobutanol blend have thus far been demonstrated by limited field testing. Briggs and Stratton (Gevo, 17 January 2011a) demonstrated the use of a 12.5 percent biobutanol blend on small gasoline engines; the National Marine Manufacturers Association (NMMA), working with the American Boat and Yacht Council (ABYC) (Gevo, 17 January 2011b), used BU16 in marine gasoline engines. In both cases, the blend was used as a “drop in fuel” without modifications to the existing fuel systems. Some of the benefits noted from these tests were:

- Reduction of carbon monoxide (CO) emissions, without increasing nitrogen oxide or mono-nitrogen oxides (NO and NO_x, respectively) and hydrocarbons (HC).
- No phase separation when water enters the fuel system, unlike that experienced with ethanol.
- Less corrosive to fuel system components than ethanol.

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The RDC has entered into Cooperative Research and Development Agreements (CRADAs) with Honda Marine and Mercury Marine to conduct the engine materials and bench testing, and solicited the technical support of the only producers of biobutanol, Gevo®, Inc.(Gevo) and Butamax™ Advanced Biofuels LLC (Butamax) for advice on the use of biobutanol.

The next steps in the project consist of materials, bench, field, and operational testing. The 25' Response Boat - Small (RB-S) and the 38' Special Purpose Craft - Training Boat (SPC-TB) will be the platforms used for testing with BU16. The RB-S has Honda Marine engines and the SPC-TB has Mercury Marine engines. Honda Marine and Mercury Marine make up the majority of outboard marine engines used by the CG, so testing on these two platforms covers the majority of the gasoline engines in use. This test plan covers the BU16 testing on the SPC-TB and RB-S. The 49' Buoy Utility Stern Loading (BUSL) has been selected for the biodiesel testing. A separate test plan will address the biodiesel testing.

2 OVERVIEW OF TESTING

This test plan was developed from:

- Information gained from site visits to Aids to Navigation Teams (ANTs) and Training Center (TRACEN) Yorktown, VA. The information was obtained via:
 - Interviews with the operators and engineers familiar with the RB-S and SPC-TB
 - Interviews with the factory-trained technicians for the RB-S and SPC-TB
 - Physical inspection of the RB-S and SPC-TB
- Discussions with potential biobutanol fuel suppliers Butamax and Gevo
- Discussions with Oak Ridge National Laboratory (ORNL), specifically about the percentage of biobutanol to use in the blended fuel and material audits of the boat fuel systems
- Recommendations from Honda Marine and Mercury Marine, the engine original equipment manufacturers (OEMs).
- Research of biobutanol via published works and the Internet

The testing will consist of four phases: materials testing, bench testing, field testing, and operational testing. The proposed test schedule is summarized in Table 1, with details shown in the platform-specific Gantt charts (Figure 1 and Figure 2).

2.1 Materials Testing

Materials testing will be conducted to determine the compatibility of the engine fuel system and fuel-wetted parts with BU16. Details on materials testing are included in Section 7.1. In general, Honda Marine and Mercury Marine will follow their own distinct test protocols and report their findings to the RDC in accordance with their respective CRADAs. For materials testing, Honda Marine will use various percentages of isobutanol blends and Mercury Marine will use four different fuels. One of the four fuels, the aggressive blend, incorporates additional corrosive materials to accelerate the deterioration that may take place on the test materials, and is detailed in Appendix C.

Table 1. Proposed testing schedule.

Test	Time Frame	Proposed Schedule
Materials Testing	Testing is expected to start in early 2012.	Honda Marine and Mercury Marine have proposed schedules for materials testing; see Appendix A and Appendix B, respectively. The proposed dates for materials testing by the OEMs are: Honda Marine: January 2012 - August 2012 Mercury Marine: March 2012 - July 2012
Bench Testing	Bench testing will commence in parallel with materials testing. Honda Marine will conduct preliminary bench testing in Japan in early 2012, followed by testing in the U.S. Mercury Marine will commence their bench testing in parallel with materials testing in early 2012.	The timeframes for on-the-water bench testing by the OEMs are: Honda Marine: September 2012 - January 2013 Mercury Marine: July 2012 - November 2012
Field Testing	Field testing will commence after boat/engine alterations have been accomplished. Field testing will take place at TRACEN Yorktown.	Honda Marine and Mercury Marine: February 2013 - March 2013 <u>Phase 1</u> : Testing on 10% ethanol in gasoline blend (E10) fuel to develop baseline data (2-3 days). Empty tanks, refuel with biobutanol blend (1 day). <u>Phase 2</u> : Testing on biobutanol blend to develop comparison data (2-3 days). <u>Phase 3</u> : Second round of biobutanol testing after 2-3 week static period (2-3 days).
Operational Testing	Operational testing will commence in 2013 immediately after field testing, assuming no problems are identified.	Honda Marine and Mercury Marine: April 2013 - March 2014 <u>Phase 1</u> : Complete seasonal operational testing using biobutanol blend. (9 months) <u>Phase 2</u> : Fuel swap testing (switch between biobutanol blend and gasoline) Gasoline: 1 month <u>Phase 3</u> : Fuel swap testing: Biobutanol blend: 1 month <u>Phase 4</u> : Gasoline: 1 month

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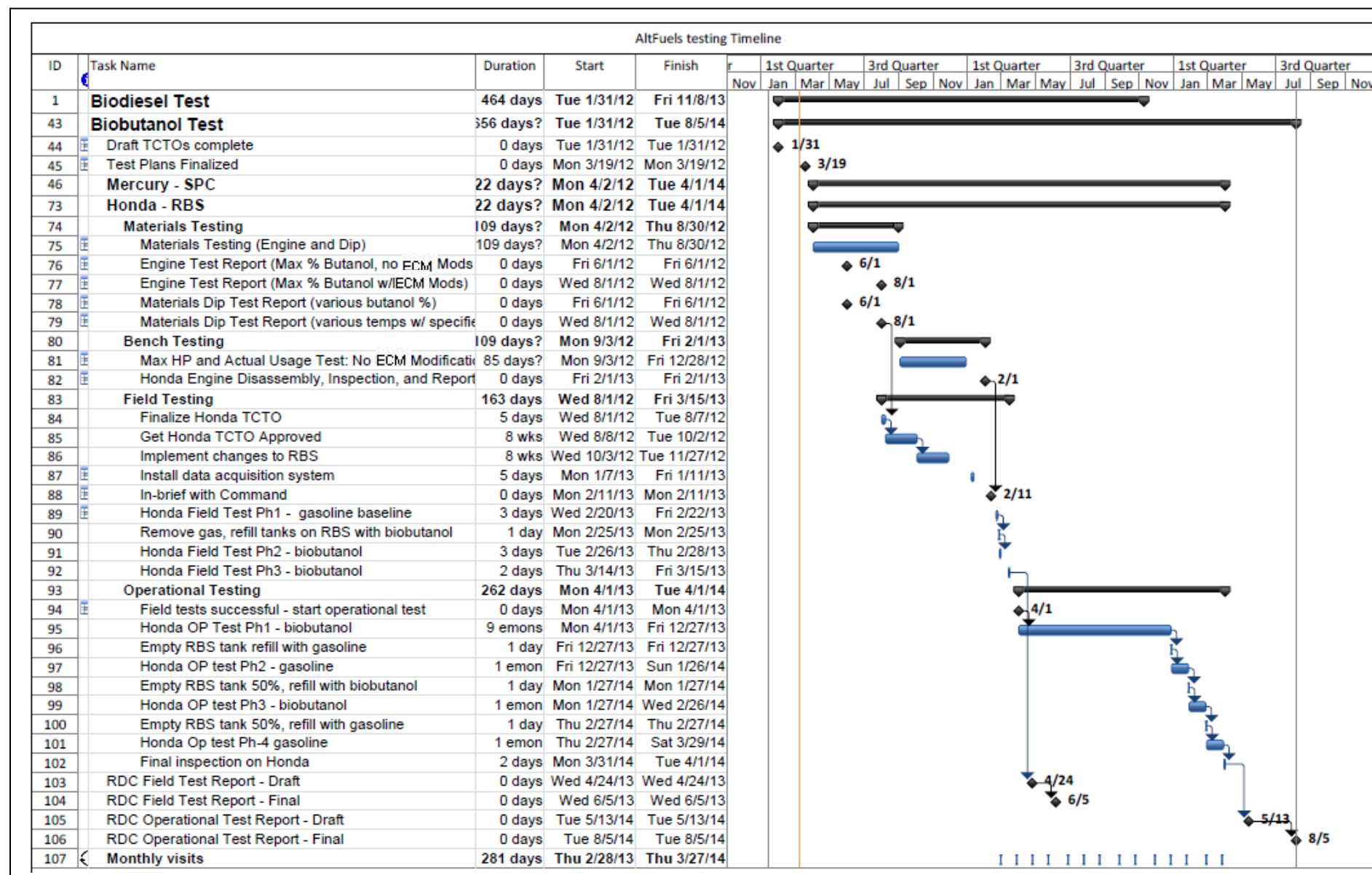


Figure 1. Honda Marine (RB-S) test timeline.



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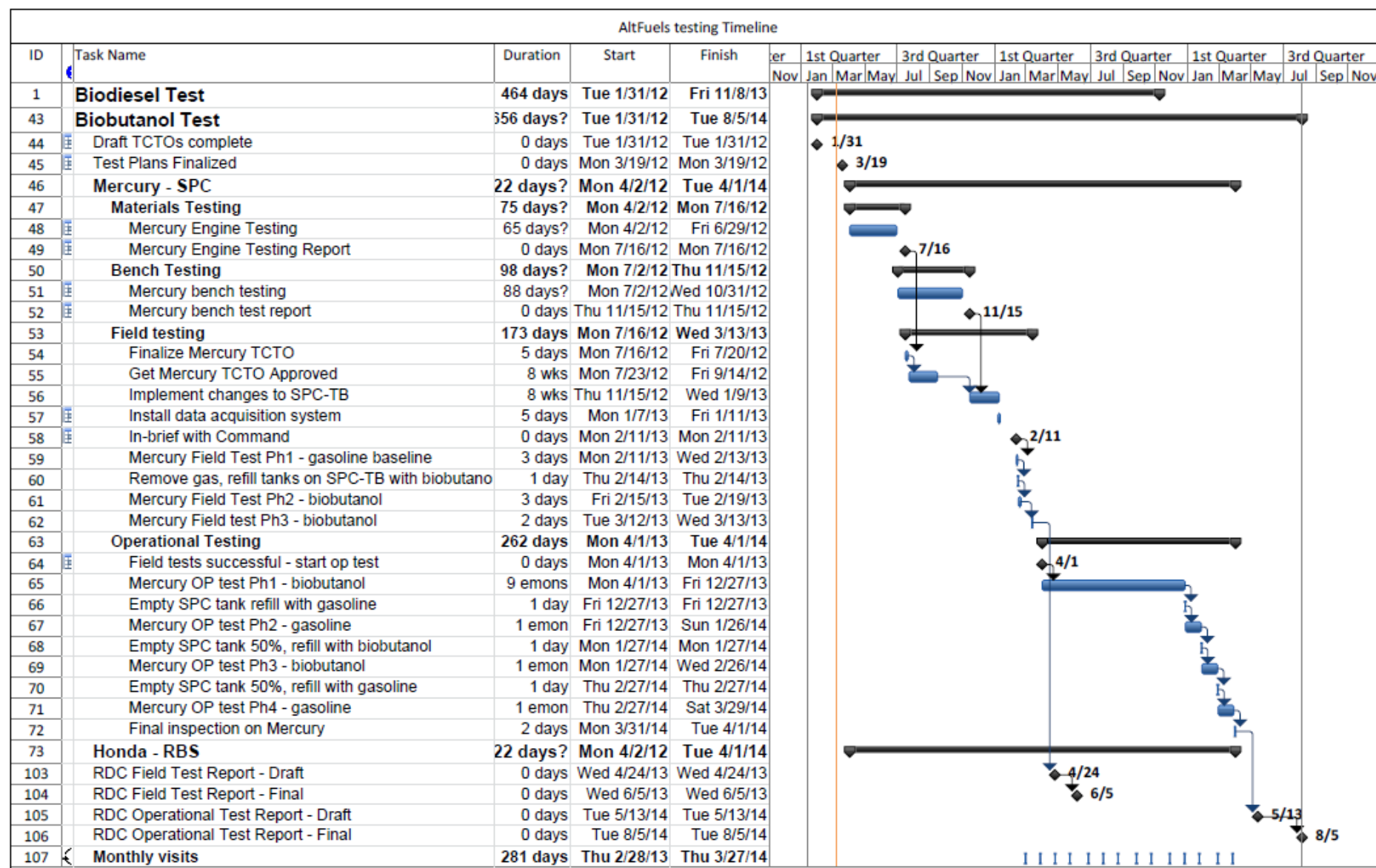


Figure 2. Mercury Marine (SPC-TB) test timeline.



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An audit of the fuel system and fuel-wetted parts for each boat was conducted to determine compatibility of the materials with BU16. Pre-testing compatibility of the fuel-wetted parts was assessed using data from manufacturers, suppliers, the University of Idaho Synfuel program, and material manufacturers such as DuPont™.

Butamax is conducting materials testing during the first half of 2012 on a variety of materials common to fuel supply and transportation systems. To date, Butamax has not shared the list of materials they are testing. This information will be reviewed for applicability to this test plan once it is received. In addition to the materials Butamax will test, Metal Shark, LLC has supplied Butamax with a sample of aluminum used in the construction of the fuel tanks on the SPC-TB, and FloScan™ has supplied Butamax with a sensor assembly to be tested. The results of materials testing are expected by the summer of 2012.

2.2 Bench Testing

Bench testing will be conducted to ensure the engines will operate satisfactorily on BU16, and determine if any adjustments are needed. Both Honda Marine and Mercury Marine will conduct bench testing in a test cell environment where engine-operating parameters such as fuel consumption, performance, and emissions can be monitored under controlled conditions, as well as on-the-water, using their own test boats. Both OEMs will report the results of their testing to the RDC upon completion. Details of the bench testing are contained in Section 7.2.

2.3 Field Testing

Field testing will be conducted to develop baseline data and diagnose and correct problems before operational testing begins. Field testing will be conducted under simulated mission operating conditions, with test personnel monitoring and recording engine and boat performance data. Field testing will also be used to educate the crew with regards to safety considerations and maintenance changes; i.e., different fuel filters or hazardous material (HAZMAT) spill procedures. Details of field testing are in Section 7.3.

2.4 Operational Testing

Operational testing will be conducted over a 12-month period to determine the feasibility of using BU16 in CG boats. The test boats will operate in a similar manner to non-test boats at TRACEN Yorktown, following standard routines as much as possible. All maintenance changes and safety procedure changes (if needed) will be incorporated into TRACEN Yorktown's operational routine in a manner similar to an operational change. In other words, changes should reflect realistic long-term goals and modifications to TRACEN Yorktown's Standard Operating Procedure (SOP). Details of operational testing are provided in Section 7.4.

3 FUEL SYSTEM PREPARATION

3.1 Fuel Blend

Butanol is a 4-carbon alcohol (butyl alcohol). Butanol or butyl alcohol can refer to any of the four isomeric alcohols of formula C_4H_9OH ; one of these four, isobutanol, will be used. Isobutanol is more similar to gasoline than it is to ethanol, and can be produced from biomass as biobutanol, as well as from fossil fuels, in which case it is called petrobutanol. Biobutanol and petrobutanol have the same chemical properties. Currently, butanol's primary use is as an industrial solvent in products such as lacquers and enamels.

Like ethanol, biobutanol is a liquid alcohol fuel that can be used in gasoline-powered internal combustion engines. Biobutanol is also compatible with ethanol blending, and can improve the blending of ethanol with gasoline. Biobutanol has a higher energy density than ethanol, thus it improves fuel economy. It also has other advantageous characteristics such as lower water absorption, which is why it was recommended (Remley, 17 December 2010) for testing by the CG. Recent breakthroughs in biobutanol processing methods, namely the discovery and development of genetically-modified microorganisms that may be used in production, have made it possible for biobutanol to begin to replace ethanol in large quantities. A 16.1 percent blend of biobutanol with gasoline (BU16) has been selected as the test fuel.

3.2 Engine and Fuel System Inspections

RB-S (Honda Marine engine) inspections: Prior to field and operational testing, Honda Marine will inspect and document the condition of engine spark plugs, fuel injectors, fuel pumps, and exhaust. The RDC and TRACEN Yorktown will discuss the results of the inspection with Honda Marine, and TRACEN Yorktown will decide whether to replace any parts. Honda Marine will conduct an engine condition assessment using a portable dynamometer and will conduct an emissions test before and after field and operational testing. The Honda Marine testing will be done with the boat on a trailer out of the water. Honda Marine has stated that any of the BF225 engines currently in service are suitable for the testing.

SPC-TB (Mercury Marine engine) inspections: Prior to field and operational testing, Mercury Marine will inspect and document the condition of engine spark plugs, fuel injectors, fuel pumps, and exhaust valves. The RDC and TRACEN Yorktown will discuss the results of the inspection with Mercury Marine, and TRACEN Yorktown will decide whether to replace any parts. Mercury Marine will conduct an engine condition assessment using their calibration evaluation test in accordance with Section 2.8 of the Mercury Marine test procedures (Appendix B). Mercury Marine has requested that an engine with "low operating hours" be selected for field and operational testing if possible. Mercury Marine technicians may replace the entire fuel system on the engines, utilizing a tented haul-out facility available at TRACEN Yorktown.

RB-S and SPC-TB fuel system inspections: The Boat Forces and Cutter Operations (BFCO) facility will inspect the entire fuel system (fuel lines, valves, hoses, seals, tank connections, and filters) for leaks and satisfactory condition prior to field and operational testing. Components that are not in satisfactory condition will be replaced.

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The U.S. Army Corps of Engineers (USACE) in their testing (Leitch, 12 September 2011) recommended setting up a monitoring program to visually inspect the equipment once a month for leaks, seeps, and seal decomposition. This recommendation is incorporated into the monthly inspection described in Section 7.4.6.

3.3 Power and Fuel Consumption

Bench Testing: Honda Marine and Mercury Marine will measure engine power, fuel consumption, and performance during bench testing; changes in performance from the baseline fuel will be noted. Bench testing protocols include baseline testing on the standard fuel (E10 gasoline) as well as BU16 to allow for comparisons between the two fuels.

Field and Operational Testing: The RB-S has a FloScan 200 series factory-installed fuel monitoring system between the fuel/water separator-filters (see Figure 3). Prior to field testing, a similar FloScan system will be installed on the SPC-TB. The FloScan system is expected to be compatible with BU16; however, Butamax will perform materials testing in the spring of 2012 to confirm compatibility. If the FloScan system does not pass the planned materials testing, then data from both engines' Engine Control Units (ECUs) will be used to monitor fuel consumption. The FloScan devices will also be connected into the data acquisition system. During field testing, fuel consumption will be noted after each test. During operational testing, the fuel consumption will be recorded weekly by the crew and collected monthly by a test team member. The test team will closely monitor total fuel consumption to ensure the available inventory is adequate and to look for anomalies in the fuel consumption rate. For example; if the fuel consumption spikes at various times or increases dramatically over a short amount of time, these events should be investigated to ensure that the engine is not being damaged and can continue to be operated safely.



Figure 3. FloScan meter currently installed on all RB-S platforms.

3.4 Emissions Testing

Mercury Marine and Honda Marine will each conduct engine exhaust emissions testing in conjunction with their bench testing (see Appendix A and Appendix B, respectively). Emissions testing will be performed for nitrogen oxide (NO), hydrocarbon (HC), and carbon monoxide (CO) using the Environmental Protection Agency (EPA) 5 mode emissions testing procedure (ISO D2 Test). Details on the Mercury Marine emissions testing are provided in Section 2.5 of the Mercury Marine Verado test procedure (Appendix B).

4 FIELD/OPERATIONAL TESTING SITE

4.1 Site Selection

TRACEN Yorktown was selected for both field and operational testing because it is a training facility that has multiple hulls of both the SPC-TB and RB-S. Because there are multiple hulls, there will be similar boats using standard gasoline (E10) at the same time and under the same environmental conditions as the test platforms using BU16. This will allow for a continuous baseline comparison. Figure 4 shows a 38' SPC-TB Class boat; Table 2 provides its operational and physical characteristics. Figure 5 shows a 25' RB-S Defender Class boat; Table 3 provides its operational and physical characteristics.



Figure 4. 38' SPC-TB at Coast Guard TRACEN Yorktown dock.

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Table 2. Operational and physical characteristics of 38' SPC-TB Class.

Operational Characteristics		Physical Characteristics	
Max Range @ Cruise Speed	260 NM ¹	LOA ²	40'-9"
Max Speed	38 knots @ 5500 RPM ³	Beam Overall (includes collar)	10'-8 3/4"
Cruise Speed	24 knots @ 4500 RPM	Operational Draft (DIW ⁴ with engines vertical)	3'-0 3/4"
Maximum Operating Distance from Shore	50 NM Range: 260 NM	Propulsion	Two Mercury Marine Verado 300 HP ⁵ , 4-stroke outboard engines
Fuel Consumption @ 6000 RPM	59.6 GPH ⁶	Generator	11.5 KW
Fuel Consumption @ 4500 RPM	35.7 GPH	Generator engine	Westerbeke diesel generator
		Fuel Tank Capacities	400 gallons: gas 28 gallons: diesel
		Number of Fuel Tanks	1 Gasoline 1 Diesel
		Crew/Student Capacity (seated)	Two crew, six students
		Deckhouse	Aluminum (5086 Grade)
		Hull	Aluminum (5086 Grade)

¹nautical mile

²length overall

³revolutions per minute

⁴dead in the water

⁵horsepower

⁶gallons per hour



Figure 5. 25' RB-S.



Table 3. Operational and physical characteristics of 25' RB-S Defender Class.

Operational Characteristics		Physical Characteristics	
Max Range @ Cruise Speed	175 NM (A Class) 150 NM (B Class)	LOA	29'-4" (A Class) 29'-6.5" (B Class)
Max Speed	46 knots @ 6000 RPM	Beam Overall (includes collar)	8'-6"
Cruise Speed	35 knots @ 4500 RPM	Operational Draft (DIW with engines vertical)	3'-3"
Maximum Operating Distance from Shore	10 NM	Propulsion	Twin Honda Marine 4-stroke outboard engines, 225 HP each, Model BF225
Fuel Consumption @ 6000 RPM	40 GPH (A Class) 44 GPH (B Class)	Generator	NA
Fuel Consumption @ 4500 RPM	28 GPH (A Class) 20 GPH (B Class)	Generator Engine	NA
		Fuel Tank Capacity	125 gal (A Class) 105 gal (B Class)
		Number of Fuel Tanks	1
		Crew/Passenger Capacity (seated)	Four crew, six passengers
		Deckhouse	Aluminum
		Hull	Aluminum

4.2 TRACEN Yorktown Site Details

The small boat facility at TRACEN Yorktown is the BFCO. BFCO is located on the west side of the Chesapeake Bay on the York River, VA (see Figure 6), with the small boats located on Wormley Creek Road on a small peninsula near the entrance to the York River. BFCO has a wooden pier that can accommodate 14 SPC-TBs and a submersible dock that can accommodate 9 RB-S's (see Figure 7). Table D-1 and Table D-2 in Appendix D show the average annual water temperature and the average air temperature, respectively, for the Yorktown area. Appendix E provides a list of the points of contact (POCs) for the site.

4.3 TRACEN Yorktown Fuel Storage

The RDC is coordinating the purchase and delivery of the isobutanol fuel (neat and blended) for the OEM bench testing, and the BU16 for field and operational testing. Gevo and Butamax have been contacted about supplying the test fuel. Gevo was provided with a preliminary estimate of the amount of test fuel required, and responded with a preliminary cost estimate. Gevo pointed out in their response that the fuel specification will be an important cost factor, as specially blended fuel will cost more to blend, produce, ship, and deliver; upwards of \$15/gallon compared to \$5/gallon for splash-blending using regular 87 octane gasoline.



Figure 6. TRACEN Yorktown.



Figure 7. Boat Forces and Cutter Operations (BFCO).

Butamax does not expect to have a pilot plant with production until late 2012 or the beginning of 2013. Gevo has indicated they will be able to deliver sufficient fuel to support field and operational testing, as they expect their commercial production to start in June 2012. As a result, Gevo will most likely supply the BU16 for the testing at TRACEN Yorktown, and Gevo plans to work with a fuel distributor, Mansfield Oil Company, to supply the fuel. The RDC has arranged for a representative from Mansfield Oil to visit TRACEN Yorktown to evaluate the site and propose a supply strategy incorporating the use of a trailerable fuel tank as described below.

The BU16 will be stored at TRACEN Yorktown in a trailerable fuel tank. An initial survey of fuel trailers has not revealed any incompatibilities with BU16. A fuel trailer such as shown in Figure 8 can be stored safely out of the way in the parking lot and towed near to the pier for fueling operations. A self-contained and self-powered fuel trailer with 100 feet of hose would be sufficient for this purpose. Figure 9 is an overhead view of where the trailer would be towed to for the fueling operations. TRACEN Yorktown has stated that they have a sufficient number of heavy-duty trucks and personnel to accomplish this.

4.4 TRACEN Yorktown Site and Boat Modifications

4.4.1 Site Modifications

No substantial site modifications are required for this project, because the preferred fuel storage solution uses a fuel trailer. The Engineering Officer and Environmental Officer at TRACEN Yorktown will identify a safe and secure location to park the fuel trailer when it is not in use. Preferably, this will be in an isolated corner of the parking lot with at least one concrete barrier located to prevent vehicles from accidentally hitting the fuel trailer. No State or Federal regulations require fire suppression or containment systems for a fuel trailer of the recommended size (500 gallons). Because the fuel trailer will be storing a gasoline blend, it is not Department of Transportation (DOT)-approved for on-road use. The fuel trailer therefore must not leave TRACEN Yorktown.

4.4.2 Boat Modifications and Preparations

Because the RB-S and SPC-TB engines currently use E10 gasoline, and isobutanol has fewer materials compatibility issues, the existing fuel system should be compatible with the BU16. This will be confirmed from the results of materials testing. The complete list of materials in the wetted-fuel systems for each platform is provided in Appendix F and Appendix G, respectively.

In order to facilitate and automate data collection during field and operational testing, a data acquisition system (described in Section 6) will be installed on each boat. This will consist of a computer and touchscreen mounted in the cabin, a Global Positioning System (GPS)/weather station mounted on top of the cabin, interfaces to the Honda Marine or Mercury Marine ECUs, and National Marine Electronics Association (NMEA) 2000™ wiring to connect the components of the system. The exact locations for the equipment installation will be determined during a site survey. Fuel consumption will be monitored on both test boats as described in Section 3.3.



Figure 8. Example fuel trailer.



Figure 9. Location of fuel trailer during refueling.

5 TRAINING

Prior to the field and operational testing phases, crew training will be held to prepare BFCO test personnel to use BU16 for the testing. Training will include the following topics (provided in a separate PowerPoint document).

- Project background
- Project goals; specifically for the biobutanol testing
- Overview of biobutanol fuel; how it is made, advantages, disadvantages, and the Material Safety Data Sheet (MSDS)
- Differences between gasoline fuel and biobutanol fuel including the effects of temperature
- Safety-related and health issues including safety regulations concerning exposure to biobutanol; i.e., skin contact, ingestion, etc.
- Changes in maintenance procedures
- Changes in Federal and State regulations with regards to reporting of spills, etc.
- Changes in fuel logistics; i.e., biobutanol delivery/storage issues
- Use/monitoring of data acquisition system

6 DATA COLLECTION PLAN

During field and operational testing, dozens of engine and boat parameters will be recorded as part of the assessment process. These parameters will be used to document the performance of the Honda Marine and Mercury Marine engines using BU16 in comparison to using E10. These data will also provide key information to help the test team diagnose any failures or performance degradations. The same data will be recorded for both field testing (baseline and BU16) and operational testing.

Most of the data will be collected using an automated data acquisition system to be installed by the RDC. This system is shown in Figure 10 and is a network of sensors connected to a computer using an NMEA 2000 bus. The data acquisition system encompasses two functional areas: boat dynamics, which consists of data about the boat motion and environment, and engine dynamics, which consists of engine-related parameters.

The boat dynamics sensor is a PB200 Weather Station that is an integrated collection of sensors. This will be installed on the top of the cabin and wired into the 12 volt panel for power. It provides environmental data (temperature, wind speed, etc.) as well as GPS position, course, speed, and boat roll and pitch. Additional weather and wave data (sea conditions) for the Chesapeake Bay area will be obtained during operational testing from online sources reporting observations from the National Oceanic and Atmospheric Administration (NOAA) PORTS system and the National Data Buoy Center (NDBC) system. Figure 11 and Figure 12 show some of the reporting locations for these two systems in the region where testing will be conducted. An example of some of the data available from these systems is shown in Figure 13. The test team will download the relevant data from the websites on a monthly basis and organize it for post-test analysis.

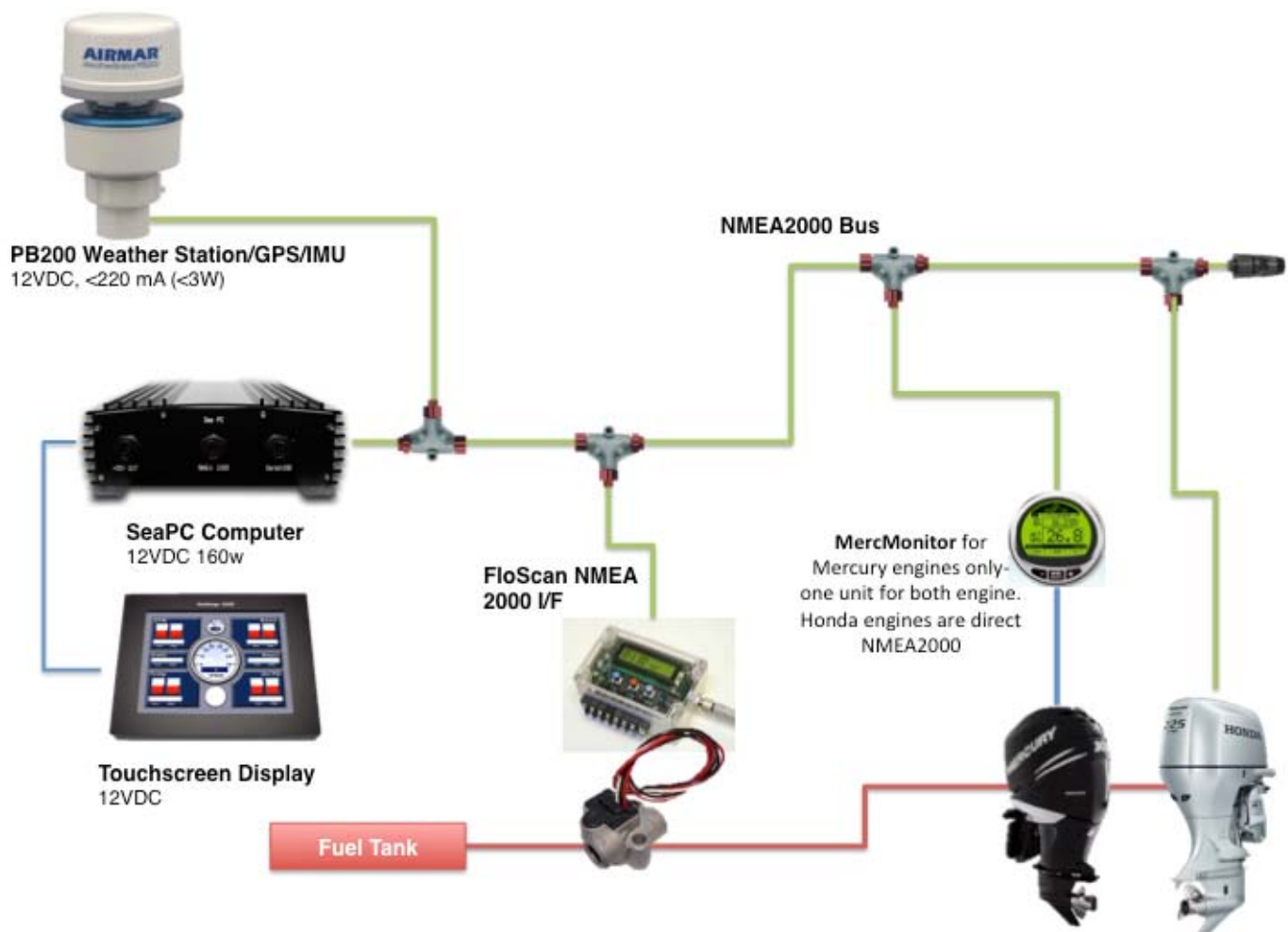


Figure 10. Data acquisition system for RB-S and SPC-TB.

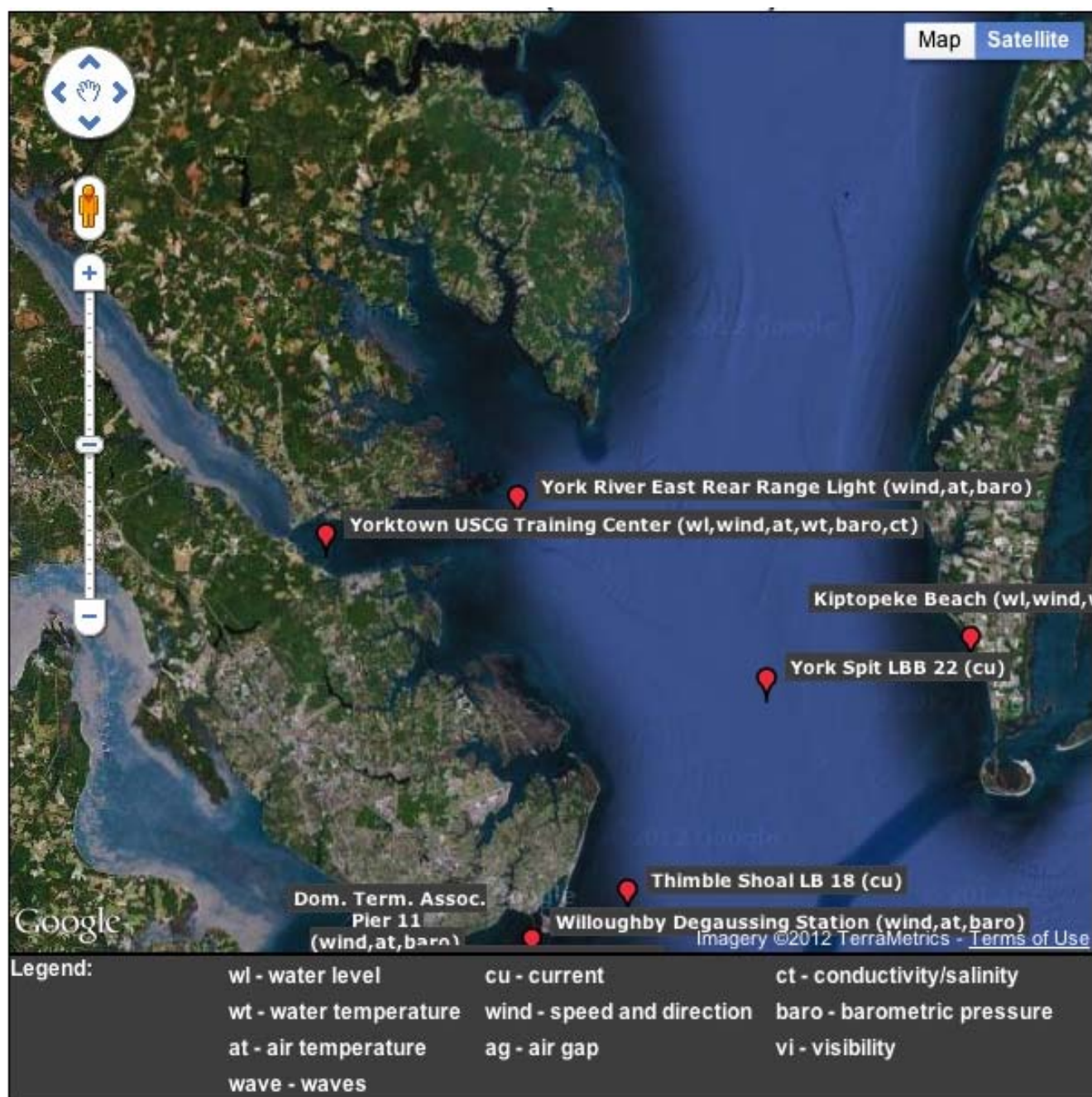


Figure 11. Data available from NOAA PORTS
(<http://tidesandcurrents.noaa.gov/ports/index.shtml?port=cs>).

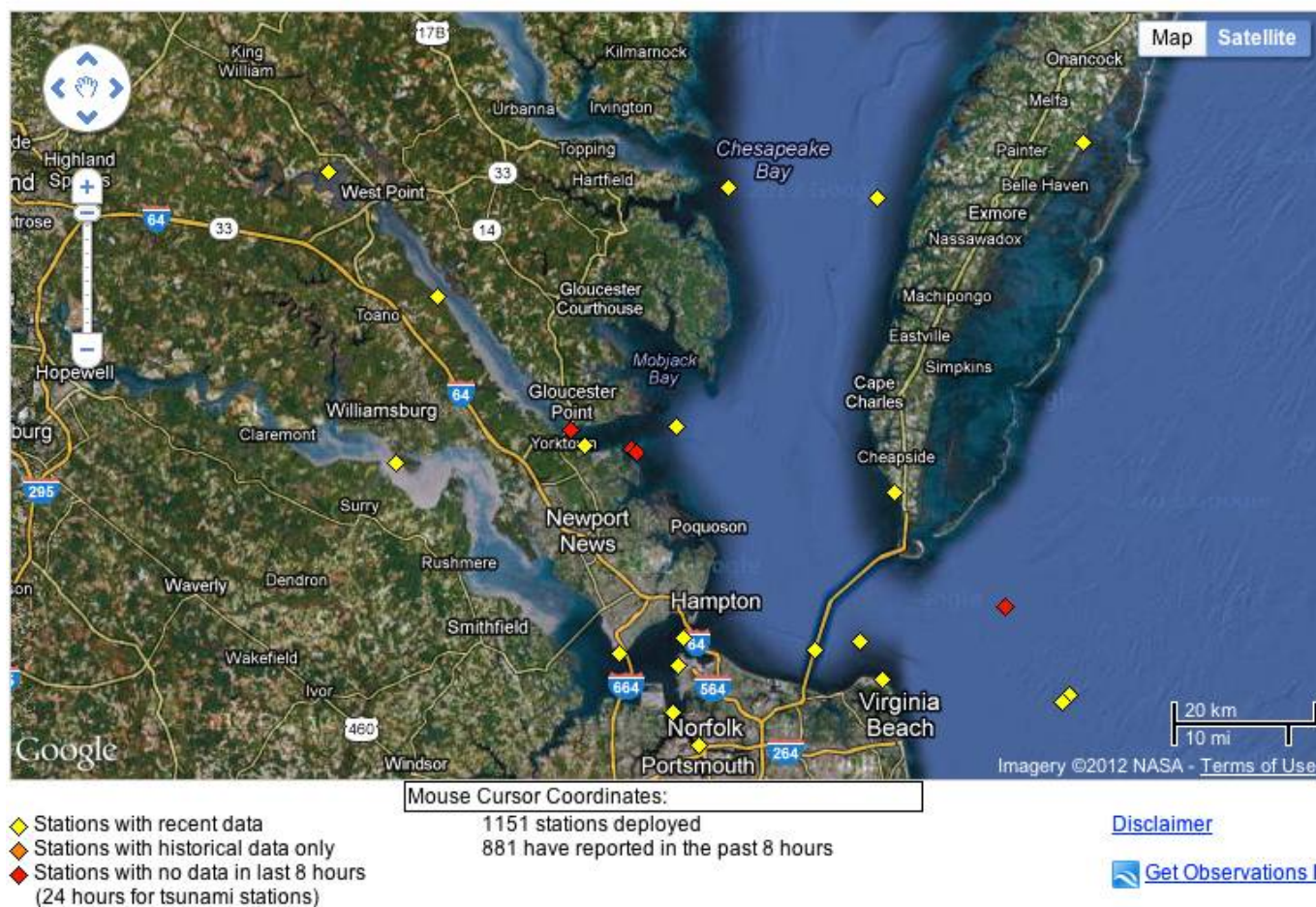


Figure 12. Data available from NDBC (<http://www.ndbc.noaa.gov/>).

Stingray Point - SR



SR Near Deltaville, VA
37.5672 N, 76.2574 W

DOWNLOAD DATA



Information

Buoy Data

Show 100 entries		Search:		
Parameter	Value	Unit	Date	Graphs
Air Temperature	61	F	2012-03-08 12:20	1 7 30
Barometric Pressure	30.26	inches	2012-03-08 12:20	1 7 30
Chlorophyll A	7.6	ug/L	2012-03-08 12:00	1 7 30
Current Direction	23	degrees	2012-03-08 12:00	1 7 30
Current Velocity	0.45	knots	2012-03-08 12:00	1 7 30
Dissolved Oxygen	11.6	mg/L	2012-03-08 12:00	1 7 30
Latitude	37.56747	degrees	2012-03-08 12:20	1 7 30
Longitude	-76.26206	degrees	2012-03-08 12:20	1 7 30
Maximum Wave Height	2.4	ft	2012-03-08 12:00	1 7 30
Mean Wave Direction	183	degrees	2012-03-08 12:00	1 7 30
Mean Wave Height	0.9	ft	2012-03-08 12:00	1 7 30
Mean Wave Period	2.1	s	2012-03-08 12:00	1 7 30
Relative Humidity	69.7	percent	2012-03-08 12:20	1 7 30
Significant Wave Height	1.4	ft	2012-03-08 12:00	1 7 30
Water Conductivity	1.45	S/m	2012-03-08 12:00	1 7 30
Water Freezing Point	30.8	F	2012-03-08 12:00	1 7 30
Water Salinity	12.5	PSU	2012-03-08 12:00	1 7 30
Water Temperature	48	F	2012-03-08 12:00	1 7 30
Wave Direction Spread	47	degrees	2012-03-08 12:00	1 7 30
Wind Chill	61	F	2012-03-08 12:20	1 7 30
Wind Direction	214	degrees	2012-03-08 12:20	1 7 30
Wind Gust	15.3	knots	2012-03-08 12:20	1 7 30
Wind Speed	12.8	knots	2012-03-08 12:20	1 7 30
Showing 1 to 23 of 23 entries				First Previous 1 Next Last

Figure 13. Example of data (http://buoybay.noaa.gov/locations/stingray-point.html#twoj_fragment1-1).

The Honda Marine BF225 and Mercury Marine Verado 300 engines are equipped with ECUs that serve as onboard control computers, and real-time engine dynamics can be accessed from the ECM via standard marine communications networks. The Honda Marine BF225 uses an NMEA 2000 network and the Mercury Marine uses a Controller Area Network (CAN)-BUS-based network. The data from the Mercury Marine Verado engine is a proprietary protocol but can be converted to NMEA 2000 with the addition of Mercury Marine's MercMonitor. NMEA 2000 interfaces will also be connected to the FloScan meters on both boats to capture fuel consumption data.



Butanol/Gasoline Test Plan

The data collection computer is the SeaPC™, manufactured by Chetco Digital Instruments, Inc. It is a ruggedized dc-powered computer specifically designed to receive, record, and display NMEA 2000 data. The SeaPC will be installed on both boats near the main breaker panel. Table 4 shows a small sample of the parameters available to be recorded. Each sensor providing data (engine, weather station, etc.) has different data transmission intervals, and the data collection software will be configured to record all data at the intervals that it is received; nominally at 1-second intervals.

Table 4. Data parameters to be monitored and recorded.

Sub-system	Parameter	Source of Data
Boat Dynamics	Position	Weather (WX) Station
	Speed over Ground	WX Station
	Course over Ground	WX Station
	Air Temperature	WX Station
	Wind Speed	WX Station
	Atmospheric Pressure	WX Station
	Humidity	WX Station
	Heading, Pitch, Roll	WX Station
Engine Dynamics	Fuel Flow	FloScan
	Engine RPM	ECU
	Engine Hours	ECU
	Engine Temp	ECU
	Oil Pressure	ECU

The weather station and the data collection computer will each have their own circuit breakers and energizing these breakers will be part of the boat checks performed before the crew gets underway. Both systems are designed to begin monitoring and recording data after being energized and a short boot-up sequence. A touchscreen monitor will be installed in a convenient location near the instrument cluster. A survey visit will be necessary to finalize the installation details, including the exact location of the computer and the monitor. Power requirements will also be discussed and reviewed with the Engineering Officer to ensure there is adequate power on both boats.

All data will be recorded on the boats and the test team will collect the recorded data during their monthly TRACEN Yorktown visits. During the monthly visit, a “check ride” will be arranged for the test team member, if possible, so that the proper operation of the data acquisition system can be verified. Although the data acquisition system is automated, the crew will need to verify that it is running, and report any discrepancies to the RDC. The pre-test training will cover the basic operation of the data acquisition system including how to power it up, how to verify proper operation, and basic troubleshooting.

7 TEST PROCEDURES

7.1 Materials Testing

The objective of materials testing is to determine the compatibility of the engine fuel system and fuel-wetted parts with BU16.

7.1.1 Fuel System Materials Testing

A materials audit of the RB-S and SPC-TB fuel system materials was conducted using material and component information found in the respective fuel system diagrams and materials lists, as well as information gathered during the TRACEN Yorktown site visit and survey of the SPC-TB. Additional information was obtained from the SPC-TB manufacturer (Metal Shark). The fuel system materials on both boats were checked for isobutanol compatibility by consulting with chemical experts, published information, and the fuel suppliers Gevo and Butamax. The list of fuel-wetted parts in the RB-S and SPC-TB fuel systems can be found in Appendix F and Appendix G, respectively, with potential problem materials highlighted. BU16 compatibility is not expected to be an issue with the fuel systems, as experts generally believe that BU16 is very similar to straight gasoline (E0), as compared with E10. The compatibility of aluminum with BU16 must be confirmed, and both Metal Shark and FloScan have provided samples to Butamax of the aluminum used in their manufacturing to be included in their materials testing being conducted this year.

7.1.2 Engine Materials Testing

Materials testing procedures agreed to by Honda Marine and Mercury Marine are presented in Appendix A and Appendix B, respectively. Each vendor is responsible for testing their engine materials, reporting any required material changes, and certifying their engines as ready for BU16 operation.

An approach that is commonly used in materials testing is the use of an aggressive blend formulation to accelerate materials degradation in order to shorten the necessary test time. The Society of Automobile Engineers (SAE) J1681 (10 January 2000) standard specifies the aggressive blend for materials compatibility testing for ethanol and methanol fuels. Because butanol is an emerging fuel that is not yet in widespread use, no industry standard exists for an aggressive butanol blend. An aggressive biobutanol specification was proposed by ORNL using the SAE J1681 standard as a model. Mercury Marine will conduct materials testing of their engine components using this aggressive blend (see Appendix C), while Honda Marine will follow its standard protocols, which do not use an aggressive blend.

7.1.2.1 Honda Marine Materials Testing

Honda Marine will perform its materials testing in Japan. Honda Marine will dip-test the fuel-wetted materials in a range of butanol blend percentages. Dip-testing is a method of testing materials where a sample of the material to be tested (called a coupon) is dipped into a sample of the fuel. The coupon is typically left in contact with the substance for a period of weeks and then checked for deterioration. The materials exposed to the fuel will be supplied in the form of coupons. Analysis of the coupons for deterioration and pitting after a specified amount of time will indicate the maximum percentage of butanol

that is compatible with their engine materials. Honda Marine will conduct a second dip test using a specified butanol percentage (probably BU16) while varying the fuel temperature to represent typical engine usage.

7.1.2.2 *Mercury Marine Materials Testing*

Mercury Marine plans to conduct materials and dynamometer testing at their facility in Wisconsin. It will assess compatibility of the fuel with engine system components by circulating four butanol blends, one being BU16, through a test engine fuel system, and then examining the fuel-wetted components for compatibility issues. Appendix B provides details of the Mercury Marine materials testing protocol.

7.2 Bench Testing

The objective of bench testing is to certify that the engines will operate satisfactorily on BU16. Both Honda Marine and Mercury Marine will conduct bench testing of the same model engines that will be used for field and operational testing: the BF225 for Honda Marine and the 300 HP Verado for Mercury Marine.

Bench testing will be composed of the following tests.

- Cold Starting
- Performance
 - Power
 - Fuel Consumption
- Endurance
- Emissions

7.2.1 Honda Marine Bench Testing

In addition to certifying that the BF225 will operate on BU16, Honda Marine's bench and materials testing will:

- Provide the CG with a Honda Marine-certified maximum percentage of butanol that can be used in unmodified Honda Marine outboard engines, while retaining the ability to use E0 or E10.
- Provide the CG with a Honda Marine-certified maximum percentage of butanol that can be used in Honda Marine outboard engines with modifications made to the ECM. This modified engine will not be compatible with E0 or E10; however, this engine should be able to run higher percentages of butanol than the unmodified engine.

Honda Marine will conduct bench testing in Japan and the U.S. Bench testing in Japan will be conducted approximately January to July 2012, at the same time as materials testing described earlier. Honda Power Products R&D Center (Japan) will be performing their bench testing using the BF150 engine. The BF150 uses a linear air-fuel (LAF) sensor, which provides feedback about the combustion process taking place inside the engine. The LAF sensor is capable of measuring air-fuel ratios as lean as 23:1, allowing the ECM to precisely control the air-fuel mixture during normal and lean burn conditions. As HGH modifies the BF150 ECM during testing, the LAF sensor will make it easier to create and dial-in a custom fuel and ignition for the ECM. HGH will extrapolate the results of testing the unmodified BF150 engine, to determine a maximum butanol blend for an unmodified BF225. The results of bench testing using the

maximum butanol percentage and modified ECM will be used only for future reference, as it does not directly support the objectives of this study.

Based on the results of the materials and bench testing in Japan, Honda Marine will conduct testing in the U.S. on a BF225 equipped with a special propeller designed to produce maximum power at wide open throttle. The test will be conducted on a boat operating on the Inter-Coastal Waterway (ICW) in Florida, using the maximum biobutanol blend and no ECM adjustments. This testing will take place approximately September to December 2012, with results to be reported to the RDC in January 2013. Similar testing will be conducted using BU16 with a normal operating profile in the ICW using the standard engine and propeller configuration. Honda Marine will also test using the maximum biobutanol percentage with ECM adjustments approximately March to June 2013. See Appendix A for details of the Honda Marine materials and bench testing.

7.2.2 Mercury Marine Bench Testing

Mercury Marine's bench testing will begin with engine dynamometer testing conducted during March 2012 to October 2012. This testing will be conducted with BU16 fuel that will be tested for specification compliance prior to the start of testing. Mercury Marine will conduct approximately three weeks of steady-state dynamometer operation to measure power output, emissions, oil dilution, fuel consumption, and engine calibration evaluation.

Following the dynamometer testing, Mercury Marine will conduct in-the-water engine calibration evaluation on a boat/engine set-up simulating Coast Guard use. The engine will be instrumented with a "black box" recorder to record specified data. The engine will be evaluated for starting (cold and warm), transient operation, shifting evaluation, and extended idle. See Appendix B for details of the Mercury Marine bench and calibration evaluation testing.

7.3 Field Testing

Field testing is intended to ensure the entire fuel system (i.e., the fuel tank all the way to the engines) is compatible with the biobutanol blend. Both test platforms must run during these field tests to the point where the test team and BFCO Engineering Officer are satisfied that no issues, such as leaks, remain. If anomalies are observed, testing will be terminated until the issue is resolved through actions such as replacing an O-ring, gasket, or fuel line. Anomalies are not anticipated; however, the engine parameters, especially engine temperature, will be closely observed during field tests to ensure that the engines are not damaged. If any engine parameters begin to move outside of normal operating range, the testing will be terminated until the cause can be determined and corrective action can be taken.

Prior to field testing, the test team will install the data acquisition system and instrumentation. Individual parameters will be recorded as described in Table 4. Given that materials and bench testing are due to be completed during 2012, information about biobutanol compatibility is currently limited, and the results of that testing may require changes to be made to the test engines and/or boats before the start of field testing in 2013. The plan (and accompanying RB-S and SPC-TB Time Compliance Technical Orders (TCTOs)) will be reviewed and updated as necessary in late 2012 or early 2013, as results of the materials and bench testing become available. The draft TCTOs for RB-S and SPC-TB are shown in Appendix H and Appendix I, respectively.

Each test will begin with the following items so that a consistent baseline is established.

1. Boat checks performed by the crew.
2. Normal engine checks performed by the crew.
3. Ensure test data sheet is filled out and ready for entries including date and time.
4. Start all data recorders.
5. Record any non-data information; i.e., weather observations, crew personnel list, fuel level, and miscellaneous information.
6. Start engines.

The following will be performed at the end of each test.

1. Stop data recording.
2. Complete the Field Testing Data Sheet form (Appendix J).
3. Confirm test data has been successfully collected.

The following will be performed on the last test for the day.

1. Shut down engines.
2. Stop data recording.
3. Copy test data onto laptop.
4. Confirm test data has been successfully copied.
5. Back up test data onto external hard drive or flash drive.
6. Secure power to test equipment.
7. Secure all equipment for the night.
8. Complete test form; ensure it is filled out completely; record observer's comments if applicable.

Honda Marine and Mercury Marine technicians will be on-site at TRACEN Yorktown for the beginning of field testing, and will inspect their engines prior to the start of testing, to the degree determined by them. The RDC test team will be on-site to help facilitate with the BFCO personnel and also to observe and assist where needed. Once this initial testing is complete, the RDC test team will complete field testing as described in Section 7.3.1. The test data sheets contained in Appendix J will be filled out for every test.

7.3.1 Specific Field Tests

The following tests will be run.

1. 60-minute idle at the pier
2. Underway for 1 hour at slow speed
3. Underway for 1 hour at half speed
4. Underway for 2 hours at full speed

7.3.2 Field Testing Phases

Field testing is planned for approximately February - March 2013 and will consist of three phases. Phase 1 will test E10 gasoline to develop baseline data; i.e., performance data using E10 to compare with performance data using BU16. Phases 2 and 3 will use BU16. Each phase will consist of the tests listed in Section 7.3.1 and is expected to take 2-3 days. After Phase 1 is completed, the BFCO will empty the fuel tanks of all E10 (as much as feasible) and then refuel with BU16. A 2-3 week period is also inserted between Phases 2 and 3 to allow time to review the data as needed.

7.3.3 Fuel Swaps during Field Testing

Because Phase 1 uses E10 gasoline and Phase 2 is conducted using BU16, the goal is to empty the tanks as much as possible between the two phases. At the conclusion of Phase 1, whatever gasoline is left in the tanks must be pumped out, and returned to the E10 fuel storage tank or transferred to another boat. After as much gasoline as possible has been removed (it is understood that this will not be 100 percent), the tanks can be refilled with BU16. Phases 2 and 3 are conducted with BU16 which then continues into operational testing, so any refueling will be done using BU16.

7.4 Operational Testing

The goal of operational testing is to ensure that BU16 can be used successfully as a replacement fuel in an operational setting and to capture any operational and functional differences using biobutanol as fuel. During the 12-month operational testing, the BFCO boat crews will go about their daily and weekly routine on the test boats as they do with other boats. Although operational testing is not intended to study and/or resolve the logistics issues associated with obtaining and handling BU16, special provisions are needed to supply the fuel required, and such provisions are described in Section 7.4.3.

7.4.1 Timeline

Phase 1: Starts immediately after field testing is complete, assuming that field testing is successful. Begin daily operations and continue for 9 months to get a full range of operations and environmental conditions.

Phase 2: Switch back to gasoline (E10). This fuel swap is done as a complete fuel swap, so towards the end of Phase 1, the boats should be operated so as to end the phase with as little BU16 as possible in the boats.

- Pump out the remaining BU16 back into the storage trailer. Again, this will not totally empty the fuel tanks, but the goal is to remove as much as possible.
- Refill the tanks with standard E10 gasoline.
- Continue normal operations for the month using E10 gasoline.

Phase 3: Switch back to BU16. This fuel swap is done as a 50-50 swap so, as the end of Phase 2 approaches, the boats should be operated so as to end Phase 2 with about half a tank of E10 left.

- Reduce fuel level in the tanks to approximately 50 percent full, transferring fuel to another boat as needed.
- Fill the tanks with BU16.
- Continue normal operations for the month using BU16.

Phase 4: Switch back to gasoline. This fuel swap is done as a 50-50 swap so, as the end of Phase 3 approaches, the boats should be operated so as to end Phase 3 with about half a tank of BU16 left.

- Reduce fuel level in the tanks to approximately 50 percent full, transferring the fuel back to the storage trailer.
- Fill the tanks with E10 gasoline.
- Continue normal operations for the month using E10.
- Conclusion of operational testing.

7.4.2 BFCO Responsibilities

During the operational testing phase, BFCO personnel are to operate within normal operating/training parameters as much as possible, following the guidance in the test plan. Operational commitments and daily and underway routine take precedence over the testing; however, there are some basic test requirements that the boat crews, boat engineers, and Engineering Officer are required to fulfill. These include:

- Conduct a visual inspection of the entire fuel system for leaks prior to any underway trips.
- Ensure data acquisition system is operating. If the computer is not running, ensure power is connected and try rebooting. If this does not resolve the problem, notify the RDC.
- Replace filters as necessary (keep all used fuel filters, noting the date and time).
- Record all maintenance such as fuel filter changes.
- Immediately contact the RDC and/or test team leader to report any and all incidents related to the test; e.g., fuel filter failures, fuel leaks, or engine malfunctions.
- Fill out operational testing data sheets required by the test plan (Appendix K).

7.4.3 Fueling Operations

Fueling procedures will be different for the test boats than for the E10-fueled boats at TRACEN Yorktown. The BU16 fuel will be delivered to TRACEN Yorktown by tank truck, and then stored in a fuel trailer. The fuel should be delivered with a fuel compliance certificate that will be received by BFCO and provided to the RDC. Fuel sampling will be conducted periodically and, if the costs are sufficiently low, sampling will be done for every fuel delivery. A decision on the fuel sampling interval will be made by the RDC prior to the start of operational testing.

The Engineering Officer will determine the best method for utilizing the fuel trailer during the fueling operations. In general, the fuel trailer will be driven to the fueling location and a hose will be extended to the boat. After successfully fueling the boat, the hose will be retracted and the fuel trailer will be returned to its storage location in the parking lot.

During the beginning of operational testing, it may take several fueling evolutions to refine the procedure to make the evolution as smooth as possible. Issues such as exact placement of the fuel trailer, path of the fuel hose, and time allotted will be adjusted as necessary. The Engineering Officer will have final authority with regards to the fueling procedure.

7.4.4 Emergency Fuel Swap Procedures

In the event that the biobutanol blend is not available and operational necessity dictates that the boats need to be refueled, they can be filled with regular gasoline. This emergency change of fuel should be noted in the operational testing data sheets (Appendix K) and the RDC should be notified as soon as possible. Once BU16 is available, the tanks should be emptied of regular gas and refilled with BU16. The gasoline removed from the tanks can be saved and used during Phase 2 or Phase 4 of operational testing.

7.4.5 Frequent Inspection During Operational Testing

The boat crew and boat engineer will have the responsibility of frequently monitoring the test boat and maintaining situational and operational awareness at all times. Training centers are very busy and have a high degree of instructor and student rotation, and it is important that all new crew members understand that they are operating a biobutanol test boat. The RDC will provide ample visual reminders such as placards and stickers to be placed on the test boats to clearly indicate which RB-S and SPC-TB is using BU16 as a fuel; however, these indicators alone should not be relied on to ensure crews are aware.

The boat crew and boat engineer will remain vigilant while underway, monitoring the engines and fuel systems as much as reasonably possible. Any anomalies observed must be noted and any safety concerns must be reported to the Engineering Officer. While underway, any observations that may be safety-related must be immediately brought to the attention of the Coxswain. Even if the anomaly does not appear to be related to the use of the BU16, the anomaly will be reported to the RDC and senior test team member. There may be instances when anomalies appear to be unrelated but ultimately could be attributed to the use of BU16 as an alternative fuel.

7.4.6 Monthly Visits by RDC

An RDC test team member will visit TRACEN Yorktown once a month to retrieve data to ensure the instrumentation is working properly, ensure test protocols are being followed, perform a visual inspection of the engines and exposed fuel systems, and meet with the Engineering Officer to collect any written information and discuss the performance of the engines in general. These visits will give the Engineering Officer and boat crew the opportunity to share any observations or additional data with the test team member. As part of this visit, the test team will get underway with each of the test platforms to observe procedures and equipment. During this visit, the team member will also repair any instrumentation that is not functioning, retrieve any filters replaced or parts failed, as well as copies of all certificates of analysis for the delivered biobutanol.

Upon return from the monthly visit, the test team member will compile the data, add the data to the master data record, and submit a written report with the results of his visit. It is possible that nearly all the data will be collected electronically; however, if it is not, then the data will be collected from engineer log sheets, separate data sheets created for this purpose (Appendix K), and by other means.

7.4.7 Test Conclusion

At the conclusion of operational testing, the two boats will be inspected by the RDC test team and BFCO engineering to ensure that there is no damage to the engines or fuel systems. Honda Marine and Mercury Marine technicians will also inspect their engines.

In addition, a wrap-up team meeting will be held at TRACEN Yorktown. This will give the test team the opportunity to remove all test equipment and to return the test platforms back to their standard configuration. The Engineering Officer and personnel who operated the boat on a routine basis will meet with the test team personnel to discuss the testing. The test team will review with BFCO personnel any incidences or anomalies not reported to the test team previously. This will also be an opportunity for any final comments or observations to be conveyed to the test team.

8 DATA ANALYSIS PLAN

8.1 Field and Operational Testing

The engine and emissions data collected in the first phase of field testing (E10 operations) will provide a baseline of performance to compare all subsequent data. During field and operational testing, engine and fuel consumption data along with course over ground/speed over ground (COG/SOG) information will be used to assess performance while using BU16 as compared to performance using E10. The boat dynamics and weather data will be used in the analysis to put the performance data into context as the environment can affect boat performance. In addition, the GPS time-tagging of the data will assist in pinpointing the exact time and location of any performance anomalies. Operational testing data will be reviewed monthly to ensure that there have been no performance degradations. The review will consist of analyzing the engine and fuel consumption data along with the COG/SOG information and comparing the results back to the baseline data.

9 SAFETY/FIRE ISSUES

The National Fire Protection Association (NFPA) 704 ratings as shown in Table 5 indicate that the biobutanol blend (isobutanol) and gasoline are similar with respect to the characteristics shown. In addition, there are no special notices (rated white) for either fuel, and the flash point of the biobutanol gasoline blend (-45 °C/-49 °F) is similar to gasoline (-43 °C/-45 °F).

Table 5. Safety/fire ratings.

Fuel	Flammability Rating (Red)	Health (Blue)	Instability/Reactivity (Yellow)
Gasoline	3	1	0
Isobutanol	3	1	0

Flammability Rating 3: Can be ignited under almost all ambient conditions.

Health Rating 1: Exposure would cause irritation with only minor residual injury.

Instability/Reactivity Rating 0: Normally stable, even under fire exposure conditions and is not reactive with water.

An MSDS for the biobutanol gasoline blend is included in Appendix L.

10 REFERENCES

- DHS Strategic Sustainability Performance Plan. (June 2011).
- Energy Independence and Security Act (EISA) of 2007. (2007). Energy Public Law 110 - 140.
- Environmental Protection Agency 5-Mode emissions testing procedure (ISO D2 Test).
- Gevo. (17 January 2011a). Gevo supplied isobutanol-gasoline blend runs well in small engines - Briggs & Stratton tests show none of the engine compatibility issues of ethanol [<http://www.gevo.com/>].
- Gevo. (17 January 2011b). Testing demonstrates Gevo's isobutanol-gasoline blend is superior to E15 fuel for boaters - NMMA evaluations shows positive results, promise for isobutanol [<http://www.gevo.com/>].
- Leitch, B. (12 September 2011). Feasibility analysis of using biodiesel fuel on US Army Corps of Engineers floating plant. USACE HQ, Washington, DC. Draft.
- Remley, R. (17 December 2010). Final report on alternative fuel options for Coast Guard vessels. USCG Research & Development Center, New London, CT. Final, RDC UDI #1116.
- SAE Standard J1681. (10 January 2000). Gasoline, alcohol, and diesel fuel surrogates for materials testing.
- The President, Federal Leadership in Environmental, Energy, and Economic Performance. (5 October 2009). Executive Order 13514.

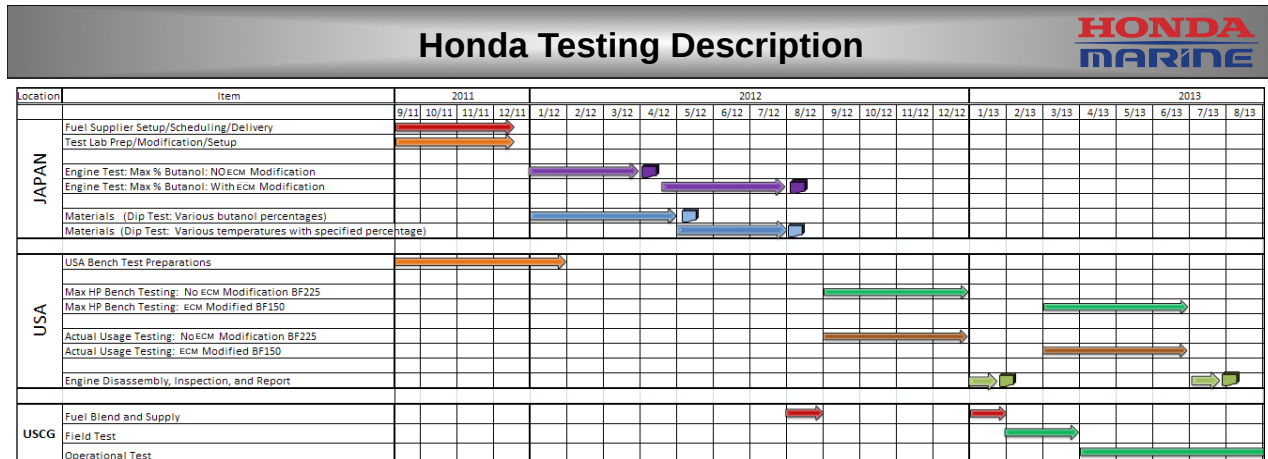
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APPENDIX A HONDA MARINE TEST PLANS



Target

- 1) Provide USCG with a specific and Honda certified maximum percentage of butanol that unmodified Honda outboard engines can run on safely while retaining the ability to use E0, E10 or a butanol blended fuel.
- 2) Provide USCG with a specific and Honda certified maximum percentage of butanol that modified Honda outboard engines can be run on with modifications made to the ECM (Engine Control Module). This modified engine will not be compatible with E0
E10, however this engine should be able to run much higher percentages of butanol than the unmodified engine.



Honda Testing Items

- 1) Honda Japan Testing:
 - A) Engine Test: Max % butanol (No ECM Modification)
 - B) Engine Test: Max % butanol (With ECM Modification)
 - C) Materials Testing: Dip Test (Various butanol percentages)
 - D) Materials Testing: Dip Test (Various temperatures with specified percentage)

- 2) Honda USA Testing
 - A) Max HP bench testing (No ECM Modification BF225)
 - B) Max HP bench testing (Modified ECM BF150)
 - C) Actual usage testing (NoECM Modification BF225)
 - D) Actual usage testing (Modified ECM BF150)



Honda Testing Description



1) Honda Japan Testing:

A) Engine Test: Max % butanol (No ECM Modification)

BF150 engine run on test bench. Various percentages of butanol fuel will be run through the engine while closely monitoring all critical engine functions as well as emissions. Fuel blend will begin with a low percentage of butanol and will gradually be increased until a critical limit of engine performance or emissions has been reached. Once a critical limit has been reached, we will have defined our maximum percentage butanol that the unmodified, mass production BF150 can operate on safely. This engine can use¹ E0, E10 and this max percentage of butanol.

B) Engine Test: Max % butanol (With ECM Modification)

This test will use the same engine and same procedure as test 1A, however the ECM (Engine Control Module) will be modified to change parameters that affect engine operation....ie A/F ratio, ignition timing, lean burn control, injector pulse timing, idle air control, etc. This test will use the percentage determined in test 1A as the lowest butanol percentage. The percentage of butanol will gradually be increased until a critical limit has been reached that cannot be compensated through ECM tuning. This will be the highest percentage butanol that Honda engines can operate on safely with a modified ECM. This ECM will be a butanol specific ECMit will not be able to run on E0 or E10.)



Honda Testing Description



1) Honda Japan Testing:

C) Materials Testing: Dip Test (Various butanol percentages)

All Honda materials exposed to fuel will be supplied in the form of coupons. These coupons will be dipped in fuel with various percentages of butanol. Analysis of the coupons after a specified amount of time will indicate the maximum percentage of butanol that is compatible with our engine materials.

D) Materials Testing: Dip Test (Various temperatures with specified percentage)

Using the specified percentage butanol blend determined in test 1C, the material coupons will be dipped and exposed to varying temperatures that will be representative of typical engine usage.

After understanding the results of test 1A, 1B, 1C and 1D. Honda can understand what the maximum percentage butanol that can be used in our unmodified engines and our modified ECM engines. Honda will recommend what percentage will be maximum for the BF225 based on BF150 test results. A full report will be generated by Honda Japan on tests 1A, 1B, 1C and 1D.



Honda Testing Description



2) Honda USA Testing

A) Max HP bench testing (No ECM modification BF225 engine)

BF225 engine will be mounted on a boat at the HRA-Florida office. A special propeller will be installed that provides maximum HP and RPM at WOT.

This boat will be operated in the ICW near the office for a set time using a fuel blend specified by Honda Japan. After the term has been completed, the engine will then be removed for disassembly/inspection.

B) Max HP bench testing (Modified ECM BF150 Engine)

This test will be the same as test 2A, however a BF150 engine with a modified ECM will be used. The fuel will be that which is specified by Honda Japan.

C) Actual usage testing (No ECM modification BF225 Engine)

This test is used to duplicate actual customer usage modes as determined by the analysis of ECM data that has been gathered for many years. This test will be conducted in the ICW near the Florida office using a normal prop, normal boat setup, and fuel specified by Honda Japan.

D) Actual usage testing (Modified ECM BF150 Engine)

This test will be the same as test 2C, however a BF150 engine with a modified ECM will be used. The fuel will be that which is specified by Honda Japan.



Honda Testing Description



Disassembly and Inspection

Before any of the engines will be used, they will be fully disassembled and inspected to benchmark wear points. HP, torque and emissions will be recorded prior to testing. After testing is complete, the engines will be disassembled, inspected and compared to initial measurements to understand the level of wear and deposits. HP, torque and emissions will be recorded and analyzed. Fuel components that come into contact with the fuel will be removed and sent to their respective suppliers for further analysis. A full report will be generated by HRA-Florida on the results of all tests.

APPENDIX B MERCURY MARINE TEST PLANS

B.1 Materials Test

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 PROCEDURE	Verado Fuel System Components- Butanol Compatibility Evaluation	ID Number: RD-xxxxx
		Revision: -
		Date: 5-Jan-2012
		Sensitivity: Non Proprietary

1. SCOPE STATEMENT:

- 1.1. Evaluate fuel compatibility of Verado fuel system with gasoline containing 16% Butanol.

2. PROCEDURE:

- 2.1. Testing to be performed with assembled 2011 L6 Verado fuel system.
- 2.2. Test 8 total assemblies as provided by Mercury Marine
- 2.3. Perform test of two complete fuel systems per fluids defined below.
 - 2.3.1. Pre Test Criteria- testing conducted at manufacturer
 - 2.3.1.1. Leak test per component specification
 - 2.3.1.2. Flow test per component specification
 - 2.3.2. Test Fluids (note Butanol is petroleum based Isobutanol)
 - 2.3.2.1. 87 octane unleaded EO
 - 2.3.2.2. 84% 87 octane unleaded containing 16% Butanol
 - 2.3.2.3. 84% ASTM D-471-79 Ref C+ 16% Aggressive Butanol
per ORNL 11-OCT-2011 recommendation (M. Kass, J. Szybist, T. Theiss)
 - 2.3.2.4. 83.7% ASTM D-471-79 Ref C fuel+ 16% Butanol+ >0.3% Tertiary Butyl Hydro-Peroxide
 - 2.3.3. Fluid exposure and refresh rate
 - 2.3.3.1. Fill each system with fluid per filling procedure
 - 2.3.3.2. Refresh fluid in assembly each 7.25 days +/-0.25 days (3 fillings total)
 - 2.3.3.3. Do not refresh test fluids 2.3.2.3 (aggressive Butanol)
 - 2.3.3.4. Exposure temperature to maintain 60° C throughout test duration of 30 days.
 - 2.3.4. Filling Procedure (caution- do not power pump until inlet hose is connected to fuel supply. Extended operation may damage pump). If fluid is not flowing into module discontinue power within 15 seconds. Visual observation of flow is recommended via clear hose at tank inlet.
 - 2.3.4.1. Connect inlet hose connection to atmospherically vented fuel supply with 3/8" ID hose.
 - 2.3.4.2. Connect harness provided to 12- 15 volt power supply
 - 2.3.4.3. Toggle pump switch on
 - 2.3.4.4. Toggle CPV (canister purge valve) switch on until vent canister light turns on then off
 - 2.3.4.5. Toggle fuel injectors on until fuel is visibly exiting all injectors then off
 - 2.3.4.6. Toggle pump switch off
 - 2.3.4.7. System filling is complete.
 - 2.3.5. Purging Procedure (caution- do not power pump until inlet hose is connected to fuel supply. Extended operation may damage pump). If fluid is not flowing into module discontinue power within 15 seconds.
 - 2.3.5.1. Disconnect inlet hose connection from atmospherically vented fuel supply with 3/8" ID hose.
 - 2.3.5.2. Connect harness provided to 12- 15 volt power supply
 - 2.3.5.3. Toggle pump switch on
 - 2.3.5.4. Toggle fuel injector and CPV switch on until steady flow discontinues from all injectors then off
 - 2.3.5.5. Confirm vent canister light turns off then toggle CPV valve off
 - 2.3.5.6. Toggle pump switch off
 - 2.3.5.7. System purge is complete.
 - 2.3.6. End of test transport
 - 2.3.6.1. Purge and close fuel system
 - 2.3.6.2. Wash any spilled fuel from external components with
 - 2.3.6.3. Cap fuel system and secure storage into returnable container.
 - 2.3.6.4. Return hardware to Mercury Marine Plant 12 attention Fuel System Component Manager
W6250-122 Pioneer Road Fond du Lac, WI 55936

- 2.3.7. Post Test Criteria- conducted at component manufacturer

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 PROCEDURE	Verado Fuel System Components- Butanol Compatibility Evaluation	ID Number: RD-xxxxx
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		Sensitivity: Non Proprietary

- 2.3.7.1. Leak test per component specification
- 2.3.7.2. Flow test per component specification
- 2.3.7.3. Visual observation for discoloration and/or material degradation factors



Butanol / Gasoline Test Plan

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 PROCEDURE	Verado Fuel System Components- Butanol Compatibility Evaluation		ID Number: RD-xxxxx
			Revision: -
			Date: 5-Jan-2012
			Sensitivity: Non Proprietary

Originally Created By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY	Approved By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY
Requested By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY	Approved By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY
Revised By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY	Approved By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY
				Approved By:	Xxxxxxx Xxxxxxx	Date:	DD-MMM-YYYY

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B.2 Bench Test

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 PROCEDURE	Verado Operating Characteristics with 16% Butanol Fuel	ID Number: RD-xxxxx
		Revision: -
		Date: 5-Jan-2012
		Sensitivity: Non Proprietary

1. SCOPE STATEMENT:

- 1.1. Evaluate the operating characteristics of the 300HP Verado with gasoline containing 16% Butanol.

2. PROCEDURE:

- 2.1. Testing to be performed with 300HP L6 Verado with hardware representative of current production engines.

2.2. Test Fuels (note Butanol is petroleum based Isobutanol)

- 2.2.1. 84% 91 octane unleaded containing 16% Butanol
- 2.2.2. EPA Tier II EEE reference emissions fuel
- 2.2.3. Document the results from the following tests to characterize the fuels:

Required Fuel Characterization Tests

- 2.2.3.1. Actual Butanol Concentration (Alcohol by Gas Chromatograph)
- 2.2.3.2. RON/MON (ASTM D2699 & D2700)
- 2.2.3.3. Distillation Curve (ASTM D86)
- 2.2.3.4. Density/Gravity (ASTM D1475)
- 2.2.3.5. Heating Value (ASTM D240)
- 2.2.3.6. Carbon/Hydrogen (ASTM E191)
- 2.2.3.7. RVP (ASTM D323)

Optional Fuel Characterization Tests

- 2.2.3.8. Copper Corrosion (ASTM D130)
- 2.2.3.9. Water Tolerance (ASTM 4814)
- 2.2.3.10. Corrosive Sulfur "Doctor Test" (ASTM D4952)
- 2.2.3.11. Existent Gum (ASTM 381)
- 2.2.3.12. Potential Gum (ASTM 873)
- 2.2.3.13. Oxygen Stability (ASTM D525)
- 2.2.3.14. Sulfur Content (ASTM D5453)

2.3. Engine/Dynamometer Test Setup

- 2.3.1. Prepare the engine by verifying the integrity of the engine with a compression check, a cylinder leakdown measurement, crankshaft endplay measurement, and a valve lash measurement.
- 2.3.2. Fit the engine with the appropriate instrumentation to satisfy the data collection requirements of the power run and emissions test.

2.4. Power Run

- 2.4.1. For the duration of the test, calculate the correction factor per ISO 3046-1. Maintain test cell ambient conditions between 0.93 and 1.07 correction factor.
- 2.4.2. Using EEE fuel, start engine and warm up at idle for 2 minutes.
- 2.4.3. Increase speed and load to emissions mode point 3 until temperature stability is attained.
- 2.4.4. Reduce speed to 2000RPM and increase load to WOT. Take data measurement after temperature stability is achieved.
- 2.4.5. Repeat step 2.4.3 for all speed steps as specified in the test procedure appropriate for the 300HP Verado.
- 2.4.6. Cool down the engine by operating at emissions mode point 4 for 5 minutes followed by 2 minutes of idle.
- 2.4.7. Shut off the engine and end the test.
- 2.4.8. Repeat steps 2.4.1 to 2.4.7 using the B16 fuel in drums.

2.5. Emissions Test

- 2.5.1. For the duration of the test, monitor test cell ambient conditions. Maintain ambient air temperature between 20°-30°C



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- 2.5.2. Perform pretest emissions bench checks to verify analyzer measurement integrity per emissions test procedure. This shall include, at a minimum, zero and span gas results, sample line leakage, hydrocarbon hangup in the sample line, and sample line/filter temperature.
- 2.5.3. Start Engine and warm up at idle for 3 minutes.
- 2.5.4. Operate engine at emissions mode point 3 for 5 minutes to continue to warm up engine.
- 2.5.5. Operate engine at rated speed/rated power (emissions mode point 1) for 10 minutes or until temperature stability is attained.
- 2.5.6. While continuing to operate at emissions mode point 1, take data to determine power and torque output for the remaining emissions calculations.
- 2.5.7. Collect emissions data for the duration specified in the table below while maintaining torque and speed stability.
- 2.5.8. If data was collected and all stability criteria were met during data collection proceed to the next emissions mode point and repeat step 2.5.7 until test is complete.
- 2.5.9. Shut off the engine and end the test.
- 2.5.10. Perform post-test emissions bench checks to verify analyzer measurement integrity per emissions test procedure. This shall include, at a minimum, zero and span gas results, and hydrocarbon hangup in the sample line.
- 2.5.11. Repeat steps 2.5.1 to 2.5.10 using the B16 fuel in drums

Mode Point	Stabilization Time (minutes)	Data Collection Time (minutes)	Speed (% of rated speed)	Torque (% of Mode 1 torque)	Weighting
1	Warm up step	2	Midpoint of range	Measured	0.06
2	2.5	2	80	71.6	0.14
3	2.5	2	60	46.5	0.15
4	4	3	40	25.3	0.25
5	7	4	Idle	0	0.40

- 2.6. Knock Evaluation at severe ambient conditions.
 - 2.6.1. Setup the conditioned air supply in the test cell.
 - 2.6.2. Shower the outside of the engine cowl inlet with the conditioned air set to 38°C and XX% relative humidity.
 - 2.6.3. Using EEE fuel, start engine and warm up at idle for 2 minutes.
 - 2.6.4. Increase speed and load to emissions mode point 3 until temperature stability is attained.
 - 2.6.5. Increase speed to 4000RPM and increase load to WOT.
 - 2.6.6. Retard the spark timing 4 degrees from the base spark advance. Take data after stability is achieved.
 - 2.6.7. Advance the spark timing 2 degrees from the previous step and take data after stability is achieved.
 - 2.6.8. Repeat step 2.6.7 until the spark timing is advanced to the point where 10% knock frequency is attained.
 - 2.6.9. Repeat steps 2.6.6 to 2.6.8 at 6100RPM / WOT and emissions mode point 2.
 - 2.6.10. Cool down the engine by operating at emissions mode point 4 for 5 minutes followed by 2 minutes of idle.
 - 2.6.11. Shut off the engine and end the test.
 - 2.6.12. Repeat steps 2.6.1 to 2.6.11 using the B16 fuel in drums
- 2.7. Calibration Evaluation-Dynamometer (abbreviated BSFC map/calibration "fingerprint")
 - 2.7.1. For the duration of the test, calculate the correction factor per ISO 3046-1. Maintain test cell ambient conditions between 0.93 and 1.07 correction factor.
 - 2.7.2. Using EEE fuel, start engine and warm up at idle for 2 minutes.
 - 2.7.3. Take data measurement after temperature stability is achieved.
 - 2.7.4. Repeat step 2.7.3 for all speed/load steps as specified in the table below.



Butanol / Gasoline Test Plan

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- 2.7.5. Cool down the engine by operating at emissions mode point 4 for 5 minutes followed by 2 minutes of idle.
- 2.7.6. Shut off the engine and end the test.
- 2.7.7. Repeat steps 2.7.1 to 2.7.6 using the B16 fuel in drums.

Log Point	Speed	Torque
-	RPM	NM
1	550	0
2	1000	40
3	1500	80
4	1500	120
5	2440	Mode 4
6	2500	160
7	2500	240
8	2500	WOT
9	3660	Mode 3
10	3500	240
11	3500	320
12	3500	WOT
13	4500	160
14	4880	Mode 2
15	4500	320
16	4500	WOT
17	5500	240
18	5500	320
19	5500	WOT
20	6100	WOT
21	6400	WOT

2.8. Calibration Evaluation-Boat (All maneuvers described in this section must be performed on both fuels)

2.8.1. Boat/Engine Setup

- 2.8.1.1. Rig the engine on an appropriate vessel to simulate Coast Guard use.
- 2.8.1.2. Connect engine to a laptop computer with engine calibration and logging software.
- 2.8.1.3. Install "Black Box" engine data recorder with appropriate data collection defined. This step is only to verify the "Black Box" recorder is programmed correctly and is collecting data properly before installing on Coast Guard vessel for step 2.9.

2.8.2. Starting Evaluation

- 2.8.2.1. Cold start the engine after being exposed to ambient temperatures overnight with each fuel (this will take multiple days to complete this step so a back-to-back comparison is not possible). There is inherent variability in this test due to the ambient conditions experienced during the test period.
- 2.8.2.2. Warm Restart: After cold start in 2.8.2.1, run engine at full throttle for 1-2 minutes, shut engine off for 1 minute and restart. Repeat on both fuels.
- 2.8.2.3. Removal from trailer simulation: Start engine, quickly shift into reverse and then rapidly shift back to neutral.

2.8.3. Transient Operation (repeat these maneuvers 3-4 times on each fuel)

- 2.8.3.1. Slow drive-away. Note any RPM surging/hunting and RPM control.
- 2.8.3.2. Rapid acceleration from idle to full throttle. Note any hesitation or misfire.
- 2.8.3.3. Rapid acceleration from 2000RPM steady-state to full throttle. Note any hesitation or misfire.
- 2.8.3.4. Rapid acceleration from 3500RPM steady-state to full throttle. Note any hesitation or misfire.
- 2.8.3.5. Rapid acceleration from 4500RPM steady-state to full throttle. Note any hesitation or misfire.
- 2.8.3.6. Rapid acceleration from idle to part throttle. Note any hesitation or misfire.
- 2.8.3.7. Rapid deceleration from steady-state, full throttle to idle in gear. Note any misfire or RPM instability.

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		Sensitivity: Non Proprietary

- 2.8.3.8. Rapid deceleration from 2000RPM steady-state to idle in gear. Note any misfire or RPM instability.
- 2.8.3.9. Rapid deceleration from 3500RPM steady-state to idle in gear. Note any misfire or RPM instability.
- 2.8.3.10. Rapid deceleration from 4500RPM steady-state to idle in gear. Note any misfire or RPM instability.
- 2.8.4. Shifting Evaluation.
 - 2.8.4.1. Rapidly shift through all gears 8 times (forward-neutral-reverse and back again).
 - 2.8.4.2. Operate boat at 3 MPH and shift from forward to reverse gear.
 - 2.8.4.3. Simulate docking the boat. Dock the boat at 2-3 docks both pulling in (bow first) and backing in (stern first).
- 2.8.5. Extended Idle
 - 2.8.5.1. Idle engine for 1 hour and then rapidly accelerate to full throttle. Note any hesitation, misfire, or RPM instability.
- 2.9. On-Site Field Test
 - 2.9.1. Repeat all testing in section 2.8 on the designated Coast Guard vessel.



Butanol / Gasoline Test Plan

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 PROCEDURE	Verado Operating Characteristics with 16% Butanol Fuel	ID Number: RD-xxxxx
		Revision: -
		Date: 5-Jan-2012
		Sensitivity: Non Proprietary

Originally Created By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY	Approved By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY
Requested By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY	Approved By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY
Revised By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY	Approved By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY
				Approved By:	XXXXXXX XXXXXXX	Date:	DD-MMM-YYYY

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APPENDIX C BIOBUTANOL BLEND SPECIFICATION

Recommendation for Aggressive Butanol Blend for US Coast Guard (USCG) Materials and Engine Testing September 8, 2011

Jim Szybist, Mike Kass & Tim Theiss
Oak Ridge National Laboratory
Fuels, Engines and Emissions Research Center

Introduction

Materials compatibility testing with fuels is typically performed using an aggressive blend formulation to accelerate materials degradation in an effort to shorten the necessary test time. The standard that specifies the aggressive blend for ethanol and methanol fuels is SAE J1681. Because butanol is an emerging fuel that is not yet in widespread use, there is not yet an accepted industry standard that specifies an aggressive butanol blend. An aggressive butanol specification has been proposed by the butanol manufacturer Gevo, Inc. and is under consideration by Underwriter's Laboratory (UL). All commercial fuel dispensing equipment will have to meet UL standards in order to obtain UL listing, so the UL test protocol will have to met anyway. In the absence of a large-scale experimental materials characterization effort, it is ORNL's recommendation to use the aggressive blend formulation proposed by Gevo, Inc. This recommendation does come with several limitations and caveats as listed below.

Aggressive Blend Formulation

The aggressive blend formulation proposed uses only iso-butanol, and added to it are four contaminants shown in the table below.

Water	1 percent
Sodium Chloride	50 ppm
Isobutyric acid	75 ppm
Sulfuric acid	27 ppm

This proposed formulation is reasonable based on the fact that it contains water, sodium chloride and sulfuric acid at similar levels to the aggressive ethanol standard specified by SAE J1681. Additionally, it contains isobutyric acid rather than the glacial acetic acid found in the aggressive ethanol standard. These organic acids are directly related to the alcohol fuel species, so the modification to use isobutyric acid is appropriate.

The proposed aggressive formulation is only for iso-butanol and does not include n-butanol or 2-butanol. The solubility parameters of the different butanol isomers are similar, so the chemical compatibility is expected to be similar as well. ORNL recommends that the Coast Guard use iso-butanol exclusively until it can be verified that n-butanol and 2-butanol do not introduce additional materials concerns. The projected major suppliers of butanol fuel in the US are currently focused on iso-butanol, so this constraint is not expected to be problematic.

The marine environment itself does represent a materials compatibility challenge because salt water itself is highly corrosive. We considered proposing a more aggressive butanol blend to reflect this more aggressive environment. Hoses developed for marine use are composed of a formulation designed by the

Butanol / Gasoline Test Plan

manufacturers to withstand the aggressive marine environment (in contrast to hoses developed solely for land-based use). Thus, we feel that a more aggressive butanol blend that includes contaminants from marine sources would be redundant to the standards already in place.

Maximum Butanol Concentration

Based on a review of available information using information provided by the EPA (but not through direct inquiry), ORNL's opinion is that the maximum butanol level allowed in the fuel is 16 percent, corresponding to 3.7 percent oxygen, which can be allowed according to the OCTAMIX waiver. The recent EPA partial waiver allowing the use of E15 in 2001 and newer light-duty vehicles does not apply to any additional applications and would not allow the use of 25 percent butanol. For 25 percent butanol to become legal, a specific waiver would have to be granted by the EPA. To our knowledge, butanol fuel suppliers are not considering such a waiver request.



APPENDIX D YORKTOWN, VA AVERAGE WATER AND AIR TEMPERATURES

Table D-1. Average annual water temperature for Yorktown, VA area.

Temp (°F)	Jan	Feb	Mar	Apr 1-15	Apr 16-30	May 1-15	May 16-31	Jun 1-15	Jun 16-30	Jul 1-15	Jul 16-31	Aug 1-15	Aug 16-31	Sep 1-15	Sep 16-30	Oct 1-15	Oct 16-31	Nov	Dec
Station YKTV2 (8637689), Yorktown, VA	36	39	46	51	56	60	66	70	69	76	77	78	77	76	74	66	61	54	44

Table D-2. Average air temperature for Yorktown, VA area.

Month	Ave High (°F)	Ave Low (°F)	Mean (°F)	Record High (°F)	Record Low (°F)
Jan	47	30	39	81	-7
Feb	51	32	42	83	1
Mar	59	38	49	90	12
Apr	69	46	58	96	22
May	76	56	66	98	31
Jun	84	64	74	104	37
Jul	87	69	78	103	51
Aug	85	68	77	104	44
Sep	80	62	71	103	38
Oct	70	50	60	96	21
Nov	61	41	51	85	15
Dec	51	33	42	82	0



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APPENDIX E SITE POCS

Unit	Name	Phone	Function	Email
TRACEN Yorktown	CDR Matt Rymer	757-856-2113	TRACEN Yorktown	matthew.a.rymer@uscg.mil
	CWO3 Jeffrey Shea	757-856-2328	TRACEN Yorktown	jeffrey.c.shea@uscg.mil
	MKC Henry Copland	757-856-2798	TRACEN Yorktown	henry.p.copland@uscg.mil
	LT Kent Hammack	757-856- 2243	Construction Officer	kent.d.hammack@uscg.mil
	Rick Hylton	757-856-2267	Environmental Engineer	rick.d.hylton@uscg.mil
	MK1 Chris Stephenson	843-991-9658	Mercury Marine Tech	christopher.l.stephenson@uscg.mil
	Scott Oberndorfer	757-856-2209	Honda Marine Tech	scott.m.oberndorfer@uscg.mil
RDC	Mike Coleman	860-287-1958 860-271-2708 C	COTR	michael.p.coleman@uscg.mil
	LT Brent Fike	860-271-2891	Technical Advisor	brent.a.fike@uscg.mil
	Rich Hansen	860-271-2866	Branch Chief	richard.l.hansen@uscg.mil
	Chris Turner	860-271-2623	Technical Advisor	arden.c.turner@uscg.mil
SFLC ¹	Matthew W. Hammond	410-762-6283	SFLC Representative	Matthew.W.Hammond@uscg.mil
SAIC	Rick Barone	617-223-5782 617-774-9913 C	Technical Advisor	richard.t.barone@uscg.mil
	Steve Ricard	860-572-2308	Program Manager	steven.a.ricard@saic.com
	Bob Young	860-572-2307	Project Manager	robert.e.young@saic.com
Alion	Dr. Greg Johnson	860-608-4669 C	Project Manager	gwjohnson@alionscience.com
	Bill Remley	904-375-2744 412-849-5132 C	Technical Expert	wremley@alionscience.com
	Mark Wiggins	860-326-3449 860-303-4537 C	Technical Expert	mwiggins@alionscience.com
	Bob Giannini	410-762-6184	Technical Expert	robert.m.giannini@uscg.mil
Mercury Marine	Tim Reid	920-924-2041	Engineer	tim_reid@mercmarine.com
	Kevin Grodzki	920-929-5195	Engineer	kevin_grodzki@mercmarine.com
Honda Marine	So Tanaka	772-321-5931	Engineer	stanaka@oh.hra.com
	Travis Watkins	772-539-3081	Engineer	twatkins@oh.hra.com
Butamax	James Baustian	302-695-9015 302-377-6643 C	Engineer	james.baustian@butamax.com
Gevo	Glen Johnston	303-858-8358 720-267-8600 C	Engineer	gjohnston@gevo.com
	Dave Munz		Engineer	dmunz@gevo.com

¹Surface Forces Logistics Center

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APPENDIX F RB-S FUEL SYSTEM MATERIALS LIST

Item #	Qty	Manufacturer or Vendor	Part #	Description	Material	Comments/ Cage Code	Compatible (Note 7)	Notes
Fuel Tank	1		NA	1/4 " - 5086 Aluminum	Aluminum		See Note 10	
Fuel Meter	1	FloScan - Fuel Flow Meter		In line fuel flow meter	See Note 6		See Note 6	Ref 8 on fuel system diagram.
1	2	EVM, Inc	3814-WSS2400N-P T/T	Top Tapped SS Pick Up Tube	Stainless	Note 4 of DWG		
2	4	American Hose and Fittings	6 FTX - SS	1/4 " Male NPT x# 6 SAE Male - Straight	Stainless	2Y147		
3	6	American Hose and Fittings	Y-50006-9-95	#6 SAE	Stainless	2Y147		
4	6	Marine Markets West	360-0560	5/16" hose (Port & Stbd)	Hose (See Notes)	1K7H6	See Note 8	See Notes 1, 2, 3 for Hose Materials
5	2	American Hose and Fittings	6 CTX-SS	1/4 " Male NPT x# 6 SAE Male - 90	Stainless	2Y147		
6	2	RACOR-PARKER	S3213	10 Micron Filter Element		31381		
7	2	American Hose and Fittings	1/4 FF-SS	1/4 " FF-SS P40P	Stainless	2Y147		
8	2	Seadog Line	337320	Thru Vent - Black	Poly	41830		Note 9
9	10	American Hose and Fittings	SFM687	5/16" Swaging Ferrule	Stainless	2Y147		
10	2	McMaster Carr	52545K55	11/16" Dia. Stepless Ear Hose Clamp	Stainless	OE328		
12	A/R	Lawrence Hose Co.	375-1126	1-1/2" A2 Fuel Hose	Hose (See Notes)	8H452	See Note 8	See Notes 1, 4 for Hose Materials
13	12	Tacoma Screw	#28 CRES Clamps	#28 CRES Hose Clamps (For Fuel Fill)	Stainless	4P686		
15	2	EVM. INC.	L-3858	3/8"x 5/8" Aluminum Hose Barb	Aluminum	Note 4 of DWG	See Note 10	
16	A/R	Lawrence Hose Co.	360-0580	A-1 F&A RESISTANT FUEL LINE	Hose (See Notes)	8H452	See Note 8	See Notes 1, 2, 3 for Hose Materials
17	2	EVM. INC.	T/H 5800	5/8" THRU-HULL VENT	Anodized Al	Note 4 of DWG	See Note 10	
18	8	TACOMA SCREW	#10 CRES CLAMPS	#10 CRES HOSE CLAMPS (FOR FUEL TANK VENT)	Stainless	4P686		
24	2	Yamaha	6Y2-24360-52	MANUAL PRIMER BULB	Fuel Resistant Rubber	43NFO	See Note 11	Supposed to be Yamaha but some boats may have Honda Marine Primer Bulbs



Butanol / Gasoline Test Plan

Item #	Qty	Manufacturer or Vendor	Part #	Description	Material	Comments/ Cage Code	Compatible (Note 7)	Notes
27	1	RACOR - PARKER	B32013	FUEL FILTER/ WATER SEPARATOR		31381	See Note 10	Aluminum Can, Plastic Bowl. Buna-N Gasket - Compatible with E10.
29	2	RACOR - PARKER	89876A 3	FUEL FILTER MANIFOLD	MISC.	31381	See Note 10	Not by Racor - Cast Aluminum?
30	1	SEADOG LINE	351110	1 -1 /2" FLIP TOP GAS FILL	Stainless	41830		
61	1	American Hose	3/8 NPT x 5/8 HB	3/8" NPT x 5/8" Hose Barb	Stainless	2Y147		
Notes:								
1	Lawrence Rubber is now Novaflex.							
2	Type 360-09 - Tube: Nitrile Thermoplastic Laminate (NTL) - Cover Black OZO; Compatible with E10, E15 to E85.							
3	Type 360-03 - Tube: Black Nitrile- Cover: Black Neoprene - Compatible up to E85.							
4	Type 375 - Tube: Nitrile - Cover: Black Neoprene.							
5	Information from RB-S Piping System Diagrams - 25-RB-S-500-001, Rev C (Shts 1-5) and Contact with component vendors.							
6	FloScan Transducer Materials:							
	Body: Die-Cast Zinc or Aluminum	See Note 10	Aluminum is better but Zinc should be avoided.					
	Rotor: Rynite		Glass reinforced PET (Polyethylene Terephthalate)					
	Rotor Pivot: Stainless Steel							
	FloScan states no problem using their Fuel Flow meters with a Bio-Butanol (16.1 percent) Gasoline blend. (E-mail of 3 Jan 2012)							
7	Compatibility Legend	Red = Not Recommended	Yellow = May be some effect	Green = Satisfactory				
8	Fair to good resistance. Potential 20 percent Hardness increase. 8-10 percent Swelling.							
9	Up to 10 percent Hardness Increase and 8-15 percent Swelling.							
10	E-Mail (9 Jan 2012) from Butamax- Lack of experience with Aluminum in fuel systems. Their opinion is that Aluminum should be OK.							
11	If used per recommended application.							



APPENDIX G SPC-TB FUEL SYSTEM MATERIALS LIST

Item (Note 7 and 8)	Description	Material	Mfr	Qty	Part Number or Markings	Compatible (Note 10)
1	3/8 " Fuel Supply Hose - A1 (Flex Hose)	Note 3	Sierra/Shields	10 Ft	Shields Series 368 Low Permeation Fuel Feed USCG Type A-1-15- SAE J 1527/ ISO 7840 – 3/8 " (16-368-0380)	
2	5/8 " Fuel Vent Hose - A1	NBR - Nitrile Rubber (Note 4)	Sierra/Shields	10 Ft	16-355-1120	
3	Fuel Tank Connection Fittings (1/4 " 90 degree)	Brass		2		See Note 11
4	Fuel Tank Shut Off Valves (1/4")	Brass	NIBCO/Smith Cooper	2	UPC 4799 (01728155C)	See Note 11
5	Brass Barbed Fitting screwed into 90 degree ftg	Brass		8		See Note 11
6	Fuel Filter/Water separator	Aluminum	RACOR-PARKER	2	S 3227, 10 Micron (320R-RAC-01)	See Note 12
7	Fuel Filter Manifold	Aluminum Alloy		2		See Note 12
8	inlet Outlet Connections on Fuel Filter Manifold	Brass		4		See Note 11
9	Fuel priming bulb	Note 2	NA	NA	NA	NA
10	Low pressure fuel filter engine mounted	Note 1				
11	High pressure engine mounted fuel filter	Note 1				
12	Electric fuel pump engine mounted	Note 1				
13	Fuel tank (400 gal)	5086 Marine Grade Aluminum		1		See Note 12
14	Fuel Tank Sending Unit	316 Type Stainless Steel	WEMA USA	1	SSS/SSL 25"	
15	Gasket, Fuel Tank Sending Unit	Note 9		1		See Note 9
16	1- 1/2 " - A2 Fuel Fill Hose	NBR - Nitrile Rubber	Sierra/Shields	24 Ft	16- 369 - 0586	
17	Deck fill	Brass or Stainless (Note 5)	Seadog	1	357040	
18	Fuel Vent	Not Fuel Wetted	Perko	2	561-DP4-CHR	See Note 11 and 13
19	1372 High Temp Sealant	Permatex Sealant (Note 6)	Permatex	NA	80088	

Notes

- 1 If engine mounted equipment, Mercury Marine will be testing.
- 2 SPC-TB Handbook has note that the engine fuel system does not require an external primer bulb. Using an external primer bulb will cause a warning horn to sound and cause an engine flooding condition.
- 3 Nylon 6 Inner Tube (Fuel Wetted). Low permeation marine fuel hose has a plastic layer tube to limit permeation. This polyester reinforced hose complies with EPA barrier veneer with an NBR outer and CARB very low permeation requirements and is weather/UV resistant. This hose is primarily used for fuel feed (gasoline up to 85 percent ethanol blended fuels/diesel/all bio-diesel blends). It meets USCG Type A1 – 15 requirements for pleasure boats and meets SAE J1527 Type A1-15, ISO 7840 Type A1, and NMMA/CE type accepted standards. The temperature ranges from -20°F to 212°F.



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4	Fire – Acol – Fuel Fill Hose resists gasoline/alcohol blends and is compounded for low permeation. It is abrasion resistant and it is reinforced with wire helix embedded between piles of HD synthetic cord. This imported hose is primarily used for fuel fill (gas or diesel) and is for pleasure boats only. It meets SAE J1527 Type A2 and ISO 7840 Type A2 NMMA/CE Type Accepted standards.		
5	Drawing states all fuel fittings are brass or stainless.		
6	Drawing States that Permatex Sealant is used on all fuel fittings.		
7	Information in red font is from Metal Shark Drawing # 38-SPC-TB-Fuel System, Rev. - Information in black font is from SPC-TB shipcheck.		
8	Green Highlight = Duplicate information from drawing and shipcheck.		
9	Telecon (6 Jan 2012) with WEMA USA for gasket material. They can provide nitrile, cork/nitrile or Viton gasket. Need to check with tank manufacturer to see what was actually used.		
10	Compatibility Legend	Red = Not Recommended	Yellow = May be some effect
11	Brass, bronze, copper, lead, tin, and zinc may accelerate the oxidation process creating fuel insolubles or gels and salts. Lead solders and zinc fittings should also be avoided.		
12	Initial opinion from Butamax is aluminum should be OK. Testing sample tank piece from Metal Shark and FloScan assy to be done by summer 2012 by Butamax.		
13	OK if non-zinc vent is used.		



APPENDIX H DRAFT RB-S TCTO

Draft Gasoline Time Compliance Technical Order (TCTO):
Data for Input to TCTO Phase 1 Form (Section 1)

Contract No. HSCG32-10-D-R00021
Task Order HSCG32-11-J-300018, Deliverable 4
Project 4103 – Operational Testing of Alternative Fuels

31 January 2012

1. Case File #: [leave blank]
2. TCTO #: [leave blank]
3. Type: RB-S
4. Title: Modification for Alternative Fuel Testing (Biobutanol) on CG-25750 (Yorktown, VA)
5. Submitted by: Coast Guard Research & Development Center
6. Submission Date: [leave blank]
7. Desired Installation Date: 3 October 2012
8. Requirement/Description: See Table 1, which lists changes recommended to CG-25750 prior to commencement of biobutanol (BU16) testing. Table 2 contains cost details for all recommended items.

Butanol / Gasoline Test Plan

Table 1. Recommended Changes to RB-S CG-25750 to Support BU16 Testing.

Task	Description	Rec.	May Need to be done	Comments
1	Fuel Tanks			
a	Compatibility		X	In general, butanol has not been found to have adverse effects on any materials typically found in gasoline fuel systems. Aluminum, such as the fuel tank on the RB-S, has not been tested yet; however, Butamax is in the process of doing materials testing on samples provided by the manufacturer with results expected summer 2012.
2	Fuel System Modifications			
a	Replace fuel system flex hoses, with BU16-compatible parts and components.		X	The current nitrile and aluminum hoses are compatible with E85 gasoline. They are probably OK with BU16 but waiting for feedback from Butamax and Gevo.
b	Replace metallic fuel line fittings and components that are not compatible with the BU16 fuel.		X	There are several aluminum fuel line fittings that may be an issue: see comments above with regards to aluminum.
c	Modify or change out fuel filters/water separators.		X	The RACOR-Parker fuel filter manifold is cast aluminum and the filter/water separator has an aluminum can: see comments above about aluminum. The fuel filter has a plastic bowl and buna-N gasket which are compatible with E10 but have not been confirmed to be compatible with BU16 yet.
3	Instrumentation			
a	FloScan fuel flow meter		X	The FloScan meters need to be confirmed to be compatible with the Honda engines, and BU16. The body of the FloScan transducer is either zinc or aluminum; this needs to be determined. Zinc should be replaced; aluminum may be OK (see comment 1a above).
b	Data recorder	X		Use output from engine ECUs to monitor engine horsepower and other parameters. A data recorder with an NMEA2000 interface must be added to the engines to automatically log the data to a flash card for monthly retrieval.
c	Nav box	X		A data collection (nav) box will be installed in a location that is determined to not interfere with operational requirements. This nav box will have a GPS receiver (L1 DGPS or WAAS), heading/pitch/roll sensors, a data collection computer (such as the Moxa UC-8418 embedded computer) for long-term data collection and a weather



Butanol / Gasoline Test Plan

Table 1. Recommended Changes to RB-S CG-25750 to Support BU16 Testing.

Task	Description	Rec.	May Need to be done	Comments
				station (such as Maretron WSO100) installed in it. The nav box will require 24 VDC and the mounting of the GPS and weather station antennas.
4	Engine Modifications			
a	Change out metallic and non-metallic parts that are not BU16-compatible based on results of Honda and Mercury material testing.		X	Modify engines as recommended by Honda. Waiting for results of their testing, which will be available on 1 August 2012.
5	Miscellaneous			
a	Provide extra fuel filter elements.		X	If the existing fuel filters are NOT compatible with BU16 and specialized fuel filters are needed, then extras need to be provided to the unit. Waiting for feedback from Butamax and Gevo on fuel filter issues.
b	Restore RB-S to pre-demonstration configuration.		X	Return test boat to the standard configuration.

Butanol / Gasoline Test Plan

Table 2. Cost Details for each TCTO Item.

TCTO Line #	Item/Service	Suggested Manufacturer	Suggested Part Number	Qty	Cost Each	Sub-Total	Install Cost	Total Cost	Notes
1a	Fuel tank			1					Note 1: A requirement for these potential items will be determined upon receipt of results of material testing and costs estimated at that time.
2a	Fuel system hoses			1					
2b	Fuel fittings			1					
2c	Fuel filter/water separators			1					
3a	FloScan			1					
3b	NMEA data recorder	Maretron	VDR100	1	\$1,050	\$1,050	\$0	\$1,050	NMEA subtotal estimate (to be installed by USCG or test team)
3c	Nav box: Weather station/GPS	New Mountain	NM100 Weather Station	1	\$1,400	\$1,400	\$0	\$1,400	
	Nav box: Data collection computer	Moxa	IA261-I/262-I Series	1	\$1,250	\$1,250	\$0	\$1,250	
	Nav box: Inertia Measurement Unit (IMU)	Honeywell	HMR2300	1	\$850	\$850	\$0	\$850	
	Nav box: Enclosure, power supply, miscellaneous cables	SKB, miscellaneous	Miscellaneous	1	\$800	\$800	\$0	\$800	
			Subtotal	1	\$4,300	\$4,300	\$0	\$4,300	Nav box subtotal estimate (to be installed by test team; estimated 4 hrs)
4a	Incompatible engine parts								See Note 1 above
5a	Extra fuel filters			30					See Note 1 above
								\$5,350	Total estimate for RB-S

APPENDIX I DRAFT SPC-TB TCTO

Draft Gasoline Time Compliance Technical Order (TCTO):
Data for Input to TCTO Phase 1 Form (Section 1)

Contract No. HSCG32-10-D-R00021
Task Order HSCG32-11-J-300018, Deliverable 4
Project 4103 – Operational Testing of Alternative Fuels

31 January 2012

1. Case File #: [leave blank]
2. TCTO #: [leave blank]
3. Type: SPC-TB
4. Title: Modification for Alternative Fuel Testing (Biobutanol) on CG-38011 (Yorktown, VA)
5. Submitted by: Coast Guard Research & Development Center
6. Submission Date: [leave blank]
7. Desired Installation Date: 17 September 2012
8. Requirement/Description: See Table 1, which lists changes recommended to CG-38011 prior to commencement of biobutanol (BU16) testing. Table 2 contains cost details for all recommended items.

Butanol / Gasoline Test Plan

Table 1. Recommended Changes to SPC-TB CG-38011 to Support BU16 testing.

Task	Description	Rec.	May Need to be Done	Comments
1	Fuel Tanks			
a	Compatibility		X	In general, butanol has not been found to have adverse effects on any materials typically found in gasoline fuel systems. Aluminum, such as the fuel tank on the SPC-TB, has not been tested yet; however, Butamax is in the process of doing materials testing on samples provided by the manufacturer with results expected summer 2012.
2	Fuel System Modifications			
a	Gasket on fuel tank sending unit		X	Gasket provided by WEMA USA; they can provide nitrile, cork/nitrile, or Viton gasket. Need to check with tank manufacturer or unit to determine what was used on CG-38011.
b	Replace metallic fuel line fittings and components that are not compatible with the BU16 fuel.		X	Brass, bronze, copper, lead, tin, and zinc may accelerate the oxidation process creating fuel insolubles or gels and salts. Lead solders and zinc fittings should also be avoided. These are found in fuel tank shut off valves, fuel tank connection fittings, and fuel filter manifold connection. Waiting for feedback from Butamax and Gevo on metallic material compatibility issues.
c	Modify or change out fuel filters/water separators.		X	Both the fuel filter manifold and fuel filter/water separator are aluminum; if aluminum is determined to be incompatible with butanol (unlikely), then these will need to be changed out.
3	Instrumentation			
a	FloScan fuel flow meter	X		The FloScan meters need to be confirmed to be compatible with the Mercury Verado engines, and BU16. The body of the FloScan transducer is either zinc or aluminum; this needs to be determined. Zinc should be replaced; aluminum may be OK (see comment 1a above).
b	Nav box	X		A data collection (nav) box will be installed in a location that is determined to not interfere with operational requirements. This nav box will have a GPS receiver (L1 DGPS or WAAS), heading/pitch/roll sensors, a data collection computer (such as the Moxa UC-8418 embedded computer) for long-term data collection and a weather station (such as Maretron WSO100) installed in it. The nav box will require 24 VDC and the mounting of the GPS and weather station antennas.
4	Engine Modifications			



Butanol / Gasoline Test Plan

Table 1. Recommended Changes to SPC-TB CG-38011 to Support BU16 testing.

Task	Description	Rec.	May Need to be Done	Comments
a	Change out metallic and non-metallic parts that are not BU16-compatible based on results of Honda and Mercury material testing.		X	Modify engines as recommended by Mercury. Waiting for results of their testing, which will be available OOA 16 July 2012.
5	Miscellaneous			
a	Provide extra fuel filter elements.		X	If the existing fuel filters are NOT compatible with BU16 and specialized fuel filters are needed, then extras need to be provided to the unit. Waiting for feedback from Butamax and Gevo on fuel filter issues.
b	Restore SPC-TB to pre demonstration configuration.		X	Return test boat to the standard configuration.



Butanol / Gasoline Test Plan

Table 2. Cost Details for each TCTO Item.

TCTO Line #	Item/Service	Suggested Manufacturer	Suggested Part Number	Qty	Cost Each	Sub-Total	Install Cost	Total Cost	Notes
1a	Fuel tank			1					Note 1: A requirement for these potential items will be determined upon receipt of results of material testing and costs estimated at that time.
2a	Gasket			1					
2b	Fuel fittings			1					
2c	Fuel filters			1					
3a	Fuel flow meter	FloScan	20B Series	1	\$3,295	\$3,295	\$1,000	\$4,295	Fuel monitoring system subtotal estimate (compatibility to be determined)
3b	Nav box: Weather station/GPS	New Mountain	NM100 Weather Station	1	\$1,400	\$1,400	\$0	\$1,400	
	Nav box: Data collection computer	Moxa	IA261-I/262-I Series	1	\$1,250	\$1,250	\$0	\$1,250	
	Nav box: Inertia Measurement Unit (IMU)	Honeywell	HMR2300	1	\$850	\$850	\$0	\$850	
	Nav box: Enclosure, power supply, misc cables	SKB, miscellaneous	Miscellaneous	1	\$800	\$800	\$0	\$800	
			Subtotal	1	\$4,300	\$4,300	\$0	\$4,300	Nav box subtotal estimate (install to be done by test team; estimated 4 hrs)
4a	Incompatible engine parts								See Note 1 above.
5a	Extra fuel filters			30					See Note 1 above.
								\$8,595	Total estimate for SPC-TB

APPENDIX J FIELD TESTING DATA SHEET

TEST 1: Pier-side 1-hour test

Date:			
	Task	Time Completed	Notes
1	Pretest Check List:		
a	Boat checks performed by the crew		
b	Normal engine checks performed by the crew		
c	Ensure test data sheet is filled out and ready for entries including date and time		
d	Start all data recorders		
e	Record any non-data information; i.e., weather observations, crew personnel list, fuel level and miscellaneous information		
f	Green-Amber-Red (GAR) by Coxswain		
g.	Start engines		
2	Test Procedure		
a	Idle until engines are at oper temp		
b	Allow engines to idle 1 hour under close observation		
c	Perform emissions testing via Honda Marine rep		
d.	Secure engines		Record fuel usage
3	Post-test checklist		
a	Shutdown engines		
b	Stop data recording		
c	Copy test data onto laptop		
d	Confirm test data has been successfully copied		
f	Backup test data onto external hard drive		If last test for the day
g	Secure power to test equipment		If last test for the day
h	Secure all of equipment for the night		If last test for the day

Butanol / Gasoline Test Plan

TEST 2: U/W slow speed 1-hour test

Date:			
Task		Time Completed	Notes
1	Pretest check List:		
a	Boat checks performed by the crew		
b	Normal engine checks performed by the crew		
c	Ensure test data sheet is filled out and ready for entries including date and time		
d	Start all data recorders		
e	Record any non-data information; i.e., weather observations, crew personnel list, fuel level and miscellaneous information		
f	Green-Amber-Red (GAR) by Coxswain		
g.	Start engines		
2	Test Procedure		
a	Idle until engines are at oper temp		
b	Get U/W. Mill about 1 hour-slow speed		
c	Return to dock		
d.	Secure engines		Record fuel usage
3	Post-test checklist		
a	Shutdown engines		
b	Stop data recording		
c	Copy test data onto laptop		
d	Confirm test data has been successfully copied		
f	Backup test data onto external hard drive		If last test for the day
g	Secure power to test equipment		If last test for the day
h	Secure all of equipment for the night		If last test for the day



Butanol / Gasoline Test Plan

TEST 3: 2-hour cruising test

Date:			
Task		Time Completed	Notes
1	Pretest check List:		
a	Boat checks performed by the crew		
b	Normal engine checks performed by the crew		
c	Ensure test data sheet is filled out and ready for entries including date and time		
d	Start all data recorders		
e	Record any non-data information; i.e., weather observations, crew personnel list, fuel level and miscellaneous information		
f	Green-Amber-Red (GAR) by Coxswain		
g.	Start engines		
2	Test Procedure		
a	Idle until engines are at oper temp		
b	Get U/W. Mill about 2 hour-cruising speed		
c	Return to dock		
d.	Secure engines		Record fuel usage
3	Post-test checklist		
a	Shutdown engines		
b	Stop data recording		
c	Copy test data onto laptop		
d	Confirm test data has been successfully copied		
f	Backup test data onto external hard drive		If last test for the day
g	Secure power to test equipment		If last test for the day
h	Secure all of equipment for the night		If last test for the day



Butanol / Gasoline Test Plan

TEST 4: 2 hour cruising speed to max speed test

Date:			
Task		Time Completed	Notes
1	Pretest Check List:		
a	Boat checks performed by the crew		
b	Normal engine checks performed by the crew		
c	Ensure test data sheet is filled out and ready for entries including date and time		
d	Start all data recorders		
e	Record any non-data information; i.e., weather observations, crew personnel list, fuel level and miscellaneous information		
f	Green-Amber-Red (GAR) by Coxswain		
g.	Start engines		
2	Test Procedure		
a	Idle until engines are at oper temp		
b	Get U/W. Mill about 2 hour cruising-max-cruising speed		Alternate from cruising and max speed-boat coxswain discretion for balance.
c	Return to dock		
d.	Secure engines		Record fuel usage
3	Post-test checklist		
a	Shutdown engines		
b	Stop data recording		
c	Copy test data onto laptop		
d	Confirm test data has been successfully copied		
f	Backup test data onto external hard drive		If last test for the day
g	Secure power to test equipment		If last test for the day
h	Secure all of equipment for the night		If last test for the day



APPENDIX K OPERATIONAL TESTING DATA SHEETS

Date	Fuel	#Gal	Event	Description of Event-Notes-Observations	Name	Signature
				Examples		
11-May-12	X	326		Sample collected		
11-May-12			X	Sample sent to lab-tracking number XL12929447563		
18-May-12			X	Spark plug failure		
30-May-12			X	Engines were over heating, inspection of the engine		
				hose showed a screw inside blocking the coolant, it		
				was determined the screw fell in during spark plug		
				change. Removed screw		
3-Jun-12	X	325		Sample collected		
3-Jun-12			X	Sample sent to lab-tracking number XL1288540275		
10-Jun-12			X	Fuel line leaking, test team leader contacted,		
				Test team tech arrived, inspected fuel line		
				determined that the hose clamp was loose,		
				FN Wrench tightened clamp		
21-Jun-12			X	Data acquisition system not running, rebooted computer but data still not being collected. RDC notified.		

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APPENDIX L BU16 MSDS

MATERIAL SAFETY DATA SHEET

Gasoline, Unleaded B16.1

MSDS DATE: 03/01/12



Material Safety Data Sheet

Section 1 – CHEMICAL PRODUCT AND COMPANY IDENTIFICATION

Gevo Inc.
345 Inverness Drive South
Bldg C, Suite 310
Englewood, CO 80127
PHONE NUMBER: (303)858-8358

Transportation Emergency (CHEMTREC): 1-800-424-9300

PRODUCT NAME: Gasoline, Unleaded B16.1

Synonyms: Blend of highly flammable petroleum distillates, also containing up to 16.1% isobutanol

Emergency Overview **WARNING!** This is a research and development product. The properties of this product have not been fully investigated. All available information is provided in this MSDS. Use caution when handling this product. Harmful or fatal if swallowed. Harmful by inhalation. Irritating to eyes, respiratory system and skin. Affects central nervous system. **FLAMMABLE!**

Section 2 – COMPOSITION AND INFORMATION ON INGREDIENTS

INGREDIENTS	PERCENTAGES (by weight)	CAS-No.	TLV (ppm)
<u>Major components</u>			
Gasoline	81-84%	8006-61-9	300 ppm
Toluene	0-18%	108-88-3	50 ppm
Isobutanol	16.1%	78-83-1	50 ppm
Benzene	0-5%	71-43-2	10 ppm
Hexane	0-5%	110-54-3	50 ppm
Cyclohexane	0-5%	110-82-7	300 ppm
Ethyl Benzene	0-5%	100-41-4	100 ppm
Naphthalene	0-5%	91-20-3	10 ppm

Section 3 – HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW

OSHA Hazards

Flammable Liquid, Target Organ Effect, Irritant, Harmful or fatal if swallowed, Aspiration Hazard

Target Organs

Central nervous system, Liver, Kidney

HMIS CLASSIFICATION

Health Hazard: 1
Chronic Health Hazard: *
Flammability: 3
Physical hazards: 0

NFPA RATING

Health Hazard: 1
Fire: 3
Reactivity Hazard: 0



POTENTIAL HEALTH EFFECTS

Eyes – Severe eye irritant. Contact may cause stinging, watering, redness, swelling, and eye damage.

Skin – Prolonged or repeated skin contact with liquid may cause defatting resulting in drying, redness and possible blistering. Practically non-toxic if absorbed following acute (single) exposure. Liquid may be absorbed through the skin in toxic amounts if large areas of skin are repeatedly exposed.

Inhalation – Inhalation of fumes or mist may result in respiratory tract irritation and central nervous system (brain) effects may include headache, dizziness, loss of balance and coordination, unconsciousness, coma, respiratory failure, and death. **WARNING:** the burning of any fuel in an area without adequate ventilation may result in hazardous levels of combustion products, including carbon monoxide, and inadequate oxygen levels, which may cause unconsciousness, suffocation, and death.

Ingestion – Aspiration hazard if liquid is inhaled into lungs, particularly from vomiting after ingestion. Aspiration may result in chemical pneumonia, severe lung damage, respiratory failure and even death. Ingestion may cause gastrointestinal disturbances, including irritation, nausea, vomiting and diarrhea, and central nervous (brain) effects. In severe cases, tremors, convulsions, loss of consciousness, coma, respiratory arrest and death may occur.

Section 4 – FIRST AID MEASURES**EMERGENCY AND FIRST AID PROCEDURES**

General Advice – Symptoms: Aspiration may cause pulmonary edema and pneumonitis. Treatment: Do not induce vomiting, use gastric lavage only. Remove from further exposure and treat symptomatically.

Eye Contact – In case of eye contact, remove contact lens and rinse immediately with plenty of water, also under the eyelids, for at least 15 minutes. Seek medical attention immediately.

Skin Contact – In case of contact, immediately flush skin with plenty of water. Take off contaminated clothing and shoes immediately. Wash contaminated clothing before re-use. Contaminated leather, particularly footwear, must be discarded. Note that contaminated clothing may be a fire hazard. Seek medical advice if symptoms persist or develop.

Inhalation – If inhaled, remove to fresh air. If not breathing, give artificial respiration. If necessary, provide additional oxygen once breathing is restored if trained to do so. Seek medical attention immediately.

Ingestion – Do NOT induce vomiting. Do not give liquids. Seek medical attention immediately. If vomiting does occur naturally, keep head below the hips to reduce the risks of aspiration. Monitor for breathing difficulties. Small amounts of material which enter the mouth should be rinsed out until the taste is dissipated.

Section 5 – FIRE FIGHTING MEASURES

FLASH POINT: -49°F (-45°C) – closed cup

AUTO IGNITION TEMP: 495°F (257°C)

FLAMMABLE LIMITS IN AIR
% BY VOLUME

LOWER
1.3%(V)

UPPER
7.6% (V)

EXTINGUISHING MEDIA:

SMALL FIRES: Any extinguisher suitable for Class B fires, dry chemical, CO₂, water spray, fire fighting foam, or Halon. **LARGE FIRES:** Water spray, fog or fire fighting foam. Water may be ineffective for fighting the fire, but may be used to cool fire-exposed containers. Keep containers and surroundings cool with water spray.

Fire Hazard: Extremely flammable liquid and vapor. This material is combustible/flammable and is sensitive to fire, heat, and static discharge. Above the flash point, explosive vapor-air mixtures may be formed. Vapors can flow along surfaces to distant ignition source and flash back.

SPECIAL PROTECTIVE EQUIPMENT FOR FIRE FIGHTERS: Firefighting activities that may result in potential exposure to high heat, smoke or toxic by-products of combustion should require NIOSH/MSHA- approved pressure demand self-contained breathing apparatus with full facepiece and full protective clothing.



FURTHER INFORMATION: Isolate area around container involved in fire. Cool tanks, shells, and containers exposed to fire and excessive heat with water. For massive fires the use of unmanned hose holders or monitor nozzles may be advantageous to further minimize personnel exposure. Major fires may require withdrawal, allowing the tank to burn. Large storage tank fires typically require specially trained personnel and equipment to extinguish the fire, often including the need for properly applied fire fighting foam. Exposure to decomposition products may be a hazard to health. Use extinguishing measures that are appropriate to local circumstances and the surrounding environment. Use water spray to cool unopened containers. Fire residues and contaminated fire extinguishing water must be disposed of in accordance with local regulations.

Section 6 – ACCIDENTAL RELEASE MEASURES

PERSONAL PRECAUTIONS: Use personal protective equipment. Avoid breathing vapors, mist or gas. Ensure adequate ventilation. Remove all sources of ignition. Beware of vapors accumulating to form explosive concentrations. Vapors can accumulate in low areas.

ENVIRONMENTAL PRECAUTIONS: Discharge into the environment must be avoided. If the product contaminates rivers and lakes or drains inform respective authorities.

METHODS FOR CLEANING UP: Contain spillage and then collect with non-combustible absorbent material, (e.g. sand, soil, diatomaceous earth, vermiculite) and place in container for disposal according to local / national regulations (see section 13). Keep in suitable, closed containers for disposal.

Section 7 – HANDLING AND STORAGE

HANDLING: Keep away from fire, sparks and heated surfaces. No smoking near areas where material is stored or handled. The product should only be stored and handled in areas with intrinsically safe electrical classification.

PROTECTION AGAINST FIRE AND EXPLOSION:

Hydrocarbon liquids including this product can act as a non-conductive flammable liquid (or static accumulators), and may form ignitable vapor-air mixtures in storage tanks or other containers. Precautions to prevent static-initiated fire or explosion during transfer, storage or handling, include but are not limited to these examples:

- (1) Ground and bond containers during product transfers. Grounding and bonding may not be adequate protection to prevent ignition or explosion of hydrocarbon liquids and vapors that are static accumulators.
- (2) Special slow load procedures for "switch loading" must be followed to avoid the static ignition hazard that can exist when higher flash point material (such as fuel oil or diesel) is loaded into tanks previously containing low flash point products (such gasoline or naphtha).
- (3) Storage tank level floats must be effectively bonded. For more information on precautions to prevent static-initiated fire or explosion, see NFPA 77, Recommended Practice on Static Electricity (2007), and API Recommended Practice 2003, Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents (2008).

STORAGE:

Keep away from flame, sparks, excessive temperatures and open flame. Use approved containers. Keep containers closed and clearly labeled. Empty or partially full product containers or vessels may contain explosive vapors. Do not pressurize, cut, heat, weld or expose containers to sources of ignition. Store in a well-ventilated area. The storage area should comply with NFPA 30 "Flammable and Combustible Liquid Code". The cleaning of tanks previously containing this product should follow API Recommended Practice (RP) 2013 "Cleaning Mobile Tanks In Flammable and Combustible Liquid Service" and API RP 2015 "Cleaning Petroleum Storage Tanks".

Section 8 – EXPOSURE CONTROL – PERSONAL PROTECTION

PERSONAL PROTECTIVE EQUIPMENT:

Respiratory protection – NIOSH/MSHA approved positive-pressure self-contained breathing apparatus (SCBA) or Type C positive-pressure supplied air with escape bottle must be used for gas concentrations above occupational exposure limits, for potential of uncontrolled release, if exposure levels are not known, or in an oxygen-deficient atmosphere.

Hand protection - Gloves constructed of nitrile, neoprene, or PVC are recommended.

Eye protection - Goggles and face shield as needed to prevent eye and face contact.

Skin and body protection - Chemical protective clothing recommended based on degree of exposure. Consult manufacturer specifications for further information.

Hygiene measures - Emergency eye wash capability should be available in the near proximity to operations presenting a potential splash exposure. Use good personal hygiene practices. Avoid repeated and/or prolonged skin exposure. Wash hands before eating, drinking, smoking, or using toilet facilities. Do not use as a cleaning solvent on the skin. Do not use solvents or harsh abrasive skin cleaners for washing this product from exposed skin areas. Waterless hand cleaners are effective. Promptly remove contaminated clothing and launder before reuse. Use care when laundering to prevent the formation of flammable vapors which could ignite via washer or dryer. Consider the need to discard contaminated leather shoes and gloves

Section 9 – PHYSICAL AND CHEMICAL PROPERTIES

PHYSICAL STATE: Liquid

ODOR: Characteristic Hydrocarbon Odor

PERCENT VOLATILE: 100%

VAPOR DENSITY (air=1): Approx 3 to 4

FREEZING POINT: Not Determined

FLASH POINT: See Above

APPEARANCE: Clear, Straw Colored

COLOR: Colorless to Slight Yellow

VAPOR PRESSURE: Not Determined

BOILING POINT: 85 to 437°F (39 to 200 °C)

SPECIFIC GRAVITY (water=1): Not Determined

SOLUBILITY IN WATER: Negligible

CONDUCTIVITY: Hydrocarbon liquids without static dissipater additive may have conductivity below 1 picoSiemens per meter (pS/m). The highest electro-static ignition risks are associated with "ultra-low conductivities" below 5 pS/m. See Section 7 for sources of information on defining safe loading and handling procedures for low conductivity products

Section 10 – STABILITY AND REACTIVITY

STORAGE STABILITY: Stable under recommended storage conditions.

CONDITIONS TO AVOID: Avoid high temperatures, open flames, sparks, welding, smoking and other ignition sources. Keep away from strong oxidizers.

MATERIALS TO AVOID: Keep away from strong oxidizers such as nitric and sulfuric acids.

INCOMPATIBILITY: Strong oxidizing agents, Acid chlorides, Acid anhydrides.

HAZARDOUS DECOMPOSITION PRODUCTS: Carbon monoxide, carbon dioxide and noncombusted hydrocarbons (smoke). Contact with nitric and sulfuric acids will form nitrocresols that can decompose violently.

HAZARDOUS REACTIONS: Vapors may form explosive mixture with air.

HAZARDOUS POLYMERIZATION: Will not occur.

Section 11 – TOXICOLOGY INFORMATION

WARNING! This is a research and development product. The properties of this product have not been fully investigated. All available information is provided in this MSDS. Use caution when handling this product.



Carcinogenicity**NTP:** Naphthalene (CAS-No.: 91-20-3)

Benzene (CAS-No.: 71-43-2)

IARC: Gasoline, natural; Low boiling point naphtha (CAS-No.: 8006-61-9)

Naphthalene (CAS-No.: 91-20-3)

Benzene (CAS-No.: 71-43-2)

Ethylbenzene (CAS-No.: 100-41-4)

OSHA: Benzene (CAS-No.: 71-43-2)**CA Prop 65:** WARNING! This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Toluene (CAS-No.: 108-88-3)

Benzene (CAS-No.: 71-43-2)

Acute oral toxicity: LD50 rat Dose: 18.8 mg/kg**Acute inhalation toxicity:** LC50 rat Dose: 20.7 mg/l Exposure time: 4 h**Skin irritation:** Irritating to skin.**Eye irritation:** Irritating to eyes.**Further information:** Liver and kidney injuries may occur. Components of the product may affect the nervous system.

IARC has determined that gasoline and gasoline exhaust are possibly carcinogenic in humans. Inhalation exposure to completely vaporized unleaded gasoline caused kidney cancers in male rats and liver tumors in female mice. The U.S. EPA has determined that the male kidney tumors are species-specific and are irrelevant for human health risk assessment. The significance of the tumors seen in female mice is not known. Exposure to light hydrocarbons in the same boiling range as this product has been associated in animal studies with effects to the central and peripheral nervous systems, liver, and kidneys. The significance of these animal models to predict similar human response to gasoline is uncertain. This product contains benzene. Human health studies indicate that prolonged and/or repeated overexposure to benzene may cause damage to the blood-forming system (particularly bone marrow), and serious blood disorders such as a plastic anemia and leukemia. Benzene is listed as a human carcinogen by the NTP, IARC,

OSHA and ACGIH: Acute toxicity of benzene results primarily from depression of the central nervous system (CNS). Inhalation of concentrations over 50 ppm can produce headache, lassitude, weariness, dizziness, drowsiness, over excitation. Exposure to very high levels can result in unconsciousness and death.

Component:**Gasoline, natural; Low boiling point naphtha**
(8006-61-9)

Acute oral toxicity: LD50 rat

Dose: 18.8 mg/kg

Acute inhalation toxicity: LC50 rat

Dose: 20.7 mg/l

Exposure time: 4 h

Skin irritation: Classification: Irritating to skin.

Result: Mild skin irritation

Eye irritation: Classification: Irritating to eyes.

Result: Moderate eye irritation

Acute oral toxicity: LD50 rat

Dose: 636 mg/kg

Acute dermal toxicity: LD50 rabbit

Dose: 12,124 mg/kg

Acute inhalation toxicity: LC50 rat

Dose: 49 mg/l

Exposure time: 4 h

Skin irritation: Classification: Irritating to skin.

Result: Mild skin irritation

Prolonged skin contact may defat the skin and produce dermatitis.

Eye irritation: Classification: Irritating to eyes.

Result: Mild eye irritation

Toluene (108-88-3)**Benzene** (71-43-2)

Acute oral toxicity: LD50 rat

Dose: 930 mg/kg

Acute inhalation toxicity: LC50 rat



Ethylbenzene (100-41-4)

Dose: 44 mg/l
Exposure time: 4 h
Skin irritation: Classification: Irritating to skin.
Result: Mild skin irritation
Repeated or prolonged exposure may cause skin irritation and dermatitis, due to degreasing properties of the product.
Eye irritation: Classification: Irritating to eyes.
Result: Risk of serious damage to eyes.

N-hexane (110-54-3)

Acute oral toxicity: LD50 rat
Dose: 3,500 mg/kg
Acute dermal toxicity: LD50 rabbit
Dose: 15,500 mg/kg
Acute inhalation toxicity: LC50 rat
Dose: 18 mg/l
Exposure time: 4 h
Skin irritation: Classification: Irritating to skin.
Result: Mild skin irritation
Eye irritation: Classification: Irritating to eyes.
Result: Risk of serious damage to eyes.
Acute oral toxicity: LD50 rat
Dose: 25,000 mg/kg
Acute dermal toxicity: LD50 rabbit
Dose: 2,001 mg/kg
Acute inhalation toxicity: LC50 rat
Dose: 171.6 mg/l
Exposure time: 4 h
Skin irritation: Classification: Irritating to skin.
Result: Skin irritation
Eye irritation: Classification: Irritating to eyes.
Result: Mild eye irritation
Teratogenicity: N11.00418960

Section 12 – ECOLOGICAL INFORMATION

ECOTOXICOLOGICAL INFORMATION

Additional ecological information: Keep out of sewers, drainage areas, and waterways. Report spills and releases, as applicable, under Federal and State regulations.

Component:**Toluene (108-88-3)**Toxicity to fish:

LC50

Species: Carassius auratus (goldfish)

Dose: 13 mg/l

Exposure time: 96 h

Acute and prolonged toxicity for aquatic invertebrates:

EC50

Species: Daphnia magna (Water flea)

Dose: 11.5 mg/l

Exposure time: 48 h

Toxicity to algae:

IC50

Species: Selenastrum capricornutum (green algae)

Dose: 12 mg/l

Exposure time: 72 h

Naphthalene (91-20-3)Toxicity to algae:

EC50

Species:



Butanol / Gasoline Test Plan

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Cyclohexane (110-82-7)

Dose: 33 mg/l
Exposure time: 24 h
Acute and prolonged toxicity for aquatic invertebrates:
EC50

Species: *Daphnia magna* (Water flea)

Dose: 3.78 mg/l

Exposure time: 48 h

N-hexane (110-54-3)

Toxicity to fish:

LC50

Species: *Pimephales promelas* (fathead minnow)

Dose: 2.5 mg/l

Exposure time: 96 h

Acute and prolonged toxicity for aquatic invertebrates:
EC50

Species: *Daphnia magna* (Water flea)

Dose: 2.1 mg/l

Exposure time: 48 h

Section 13 – DISPOSAL CONSIDERATIONS

PRODUCT:

Whatever cannot be saved for recovery or recycling should be handled as hazardous waste and sent to a RCRA approved waste facility. Processing, use or contamination of this product may change the waste management options. State and local disposal regulations may differ from federal disposal regulations. Dispose of container and unused contents in accordance with federal, state and local requirements.

CONTAMINATED PACKAGING:

Empty remaining contents. Do not re-use empty containers. Empty containers should be transported/delivered using a registered waste carrier to local recyclers for disposal. Dispose of container and unused contents in accordance with federal, state and local requirements.

Section 14 – TRANSPORTATION

DOT (US)

UN-Number: 1203	Class: 3	Packaging group: II
Proper shipping name:	Gasoline	
Marine pollutant:	No	
Poison Inhalation Hazard:	No	

IATA

UN-Number: 1203	Class: 3	Packaging group: II
Proper shipping name:	Gasoline	



Section 15 – REGULATORY INFORMATION

OSHA Hazards: Flammable liquid, Highly toxic by ingestion, Moderate skin irritant, Severe eye irritant, Carcinogen

SARA 311/312 Hazards: Fire Hazard, Acute Health Hazard, and Chronic Health Hazard

CERCLA SECTION 103 and SARA SECTION 304 (RELEASE TO THE ENVIRONMENT)

The CERCLA definition of hazardous substances contains a "petroleum exclusion" clause which exempts crude oil. Fractions of crude oil, and products (both finished and intermediate) from the crude oil refining process and any indigenous components of such from the CERCLA Section 103 reporting requirements. However, other federal reporting requirements, including SARA Section 304, as well as the Clean Water Act may still apply.

California Prop. 65: WARNING! This product contains a chemical known to the State of California to cause birth defects or other reproductive harm.

Toluene 108-88-3

Benzene 71-43-2

Section 16 – OTHER INFORMATION

Prepared By: Gevo Inc.

DATE: May 23, 2011

DISCLAIMER: The information provided in this Material Safety Data Sheet is correct to the best of our knowledge, information and belief at the date of its publication. The information given is designed only as guidance for safe handling, use, processing, storage, transportation, disposal and release and is not to be considered a warranty or quality specification. The information relates only to the specific material designated and may not be valid for such material used in combination with any other materials or in any process, unless specified in the text.

