Washington State Ferries Biodiesel Project Executive Summary

In 2004, WSF canceled a biodiesel fuel test because of "product quality issues" that caused the fuel purifiers to clog. The cancelation of this test and the poor results negatively impacted the use of biodiesel in marine application in the Pacific Northwest.

In 2006, The U.S. Department of Energy awarded the Puget Sound Clean Air Agency a grant to manage a scientific study investigating appropriate fuel specifications for biodiesel, fuel handling procedures and to conduct a fuel test using biodiesel fuels in WSF operations. The Agency put together a project team comprised of experts in fields of biodiesel research and analysis, biodiesel production, marine engineering and WSF personnel. The team reviewed biodiesel technical papers, reviewed the 2004 fuel test results, designed a fuel test plan and provided technical assistance during the test.

The research reviewed the available information on the 2004 fuel test and conducted mock laboratory experiments, but was not able to determine why the fuel filters clogged. The team then conducted a literature review and designed a fuel test plan. The team implemented a controlled introduction of biodiesel fuels to the test vessels while monitoring the environmental conditions on the vessels and checking fuel quality throughout the fuel distribution system.

The fuel test was conducted on the same three vessels that participated in the canceled 2004 test using the same ferry routes. Each vessel used biodiesel produced from a different feedstock (i.e. soy, canola and yellow grease). The vessels all ran on ultra low sulfur diesel blended with biodiesel. The percentage of biodiesel was incrementally raised form from 5 to 20 percent. Once the vessels reached the 20 percent level, they continued at this blend ratio for the remainder of the test. Fuel samples were taken from the fuel manufacturer, during fueling operations and at several points onboard each vessel. WSF Engineers monitored the performance of the fuel systems and engines.

Each test vessel did experience a microbial growth bloom that produced a build up of material in the fuel purifiers similar to material witnessed in the 2004 fuel test. A biocide was added with each fuel shipment and the problem subsided.

In January of 2009, the WSF successfully completed an eleven month biodiesel fuel test using approximately 1,395,000 gallons of biodiesel blended fuels. The project demonstrated that biodiesel can be used successfully in marine vessels and that current ASTM specifications are satisfactory for marine vessels. Microbial growth in biodiesel diesel interface should be monitored. An inspection of the engines showed no signs of being negatively impacted by the test.

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(2-87)
(Previous GC-792)

OMB Control No.
1910-0800

PATENT CERTIFICATION

RECEIVED JUL - 8 2009

Washington State University
Contractor

☐ Interim Certification
☒ Final Certification

DOE Prime and/or Subcontract Nos.

Contractor hereby certifies that:

1. All procedures for identifying and disclosing subject inventions as required by the patent clause of the contract have been followed throughout the reporting period.

2. There were no subcontracts or purchase orders involving research, development, and demonstration except as follows: [State none when applicable.] None

3. No inventions or discoveries were made or conceived in the course of or under this contract other than the following *(Certification includes* ☒*, does not include* ☐ *all subordinates):* None

   [State none when applicable.]

TITLE	INVENTOR	DATE REPORTED	DOE "S" NO.*
None			

4. The completion date of this contract is as follows: 4-30-09

5. The following period is covered by this certification:

May 11, 2007 to April 30, 2009
Month Day Year — Month Day Year

Washington State University
Contractor

P.O. Box 646120
Pullman, Washington 99164-6120
Address

[signature]
Signature

Shulin Chen

July 7, 2009
Date of Certification

* Also include Subcontract No. if available

U.S. DEPARTMENT OF ENERGY JUNE 2005

FINANCIAL ASSISTANCE PROPERTY CLOSEOUT CERTIFICATION

Award Number	**Recipient** *(Name and address)*
DE-FG36-06GO86032.A000	Puget Sound Clean Air Agency 1904 3rd Avenue- suite 105 Seattle, WA 98101

The purpose of this report is to facilitate the closeout of the Award. Based on the records maintained by the Recipient in accordance with the Property Management standards set forth in the Award, the following data reflects the Recipient's closeout inventory of real and personal property that was provided by the Department of Energy (DOE) or partially or wholly acquired with project funds.

I. EQUIPMENT

A. **Federally-Owned**: *(Government Furnished Equipment): (10 CFR 600.133(a), 600.232, 600.322, or Federal Demonstration Partnership (FDP) General Terms and Conditions No. 33, as applicable):* X No ☐ Yes

*(If **yes,** attach property inventory list that includes item description, manufacturer, model, serial number, original acquisition date, original acquisition cost and disposal condition code per the Federal Management Regulation 102-36.240)*

B. **Equipment Acquired with Award Funds where Title Vests in the Recipient with further obligations to DOE:** *(10 CFR 600.133, 600.134, 600.232, or 600.321, as applicable)*

X No ☐ Yes

If **yes,** does the equipment have a per unit fair market value of $5,000 or more? ☐No ☐ Yes

*(If **yes**, attach a property inventory list that includes item description, manufacturer, model, serial number, original acquisition date, original acquisition cost, disposal condition code per the Federal Management Regulation 102-36-240 and one of the disposition codes listed below)*

(1) The property will continue to be used for the purposes authorized in the Award.

(2) The property is no longer needed for the purposes of the Award, and will be used on another Federally sponsored activity *(List Activity and Federal Agency):*

(3) The Recipient wishes to retain the property and compensate DOE for its share of the current per unit fair market value. *(Identify the fair market value on the attached property inventory list and describe how the value was determined).*

(4) The property is no longer needed for the purposes of the Award or other Federally sponsored activities and the Recipient requests DOE disposition instructions.

II. SUPPLIES (*10 CFR 600.135, 600.233, 600.324, or FDP General Terms and Conditions No. 35, as applicable*)

Does the residual inventory of unused supplies exceed $5,000 in total aggregate value? X No ☐ Yes *(if **yes**, check block below)*

☐ The supplies will be used on another Federally sponsored activity *(List Activity and Federal Agency).*

☐ The supplies will be sold or retained for use on non-Federally sponsored activities and the Recipient will compensate DOE for its share of the sales proceeds (or estimate of current fair market value). Attach a list of the supplies and complete the following Worksheet:

Sale proceeds or estimate of current fair market value.............................. $____________

Percentage of Federal participation .... ____________%

Federal share .... $____________

Selling and handling allowance .... $____________

Amount to be remitted to DOE .... $____________

U.S. DEPARTMENT OF ENERGY

FINANCIAL ASSISTANCE PROPERTY CLOSEOUT CERTIFICATION

III. REAL PROPERTY: *(Real Estate - 10 CFR 600.132, /600.231, 600.321, or FDP General Terms and Conditions No. 32, as applicable)* X No ☐ Yes *(If **yes,** complete A –C)*

A. Description of Real Property:

B. Complete Address of Real Property:

C. Period of Federal Interest in the Property: From ________ To ________ (Unless the award specifies otherwise, the Federal Interest in the property ends when the award project period ends.)

D. Disposition Preference Request. If the period of Federal Interest in the property exceeds the project period, check one of the following blocks to indicate your disposition preference:

- ☐ Transfer property to another Federal award.
- ☐ Sell and compensate DOE.
- ☐ Return to DOE.
- ☐ Retain title and compensate DOE for its share of the current fair market value of the property.

Certification: I certify to the best of my knowledge and belief that all information presented in this report is true, correct and complete, and constitutes a material representation of fact upon which the Federal government may rely.

Name	Signature	Title	Date
Thomas J. Hudson	[signature]	Inspector	July 8, 2009

U.S. DEPARTMENT OF ENERGY

FINANCIAL ASSISTANCE PROPERTY CLOSEOUT CERTIFICATION

To be completed by the Department of Energy:

DOE PROPERTY DISPOSITION

☐ Negative Report

☐ Real Property:

☐ Equipment:

☐ Supplies:

Property Management Official Name	Signature	Date

Washington State Ferry Biodiesel Research & Demonstration Project

Final Report

April 30, 2009

Developed by
Washington State University
University of Idaho
The Glosten Associates, Inc.
Imperium Renewables, Inc.

Acknowledgment: This material is based upon work supported by the Department of Energy under Award Number DE-FG36-06GO86032.

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1. Executive Summary

The Washington State Ferry (WSF) system conducted a pilot biodiesel fuel test in 2004 over a four-month period using a B20 biodiesel blend (20% soy biodiesel and 80% low sulfur diesel) in three vessels. This pilot program experienced challenges due to excessive clogging problems in the ferries' centrifugal fuel purifiers and plugging of fuel filters during the test. While these operational issues were challenging, the test was successful in that the ferry system learned important information that would assist in their 2008 Biodiesel Research and Demonstration Project. This demonstration project was important as WSF vessels burn approximately 18,000,000 gallons of diesel fuel per year. Diesel particulate emissions have been identified as the most significant airborne health risk in the Puget Sound region. The Environmental Protection Agency projects that using a B20 fuel is expected to reduce diesel particulate by approximately 10%, carbon monoxide by 11%, and hydrocarbon emissions by 21%.

The US Department of Energy (DOE) awarded a grant to Puget Sound Clean Air Agency (PSCAA) to perform a scientific study to determine appropriate fuel specifications, fuel handling procedures, and conduct a fuel trial using biodiesel-blended fuels in WSF operations. Washington State University (WSU) was selected to lead the research project team conducting the two-year project. The team members included the University of Idaho (UI), Imperium Renewables, Inc. (IRI), and The Glosten Associates. The goals of the project were to (1) test current fuel specifications for biodiesel and biodiesel-blended fuels, (2) develop biodiesel product handling guidelines for use in a marine environment, and (3) demonstrate that biodiesel-blended fuels can be successfully used in marine applications in the Pacific Northwest. The fuel test work plan was designed to test the use of biodiesel on three WSF vessels during normal vessel operations. Vessels and routes selected were the same as those used in the 2004 pilot test. All 3 vessels were run on B20, which was the highest biodiesel blend used in the ferry tests.

Biodiesel from different feedstock sources was tested in each vessel, including canola-based biodiesel, soy-based biodiesel, and biodiesel with a high cloud point. All biodiesel used met the most current version of the ASTM D6751 specification. The fuel blends tested were incrementally raised from 5% to 20%, with samples being taken at critical junctures to ensure fuel quality. Excess sludge buildup formed in the fuel purifier of one of the vessels after one month of operation, which was similar to the problem experienced in the 2004 pilot test. The research team performed extensive research to find causes of the problem. The sludge samples studied contained metal (~11% ash), water (11-17%), major fractions of organic materials including 8-octadecenoic acid methyl ester from canola biodiesel, and bacteria. WSU researchers found active bacteria were present in the sludge samples from the purifier and the bacteria played a key role in the sludge formation. Microbial growth in the ferry system was one of the major causes for excessive sludge formation that resulted in filter clogging. Discussions with WSF operators indicated that sludge formation from microbial growth has been encountered with conventional diesel fuel also. The excessive sludge problem was solved by the application of biocide in the fuel during the studied period. Biocide application is strongly recommended when biodiesel blend fuels are used in marine applications.

This project demonstrated the viability of using B20 biodiesel in year-round marine conditions. Results obtained from this project are expected to be directly transferable to other marine applications, as well as being beneficial to land-based end-users. Key lessons learned are:

a) ASTM biodiesel fuel standards provided adequate safeguards to ensure high product quality.

b) Fuel quality was not affected by biodiesel feedstock (i.e., soy, canola, and high cloud point fuel).

c) The percentage of biodiesel (B5–B20) used in the fuel did not impact vessel operations.

d) Use of biocides is recommended in all future testing with biodiesel. Although comparison of sludge formation between conventional diesel fuel and biodiesel were primarily anecdotal, vessel operations using biodiesel may require increased maintenance of fuel filtration systems.

e) The high humidity of marine environments appears to promote microbial growth.

2. Project Background

2.1. *Project History*

The Washington State Ferry (WSF) system is the largest ferry system in the U.S. and is a large consumer of diesel fuel in the Puget Sound region. Since 2003, WSF has been implementing cleaner burning fuels in its fleet. The movement to lower sulfur-containing fuels has made a significant improvement in vessel exhaust emissions. Efforts to implement bio-based diesel fuel continue these cleaner burning fuel initiatives.

WSF conducted a pilot biodiesel fuel test in 2004 over a period of four months and again in 2005 for one month using a B20 biodiesel blend of soy in three vessels. These tests showed that excessive clogging of the ferries fuel purifiers and fuel filters caused operational maintenance issues. The tests were useful in demonstrating that a bio-based fuel could be burned successfully in marine diesel engines.

WSF is potentially one of the largest consumers of biodiesel fuel in the Pacific Northwest region, and problems experienced by WSF may impede efforts to expand the use of biodiesel products in marine and land-based fleets. To address the problems of using biodiesel in WSF applications, Washington State Senator Cantwell helped secure $500,000 in congressionally directed funds from the U.S. Department of Energy (DOE). A grant was awarded to Puget Sound Clean Air Agency to manage a scientific study that would determine appropriate fuel specifications and fuel-handling procedures for using biodiesel-blended fuels in WSF operations. As part of the funding, Seattle City Light contributed $350,000 for the differential costs between the biodiesel and the petroleum diesel.

2.2. Project Goals

The goals of the project were to:

(1) test current fuel specifications for biodiesel and biodiesel-blended fuels,

(2) develop biodiesel product handling guidelines for use in a marine environment, and

(3) demonstrate that biodiesel and or biodiesel-blended fuels can be successfully used in marine applications in the Pacific Northwest.

The project included five objectives:

<u>Objective 1</u>: Identify fuel specifications and product handling guidelines for biodiesel and biodiesel-blended fuels to help ensure that high quality fuel is delivered to end-users.

<u>Objective 2</u>: Recommend test methods to determine if biodiesel and biodiesel-blended fuel meet the recommended fuel specifications.

<u>Objective 3</u>: Recommend a sampling protocol to ensure that biodiesel products meet the recommended fuel specifications throughout the fuel distribution network.

<u>Objective 4</u>: Develop a fuel test work plan for the WSF system.

<u>Objective 5</u>: Provide oversight for WSF fuel testing and provide trouble shooting expertise for any operational problems that may occur.

To accomplish the project goals and achieve these objectives, a two-year study was designed. The activities of the first year focused on information gathering, development of recommendations for fuel specifications and fuel handling guidelines, and development of a work plan for field testing of these recommendations. The second year of the project focused on conducting tests of biodiesel-blended fuel on three WSF vessels based on these recommendations. It was anticipated that the fuel specifications and product handling guidelines developed and vetted during the fuel test period would establish methods and procedures to ensure that high quality biodiesel fuel was delivered and used appropriately in marine applications. It was also anticipated that the safeguards developed to help ensure product quality in the marine sector would benefit and be directly transferable to land-based end-users.

2.3. Project Organization

Washington State University (WSU) was selected to lead a research project team to conduct the project. Team members included the University of Idaho (UI), Imperium Renewables, Inc. (IRI), and The Glosten Associates. This multi-disciplinary team required clear delineation of roles and responsibility to facilitate direct and efficient communications. The roles and responsibilities of the team members were determined based on the expertise of the individual consultants involved (Table 1). In addition, the research team depended on the knowledge and expertise of WSF personnel throughout the project.

Table 1. Roles and Responsibilities of Involved Parties

Organization	Roles and Responsibility
PSCAA	**Project Manager:** Project management, monitor contract issues and deliverables
WSU	**Project Lead:** Overall research project management and research team coordination
	Meeting and teleconference coordination
	Immediate assistance during fuel testing
	Analysis for certain precipitate parameters
	Tracking analytical results of samples
	Documenting information for final report
	Trouble-shooting, analysis, and recommendations
UI	Trouble-shooting and recommendations
	Receive samples and conduct related analysis
	Conduct additional research as necessary
Glosten Associates	Perform vessel checks prior to testing phase
	Identify sampling and temperature monitoring locations in the vessels' fuel systems
	Ensure sound marine practices are incorporated in all testing and monitoring
	Assist WSU in monitoring fuel test and provide technical assistance, trouble-shooting, and problem solving to WSF during fuel trials
	Provide personnel to monitor operational procedures and collect samples or obtain data in accordance with Final Fuel Test Work Plan
	Submit incident reports to WSU and the Project Manager
	Collect, label, package and vessel fuel samples to a sample storage center or laboratories designated by the Project Manager
	Sampling and data collection as needed

Imperium Renewables	Assist with lab analysis as needed
	Provide information related to biodiesel processing
WSF	Provide three vessels as test platforms for the duration of fuel testing phase
	Prepare the vessels' fuel tanks for receipt of biodiesel fuel
	Modify the vessels' fuel systems to install temperature sensing and fuel sampling ports.
	Monitor and report problems
	Provide onboard sample collection and storage

2.4. Project Tasks

The project consisted of two phases: (1) an introductory research and evaluation phase, and (2) a fuel trial demonstration phase on selected WSF vessels. The team performed the following tasks.

Task I. Review of scientific studies and technical papers

This literature review sought to provide insight into the problems WSF encountered during the 2004 and 2005 biodiesel pilot tests. The following biodiesel and biodiesel-blended fuel quality issues were addressed:

- Fuel quality and test methods;
- Fuel chemistry;
- Lessons learned from previous and current applications;
- Effects of environmental conditions on fuel quality;
- Fuel handling practices and guidelines.

Task II. Review of the 2004 WSF biodiesel fuel test

The team conducted a thorough review of the 2004 WSF biodiesel pilot test results, discussed the possible causes of problems in that test, and conducted lab scale experiments in an attempt to recreate the conditions that occurred during the 2004 test.

Task II A. Review the 2004 WSF Biodiesel Fuel Test

This task included a review of the 2004 WSF biodiesel pilot test through interviews of WSF's project managers, vessel engineers, fuel distributors, and other involved parties. Information was collected on measures taken to prepare the vessels for testing; procedures used by the WSF fuel distributor to transport, store, and blend neat biodiesel, as well as transportation and fueling of WSF vessels with biodiesel-blended fuels; fuel testing methods used to determine neat biodiesel and biodiesel-blended fuel quality; sample tracking methods; and lessons learned during the test.

Task II B. Evaluate WSF Fuel System Environmental Parameters and Compatibility

The team identified environmental conditions inside the WSF test vessel fuel systems and evaluated fuel system equipment compatibility for use with biodiesel-blended fuels, which could have a negative impact on biodiesel and biodiesel-blended fuel quality. The team also designed test procedures to evaluate the environmental conditions inside the vessels' fuel tanks such as fuel temperature, moisture levels, and other relevant parameters that may affect fuel quality.

Task II C. Perform experimental research at lab scale

In order to provide the technical basis for developing the work plan for the second year demonstration phase, the team designed and conducted experimental research in the lab to supplement the information obtained from the literature review and the review of the 2004 WSF biodiesel pilot test. The team also proposed initial hypotheses for possible causes of the filter clogging problems, which were identified in the literature review and the analysis of the 2004 WSF biodiesel pilot test, and in the laboratory experiments. The outcome of this research was to recommend fuel quality control procedures and report on possible cause(s) of the filter clogging problems under various conditions. These recommendations were incorporated into the project work plan.

Task III. Develop 2008 Biodiesel Fuel Test Work Plan

To test the current fuel specification and product handling guidelines, a work plan was developed based on the findings from Tasks I and II. The 2008 biodiesel fuel test plan was designed to test current available biodiesel fuel options and to maximum our understanding of how biodiesel fuels work in a marine environment.

The 2008 biodiesel fuel test work plan included the following objectives.

- A detailed work schedule for completing the fuel test.
- Roles and responsibilities of each party involved during the fuel test.
- Fuel specifications for WSF biodiesel and biodiesel blends, including percent of biodiesel that should be blended with diesel fuel during each phase of the test.
- Location in the fuel distribution network where fuel quality tests should be performed.
- Sampling protocols and testing intervals to use when testing biodiesel and biodiesel-blended products.
- A sample tracking system for biodiesel and biodiesel-blended fuels to use during the fuel test.
- Fuel blending and handling guidelines for biodiesel and biodiesel-blended fuels.
- Procedures for cleaning WSF vessels' fuel tanks.
- Types of biodiesel feedstock to use during the fuel test.
- Fuel and vessel parameters to monitor during the fuel tests.
- A corrective action plan that identified who was to be contacted and what procedures were to be followed if operational problems occur during the fuel test, including 24 hour contact information for essential personnel during the test.

Task IV. Implement Final 2008 Biodiesel Fuel Test Work Plan

The 2008 demonstration phase of the fuel test was scheduled to be conducted over a period of twelve months, but project delays and vessel availability restricted the test to approximately 11 months, beginning on March 9, 2008, with the *M/V Issaquah*. The fuel test work plan was designed to be conducted on three WSF vessels under normal vessel operating conditions. The vessels and routes selected were the same vessels and routes used for testing biodiesel applications in 2004 and 2005. The test was conducted on the *M/V Issaquah*, the *M/V Tillikum*, and the *M/V Klahowya*, all operating on the Fauntleroy-Vashon-Southworth route. The team monitored the fuel test and provided technical assistance and troubleshooting during the fuel demonstration phase.

Vessels used for demonstration phase

The *M/V Issaquah* (see Figures 1 and 2) is one of six vessels of the class by the same name. She was built by Marine Power and Equipment in Seattle, WA, and delivered to WSF in 1979. She has two General Electric diesel engines generating 5,000 hp which drive controllable pitch propellers through reduction gears. She is 328 feet long and carries 1,200 passengers and 124 autos.

The *M/V Klahowya* and *M/V Tillikum* (see Figure 3) are two of three vessels of the Evergreen State class. They were built in Seattle, WA and delivered to WSF in 1958 and 1959 respectively. They each have two Electro Motive Diesel (EMD) engines generating 2,500 hp, which make up the prime movers in these diesel-electric vessels. They are 310 feet long, carry 87 autos, and 800 and 1,200 passengers, respectively.

Figure 1. *M/V Issaquah* in operation.

Figure 2. *M/V Issaquah* with biodiesel decals affixed under pilot house.

Figure 3. *M/V Tillikum* in operation.

Task V. Provide progress and final reports

The team submitted quarterly progress reports and monthly status reports. In addition, the entire team participated in scheduled teleconference meetings and conferences in person to discuss the activities of the previous month, the progress toward current deliverables, and to establish goals for the following period.

3. Literature Review

The team conducted a literature review of the existing knowledge on biodiesel obtained from utilization-related scientific studies and technical papers documenting experience in using biodiesel and biodiesel blends as diesel engine fuel. The purpose of a literature review was to review current fuel standards and specifications and biodiesel product handling guidelines for applicability in marine applications. This literature review included a brief introduction and overview of the following topics, listed in separate sections: (1) fuel quality specification and test methods, (2) characterization of biodiesel fuel and alternate test methods, (3) fuel application and fuel quality in both marine and land-based environments, (4) effects of environmental conditions on fuel quality, (5) fuel storage, stability, transport, and blending, (6) effects of biodiesel production on its quality, and (7) other biodiesel research.

Summary of Findings of Literature Review

Findings pertinent to this project are summarized below. Detailed information on the literature review can be found in Appendix A (Literature Review Report). For biodiesel quality, the most critical fuel quality parameter is the total glycerin content. Another set of important quality parameters are the levels of sulfur, phosphorus, sodium, potassium, calcium, and magnesium. Biodiesel products in the U.S. must meet the ASTM D6751 quality standard specification. In this specification, values of physical properties and impurities for commercial products are set out, including, but not limited to viscosity, water and sediment, cetane number, cloud point, acid number, glycerin, phosphorus, and oxidation.

Another factor affecting biodiesel quality is environmental conditions, which mainly affect cold flow properties. Biodiesel has a relatively high cloud point and pour point, which limit its application as B100 in low temperature conditions. In addition, biodiesel has a strong tendency to absorb moisture due to its chemical properties, providing a negative factor for biodiesel application in the high humidity of a marine environment.

When running engines on biodiesel blends, fuel filter clogging has been a recurring issue. Symptoms similar to those on the WSF vessels experienced in 2004 have been reported by others, including white milky fluid in fuel bowls, black deposits between filter pleats and a general increase in filter servicing and change-out. None of these symptoms were reported to have occurred at the extreme levels reported by WSF in the 2004 test, and centrifugal fuel purifiers were not mentioned in other applications. However, marine fuel systems are somewhat different from other applications in that most others do not centrifuge their fuel.

The literature review suggests that several factors, including *water content*, *temperature*, and *oxidation*, could affect biodiesel quality. The findings relative to this project are listed below.

a) Analysis suggests that biodiesel oxidation may **not** be a key factor in clogging, due to the limited availability of free oxygen, short dwell time, and low temperature.

b) Cold flow properties, as reflected by relatively high cloud and pour points, may limit biodiesel-blended fuel applications under low temperature conditions because particles might be formed in fuel.

c) Biodiesel has a strong tendency to absorb moisture due to its chemical properties. Because of this tendency, the use of biodiesel in a high humidity marine environment is challenging. Minor compounds, such as sterol glucosides, could form precipitates which agglomerate over time into flocs and sediment, probably leading to clogged filters. The sterol glucoside content can vary from supplier to supplier based on both the biodiesel origin and the form of processing technology.

d) Actual operational tests have shown that tank cleaning before transitions from long-term petroleum diesel fuel use to biodiesel is necessary for effective problem-free biodiesel operation.

4. Evaluation of 2004 WSF Biodiesel Pilot Tests

In addition to the literature review that provided general information on some experiences regarding practical uses of biodiesel and its blends as diesel engine fuel, the evaluation of the WSF 2004 fuel tests provided invaluable information on biodiesel usage in WSF vessel fuel systems. The team reviewed the 2004 WSF fuel test to better understand the possible factors that caused the challenges in those tests.

4.1. WSF 2004 Biodiesel Pilot Tests

In the second half of 2004 and in the first quarter of 2005, WSF operated three of its vessels with a 20% biodiesel blend as part of its "Clean Fuel Initiative." The trial was suspended in December 2004 because of "product quality issues" related to clogged fuel filters and fuel purifiers. The trial was restarted in March 2005, only to be terminated again due to similar issues. Though not well documented, the WSF trial led to the conclusion that biodiesel blends may not be suitable as direct substitutes for petroleum based diesel fuel in WSF vessels.

The first load of soy-based B20 was taken on the *M/V Issaquah* (Vessel #1) on July 17, 2004, the *M/V Tillikum* **(**Vessel #2) on August 16, 2004, and the *M/V Klahowya* (Vessel #3) on August 17, 2004. Biodiesel trials on WSF vessels were suspended in mid-December 2004 because of ongoing filter clogging problems.

A follow-on trial commenced in March 2005, after adopting modified blending procedures and standards for fuel quality. The *M/V Tillikum* took a load of B20 on March 1, 2005. A decision was made to terminate the trial for the *M/V Tillikum* on March 28, 2005, due to similar filter clogging issues.

During the onboard trials, engine-mounted spin-on filters, off engine coalescing filters, and the centrifugal fuel purifiers became clogged with contaminants described alternately as a:

- milky white gelatinous substance,
- butterscotch mousse, or
- black grainy material with a grease-like texture.

It is difficult to believe that these three descriptions could apply to the same substance. While the first two descriptions might describe an oil-in-water emulsion, the last description does not match the others.

The centrifugal fuel purifier is designed to separate water and solid contaminants from the fuel by relying on differences in densities and centrifugal force (up to 10,000 times that of gravity). It is unclear whether such a device could create unintended effects such as clogging. It may depend on fuel quality.

In an attempt to overcome the filter clogging and purifier sludge buildup, improved blending techniques and the addition of cold-filtering were added as corrective measures and undertaken during the trial, as follow:

- B100 was loaded at a higher temperature (110^{o}F vs. 100^{o}F) into insulated (vs. un-insulated) rail cars for transport to Tacoma. The first load vessel in this manner arrived at a temperature of 60^{o}F.

- Rigorous testing of B100 was invoked upon arrival of the rail car, including tests for water and sediment and acid number. It was necessary that the results of these tests pass the requirements of the ASTM D6751 standard specification.

- Samples of B100 taken during loading of the tank truck should have been retained for testing later, as required. The samples were retained, but were later discarded when the pilot test was suspended.

- A second filtering was considered as B100 was loaded onto the tank truck. This filtering step is required to assure B100 quality before blending. However, this filtering step was not put in place prior to the suspension of the trial.

- It was intended that samples of B20 be randomly pulled from the center of a truck compartment and retained for future testing. It was unclear whether such samples were indeed retained.

The findings pertinent to this review of the 2004 test are summarized below.

a) Biodiesel blends appeared to be the cause of operational problems when used as a direct substitute for petroleum based diesel fuel in marine vessels.

b) Fuel tank cleaning methods and protocols for vessels should be reviewed and documented.

c) WSF fuel contract specifications for biodiesel fuels should be revised to use the most updated ASTM requirements.

d) Sterols may have been precipitating out during rail transportation of B100 from the Midwest. The process has been observed to occur in some cases when temperatures drop below 45 to 50^o F. These precipitates will not re-dissolve, even when heated.

e) The high iron content measured in the filter residues may indicate that iron was "leaching" out of the vessels steel fuel tanks.

f) The range of fuel tank surface temperatures should be established and reviewed as one environmental parameter affecting the properties of the fuel blend.

Detailed information for the WSF 2004 pilot tests can be found in Appendix B (WSF 2004 Biodiesel Pilot Test Report).

4.2. Evaluation of WSF Fuel Systems

The physical, chemical, and biological environments of the WSF fuel system may affect biodiesel fuel quality. This WSF fuel system evaluation specifies the fuel quality requirements relative to important environmental parameters, procedures, and assessment results regarding compatibility of the vessel's environment. Physical parameters include temperature, moisture level, and storage time; chemical parameters include exposure to oxygen, tank materials, possible deposition at the fuel tank surface and tank bottom, and quality of hose and materials of piping in the fuel line system; and biological parameters include bacterial and mold growth.

It is important to note that biodiesel fuel is not simply stored in a static environment in a tank on a marine vessel. It is transferred into a storage tank; in the case of WSF, the fuel is transferred from a tanker truck. The fuel is therefore subject to sloshing during transfer into and while in the storage tank. The fuel is then transferred from the storage tanks into fuel day tanks through centrifugal fuel purifiers, pumps, and filters.

Finally, the fuel is pumped under pressure in service piping through filters, hoses, and engine fuel injection equipment, into the engine for combustion, with some fuel returning to the fuel oil day tanks. In this way, environmental conditions under which the biodiesel is used in a vessel are not only weather dependent, but are also impacted by the processes inherent within marine vessel operations.

The biodiesel handling guidelines issued from the National Biodiesel Board (NBB) suggested that bacteria and mold may grow if condensed water accumulates in biodiesel fuel. It was also speculated that some of the sludge found at the bottom of the WSF fuel tank during the 2004 test might be due to biological growth. This bacteria and mold may use biodiesel and diesel hydrocarbons as a food source. They may then grow as a film or slime in the tank, and accumulate as sediment. These hydrocarbon-degrading microbes often have a reddish-orange color and tend to form mats. The slime and sediment created by these mats may break loose and accumulate in the fuel filters, resulting in filter clogging problems. The bacteria can be detected with onboard test kits.

Biocides can kill the bacteria and molds growing in the fuel tank, and the presence of the biocide does not interfere with engine operation. The biocides can inhibit the growth of microbes over long periods of time in very low concentrations. The biocide manufacturer recommends that when microbial contamination is observed, a shock treatment of a high dosage of biocide should be added to the fuel, followed by a lower maintenance dose.

If high moisture conditions are chronic, then biocides are recommended for continuous use at the maintenance level dosage. When shock treatments are used, it is advisable to clean the fuel tank afterwards to prevent any residue from the infestation from plugging fuel filters. Cleaning is not always possible due to vessel operational considerations, so it should be expected that fuel filters will need to be changed out at a higher frequency. Biocide products are typically pesticides, and they may provide a solution to this problem.

The detailed information for the evaluation of WSF's fuel systems can be found in Appendix C (WSF Fuel System Environmental Parameters and Compatibility Evaluation).

4.3. Laboratory Research Findings

The purpose of the Phase 1 lab test was to provide technical support for the 2008 Phase 2 field fuel test. In the lab tests, the effects on biodiesel quality of minor compounds, water content, and temperature on precipitate formation, which could lead to filter clogging, were studied.

The team also simulated the fuel purifier on the ferries with a centrifuge, since the 2004 test showed a "butterscotch pudding" type material in the centrifugal fuel purifiers of the vessels.

Figure 4. Fuel purifier sludge from 2004 biodiesel pilot tests.

The lab findings are summarized below.

a) The laboratory tests confirmed that insoluble particles (precipitates) in B20 were formed under certain conditions in the presence of water. Incubation at warm temperatures, such as 100°F, favored precipitate formation. The precipitates obtained were identified as sterol glycosides.

b) The effect of the fuel purifier on formation of the material was investigated with fuel purifier tests using B20. However, the tests did not result in any material such as that noted during the 2004 test and shown in Figure 4. No difference was found between soy and canola based biodiesel. Varying water content, flow rate, temperature, etc., also did not produce a material similar to that observed in 2004. A thin milky emulsion inside the centrifugal fuel purifier was observed under some conditions, but it was not stable and the emulsion broke down as soon as it was collected.

It must be noted that it was not possible to simulate ferry operating conditions during the laboratory tests. These preliminary results from the laboratories did not specifically identify the causes of the clogging problems in the 2004 test, but did provide additional insight for further testing.

Detailed information about the lab research can be found in Appendix D (Laboratory Research Report).

5. Work Plan and Recommendations for the 2008 Tests

5.1. Development of the Work Plan for the 2008 Trials

Based on the findings from the literature review, the evaluation of the 2004 test, and the laboratory results, the team developed and submitted a draft project work plan to the Project Manager for review. The team also interviewed WSF Project Managers, Engineers and Operators, Biodiesel Providers, Distributors, and other parties involved in the 2004 test. The draft project work plan included recommendations, methods and procedures, a detailed work schedule for completing the 2008 test, and all of the deliverables required by this project.

As part of the project work plan, the team developed a one year fuel trial (demonstration phase) to test the fuel specifications, product handling guidelines, and operational compatibility of biodiesel products for use in a marine environment.

Upon completion of the draft work plan, the team sent the plan to four well-known experts in the biodiesel field for peer review. The experts consulted were Mr. Steve Howell from Marc IV Consulting, LLC; Dr. Leon Schumacher from the University of Missouri; Dr. Charles Peterson from the University of Idaho; and Dr. Gerhard Knothe from the National Center for Agricultural Utilization Research (NCAUR) of the USDA. The team collected and reviewed the comments from the experts and conducted further discussion with them. The comments from the expert reviewers provided important information for the revision of the work plan for the 2008 trials. For example, all four expert reviewers supported the assertion that biodiesel oxidation probably did not play an important role in the filter clogging problems in the 2004 test, which was an important statement to the work plan. Finally, the team worked with the Project Manager to incorporate all the comments and to finalize the project work plan.

Detailed information regarding the work plan can be found in Appendix E (Work Plan for 2008 Biodiesel Test).

5.2. Recommendations for Preventing the Filter Clogging Problems

The main goal of this part of the project was to provide recommendations for preventing the filter clogging problem that occurred during the 2004 test. The entire team discussed and agreed to the recommendations for the 2008 trials as summarized below:

1) The fuel tanks, including fuel storage (deep) and service (day) tanks, should be cleaned before loading the biodiesel-blended fuel. While the team concurred that system cleanliness was an important factor, operating schedules for the ferries may have precluded aggressive fuel system cleaning before biodiesel was introduced. The cleaning procedure was developed for the 2008 fuel test project to ensure a successful introduction of biodiesel into the WSF fuel system. The current standard cleaning procedure used onboard WSF vessels results in a small amount of moisture, sediment, and possibly detergent residue in the tank. There was concern that moisture and any remnants of detergents used in the cleaning process may contribute to the formation of emulsions.
2) During the 2008 fuel test in the ferry vessels, additional laboratory work was recommended to help understand the causes of the filter clogging.
3) Since laboratory tests were unable to mimic the unique operating conditions of a ferry, the exact cause was to be confirmed in the actual test with the ferry, should clogging occur again. Three possible causes and corresponding measures to deal with anticipated problems were identified.

Potential Cause 1 - Minor compounds form precipitates under unique ferry conditions

Prevention measures: (i) Biodiesel fuel to be used in the 2008 Ferry test must pass the cold soak filtration test (<360 seconds) as a specification requirement; and (ii) Ferries might start with fuels containing a low content of the minor compounds, such as sterols, through process or feedstock selection.

Corrective actions if this problem occurs again: (i) Recommend adding a desiccation process in the ferry system and taking any additional measures to prevent water from entering into fuel, (ii) require distilled fuel, and (iii) refine the laboratory tests to confirm the observations and devise alternative corrective actions.

Glosten advised that adding desiccant filters to the tank vent system would deviate significantly from customary marine practice. It would be impractical to design and test a system and seek even conditional regulatory approvals under the schedule and budget constraints imposed by the demonstration project.

Potential Cause 2 - Tank deposits dissolved during the operation

Prevention measure: Thoroughly clean the entire fuel system, especially the tanks.

Corrective action if this problem occurs again: Load B20 in the tank and re-circulate it by pump for a couple of days prior to use. This process may allow the B20 enough time to dissolve the tank deposits. Samples should be taken regularly and their filterability characterized to determine whether the tank deposits have been removed and when the cleaning process should be complete. Samples should be also taken and sent for analysis. For example, the chemical makeup of the deposits in the samples can be determined by inductively coupled plasma (ICP) at the University of Idaho to determine the chemical makeup of the deposits.

Potential Cause 3 – Micro-organism growth/microbial contamination

Prevention measures: (i) Fuel should be obtained only from BQ 9000 certified biodiesel producers or marketers for the 2008 test, and (ii) all B20 added to the ferries should be treated by ferry personnel with a commercial biocide.

In addition, samples of the biodiesel-blended fuel should be checked for microbial contamination during initial loading operations by having ferry operators collect samples from the fueling lines during refueling. These samples should be shipped to UI for analysis to determine whether microbes are present.

Corrective action if this problem occurs again: Additional commercial biocide currently used by WSF should be added to fuel in the tanks.

5.3. Biodiesel Feedstocks, Biodiesel Specifications, Biodiesel Filtration, Tank Cleaning, and Sampling

In order to investigate types of fuel feedstocks and manage the 2008 test, specific fuel sources and procedures were proposed.

(i) WSF made three vessels available for the 2008 fuel test. It was determined that in order to maximize the test results, biodiesel from different feedstock sources and/or processing technologies should be tested in each vessel. The following fuel types were chosen:

Fuel Type 1: Canola-based biodiesel

Fuel Type 2: Soy-based biodiesel

Fuel Type 3: Biodiesel with a high cloud point, such as recycled restaurant oil or animal fat-based biodiesel.

The fuel test plan was developed based on the following principles: (a) start with a biodiesel feedstock that has the highest likelihood of success based on the current knowledge regarding potential cause of filter clogging; (b) use different feedstocks such as canola, soy, and high cloud point biodiesel; (c) gradually increase the number of vessels to allow the research team opportunities to devise solutions if problems occur; (d) increase the biodiesel component gradually, starting at 5% and increasing to 10% and 20%; (e) restrict the biodiesel blends to a maximum of 20%; and (f) be respectful of WSF vessel operational needs so as to not cause vessel service disruptions.

(ii) Require all biodiesel used to meet the most current version of the ASTM D6751 specification. The fuel specification covers a biodiesel fuel blend containing 20% biodiesel with the remainder being ultra low-sulfur diesel fuel oil. This fuel blend (B20) was intended for use in diesel combustion engines. Biodiesel (B20) should be delivered blended and was subject to inspections and analysis upon delivery. The team proposed product performance requirements, total quality management/quality assurance, and manufacturer's quality assurance for blend stock (B100).

(iii) The team developed sampling procedures and measurements for the 2008 test, considering collection of adequate samples and proper sampling techniques were key elements for the success of the project. Three types of samples were collected during the test.

1) B100 samples were collected by the fuel supplier prior to blending. The main purpose of this type of sample was to make sure that the fuel met the required specifications, such as glycerin content, water content, and cold soak filtration.
2) Biodiesel blend samples were taken at the time of fueling the vessel, and were collected by each vessel's chief engineer or person in charge of the fueling operation. The purpose of the fuel samples collected on board the ferry was to test any changes in the blended biodiesel during the transporting of the fuel to the ferry. The first two types of samples were to be collected regularly according to the schedule described in the work plan.
3) Samples taken only if clogging problems occurred. These samples were to be used for trouble-shooting and diagnosis so as to identify the cause of the problem.

In addition, fuel temperature and filter pressure drop measurements were logged by vessels' crew members during the normal operation of the ferries. All readings, including fuel temperatures and pressures, were recorded in a log book, with copies submitted weekly by email to the WSF Port Engineer.

Note the *M/V Issaquah* did not have Racor filters, so no pressure drop measurements were available on this vessel. Racor fuel filters are coalescing-type filters designed to filter particulate matter and water.

Fuel temperatures were monitored in the deep storage tanks and at the exit of the day tank. This provided an indication of whether the fuel was reaching temperatures where oxidative degradation was likely. Generally, thermal and oxidative degradation of the fuel would not be considered likely during the limited time that the fuel is on-board the ferry, but if the fuel temperatures were high due to fuel recirculation through the engine fuel return system, some chemical changes were possible.

(iv) A trouble-shooting procedure and organization responsibility were developed in response to the following situations:

1) Filter clogging.
2) Precipitates found in fuel samples.

3) Other unusual phenomena observed after the introduction of the biodiesel blends.

The objective of this procedure was to define the most efficient pathway for the research team to identify filter clogging causes and find solutions to the problems. Figure 5 shows the flowchart of the diagnosis and technical assistance.

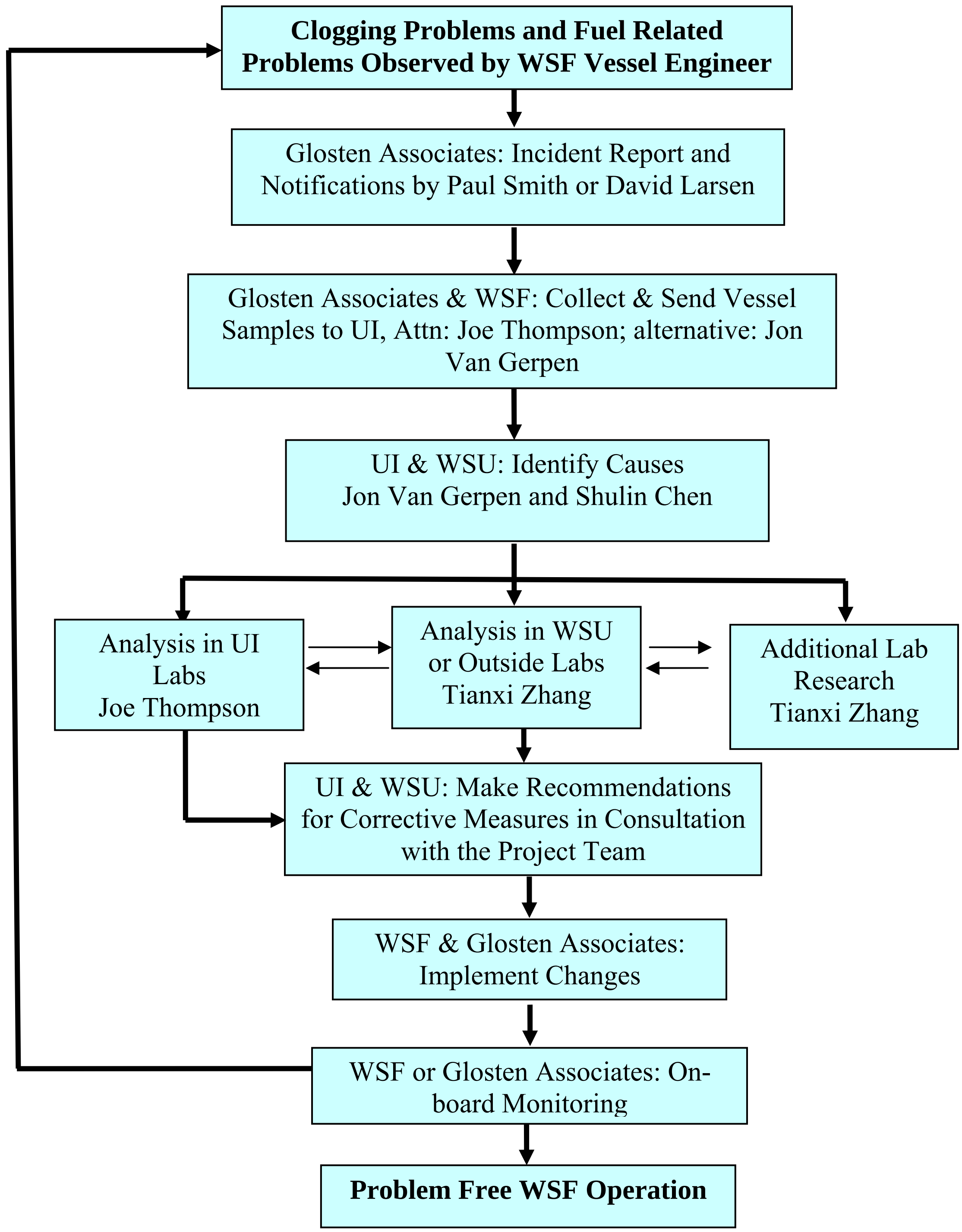

Figure 5. Flowchart for trouble-shooting with diagnosis and cause identification.

(v) Incident reports and notifications were implemented to promptly notify the research team of operational anomalies, allowing them the opportunity to witness the events firsthand, and to provide WSF Vessel Engineers with access to additional engineering resources around the clock.

In the event of an anomaly involving the fuel system, the responsible onboard Vessel Engineer or vessel Port Engineer was to assemble the basic information and forward it to The Glosten Associates by phone or e-mail.

The Glosten Associates Engineering Responder was to:

1. Provide his or her best endeavor to answer any technical questions posed as quickly as possible,
2. Determine whether a vessel visit by Glosten Associates or another member of the scientific study team is appropriate to document the conditions found or suggest corrective measures,
3. Arrange for the vessel visit (if required) through the WSF 24-hour Operations Center,
4. Commence additional notifications to the scientific study team, and
5. Maintain a running log of all incident reports, conversations, vessel visits, and corrective measure recommendations for use by the study team.

(vi) Vessel preparation, including tank cleaning procedures and vessel modifications, onboard monitoring and sampling, was implemented.

Tank cleaning procedure

A fuel storage tank cleaning procedure was developed to ensure successful introduction of biodiesel into the WSF fuel system. Biodiesel's tendency to absorb water and its solvent properties make tank surface cleanliness especially important.

6. Implementation of the 2008 Fuel Tests

6.1. Biodiesel Supply

Throughout this project, the three vessels used biodiesel blend fuels, primarily B5, B10, and B20 blends with petrodiesel. The #2 diesel used was dyed ultra low sulfur diesel (ULSD-D) from the Olympic Pipeline. The soybean-based B100 biodiesel came from Cargill, canola-based B100 came from Imperium Renewables, and high cloud point B100 came from Gen X. The *M/V Issaquah* took soybean-based blends, the *M/V Tillikum* took canola-based blends, and the *M/V Klahowya* took high cloud point blends. The highest blend ratio for all three vessels was B20. All B100 used in this project met current ASTM 6751 specifications.

Table 2. Fuel Type Information for WSF Vessels

Vessel	Fuel Type	Supplier	Blends Used
M/V Issaquah	soy	Cargill	B5, B10, B20
M/V Tillikum	canola	Imperium Renewables	B5, B10, B20
M/V Klahowya	high cloud point	Gen X	B5, B10, B20

The fuels were blended using the splash method by Rainier Petroleum Corporation, WSF's contracted fuel supplier. The truck and trailer compartments were loaded through a meter with the appropriate biodiesel blend percentages by volume.

Figure 6. Meter to dispense soy biodiesel.

Figure 7. Filter to dispense soy biodiesel.

The truck and trailer then proceeded to the load rack and 80% petroleum diesel was then bottom loaded. The loading rate of 300 gallons per minute was thought to provide sufficient agitation for proper "in-truck" blending. Splash mixing continued while the truck/trailer proceeded to the ferry and until the fuel was delivered to each vessel's fuel tank.

All fuels were delivered via truck and trailer by Rainier Petroleum. Fuel was dispensed into the ferry tanks through a four inch hose by gravity. Approximately 45 minutes was needed to unload a full truck and trailer containing approximately 9,000 gallons per load.

December 2008 was a challenging month due to regional weather conditions including cold temperatures, snow, and ice. This hampered not only biodiesel fuel delivery to the vessels, but also the fuel supplier's ability to load the biodiesel product at the distribution facility. Also, cold weather affected the high cloud point biodiesel, and an inordinate amount of time was taken to move the product into inside storage and heated tanks to keep it from gelling. The *M/V Klahowya*, the vessel burning the high cloud point fuel, had to revert to 100% ULSD-D fuel for a 2-week period until the cold weather passed.

Figure 8. Stainless steel totes used to store soy biodiesel.

Figure 9. Rail cars delivering soy based biodiesel to Rainier Petroleum.

Detailed information for the fuel quality data sheet can be found in Appendix F (Fuel Quality Data Sheets).

6.2. Vessel Preparation

Before the 2008 fuel test, WSF prepared the vessels for the biodiesel testing. This included tank cleaning and installation of monitoring devices (temperature and sampling ports).

Biodiesel Tank Cleaning Procedure

The initial condition of the fuel storage tanks and fuel day tanks on all three vessels in the test program were uncoated mild steel fuel tanks. The tanks were original steel and therefore at least 25 years old (*M/V Issaquah*) or 50 years old (*M/V Tillikum & M/V Klahowya*). The tanks were said to be "dirtier than average" by Emerald Services, the then current cleaning contractor for WSF. Sediment coating the tank walls was described as "a combination of rust blooms and blackish slime".

The cause of this contamination was believed to be a result of the following combination of effects:

- age,
- intermittent batches of poor quality petroleum diesel fuel,
- lack of surface tank coating, and
- infrequent tank cleaning, e.g., not more than once in five years.

Recommended Biodiesel Tank Cleaning Procedure

- Open, empty, and ventilate the tanks.
- Ensure all fuel suction, fill, sounding, and vent lines are completely drained back to the tank.
- Visually inspect fuel suction, fill, sounding, and vent lines (if possible) for contamination.
- Secure all valves to and from the tank and tag out.
- Have a marine chemist certifies tanks as safe for entry and establishes the level of personal protective equipment (PPE) required for safe entry.
- Have personnel take photographs of tank conditions prior to cleaning. Gross removal of scale and sediments using hand tools if necessary (tile scrapers, flat-nose shovels, etc.).
- If not too dirty, use high pressure hot-water to wash all tank surfaces at 3,000 psi using hand wand. Pump or vacuum wash water to a certified storage tank (i.e., vac truck) for eventual manifesting and disposal. Collect and remove any additional scale and sediments dislodged in the pressure washing process.
- If large quantities of sediment, scale, or slime are found in the tanks, perform a preliminary wash with Zep Industrial Purple Cleaner and Degreaser, followed by multiple hot water washes.
- Squeegee excess water from internal surfaces and remove from tank by pump or vacuum.
- Wipe all surfaces down with lint-free rags wetted with B100.
- Have personnel take photographs of tank conditions after cleaning.
- After final inspection for cleanliness and photo documentation, close tank and prepare to receive fuel.
- All personnel inside the “hot zone” should be certified HAZWOPRs (29 CFR 1910.120).

Figure 10. Vessel deep fuel tank prior to cleaning.

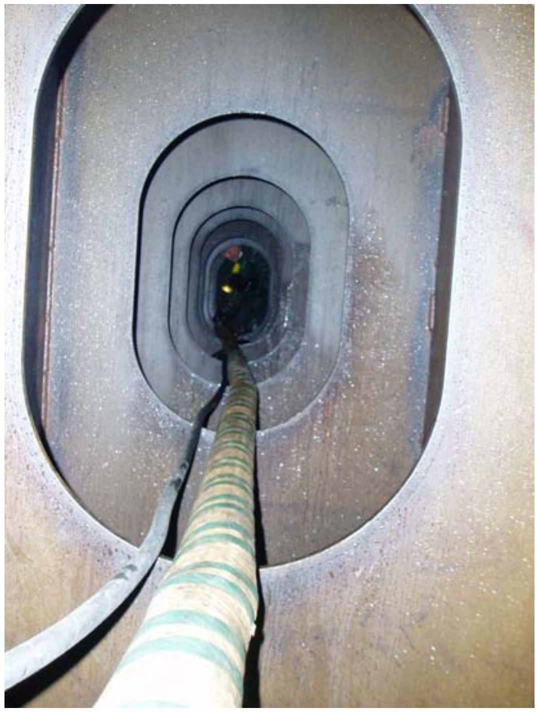

Figure 11. Vessel deep fuel tank during cleaning.

Figure 12. Vessel deep fuel tank after B100 hand wipe down.

All of the vessels were modified for temperature and sampling ports.

Basic Assumptions for the Modifications

1. Welded connections were preferred to threaded to keep leaks to a minimum.
2. Hot work requires gas freeing if done in place. Therefore, removable pieces (flanged, union, or threaded) are preferred to allow removal of a section to the shop for modification and reinstallation without having to gas free the entire fuel system.

Additional observations for the *M/V Issaquah* are listed below:

1. Existing sampling points were already available near the desired locations. The project team determined these would be adequate for the purposes of this project. See the sampling locations on the drawing in Appendix G (WSF Vessel Modifications).
2. Temperature gauges were installed at the suction manifold of the fuel purifier. It was determined that installing temperature gauges at the fuel oil storage tanks would be cost prohibitive for this project, as it would have required the entire fuel system to be gas-freed and additional vessel out of service time.
3. The temperature gauges were installed using threaded connections.

Detailed information for the modifications of the vessels can be found in Appendix G (WSF Vessel Modifications).

6.3. Enhanced Lube Oil Analysis

WSF desired to have enhanced lubricating engine oil analysis for the duration of the test period. WSF preventative maintenance system calls for periodic lube oil analysis on all operating machinery. In this way, contaminants and wear metals can be trended and maintenance actions can be derived from the findings. The ferry system contracts this work out to a third party specialist who is currently Stavely Services, located in Portland, OR. WSF engineers met with their contracted lubricant supplier in order to identify what additional parameters should be monitored during the biodiesel testing phase. The lube suppliers called on their additive package technical engineers to assist with those decisions, as well.

All three vessels were using a Chevron multi-viscosity lubricant in the crankcases. The oil had a designation of DELO 477 CFO 20w 40. Chevron's additive package in this oil was manufactured by their subsidiary, Oronite. Based on the meetings that were held, it was determined that the WSF lube oil analysis program could be augmented with four additional tests. WSF added the following additional test requirements to their analysis requirements for the three vessels burning biodiesel. They were:

1) Total Base Number (TBN),
2) Total Acid Number (TAN),
3) Oxidation and Nitration, and
4) LMOA Pentane Insoluble.

Detailed information on the lubricant lab test results can be found in Appendix H (All Vessels Main Engine Lubricant Analysis Results).

6.4. Operation of the Fuel Tests

WSF started the 2008 fuel test in March 2008, and completed the test in February 2009. The demonstration phase was terminated due to exhausted project funding. All three vessels ran on B20 fuel with only minor problems.

Vessel #1 (M/V Issaquah)

The first load of soy B5 blend was burned in the engines on March 10, 2008. The fuel was shifted to soy B10 blend on April 5, 2008. The *M/V Issaquah* ran soy based B20 between May 16, 2008, and February 2, 2009. Filter clogging was reported on July 31, 2008. This problem was solved with the application of Biobor biocide. This vessel took the final load of soy based B20 on February 2, 2009, and subsequently the pilot test on this vessel was terminated with no further problems reported.

Figure 13. *M/V Issaquah* main propulsion engine, GE 7 FDM 12 EFI.

Figure 14. *M/V Issaquah* vessel service engine, Detroit Series 60 DDEC.

Vessel #2 (M/V Tillikum)

The first canola B5 blend was loaded on April 7, 2008. The system appeared to be running well, without excessive clogging, until the *M/V Tillikum* was taken out of service for maintenance from April 28, to May 16, 2008. After May 16, the *M/V Tillikum* returned to service and continued to burn the canola B5 blend. However, an increase in sludge buildup within the fuel purifier was reported on May 23, 2008. The observed sludge buildup in the purifier remained for approximately two months without noticeable improvement. The purifier was cleaned twice a week as opposed to the usual once per week. WSU recommended the application of Biobor biocide on the *M/V Tillikum* to alleviate microbial growth in the fuel tanks, the suspected cause of the purifier sludge. The sludge problem subsided soon after the biocide application. Thereafter, the *M/V Tillikum* shifted to canola B10. The *M/V Tillikum* ran canola B20 between October 6, 2008, and February 10, 2009. This vessel took the final load of the canola-based B20 on February 10, 2009. During the testing, biobor biocide was applied irregularly, the purifier was cleaned twice a week, and the Racor filters were changed approximately every four months.

The *M/V Tillikum* took a load (9,002 gallons) of 100% ultra-low sulfur diesel (ULSD) on December 19, 2008, and then took another load (6,697 gallons) of 100% ULSD on December 25, 2008, because crystals were visible in the outdoor storage of canola fuel (B100) at the time of loading the truck. The temperature was below 20^{o}F. Use of B20 canola fuel was resumed in the subsequent loading of the fuel.

For a complete description of the results of testing these injectors, see Appendix I (WSF *M/V Tillikum* Vessel Operations).

Figure 15. *M/V Tillikum* main propulsion engine shown with fuel injectors removed (rags in place).

Vessel #3 (M/V Klahowya)

The *M/V Klahowya* was loaded with a high cloud point fuel of B5 (tallow-based biodiesel blend) on July 19, 2008. B10 was first loaded on August 17, and B20 was loaded and run between October 3, 2008 and February 3, 2009. The cloud point of this tallow-based biodiesel was 38^{o}F, as reported by Rainier Petroleum Corporation, WSF's fuel supplier. Biobor biocide at a maintenance level (1 gallon biocide in 10,000 gallon of fuel) was added to the tallow-based fuel in the *M/V Klahowya*. This vessel took the final load of the high cloud point fuel of B20 on February 3, 2009 and subsequently the pilot test in this vessel was terminated with no problems reported. During the test, filters were replaced approximately every ten days and the purifier was cleaned twice a week.

Note that the *M/V Klahowya* also took two loads of ULSD around December 19 and 26, 2008, due to the cold weather. The B20 blend was resumed in subsequent loads of fuel.

Figure 16. *M/V Klahowya / Tillikum* main propulsion engine
EMD 12-645-F7B.

Figure 17. *M/V Klahowya/Tillikum* vessels service engine
Cummins NTA 855.

Through this project, the three vessels used consumed a total of 1,395,604 gallons of blended fuels. The biodiesel component in the blended fuels was 201,600 gallons. The detailed fuel consumptions during the test period are shown in Tables 3 and 4.

Table 3. Total Blended Fuel Consumption for Test Period (2008-2009)

Sum of Total Fuel Delivered (Gallons)	Year/Month												
	2008									**2009**			**Grand Total**
Fuel Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	
B-5	86,381	57,618	19,200	37,802	94,208	53,111	9,600					9,000		366,920
B-10		48,014	9,603			62,203	96,010					9,000		224,830
B-20			46,783	67,208	46,801	64,800	56,409	154,401	116,440	105,301	136,111	9,600		803,854
Grand Total	86,381	105,632	75,586	105,010	141,009	180,114	162,019	154,401	116,440	105,301	136,111	27,600	0	**1,395,604**

Table 4. Biodiesel Component in the Blended Fuel for Test Period (2008-2009)

Sum of Total Biodiesel Delivered (Gallons)	Year/Month												
	2008									**2009**			**Grand Total**
Fuel Type	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	
B-5	4,319	2,881	960	1,890	4,710	2,656	480					450		18,346
B-10		4,801	960			6,220	9,601					900		22,483
B-20			9,357	13,442	9,360	12,960	11,282	30,880	23,288	21,060	27,222	1,920		160,771
Grand Total		7,682	11,277	15,332	14,071	21,836	21,363	30,880	23,288	21,060	27,222	3,270	0	**201,600**

The engine hours for all three vessels during the 2008 tests are as follows:

Issaquah	Tillikum	Klahowya
#1 engine – 5,980 hours	#1 engine – 5,248 hours	#1 engine – 5,075 hours
#2 engine – 5,983 hours	#2 engine – 5,249 hours	#2 engine – 5,080 hours

Detailed information for the operation of the fuel tests can be found in Appendix I (WSF *M/V Tillikum* Vessel Operations).

6.5. Fuel and Sludge Sampling

Laboratory centrifuge testing was performed in an attempt to recreate the "butterscotch mousse" that was found to be clogging the vessel fuel purifier (centrifuges used to remove water and impurities from the fuel as it was pumped from the storage tanks) during the 2004 trial with B20 (see Appendix D and Figure 18). This attempt to reproduce the mousse-like material was not successful and the only emulsions that were found were unstable and not similar to those noted in 2004. In order to keep track of the fuels going into the vessels and be able to back track if problems arose, a sampling protocol was built into the 2008 test plan. As samples came in, analytical tests performed at the UI included fuel quality testing, purifier and filter sludge analysis, and biodiesel blend level approximations.

Figure 18. Fuel purifier disk stack with "butterscotch mousse".

Fuel quality tests included viscosity, acid value, dissolved water, cold soak, and free and total glycerin tests. Cloud point and fatty acid profiles were determined for the two high cloud point fuels that were evaluated for use in the *M/V Klahowya*. These tests were performed using methodology outlined in ASTM 6751 specifications for biodiesel (see Appendix F). Sludge samples were subjected to a micro screening test for metals by ICP, ash determination, and tests for the detection of bacteria, mold, and yeast. Blend level tests were performed in Milwaukee, WI, by Paradigm Sensors.

6.5.1 Fuel quality

Routine samples of B100 were received from Sound Refining (soy based) and Rainier Petroleum (canola based) at the initial stage of the trial. Quality tests of dissolved water, viscosity, acid value, and glycerides were run on these samples to verify that the fuel met the current ASTM standards. The results of these tests are shown in Table 5.

The only parameter found to be out of specification was the dissolved water in the high cloud point sample (tallow based). Additional samples of this fuel were requested but never received. Once the fuel was found to be of consistent quality, archival sampling was continued on the vessels in case a problem arose. These samples were not sent to the UI lab. Several B5 samples from the *M/V Tillikum* were received and checked for dissolved water and viscosity and were found to be of good quality. The B100 samples designated as RP1 through RP4 in Table 5 were also subjected to the cold soak test, and all passed within 3 minutes.

Figure 19. B5 samples being drawn on WSF vessels.

Table 5. Property Measurements of B100 and B5 Samples

Sample ID	Location	Sample Date	KF Water	Viscosity	Acid Value	Glycerin Free	Glycerin Total
			ppm	mm^2/sec		% wt	% wt
SR1, SME	Refinery	3/8/2008	266.00	4.08	0.26	0.00	0.12
SR2, SME	Refinery	4/8/2008	252.59	4.08	0.28	0.01	0.12
SR3, B100	Refinery	4/19/2008	196.82	4.06	0.31	0.00	0.11
SR4, B100	Refinery	4/26/2008	214.85	4.94	0.29	0.01	0.10
SR5, B100	Refinery	4/12/2008	206.17	4.08	0.33	0.01	0.10
SR6, B100	Refinery	5/3/2008	171.03	4.07	0.34	0.00	0.10
SR7, B100	Refinery	5/10/2008	215.75	4.19	0.35	0.01	0.14
SR8, B100	Refinery	5/17/2008	258.43	4.06	0.30	0.00	0.14
SR9, B100	Refinery	5/25/2008	276.43	4.07	0.30	0.01	0.14
SR10, B100	Refinery	6/2/2008	256.58	3.80	0.30	0.00	0.14
SR11, B100	Refinery	6/11/2008	207.93	4.07	0.36	0.01	0.14
SR12, B100	Refinery	6/14/2008	162.03	4.16	0.45	0.00	0.13
SR13, B100	Refinery	6/21/2008	179.92	4.08	0.39	0.00	0.14
SR14, B100	Refinery	6/27/2008	234.49	4.07	0.43	0.00	0.13
SR 15, B100	Refinery	7/6/2008	250.50	4.06	0.46		
HC 1, B100	Distributor	7/25/2008	720.00	5.01	0.52		
RP1, B100	Distributor	4/1/2008	147.13	4.24	0.16	0.00	0.02
RP2, B100	Distributor	4/7/2008	153.65	4.07	0.17	0.00	0.03
RP3, B100	Distributor	4/21/2008	195.65	4.33	0.19	0.01	0.04
RP4, B100	Distributor	4/24/2008	87.64	4.31	0.21	0.00	0.02
T1, B5	Vessel	5/24/2008	46.36	2.31			
T2, B5	Vessel	5/27/2008	39.78	2.38			
T3, B5	Vessel	5/30/2008	40.96	2.34			
T4, B5	Vessel	6/1/2008	44.11	2.34			
T5, B5	Vessel	6/2/2008	45.71	2.36			

SR – Sound Refining; RP – Rainier Petroleum; T – *M/V Tillikum;* HC – High Cloud

In addition, UI tested the oxidative stability of the canola biodiesel sample from Imperium Renewables. The result showed the stability to be 5.86 hours. The value in the ASTM specification is a 3 hour minimum, so this fuel met the specification by a wide margin.

6.5.2. Purifier sludge sampling

During the course of the project, there were occasional incidents where ferry engineers reported that there were elevated levels of sludge found in the fuel purifiers. In an attempt to identify the cause of these incidents, sludge samples were collected by WSF Engine Crew Members and sent to the UI lab. The samples were analyzed for microbial action using Bug Alert test strips, as well as for ash and trace elements by ICP. All of the sludge samples tested positive for microbes with the exception of the last sample received from the *M/V Klahowya* in November 2008.

Table 6 shows the data from all of the samples received. When the *M/V Issaquah* exhibited abnormal purifier sludge buildup (while running B10 SME), UI requested a sludge sample from the *M/V Klahowya*, which was then running diesel, to be used as a comparison.

Figure 20. *M/V Issaquah* with abnormal sludge buildup in fuel purifier.

The metal analyses of the two samples were generally consistent, indicating the sludge was probably not associated with biodiesel use. Since both samples tested positive for microbial contamination, a recommendation was made to WSF that the fuel be treated with a biocide, Biobor JF. Use of the biocide caused the purifier sludge levels to return to normal.

Figure 21. Biobor JF.

Figure 22. Oil purifier without Biobor.

Figure 23. Oil purifier w/3 treatments of Biobor.

Sludge accumulation in the fuel purifier on the *M/V Tillikum* became a problem with canola-based B5 in May after a two week out of service period. Two of these samples were submitted as received and the other was dissolved in ethyl ether, allowed to settle, and split into solid and liquid fractions, and the ether removed before submitting to the lab.

The third set of samples was from a filter plugging incident on the *M/V Issaquah* in July with B20. One was sludge from the purifier and the other was scraped from the inside of the filter. The final sample was from a routine cleaning of the *M/V Klahowya* purifier running high cloud based B20.

Nothing definitive was concluded from this data. Ash levels ranged from 2 to 28%. This is a wide range and is likely based on how and where the samples were collected and what percent was an emulsion with fuel and water. However, the vast majority of the samples were volatile organic material.

The metals analysis showed very high levels of calcium, iron, sodium, and sulfur. Such high levels of these materials in diesel or biodiesel was unexpected, except for the iron, since the fuel was stored in steel tanks. The source of the iron was likely the tank walls themselves. The source of the other metals was speculated to be lube oil contamination. The most significant finding from the sludge sampling was the consistent presence of microbes that seemed to respond well to treatment with biocides.

Table 6. Trace Element Screen of Purifier and Filter Sludge by ICP

					After Ether Extraction		***M/V Issaquah* Incident**		
Date	3/12/2008	4/11/2008	5/27/2008	5/30/2008	5/30/2008	5/30/2008	7/30/2008	7/30/2008	11/11/2008
ppm	***M/V Issaquah***	***M/V Klahowya***	***M/V Tillikum***	***M/V Tillikum***	***Tk*-Solid**	***Tk*-Liquid**	**Purifier**	**Filter**	***M/V Klahowya***
Ash	140,000	280,000	110,000	140,000			40,000	21,000	40,000
Arsenic	<38	<38	<38	<38	<38	<38	< 38	< 38	< 38
Barium	1,100	3.3	26	24	53	7.7	11	11	14
Beryllium	<0.38	<0.38	<0.38	<0.38	<0.38	<0.38	< 0.38	< 0.38	< 0.38
Calcium	23,000	90,000	30,000	21,000	51,000	6,500	5,400	6,400	12,000
Cadmiun	13	<1.5	<1.5	<1.5	2	<1.5	< 1.5	< 1.5	< 1.5
Cobalt	12	2.9	<1.5	<1.5	<1.5	<1.5	< 1.5	< 1.5	< 1.5
Chromium	130	190	28	37	65	11	250	50	55
Copper	310	34	92	50	100	27	120	19	28
Iron	62,000	4,900	1,600	2,400	4,500	790	16,000	5,700	4,600
Potassium	390	360	89	70	<38	<38	< 38	190	210
Magnesium	850	390	1,500	1,600	1,600	250	96	40	1,600
Manganese	810	38	41	33	66	9	99	31	50
Molybdenum	25	49	160	80	120	67	88	100	24
Sodium	430	1,300	4,400	6,000	1,900	<380	1,500	< 380	660
Nickel	87	77	7	6.9	10	<3.8	24	24	6.1
Phosphorus	400	210	4,400	4,100	7,900	1,100	210	120	560
Lead	420	11	34	18	41	7.6	25	22	9.0
Sulfur	3,900	14,000	5,000	4,500	3,700	2,100	9,000	1,100	2,600
Vanadium	21	3	4.1	5.8	8	4.4	12	6.2	< 0.75
Zinc	1,400	150	230	140	320	61	110	230	120

Tk = M/V Tillikum

As a result of studying this data and comparing it with typical lube oil analysis, there was speculation that the source of the metals in the purifier sludge might be lube oil contamination. In other biodiesel tests, it had been found that free fatty acids formed by hydrolysis of the biodiesel can react with detergent additives in lube oil to produce greasy precipitates that appear similar to those noted in the purifier bowls. WSF engineers suggested that the contamination might originate from transporting biodiesel in tankers that had previously held lubricating oil but that on-board contamination was unlikely since there was no location in the fuel system where fuel and oil can mix. Checking with the fuel supplier confirmed that biodiesel was not transported in trucks that had also hauled lubricating oil.

To further investigate this idea, three samples of B5 from various sample points on the *M/V Tillikum* were distilled down to the T85 point to remove most of the volatile material and to concentrate the metals. Sample T1 was from the fuel loading manifold on the vessels auto deck, T2 might be from the barge as marked on the sample bottle, and T3 was from a point before the purifier. T3 was sent to Stavely Services Fluids Analysis Lab in Portland, Oregon. Spectrochemical analysis method ASTM D5184 was run and the data can be found in Table 7. The other two distilled samples were sent to Imperium Renewables for analysis. T1 was 85% concentrated and T2 was 87% concentrated. K, Mn, Na, and P were all present at <1ppm.

Table 7. Spectrochemical Analysis Method ASTM D5184
(results for T3, a B5 sample taken from a point before the purifier)

Metals	ppm
Aluminum	<1
Barium	<1
Calcium	4
Chromium	<1
Copper	<1
Iron	<1
Potassium	<1
Manganese	<1
Molybdenum	<1
Sodium	<1
Nickel	<1
Phosphorus	<1
Lead	<1
Silicon	7
Tin	<1
Titanium	<1
Vanadium	<1
Zinc	<1

As shown in Table 7, the metal content of the fuel was very low, with most levels below the detection threshold of 1 ppm. These data indicate metals were not found in the fuel when it moved from the deep tanks to the purifier. If metals found in the sludge samples were a result of lube oil contamination, the source was not identified. The possibility exists that the metals originated from an on-board source other than lube oil. At this point, the assumption is that when microbial contamination occurs, the microbes extract inorganic minerals from the fuel and concentrate them in their cells. When the microbes are caught in the purifier, the cells create the sludge that must be removed periodically.

In an attempt to understand the structure of the sludge, samples were submitted to the UI analytical lab for examination under an electron microscope (Figure 24). The photographs did not show individual cells but indicate that the sludge is amorphous and fibrous.

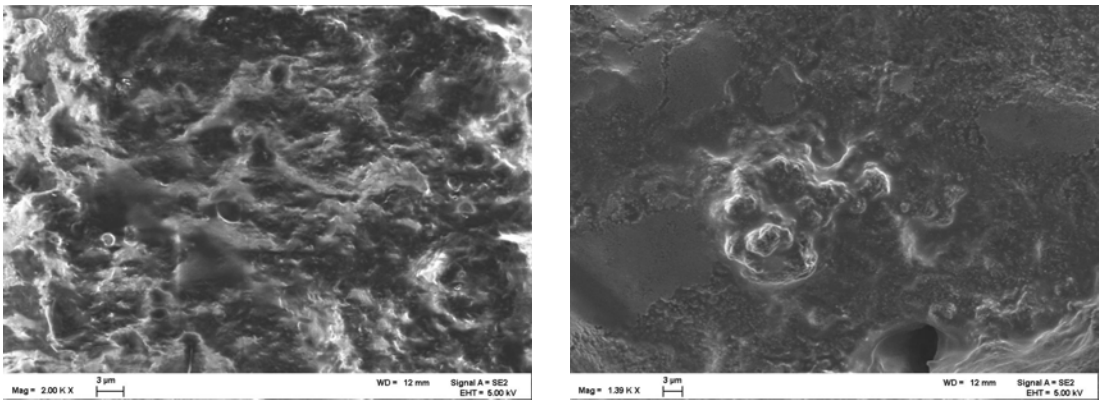

Figure 24. Sludge under an electron microscope.

6.5.3. Blend level testing

Once all three vessels were up to running on B20, it was decided to check the blend levels to see how close they were to 20% biodiesel. The first two samples were obtained from the fuel-loading manifold on auto deck as the vessels were being fueled. These samples from the *M/V Tillikum* and the *M/V Klahowya* were sent to Paradigm Sensors for analysis and came back as B44 and B32 respectively. This led to the speculation that the fuel in the trucks was not mixed well and so the sampling was flawed. This theory was confirmed with a series of viscosity measurements using lab generated blends and previous B5 samples. A second set of samples was taken after the purifiers in all three vessels. This fuel would have had ample time to mix in the main fuel storage tanks. These were then analyzed by Paradigm Sensors and the results are shown in Table 8. Table 8 shows that the blend levels were close to B20 specifications

Table 8. Blend Levels after the Purifier in WSF Vessels

Sample	% Biodiesel
M/V Issaquah	18.97
M/V Tillikum	17.20
M/V Klahowya	16.50

In conclusion, the main problems reported by the chief engineers on the three vessels were increased purifier cleaning frequency and some fuel filter plugging on all vessels. From the fuel analysis at the UI lab, the B100 samples were shown to be of consistently good quality and ruled out as the possible problem. The metal analysis indicated that the samples collected from the plugged filters were similar to the samples collected from purifier bowls. All of the sludge samples showed high levels of iron, calcium, sodium, phosphorus, and sulfur. It was concluded that what plugged the filters was probably the same material recovered from the purifiers. The positive test for microbial growth in the purifier and filter samples indicated that microbial growth has been a consistent problem with the ferries. Anecdotal evidence received from ferry engineers during visits suggests that the vessels using only diesel fuel also have this problem occasionally. This should be expected in a moist environment like that found on board vessels because anytime diesel fuel is stored in the presence of water, microbial growth will occur. It was recommended that all fuel used for the biodiesel test project be treated with a biocide. At a cost of 0.5-0.6 cents/gallon, this would amount to only 0.1 to 0.3% of the cost of the fuel. It was noted that when a biocide was used on any of the vessels, the problems with increased purifier cleaning and filter plugging diminished.

Detailed information for the sampling record during WSF fuel tests can be found in Appendix J (WSF Biodiesel Test Samples).

6.6. Trouble-Shooting Research

The overall purpose of this research was to analyze both fuel and sludge samples taken during the pilot test. The samples were analyzed so as to provide the information necessary to diagnose causes of excess sludge formation and subsequently make recommendations to solve the clogging problem. Specifically, the trouble-shooting research included (1) fuel quality analysis using ASTM methods and (2) sludge characterization using several chemical and biological methods. Based on these analyses, the cause was identified and recommendations made for trouble-free fuel testing.

6.6.1. Fuel quality analysis

UI analyzed the fuel samples of B100 and biodiesel fuel blends collected by WSF. All samples tested met the ASTM specification. Thus, biodiesel quality appears not to be a problem. Detailed information can be found in Section 6.5 (Fuel and Sludge Sampling).

6.6.2. Sludge characterization and microbial identification

Several methods, such as pyrolysis-GC/MS (Py-GC/MS), thermogravimetic analysis (TGA), ion chromatography (IC), and microbial identification were used to characterize the sludge samples obtained during the pilot test.

6.6.2.1. Organic materials in the sludge

Organic materials in the sludge were characterized using pyrolysis-GC/MS (Py-GC/MS) and thermogravimetic analysis (TGA). GC/MS suggested that the highest peak in the GC chromatograph was 8-octadecenoic acid methyl ester ($C_{19}H_{36}O_2$), which should come from canola biodiesel, indicating the sludge contained an 8-octadecenoic acid methyl ester fraction.

TGA demonstrated that the sludge consisted of two major fractions with different properties. One fraction may contain heavy components. However, this was a small fraction, approximately 6% of the sludge. A large fraction of the sludge included light compounds with low molecular weight including water.

6.6.2.2. Water content in the sludge samples

Water content in the wet sludge was determined using the Karl Fischer (K-F) titration method. Before the titration, the wet sludge samples were dispersed into one of two organic solvents either chloroform or pyridine (which is miscible in water). These two solvents were chosen because the sludge appeared to be dispersed well in the solvents. Water content in the wet sludge was approximately 11.7 ± 1.1% (w/w) determined in chloroform. Water in the sludge could dissolve in pyridine. Water content in the wet sludge was approximately 17.2 ± 2.2% (w/w) determined from the pyridine. Therefore, water was a fraction of the wet sludge in the range of 11-17 % (w/w).

6.6.2.3. Microbial role in the sludge formation

The objectives of this effort were to investigate the presence of active microbes in the sludge, isolation of microbes from the sludge, and biocide influence on microbial growth.

6.6.2.3.1. Observation of the sludge samples under a microscope

A sludge sample from the purifier of the *M/V Tillikum* was collected on July 15, 2008. In order to look at the micro structure and microbial presence, this sludge sample was observed under a microscope. A typical image of the sludge is shown in Figure 25. It appears that some separated micro domains were present in this sample. Sizes of the micro domains typically ranged from 30-150 µm. In addition, a great number of active bacteria were found in the micro domains, as shown in Figure 26. Some had a round shape and others had a rod shape. It appears that there were several bacteria species present in the samples. No yeast or fungi were observed in this sludge sample.

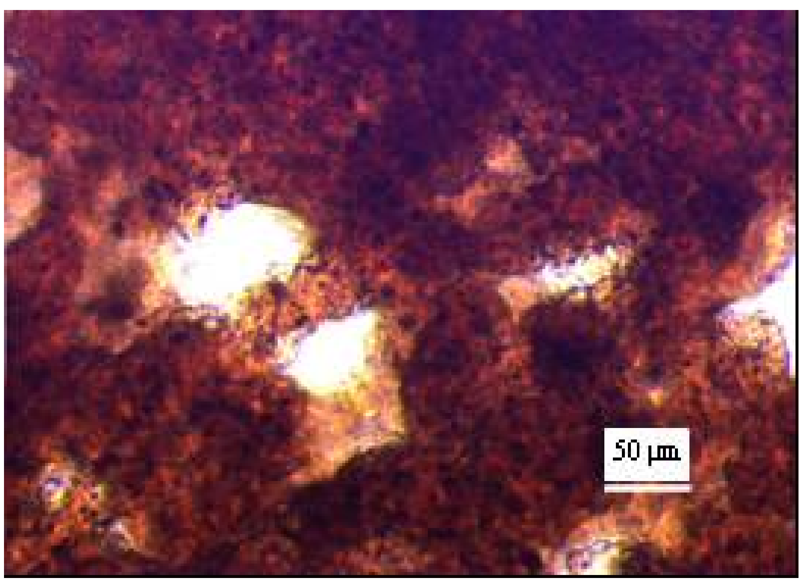

Figure 25. Sludge from the purifier of the *M/V Tillikum* under light microscopy.
(separated micro domains appear white)

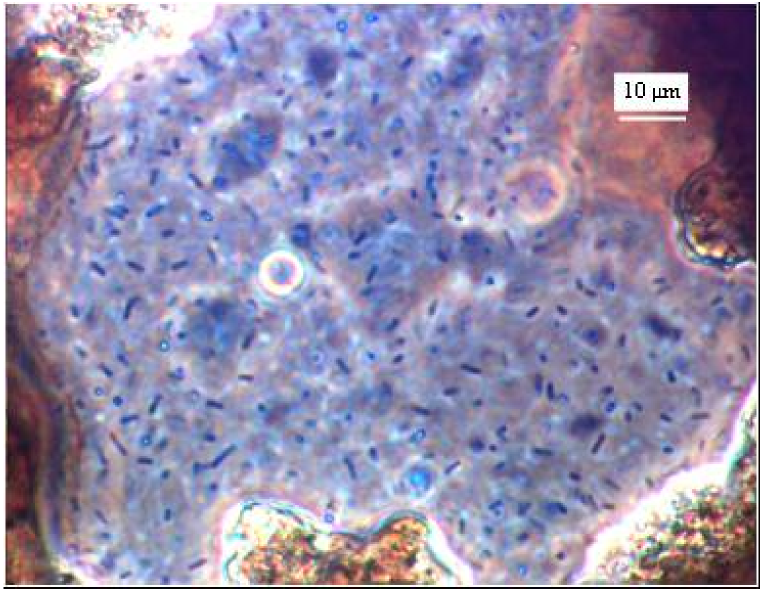

Figure 26. Bacteria in the sludge from the purifier of the *M/V Tillikum* under light microscopy. (active bacteria appear blue and are rod and round in shape)

Another sludge sample from the purifier of the *M/V Issaquah* collected on July 30, 2008, and observed under a microscope. Again, many active bacteria were found in the sludge.

The microbial tests on the sludge were conducted with test kits. The results were shown to be microbial positive, which further confirms that active microbes were present in the sludge samples. However, the B5 fuel samples tested negative, so it did not appear that the microbes were coming from the fuel supplier.

6.6.2.3.2. Isolation of microbes from the sludge of the M/V Tillikum purifier

To identify microbes from the sludge of the *M/V Tillikum* purifier collected on July 15, 2008, four types of solid media for microbial growth were used. Plate count agar (PCA) was designed for detection of bacteria, potato dextran agar (PDA) was used for cultivation of fungi possibly present in the sludge, malt extract agar (MEA) was used mainly for cultivation of potential yeasts grown in the sludge, and anaerobic agar (AA) was designated for observation of microorganisms that could grow under anaerobic conditions. PCA contained a pancreatic digest of casein, yeast extract, dextrose, and agar; PDA contained potato starch, dextrose, and agar; MEA contained maltose, dextrose, glycerol, peptone, and agar; and AA contained agar with casein Peptone, sodium chloride, dextrose, sodium thioglycollate, soy Peptone, L-cystine, agar, sodium sulfoxyl formaldehyde, and methylene blue.

Large numbers of bacterial colonies grew on each type of medium. However, no fungi or yeast colonies were found on the plates. Thus, bacteria were the dominant microorganisms in the sludge. Table 9 shows the results of quantitative analysis by cell count. The number of bacteria in the sludge from three types of culture attained a level of 10^8 per gram of wet sludge. The bacteria also grew well in both anaerobic and aerobic conditions without a significant difference.

Table 9. Bactrial Numbers in Sludge on Various Cultural Media

Medium Type	Culture Condition	Microbial Number per Gram of Wet Sludge (mean value in triplicate samples)
Anaerobic agar	anaerobic	5.28×10^7
PCA	aerobic	2.43×10^8
2 layers of PCA	anaerobic	1.44×10^8
2 layers of PCA	aerobic	1.51×10^8

6.6.2.3.3. Isolation of viscous material from the aqueous solution from the M/V Tillikum purifier

High viscosity in the aqueous solution was observed in presence of excess sludge in the *M/V Tillikum* purifier. It was speculated that polysaccharides were produced by the microbes and that provided high viscosity in the solution. Isolation of the viscous material from the water was attempted. The isolated materials were analyzed to determine the monosaccharide composition using ion chromatography (IC). Galactose and glucose were found in this sample. The detection of two sugars supported the presence of polysaccharides, which are typically produced by bacteria.

In summary, lab research results showed that the sludge samples contained metal, microbes, water, and oil fractions (such as 8-octadecenoic acid methyl ester) from canola biodiesel and light compounds, possibly from diesel. Active bacteria were present in the sludge samples from the purifiers. The bacteria can grow in the presence of the B5 fuel and water. Bacterial contamination is one of major causes of the excess sludge formation.

6.6.2.4. Microbial identification

It is noted that the bacteria in the sludge could contain several types of strains. Isolation of the bacteria was conducted using plate streaking and gradient dilution methods. Five types of bacterial strains which could be dominant in the sludge sample were obtained after the isolation. Identification of these five strains was done using molecular biological methods, including DNA extraction, 16s rRNA amplification, 16s rRNA gene cloning, and DNA sequencing and analysis.

Three bacteria of the five strains were identified as *Staphylococcus epidermidis*, *Klebsiella oxytoca,* and a potentially novel strain of *Klebsilla*. The three identified bacteria are opportunistic disease-causing microorganisms. It appeared that none of these three microbes had been reported in contaminated diesel fuel or soil environments. Identification of the other two strains will require further research.

Detailed information on the sludge characterization and microbial identification can be found in Appendix K (Sludge Characterization and Microbial Identification).

7. Conclusions and Recommendations

The biodiesel fuel demonstration showed that biodiesel-blended fuels can be used in marine applications. Problems such as filter clogging may arise unless preventative measures are taken. The conclusions and recommendations for biodiesel applications resulting from study are listed below.

1) Biodiesel fuels that meet the current ASTM 6751 specifications can be used at the level of B20 for marine application.
2) Fuel quality was not affected by feedstocks from which the biodiesel was derived, either soy, canola, high cloud point (i.e., restaurant oil or animal fat).
3) Fuel tanks on board marine vessels will benefit from cleaning prior to introducing biodiesel blends.
4) Microbial growth in the ferry system was identified as the major cause for sludge formation resulting in filter clogging/fuel purifier sludge problems observed in the WSF biodiesel test vessels.
5) Vessel operations using biodiesel may require increased maintenance of fuel filtration systems.
6) The percentage of biodiesel (B5–B20) used in the fuel did not impact vessel operations or maintenance of machinery.
7) Bacteria obtained from sludge can be grown in the presence of biodiesel blends and water in anaerobic and aerobic conditions.
8) The bacteria in the sludge could contain several strains. Five bacterial strains which could be dominant in the sludge sample were obtained.
9) Three bacteria of the five dominant strains were identified as *Staphylococcus epidermidis*, *Klebsiella oxytoca,* and a potentially novel strain of *Klebsilla*.
10) Viscous polysaccharides dissolved in the water of the purifier could be produced by the bacteria.
11) The sludge samples obtained from this test contained metal, microbes, water, and oil fractions (such as 8-octadecenoic acid methyl ester) from canola biodiesel and light compounds that were possibly from diesel.
12) The excessive sludge problem was solved by application of biocide in the fuel.
13) Biocide application is strongly recommended when biodiesel blends are used in marine conditions. The biocides can inhibit the growth of microbes over long periods of time in very low concentrations. The presence of the biocide does not interfere with engine operation. Biocide products are typically pesticides. Detailed information about the mechanism of sludge formation is still unclear. Further research requires understanding the relationship between bacteria and other components in the sludge.
14) Further investigation is needed to identify the remaining bacterial strains and microbial population in the sludge.
15) More information is needed about biocide function in the microbial growth, such as interaction between biocide and specific microbial species. This information would be useful to screen better biocides in terms of higher performance and lower cost.
16) It is recommended to conduct a pilot demonstration test using biodiesel fuel for a longer term, such as 3-5 years. Several other factors that were not included in this test should be considered. These include engine performance, engine longevity, fuel efficiency, exhaust gas emissions, fuel system injectors, and conditions of hoses and seals.

8. Appendices

A. Literature Review Report

B. WSF 2004 Biodiesel Pilot Test Report

C. WSF Fuel System Environmental Parameters and Compatibility Evaluation

D. Laboratory Research Report

E. Work Plan for 2008 Biodiesel Test

F. Fuel Quality Data Sheets

G. WSF Vessel Modifications

H. All Vessels Main Engine Lubricant Analysis Results

I. WSF *M/V Tillikum* Vessel Operations

J. WSF Biodiesel Test Samples

K. Sludge Characterization and Microbial Identification

Contract No. 200700001

Washington State Ferry Biodiesel Project

Literature Review Report for September 05, 2007

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Summary

Biodiesel is a mixture of methyl esters of long chain fatty acids, produced typically by alkali-catalyzed transesterification from vegetable oils. For biodiesel quality, the most critical fuel quality parameter is the total glycerin content. Another set of important quality parameters are the levels of sulfur, phosphorus, sodium, potassium, calcium and magnesium. Biodiesel products in the U.S. must meet ASTM D6751 quality standard specification. In this specification, values of physical properties and impurities for commercial products are set out, including viscosity, water and sediment, cetane number, cloud point, acid number, glycerin, phosphorus, etc. One of the important parameters, oxidation stability, current ASTM D6751 addresses this although European standard EN 14212 require a higher level of oxygen stability.

Other factors affecting biodiesel quality are environmental conditions, which are mainly the cold flow properties. Biodiesel has a relatively higher cloud point and pour point, which limits its application as B100 in low temperature conditions. In addition, biodiesel has a strong tendency to absorb moisture due to its chemical properties. This can be a significant concern for biodiesel applications in high humidity marine environment.

When running engines on biodiesel blends, fuel filter clogging is a recurring theme. Biodiesel users describe symptoms similar to those on the WSF vessels were reported, such as white milky fluid in fuel bowls, black deposits between filter pleats and a general increase in filter servicing and change-out. None were reported to have occurred at the extreme levels reported by WSF, and centrifugal separators were not mentioned in other applications.

1. Introduction

This document serves as a literature review report for the Washington State Ferry Biodiesel Project (Contract No. 200700001). The purpose of this project is to develop and test new fuel specifications for biodiesel and biodiesel blended fuels, as well as biodiesel product handling guidelines for use in a marine environment. To test the fuel specification and product handling guidelines, a work plan was developed and then implemented on board Washington State Ferries (WSF) vessels for a period of one year. In order to develop a successful project work plan for the fuel test, the project team reviewed specific scientific studies and technical documents related to the topic. This literature review report includes a brief introduction and overviews of the following topics listed in separate sections: (1) fuel quality specification and test methods, (2) characterization of biodiesel fuel and alternate test methods, (3) fuel usage in both marine and land-based applications, (4) the effects of environmental conditions on fuel quality, (5) fuel storage, stability, transport, and blending, (6) the effects of biodiesel production on its quality, and (7) other related biodiesel research.

2. Fuel Quality Specification and Test Methods

2.1 Biodiesel standard specifications

Biodiesel is typically produced from vegetable oils. The biodiesel products must meet some standards established in various countries and regions around world, including the United States (ASTM D6751), Europe (EN 14214) etc. Table 1 lists the standard specifications of biodiesel in the United States (ASTM 6751-07a), Europe (14214-225), Japanese Industrial Standard, and the U.S. Department of Defense (B19-B21 specification).

Table 1 Biodiesel standard specifications

		EUROPE	**USA**	**Japan**	**Dept of Defense**
	Specification units	EN 14214:2005	ASTM 6751-07a	Japanese Industrial Std.	B19-B21 Spec
				(voluntary spec)	
Fatty Acid Methyl Ester Content	% (V/V)	100	100	100	19.0-20.0
Density 15°C	g/cm³	0.86-0.90		0.86-0.90	
Viscosity 40°C	mm²/s	3.5-5.0	1.9-6.0	3.5-5.0	1.3 - 4.1
Distillation	90% @ °C		360		343
Flashpoint	°C	120 min	130 min	120min	38min
CFPP (Plug Point)	°C	Country spec		*report	
Cloud point	°C		* report		
Sulphur	mg/kg	10 max	15 max	10 max	0.015 / 0.05 / 0.5
Carbon Residue(B100 dist.residue)	%mass		0.05 max		
Carbon residue (B10 dist.residue)	%mass	0.3 max		0.3 max	.35 max
Sulphated ash	%mass	0.02 max	0.02 max	0.02 max	
Ash content	%mass				0.01
Water (dissolved)	mg/kg	500 max	500 max	500 max	
Water and Sediment					0.05
Total contamination	mg/kg	24 max		24 max	

Copper corrosion@50 C, for 3h	3h/50°C	No.1	No.3	No.1	No.3
Oxidation stability	hrs;110°C	6 hours min	3	record	
Cetane number		51 min	47 min	51 min	40
Acid value	mgKOH /g	0.5 max	0.5 max	0.5 max	0.200
Methanol	%mass	0.20 max	0.20 max	0.20 max	
Ester content	%mass	96.5 min		96.5	
Monoglyceride	%mass	0.8 max		0.8 max	
Diglyceride	%mass	0.2 max		0.2 max	
Triglyceride	%mass	0.2 max		0.2 max	
Free glycerol	%mass	0.02 max	0.02 max	0.02 max	
Total glycerol	%mass	0.25 max	0.24 max	0.25 max	
Iodine value	g I/100g	120 max		120	
Linolenic acid ME	%mass	12 max		12 max	
C(x:4) & greater unsaturated esters	%mass	1 max			
Phosphorus	mg/kg	10 max	10 max	10 max	
Alkalinity	mg/kg				
Gp I metals (Na, K)	mg/kg	5 max	5 max	5 max	
GpII metals (Ca, Mg)	mg/kg	5 max	5 max	5 max	
Storage Stability, total insolubles,	mg/100ml				4 max
Thermal Stability, 90 mins	pad % reflectance, min				70 min
Aromaticity	%mass				35
Lubricity / wear	µm at 60°C				

*agreement between producer and customer

2.2. Biodiesel industry steps up quality enforcement efforts in US

The American society of Testing and Materials (ASTM) has continued to refine quality guidelines for Biodiesel since original specification guideline created in December 2001. Since 2004, there have been three revisions:

D6751 06 (June 2006)
D6751 06b (Jan 2007)
D6751 07a (Mar 2007) Current

Several specifications have been added or made more stringent reflecting a movement toward the more mature knowledge base of the European specs as well as developing knowledge in the US industry. These changes include:

- Metals added: Gp I (Na, K) and Gp II (Ca, Mg). No metals testing previously.
- Water: New test to insure extremely low water content
- Methanol: More accurate method to insure minimal methanol content; hence a higher flashpoint.
- Oxidation Stability: Newly added to assure stability of product/shelf life

The National Biodiesel Board (NBB) is the national not-for-profit trade association representing the biodiesel industry as the coordinating body for advocacy, research and development in the United States.

The NBB is undertaking a project to work with states to catalog information regarding their authority to regulate fuels; their status in adopting ASTM D6751 as the fuel specification for biodiesel; enforcement procedures; and to assess their capacity to analyze samples.

The National Biodiesel Accreditation Program is a cooperative and voluntary program for the accreditation of producers and marketers of biodiesel fuel called BQ-9000. The program, which began in 2004, is a unique combination of the ASTM standard for biodiesel, ASTM D 6751, and a quality systems program that includes storage, sampling, testing, blending, shipping, distribution, and fuel management practices.

BQ-9000 helps companies improve their fuel testing and greatly reduce any chance of producing or distributing inadequate fuel. To receive accreditation, companies must pass a rigorous review and inspection of their quality control processes by an independent auditor. This ensures that quality control is fully implemented.

In the interim period since the original Washington State Ferries biofuel test of 2004-05, there have been continued improvements in manufacturing and handling processes and the monitoring of these systems as indicated in Section 2.1 above.

Also, in 2004, the feedstocks available to the U.S. Biodiesel market were largely limited to soy and animal fat, and available only out of the Midwest. There are now other feedstocks in use such as Canola, and producers located in the Pacific Northwest broadening source options for local consumers. Additionally, there are now local testing laboratories established specifically for Biodiesel analysis.

2.3. References

Quality Specifications

EN: http://www.ebb-eu.org

ASTM: nbb.org

JIS: http://www.dieselet.com/standards/jp/fuel_biodiesel

DOD: http://www.desc.dla.mil/DCM/Files/DESC%20-%20Biodiesel%20Specs%20_%20Northern%20Usage.pt#287,7,slide7

Industry Quality Enforcement Efforts

www.astm.org

www.biodiesel.org

www.bq9000.org

3. Characterization of Biodiesel Fuel and Alternate Test Methods

3.1. Biodiesel physical properties and their characterizations

Viscosity is one of the most important biodiesel fuel physical properties. Ranges of acceptable kinetic viscosity at 40 ^{o}C are 1.9 – 6.0 mm^2/s as required by ASTM D6751 specification. The kinetic viscosity of fatty compounds (such as those found in biodiesel fuel) is significantly influenced by compound structure, including chain length, the position, number, and nature of double bonds, and the nature of oxygenated moieties [1]. Biodiesel viscosity is also dependent on temperature. It is reported that biodiesel viscosity can be calculated in the range from 273 K to 303 K with one equation [2].

Another important physical property of biodiesel fuel is solubility. Intersolubility of the biodiesel components in ethanol, methanol and diesel fuel was characterized [3]. For instance, rapeseed oil ethyl and methyl esters are soluble in ethanol and diesel fuel without limitation. However, an increase in moisture levels in ethanol results in decreasing intersolubility of biodiesel components, which suggests avoiding increased moisture content during fuel storage.

3.2. Biodiesel chemical properties and their characterizations

Oxidation stability is one of the most important chemical properties of biodiesel. Because of its chemical structure, biodiesel is sensitive to oxidative degradation, which results in the formation of corrosive acids and deposits. The main factors affecting biodiesel stability are natural antioxidant content, polyunsaturated fatty ester content, and the level of mono- and diglycerides. However, there was no oxidation stability requirement in the US biodiesel standard specification ASTM D6751, although European standard EN 14212 does contain one. The lack of agreement on which oxidation stability test method specified was the primary reason for the absence of an oxidation stability requirement in the ASTM D6751 specification [4]. Modified ASTM Test Method D2274 and European Rancimat test were considered for an oxidation stability test in U.S. Now the current ASTM D6751-07a specification has the oxidation stability requirement, setting three hours using Rancimat method instead of the six hours standard used in Europe.

A modified version of ASTM Test Method D2274 may distinguish between stable and unstable B100 samples in some cases. Consideration of Test Method D2274 for biodiesel oxidation stability means selection of three parameters: test temperature between 95 ^{o}C and 110 ^{o}C; test time (e.g. 16 hours); and the ratio of aged B100 to non-polar solvent (iso-octane) for measuring solubility effects.

The most appropriate testing conditions are at 95^{o}C for 16 hours. The test temperature ranging from 95^{o}C to 110 ^{o}C has almost no effect on the measured total insoluble but a very marked effect on the amount of iso-octane insoluble [5]. These results suggest the significant ability of B100 to solubilize polymers formed during oxidation. This test gives no induction period, presuming that all antioxidant capacity in the B100 is consumed during the test. Thus this test is a measure of the tendency of B100 to form polymers and insolubles.

Unlike D2274, Rancimat in Europe tests using an induction period, which is the amount of time from the beginning of the air purge until a sharp increase in the measurement is observed. This method does not give any measure of polymer forming tendency. The induction period prior to the onset of rapid oxidation is measured. The European specification requires Rancimat Induction Period at 110 ^{o}C to be more than six (6) hours. One significant difference for use of the Rancimat test is the biodiesel origin. Most of the biodiesel produced in Europe is rapeseed-based, but most of the biodiesel produced in the U.S. is made from soybeans or yellow grease. The rapeseed biodiesel tends to have significantly longer Rancimat induction periods than either the soy or yellow grease biodiesel because of different polyunsaturated content. Many U.S. biodiesel users reported have induction periods of 1-4 hours less than the 6 hours minimum requirement of the European specification [4, 5].

Antioxidants as additives in the biodiesel can protect against oxidation. Biodiesel blends with ultra low sulfur diesel (ULSD) may tend to be more susceptible to oxidation as natural inhibitors are removed along with the sulfur compounds.

3.3. Alternate test methods for biodiesel fuel

3.3.1. Test Methods Using Modern Techniques

High concentrations of monoglycerides and diglycerides in biodiesel not only affect the fuel quality, but also indicate incomplete reactions during production. The levels of these compounds were determined using advanced methods such as infrared spectrometry (FT-IR), Raman spectra, NMR, gel permeation chromatography (GPC), HLPC, and gas chromatography-mass spectrometry (GC-MS), etc. [6, 7]. It is reported that this approach using the advanced modern techniques is superior to typical methods in terms of the short time required and greater information gathered on the molecular structure level.

Trace elements in biodiesel are often required but must be monitored. For example, the phosphorus concentration is limited to below 10 mg/kg according to the ASTM D6751 standard. It is suggested to monitor the sodium, potassium, calcium, and magnesium levels in biodiesel due to their ability to form undesirable compounds in the engines. In this study, the determination of calcium, chlorine, potassium, magnesium, sodium, and phosphorus in biodiesel was investigated by using advanced inductively coupled plasma (ICP) technique [8]. The results demonstrated that this method can detect these elements to very low levels (e.g., µg/kg concentrations for sodium and potassium).

3.3.2. Field Test Methods Using Test Kits

Some field test methods are available for testing fuel quality. In Washington State Department of Agriculture (WSDA)'s motor fuel quality program, several tests from several companies are considered. These tests include Titra-Lube TAN test for total acid number values [9], pHLip test for B100 quality [10], Fleet Biodiesel tests [11], and InfraCal Filtometer [12], etc. The WSF biodiesel project did not use field test kits because the sample methods are operationally difficult to employ and provide limited scientific value.

3.4. References

1. Kinetic viscosity of biodiesel fuel components and related compounds. Influence of compound structure and comparison to petrodiesel fuel components. Gerhard Knothe, Kevin R. Steidley, ***Fuel*. 2005,** 84:1059-1065.
2. Measurement of the temperature dependent viscosity of biodiesel fuels. S. Kerschbaum, and G. Rinke, ***Fuel*. 2004**, 83:287-291.
3. Solubility of multi-component biodiesel fuel systems. Violeta Makareviciene, Egle Sendzikiene, Prutenis Janulis, ***Bioresource Technology*. 2005,** 96:611-616.
4. An evaluation and comparison test of methods to measure oxidation stability of neat biodiesel: September 2003 – May 2005. S. R. Westbrook, ***National Renewable Energy Laboratory*. 2005**.
5. Stability of biodiesel and biodiesel blends: interim report. R.L. McCormick, T.L. Alleman, J.A. Waynick, S.R. Westbrook, S. Porter, ***National Renewable Energy Laboratory*. 2006**.
6. Analysis of monoglycerides and diglycerides in biodiesel fuel by GC-MS and FTIR. Ngee Sing Chong, Subathra Ramamoorthy, Christopher Ashford, Avrill Buerstetta, Kiran Donthula, and Beng Guat Ooi, ***The 233rd ACS National Meeting***, Chicago, IL, USA, March 25-29, **2007**.
7. Application of Raman spectroscopy to monitor and quantify ethyl esters in soybean oil transesterification. Grace F. Chesti, Julio L. de Macedo, Valdeilson S. Braga, Antonio T.C.P. de Souza, Vincente C.I. Parente, Esdras S. Figueredo, Ines S. Resck, Jose A. Dias, Silva C. L. Dias. ***Journal of the American Oil Chemists' Society*. 2006,** 83:597-601.
8. Analysis of biodiesel by argon-oxygen mixed-gas inductively coupled plasma optical emission spectrometry. M. Edlund, H. Visser, P. Heitland, ***Journal of Analytical Atomic Spectrometry*. 2002,** 17:232-235.

9. Titra-Lube TAN test Kit: Quantitative test kit to determine total acid number values between 0 and 2 in petroleum products and lubricating oils. ***Dexsil***, **2006**.
10. Field test kit for B100 quality: pHLip test. ***Cytoculture International Inc.***, **2007**.
11. Biodiesel Field Test Kits. ***Fleet Biodiesel***, **2007**.
12. Measuring the biofuel blend ratios in gasoline and diesel fuel, Wikls Enterprise Inc., 2006.

4. Fuel Usage in Marine and Land-Based Applications

4.1 Marine applications including fuel quality challenges and solutions

Several pilot tests have been performed under marine conditions. The results of these tests, in particular for filter clogging problems, are presented below.

Case 1: BioMer project "biodiesel demonstration and assessment for tour boats" in Canada in 2004.

This project was conducted in the Old Port of Montreal and Lachine Canal National Historic Site in Canada by the BioMer team from mid-May to mid-October 2004. The BioMer project had three objectives: (1) to test the use of neat biodiesel (B100) and various blends as alternative fuels for tour boats of various sizes; (2) to asses the economic viability and benefits of the use of biodiesel to the industry's routine operations; and (3) to measure the various environmental impacts (e.g. polluting emissions, biodiesel biodegradability and toxicity) resulting from use of biodiesel.

The biodiesel was supplied by Rothsay's Sainte-Catherine plant in Quebec. The 12 boats used, in various boat capacity sizes from 12 to 750 passengers, consumed a total of 116,685 liters of cooking-oil-based biodiesel, primarily B100, and in certain instances in B5, B10, and B20 blends with petrodiesel (low-sulfur-500 ppm) throughout this project. Biodiesel CP was not an issue in this project because the project was conducted during the summer. It is to be noted that all on-board fuels tanks were NOT cleaned before fueling with biodiesel.

In spite of higher cloud point for the biodiesel used (origin of recycled cooking oil), there were no serious filter-plugging issues. Although filter plugging problems did occur in some trials (leading to more frequent filter change), customer service was not impacted. The conclusions and recommendations made by the BioMer project team included:

- Begin using B20 before going on to Bl00 to ensure a smooth conversion to biodiesel and give users time to become familiar with the biofuel (use, maintenance, precautions, etc.).
- Verify with engine manufacturers whether guarantees remain valid after converting to biodiesel Note that weaker blends (from B5 to B20) are more widely accepted by engine manufacturers than Bl00.
- Use B20 since it offers excellent performance and maximizes engine efficiency without affecting fuel consumption.
- Tune diesel engines, e.g., by adjusting injection timing and duration, to optimize efficiency and performance before any use of Bl00. Note that after such tuning, the engine must only run on B100 and must be retuned to run again on petrodiesel
- Thoroughly clean on board and dockside fuel tanks to reduce the release of buildup due to the fuel's solvent action before starting to use biodiesel blends stronger than 5%.
- Schedule three or four additional filter changes during the cleansing period if prior cleaning is not feasible.
- Check the filtering process from tank to boat engine to make sure that large filters with the same mesh size are used at all stages, if possible, in order to counter the effects of buildup release.
- Benefit from a lower concentration like B20, which yields a very significant reduction in emissions with no pronounced increase in NOx emissions, even though B100 leads to a more impressive reduction.
- Use more competitively priced B20 rather than higher-cost B100.
- Respond to any biodiesel spill with the same measures as for a petrodiesel spill since biodiesel, even though generally less environmentally harmful than petrodiesel, is still a fuel and can have an environmental impact should a major spill in water occur.

Fuel Filter Clogging Issues

Fuel filter clogging was reported six weeks after converting to biodiesel for the BioMer project, which required the changing of fuel filters frequently. In order to understand the clogging origins, the project team has conducted a series of tests and analyses to answer three key questions:

(1) Does biodiesel adversely affect fuel filters? (Yes.)
(2) Was standard biodiesel delivered during this period? (Yes. It met ASTM D6751.)
(3) Was the clogging merely due to the solvent and cleansing effects of biodiesel? (No. mold was present, too.)

The most plausible reason for filter clogging may be the release of tank buildup as a result of biodiesel solvent properties. In order to prove that, two samples (one for B100 and another for B10) were taken directly from the clogged filters. QETE conducted tests (e.g., acid number, water and sediment, water content, mold and bacteria present, and gum test) to identify components of the sludge. The results of the B100 sample showed that filter clogging was caused by a large amount of sediment, primarily composed of gums and varnishes. The B100 tests did not detect water, mold or bacteria in the sample. However, analysis of the B10 sample indicated that water and traces of mold and bacteria were present in this sample. The source of water was not clear. The water may provide favorable conditions for bacteria and mold to grow in the fuel.

It was concluded that biodiesel use gave rise to only minor incidents due to fuel filter problems. Fuel filters clogged quickly and frequent filter changes were required for a certain period of time. The clogging that occurred six weeks after the biodiesel was introduced was caused by the solvent properties of biodiesel.

Case 2: Biodiesel tests in ferry fleet in San Francisco Bay in 2002 and 2005.

A ferry operated by Blue & Gold Fleet on San Francisco Bay, California, was tested for diesel engine emissions from August 2001 to April 2002, using three types of fuels: neat diesel, B20, and B100 soybean biodiesel. The test vessel Oski was equipped with two identical Detroit Diesel engines at port and starboard. For each fuel type, the test engine RPM ranged from approximately 600 RPM to approximately 1,700 RPM. The results were not conclusive due to test methodology questions.

A project of “Biodiesel on the Bay: Feasibility of Operating San Francisco Bay Ferries on Biodiesel and Installing a Marine Biodiesel Fueling Station” was conducted by Bluewater

Network collaborating with Red and White Fleet and Orange Diesel of Berkeley to operate the Harbor Queen on B20 in San Francisco in June 2005 (Bluewater Network, 2006). In the week-long trial period, the project demonstrated that no technical or supply hurdles exist that would prevent a ferry operator to run on biodiesel; cost and distribution remain the primary issues.

Case 3: National Oceanic and Atmospheric Administration (NOAA) Green Ship Initiative on the Great Lakes

The NOAA Great Lakes Environmental Research Laboratory (GLERL)'Green Ship' initiative has run a six year trial using B100 in three vessels. We have contacted Dennis Donahue of GLERL to request any documentation on this trial. There is no technical report currently available.

Case 4: "A Feasibility Study for the Use of Bio-diesel Type Fuels" by the U.S. Navy

The US Navy prohibits the use of biodiesel fuel for tactical applications and does not support tactical fleet demonstrations until all technical related concerns are resolved through this study. Concerns associated with biodiesel application in a marine environment include in order of priority, fuel stability, formation of emulsified gel layers, and long-term engine durability. The technical concerns are listed below:

- Significantly more susceptible to storage instability (oxidation) than petroleum-based fuel;
- Biodiesel instability is accelerated by high temperature conditions;
- Poor cold weather properties;
- Biodiesel is highly hydroscopic in nature. In the presence of water, a heavy milky emulsion could be formed, which causes hydrolysis of the ester, subsequently forming acids. These acids will lead to increased corrosion and increased maintenance needs in fuel systems containing steel, zinc, and aluminum. In addition, biodiesel, due to its affinity for water, is an excellent medium for the promotion of microbial growth;
- Biodiesel may interact adversely with certain elastomers and plastics;
- Biodiesel may have a "solvency" effect in cleaning existing fuel system deposits; and
- Intermittent use of biodiesel may cause an increase in required filter replacements.
- The use of additives to control stability, microbes and cold flow has not been fully understood during application of biodiesel fuels.

- Biodiesel fuel is an excellent medium for microbial growth which is more prevalent in biodiesel fuels than in petroleum-based fuel. Water needs to be controlled since microorganisms usually grow at the fuel-water interface. However, water control is a problem in marine applications as fuel tanks are vented to the atmosphere.

Case 5: Biodiesel Marine Marketing Opportunities: Successes and Challenges in the Chesapeake

Another early trial program on biodiesel use in recreational vessels also showed very encouraging results [10]. Boaters have shown interest in using biodiesel in their diesel powered vessels because of the benefits it has brought to the boating experience. Many boaters indicated that safety, lack of smoke, and the dramatic change in exhaust odor as reasons to use biodiesel or biodiesel blends. In addition, the use of biodiesel did not require any engine modifications. No difficulties and/or concerns regarding biodiesel quality were reported. The trail was conducted mainly in warm weather.

4.2 Land-based application including fuel quality, challenges and solutions

Several road tests have been performed in land-based applications. The results of these tests, in particular for filter clogging problems, are summarized below.

Case 1: "100,000-mile evaluation of transit buses operated on biodiesel blends (B20)" in 2006, Boulder, Colorado, USA

The objective of this study was to compare transit buses (nine 40-ft. vehicles), five buses operating on with B20, and four buses operating as a control group on petroleum diesel, as to engine performance, fuel economy, maintenance, and emissions. All buses ran about 100,000 miles over two years.

There were only occasional fuel filter plugging events for the B20-fueled buses. Two buses reported engine misfiring and stalling caused by plugging fuel filters. A brown "grease-like" material was found in the filter pleats. In order to understand the cause of this plugging problem, five samples of the fuel were taken from the fuel tank and tested for several parameters, such as percentage of biodiesel, water content, microbial contamination, etc. The results indicated that none of the samples exhibited excessively high levels of biodiesel (15.0 % - 20.3 %). The water content in the samples was 72 ppm to 97 ppm, which were higher levels than typical diesel fuel, but not excessively high. In addition, the microbial growth test did not indicate microbial contamination. Tests were also conducted on the gelatinous residue on the filter. GC-MS analysis detected plant sterols present in the residue sample, suggesting that high levels of plant sterols may have caused the filter plugging in this trial. However, due to the fact that only one sample was taken for such an analysis it cannot draw a conclusion as to the plugging problem. Therefore the exact cause could not be conclusively determined although the plugging problem was likely caused by out-of-spec biodiesel due to the sterols.

In the 100,000-mile evaluation of the buses operated on B20 and petrodiesel, there was no significant difference between the average fuel economies of the two groups. Engine and fuel system related maintenance costs were nearly the same.

Case 2: "Long range on road test with twenty percent rapeseed biodiesel" in 1999, Moscow, Idaho, USA.

Rapeseed Biodiesel (B20) was tested in an on-the-road pickup truck operated for 100,000 miles. It was reported that rust was formed in the biodiesel tank and was transferred to the fuel filter during the first 19,800 miles. The filters were replaced approximately every 3,000 miles due to filter plugging problems. The solution to the filter plugging was that the mild steel tank and combining chamber were replaced with a stainless steel tank, and the diesel fuel supplier was changed. After that, the filter plugging problem was solved.

4.3 Biodiesel and the blend tests in engines

Tests in engines using biodiesel and the blends are summarized below.

Case 1: "Study of using JP-8 aviation fuel and biodiesel in CI engines" in 2003

In this study, the stationary Petter engine (model AV1-LAB with single cylinder, indirect injection) was employed to test emission and consumption measurements. The engine was fueled with two different fuels containing biodiesel at various ratios. The fuels were JP-8 aviation fuel and blends of the JP-8 containing 13, 30 and 50% biodiesel from sunflower oil and olive oil. It was reported that the two types of biodiesel tested performed in a similar way, and the biodiesel addition in the JP-8 fuel improved the emissions of particulate matter (PM).

Case 2: "The engine tests of biodiesel from used frying oil" in 2004.

The objective of this study was to evaluate engine performance and emissions using pure biodiesel from frying oil in comparison with no. 2 diesel fuel in Turkey. The tests were in a Fiat Doblo 1.9 DS, four-cylinder, four-stroke, 46 kW diesel engine. It was concluded that the biodiesel was a more environmentally friendly fuel than no. 2 diesel, with a CO emission reduction of 8.59%, HC reduction of 30.66%, and particulate matter reduction of 63.6%. In addition, the biodiesel consumption was 2.43% less than that of no. 2 diesel.

Case 3: "Biodiesel development and characterization for use as fuel in compression ignition engines" in 2001.

A typical engine used in the agricultural sector of India, with a single cylinder, direct injection, water-cooled, portable diesel 4 kW rating, with an alternator coupled to it, was investigated in this study. The engine was provided with a centrifugal governor at the rated speed of 1,500 rpm. This test was aimed at optimizing the concentrations of biodiesel from linseed oil to be used for long term engine operation. Several blends ranged from 0 (neat diesel) to B100 (neat biodiesel), were tested, including B5, B10, B15, B20, B25, B30, B40, B50, and B75. These blends were then subjected to performance and emission tests on the engine. Based on these tests, it was concluded that biodiesel fuel can be used in existing conventional diesel engines without any major modifications required in the system, as proved by long term endurance tests. The results indicated B20 gave the best performance among all the blends tested, improving the thermal efficiency of the engine by 2.5 %, and reducing the exhaust emissions and the brake specific energy consumption.

4.4. References

1. BioMer project "biodiesel demonstration and assessment for tour boats" Canada.
2. Biodiesel on the Bay: Feasibility of Operating San Francisco Bay Ferries on Biodiesel and Installing a Marine Biodiesel Fueling Station. BlueWater Network. 2002, 2006.
3. National Oceanic and Atmospheric Administration (NOAA) Green Ship Initiative in the Great Lakes.
4. "A Feasibility Study for the Use of Bio-diesel Type Fuels" by U.S. Coast Guard, March 9, 2007.
5. 100,000-mile evaluation of transit buses operated on biodiesel blends (B20). Kenneth Proc, Robb Barnitt, R. Robert Hayes, Matthew Ratcliff, and Robert L. McCormick, National

Renewable Energy Laboratory, U.S Department of Energy, Presented at the ***Power train and Fluid Systems Conference and Exhibition***, October 2006, Toronto, Canada.

6. Long range on road test with twenty percent rapeseed biodiesel. C.L. Peterson, J.C. Thompson, J.S. Taberski, D.L. Reece, G. Fleischman, ***Applied Engineering in Agriculture***. 1999. 15: 91-101.
7. Study of using JP-8 aviation fuel and biodiesel in CI engines. P. Arkoudeas, S. Kalligeros, F. Zannikos, G. Anastopoulos, D. Karonis, D. Korres, E. Lois, ***Energy Conversion and Management***. 2003. 44: 1013-1025.
8. The engine tests of biodiesel from used frying oil. Yahya Ulusoy, Yucel Tekin, Merve Cetinkaya, Filiz Karaosmanoglu, ***Energy Sources***. 2004. 26: 927-932.
9. Biodiesel development and characterization for use as fuel in compression ignition engines. A. K. Agarwal, L.M. Das, ***Journal of Engineering for Gas Turbines and Power***. 2001. 123: 440-447.
10. Biodiesel Marine Marketing Opportunities: Successes and Challenges in the Chesapeake Bay. J.A. Weber, S. Howell, S. Hammond. 1998. Accessed on Aug. 15, 2007 at *http://www.marciv.com/papers/biodiesel_marine_marketing1998.htm.*

5. Effects of Environmental Conditions on Fuel Quality

5.1. Biodiesel cold flow issues

Cold flow properties are important in biodiesel utilization. Due to the nature of its origin, biodiesel starts to crystallize (become “cloudy”) or gel (or “solidify”) at higher temperatures than petrol-diesel. When biodiesel becomes cloudy at low temperatures, the crystals formed would likely clog fuel filters. When temperatures are even lower, biodiesel starts to show jelly-like behavior and cannot be pumped. Scientifically, three parameters are used to evaluate biodiesel’s cold flow properties: cloud point, pour point, and cold filter plugging point.

Cloud point (CP) is defined as the temperature at which crystals of organic matter in the biodiesel are visualized when measured by lowering its temperature according to the procedures described by ASTM D2500.

Pour point (PP) is the temperature at which biodiesel turns to a jelly-like semi-solid. The actual test of PP involves cooling the fuel sample and checking the temperature every 3 degrees C.

When a temperature is found where the fluid does not move when the container is turned on its side, then 3 degrees is added to this temperature to get the pour point (the lowest temperature at which the fuel can be poured). For fuels (like some biodiesel fuels) that gel quickly, the pour point can actually come out to be equal to or higher than the cloud point.

Cold filter plugging point (CFPP) is the temperature at which the crystals formed after reaching CP have accumulated enough on the fuel filter so that the flow through the filter has been significantly restricted. CFPP is affected by many variables and conditions, for example, it will vary, for the same fuel, depending on how fast the temperature drops. Although CFPP is a practical parameter, it is not easily measured in laboratories. CFPP has been shown to be well correlated with CP. Since CP and PP are relatively easy to measure, they are commonly used to characterize the cold flow operability of biodiesel fuels.

Cold flow properties of biodiesel are determined by many factors, including the types of feedstock, which determines the chemical profiles the feedstock contains, the impurities in the biodiesel, addition of cold flow property enhancers, etc. Specifically, biodiesel cloud point is highly related to the fatty acid composition of biodiesel. High percentages of saturated fatty acids of long- and linear- chains are responsible for high cloud points. In using biodiesel under cold weather conditions, a general guideline for storing B100 biodiesel is that the storage temperatures should be at least 5°F to 10°F higher than the cloud point of the biodiesel (Biodiesel Handling and Use Guideline. U.S. DOE, 2006). The practice of blending biodiesel and petro-diesel varies and different methodologies are developed especially under cold weather conditions (e.g., Copeland et al., *US Patent Application,* 2006). A study on cold weather blending (Cold Flow Blending Consortium, 2005) revealed that circulating diesel or biodiesel fuels through a pump does not match up with real world rack blending systems and the practice may have provided additional shearing and mixing that helped to eliminate crystallization. Successful B2 blends were prepared when biodiesel was 10°F above its **CP**, however, no further tests were reported on blends of biodiesel levels higher than B2.

Extensive research has been conducted on cold flow properties of biodiesel from various feedstocks. Some of the key findings in published literature are briefly discussed below.

Dunn (2005) has summarized the cold flow properties of methyl and ethyl esters of biodiesel derived from several feedstocks from various resources. The properties of CP, PP, and CFPP of these biodiesels vary quite widely and obvious differences in CP and PP between biodiesel and petro-diesel exist (note that the CP and PP for regular #2 petro-diesel are -16°C and -27°C, respectively).

Table 2. Cold flow properties of biodiesel derived from different feedstocks (Dunn, 2005).

	Oil or fat	Alkyl group	CP (°C)	PP (°C)	CFPP (°C)
1	Babassu	Methyl	4		
2	Canola	Methyl	1	-9	
3	Canola	Ethyl	-1	-6	
4	Coconut	Ethyl	5	-3	
5	Cottonseed	Methyl	-4		
6	Linseed	Methyl	0	-9	
7	Linseed	Ethyl	-2	-6	
8	Mustard seed	Ethyl	1	-15	
9	Olive	Methyl	-2	-3	-6
10	Palm	Methyl	13	16	
11	Palm	Ethyl	8	6	
12	Peanut	Methyl	5		
13	Rapeseed	Methyl	-2	-9	-8
14	Rapeseed	Ethyl	-2	-15	
15	Safflower	Methyl	-6		
16	Safflower	Ethyl	-6	-6	
17	Soybean	Methyl	0	-2	-2
18	Soybean	Ethyl	1	-4	
19	Sunflower seed	Methyl	2	-3	-2
20	Sunflower seed	Ethyl	-1	-5	
21	HO Sunflower seed	Methyl	-12		
22	Tallow	Methyl	17	15	9
23	Tallow	Ethyl	15	12	8
24	Used hydrogenated Soybean	Ethyl	7	6	
25	Waste cooking	Methyl	-1		
26	Waste grease	Ethyl	9	-3	0
27	Waste olive	Methyl	-2	-6	-9

Table 3. Cold flow properties of biodiesel/petro-diesel blends (Dunn, 2005).

	Oil or Fat	Alkyl group	Diesel grade	Blend ratio	CP (°C)	PP (°C)	CFPP (°C)
1	(Petro-diesel)	-	D-1	B0	-31	-46	-42
2	Soybean	Methyl	D-1	B10	-22	-42	
3	Soybean	Methyl	D-1	B20	-17	-30	-27
4	Soybean	Methyl	D-1	B30	-14	-25	-20
5	Soybean/tallow	Methyl	D-1	B20	-21	-29	-21
6	Soybean/tallow	Methyl	D-1	B30	-13	-24	-18
7	(Petro-diesel)	-	D-2	B0	-16	-27	-18
8	Coconut	Ethyl	D-2	B20	-7	-15	
9	Rapeseed	Ethyl	D-2	B20	-13	-15	
10	Soybean	Methyl	D-2	B20	-14	-21	-14
11	Soybean	Methyl	D-2	B30	-10	-17	-12
12	HO sunflower seed	Methyl	D-2	B30		-12	
13	Tallow	Methyl	D-2	B20	-5	-9	-8
14	Tallow	Ethyl	D-2	B20	-3	-12	-10
15	Soybean/tallow	Methyl	D-2	B20	-12	-20	-13
16	Soybean/tallow	Methyl	D-2	B30	-10	-12	-11
17	Used hydrogenated soybean	Ethyl	D-2	B20	-9	-9	
18	Waste grease	Ethyl	D-2	B20	-12	-21	-12

Fuel additives are used to improve the cold flow properties of petro-diesel. Similar products are claimed effective for use in biodiesels to reduce the pour point temperatures. In general, these additives act by distorting the wax crystal shape and size to inhibit crystal growth and thereby reducing PP temperatures. The additives usually contain copolymers of ethylene and vinyl acetate or other olefin-ester copolymers. A study was conducted at the University of Idaho to evaluate the performance of different biodiesel additives on reducing PP and CP of soy biodiesel and its blends with #2 diesel (Shrestha et al., 2007). It was found that the reductions in CP were about 0°C to 1.3 ºC and a maximum reduction in cloud point of 1.8°C was observed with one additive on B20. Most of the differences between the additives were not statistically significant. In reducing the PP of the B5 blend, all of the fuel additives tested were equally effective into reducing B5 PP to -36°C or lower (note that #2 diesel has a CP of -17°C and PP of -22°C). For B20, three of the four fuel additives reduced the PP to -36°C or lower. It is to be mentioned, however, that the additives had almost no significant effects on the PP for B100 according to statistical analysis. It is concluded that the fuel additives were more effective in petro-diesel fuel than in the soy biodiesel. The observed reduction in PP at the B5 and B20 may primarily be due to the PP depression of the petro-diesel. Even though the fuel additives were recommended for use in biodiesel, none of them has shown effectiveness in reducing CP and PP for B100.

The above findings are in agreement with the conclusions drawn by Dunn et al. in 1996 on other types of cold flow improvers for petro-diesel fuels (Table 3), although other researchers have indicated that the additives were more effective in their studies (e.g., Çetinkaya et al., 2005).

Table 4. Cold flow properties of biodiesel and biodiesel/petro-diesel blends treated with cold flow improver additives (Dunn et al., 1996).

	Biodiesel	**Diesel**	**Blend ratio**	**Additive**	**Loading** (ppm)	**CP** (°C)	**PP** (°C)
1	SME	-	B100	DFI-100	1000	-2	-6
2	SME	-	B100	DFI-200	1000	-1	-8
3	SME	-	B100	Hitec 672	1000	-2	-6
4	SME	-	B100	OS110050	1000	-1	-7
5	SME	-	B100	Paramins	1000	0	-5
6	SME	-	B100	Winterflow	1000	0	-5
7	SME	D-1	B30	DFI-l00	1000	-14	-49
8	SME	D-1	B30	DFI-200	1000	-21	-45
9	SME	D-1	B30	Hitech 672	1000	-13	-44
10	SME	D-1	B30	SO110050	1000	-17	-46
11	SME	D-1	B30	Paramins	1000	-14	-29
12	SME	D-1	B30	Winterflow	1000	-19	-39
13	SME	D-2	B20	DFI-l00	1000	-14	-26
14	SME	D-2	B20	OFI-200	1000	-14	-32
15	SME	D-2	B20	Hitech672	1000	-14	-27
16	SME	D-2	B20	OS110050	1000	-15	-18
17	SME	D-2	8B20	Paramins	1000	-14	-27
18	SME	D-2	B20	Winterflow	1000	-13	-39

Selvidge (2006) has patented a method for improving cold weather performance of biodiesel fuels by inhibiting filter deposits due to water content at low temperature. He claimed that biodiesel fuels can include chemical additives such as glycol ethers to prevent or inhibit low temperature filter deposits when used in low temperature conditions. Selvidge stated in the patent that water rich phase will precipitate, freeze, and form a problematic solid phase in the diesel fuel-biodiesel mixture. The circumstance could be true; however, it is unlikely under typical low temperature conditions.

Esters of branched-chain alcohols have the tendency to reduce biodiesel crystallization temperature. Isopropyl and 2- butyl esters of soybean oil crystallized at 7-l1 and 12-14°C lower, respectively, than the corresponding methyl esters. The benefit of the branched-chain esters in lowering crystallization temperatures increased when the esters were blended with diesel fuel (Lee et al., 1995). This effect can be clearly seen by comparing the esters made of C3 and C4 alcohols, and with methyl and ethyl esters (table 5).

Table 5. Cold flow properties of selected mono-alkyl esters (Dunn, 2005).

	Oil or Fat	Alkyl group	CP (°C)	PP (°C)	CFPP (°C)
1	Canola	Isopropyl (C3)	7	-12	
2	Canola	n-Butyl (C4)	-6	-16	
3	Linseed	Isopropyl (C3)	3	-12	
4	Linseed	n-Butyl (C4)	-10	-13	
5	Soybean	Isopropyl (C3)	-9	-12	
6	Soybean	n-Butyl (C4)	-3	-7	
7	Soybean	2-Butyl (C4)	-12	-15	
8	Tallow	n-Propyl (C3)	12	9	7
9	Tallow	Isopropyl (C3)	8	0	7
10	Tallow	n-Butyl (C4)	9	6	3
11	Tallow	Isobutyl (C4)	8	3	8
12	Tallow	2-Butyl (C4)	9	0	4

Winterization has been shown to be an effective way to decrease CFPP values. When methyl esters of waste cooking oil were winterized at 1, 0, -1, and -2°C, the saturate FFA esters were decreased by 1.5-6% and the CFPPs were reduced by 2-4°C (Gomez et al., 2002). These results are in agreement with the research on methyl esters of soybean oil by Lee et al. (1996).

To have better cold temperature behaviors, the use of biodiesel prepared from animal fats needs to be carefully formulated. A research on methyl esters of vegetable oils and animal fats has shown that mixtures with CFPP values of -5°C and lower may contain up to 25% of pork lard methyl esters. Only 5% of biodiesel from animal fats can be used in winter time in cold climate conditions such as in Europe (Kazancev et al., 2006).

Biodiesel cold flow properties can also be altered by chemically modifying the molecular structures of biodiesel constituents. Yori et al. (2006) reported that the cloud point decreases by 4~6.5°C were achieved on a soybean oil based biodiesel, which has an initial cloud point of 5.2°C, through an isomerization (or branching) under medium-level of temperatures (125-200°C) and a solid acid catalyst (Yori et al., 2006). However, the application of this technique to bulk biodiesel processing is questionable due to its obviously related cost issues.

5.2. Engine and winter road test performances of biodiesel

Studies on engine performance using biodiesel as an alternative diesel fuel have been widely conducted (e.g., Marshall et al., 1995; Peterson and Reece, 1996; Peterson et al., 1996; Haas et al., 2001; Arnal et al., 2002; Arnal et al., 2003; Canakci and Van Gerpen, 2003; Ramadhas et al., 2005; Lin and Lin, 2006). General conclusions that are agreed on by most researchers include more efficient combustion, less torque and power output, much lowered emissions, and contradictorily higher NOx emissions. For example, Çetinkaya et al. has conducted a project to investigate the engine and road performance of a vehicle fueled with biodiesel originated from used cooking oil (Çetinkaya et al., 2005). One of the tests was on a vehicle with a four-stroke, four-cylinder, 75 kW Renault Mégane Diesel engine in winter conditions. The tests included 7500 km road tests in urban and long distance traffic. The results showed that carbonization of the injectors was observed with biodiesel usage as a result of winter conditions and insufficient combustion in the initial test; the injectors were observed to be cleaner. This statement seems contradictory. In the second stage test, no carbonization was observed on the surface of the cylinders and piston heads. Despite other minor concerns, such as lower torque and power output, biodiesel originated from used cooking oil was recommended as a diesel fuel alternative for winter conditions. Due to the consideration that engine test and performance are not the focus of this review, as an example of such tests, the studies conducted at the University of Idaho are summarized below.

Multiple engine and road tests have been conducted at the University of Idaho (UI) (Lowe et al., 1998; Peterson and Thompson, 1998; Peterson et al., 1999; Chase et al., 2000). The UI worked with four diesel-powered pickups in the biodiesel tests. Engines were not modified, but modifications have been made to the pickups for testing convenience. Total of four vehicles were used: a 1992 Dodge pickup on B20, a Ford pickup on 20% raw rapeseed oil and 80% D2, a 1994 Dodge pickup on B100 REE, and a 1995 Dodge Truck on B100. The goal was to operate each vehicle about 25,000 miles per year, and to reach 100,000 miles in about four years.

All vehicles were tested on a chassis dynamometer every 10,000 to 15,000 miles to obtain information on horsepower to the wheels, torque, fuel consumption, fuel temperature, inlet air temperature, coolant temperature, exhaust temperature, engine blow by, engine rpm, and turbo boost pressure. Oil samples were taken at each oil change, which was every 3,000 to 4,000 miles, and analyzed for wear metals and physical tests for antifreeze, fuel dilution, water and viscosity. An infrared analysis of the oil checks for soot, sulfur, nitration, and oxidation. The tank heating system performed well during the cold winter months keeping the biodiesel at 50°F.

As of January 1995, the on-road vehicle tests were progressing very well. No major mechanical difficulties had occurred. The two 1992 on-road vehicles, one fueled with B20 and one 20% raw rapeseed oil have reached 55,400 miles and 46,500 miles respectively. Reduced fuel filter life had been a problem in the B20 RME blend fueled vehicle. Continuous improvements to the onboard mixing system have been made in order to obtain a more accurate mixture.

At the 16,000 mile dynamometer test, the 1994 pickup fueled with the B100 had a 7.8% reduction in horsepower compared to D2; the 1992 pickup, at the 50,000 mile dynamometer test, had horsepower changes of -1.5 and-2.9% when fueled with B20 blend and B100 RME, respectively. The injectors and compression were tested at each dynamometer inspection. Injector valve opening pressures (VOP) varied as much as 100 psi. No differences were noted between the cylinder compression tests.

In summer 1994, personnel from UI drove the 1994 Dodge 2500 pickup 8,742 miles at an average of 18.7 mpg, fueled only with B100 ethyl ester of rapeseed oil in a coast-to-coast trip. All of the B100 REE fuel was carried onboard.

The UI, along with the Montana Department of Environmental Quality, Wyoming Department of Commerce, Dodge Truck, and J.R. Simplot Company explored the market for biodiesel in the tourism industry and other environmentally sensitive applications. The Dodge Truck Division of Chrysler Corporation supplied a 1995 diesel pickup, fueled with B100 REE and operated by the National Park Service in Yellowstone National Park through 1996. This “Biodiesel in the Park” program has been a great success and now the biodiesel uses are applied to all tour buses in the Yellowstone National Park (U.S. Department of the Interior National Park Service, 2005).

5.3. Effect of marine conditions on biodiesel quality

Two common circumstances have to be considered when biodiesel is considered for use in marine conditions. The first is the relatively low but constant sea water temperature year around. The sea water temperatures in the Puget Sound region are in the range of 46-56°F (7.8-13.3°C) at Seattle ports (National Oceanographic Data Center, 2007). This temperature range is above most of the biodiesel CPs except biodiesel from palm oil, tallow, and hydrogenated waste cooking oil (see Table 1), and is not a negative factor that dramatically affects biodiesel uses in marine vessels, especially when used as petro- and bio-diesel blends. Therefore, careful selection of the proper types of biodiesel and/or use of proper level of blends would take care of this concern.

The second circumstance is the high moisture environment where the biodiesel is to be used. Due to its tendency to absorb moisture, fuel properties can be adversely affected. This can lead to fuel delivery problems, which are a common challenge in the use of biodiesel on marine vessels.

Biodiesel has the characteristics of absorbing more moisture than fossil diesel. High water solubility in biodiesel may cause problems in handling, transportation and storage. Generally, high moisture content in biodiesel is often caused by improper treatment after water washing or by the absorption of moisture from the atmosphere during storage. Condensation and precipitation may occur if the moisture content in biodiesel is beyond its saturation point as its storage temperature decreases. Microbial growth, storage container corrosion, and fuel contamination are examples of the consequences of high fuel moisture content.

Experiments were conducted at the University of Idaho to explore moisture absorption of biodiesel of different origins (He et al., 2007). Results have shown that the moisture absorbency at given temperatures has no significant differences regardless the origins of the vegetable oils or alcohols used. As a clear contrast, biodiesel absorbed 1,000 to 1,700 ppm (or 0.1%wt to 0.17%wt) moisture from 4 to 35°C, which was 15~25 times higher than that of petro-diesel in the same temperature range. The level of moisture content in biodiesel had a strong linear relationship with its temperature. Moisture absorption into biodiesel is a very fast process. The moisture content in biodiesel will reach equilibrium levels under constant relative humidity within 24 hours. The moisture absorption rate in biodiesel was much faster than in petro-diesel. As temperature increased, biodiesel had a 22.2 ppm/°C moisture absorbing rate which is more than 9 times higher than that of petro-diesel. This may lead to the phenomenon that high moisture was absorbed by stored biodiesel at high temperature and water would precipitate out due to the low solubility once the temperatures drops.

Results also showed that in biodiesel and petro-diesel blends, both the temperature and the level of blending affected the moisture absorbance linearly. The combination effects of individual parameters and their interactions affected the moisture content at varying levels. It was observed that the moisture contents of petro- and bio-diesel blends were not a simple addition of the two moisture contents of biodiesel and petro-diesel. Blending did create a mixture that tended to decrease absorbing moisture into the blends, which may lead to water precipitation to the bottom of storage containers.

A text of Marine Biodiesel In Recreational Boats was written by von Wedel, where general information about biodiesel, such as its production, environmental advantages, low impact on marine environment, engine performance, etc. were described (von Wedel, 1999). No specific technical information on biodiesel uses in marine environment or test trial data was provided. However, a survey conducted by his project group revealed that most boaters were happy with the use of biodiesel in their boats on the San Francisco Bay (Survey of 100 Recreational Boaters Using Biodiesel 1994-1997. CytoCulture, 1997). Eighty seven of the 100 surveys responded with “no problem”. Among the boaters who experienced problems, four (4) had “fuel filter clogging” problem and six (6) had “fuel tank sediment” problem. “To avoid condensation of the moist sea air inside a cold fuel tank” is one of the suggestions the author recommended for preventing the problem from happening.

The effects of environmental conditions on biodiesel quality are mainly the cold flow properties. Compared to petro-diesel, biodiesel has relatively higher cloud point and pour pint which limits its application as a pure fuel (i.e., B100) in low temperature conditions. Proper procedures should be taken in biodiesel fuel transportation, storage, blending, and utilization to avoid fuel filter clogging problems. Although some existing fuel improving additives can lower biodiesel PP, they generally do not work well for improving biodiesel CP. Considering that the temperatures of sea water are 46-56°F year around in Seattle ports, blended fuels such as B20 may be more appropriate than B100 for use in marine applications including the WSF fleet.

Biodiesel has a comparatively strong affinity for moisture as compared with petro-diesel. Due to the high humidity conditions on marine vessels, there is significant risk of moisture being absorbed into the fuel which can adversely effect fuel properties and lead to a host of onboard problems, including filter clogging. If possible, measures should be taken to minimize this risk. In spite of the challenges many biodiesel applications in marine environment have been successful and proven that the environmental issues can be resolved and/or prevented if proper biodiesel handling procedures are established and followed.

5.4. References

1. A 1994 REE Biodiesel Fueled, Cummins 5.9L Powered, Dodge Pickup. C.L. Peterson and J. Thompson. 1998. ***Final Report of Contract No DE-f651-95R020589***. University of Idaho, Moscow, ID.
2. A 322,000 kilometer (200,000 mile) over the road test with HySee Biodiesel in a Heavy Duty Truck. Chase, C.L., C.L. Peterson, G.A. Lowe, P. Mann, J.A. Smith, and N. Kado. 2000. ***SAE Technical Paper 2000-10-2467***. Warrendale, PA 15096-0001.
3. Biodiesel cold weather blending study. Cold Flow Blending Consortium, **2005**.
4. Biodiesel Handling and Use Guideline. US DOE. 2ed. Edition. 2006.
5. Blending biodiesel with diesel fuel in cold locations. Ken Copeland, Rita Hardy, Jeff Johnson, Charles Selvidge, Kirk Walztoni, ***United States Patent Application Publication.*** ***2006, #***20060037237.

6. Cold flow properties of fuel mixtures containing biodiesel derived from animal fatty waste. Kiril Kazancev, Violeta Makareviciene, Valdas Paulauskas, Prutenis Janulis, ***European Journal of Lipid Science Technology.*** **2006**, 108(9):753-758.

7. Cold weather properties and performance of biodiesel. R. O, Dunn. In ***The biodiesel Handbook***, ed. G. Knothe, J. Krahl, J. Van Gerpen, pp83-121. AOCS Press. 2005.

8. Comparison of engine performance and Emissions for petroleum diesel fuel, yellow grease biodiesel and soybean oil biodiesel. A. Canakci, and J. H. Van Gerpen. ***Trans. ASAE.*** **2003**, 46 (4): 937-944.

9. Depression of the cloud point of biodiesel by reaction over solid acids. Juan C. Yori, Miguel A. D'Amato, Javier M. Grau, Carlos L. Pieck, and Carlos R. Vera. ***Energy and Fuels.*** **2006**, 20(6):2721-2726.

10. Diesel engine performance and emission characteristics of biodiesel produced by the peroxidation process. C. Lin, H. Lin. ***Fuel***. **2006**, 85(3): 298-305.

11. Effectiveness of cold flow additives on various biodiesel, diesel and their blends. D.S. Shrestha, J. Van Gerpen, and J. Thompson. Manuscript submitted to ***Trans. ASABE***. **2007**.

12. Emissions Characteristics of Ethyl and Methyl Ester of Rapeseed Oil Compared with Low Sulfur Diesel Control Fuel in a Chassis Dynamometer Test of a Pickup Truck. C. Peterson, and D. Reece. ***Transactions of ASAE,*** **1996**, 39(3): 805-806.

13. Engine and winter road test performances of used cooking oil originated biodiesel. Merve Cetinkaya, Yahya Ulusoy, Yucel Tekin, and Filiz Karaosmanoglu, ***Energy Conversion and Management.*** **2005**, 46(7-8): 1279-1291.

14. Engine Exhaust Emissions Evaluation of a Cummins L10E When Fueled with a Biodiesel Blend. W. Marshall, L.G. Schumacher, S.A. Howell. 1995. ***SAE Paper No. 952363***. SAE, Warrendale, PA.

15. Engine performance of biodiesel fuel prepared from soybean soapstock: A high quality renewable fuel produced from a waste feedstock. M. Haas, K. Scott, T. Alleman, R. McCormick. ***Energy and Fuels***. **2001**, 15(5):1207-1212.

16. Exhaust emissions from a diesel engine fueled with transesterified waste olive oil. M. P. Dorado, E. Ballesteros, J. M. Arnal, J. Gómez and F. J. López. ***Fuel.*** **2003**, 82(11): 1311-1315.

17. Improving the low-temperature properties of alternative diesel fuels: vegetable oil-derived methyl esters. R.O. Dunn, M.W. Shockley, M.O. Bagby, ***JAOCS***, **1996**, 73(12):1719-1728.

18. Long-Range On-road Test with Twenty-percent Rapeseed Biodiesel. C.L. Peterson, J.C. Thompson, J.S. Taberski, D.L. Reece, and G. Fleischman. ***Applied Engineering in Agriculture***. **1999**, 15(2):91-101.

19. Low temperature biodiesel diesel blend. Charles Selvidge, ***United States Patent Application*** **2006**, #20060236598.

20. Marine Biodiesel. Randall von Wedel, **1999**. Accessed on Aug. 15, 2007 at *http://www.cytoculture.com/Biodiesel%20Handbook.htm*.

21. Moisture absorption in biodiesel and its petro-diesel blends. He, B., J. Thompson, D. Routt, and J. Van Gerpen. ***Applied Eng. Agri.*** **2007**, 23(1): 71-76

22. Northern Pacific Coast Water Temperature Guide. National Oceanographic Data Center. 2007. Accessed on Aug. 15, 2007 at *http://www.nodc.noaa.gov/dsdt/cwtg/npac.html*.

23. One-Thousand-Hour Engine Durability Test with HySEE and Using a 5x-EMA Test Cycle. C.L. Peterson, J.C. Thompson, and J.S. Taberski. ***Transactions of the ASAE***. **1996**, 42(1): 23-30.

24. Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil. A. Ramadhas, C. Muraleedharan, S. Jayaraj. ***Renewable Energy***. **2005**, 30(12):1789-1800.

25. Producing HySEE Biodiesel from Used French Fry Oil and Ethanol for an Over-The-Road Truck. Lowe, G.A., C.L. Peterson, J.C. Thompson, J.S. Taberski, P.T. Mann, and C.L. Chase. Presented at the 1998 ASAE Annual International Meeting. 1998. Paper No. 986081. ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA.

26. Reducing the crystallization temperature of biodiesel by winterizing methyl soyate. Inmok Lee, Lawrence A Johnson, Earl G. Hammond, ***Journal of the American Oil Chemists' Society***. **1996,** 73:631-636.

27. Survey of 100 Recreational Boaters Using Biodiesel 1994-1997. CytoCulture. 1997. Accessed online on Aug.15, 2007 at *http://www.cytoculture.com/Bdiesel.html*.

28. The effect of a waste vegetable oil blend with diesel fuel on engine performance. MP Dorado, JM Arnal, J. Gomez, A. Gil, and FJ Lopez. ***Transactions of the ASAE***. 2002, 45:(3). 519-523.

29. Use of branched-chain esters to reduce the crystallization temperature of biodiesel. Inmok Lee, Lawrence A. Johnson, Earl G. Hammond, ***Journal of the American Oil Chemists' Society***. **1995,** 72:1155-1160.

30. Winterisation of waste cooking oil methyl ester to improve cold temperature fuel properties. M.E. Gonzalez Gomez, R. Howard-Hildige, J.J. Leahy, B. Rice, ***Fuel***. **2002**, 81(1):33-39.

31. Yellowstone National Park Sustainability Update. U.S. Department of the Interior National Park Service. 2005. Accessed online on Aug. 15, 2007 at *http://www.nature.nps.gov/sustainabilityNews/search_docs/CEI_Park_Updates/Yellowstone_Update_Page.htm*.

6. Fuel Storage, Stability, Transport, and Blending

6.1. Biodiesel fuel storage and stability

After its production, biodiesel fuel typically is held in a storage tank. Long term storage can lead to fuel deterioration, including gum formation. Biodiesel stability refers to two issues: (1) oxidative stability related to long term storage, and (2) thermal stability related to aging at elevated temperatures and/or pressures as fuel is circulated through an engine's fuel system. Biodiesel oxidation and aging can lead to high acid numbers, high viscosity, and the formation of gums and sediments that may clog fuel filters.

Some studies have been performed on the relationship between storage and stability. Two-year storage in two types of containers, steel and glass, was investigated with methyl and ethyl esters of rapeseed [1]. This study focused on gum formations due to oxidative polymerization. Significant changes were found in the values of five measured parameters during storage. The peroxide, acid values, density, and viscosity tended to increase, while the heat of combustion decreased over the storage time. The results also showed that no significant effect was found based on container type.

Another study was conducted on biodiesel stability under commercial storage conditions for one year [2]. Eleven different feedstock samples, such as rapeseed, sunflower, a mix of both, etc., were collected to test the fuel quality. The results demonstrated that all samples met the specification limits at the end of the one-year storage period, with the exception of Rancimat Induction Period (RIP) testing for oxidation stability. Oxidation stability was the most significant change based on the Rancimat test method. The RIP decreased with time, and the rate of this decrease depends on the fuel quality and storage conditions.

The National Renewable Energy Laboratory conducted a survey of the quality and stability of biodiesel fuel and biodiesel blends in the United States in 2004 [3]. 27 B100 samples and 50 B20 samples were collected from distributors nationwide. 85% of the B100 samples met all the requirements of ASTM D 6751. The B20 samples showed high levels of peroxides, indicating the formation of peroxides as the initial step in fuel oxidation.

Biodiesel degradation characterization was also investigated under different storage conditions [4]. Twelve biodiesel samples were divided into three groups and stored at different temperatures and environments over a period of 52 weeks. It was concluded that temperature and air exposure are two important factors in biodiesel degradation. The degradation rate is greatly increased if the biodiesel is stored at a high temperature (e.g., 40 ^{o}C) and exposed to ambient air. However, the temperature or air exposure alone had little influence on the biodiesel degradation. In addition, high levels of water in the biodiesel enhanced the biodiesel degradation due to its hydrolysis, but its effect is much less than the temperature and air exposure factors.
Recently, thermal and oxidation degradation of castor oil biodiesel was reported [5]. This study was performed on the degradation process of biodiesel at different high temperatures and exposure times. Results showed that the biodiesel was thermally stable up to 150 ^{o}C, but that gum formation occurred at 210 ^{o}C after 48 hours, suggesting the oxidative polymerization of biodiesel was completed.

6.2. Biodiesel fuel transport

It is noted that biodiesel transportation containers must not be contaminated. The following procedures are recommended for biodiesel distributors and transporters [6].

- Trucks and railcars are made of aluminum, carbon steel or stainless steel.
- Proper inspection and/or washout for certification.
- Check for previous load carried and residuals. Some residuals may not be acceptable, such as food products or raw vegetable oils, gasoline, or lubricants.
- No residual water.
- Clean hoses and seals.
- Proper insulation or heating methods may be needed if transporting during cold weather.

When shipping in cold weather, biodiesel should be transported in one of the following ways:

- Temperature under 130 ^{o}F to 80 ^{o}F in tanker trucks for immediate delivery;
- Temperature under 120 ^{o}F to 130 ^{o}F in railcars for delivery within 7 – 8 days;
- Frozen in railcars equipped with external steam coils in order that the fuel in the railcars is liquid at the final destination;
- A blend of biodiesel and winter diesel fuel in either railcars or tanker trucks.

It is important that B100 and its blends be stored and handled at temperatures above their cloud point.

6.3. Biodiesel blending with diesel

The most popular biodiesel blend is B20. Biodiesel is blended into diesel fuel via three different methods commonly used in practice.

(1) Splash Blending

Splash blending is loading both biodiesel and diesel into a vessel separately with relatively little preliminary mixing. The vessel is typically an individual vehicle tank or fuel delivery truck, or a drum or a tote. Once both the diesel and biodiesel are loaded into the vessel, the fuels are sufficiently mixed by agitation of the vessel contents during driving.

(2) In-Tank Blending

This process also typically loads the biodiesel and diesel separately. In some cases, however, in-tank blending loads fuels at the same time through different incoming sources, but at a high fill rate. This is similar to splash blending but without the required agitation of the vessel contents by driving. In-tank blending is usually sufficient to get a homogenous blend since the biodiesel and diesel mix readily.

(3) In-Line Blending

In-line blending is when the biodiesel is added to a stream of diesel as it travels through a pipe or hose. The biodiesel and diesel become thoroughly mixed by the turbulent movement through the pipe. The biodiesel is added slowly and continuously to the moving stream of diesel. This is similar to the way other additives are blended into diesel, and is most commonly used at pipeline terminals and racks.

Blending can be a concern in cold weather when the temperature is below the cloud point of B100, because crystals may form during blending. Blending properties of biodiesel were studied under low temperatures in order to define operating parameters [7]. Splash blending tests were performed in making B20. Results indicated that the biodiesel must be kept at least 10 ^{o}F above its cloud point to ensure successful blending. The target temperature for blending should be determined on an individual basis because of the various fuel properties.

It is also a good idea to filter biodiesel blends in northern (colder) climates because the crystallized saturated fatty acid methyl esters formed may cause filter clogging.

6.4. References

1. Two year storage study with methyl and ethyl esters of rapeseed. J.C. Thompson, C.L. Peterson, D.L. Reece, S.M. Beck, ***Transactions of the ASAE***. **1998,** 41:931-939
2. Biodiesel stability under commercial storage conditions over one year. Paolo Bondioli, Ada Gasparoli, Laura Della Bella, Silvia tagliabue, Guido Toso, ***European Journal of Lipid Science and Technology***. **2003**.105:735-741.
3. Survey of the quality and stability of biodiesel blends in the United States in 2004. R.L. McCormick, T.L. Alleman, M. Ratcliff, L. Moens, and R. Lawrence, ***National Renewable Energy Laboratory.*** **2005.**
4. Degradation of biodiesel under different storage conditions. D.Y.C. Leung, B.C.P. Koo, Y. Guo, ***Bioresource technology***. **2006**, 97:250-256.
5. Thermal and oxidative degradation of castor oil biodiesel. Marta M. Conceicao, Valter J. Fernandes, Jr., Antonio, Mirna F. Farias, Ieda M. G. Santos, and Antonio G. Souza, ***Energy and Fuels***. **2007,** 21:1522-1527.

6. Biodiesel handling and use guidelines. Third Edition, ***U.S. Department of Energy***, **Energy Efficiency and Renewable Energy, September 2006**.
7. Biodiesel cold weather blending study. ***Cold flow blending consortium and the National Biodiesel Board***. **2005**.

7. Effects of Biodiesel Production on its Quality

The most critical fuel quality parameter for biodiesel production is the total glycerin. In the original vegetable oil or fat, the glycerin composes approximately 10.5% of the molecules. This must be reduced to 0.24% or less by the fuel production process. The residual glycerin might be in the form of free glycerin, or as bound glycerin consisting of the triglycerides from the original oil or partially reacted mono- and diglycerides. Elevated levels of total glycerin can increase the tendency of the fuel to form solid precipitates in the engine's fuel system which may plug the fuel filter (Van Gerpen et al., 1997). The monoglycerides of saturated fatty acids have very high melting points (e.g., 77°C for monopalmitin) and have low solubility in the biodiesel (Yu et al., 1998). High total glycerin levels can also raise the carbon residue of the fuel, causing it to fail to meet another specification within the ASTM standard (Van Gerpen et al., 1997).

Another set of important quality parameters for the fuel are the levels of trace elements such as sulfur, phosphorus, sodium, potassium, calcium and magnesium. Vegetable oils are typically very low in sulfur but animal fats can contain 30-60 ppm of sulfur. Phosphorus originates in phospholipid compounds extracted from the plant during the oil extraction process (Erickson, 1995). These compounds are usually removed during oil processing in an operation called *degumming*, but the desire to reduce feedstock costs has caused some producers to use oil that has only been partially degummed. Some producers have seen high phosphorus levels in the fuel produced from these partially degummed oils (Van Gerpen, 2005). Other metallic contaminants such as sodium and potassium from the catalyst or calcium and magnesium from the wash water may cause high ash deposits in the engine. All of these contaminants may cause deactivation of the exhaust after treatment devices that are required on on-highway diesel engines in 2007 and after. It also does not apply to the engines on WSF ferries which are not outfitted with exhaust after-treatment.

7.1. Effect of Residual Alcohol on Fuel Quality

Production of biodiesel generally uses 100% excess methanol (Van Gerpen, 2005). This excess methanol must be recovered both for cost reasons and to minimize emissions. Small amounts of methanol left in the biodiesel will lower the flashpoint of the fuel.

Figure 1 shows that as little as 0.1% residual methanol can lower the flashpoint below the 130°C level required by the ASTM specification (ASTM, 2007). Reducing the methanol to this level or below requires heating the fuel to sufficient temperature (usually 70°C or higher) so that the methanol vaporizes and leaves the less volatile methyl esters behind. This is an energy intensive process and some processors, as a result of attempting to reduce energy costs, have used methanol recovery processes that do not remove sufficient methanol to meet the ASTM specification.

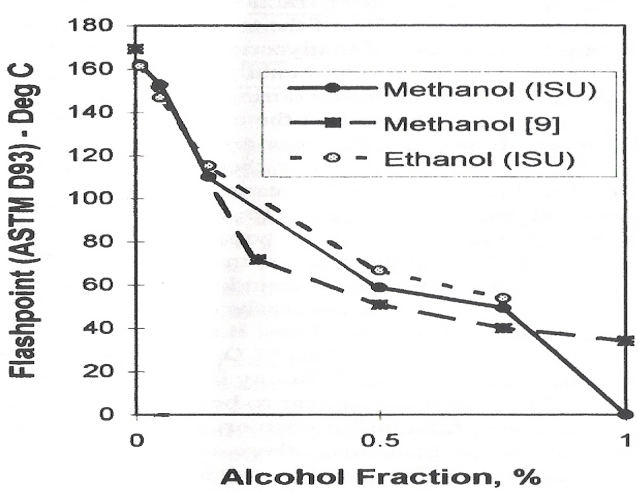

Figure 1. Biodiesel Flashpoint for Varying Alcohol levels (Van Gerpen et al., 1997)

7.2. Crude Glycerol and Fuel Quality

Glycerol has a very low solubility in biodiesel (Van Gerpen et al., 1997), so if a portion of the glycerol produced by the transesterification reaction is left in the fuel, it is likely to be in the form of small droplets. Over time these droplets will settle to the bottom of a storage tank and collect as a pool of glycerin. The glycerin may attract water and monoglycerides from the fuel (Van Gerpen et al., 1997). If the glycerin is drawn into the engine it is too viscous to pass through the engine's fuel filter and the engine will usually cease to run until the filter can be changed.

Fuel quality is absolutely essential for trouble-free operation of engines on biodiesel. Most operational problems associated with fuel quality will result in fuel filter plugging and potentially stop the engine until the filter is changed. Other issues, such as the flash point, relate to safety and fuel that does not meet the specification present a serious safety concern. Other specifications are included to protect ancillary equipment such as the particulate filters and catalytic converters that are required on new diesel engines. This is an on-road requirement, not yet applicable to the marine sector. EPA has not yet finalized marine tier 3 and tier 4 standards for diesel engines. However, it is likely that tier 4 standards will only be possible by the use of exhaust after-treatment devices. But since this is not the case with the engines on these vessels, it is not relevant to the discussion and may only confuse the issue.

References

1. Biodiesel Processing and Production. J. Van Gerpen. ***Fuel Processing Technology***, **2005**, 86: 1097-1107.

2. Degumming and Lecithin Production and Utilization. D.R. Erickson. From D.R. Erickson, Editor, ***Practical Handbook of Soybean Processing and Utilization***. **1995**. AOCS Press, Champaign, IL.

3. Determining the Influence of Contaminants on Biodiesel Properties. J. Van Gerpen, E. Hammond, L. Yu, and A. Monyem. ***SAE Paper 971685***, presented at the SAE Spring Fuels and Lubricants Meeting, May, 1997.

4. The Influence of Trace Components on the Melting Point of Methyl Soyate. L. Yu, I. Lee, E. Hammond, L. Johnson, and J. H. Van Gerpen. ***Journal of the American Oil Chemists Society***, **1998**, 75(12): 1821-1824.

8. Other Biodiesel Related Research

This section describes additional research on improvements in current production techniques, alternative feedstocks for biodiesel production, and biodiesel production through other techniques.

8.1. Improvements in current production techniques

Biodiesel is produced commonly by transesterification of a catalyzed reaction. Several factors, including the type of catalyst, molar ratio of alcohol to vegetable oil, temperature, water content, and free fatty acid content, have an influence on the transesterification reaction [1, 2]. The following are some examples of approaches to biodiesel production research.

One of approached on improvements of biodiesel production is to use new reactors. The optimization of transesterification of canola oil was investigated using a continuous-flow reactive distillation (RD) system [3]. Six process variables, including the feed methanol to triglycerides molar ratio, reaction time, temperature, catalyst concentration, methanol circulation mode, and catalyst formation, were optimized. Results showed that the optimum product yields ranged from 96.8 % to 98.6 % with the productivity ranging from7.2 m^3/m^3. h to 18.5 m^3/m^3. h. A two-phase membrane reactor was developed to enhance mass transfer of canola oil in methanol in the early stages of transesterification [4]. It was reported that this reactor enabled the separation of reaction products (biodiesel/glycerol in methanol) from original canola oil feed. One of the advantages in using this reactor is to yield high purity biodiesel and shift the reaction equilibrium to the product side.

Another improvement in biodiesel production was attempted based on the application of ultrasound [5]. It is claimed that the application of ultrasound improves the efficiency of biodiesel production from materials not typically used for this purpose, such as seed cake. Advantages of this technique include elimination of saponification, low reaction times, milder reaction conditions, and higher biodiesel yields.

The biodiesel production by supercritical alcohol, such as methanol, ethanol, propanol and butanol, has proved to be one of most promising process [6]. This supercritical method allows a simple process and high yield because of the simultaneous transesterification of triacylglycerols and methyl esterification of fatty acids. It was reported that the conversion yield was raised 50 – 95 % for a short first 10 minutes in the supercritical alcohol transesterification [6]. In addition, the presence of water positively affected the formation of methyl esters in the supercritical method. However, the presence of water has negative effects on the yields of methyl esters in the current alkali-catalyzed method because water can cause soap formation, as well as consumes catalysis and reduces catalyst effectiveness. Furthermore, it has been reported that supercritical methanol combined with CO_2 is superior to the common supercritical methanol method on lower reaction temperature and lower pressure required [7]. These relatively mild reaction conditions led to less energy and resulted in lower production cost.

8.2 Alternative feedstocks for biodiesel production

The majority of current biodiesel production cost (60 – 90%) arises from the cost of feedstock oil. Thus the use of cheap feedstocks, including waste frying oil, should greatly reduce the cost of biodiesel production. The two-stage transesterification process was developed using waste frying oil [8]. The biodiesel produced using waste frying oil has similar properties to No. 2 diesel. Therefore, the use of waste frying oil is an effective way to reduce the raw material cost.

Another potential type of feedstock may be microalgae oil, because microalgae use light to produce oils. Oil productivity from some microalgae exceeds the oil productivity of the producing oil crop, although the process cost for biodiesel production using microalgae may be not economically competitive with petrodiesel [9]. There are technical limitations to producing microalgae biodiesel. It is noted that improvements to algal biology are required for producing low-cost microalgae biodiesel [9]. Unlike commonly phototrophic microalgal oil utilizing sunlight, heterotrophic microalgal oil using a photobioreactor has been suggested to produce biodiesel [10]. Heterotrophic growth of some microalgae has been proved to efficiently produce biomass and lipids in high densities, potentially reducing the cost of microalgal oil.

8.3. Biodiesel production through other techniques

The catalyst is one of the most important factors for biodiesel production. Unlike commonly used alkali-catalyzed transesterification for biodiesel production, acid-catalyzed transesterification (such as by using sulfonic and sulfuric acids) has not been developed because of its slower reaction rate [6]. However, the acid-catalyzed process offers benefits due to its independence from free acid content, which in turn favors raw materials containing high free fatty acids such as waste cooking oils.

Another approach to biodiesel production is to use a new heterogeneous catalyst including solid superacid catalysts of metal oxides [6, 11]. For instance, a superacid catalyst consists of a mixed oxide of zinc and aluminum promoting the transesterification reaction without catalyst loss. It is claimed that such a process can provide simple purification of products, very high yields of methyl esters (e.g., 98 %), high purity of glycerin (>98%), and the absence of special chemical requirements as well as waste streams [11].

Enzymes as catalysts are also proposed in the production of biodiesel. It is important to note that glycerol can be easily recovered without any complex process, free fatty acids in the oils can be converted into methyl esters, and subsequent wastewater treatment may not be required [12]. Lipases are typical enzymes that can be used for biodiesel production. It should be noted, however, that enzymes are expensive and the reaction yields as well as the reaction times are still unfavorable compared to the alkali-catalyzed systems.

8.4. References

1. Biodiesel production: a review. Fangrui Ma, Milford A. Hanna, ***Bioresource Technology.*** **1999**, 70:1-15.
2. Technical aspects of biodiesel production by transesterification - A review. L.C. Meher, Sagar D. Vidya, S.N. Naik, ***Renewable and Sustainable Energy Reviews***. **2006,** 10:248-268.
3. Experimental optimization of a continuous-flow reactive distillation reactor for biodiesel production. B.B. He, A.P. Singh, J.C. Thompson, ***Transactions of the American Society of Agricultural Engineers***. **2005,** 48:2237-2243.
4. Biodiesel production using a membrane reactor. M.A. Dube, A.Y. Tremblay, J. Liu., ***Bioresource Technology.*** **2007**, 98:639-647.
5. Improvement of biodiesel production based on the application of ultrasound: Monitoring of the procedure by FTIR spectroscopy. N.G. Siatis, A.C. Kimbaris, C.S. Pappas, P.A. Tarantilis, M.G. Polissiou. ***Journal of the American Oil Chemists' Society***. **2006,** 83:53-57**.**
6. Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods. Ayhan Demirbas, ***Progress in Energy and Combustion Science.*** **2005,** 31:466-487.
7. Preparation of biodiesel from soybean oil using supercritical methanol and CO2 as co-solvent. Hengwen, Weiliang Cao, Jingchang Zhang, ***Process Biochemistry*****. 2005,** 40:3148-3151.

8. Biodiesel from used frying oil. Variables affecting the yields and characteristics of the biodiesel. Jose M. Encinar, Juan F. Gonzalez, Antonio Rodriguez- Reinares***, Industrial and Engineering Chemistry Research***. **2005,** 44:5491- 5499.
9. Biodiesel from microalgae. Yusuf Chisti. ***Biotechnology Advances***, **2007**, 25:294-306.
10. Biodiesel production from heterotrophic microalgal oil. Xiao Miao, Qingyu Wu, ***Bioresource Technology***. **2006**, 97:841-846.
11. New heterogeneous process for biodiesel production: A way to improve the quality and the value of the crude glycerin produced by biodiesel plants. L. Bournay, D. Casanave, B. Delfort, G Hillion, J.A. Chodorge***, Catalysis Today.*** **2005,** 106:190-192.
12. Possible methods for biodiesel production. J.M. Marchetti, V.U. Miguel, A.F. Errazu, ***Renewable & Sustainable Energy Reviews***. **2007**, 11:1300-1311.

Appendix B: WSF 2004 Biodiesel Pilot Test Report

Contract No. 200700001

Washington State Ferry Biodiesel Project (Task II A)

Report of Findings from 2004 WSF Biodiesel Pilot Test

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Summary

In the second half of 2004 and in the first quarter of 2005 Washington State Ferries ran three of its vessels with a biodiesel blend as part of its “Clean Fuel Initiative.” The trial was suspended in December 2004 because of “product quality issues” that manifested themselves as clogged fuel filters and purifiers. The trial was restarted in March 2005, only to be terminated again due to similar issues. Though not well documented, the WSF trial produced anecdotal evidence that biodiesel blends may not be a direct substitute for petroleum based diesel fuel in vessels.

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Timeline

July 17, 2004 – ***Issaquah*** takes first load of B20

August 16, 2004 – ***Tillikum*** takes first load of B20

August 17, 2004 – ***Klahowya*** takes first load of B20

Within the first 24 hours, each vessel experiences and reports fuel issues. Problems are thought to be related to start-up issues, "e.g., biodiesel cleaning the fuel lines, etc."

- Milky white gelatinous substance discharge from fuel purifier
- Racor filters have black substance in them
- Racors need to be changed twice daily (normally 4 to 6 months between changes)
- On-engine fuel filter runs black when drained
- Boiler filter (no pre-centrifuging) is caked black between filter pleats

Vessel Reports

September 27, 2004 – Chief Engineer on ***Tillikum*** reports serious concerns over filter consumption. Suspects "bugs" (microbial action in the fuel). Treated tanks with "Biobore." Found some water when he bottom drained tanks. [Note: Tillikum was out of service more than two weeks after taking on a fresh load of B20. Long "dwell time" was thought to have contributed to the issue.]

September 30, 2004 - Chief Engineer on ***Tillikum*** requests authority to run two loads of 100% low-sulfur diesel in an attempt to "clean up" his fuel system. Request appears to have been granted, but the results are not documented. Fuel supplier, Reinhard, notified.

December 9, 2004 – Problems continue aboard WSF vessels. Troubleshooting discussions begin between WSF, Pacific Northwest Energy (PNWE – the local distributor of biodiesel products), Reinhard Fuels (Reinhard – the transportation contractor).

December 10, 2004 – PNWE representative suggests that product quality from his supplier, West Central Soy (WCS) may be an issue. West Central is engaged in the troubleshooting discussion.

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Mid-December, 2004 – Biodiesel trial on WSF vessels suspended.
December 22, 2004 – Meeting onboard ***Tillikum*** including vessel's chief engineer, and representatives from PNWE and WCS. WCS representative took possession of a filter sample and purifier sludge sample.

January 2005 – Representatives of WCS and PNWE as well as independent experts and proponents of biodiesel fuels meet with WSF. Discussions on possible causes and solutions continue throughout the month. Blending of bio and petro emerges as a target for improvement. Decision made to use B20 blend again when trial recommences.

January 30 to February 2, 2005 – WSF representatives attend National Biodiesel Board annual conference. Sidebar meetings with concerned parties produced new "Quality Control Measures for Transporting, Handling and Blending Biodiesel."

March 1, 2005 – ***Tillikum*** takes first load of B20 with new procedures in place. By 10:00 the same morning, pressure differentials in filters are already increasing. Chief engineer reports that he expects to have to change filters within the next 6 or 7 hours.

March 3, 2005 – ***Tillikum*** takes second load of B20.

March 4, 2005 – 18 filter changes in the first three days. Filters are black as before. Fuel purifier shows signs of brown sludge, but not as bad as before.

March 10, 2005 – 30,000 gallons of B20 received in total on March 1st, 4th and 8th. 34 filters used in 8 days of operation. In 2 months during which the vessel operated on low sulfur diesel, no Racor filters were changed. The purifier does not seem to be as dirty as in the first trial.

March 22, 2005 – Filter change-outs continue at the rate of about 4 per day. Purifier requires service (cleaning) once every two days.

March 28, 2005 – Decision is made to terminate Biodiesel trial on ***Tillikum***.

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Vessel Preparation

In preparation for the fuel trials, WSF maintenance personnel:

- Cleaned all vessel fuel storage and service tanks. The exact cleaning protocol that was used is not known. The cleaning process apparently used only pressurized water without organic solvents and then wipes down by hand before loading the fuel. It is also not known how much water was used per tank, nor were any observations and/or tests made after cleaning to determine the level of cleaning achieved.

- Inspected all fuel lines. Natural rubber components were replaced. It is not known what materials were used to replace them.

Conclusions & Recommendations

1. The cleaning methods and protocols should be documented and reviewed.

2. The materials that were used in place of natural rubber should be identified and reviewed for compatibility.

Fuel Acquisition and Blending

Procurement

WSF worked with the Office of State Procurement to write specifications for biodiesel and procure it through existing state fuel contracts. The basis of the biodiesel specification was ASTM Standard D-6751-02, the Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels. It should be noted that including the suffix "-02" in the specification is inappropriate. It indicates the year of the revision to the Standard. This standard, in particular, has undergone several updates since its introduction as a product specification in 1999 and as a standard specification in 2002. The procurement specification should instead refer to "the most recent revision of ASTM Standard D-6751."

Blending

Initially, it was reported that blending took place onboard the vessels. Reportedly, B100 was loaded onto the vessel in the approximate quantity necessary to produce a B20 blend. Diesel fuel was then loaded on top. The initial blending procedure was modified after problems were reported, and fuel was blended in delivery trucks. Beginning in October 2004, trucks were loaded first with biodiesel, then with low-sulfur petrodiesel at a fairly high flow rate (400 GPM bottom loading) to encourage mixing. The two constituents were added in the quantities necessary to produce a B20 blend.

Based on B100 product quality concerns, a "cold-filtering" step as rail cars were being loaded may have been added before the trials recommenced in early 2005. Details of this process are unclear.

B100 blend stock (100% virgin soy) was purchased from a supplier in Iowa, West Central Soy. It was loaded at (100 degrees F) onto 25,000-gallon rail cars belonging to the supplier. Cars were reportedly "cleaned with biodiesel prior to loading." No specific information was presented on whether the tank cars were insulated. It is presumed that the cars were not insulated, since it was reported that, upon arrival at the distributor's facility in Tacoma, "rail car is unloaded to shoreside tank. Tank is heated to 100 degrees F."

Additional Discussions and Troubleshooting

A round table discussion took place during a biodiesel conference in early 2005 by the entire team. The results were summarized as follows:

- The blended fuel seen onboard may not have been B20. There is a suspicion that at times, mixtures as high as B60 may have been passing through the vessel's fuel system.
- Sterols may have been precipitating out during rail transportation of B100 from the Midwest. The process is believed to occur when temperatures drop below 45 or 50 degrees F. Precipitates will not re-dissolve even when heated.
- Results of laboratory analysis of samples from the WSF fuel purifiers were not available.
- Issues of incompatibility of biodiesel and "yellow metals" may have been overstated. Yellow metals are presumably brasses and bronzes.

Conclusions & Recommendations

1. Revise the biodiesel fuel specification to drop the suffix and invoke the most recent revision.

2. Design laboratory blending tests that can identify any propensity of the fuels to separate or stratify after blending, particularly when subjected to temperature changes or mechanical purifiers (see additional discussion in "Filter/Purifier Problems" section).

3. Establish whether the precipitation of sterols at cold temperatures is a reversible process, either through literature searches or laboratory experiments.

4. Document and evaluate the effectiveness of cold filtering process. If the process removes anti-oxidant characteristics of the blend, determine how this can affect storage and use aboard vessels.

Filter/Purifier Problems

During the onboard trials, both spin-on filters (presumably of the paper element type) and mechanical separators (centrifugal and coalescing style) became clogged with contaminants described alternately as:

- Milky white gelatinous substance
- Butterscotch pudding
- Black grainy material with a grease-like texture

It is difficult to believe that these three descriptions could apply to the same substance. While the first two could describe an oil-in-water emulsion, the last one does not. There is an indication that one or more of the substances found clogging filters was subjected to laboratory analysis. An unsigned document dated May 12, 2005, titled "Analysis results for samples sent by Tina Stolz from fuel separators on Washington State Ferries" was reviewed. It indicated that the black grainy substance, believed to have been collected from a centrifugal separator, exhibited high water content and high iron content reported by the University of Idaho.

The centrifugal separator (purifier) is designed to separate water and solid contaminants from the fuel by relying on differences in densities and centrifugal force (up to 10,000 times that of gravity). It is unclear whether such a device could create unintended effects, such as:

- Emulsification (rather than separation) of free water with the biodiesel component (due to its higher hygroscopic nature than diesel), or
- Separation of insoluble components from the blend fuel.

Conclusions & Recommendations:

1. The theory of operation of the centrifugal separator must be better understood before concluding that the water content is high. Gross separation of water and oil occurs in the purifier bowl, where the sample was extracted. It is better to know how or when separated water is ejected from the purifier bowl.

2. The accelerated separation effects caused by the centrifugal separator must be taken into account when identifying any propensity of the constituents of B20 to separate or stratify after blending.

3. The possibility that the purifier could be inadvertently adding the mixing energy necessary to create hard emulsions of biodiesel and water should be investigated.

4. The high iron content may indicate that the corrosive and solvent behavior of biodiesel is effectively “leaching” the iron out of the steel tanks. Evaluate the effect of biodiesel blends on uncoated steel. The effect of varying amounts of sterols in solution should also be investigated.

Guidance Received from Bio Industry

WSF attended a biodiesel conference sponsored by the National Biodiesel Board during the winter of 2005. Much of the information gathered there, which included meetings with the Bio supplier in Iowa -- West Central Soy -- focused on the temperature extremes during transport. These led to the formulation of improved handling procedures that were invoked before the trial recommenced in March 2005.

Corrective Measures Attempted

In addition to the improved blending techniques and the addition of cold-filtering as described above, the following additional corrective measures were undertaken during the trial.

- B100 was loaded at a higher temperature (110F vs. 100F) into insulated (vs. un-insulated) rail cars for transport to Tacoma. The first load shipped in this manner arrived at a temperature of 60 ^{o}F.

- Rigorous testing of B100 was invoked upon arrival of the rail car, including tests, "…for water and sediment, swirl test, spin test and acid number." The results from these tests must pass the requirements of the ASTM D6751 standard specification.

- Sampling of the B100 as it is loaded on the tank truck "will be retained for testing later as required." It is unclear if these samples have indeed been retained.

- A second filtering as B100 is loaded on the tank truck was considered. It is unclear whether this was actually done. This filtering step is required to assure B100 quality before blending.

- A sample of B20 was to be pulled from the middle of a truck compartment at random, and retained for future testing. It is unclear whether these samples were indeed retained and analyzed. Some discussion indicates that the delivery company failed to execute the sampling program. The delivery company seems not to have another filtering mechanism to remove any possible insoluble species produced during the fuel blending.

Conclusions & Recommendations:

1. Ascertain whether these improvements were undertaken. If they were, attempt to discern where and when.

2. Identify the B100 tests conducted upon arrival of the railcars in Tacoma and secure the reports therefrom. Determine whether the information so derived can provide an indication of the nature and source of the filter-clogging episodes.

3. Locate the B100 and B20 samples that were gathered, if any, and take possession of them for cataloguing and analysis.

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Fuel Tank Residues

In June 2005, several months after the second biodiesel trial onboard ***Tillikum*** was aborted, the opportunity presented itself to inspect the fuel tanks. “There was a brownish slime in way of the water contact area in the bottom turn of the bilge. The rest of the tank appeared clean with a slight rust bloom on the tank top.” This was alternately described as “a brown slime below the normal waterline and dry brown patina above.” These two descriptions are consistent with one another.

The deep fuel tanks on the ferries are “single skin tanks” meaning that a tank boundary is the hull of the ship. A part of that boundary is submerged in seawater, while another part is exposed to air, direct sunlight, and spray, leading to a very broad range of surface temperatures.

A sample of the brown slime scraped from the filters was delivered to the University of Idaho for analysis. The results exhibited high water content and high iron content in the sample.

Conclusions & Recommendations:

1. The results of the sludge analysis, if any, should be captured.

2. The range of surface temperatures should be established and reviewed as one environmental parameter affecting the properties of the fuel blend.

3. The “rust bloom” should be investigated and explained.

Guidance Received from Engine Manufacturers

The Detroit Diesel policy on the use of biodiesel blended fuels is vague. Their Engine Requirements document Paragraph 5.1.4 states, “Biodiesel meeting ASTM D 6751 specifications can be blended up to 20% maximum by volume in diesel fuel. The resulting mixture must meet the fuel properties listed [in a table describing the attributes of acceptable diesel fuel].” This statement would lead one to believe that B-20 is an acceptable fuel. Unfortunately, the statement

is immediately followed by the disclaimer, “Failures attributed to the use of biodiesel will not be covered by Detroit diesel product warranty.”

They elaborate further by offering a quote from a document referred to as *World Wide Fuel Charter – Draft for Comments – June 2002, page 46,* "… for reference and guidance: 'Based on the technical effects of FAME [Fatty Acid Methyl Esters], it is strongly advised that FAME content be restricted to less than 5%. As a pure fuel, or at higher levels in diesel fuel, the vehicles need to be adapted to the fuel, and particular care is needed to avoid problems.'"

So, it would appear that Detroit Diesel is acknowledging the existence of B-20 as a motor fuel, advocating the use of blends not greater than B-5, and accepting no responsibility for honoring engine warranties for engines burning biodiesel. However, engine manufacturers all have similar warranty statements relating to fuels. Since they do not sell fuels, they do not take responsibility for problems caused by the fuel – it doesn't matter whether the fuel is diesel fuel or biodiesel. Engine manufacturers will also honor warranties for problems that relate to the parts and assembly of their engines. The fuel you use does not affect this unless the fuel is the cause of the problem – then it is the fuel supply problem. So, it is not reasonable to expect a statement from Detroit Diesel that they will honor their warranties on a specific fuel. The companies will make recommendations about fuels but this does not relate to warranties

Detroit Diesel's former sister company, Electromotive (or EMD), takes a slightly different tack in its Maintenance Instruction on fuel recommendations. "EMD does not approve or prohibit the use of biodiesel fuels or biodiesel blends with distillate fuels…. If a failure arises as a result of using a specific fuel, it will be the responsibility of the fuel supplier and/or the customer to accept the costs incurred." The instruction then goes on to offer some "recommendations" which appear to be more akin to warnings, "for those customers considering the use of biodiesel fuels." They point out that biodiesel may have:

- Lower energy content (BTU/unit)
- Hygroscopic characteristics
- Poor lubricity
- Poor stability
- High viscosity at low temperatures
- Varying compatibility with elastomers in use in vessel fuel systems
- A tendency to encourage microbial growth

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Advice received by WSF from GE Transportation quotes from the Engine Manufacturers Association guidance: "Though similar to conventional diesel fuel, biodiesel and biodiesel blends can cause engine performance problems such as injector tip plugging, severe coking, piston ring sticking, or catastrophic engine lubrication degradation."

It should be noted that all engine warranties only cover hardware and never cover damage caused by fuel. Also, it should be noted that the information presented as guidance available at the time of the trials is outdated and in some cases inaccurate. Any conclusions being drawn at this point in time for use going forward should take into consideration the most current statements of the original engine manufacturer.

Anecdotal Results of Marine Trials

Despite all the negativity surrounding the engine manufacturers' company line, a distributor chose to forward a testimonial to WSF from American River Transport Company (ARTCO), who ran a trial in one of its boats over a 14-month period in 2002-03. The boat was equipped with EMD main engines and a Detroit Diesel auxiliary. The only difficulty encountered during the ARTCO trial was a plugged "spin-on filter" that had to be changed shortly after the start of the test. This was attributed to the solvent properties of the biofuel.

Detroit Diesel also chose to share some information from a trial at the Channel Islands National Park. The conclusions were that oil change intervals had to be shortened and that fuel lines "deteriorate in 10-12 months from the inside out."

Conclusions & Recommendations:

1. The engine manufacturers of most interest to WSF have NOT approved the use of biodiesel blends for fuel. Engine manufacturers don't approve or disapprove fuels. All fuels are used at the vessel owner's and the fuel supplier's risk. The engine manufacturer is only responsible for the hardware. The use of biodiesel blends will be at the vessel owner's risk. This may become an issue in any new building or repowering programs that WSF may undertake.

2. There is no information in either of the trials (for which engine manufacturers offered anecdotal performance data) that fuel systems included mechanical fuel purifiers, such as centrifugal separators or plate coalescers. The absence of mechanical purifiers should be confirmed.

Speculations as to Possible Reasons for the Clogging Problems

A combination of factors may have contributed to formation of clogging materials resulting in the clogging problems in the 2004 test. The possible factors for the problems are discussed below. The following discussions, however, remain speculative.

- *High impurity contents in the B20 blend*

  The impurities in biodiesel, such as glycerin, glucosides, sterols, and monoglycerides, at high levels may form precipitates when biodiesel blends with petroleum diesel, resulting in filter clogging problems. In addition, low temperatures in the marine environment could enhance the formation of the clogging precipitates.

- *High water content in the B20 blend*

  Biodiesel has more polar property than diesel because of the presence of 11% wt oxygen. During its operation process, the polar B20 may absorb moisture under the marine environment through condensation, causing the B20 blend to be "out of spec" for water content. Excess water in the biodiesel or B20 blend in a metal storage tank may lead to corrosion and high sediment levels having high metal content, causing filter clogging.

- *Biodiesel oxidation*

  Oxidation stability is one of the most important properties of biodiesel. Because of its chemical structure, biodiesel is sensitive to oxidative degradation which results in the formation of corrosive acids and deposits. The oxidative reaction could have occurred during the 2004 WSF test due to the Northwest environmental conditions and the WSF vessel structure. High temperatures during the operation could enhance the biodiesel oxidation.

- *Incomplete tank cleaning*

Pure biodiesel and biodiesel blends have excellent solvent properties. The use of petrodiesel, especially #2 petrodiesel, leaves over time a deposit in the bottom of fuel lines, tanks, and delivery systems. Biodiesel could loosen or partially dissolve these sediments, and thus lead to the need to change filters more frequently when first using biodiesel until the entire system has been cleaned of these sediment deposits. In the 2004 fuel test, incomplete cleaning could have occurred since only water was apparently used during the cleaning process. As previously discussed, there seem not to have been any criteria and/or tests to ensure completed cleaning during the 2004 test.

Contract No. 200700001

Washington State Ferry Biodiesel Project (Task II B)

Report of WSF Fuel System Environmental Process and Compatibility Evaluation

Submitted by

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This document was developed based on contributions from Glosten Associates who developed "Environmental Parameters Test Plan" and "Materials Compatibility Survey Report"

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Summary

The physical, chemical, and biological environments of the Washington State Ferry (WSF) fuel system may impact biodiesel fuel quality. This report will specify the fuel quality requirement in terms of important environmental parameters, procedures, and assessment results regarding compatibility of the vessel environment with respect to these parameters. The environmental parameters were identified and measured conditions to which biodiesel fuel is subjected aboard WSF vessels. Physical parameters include temperature, moisture level, storage time; chemical parameters include exposure to oxygen, tank materials, possible deposition at the fuel tank surface and at the tank bottom, quality of hose and other materials in the fuel line system; and biological parameters include bacterial and mold growth.

The material compatibility survey is intended to determine whether the WSF test vessel(s) fuel systems are compatible with extended operation on biodiesel and blended biodiesel fuels. The

survey includes an assessment of hoses, equipment and equipment components for materials incompatible with biodiesel or biodiesel blends. It also identifies equipment and equipment components that may experience accelerated wear, especially at higher biodiesel blend ratios.

1. Environmental Parameters inside the WSF test Vessel Fuel Systems

The extreme ranges of temperature, humidity and pressure in the fuel system were examined. The section below summarizes the findings for each parameter as well as other important environmental parameters.

1.1. Temperature influence

Fuel temperature varies in the WSF system, which may affect the biodiesel properties and quality. Some impurities in B20 biodiesel, such as plant sterols, could become insoluble due to their low solubility at low temperature. On the other hand, biodiesel could be oxidative at high temperatures, leading to the formation of other insoluble species in the fuel. These insoluble species could lead to filter clogging. It is important to understand the temperatures which the biodiesel blended fuel is exposed to in the WSF fuel system, as described below.

a. Fuel storage. It is just as important to monitor the temperature of the ullage (air) space in the tank above the fuel as it is to monitor the temperature of the fuel itself. A time history of both parameters would be helpful in understanding how (or whether) condensation forms.
b. Bunkering event. There may be rapid cooling of the relatively warm fuel oil when it is transferred from the tank truck to the vessel storage tanks. It is interested in whether this rapid cooling might promote precipitation within the biodiesel formulation.
c. Fuel service. Not all fuel oil that is delivered to the engines is consumed. Some is returned as hot oil to the fuel oil day tank by way of a fuel oil cooler. The effect of this significant heating and cooling cycling of the fuel formulation should be understood.
d. Measurement.

   i. Access to fuel tanks is limited to fill tubes, sounding tubes, and fuel transfer connections, none of which may be suitable for taking accurate fuel temperature readings at different depths in the tank. This may require removal of a manhole to hang special instrumentation (explosion proof or spark ignition protected) for accurate readings.

ii. Ullage space temperature measurement would similarly require removal of a manhole to hang special instrumentation for accurate readings.

iii. Tank skin temperature can be measured with infrared heat guns, with compensation for opacity and material of the measured surface. Outside tank temperature measurement will be more difficult.

iv. Service piping temperature can be measured with standard temperature gauges or heat guns.

The fuel may see temperature extremes ranging from 40 °F to 120°F.

The lower temperature extreme represents the lower of seawater temperature in contact with the vessel's tank (46°F[1]) or the lowest ambient air temperature in the engine room, where the day tank is located (estimated to be 40°F).

The upper temperature extreme is the higher of the highest ambient air temperature in the engine room (105°F) or the temperature of the diesel fuel returning to the day tank from the engine (estimated to be 120°F).

Fuel temperatures were measured aboard ***M/V Tillikum*** in normal operation on September 17, 2008. Conditions would be similar for ***M/V Klahowya*** (sister vessel), but not necessarily for ***M/V Issaquah*** (different engines and fuel system design).

Conditions were as follows:

- Ambient air temperature: ~ 55°F,
- Engine room air temperature: ~92°F
- Day tank fuel temperature: ~95°F
- Fuel return temperature (off engine): ~105°F

[1] Source: NOAA/NOS Seawater Temperature data collected between 1993 and 2003 at Tacoma, Seattle, Port Townsend and Friday Harbor. Extreme low seawater temperatures were consistent among the four reporting stations.

From discussions with the crew, likely temperature ranges would be:

- Ambient air temperature: ~ 40-85°F,
- Engine room air temperature: ~90-105°F (manually controlled ventilation rates)
- Day tank fuel temperature: ~95-110°F (~+5°F over compartment temperature)
- Fuel return temperature (off engine): ~105-120°F (~+15°F over compartment temperature – but a function of engine load)

Recommendation: No additional temperature measurements are required unless laboratory trials dictate otherwise.

1.2. Moisture levels

Higher levels of moisture in fuels may exist in marine ferry conditions than in land-based conditions. Moisture condensation in biodiesel fuel, particularly during rainy periods, may occur because biodiesel has an affinity to water. The biodiesel standard specification limits a certain level of water content. The biodiesel may be out of spec if high levels of condensed moisture are present in the fuel. Thus, the moisture is considered as a negative factor for biodiesel applications in marine conditions.

Moisture condensate eventually settles to the bottom of the fuel tank, and is typically drained by operating personnel to a slop tank. Fuel suction/delivery lines are purposely placed several inches above the bottom of the tank to minimize the amount of water delivered to the fuel system.

Water can also be introduced in the fuel at the air/oil interface. Biodiesel blends may have an affinity for absorbing free water at the oil/water interface. Thus condensation is likely to be a contributing factor to the increased moisture content. It is important to understand that marine vessel tanks “breathe.” They are open to the atmosphere through vent pipes. As the tanks are filled and emptied, they expand and contract due to the diurnal cycle, and fuel vapor and humid air are exchanged. As a result, the water vapor in the ullage space is constantly being replenished. Knowing the relative humidity of the air in the ullage space of the storage and day tanks as a function of time may be important in understanding the rate at which water vapor is absorbed by the fuel. Research shows that moisture absorption into biodiesel is a very fast process. High moisture levels may be absorbed by biodiesel at high temperatures and water would then precipitate out once the temperature drops.

As with temperature, humidity measurement in the ullage space would require removal of a manhole to install instrumentation.

Relative humidity will range up to 100%. Ambient temperatures of atmospheric air drawn into fuel tanks will range from 23°F to 85°F.[2]

The fuel tanks aboard WSF vessels are vented to the atmosphere. Because of the proximity of the tank vents to the seawater surface, the air in the ullage space above the fuel in all storage and day tanks can be expected to range close to 100% relative humidity. Air temperature in the ullage space can transit the dew point one or more times during a day's operation. Passing the dew point as temperature decreases will cause water vapor to condense inside the tank. This can be a localized phenomenon around steel boundaries in contact with cool seawater, or it can be more generalized, with the formation of "fog" in the ullage space.

Recommendation: No additional humidity monitoring is recommended unless laboratory trials dictate otherwise.

1.3. Pressure

Another parameter is pressure -- including pressure in both transfer and service systems. The pressure may change abruptly during operation. Another parameter is process kinetics, including centrifuge, pumping, and pipe turbulence impacts.

Fuel may experience pressures ranging from a 5 psi vacuum to 50 psi positive pressure.

[2] Source: ASHRAE 1997 Fundamentals, Outside Air Temperatures at 99.6 percentile

Fuel pressures in the storage tanks will be atmospheric. Fuel pressures in the piping will range from about a 5 psi vacuum on the suction side of the transfer pump (or engine fuel pump) up to about 50 psi on the discharge side of the transfer pump. These are the pressures likely to be seen by fuel returning to the tanks from the engine(s) or moved during transfer operations. Fuel pressures noted aboard ***Tillikum*** ranged up to 41 psi.

Recommendation: No additional pressure measurements are recommended unless laboratory trials dictate otherwise.

1.4. Storage time

Biodiesel is less stable than conventional diesel. For example, the National Biodiesel Board (NBB) recommends that B20 be used within six (6) months. As biodiesel ages in storage, the acid number tends to increase and then goes “out of spec”. Under marine conditions (such as increased moisture level, temperature change, and exposure to oxygen, etc.) biodiesel may be less stable in a WSF vessel than neat biodiesel in land storage for production and transportation.

Storage or dwell time aboard the ferries may be retrievable from the fuel logs, if they are still available. Consideration should also be given to the expected level of mixing of “fresh bunkers” which are loaded into “remaining bunkers.” The vessel can inform the team of typical ratios of fresh bunkers to remaining bunkers.

1.4. Exposure to oxygen (air)

Biodiesel oxidation can lead to high acid number, high viscosity, and the formation of gums and sediments resulting in filter clogging. In biodiesel, the higher the level of unsaturated fatty acids, the more likely it is that fuel will be oxidized. The points of unsaturation on the biodiesel molecule can react with oxygen, forming peroxides that break down into acids, sediments, and gums.

Keep in mind that “tank breathing” as described above may be constantly replenishing the oxygen supply. Therefore the biodiesel blended fuels are constantly exposed to oxygen in the WSF fuel system.

Measuring oxygen content in the ullage space as a function of time can provide information on the rate of oxidation.

1.5. Biological Parameters

Bacteria and mold may grow if condensed water accumulates in the bottom of the WSF fuel tank. This bacteria and mold may use biodiesel and diesel hydrocarbons as a food source. They then may grow as film or slime in the tank, and accumulate as sediment. These hydrocarbon-degrading microbes often have a reddish orange color and tend to form mats. The slime and sediment might break loose and accumulate in the fuel filter, resulting in the clogging problem. The bacteria and mold can be detected if the samples are available.

Biocides may kill the bacteria and molds growing in the fuel tank without interfering with the engine operation. The biocides can also inhibit the growth of microbes over long periods of time in very low concentrations. It is noted that biocide products typically are very toxic.

Additional consideration:

1. After years of use with petroleum oil there is expected to be significant deposits in the fuel tanks. Biodiesel users have noted significant fallout of these deposits due to the aggressive natural solvent properties of the biodiesel.
2. Iron oxide or rust can also have a catalytic effect on the oxidation of the biodiesel.
3. If the biodiesel contained large amounts of water or was not properly separated in the wash stage of the production process it would increase the risk of emulsion in the fuel tanks.
4. Because of the biodiesel’s affinity to water it is not necessary to see free water in the fuel before forming emulsions. The fuel must be tested regularly to determine water content.

It is noted that biodiesel fuel is not simply stored in a tank on a marine vessel. It is transferred into a storage tank -- in the case of WSF, from a tanker truck. It is therefore subject to sloshing while in the storage tank. It is then transferred from the storage tanks into fuel oil day tanks through purifiers, pumps, and filters. It is pumped at pressure through service piping through filters, hoses and engine equipment, with some fuel returning to the fuel oils day tanks. In this way, environmental conditions under which the biodiesel is used in the ship are not simply weather dependant, but are also impacted by the processes inherent with marine vessel operations.

2. Material Compatibility

Biodiesel may have adversely impacted natural and nitrile rubber seals in the WSF vessel fuel system. In addition, brass, bronze, copper, etc., may be oxidized due to contact with biodiesel, thereby creating metal sediments.

Material compatibility is also significantly affected by other conditions such as flow temperature, contact time (i.e., when passing through a pipe or hose at velocity), flow turbulence, flow pressure and electrical bonding.

2.1. Fuel Storage Tank Materials

The fuel storage tanks and fuel day tanks on all three vessels under consideration for this test program have uncoated mild steel fuel tanks. The tanks are likely original steel, and therefore at least 25 years old (*M/V Issaquah*) to 50 years old (*M/V Tillikum/Klahowya*). Biodiesel is known to have good solvent properties, which will likely remove anything left on the bulkheads of the fuel tanks. Any substances removed from the tank bulkheads will end up passing through the purifiers and filters, likely requiring accelerated purifier cleaning intervals and increased filter replacements due to clogging.

Recommendation: The fuel tanks should be thoroughly decontaminated prior to introducing biodiesel into the vessels. Tank cleaning protocols will be developed as part of the ongoing work.

2.2. Fuel System Piping Materials

The majority of the fuel system piping materials on all three vessels is as follows:

- Piping - ASTM A53 or A106 carbon steel, uncoated.
- Pipe Fittings – ASTM A234 carbon steel and/or ASTM A197 malleable iron.
- Valves – ASTM A395 nodular iron, ASTM A126 cast nodular iron and/or ASTM A216 cast steel.

- Valve trim – bronze (ASTM B61), aluminum and/or stainless steel (ASTM A312).
- Gasket material – unknown – assumed to be Cloth Inserted Neoprene.

As discussed above, biodiesel is known to have good solvent properties which will likely remove anything on the interior of the piping. Any substances removed from the piping will end up passing through the purifiers and filters, likely requiring accelerated purifier cleaning intervals and increased filter replacements due to clogging. Biodiesel also increases the rate of oxidation, and could cause accelerated wastage in piping.

Recommendation: Increase monitoring of the differential pressure gages at the filters indicating clogging, and decrease purifier cleaning intervals until foreign particle presence is diminished. The frequency of inspection and thickness gauging of fuel piping may have to be increased if biodiesel blends are adopted on a fulltime basis.

2.3. Fuel Transfer Pump Materials

The fuel transfer pumps are primarily cast iron construction with elastomer-based seals. As discussed above, biodiesel is known to have good solvent properties, which will likely remove anything on the interior of the pumps. Any substances removed from the pumps will end up passing through the purifiers and filters, likely requiring accelerated purifier cleaning intervals and increased filter replacements due to clogging.

Recommendation: Increase monitoring of the differential pressure gages at the filters indicating clogging, and decrease purifier cleaning intervals until foreign particle presence is diminished. Check transfer pump seals regularly.

2.4. Main Engines – Electro Motive Diesel (EMD) – M/V Tillikum/Klahowya

EMD representatives have an internal presentation for their sales staff discussing the use of biodiesel in the EMD 12V645 F7B main engines. That presentation is included as an attachment to this report (please note the proprietary nature of these materials). The report is developed for the locomotive industry (which is 95% of EMD's business), but is applicable to the WSF vessels.

Separately, WSF is reported to use Aeroquip FC234 hoses in the fuel systems on all engines. These hoses are not fully compatible with biodiesel and may experience premature failure. There is no known replacement for these hoses bearing U.S. Coast Guard (USCG) approval.

EMD concerns:

- Fuel water retention and stability when stored.
- Compatibility with elastomers (seals and hoses).
- Injector tip and injector pump wear.
- Plugged fuel filters.

Recommendation: Obtain EMD's assistance in monitoring engine performance and engine component performance during the duration of the test.

EMD recommends:

- Inspect seals and hoses regularly – replace as necessary.
- Monitor lube oil condition.
- Monitor fuel and lube oil filter condition closely.

2.5. Main Engines – General Electric (M/V Issaquah)

The local General Electric diesel engine representatives have been contacted repeatedly, but have not yet responded with manufacturer's published information on the compatibility of the GE FDM12 main engines with biodiesel and biodiesel blends. The GE engines serve the same primary locomotive industry as does EMD. It is likely these engines face similar concerns and issues. Until we receive other information, our recommendations will be the same as for the EMD engines.

Separately, WSF is reported to use Aeroquip FC234 hoses in the fuel systems on all engines. These hoses are not fully compatible with biodiesel and may experience premature failure.

Recommendation: Until other information is received, recommendations will be the same as for the EMD engines.

- Inspect seals and hoses regularly.

- Monitor lube oil condition.
- Monitor fuel and lube oil filter condition closely.

2.6. Auxiliary Engines – Detroit Diesel (all three vessels)

The local Detroit Diesel engine representatives have been contacted and supplied Reference 5 with information on the compatibility of the Series 60 auxiliary diesel engines (ship service generator engines) with biodiesel and biodiesel blends. Detroit Diesel does not approve the Series 60 engine for biodiesel blends of over B5. In discussing modifications/conversions for biodiesel operation at higher blend ratios, among the most significant measures is to check engine lube oil for compatibility with biodiesel. In addition, the engines should also be expected to produce approximately 8-10% less output than on petro-diesel.

Separately, WSF is reported to use Aeroquip FC234 hoses in the fuel systems on all engines. These hoses are not fully compatible with biodiesel and may experience premature failure.

Recommendation:

- Check engine lube oil for compatibility with manufacturer's recommendations – change lube oil type if necessary.
- Monitor engine load to make sure engines are not overloaded.
- Inspect seals and hoses regularly.
- Monitor lube oil condition.
- Monitor fuel and lube oil filter condition closely.

Contract No. 200700001

Washington State Ferry Biodiesel Project (Task II C)

Revised Laboratory Research Report

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Appendix D: Laboratory Research Report

Summary

The purpose of this lab test is to provide technical support for the 2008 biodiesel fuel test. In current lab tests, the effects of biodiesel quality were studied, including minor compounds, water content, and temperature, on precipitate formation, which could lead to fuel filter clogging. The insoluble particles (precipitates) in B20 are formed under certain conditions. Laboratory tests showed that clogging precipitates can be formed in the presence of water. Incubation at warm temperatures, such as 38^{o}C, favored the precipitates formation. However, the composition of the precipitate is not currently clear and requires further research. It was also attempted to simulate the centrifugal fuel purifier on the WSF by running B20 and a combination of B20 and water through a centrifuge. This was an attempt to replicate the "butterscotch pudding type material" observed in the 2004 test. However, the tests have not resulted in the production of any butterscotch pudding type material such as that noted during the 2004 test. No difference was found between biodiesel produced from soy or canola. Varying water content, flow rate, temperature, etc., also did not show any emulsions like those observed in 2004. A thin milky emulsion inside the centrifuge was observed under some conditions but it was not stable and it broke down as soon as it was to be collected.

It must be pointed out that the lab results in this report are based on the information and knowledge the project team currently has. As the research progresses, new lab tests may be proposed to reflect and build on what has been learned.

Laboratory Research on Identifications of the Causes of Clogging

1. Biodiesel suppliers for the B20 blend

This test started with biodiesel from three different suppliers. Considering that soybean and canola are the two dominant feedstocks, this test focused on them. The soybean biodiesel was obtained from Renewable Energy Group (REG, or as previously named, West Central Soy) which also supplied the biodiesel for the 2004 ferry fuel test. The canola biodiesel was obtained from Imperium Renewables (IR) in Washington State. The samples from both biodiesel suppliers met current ASTM D6751-07a specifications. Another soybean biodiesel was obtained from the University of Georgia. This soy sample had high contents of diglycerides and triglycerides (data shown in Table 2 below). Therefore, this soybean biodiesel sample was not used in further tests.

1.1 Experimental procedures

Blending the two biodiesel samples separately with #2 ultra low sulfur diesel (ULSD) from local Busch Distributors was done in the lab to produce B20 with total volume of 3.5 liters. Water was not added to the B20 samples. After mixing, the B20 samples were settled under two temperatures, that is, either room temperature (about 25 ^{o}C) or 38 ^{o}C which could be achieved in the Ferry system. These samples were aged overnight to ensure temperature equilibrium. Then the samples were filtered by passing them through Whatman glass microfibre filter (934-AH with pore size of 1.5 μm) under vacuum.

1.2 Results and discussion

Observations were made in terms of precipitates and filtration. Figure 1 shows the pictures of soy B20 and B100. Both samples are clear solution, and they can easily pass through the filter, suggesting no clogging problem.

Figure 1 (a) Soy B20 Soy without water

Figure 1 (b) Soy B100 without water

The canola samples have also shown the clear solution obtained above, with the same indication of no significant precipitates formed.

2. Effect of minor compound content in the B20 blend and temperature

Recently, the Archer Daniels Midland (ADM) reported that minor components, such as monoglycerides (MG), sterol glucosides (SG), soaps, and water, affected the cloud point (CP) and filterability of the biodiesel after a cold soak treatment (Biorenewable Resources No. 4 in September 2007). MG and soaps or water in combination with MG had significant impact on CP. SG did not have a negative effect on CP. However, the filter test response was particularly sensitive to SG and soaps. The effect of MG concentration was much less dramatic. Water negatively affected the filterability of the tested fuel. Interactions between water and other components were suggested but not conclusive. The mechanism of these interactions needs further investigation.

In our lab tests, B20 was used rather than B100 as reported by ADM since the ferry used B20 in the 2004 test. The effects of the minor compounds on the filter performance were studied using the two biodiesel samples containing different levels of the minor compounds. In addition, during the operation process in the ferry, the biodiesel blends might absorb water from air, and water also enters the fuel through condensation, causing an increase of water content in the fuel. The water in the B20 blend may exacerbate the formation of precipitates, causing filter clogging. Temperature could also affect the precipitate formation. The effects of water and temperature on precipitate formation were investigated in this test.

2.1 Experimental procedure

The experimental procedure was similar to that described in section 1.1. The differences were water addition and temperature control. Water in concentration of 0.1 % (v/v) was added into the soy and canola B20 samples since the B20 would be saturated at this level of water. After mixing, the B20 samples were settled in a 38 ^{o}C oven overnight. In the morning, the oven was turned off and the oven door was not opened, so that the temperature decreased slowly. It took several hours to cool down to room temperature. After that, the samples were filtered by passing through the Whatman filter under vacuum.

2.2 Results and discussion

The excess water can be observed in the bottom of the bottle, suggesting that the B20 was saturated with water in concentration of 0.1 % (v/v). Figure 2 shows the soy B20 samples. The soy B20 sample in the presence of water looks cloudy (Figure 2(b)) after incubating in 38^{o}C, as compared with the clear sample (Figure 2 (a)) without 38^{o}C incubation.

Figure 2 (a) Soy B20 without 38 ^{o}C incubation

Figure 2 (b) Soy B20 with 38 ^{o}C incubation

However, the canola B20 samples did not look much different. Figure 3 shows the canola B20 samples. Figure 3 (a) and Figure 3 (b) did not appear significantly different.

Figure 3 (a) Canola B20 without 38 ^{o}C incubation

Figure 3 (b) Canola B20 with 38 ^{o}C incubation

The clear soy B20 turned cloudy, suggesting some insoluble materials formation. In order to reflect this change, absorbance or scattering was measured at 700 nm using a spectrometer. The 700 nm was selected because both the soy and canola biodiesel and the diesel do not have any absorbance at this wavelength. Thus the original B20 did not have the absorbance at 700 nm. The change of absorbance or scattering could come from the insoluble suspended particles in the samples. Table 1 below shows the absorbance or scattering for the B20 samples. Only the soy Sample (TZ-B2-3#) studied here and shown in Figure 2 (b) had a significant change of the scattering of 0.198, suggesting that the light at 700 nm was scattering by the particles from the cloudy soy B20 sample. This scattering result indicated the particles formed only in the presence of water and incubation at 38 ^{o}C. This sample was also observed under a microscope and the particles can be found. However, particles could not be found from other clear samples under the microscope.

Table 1 Absorbance or scattering at 700 nm for the B20 samples.

B20 Sample ID	Biodiesel stock	Water (% v/v)	Incubation at 38 ^{o}C	Absorbance or Scattering
TZ-B2-9#	Soy	0	No	0
TZ-B2-1#	Soy	0	Yes	0
TZ-B2-10#	Soy	0.1	No	0
TZ-B2-3#	Soy	0.1	Yes	0.198
TZ-B3-1#	Canola	0.1	No	0
TZ-B3-3#	Canola	0.1	Yes	0

In order to determine whether these samples can cause filter clogging problems, filtration experiments were also conducted. All the canola B20 samples can pass through the 1.5 μm filter without any problems, suggesting the canola sample studied did not lead to the filter clogging. However, the cloudy soy B20 had significant filter clogging. This soy B20 could pass easily through the filter at the beginning, and gradually became difficult as more liquid passed through the filter. The filter was shown to have a significant clogging problem after passing through about 2.5 liters of the soy B20. Therefore the particles in this sample would result in filter clogging.

Identification of the particle composition from the filter was investigated. The insoluble precipitates from the filter paper appeared to dissolve in methylene chloride (CH_2Cl_2), but did not dissolve well in either methanol or chloroform ($CHCl_3$). The precipitates dissolved in methylene chloride were analyzed using GC at the University of Idaho, in comparison with B100 and diesel used. Figure 4 shows the GC results. Figure 4 (a) shows the precipitate results. These precipitate peaks appeared differently from those of the soy B100 (Figure 4 (b)) and the diesel (Figure 4 (d)). These results suggested that the precipitate composition is much different from either the soy biodiesel or the diesel.

However, the precipitate composition could not be determined from these Figures. Further research, such as analysis using FT-IR, and GC/MS, *etc*., is needed to identify the precipitate composition.

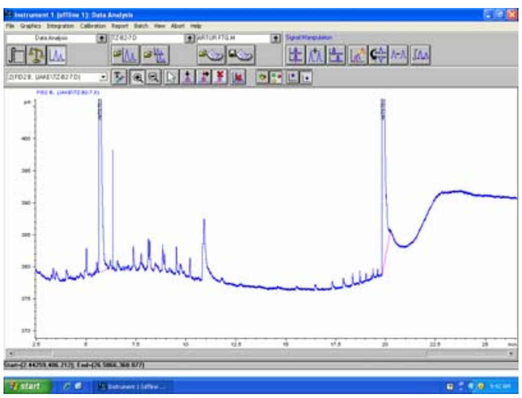


Figure 4 (a) Precipitates dissolved in CH_2Cl_2 from soy B20

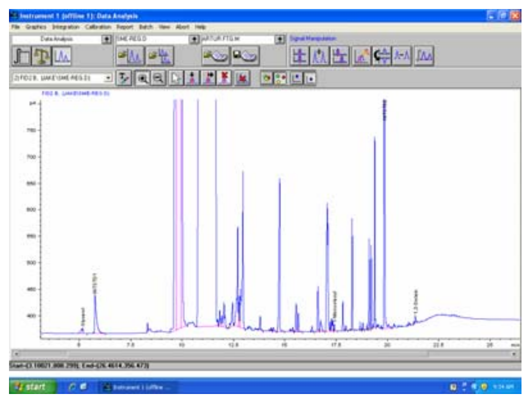


Figure 4 (b) Soy B100 used for B20

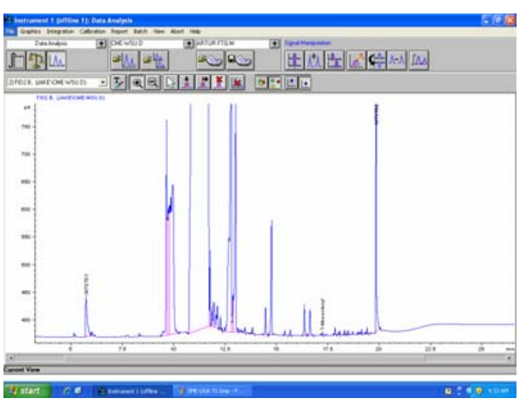


Figure 4 (c) Canola B100 from Imperium Renewable

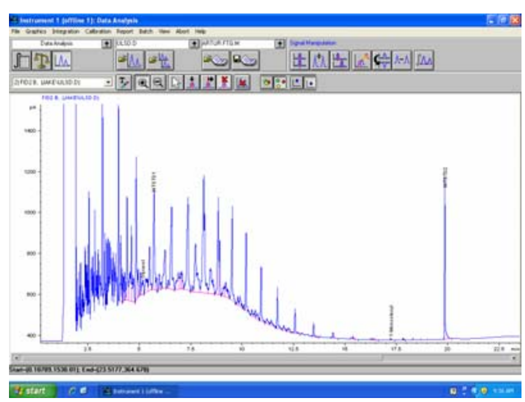


Figure 4 (d) ultra low sulfur diesel used for B20

However, some minor compounds were able to be determined by this GC analysis. Table 2 shows the results of the B100 samples. Comparing the soy B100 with the canola B100 sample, the canola sample has lower contents of these minor compounds (such as glycerin, monoglycerids, and diglycerides) than those of the soy sample. The results for contents of the minor compounds suggested that the canola biodiesel has better quality than the soy biodiesel. However, the sterol glucoside content has not obtained. Sterol glucoside cannot be determined by this common GC analysis as it is a heavier compound. As reported by ADM, the minor compounds combined with water may form precipitates which results in filter clogging. In the tests reported, water was added into the B20 samples. The soy sample tended to form the precipitates by the minor compounds with water under certain conditions. The canola sample was not able to form precipitates because of the low content of the minor compounds.

Table 2 Composition of some minor compounds in the B100 samples

Sample	Free glycerin (% w/w)	Total glycerin (% w/w)	Monoglycerids (% w/w)	Diglycerides (% w/w)	Triglycerides (% w/w)
CME–IR [1]	0.004	0.0205	0.0636	0	0
SME-REG [2]	0.01	0.1510	0.528	0.0284	0
SME-UGA [3]	0.00007	0.1824	0.5136	0.2538	0.1102

* 1: CME-IR was the canola B100 from Imperium Renewables;
2: SME-REG was the soy B100 from REG;
3: SME-UGA was the soy B100 from the University of Georgia.

It should be noted that it is not concluded that canola biodiesel can form the precipitates while soy biodiesel is not able to form the precipitates. Biodiesel origin may not be a dominant factor on the precipitate formation, although soy oil may contain higher sterol glucosides than canola oil. Contents of the minor compounds remaining in biodiesel are dependant on both feedstocks and the production process. Soy biodiesel may have very low content of sterol glucosides because the sterol glucosides are removed during production. Thus it may be focused on content of the minor compounds in biodiesel rather than the biodiesel origin.

3. Incomplete tank cleaning

It is very difficult to simulate ferry tank cleaning conditions. While it was planned to do a pilot ferry dock-side test of this hypothesis during November 2007, the test was cancelled due to the ferry being unavailable. So, this hypothesis will be evaluated in the 2008 fuel test.

4. Biodiesel oxidation stability

Oxidation stability is one of the most important properties of biodiesel. As this project progresses, more information is obtained on biodiesel application and the WSF systems, including operating conditions. It is believed that biodiesel oxidation may not have significantly contributed to the filter clogging in the 2004 test. Dr. Steve Howell, a reviewer of the 2008 work plan, has supported our statement of oxidation stability. A simple test was also performed to confirm oxidation stability. A B20 sample was exposed to air for more than a week. This sample remained in a clear solution without any significant change. The sample also can easily pass through the filter, suggesting that the oxidation may not be a cause for the filter clogging problem.

5. Centrifuge tests with B20 with CME and SME (University of Idaho)

Test Set-up:

ULSD and off-road diesel from Busch Distributors was blended with CME from Imperium and SME from REG to a B20 blend, and water was added at varying percentages in a 10 gallon vessel. A mixer paddle driven by a Dayton gear motor rotating at 100 rpm was mounted in order to keep the water mixed. A Cole-Parmer Easy Load II peristaltic pump with #6401-24 tubing was used to feed the centrifuge at varying rates from 500 to 1500 ml/min. The inlet tubing to the pump was positioned near the bottom of the vessel. The centrifuge was an Alpha Laval model WSB 103B-74-60 using 55 disks, running at a bowl speed of 8600 rpm. Two sets of disks were used. Disk set 1 had the flow holes in the middle of the skirt while disk set 2 had the holes near the bottom of the skirt. Both light and heavy phase outlets were directed back into the vessel for recirculation. During cold temperature trials, the 10 gallon vessel was placed outside and an additional peristaltic pump was employed to transfer the output from the centrifuge back to the cold environment. Initial tests were 4 hours in duration and subsequent tests were terminated at 2 hours.

Testing protocol:

B20 – no water – no prime

Vary Flow Rate – 500, 1000, 1500

Temperature – Ambient, 10 C and 60 C

Water – 1, 2, 3 and 5%

Catalysts – 0.1% (16 grams per 5 gal of fuel) iron oxide, salt, soap, dye (used in off-road diesel)

High Temp trial: 500 ml/min, 2% H2O, 60 C – used barrel heater w/ temp control.

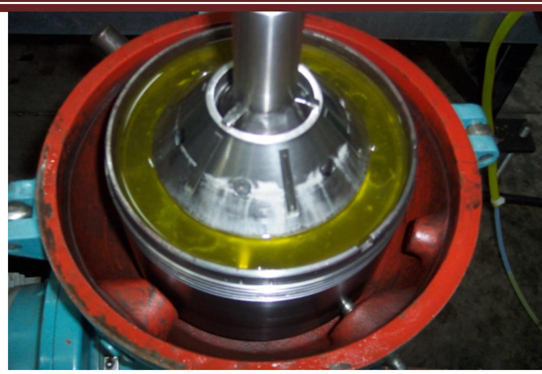
Teats with CME:

The first test with CME B20 with 1% water and at a flow rate of 1000 ml/min at 24°C produced a little sludge in the solids basket but was never repeated. The sludge is believed to be formed by residue from the centrifuge, lines and mixing vessel that were dissolved and subsequently spun out.

Subsequent testing with CME B20 at water contents of 2 and 3 % water and flow rates of 500, 1000 and 1500 ml/min at 24°C consistently produced whitish flakes of fuel/water emulsion in the bowl and between the disks. This flakey emulsion was weak and tended to break up upon disassembly. Light phase output was always clear and bright using disk set 1.

Tests with SME:

SME B20 tests were conducted in the same manner starting with 1% water, then 2 and 3% with flow rates of 500, 1000 and 1500 ml/min at 24°C. The same results was experienced as with disk set 1. At 3% water the KF moisture of the light phase output was 105 ppm @ 500 ml/min, 110 ppm @ 1000 ml/min, and 113 ppm @ 1500 ml/min at the 3% water loading.



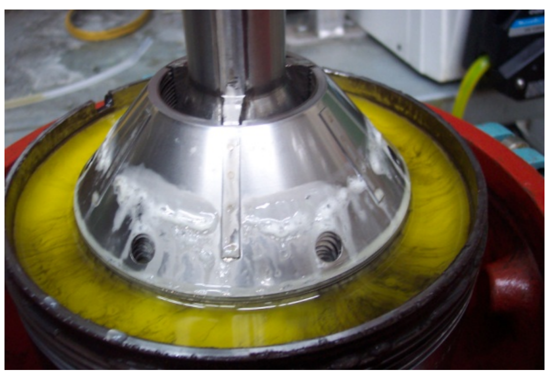
Disk set 2

The light phase output was cloudy at 1500 ml/min, not at 500 and 1000 ml/min flow rates. A similar flaky emulsion was found as before on disassembly. With this set of disks, the fuel must travel farther into the water interface before exiting.

Cold trials:

1. Temp 10°C SME B20, 5% water, Disk set 2

A similar but more pronounced emulsion was found upon disassembly, possibly due to the colder temperature. After a short period of time the emulsion dissolved and appeared to be about 90% to 95 % water with the remainder being fuel. Light phase was very cloudy at 1500 and 1000 ml/min and slightly cloudy at 500 ml/min, however, they all cleared up on heating.



2. Temp 8°C, SME B20, 3% water, Disk set 1

A light emulsion was found on the disks at the phase interface; this was much less than was noticed in the previous trial. It is believed that the holes in disk set 2 are positioned more optimally for this type of separation. Light phase was clear from all three flow rates after slight warming.

SME B20 without water and without priming the centrifuge:

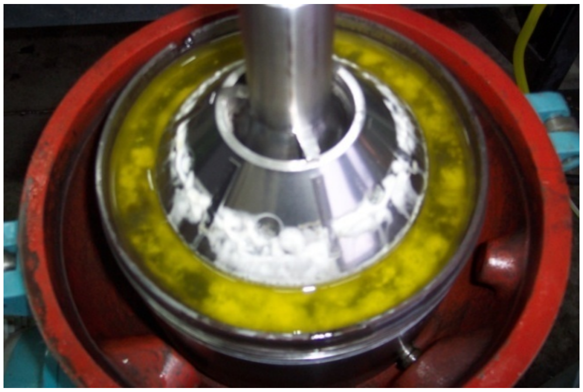
This was done at ambient temperature and at 1000 ml/min flow rate. The fuel exited the heavy phase outlet. Diesel fumes were very heavy in the room after an hour of running. Upon disassembly, the fuel was clear and the disk stack and bowl were very clean.

Elevated temperature run:

SME B20 with 2% water and centrifuge primed, disk set 1. Fuel temperature was 60°C, flow rate was 500 ml/min. Light phase output was clear. Fuel in the bowl was clear and there was a slight hint of whitish emulsion on the disks.

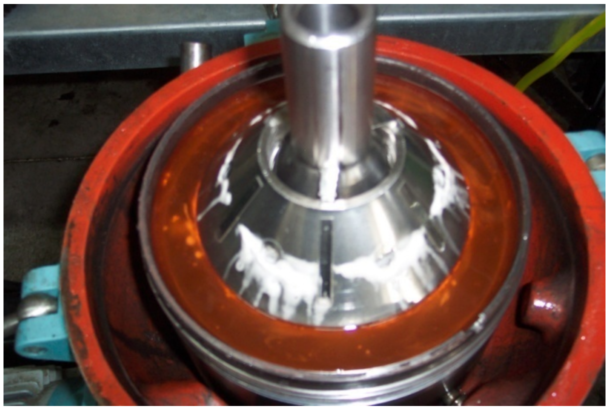
Catalyst trials:

1. SME B20, 5% water, disk set 1, ambient temperature, 1000 ml/min flow rate and 0.1% salt. A fair amount of white emulsion was noted floating in the bowl and between the disks in the area of the phase interface. Light phase output was clear.



2. Same as previous test with 0.1% soap added with the salt. Similar outcome, however, surprisingly there seemed to be a little less emulsion than the previous test.

3. SME B20, off-road diesel, 2% water, disk set 1, ambient temp, 1000 ml/min. Similar result as before with a white emulsion ring on the disks.



4. SME B20, off-road diesel, 3% water, disk set 1, ambient temp, 1000 ml/min, 0.1% salt and 0.1% iron oxide. This combination, although the emulsion on the disks was not significant, did create a semi-gelatinous sludge in the bowl. This was an emulsion of mostly water that broke down after a period of time.

A series of tests with soy and canola B20 blends with ULSD and off-road diesel were run with several contaminants such as water, salt, soap and iron oxide, alone and in combination. The water content was varied from 2 to 5%, the flow rate was varied from 500 to 1500 ml/min, and several different temperatures were used as well. The salt, soap and ferric oxide were added at 0.1% by weight. Under most conditions we saw a milky unstable emulsion on the centrifuge disks around the area of the phase interface. This emulsion was about 95% water and broke down over a short period of time after the disk stack was pulled out. A test with iron oxide and salt produced a pudding-like product in the bowl. It is not clear at this point how similar it was to what was found in the 2004 ferry trials. It was able to be collected with a spoon but broke down over a short period of time.

6. Multiple factors for the clogging problems

The lab tests above have included multiple factors, such as minor compounds including water content, and temperature, and centrifuge process using B20.

It is planned to do more lab tests. These lab tests include evaluating minor components and growth of microbes. WSU will investigate the minor components for the filterability. Statistically designed experiments will be developed to study the influence of sterol glucosides (SG), soap, water and temperature on the filterability. B20 will be used for these tests rather than B100, which has been reported by ADM. Considering the operating conditions of the ferry, the lab tests will cover temperatures up to 120°F, up to 100% relative humidity. Compared with the tests conducted previously, the new tests will consider the combined impact of different factors.

UI may do some extra testing involving growth of microbes. To actually develop a sample of fuel that is contaminated would take some time, however, UI may be able to get a sample of algae or yeast from the microbiology department and mix it with some fuel and then see what happens when we centrifuge it out. It might produce a material that is similar to the butterscotch pudding seen in 2004.

These new lab tests will further narrow down the possible clogging causes for the 2004 tests. As described, some precipitates were obtained from the B20 under certain conditions. This result suggested that the minor components in the fuel might contribute to the precipitate formation. Further tests on this topic will provide more evidence to support this potential cause.

Conclusions and Recommendations

The precipitates from B20 could be formed in certain conditions, although the biodiesel studied met the current standard specification. Multiple factors, including biodiesel quality, minor compounds, and temperature affected the precipitate formation. Precipitates were obtained from the soy biodiesel blend B20 tested. The canola biodiesel blend B20 studied did not precipitate. The precipitates from soy were formed in the presence of water, and high temperature, such as 38 ^{o}C, favored precipitate formation. The precipitates obtained would lead to the filter clogging problems.

The centrifuge tests using B20, while varying water content, flow rate, temperature, etc., have not been able to result in any butterscotch pudding type material like that noted during the 2004 test. No difference was found between the two types of biodiesels. A thin milky emulsion inside the centrifuge was observed under some conditions but it was not stable and it broke down as soon as it was about to be collected. Since a thick stable emulsion was not produced over the course of these tests, it would have to be concluded that the exact conditions that caused problems for WSF were not replicated, although the sludge formed with the addition of iron oxide may point to deposits coming from the walls of the vessel deep tanks. It is not known at this time what exact conditions were responsible, be they contamination by sterols, algae, tank deposits or a combination of things, however, our recommendation would be to continue on as planned with the phase-in of biodiesel testing on the ferries themselves.

It was also recommended to do an additional test in the biodiesel specification for the 2008 fuel test based on the lab research results above. This test is described below.

Additional testing

(1) Sample preparation

One gallon of B20 sample will be made using the testing biodiesel of 0.2 gallon with #2 ultra low sulfur diesel of 0.8 gallon. Water in concentration of 0.1 % (v/v) will be added to the B20 sample as the B20 would be saturated at this level of water. After mixing, the B20 samples will be settled in a 38 ± 1 ^{o}C oven overnight. Then the oven will be turned off. The oven will not be opened until the sample reaches room temperature (about 25 ^{o}C). It is noted that the temperature is allowed to decrease slowly in order to incubate precipitate formation. It is better to cool down overnight to room temperature.

(2) Evaluation of the B20 sample

This B20 sample should pass two types of tests described below.

(a) Absorbance or scattering test

The B20 sample should look like a clear solution the same as the original B20 in the absence of water and without the 38 ^{o}C incubation. In addition, absorbance or scattering at 700 nm will be measured with water as a blank. The absorbance should be zero if no suspended particles are formed.

(b) Filtration test

The B20 sample will be filtered by passing through a Whatman glass microfibre filter (934-AH with pore size of 1.5 μm) under vacuum. This one-gallon B20 sample should pass through the 1.5 μm filter without any problems if no insoluble particles are suspended and present in the solution. However, if a cloudy sample is obtained, the cloudy B20 sample could lead to significant filter clogging.

In conclusion, the biodiesel used for the 2008 fuel test must meet current ASTM D 6751-07a standard specification and should pass the additional testing described above without any filter clogging problems.

Work Plan for Washington State Ferry 2008 Biodiesel Test

February 5th, 2008

By

Washington State University
The University of Idaho
The Glosten Associates, Inc.
Imperium Renewables, Inc.

Appendix E: Work Plan for 2008 Biodiesel Test

Part 1. Introduction

The Washington State Ferry (WSF) system conducted a pilot biodiesel fuel program in 2004 over a period of several months using a B20 biodiesel blend. This test and program was not successful in that excessive clogging problems occurred in the ferries' fuel purifiers and fuel filters. WSF is potentially one of the largest consumers of biodiesel fuel in the Pacific Northwest region, and problems experienced by WSF may impede efforts to expand the use of biodiesel products in marine and land-based fleets. To address the problems facing biodiesel application in the ferry systems, the U.S. Department of Energy (DOE) awarded a grant to Puget Sound Clean Air Agency to perform a two year scientific study to determine appropriate fuel specifications and fuel handling procedures for using biodiesel blended fuels in WSF operations, with the results expected to be directly transferable to other marine applications as well as beneficial to land-based end-users. The first year of the study has focused on information gathering and development of a work plan while the second year will be devoted to testing the knowledge gained in year one by conducting biodiesel blended fuel tests on WSF vessels. Washington State University (WSU) was selected to lead a research project team to conduct the project. The team members include the University of Idaho (UI), Imperium Renewables, Inc (IRI), and Glosten Associates.

This document has been developed as the work plan for the biodiesel blended fuel tests on WSF vessels during the second year (2008). It consists of the following parts:

Part 1: Introduction and roles and responsibilities
Part 2: Summary of the key findings of the project from year one
Part 3: Overview of the test plan
Part 4: Sampling procedures and measurements
Part 5: Trouble-shooting procedures
Part 6: Incident report and notifications
Part 7: Fuel specifications
Part 8: Vessel preparation (including tank cleaning procedures, vessel modifications for shipboard monitoring & sampling)
Part 9: Appendices 1, 2, 3, 4 and 5

The first draft of this plan was completed on December 19, 2007 and was sent out for review and comments. Since then: (1) many valuable comments were received from the external reviewers, (2) additional lab research has been provided for more information; and (3) extensive discussions among the project team have lead to a clearer course of action. As a result, the earlier version was significantly revised to reflect these advancements. This version will serve as the final plan although it is recognized future changes may be necessary as the test progresses. Deviations from this plan need to be communicated via-mail to the research team and approved by the Project Lead (WSU).

This complex, multi-disciplinary project requires clear delineation of roles and responsibility to facilitate direct and efficient communications. The roles and responsibilities of all project participants are specified in the Table 1 below according to the contract.

Appendix E: Work Plan for 2008 Biodiesel Test

Table 1 Roles and Responsibilities of Involved Parties and Communication Protocol

Organization	**Roles and Responsibility**
PSCAA	Project management, monitor contract issues and deliverables – Project Manager
WSU	Overall research project management and research team coordination, Project Lead
	Meeting and telephone conference coordination, and immediate assistance
	Lab analysis for certain parameters of precipitates
	Additional lab research
	Tracking the analytical results of analyzed samples
	Documenting information for final report
	Trouble-shooting analysis and recommendations
UI	Trouble-shooting and recommendations
	Receive samples and conduct related analysis
	Conduct additional research deemed necessary
Glosten	Assist WSU in monitoring the fuel test and provide technical assistance, trouble-shooting and problem solving to WSF during the fuel trials
	Provide personnel to monitor operational procedures, and collect samples or obtain data in accordance with the Final Fuel Test Work Plan
	Submit incident reports to WSU and the Project Manager.
	Collecting, labeling, packaging and shipping fuel samples to a sample storage center or laboratories designated by the Project Manager
	Additional sampling and data collection may

	also be required as needed
Imperium Renewables	Provide sampling containers
	Assist with lab analysis if needed
	Provide biodiesel processing related information
WSF	Monitoring and reporting problems, on board sample collection and storage

Part 2: Summary of the key findings of the project from Year One

Main tasks completed in Year One include: (1) a comprehensive literature review; (2) development of a 2004 fuel test report; (3) laboratory research; and (4) completion of a marine environmental compatibility assessment. These tasks, along with the comments from four external reviewers, provided important new information that serves as the basis for the development and revision of this plan. These findings are summarized below:

- The literature review suggested that several factors, including *water content*, *temperature*, and *oxidation*, could affect biodiesel quality. From this review, along with consideration of the actual operational condition, the research team has narrowed down the hypotheses for the types of possible causes of clogging problems that may have occurred in the 2004 WSF Test.

  1) Analysis suggests that biodiesel oxidation may **not** be a key factor in the clogging due to the limited availability of free oxygen, short times, and low temperature.

  2) Cold flow properties, as reflected by relatively high cloud and pour points, may limit B100 application under low temperature conditions.

  3) Biodiesel has a strong tendency to absorb moisture due to its chemical properties, providing a negative factor to biodiesel application in the high humidity marine environment. "Sterol Glucosides" could form precipitates which agglomerate over time into flocks and sediment, probably leading to clogged filters. The sterol glucoside content can vary from supplier to supplier based on both the biodiesel origin and the form of process technology.

  4) Actual operation tests have shown that tank cleaning is an important factor necessary for effective problem-free biodiesel operation.

- Laboratory tests have provided additional technical information that is useful for the 2008 biodiesel fuel test.

  1) In current laboratory tests, we have studied the effects of biodiesel quality, including minor compounds, water content, and temperature, on precipitate formation, which could lead to filter clogging. The tests confirmed that insoluble particles (precipitates) in B20 are formed under certain conditions and in particular in the presence of water. Incubation at warm temperatures, such as 38^oC, favored the precipitates' formation. However, the precipitate composition is not currently clear and requires further research.

2) We also simulated the fuel purifier on the ferries with a centrifuge, since the 2004 test showed a butterscotch pudding type material in the purifiers of the boats. The effect of the fuel purifier on formation of the butterscotch pudding type material was investigated with centrifuge tests using B20. However, the tests have not resulted in any butterscotch pudding type material such as that noted during the 2004 test. No difference was found between soy and canola based biodiesel. Varying water content, flow rate, temperature, etc., also did not show the production of emulsions like those observed in 2004. A thin milky emulsion inside the centrifuge was observed under some conditions but it was not stable and it broke down as soon as it was collected. It must be noted that the laboratory tests were unable to simulate the real ferry conditions. These preliminary results from the laboratories do not specifically identify the causes of the clogging problems in the 2004 test but do give additional insight for further hypothesis testing. More laboratory experiments are on-going to gain more information.

3) During the 2008 fuel test in Ferry systems, additional laboratory work will be continued to help understand the clogging causes. Recommendations will be made for further improving the 2008 fuel implementation based on the laboratory research.

- Reviewers for the draft work plan support the assertion that biodiesel oxidation may not play an important role in the clogging problems in the 2004 test.

  1) They pointed out the need for a thorough cleaning of the entire fuel system, including the tanks, before loading the biodiesel fuel. While we concur that system cleanliness is an important factor, operating schedules for the ferries may preclude aggressive fuel system cleaning before biodiesel is introduced.

  2) It was commented that a combination of certain minor compounds (monoglycerides, water, sterol glucosides, and soap) at particular concentrations could result in the potential for the formation of a precipitate above the cloud point that could clog filters or fall out of solution. This statement supports our laboratory results.

The main goal of this phase of the project was to provide recommendations for preventing the extreme filter clogging that occurred in the 2004 test. Since we were unable to mimic the unique operating conditions of the ferry in laboratory testing, the exact cause will have to be confirmed in the actual test with the ferry, should clogging occur again. The following description communicates the three possible causes and identified measures to deal with the problems if they occur.

Potential Cause 1 - Minor compounds form precipitates under unique ferry conditions

<u>Prevention measures</u>: (1) Biodiesel fuel to be used in the 2008 Ferry test must pass the cold soak filtration test as a specification requirement; (2) start with fuels containing a low content of the minor compounds through process or feedstock selection.

<u>Corrective actions if this problem occurs again</u>: (1) Recommend adding a desiccation process in the ferry system to prevent excess moisture entering the fuel, and taking any other measures to prevent water entering into fuel; (2) require distilled fuel; and (3) refine the laboratory tests to confirm the observations and devise alternative corrective actions. Glosten should investigate

what types of desiccant filters will work best for WSF application as well as cost, model #, and availability.

Potential Cause 2 - Tank deposits dissolved during the operation

Prevention measures: (1) thorough cleaning of the entire fuel system, especially the tanks.

Corrective actions if this problem occurs again: (1) soak B20 in the tank and re-circulate it by pump for a couple of days, prior to use. This process may allow the B20 to have enough time to dissolve the tank deposits. Samples will be taken regularly and their filterability will be characterized to determine whether the tank deposits have been removed and when the cleaning process is complete. Samples will also be taken for later analysis by inductively coupled plasma (ICP) at the University of Idaho to determine the chemical makeup of the deposits.

Potential Cause 3 – Micro-organism growth/microbial contamination

Prevention measures: (1) BQ 9000 certified biodiesel producers or marketers will be selected for the 2008 test. All B20 added to the ferries should be treated by ferry personnel with a commercial biocide. In addition, samples of the biodiesel blended fuel will be checked for microbial contamination during initial loading operations. Ferry operators are currently required to collect samples from the fueling lines during refueling. The samples collected during the first two refueling operations will shipped to UI for analysis to determine whether microbes are present.

Corrective actions if this problem occurs again: (1) additional commercial biocide currently used in the WSF will be added to fuel in the tanks.

Part 3: Overview of the test plan

There are three vessels available for the 2008 fuel test. Biodiesel from different feedstock sources and/or processing technologies will be tested in each. The fuel types are described below:

Fuel Type 1: Canola-based biodiesel

Fuel Type 2: Soy-based biodiesel

Fuel Type 3: Biodiesel with a high cloud point, such as recycled restaurant oil or animal fat based.

The strategy consists of three components: (1) starting with the scenarios with the highest likelihood of success based on the current knowledge on the potential cause of clogging; (2) increase the number of vessels in phases or steps so as to allow the research team to devise solutions if problems occur; and (3) push the limit using higher cloud point and/or higher percentage (such as B25, B30) of Fuel Types 1 and 2 after success in each step, to learn more and to maximize the value of the project.

Appendix E: Work Plan for 2008 Biodiesel Test

Our preliminary laboratory research results and additional information provided by the reviewers have suggested that biodiesel quality could be a major factor leading to precipitate formation, and consequently, resulting in the filter clogging problem even when the biodiesel studied met the current ASTM D 6751 standard specification. Therefore, Vessel #1 (Tillikum) will test biodiesel with a low content of minor compounds such as canola biodiesel processed via a distillation process. Vessel #2 (Klahowya) will test soy biodiesel. Vessel #3 (Issaquah) will test high cloud point biodiesel as well as higher percentages (such as B25, B30) of Fuel Types 1 and 2 if these fuels are tested successfully as B20 in Vessels 1 and 2.

Table 2 below shows the suggested test timeline for each vessel. It should be noted that the options marked with "*" will be implemented only if the test scheduled prior to it are successful. Also, this schedule can be adjusted according to the actual implementation situation.

Table 2 Proposed schedules for the 2008 fuel test in each vessel

Timeline	Vessel #1	Vessel #2	Vessel #3
February 2008	Clean tank B5 (Fuel Type 1) for four weeks		
March 2008	B10 (Fuel Type 1) from the week 5 for four weeks		
April 2008	B20 (Fuel Type 1) from week 9	Clean tank B 5 (Fuel Type 2) for four weeks	
May 2008	B20 (Fuel Type 1)	B 10 (Fuel Type 2) for four weeks	Clean tank B5 (Fuel Type 3) for four weeks
June 2008	B20 (Fuel Type 1)	B20 (Fuel Type 2)	B10 (Fuel Type 3) for four weeks
July 2008	B20 (Fuel Type 1)	B20 (Fuel Type 2)	B20 (Fuel Type 3)
August 2008	B20 (Fuel Type 2)* Or B20 (Fuel Type 1)	B20 (Fuel Type 2)	B20 (Fuel Type 3)
September 2008	B20 (Fuel Type 2) Or B20 (Fuel Type 1)	B20 (Fuel Type 1)* Or B20 (Fuel Type 2)	B25 (Fuel Type 1)*
October 2008	B20 (Fuel Type 2) Or B20 (Fuel Type 1)	B20 (Fuel Type 1) Or B20 (Fuel Type 2)	B25 (Fuel Type 1)*
November 2008	B20 (Fuel Type 2) Or B20 (Fuel Type 1)	B20 (Fuel Type 1) Or B20 (Fuel Type 2)	B30 (Fuel Type 2)*
December 2008	B20 (Fuel Type 2) Or B20 (Fuel Type 1)	B20 (Fuel Type 1) Or B20 (Fuel Type 2)	B30 (Fuel Type 2)*
January 2009	B20 (Fuel Type 2) Or	B20 (Fuel Type 1) Or	B30 (Fuel Type 2)*

	B20 (Fuel Type 1)	B20 (Fuel Type 2)	
February 2009	Program Review	Program Review	Program Review

Before the test, the fuel tanks of Tillikum will be cleaned in accordance with the procedure presented in Part 8 below. This will involve pressure washing the insides of the tanks and then wiping down the surfaces of the tanks to remove any residual water. The insides of the tanks should be photographed to document the condition of the surfaces.

The fuel to be used for the first four weeks will be B5. The concentration of biodiesel will increase to 10% for the fifth week and to 20% for the ninth and succeeding weeks. Records will be kept for the date on which refueling occurs, the amount of fuel, and the fuel type (e.g. B5, B10, B20, etc.).

Part 4: Sampling procedures and measurements

Adequate samples and proper sampling are key elements for the success of the project. There will be three types of samples collected during the test.

1) The first type is B100 samples which will be collected by the fuel supplier prior to blending taking place. The main purpose of this type of sample is to make sure that the fuel meets the required specifications.

2) The second type of sample will be the biodiesel blend samples taken at the time of fueling the vessel that will be collected by the vessel Chief Engineer or vessel PIC of the fueling operation. The purpose to these fuel samples collected on-board the ferry is to detect any changes in the blended biodiesel due to the operating conditions of the ferry. The first two types of samples will be collected regularly according to the schedule described in this plan.

3) The third type of samples will be taken only if clogging problems occur. These samples will be used for trouble-shooting and diagnosis so that the cause of the problem can be identified. During normal operations, frequent sampling of representative biodiesel blends is the main concern of the project team. Table 3 below shows the sampling frequency for these samples for each vessel during operation.

Table 3 Biodiesel blend sampling frequency for each vessel

Time from start of test	**Sample frequency**	**Biodiesel %**	**Notes**	**# of samples in storage**
Week 1	12 hours (A.M and P.M.)	5%		14
Week 2	12 hours (A.M.	5%		28

	and P.M.)			
Week 3	24 hours	5%	Dump A.M. samples from Week 1	28
Week 4	24 hours	5%	Dump A.M. samples from Week 2	28
Week 5	12 hours (A.M. and P.M.)	10%	Dump all samples from Week 1.	35
Week 6	12 hours (A.M. and P.M.)	10%	Dump all samples from Week 2.	42
Week 7	24 hours	10%	Dump A.M. samples from Week 5 and all samples from Week 3.	35
Week 8	24 hours	10%	Dump A.M. samples from Week 6 and all samples from Week 4.	28
Week 9	12 hours (A.M. and P.M.)	20%	Dump all samples from Week 5.	35
Week 10	12 hours (A.M. and P.M.)	20%	Dump all samples from Week 6.	42
Week 11	24 hours	20%	Dump A.M. samples from Week 9 and all samples from Week 7.	35
Week 12	24 hours	20%	Dump A.M. samples from Week 10 and all samples from Week 8.	28
Following weeks	24 hours	20%	Dump all samples more than 4 weeks old.	28

During the *First Week* of the test, one quart of fuel samples will be collected from the inlet of the fuel purifier at 12 hour intervals. If it is not possible to collect a fuel sample at this point due to low line pressure, then a sample at the purifier exit is acceptable, but the sample should be marked as such. There should be 14 samples in storage at the end of the first week. During the *Second Week* samples will again be collected at 12 hour intervals. This will add another 14 samples to the storage inventory. During the *Third Week* samples will be collected at 24 hour intervals but the fuel samples collected during the morning (A.M.) of week 1 can be dumped and the containers reused. This should give a total of 28 samples in storage. Note that when the samples are dumped, the fuel should be visually checked for signs of cloudiness, particulate matter, or sludge in the sample. If any of this is found, the balance of the sample should be kept and the observation reported to Paul Brodeur and the Glosten research team. Glosten should include this check in training WSF crews.

During *Week Four* the samples will be collected at 24 hour intervals and the A.M. samples from week 2 can be dumped and the containers reused. During *Week Five* the sampling interval will be increased to 24 hours. The remaining samples from week 1 can be dumped and the A.M. samples from week 3 can be dumped. During *Week Six* samples will be collected every 24 hours. The remaining samples from week 2 can be dumped and the A.M. samples from week 4 can be dumped. From *Week Seven* on sampling will occur once per day and any samples older than 4 weeks can be dumped.

Samples shall be disposed of in the vessel's waste oil tank.

1. All of the samples are to be kept on-board the boats. Only those samples that actually need to be analyzed because some concern will leave the boat.
2. All B20 used on the ferries will be treated with a maintenance dose of biocide by the WSF operators.
3. Glosten shall be responsible for collecting, labeling, packaging, and storing the fuel samples on the ferry, shipping the samples to UI or any other laboratories or storage centers designated by the Project Manager provided with the information from Item 5 below.
4. The ferry operators will presumably see the problems first hand and will inform Paul Brodeur and Glosten. Further decisions will be made according to the "trouble shooting procedures."
5. Imperium Renewables is in charge of providing guidance on packing and shipping. UI (Joe Thompson) will provide a procedure by February 15th with shipping information such as Label Master and Lab Safety.
6. Once the decision has been made according to the "trouble-shooting procedures" that samples should be analyzed, samples will be shipped to UI for preliminary analysis of soap, water, microbial growth, metallic compounds, etc.
7. The cost of these tests in the UI lab is included in UI's contract. If UI, with consulting from WSU, is still unsure, UI will propose additional testing by outside labs in consultation with WSU. If deemed necessary, a telephone conference will be held among the group to make a decision. WSU will be responsible for coordinating such conference calls. WSU will pay for the analysis done by outside labs.
8. The refueling samples (one gallon) will be taken by vessel personnel and retained on board. They do not need to be analyzed unless WSF Staff observe a problem on-board the vessel. If a problem is found, then those refueling samples will be sent to the UI lab for analysis, according to the "trouble-shooting procedures". The samples will be kept by the vessel for one month unless these samples are required to be sent to the UI lab. Otherwise, they can be discarded after one month.
9. Fuel specification requires that the fuel suppliers take a sample of the B100 (one gallon) prior to blending. Supplier will also be required to send the sample to UI directly. UI will run the tests in the lab to ensure that the COA is accurate including free and total glycerin, flash point, cold filtration, water content, etc.

10. Each supplier is also required to take another B100 sample (one gallon) in the first shipment of B100 fuel. This sample will be sent directly out to Magellan Midstream Partners, a certified laboratory, for a full specification ASTM D6751-07b analysis. Future B100 samples additional to that required in (8) above may be required by UI for the same purpose. Cost for these analyses will be covered by the PSCAA, with the total available amount being $10,000. If the analysis results of the B100 samples from the UI lab are found to have significant differences with those from COA then the B100 samples will be sent to the Magellan Midstream Partners lab for a full specification analysis. The cost will be paid by the PSCAA, within the total available amount of $10,000. It would be best is the fuel distributor would do this and add any cost to the fuel invoice. Tom Hudson will make arrangements with Paul Brodeur to reimburse if necessary.
11. If something unusual is noted during vessel operation, additional samples will be taken according to the "trouble-shooting procedure."

Fuel samples will be labeled with the following information:

1. Vessel Name
2. Sample ID number (per system developed by Glosten)
3. Person collecting the sample
4. Date
5. Time of day
6. Location where sample was collected
7. Type of fuel (e.g. B5, B10, B20 etc.)

Fuel temperature and filter pressure drop measurements will be logged by crew members during the normal operation of the ferry. Table 4 shows the recording intervals specified during the test. Note that the readings are to be taken more frequently during the time immediately following a fuel change. However, this frequency could be changed based on real implementation situations.

Table 4 Recording intervals for fuel temperature and filter pressure drop

Month 1	B5	Every Monday and Thursday
Month 2	B10	Every Monday and Thursday
Month 3	B20	Every Monday and Thursday
Month 4	B20	Every Monday and Thursday
Month 5	B20	Every Monday and Thursday
Month 6	B20	Every Monday and Thursday
Month 7	B20	Every Wednesday
Month 8	B20	Every Wednesday
Month 9	B20	Every Wednesday
Month 10	B20	Every Wednesday
Month 11	B20	Every Wednesday
Month 12	B20	Every Wednesday

The measurements listed below are to be taken at the intervals stated above. All readings including fuel temperatures and pressures should be recorded in a log-book with copies submitted electronically weekly by email to Paul Brodeur. Glosten will develop the log-book by filling out electronically.

1. Fuel temperature from port fuel tank
2. Fuel temperature from starboard fuel tank
3. Fuel temperature at exit of day tank
4. Pressure drop across the port Racor filter
5. Pressure drop across the starboard Racor filter

It is noted that the vessel Issaquah does not have Racor filters. Thus we are unable to read pressure drop in this vessel.

Fuel temperatures will be monitored in the deep tanks and at the exit of the day tank. This will provide an indication of whether the fuel is reaching temperatures where oxidative degradation is likely. Generally, thermal and oxidative degradation of the fuel would not be considered likely during the limited time that the fuel is on-board the ferry, but if the fuel temperatures are high due to fuel recirculation through the engine fuel system, some chemical changes are possible.

Part 5. Trouble-shooting Procedure and Organization Responsibility

This procedure was developed as a response to the following situations:

1. Filter clogging
2. Precipitates found in fuel samples
3. Other unusual phenomena observed after the introduction of the biodiesel blends

The objective of this procedure is to define the most efficient pathway among the research team for identifying clogging causes and finding solutions to the problems. Figure 1 shows the flowchart of the diagnosis and technical assistance.

According to this procedure, Glosten will start "Incident Report and Notifications" described in Section 7 after WSF staff observes the clogging problems during ferry operation. Then Glosten will immediately, with assistance of WSF engineers, collect and ship the samples to the UI laboratory:

Joe Thompson
72 James Martin Laboratory
University of Idaho
Moscow, ID 83844

The samples include:

- Fuel sample (1 Qt) from exit of fuel purifier
- Fuel sample (1 Qt) before fuel purifier
- Fuel sample (1 Qt) from inlet of port Racor filter
- Fuel sample (1 Qt) from inlet of starboard Racor filter
- Clogging material from fuel purifier

- Clogging material from filter or filter contained clogging material

It should be noted that the Issaquah will be unable to take any sample from the Racor filter as the Issaquah does not have Racor filter.

The purpose of the fuel samples collected from the various locations on-board the ferry is to allow the investigation of fuel quality issues that may occur during operation. The biodiesel test conducted in 2004 found problems with sludge formation in the fuel purifier and plugging of the Racor filters immediately in front of the engines. If the fuel entering the purifier from the deep tanks is contaminated and this is the source of the sludge found in the purifier, then sampling this fuel should provide an indication of the source of the problem. It would be preferable to sample the fuel in front of the purifier. When such a sample is desired, vessel engineers shall momentarily bypass the separator to allow a sample to be drawn that is representative of the fuel flowing into the separator. Immediately upon completion of the sampling, the valve alignment shall be restored to “normal” operation.

Fuel samples will also be taken from the lines in front of the Racor filters to characterize the fuel that may be causing those filters to plug. These samples must be taken in front of the filter since the filters are removing the contaminants and the downstream fuel is presumed to be free of the contaminants. The level of blockage in the Racor filters will be monitored by measuring the pressure drop across the two sets of filters. Any filters replaced due to contaminants during the trial shall be double bagged, marked and stored for analysis.

Collection of clogging material and/or any clogged filters must be done carefully. It should be done in such a way so the material on the filter is not allowed to melt or drain away. The filter should be stored upside down in a plastic ziplock bag. In order to determine its composition of the material without misleading analysis, the storing temperatures will be similar to what the filter was experiencing when the problem occurred. During sample shipping, it should be kept in cold temperature.

Appendix E: Work Plan for 2008 Biodiesel Test

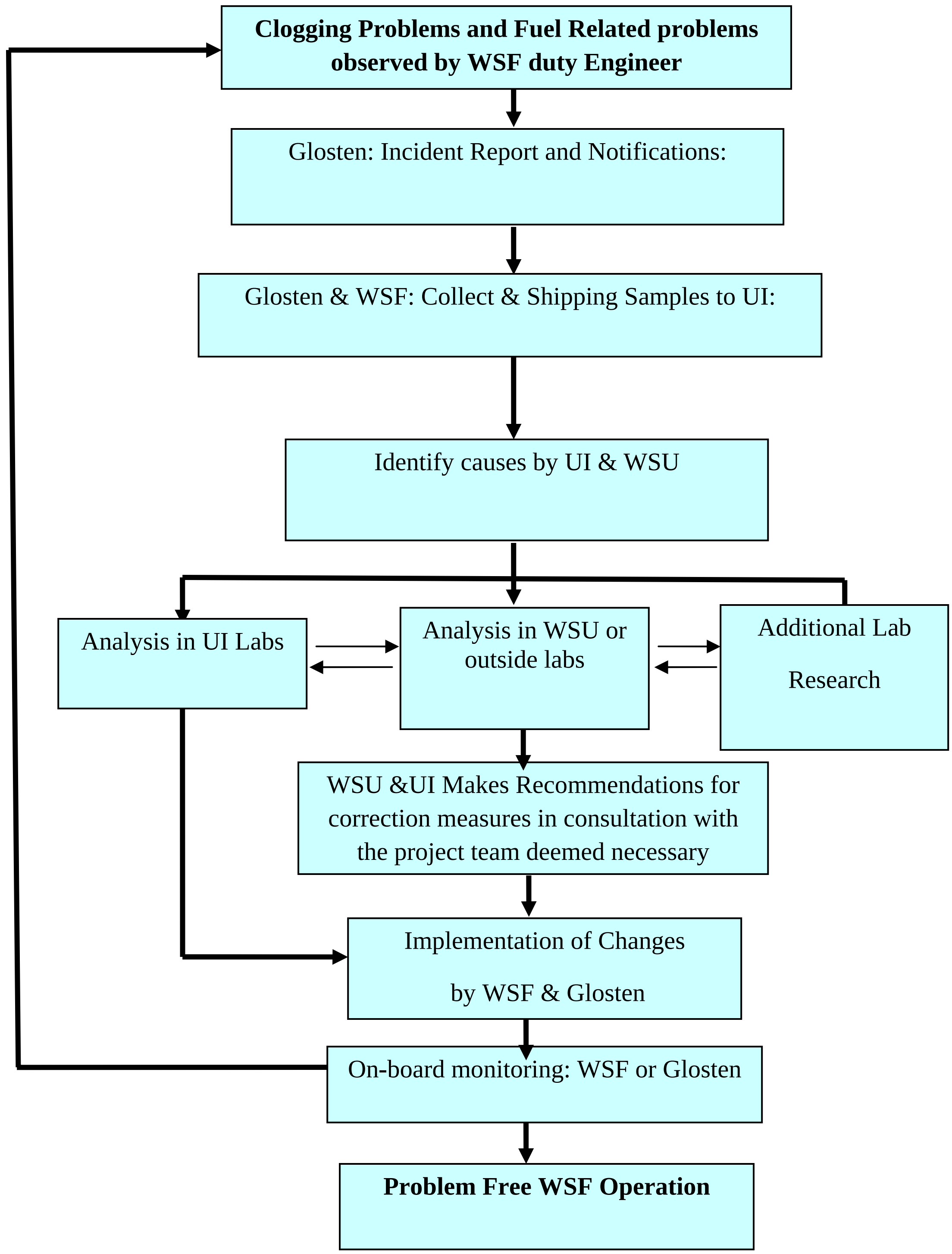


Figure 1. Flowchart for trouble-shooting with diagnosis and cause identification

With an aim at identifying cause(s) of the clogging, both labs at UI and WSU will analyze the samples. As for the fuel samples, UI will run some tests using ASTM methods, including micro-organism growth, acid number, soap, contents of water, metal (e.g. iron & sodium), glycerin, and monoglycerides. High micro-organism counts could suggest that micro-organisms are a leading cause of clogging. If high iron content is found in the fuel, it might suggest that the tank deposits have dissolved and contributed to clogging. High content of water and/or sodium indicate sea water entered into the fuel. WSU with assistance of UI will focus on determining of the composition of the clogging material using GC/MS, FT-IT, and NMR etc. First of all, the clogging material will be separated from the liquid by high speed centrifugation at 12,000 rpm for 20 minutes. If a clean liquid fraction is obtained, this liquid fraction will be analyzed in the UI lab for same tests of fuel described above. The precipitates in the bottom of the centrifuge tube, or whole clogging material if centrifuge cannot separate the liquid fraction, will be attempted to be dissolved in different organic solvents (e.g. methanol, acetate, pyridine etc) and acid water since most analysis techniques requires the solution in a liquid form. And solvent dissolving performance will indicate the type of clogging material, such as inorganic metal compounds, polymer, sterol glucosides, etc. For instance, sterol glucosides are not soluble in methanol, but dissolve in pyridine. Then several methods, such as GC/MS, FT-IR, and NMR, will be used to determine the composition. If the main composition of the clogging material is unable to be determined, the sample will be sent to outside labs for further analysis. Outcomes from these analyses will assist in answering whether or not minor compounds including sterol glucosides play an important role in the clogging problems.

Another important part of the trouble-shooting process is additional laboratory research in WSU and UI. WSU will be conducting a set of comprehensive tests to evaluate the effect of several major factors and their combination on precipitate formations. Additionally, the WSU lab will be prepared to conduct research that is specifically designed to help with the trouble-shooting process addressing the specific problem situation reported from the on-board monitoring personnel and Glosten. This laboratory research is different from the lab analysis activities in that the laboratory analysis activities will identify the composition of the clogging material (or participates), whereas the laboratory research will assist in confirming the factors and processes that led to the formation of participates and clogged filters.

During the trouble-shooting process, WSU (Tianxi Zhang, phone: 509-335-3241, fax: 509-335-2722; e-mail txzhang@wsu.edu) will be the central point of information collection and dissemination. Any pertinent information, including but not limited to analytical results, field observation notes, and sample labeling should be sent to him.

After identifying the causes, WSU and UI will, in consultation with Glosten and WSF, recommend corrective actions for the problems. Glosten will assist WSU in monitoring the fuel test and provide technical assistance, trouble-shooting and problem solving during the fuel test. Glosten will also provide personnel to monitor operational procedures. If the problems still remain, a new round of sample collection and cause identification will start and the procedures will be repeated until the problems are solved.

Part 6: Incident report and notifications

The intent of this section is two-fold:

1. To provide prompt notification of operational anomalies to the scientific study team engaged by the Puget Sound Clean Air Agency and to allow them the opportunity to witness the events firsthand, and

2. To provide WSF Duty Engineers with access to additional engineering resources around the clock.

WSF Notification
Note: The following instructions do not in any way replace or modify WSF Policies, Procedures or Standing Orders to WSF Operating Engineers. The notifications herein are for the benefit of the scientific study team engaged for the 2008 Biodiesel Fuel Trials.

In the event of an anomaly involving the fuel system, the responsible onboard marine engineer, or vessel Port Engineer should assemble the basic information requested in Appendix 4 and forward it to The Glosten Associates by phone or e-mail during regular business hours.

If the anomaly is such that an engineering consultation is desired after hours, the responsible onboard marine engineer or Port Engineer should assemble the basic information requested and call:

In both cases, the Glosten engineering responder will:

1. Provide his (her) best endeavor to answer any technical questions posed as quickly as possible.
2. Determine whether a ship visit by Glosten or another member of the scientific study team is appropriate to document the conditions found or suggest corrective measures.
3. Arrange for the ship visit (if required) through the WSF 24-hour Operations Center
4. Commence additional notifications to the scientific study team, in accordance with Appendix 5.
5. Maintain a running log of all incident reports, conversations, ship visits and corrective measure recommendations for the use of the study team.

Part 7: Fuel specifications

Scope
This specification covers a biodiesel fuel blend containing 20 percent (%) biodiesel with the remainder being ultra low-sulfur diesel fuel oil. This fuel blend, hereafter referred to as B20, is intended for use in diesel combustion engines. Biodiesel (B20) shall be delivered blended and is subject to inspections and analysis upon delivery.

Product Performance Requirements
Biodiesel (B100) blend stock shall meet the requirements of the most current version of ASTM D6751. Any additives incorporated in the biodiesel blend stock are to be documented by concentration and compound name in the COA. B100 blend stock found to be older than 60 days will be subject to higher scrutiny. Ultra low sulfur petroleum diesel shall meet the requirements of ASTM D975 and contain less than 0.0015% mass sulfur determined by ASTM D4294 or equivalent. The ultra low sulfur petroleum diesel should contain red dye to identify it as a non-taxable fuel. The supplier of the B20 fuel should provide all information known to them about additives in the petroleum diesel fuel to Paul Brodeur of the WSF.

Appendix E: Work Plan for 2008 Biodiesel Test

Biodiesel (B20) shall be a blend consisting of 20% by volume (up to ±1% error permitted, i.e. blends found to be between B19 and B21 are acceptable) 100% biodiesel blend stock mixed with 80% ultra low sulfur (ULSD) petroleum diesel, i.e., a blend of 1 part 100% biodiesel blended with 4 parts ULSD diesel. Alternate blend percentages may be specified on occasion depending on the needs of the WSF. Normally, ultra low sulfur No. 2 diesel shall be used except when a partial mix with ultra low sulfur No. 1 is used to maintain cloud point requirements. The cloud point of the B20 blend should be no higher than 20°F (-6.7°C).This information may help understanding precipitate formation related to temperature. However, it may not address filter clogging above the cloud point shown in the lab finding.

Biodiesel (B5) shall be a blend consisting of 5% (v/v) biodiesel and 95 % (v/v) ULSD diesel fuel, i.e., a blend of 1 part biodiesel and 19 parts ULSD diesel fuel. Tolerance of 1 percent is desired (B4 to B6 are acceptable).

Biodiesel (B10) shall be a blend consisting of 10% (v/v) biodiesel and 90% (v/v) ULSD diesel fuel, i.e., a blend of 1 part biodiesel and 9 parts ULSD diesel fuel. Tolerance of 1 percent is desired (B9 to B11 are acceptable).

Total Quality Management/Quality Assurance
The biodiesel source producer shall be a BQ 9000 accredited producer or if a BQ 9000 certified marketer is engaged, shall be suitably vetted by the marketer. The producer's quality program shall ensure a system for monitoring the quality of their biodiesel, including:

- Sampling
- Testing
- Storage
- Retain Samples
- Shipping

The biodiesel distributor shall be a BQ 9000 certified marketer or in the process of applying for this accreditation. This category is for distribution companies who sell biodiesel and biodiesel blends. This is an important designation, because proper handling of biodiesel is as critical to fuel quality as proper production. In addition, the biodiesel must pass the cold soak filtration test.

Manufacturer's quality assurance for blend stock (B100)
- Provide the manufacturers "Certificate of Analysis" (COA) for every batch of B100 that is blended into B20 delivered to WSF.
- Certificate of analysis must be for actual lot delivered.
- Certificate of analysis must include at least the following properties:

Property	Test Method	Limits
Flash point, °C	Per ASTM D 6751	per ASTM D6751
Water and Sediment, volume %	Per ASTM D 6751	per ASTM D6751
Cloud point, °C	Per ASTM D 6751	per ASTM D6751

Acid number, mg KOH/gm	Per ASTM D 6751	per ASTM D6751
Free glycerin, % mass	Per ASTM D 6751	per ASTM D6751
Total glycerin, % mass	Per ASTM D 6751	per ASTM D6751
Sulfur, ppm	Per ASTM D 6751	Per ASTM D 6751
Stability, hr	Per ASTM D 6751	per ASTM D 6751
Visual appearance	ASTM D 4176 Procedure	2 max
Cold soak filtration	Minnesota test method	360 sec max

- Any additives, conditioners, and biocides used in the B100 are to be documented by concentration and compound name in the COA.
- Maintain on file the B100 COA for three years.
- B100 storage to be older than 60 days will be subject to higher scrutiny.
- WSF will obtain information of paperwork including delivering, by the producer and receiving by the user. All the information obtained from WSF should be sent to WSU for tracking.

B100 / B20 sampling, blending and storage procedures
The biodiesel supplier will be responsible for collecting two types of samples. The first is a 1 gallon sample (or four 1-quart samples) of B100 immediately before blending. This sample must be obtained from the actual lot of biodiesel that will be used to provide the blend to the vessels. The second sample will be of the B20 blend prior to delivery in to the WSF vessel fuel system. These samples will be shipped in steel containers to the following address:

Joe Thompson
72 James Martin Laboratory
University of Idaho
Moscow, ID 83844

The sample shipment should include copies of the Certificate of Analysis for the actual lot of B100 delivered. Some parameters for the sample will be analyzed using ASTM methods in the UI lab, such as acid number, water and sediment, viscosity, contents of free and total glycerin, and monoglycerides.

Supplier will collect 1 gallon sample (or four 1-quart samples) of B20 blend immediately before filling the vessels fuel tanks. These samples shall be shipped in a steel container to the following address:

Joe Thompson
72 James Martin Laboratory
University of Idaho
Moscow, ID 83844

Ensure truck and trailers by both suppliers and transporters used for biodiesel blend deliveries are solely used for distillate fuel delivery. Ensure tank farm linies and hoses are solely used for distillate fuel delivery. If storage and delivery tanks, lines, and equipment are not dedicated exclusively to the storage and transport of B100, provide certification of commercial steam cleaning of all equipment prior to the initial transfer and storage of B100.

The biodiesel should be blended using in-line injection blending at the truck load out racks. These fuels must be blended at a minimum of 50 degrees F prior to delivery. While in line blending is preferred, splash blending in a truck will be also acceptable provided there is enough mixing provided both by the input of the fuels into the truck and that created by driving to the location.

Part 8: Vessel preparation (including tank cleaning procedures, vessel modifications for shipboard monitoring & sampling)

Tanks cleaning procedure

A fuel storage tank cleaning procedure must be selected to ensure a successful introduction of biodiesel into the WSF's fuel system. Biodiesel's tendency to absorb water and solvent properties make tank surface cleanliness especially important.

Current Fuel Storage Tank Condition

The fuel storage tanks and fuel day tanks on all three vessels under consideration for this test program have uncoated mild steel fuel tanks. The tanks are original steel, and therefore at least 25 years old (M/V Issaquah) to 50 years old (M/V Tillikum/Klahowya). The tanks are said to be "dirtier than average" by Emerald Services (current cleaning contractor). Sediment coating the tank walls is described as "a combination of rust blooms and blackish slime". The cause of this contamination is believed to be a result of the following combination of effects:

- Age
- Slow fuel consumption rates
- Intermittent batches of poor quality fuel
- No surface coating

Fuel Storage Tank Cleaning Procedures and Recommendations

The current cleaning procedure used onboard WSF vessels results in a small amount of moisture, sediment and possibly detergent residue in the tank. There is concern that moisture and any remnants of detergents used in the cleaning process may contribute to the formation of emulsions. At present, it is recommended that planning for the 2008 trial proceed on the basis of preparing the test vessels using the proposed tank cleaning procedure. This recommendation is made without regard to any budget constraints that may dictate otherwise. Brief descriptions of the proposed procedure follow.

Proposed Biodiesel Tank Cleaning Procedure

Open, empty, and ventilate the tanks. Ensure that all fuel suction, fill, sounding and vent lines are completely drained back to the tank. Visually inspect fuel suction, fill, sounding and vent lines (if possible) for contamination. Secure all valves to and from the tank and tag out.

- Have a marine chemist certify tanks safe for entry and establish the level of PPE required for safe entry.
- WSF personnel to take photographs of tank conditions prior to cleaning.

- If necessary, gross removal of scale and sediments using hand tools (tile scrapers, flat-nose shovels…).
- If not too dirty, high pressure, hot-water wash all tank surfaces at 3000 psi using hand wand. Pump or vacuum wash water to a certified storage tank (i.e. Vac Truck) for eventual manifesting and disposal. Collect and remove any additional scale and sediments dislodged in the pressure washing process.
- If large quantities of sediment, scale or slime are found in the tanks, perform a preliminary wash with Zep Industrial Purple Cleaner and Degreaser, followed by multiple hot water washes.
- Squeegee excess water from internal surfaces and remove from tank by pump or vacuum.
- Wipe all surfaces down with lint-free rags wetted with B-100.
- WSF personnel to take photographs of tank conditions after cleaning is accomplished.
- After final inspection for cleanliness and photo documentation, close tank and prepare to receive fuel.

All personnel inside "the hot zone" should be certified HAZWOPRs (29 CFR 1910.120).

Candidate Local Contractors
WSF reports that it has a standing contract with Emerald Services for tank cleaning and disposal.

Vessel modifications for shipboard monitoring & sampling
Appendix 2 outlines the modifications necessary to the fuel system on the M/V Issaquah for adding the sampling points and temperature monitoring points desired by the Biodiesel Team. Additional observations for the Issaquah are listed below.
Existing sampling points are already available near the desired locations. We have assumed these will be adequate for the purposes of this project. Please review the sampling locations on the drawing. Installing temperature gages at the fuel oil storage tanks will be expensive (hot work required unless threaded connections will be allowed) and will result in gages below the engine room floorplates, which makes reading the gages a time-consuming effort (must remove floor plates first, record the reading and then replace the floor plates). Therefore, we have proposed an alternate location for the gages at the suction manifold of the purifier. The proposed temperature gage locations will either be drilled/tapped or will need some hot work done in place.

Appendix 3 outlines the modifications necessary to the fuel systems on the M/V Tillikum and M/V Klahowya for adding sampling points and temperature monitoring points desired by the Biodiesel Team.

Basic Assumptions for the Modifications
Welded connections are preferred to threaded to keep leaks to a minimum.
Hot work will need gas freeing if done in place. Therefore, removable pieces (flanged, union or threaded) are preferred to allow removal of a section to the shop for modification and reinstallation without having to gas free the entire fuel system.

Part 9: Appendix

Appendix E: Work Plan for 2008 Biodiesel Test

Appendix 1: Zep Industrial Purple Cleaner and Degreaser, MSDS (Attachment 1 will be inserted here)
Appendix 2 Issaquah 130 Fuel System Modifications (Attachment 2 will be inserted here)
Appendix 3 Evergreen Class Fuel System Modifications (Attachment 3 will be inserted here)

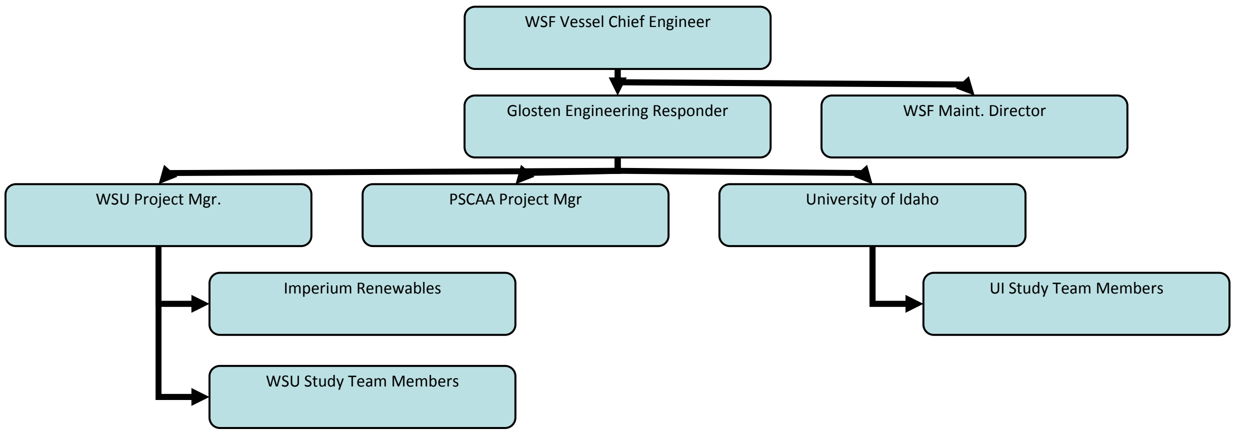
Appendix 4 -- 2008 WSF Biodiesel Trial Incident Report

Vessel Name	
Date and Time Incident First Noticed	
Position and Name of Person Reporting Incident	
Location at Time Incident First Noticed	
Brief Description of Anomaly (e.g. “high differential pressure reading on main engine #2 fuel filter”)	
Vessel systems affected (e.g. “purifiers”)	
Corrective measures initiated (e.g. “bypassing filters and replacing elements”)	
Probable consequences if left untreated (e.g. “main engine shutdown.”)	
Significant measurements and operating parameters Fuel temperature at purifier inlet Pressure (vacuum) upstream of main fuel transfer pump Pressure downstream of main fuel transfer pump Pressure (vacuum) upstream of purifier Pressure downstream of purifier Differential pressure at main engine filters Sounding (ullage) of day tank Soundings (ullages) of fuel oil storage tanks	
Ambient Weather Conditions Air temperature Seawater temperature Sea conditions Barometric pressure	

Appendix 5 -- Notifications

Notification Tree

Appendix E: Work Plan for 2008 Biodiesel Test



The Glosten Engineering Responder will determine the criticality of subsequent notifications. Most are expected to require e-mail notification to be received during normal business hours. Incidents judged by the Glosten Engineering Responder to be particularly anomalous may dictate after-hours notification by telephone.

Scientific Study Team

Name	Affiliation
Hudson	Puget Sound Clean Air Council
Chen	Washington State University
Zhang	Washington State University
Million	Washington State University
Garcia-Perez	Washington State University
Van Gerpen	University of Idaho
He	University of Idaho
Mulder	University of Idaho
Thompson	University of Idaho
Herkes	University of Idaho
Ellis	Imperium Renewables
Larsen	The Glosten Associates
Smith	The Glosten Associates
Renehan	The Glosten Associates
Ritchie	The Glosten Associates
Brodeur	Washington State Ferries

GORGE ANALYTICAL
1107 13th Street
Hood River, Oregon 97031
541.980.7168 (office)
866.293.1337 (fax)

Client: Gen-X Energy Group, Inc
Client Sample ID: 200812015-1
Date/Time Received: 12/5/2008 10:10
GA Sample Number: 0012008340101
Contact Name: Scott Johnson
Date/Time Sampled: 12/4/2008 9:34
Sample Matrix: B100 Biodiesel
Feedstock: Soy Blend

Summary of Analytical Results

Analysis Performed	Analytical Method	Date Analyzed	Result	Reporting Units	ASTM Criterion *	Acceptable/ Unacceptable
Total Glycerin	ASTM D6584-08	12/8/2008	**0.163**	% Mass	0.240 max	Acceptable
Free Glycerin	ASTM D6584-08	12/8/2008	**ND**	% Mass	0.020 max	Acceptable
Monoglycerides	ASTM D6584-08	12/8/2008	**0.137**	% Mass	N/A	N/A
Diglycerides	ASTM D6584-08	12/8/2008	**0.026**	% Mass	N/A	N/A
Triglycerides	ASTM D6584-08	12/8/2008	**ND**	% Mass	N/A	N/A
Flash Point	ASTM D93-08	12/9/2008	**174.0**	°C	93 min	Acceptable
Total Acid Number	ASTM D664-07	12/9/2008	**0.36**	mg KOH/g	0.50 max	Acceptable
Cloud Point	ASTM D2500-05	12/9/2008	**1**	°C	Report	N/A
Water and Sediment	ASTM D2709-96(2006)	12/9/2008	**0.03**	% Volume	0.05 max	Acceptable
Visual Inspection (Part 1)	ASTM D4176-04 ε1	12/9/2008	**1**	Haze Rating	Report**	N/A
Visual Inspection (Part 2)	ASTM D4176-04 ε1	12/9/2008	**Free of Particulate**	N/A	Report**	N/A
Karl Fischer Moisture	ASTM D6304-07	12/9/2008	**0.027**	% Mass	N/A	N/A
Cold Soak Filtration	ASTM D6751-08 Annex A	12/8/2008	**166.1**	seconds	360 **	Acceptable

*** ASTM criteria are for B100 biodiesel.**
**** ORS criteria are for B100 biodiesel**
Visual Inspection (Procedure 2) was performed at 21.5° C.
** B100 intended for blending into diesel fuel that is expected to give satisfactory vehicle performance at fuel temperatures at or below −12°C shall comply with a cold soak filterability limit of 200 s maximum.

ND = non-detect. Free glycerin was not detected at or above 0.001% mass (the detection limit for free glycerin) and triglycerides were not detected at or above 0.002% mass (the detection limit for triglycerides).

These results are for the exclusive use of the client to whom they are issued.

Reviewed By: MD Fetkenhour **Date:** 12/19/2008

Client-Based Solutions and High Quality, Rapid Results

Certificate for Biodiesel

Certificate Identification Number: 2008-56

(To support a claim related to biodiesel mixture under the Internal Revenue Code)

The Undersigned biodiesel processor ("Producer") hereby certifies the following under penalties of Perjury:

1. Producer Name, Address and employer identification number:
   Gen-X Energy Group, Inc.
   544 Grain Terminal Road
   Burbank, WA 99323
   ID# 20-5765111

2. Name, address and employee identification number of person buying biodiesel from Producer:
   Fitz Enterprise Inc. DBA Star Oilco
   232 NE Middlefield Road
   Portland, OR 97211
   ID# 93-0691471

3. Date and location of sale to Buyer December 30, 2008 Location Portland, OR

4. This Certificate applies to 3004.46 gallons of biodiesel.

5. **Producer certificate that the biodiesel to which this certificate relates is:**
   0 % Agri-biodiesel (derived solely from virgin oils)
   100 % Biodiesel other than Agri-biodiesel

This certificate applies to the following sale:

Invoice or delivery ticket number: AA 040 Total number of gallons sold under that invoices and delivery ticket number (including biodiesel not covered by this certificate) 3004.46

Total number of certificates issued for that invoice or delivery ticket number: 1

6. Names address and employer identification number or reseller to whom the certificate is issued (only in the case of certificates reissued to a reseller after the return of the original certificate):
   Gen-X Energy Group Inc
   544 Grain Terminal Road Burbank, WA 99323

7. Original certificate identification number (only in the case of certificates reissued to a reseller after the return of the original certificate): 2007-005395 AB, NB, M.

Producer is registered as a biodiesel producer with registration number 2007-005395 AB, NB, M. Producer certifies that the biodiesel to which this certificate relates is monoalkyl esters of long chain fatty acids derived from plant or animal matter that meets the requirements of the American Society of Testing and Materials D6751 and the registration requirements for fuels and fuels additives established by the EPA under section 211 or the Clean Air Act (42 U.S.C. 7545).

Producer understands that the fraudulent use of this certificate may subject producer and all parties making any fraudulent use of this certificate to a fine or imprisonment, or both, together with the costs of prosecution.

Printed or typed name of person signing this certificate: Jaime Adams

Title: Office

Signature: Jaime Adams

Date: 12/30/08

Notes:

TEMPERATURE VOLUME COMPENSATION

GEN-X ENERGY GROUP, INC. BIODIESEL LOADING TERMINAL

544 Grain Terminal Rd.
Burbank, WA 99323
(509) 547-2447

Standard Wt. @ 60F	7.5092
Load Temperature (F)	116.000
Indicated Load Volume	3,050.000
Density @ Load Temperature (F)	7.3989
Weight Compensation	0.110
Volume Compensation	45.54
Delivered Volume Corrected to 60F	3,004.46

DATE	12/30/2008
TIME IN	9:50 AM
TIME OUT	10:40:00 AM
TRUCK NUMBER	
TRAILER NUMBER	
LOADING OPERATOR	Josh Patton
DRIVER SIGNATURE	Cannon 12/30/08

SECTION 4.G
OLYMPIC PIPE LINE COMPANY
PRODUCT SPECIFICATIONS FOR ULTRA-LOW SULFUR DIESEL FUEL #2
PRODUCT CODE D85 (1)

Product Property	ASTM Test Method	Minimum	Maximum	Note
Gravity, API @ 60° F	D1298/ D4052	30	39	(8)
Flash Point, ° F.	D93	125		(2)
Viscosity, cst @ 104° F.	D445	1.9	4.1	
Cloud Point, ° F.	D2500 / D5773	ASTM		(4)
Pour Point, ° F.	D97 / D5949	ASTM		(5)
Total Sulfur, ppm	D2622, D5453, D7039		8	(7)
Corrosion, 3 hrs @ 122° F	D130		1	
Carbon Residue, wt. %	D524		0.35	
Ash, wt. %	D482		0.01	
Sediment & Water, % by volume	D1796		0.05	
Cetane Number	D613	40.0		
Cetane Index or Aromatic, vol. %	D976 / D4737B D1319	40.0	 35.0	(6)
Lubricity, HFRR @60C, micron	D6079		Report	(9)
Distillation, ° F, 50% recovered 90% recovered End Point	D86	 Report 540	 640 700	
Haze Rating, @ 72° F.	D4176		2	
Color	D1500		2.5	
Workmanship		Clear and Bright		(3)
Product Acceptance Temperature			120° F	

* Specification is at the refinery gate for test fuel type ULSD No.2 effective June 1, 2006.

NOTES:

1. In addition to above specification, products must meet the ASTM D975 or latest revision.
2. Test method D93 is the referee method.
3. Product shall be clear and bright and free of suspended matter and water at 72° F or below.
4. Maximum Cloud Pt., +14° F., - November through February.
   Maximum Cloud Pt., +24° F., - March through October
   Alternate method D5773 may be used, but in case of dispute, D2500 will be absolute.
5. Maximum Pour Pt., +0° F., - November through February
   Maximum Pour Pt., +15° F., - March through October
   Alternate method D5949 may be used, but in case of dispute, D97 will be absolute.
6. EPA minimum requirement.
7. Pipeline specification for acceptance into the pipeline.
8. Federal register Vol. 66, No.12, pg 5167, Jan. 18, 2001, 40 CFR part 80, sec 86.113-07 States fuel specifications unless otherwise revised.
9. Lubricity specification for this fuel may not meet the 520 spec. max. ASTM requirement –no additive allowed.

Imperium Grays Harbor

Typical Production for Distilled Canola Methyl Esters

Analysis	Units	Results for B100	EN Limits	Test Method
Ester Content	% (m/m)	≥ 99%	96.5 min	EN 14103
Density	kg/m3	860-900	860-900	EN ISO 3675 EN ISO 12185
Cold Filter Plug Point	Celsius	Grade D (-10 to -14 C)	A – F Grade	EN 116
Viscosity @ 40 C	mm²/s	3.5 – 5.0	3.5 – 5.0	EN ISO 3104
Flash Point	Celsius	> 130	120 min	EN ISO 3679
Sulfur content	mg/kg	≤ 2	10 max	EN ISO 20846 EN ISO 20884
Carbon Residue	% (m/m)	≤ 0.30	0.30 max	EN ISO 10370
Cetane Number		≥ 51	51 min	EN ISO 5165
Sulfated Ash content	% (m/m)	≤ 0.01	0.02 max	ISO 3987
Water content	mg/kg	≤ 250	500 max	EN ISO 12937
Total contamination	mg/kg	< 20	24 max	EN 12662
Copper strip corrosion	Rating	1a	Class 1	EN ISO 2160
Oxidation Stability	hours	> 6	6 min	EN 14112
Acid Value	mg KOH/g	< 0.30	0.50 max	EN 14104
Iodine Value	gr iodine/100 gr	< 120	120 max	EN 14111
Linolenic acid methyl ester	% m/m	< 12	12 max	EN 14103
Polyunsaturated methyl esters	% m/m	≤ 1	1 max	
Methanol content	% m/m	< 0.05	0.20 max	EN 14110
Monoglyceride content	% m/m	< 0.20	0.80 max	EN 14105
Diglyceride content	% m/m	< 0.05	0.20 max	EN 14105
Triglyceride content	% m/m	< 0.05	0.20 max	EN 14105
Free Glycerin	% m/m	< 0.005	0.02 max	EN 14105 EN 14106
Total Glycerin	% m/m	< 0.025	0.25 max	EN 14105
Group I Metals (Na+MG)	mg/kg	≤ 2	5 max	EN 14108 EN 14109
Group II metals (Ca+Mg)	mg/kg	≤ 2	5 max	EN 14538
Phosphorus content	mg/kg	< 5	10 max	EN 14107

PASEO CARGILL ENERGY LLC.

RAINIER PETROLEUM
SIDING 1616 & 1617
40 S SPOKANE ST
SEATTLE, WA USA 98134

BIODIESEL

(Soy Fatty Acid Methyl Ester)

Certificate of Analysis

Lot Number	KCBD08070709
Car/Truck	TILX 291038
Load Order	100275
Load Date	Friday, July 11, 2008

PROPERTY	METHOD	SPECIFICATION	RESULT
Visual Appearance	ASTM D 4176	2.0 max.	1.0
Acid Number	ASTM D 664	0.50 max. mg KOH/g	0.35 mg KOH/g
Cloud Point	ASTM D 2500	Report °C	0 °C
Flash Point	ASTM D 93	130 min. °C	178 ° C
Water & Sediment	ASTM D 2709	0.050 max. % vol	0.002 % vol
Free Glycerin	ASTM D 6584	0.020 max. %	0.006 %
Total Glycerin	ASTM D 6584	0.240 max. %	0.171 %
Monoglycerides	ASTM D 6584	Report %	0.550 %
Diglycerides	ASTM D 6584	Report %	0.122 %
Triglycerides	ASTM D 6584	Report %	0.042 %
Sulfated Ash *	ASTM D 874	0.020 max. mass%	0.005 mass %
Carbon Residue *	ASTM D 4530	0.050 max. mass%	<0.050 mass %
Cetane *	ASTM D 613	47 min.	50
Copper Strip Corrosion *	ASTM D 130	3 max.	1
Phos Content *	ASTM D 4951	10 max. ppm	<10 ppm
Sulfur Content	ASTM D 4951	0.00-15.00 ppm	1.00 PPM
Kinematic Viscosity *	ASTM D 445	1.90-6.00 mm2/sec	4.09 mm2/sec
Moisture (Karl Fisher)	Volumetirc	Report %	0.037 %
Cold Soak Filtration	ASTM D 6217 (modified)	Report sec.	189 SEC
Oxidative Stability	EN 14112	3 hrs min	5.0 HR
Group I Metals *	EN 14538	5 ppm Max	0.0 PPM
Group II Metals *	EN 14538	5 ppm Max	0.2 PPM
Vacuum Distillation *	ASTM D 1160	360° C Max @ 90%	353.1 DEGC

* These results are based on typical analysis.

** 0.1% #2 diesel fuel has been blended with this load.

Approval:

Date: *Friday, July 11, 2008*

PASEO CARGILL ENERGY LLC 1920 E FRONT ST KANSAS CITY, MO 64120

ph: 816-245-0514 fax: 816-245-0509

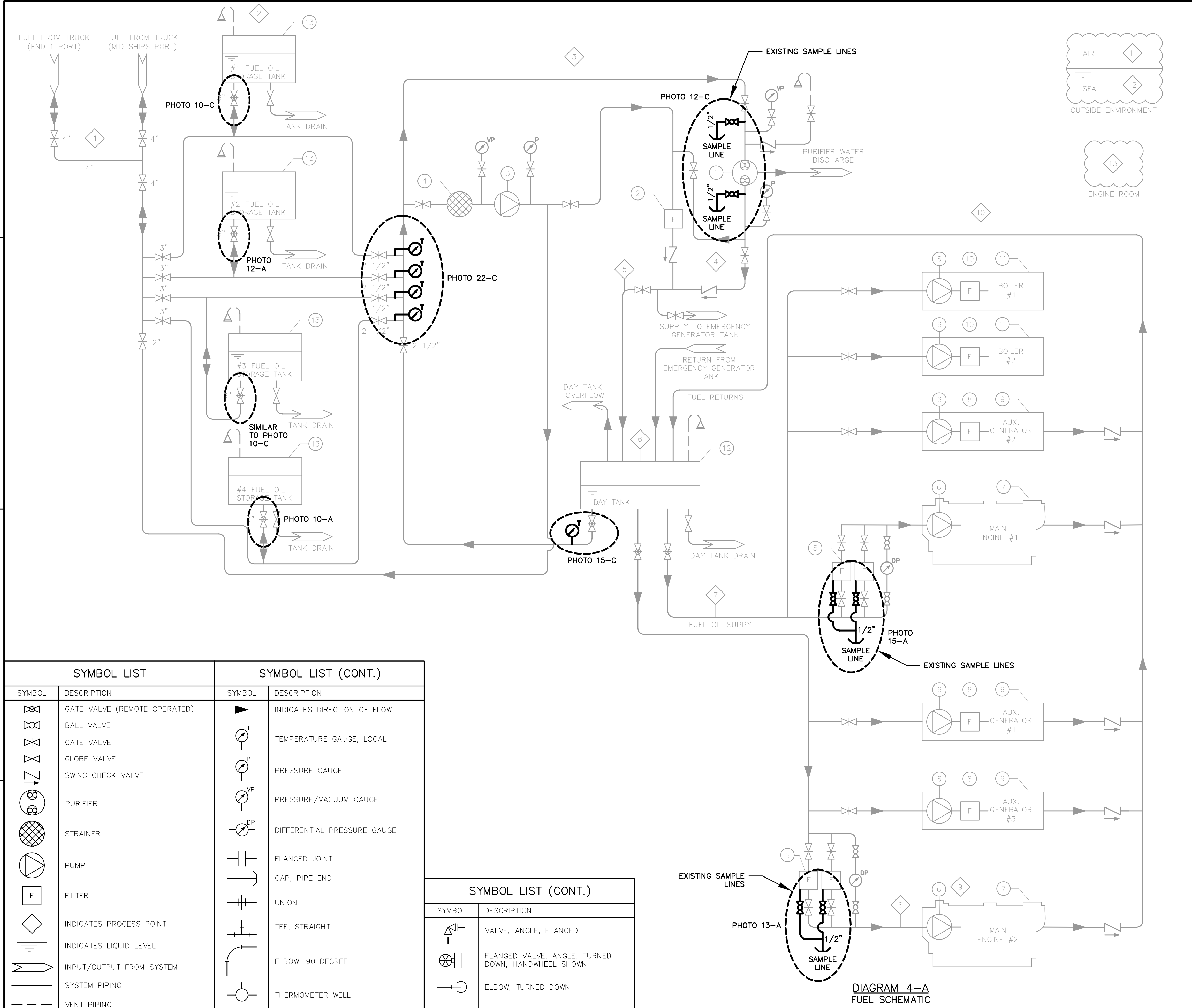


DIAGRAM 4–A
FUEL SCHEMATIC

SYMBOL LIST

SYMBOL	DESCRIPTION
	GATE VALVE (REMOTE OPERATED)
	BALL VALVE
	GATE VALVE
	GLOBE VALVE
	SWING CHECK VALVE
	PURIFIER
	STRAINER
	PUMP
F	FILTER
	INDICATES PROCESS POINT
	INDICATES LIQUID LEVEL
	INPUT/OUTPUT FROM SYSTEM
	SYSTEM PIPING
	VENT PIPING

SYMBOL LIST (CONT.)

SYMBOL	DESCRIPTION
	INDICATES DIRECTION OF FLOW
T	TEMPERATURE GAUGE, LOCAL
P	PRESSURE GAUGE
VP	PRESSURE/VACUUM GAUGE
DP	DIFFERENTIAL PRESSURE GAUGE
	FLANGED JOINT
	CAP, PIPE END
	UNION
	TEE, STRAIGHT
	ELBOW, 90 DEGREE
	THERMOMETER WELL

SYMBOL LIST (CONT.)

SYMBOL	DESCRIPTION
	VALVE, ANGLE, FLANGED
	FLANGED VALVE, ANGLE, TURNED DOWN, HANDWHEEL SHOWN
	ELBOW, TURNED DOWN

GENERAL NOTES

REFERENCES

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

PUGET SOUND CLEAN AIR AGENCY
SEATTLE, WA

WSF BIODIESEL STUDY
ISSAQUAH 130 FUEL SYSTEM MODIFICATIONS
FUEL SYSTEM SCHEMATIC

DAVID W. LARSEN — STATE OF WASHINGTON — REGISTERED PROFESSIONAL ENGINEER — EXPIRES 08/26/
SIGNED COPY ON FILE

THE GLOSTEN ASSOCIATES
Consulting Engineers Serving the Marine Community
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TEL 206.624.7850
FAX 206.682.9117
WEB www.glosten.com

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Scale	Drawing Number	Sheet	Rev
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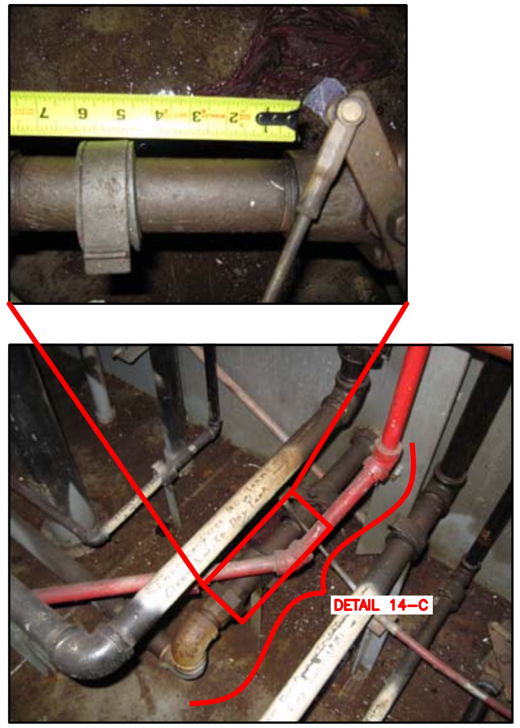
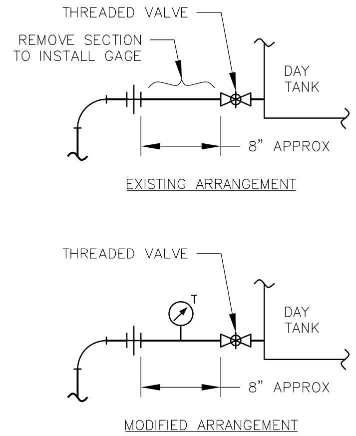


PHOTO 15-C
DAY TANK SUCTION



DETAIL 14-C
DAY TANK SUCTION MODIFICATIONS

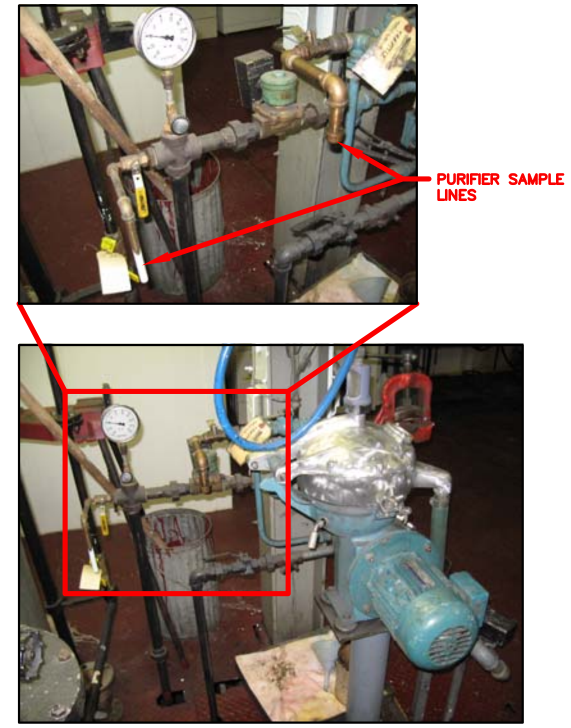


PHOTO 12-C
EXISTING PURIFIER SAMPLE LINES
(NO MODIFICATION REQUIRED)

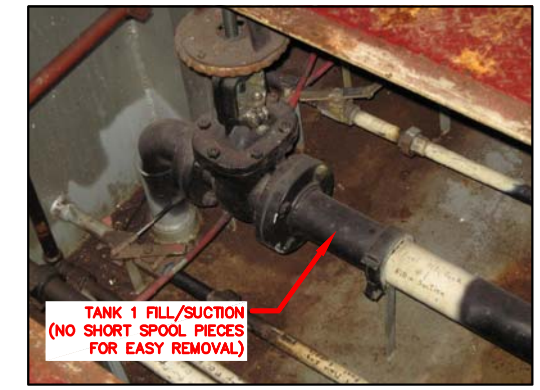


PHOTO 10-C
FO STORAGE TANK 1
FILL/SUCTION

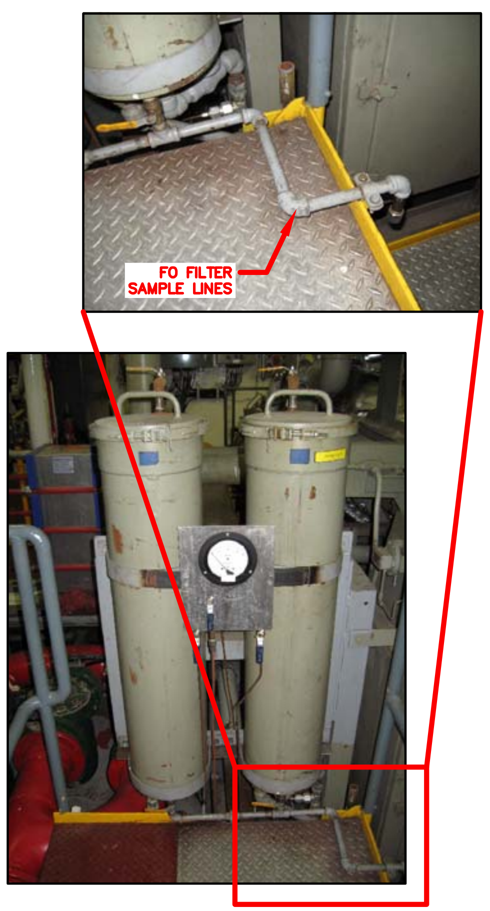
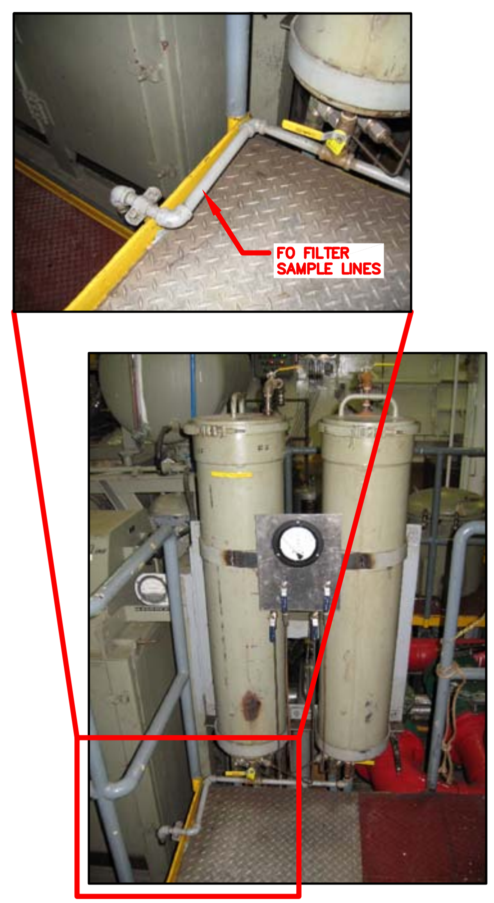


PHOTO 15-A
EXISTING FUEL FILTER NO. 1 SAMPLE LINES
(NO MODIFICATION REQUIRED)



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EXISTING FUEL FILTER NO. 2 SAMPLE LINES
(NO MODIFICATION REQUIRED)

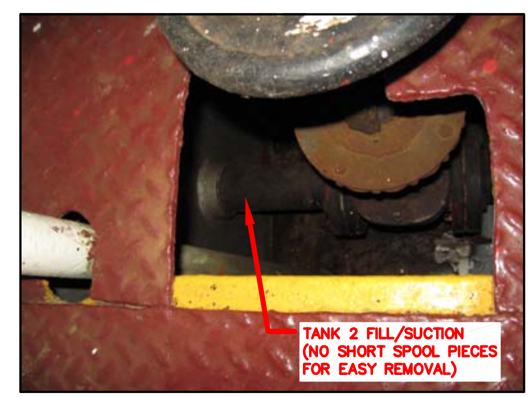

PHOTO 12-A
FO STORAGE TANK 2
FILL/SUCTION

PHOTO 10-A
FO STORAGE TANK 4
FILL/SUCTION

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FUEL SYSTEM MODIFICATIONS

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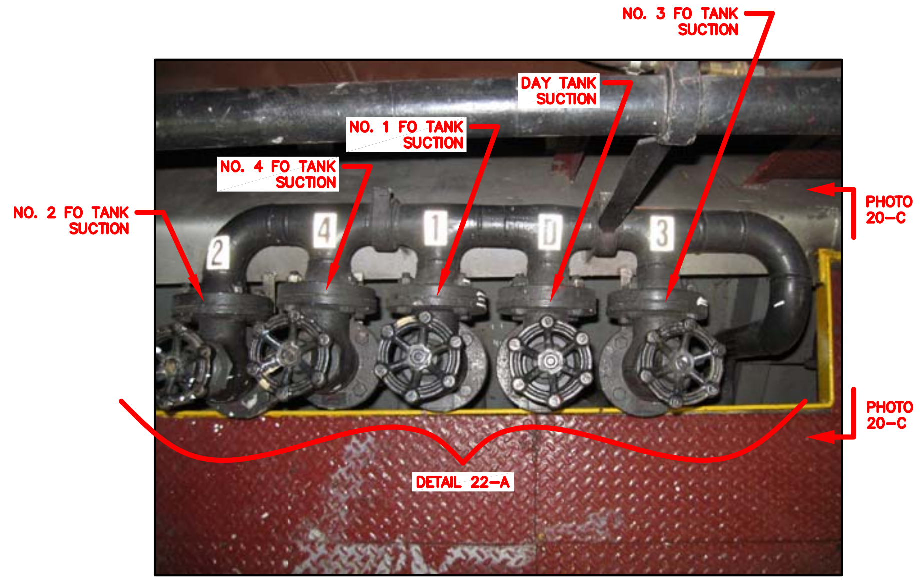


PHOTO 22-C
FO TANK SUCTION MANIFOLD
(OVERHEAD VIEW)

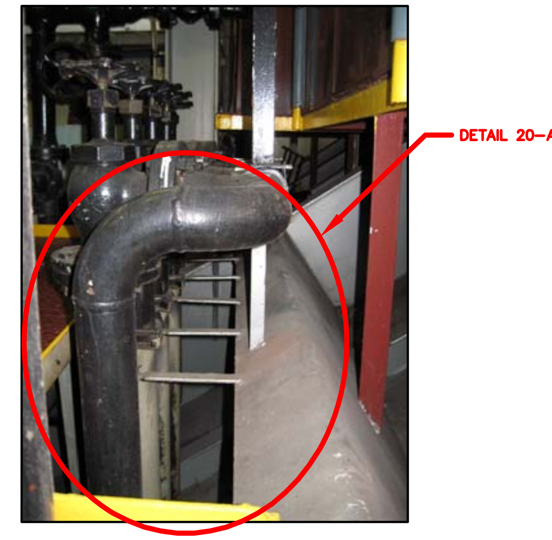
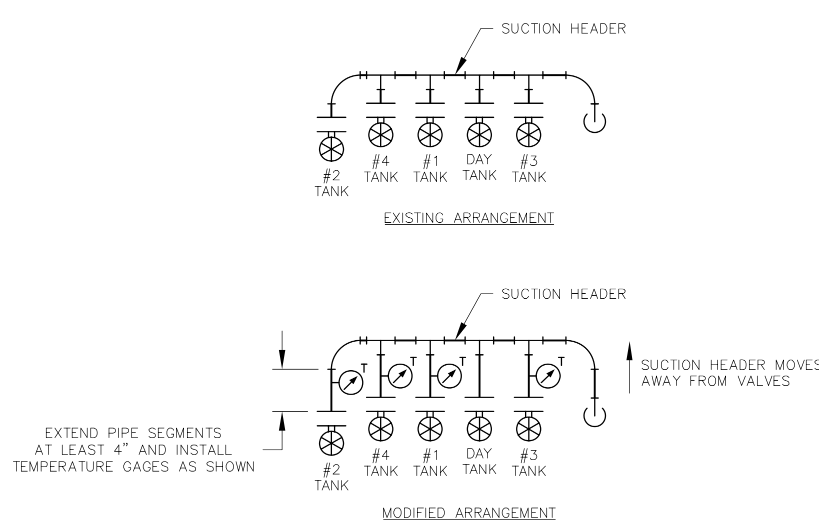
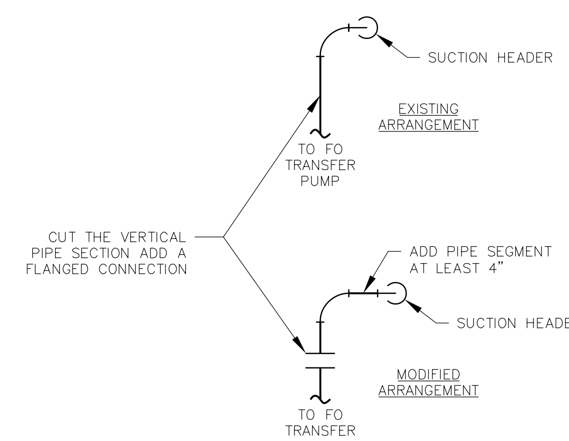


PHOTO 20-C
FO TANK SUCTION MANIFOLD
(SIDE PROFILE)



DETAIL 22-A
FO TANK SUCTION MANIFOLD
(OVERHEAD VIEW)



DETAIL 20-A
FO TANK SUCTION MANIFOLD
(SIDE PROFILE VIEW)

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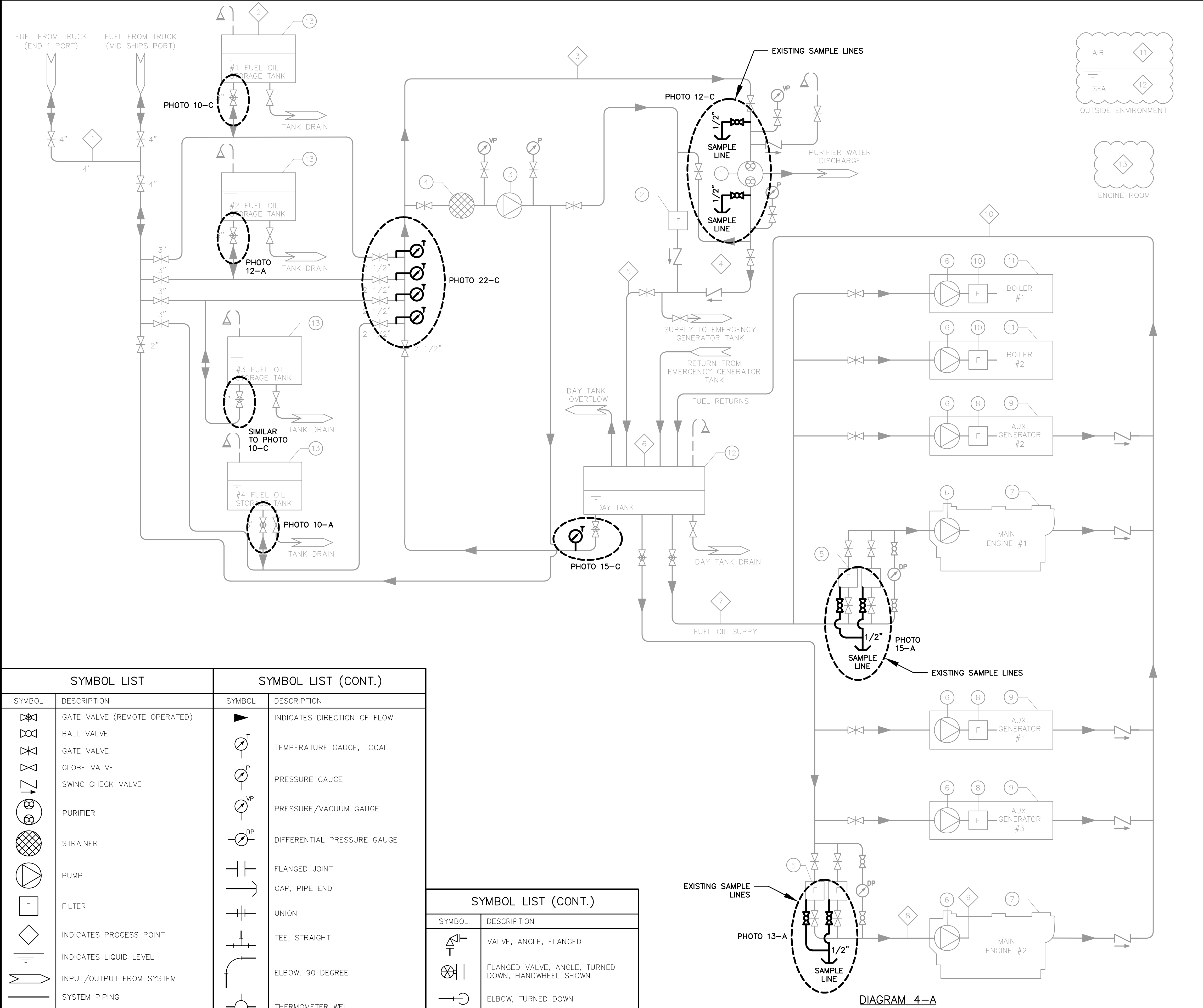

DIAGRAM 4–A
FUEL SCHEMATIC

GENERAL NOTES

REFERENCES

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED

SYMBOL LIST

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	PURIFIER
	STRAINER
	PUMP
F	FILTER
	INDICATES PROCESS POINT
	INDICATES LIQUID LEVEL
	INPUT/OUTPUT FROM SYSTEM
	SYSTEM PIPING
	VENT PIPING

SYMBOL LIST (CONT.)

SYMBOL	DESCRIPTION
	INDICATES DIRECTION OF FLOW
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P	PRESSURE GAUGE
VP	PRESSURE/VACUUM GAUGE
DP	DIFFERENTIAL PRESSURE GAUGE
	FLANGED JOINT
	CAP, PIPE END
	UNION
	TEE, STRAIGHT
	ELBOW, 90 DEGREE
	THERMOMETER WELL

SYMBOL LIST (CONT.)

SYMBOL	DESCRIPTION
	VALVE, ANGLE, FLANGED
	FLANGED VALVE, ANGLE, TURNED DOWN, HANDWHEEL SHOWN
	ELBOW, TURNED DOWN

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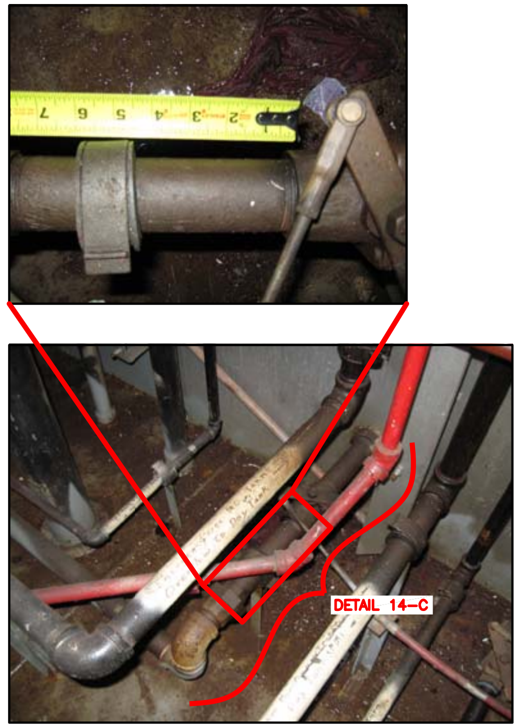
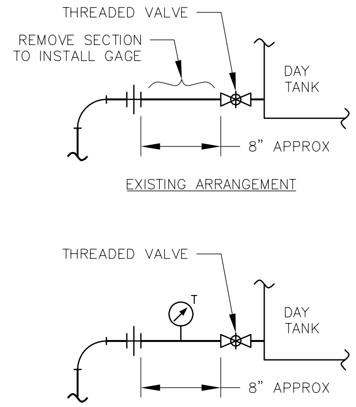


PHOTO 15-C
DAY TANK SUCTION



DETAIL 14-C
DAY TANK SUCTION MODIFICATIONS

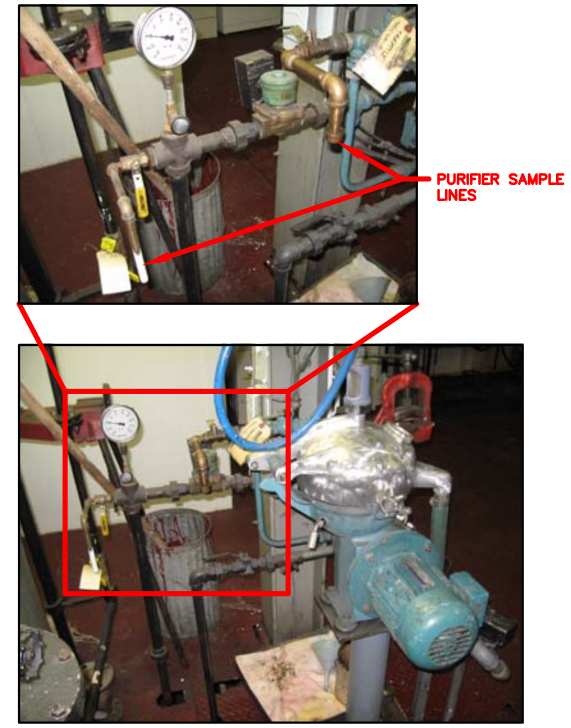


PHOTO 12-C
EXISTING PURIFIER SAMPLE LINES
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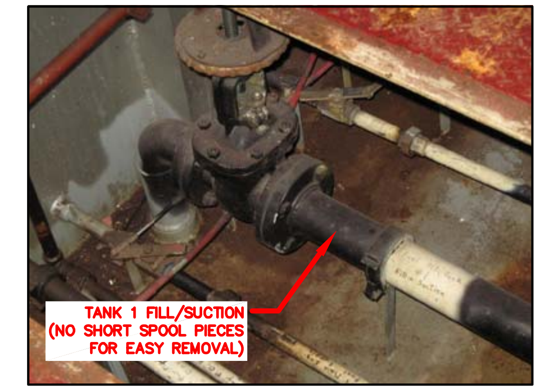
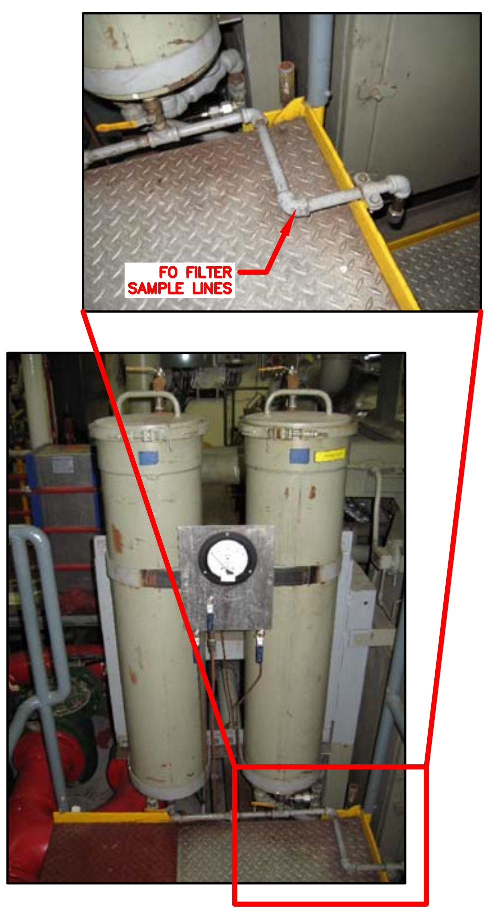


PHOTO 10-C
FO STORAGE TANK 1
FILL/SUCTION



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EXISTING FUEL FILTER NO. 1 SAMPLE LINES
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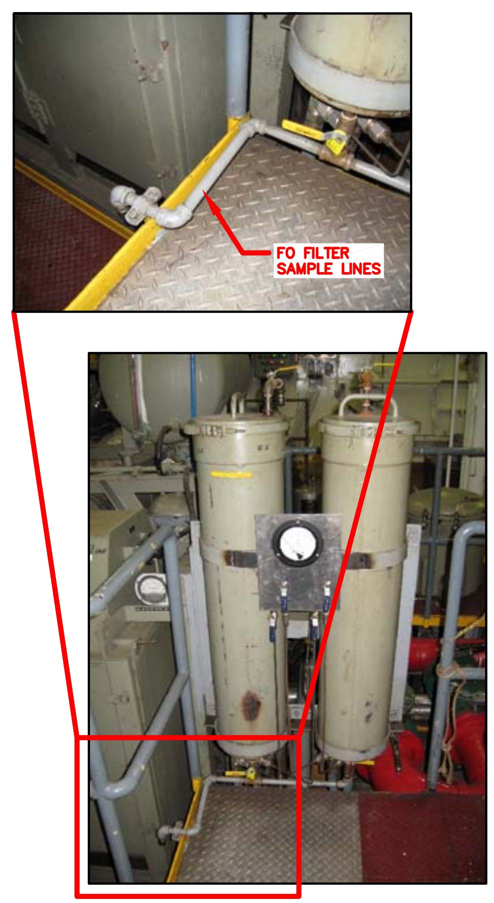

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(NO MODIFICATION REQUIRED)

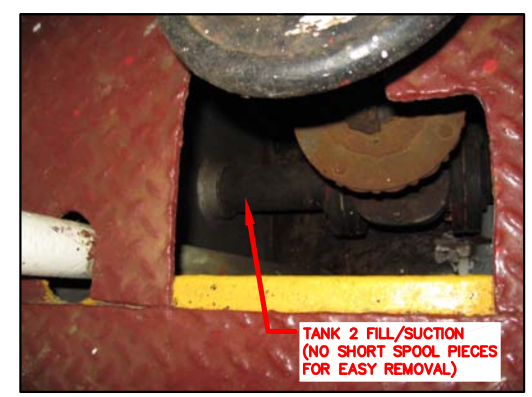

PHOTO 12-A
FO STORAGE TANK 2
FILL/SUCTION

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FO STORAGE TANK 4
FILL/SUCTION

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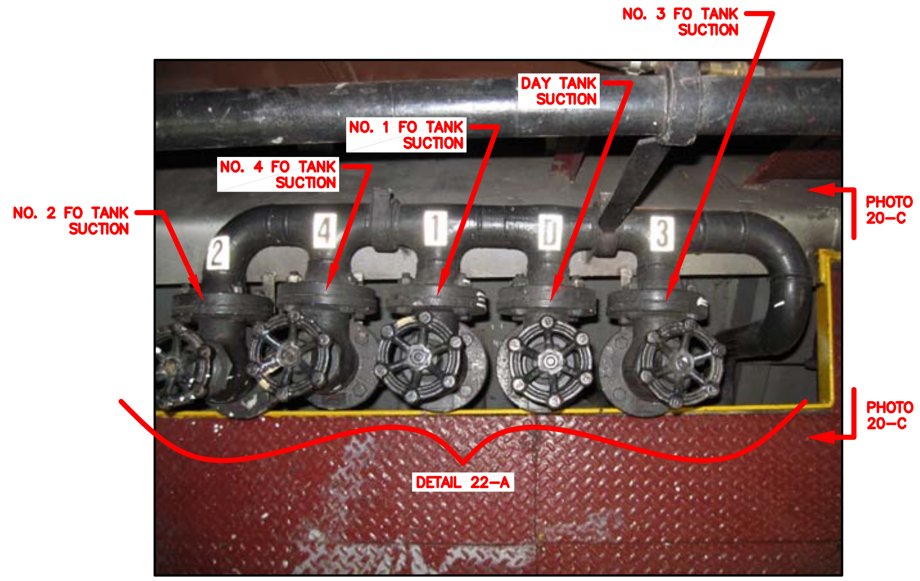


PHOTO 22–C
FO TANK SUCTION MANIFOLD
(OVERHEAD VIEW)

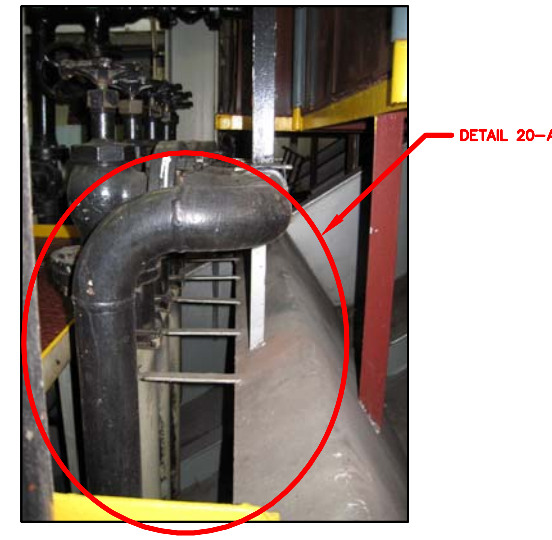
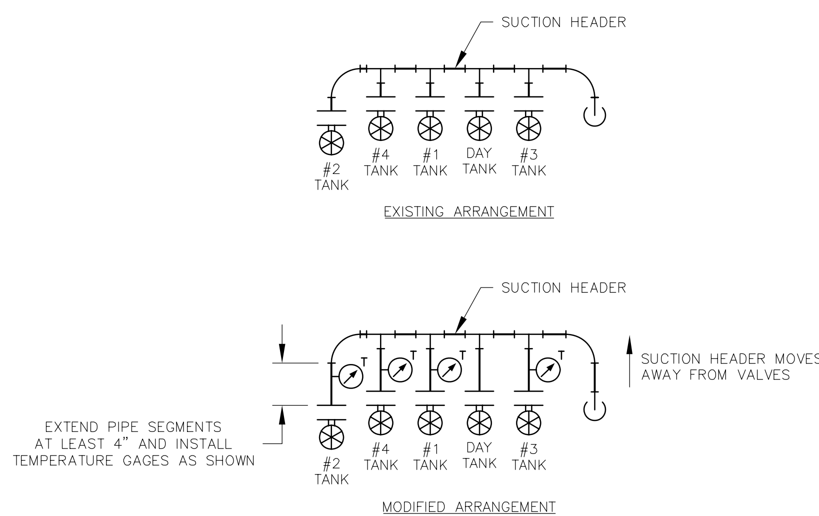
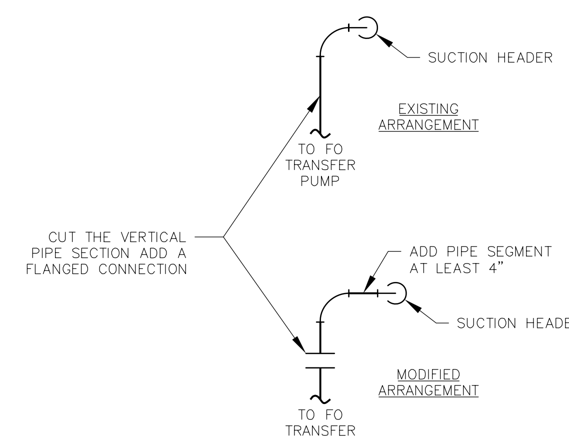


PHOTO 20–C
FO TANK SUCTION MANIFOLD
(SIDE PROFILE)



DETAIL 22–A
FO TANK SUCTION MANIFOLD
(OVERHEAD VIEW)



DETAIL 20–A
FO TANK SUCTION MANIFOLD
(SIDE PROFILE VIEW)

PUGET SOUND CLEAN AIR AGENCY
SEATTLE, WA

WSF BIODIESEL STUDY
ISSAQUAH 130 FUEL SYSTEM MODIFICATIONS
FUEL SYSTEM MODIFICATIONS

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Scale	Drawing Number	Sheet	Rev
NO SCALE	07070–03	3 of 3	–

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF ISSAQUAH 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE	**Fuel Type:** BIODIESEL-B5	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: GE	**Oil Brand:** CHEVRON	
	Model: 7FDM-12	**Oil Type:** MREO DELO477CFO	
Customer No: 20386655	**Equip. Make:**	**Fluid Grade:** 40	**End User:**
Unit No: ISSAQUAH	**Equip. Model:**	**Ser.No:** 100464466	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
84284 Normal	10/31/08 11/06/08	3263 33292	5	0	0	0	0	2	0	0	0	0	5	25	5444	0	9	4	123	2
75378 Normal	10/01/08 10/08/08	2667 32696	6	0	0	0	0	3	0	0	0	0	5	27	6116	0	9	4	132	2
64860 Normal	09/01/08 09/04/08	2089 32118	6	0	0	0	0	3	0	0	0	0	5	26	5751	0	10	4	128	2
57598 Normal	08/01/08 08/07/08	1488 31517	5	0	0	0	0	2	0	0	0	0	5	23	5361	0	4	4	111	2

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
84284	2	2	5	0	0	NO	<1	0.1	15.52	143.62	12	9.7	2.6	19
75378	3	2	5	0	0	NO	<1	0.2	15.55	141.70	11	10.5	3.6	18
64860	3	3	5	0	0	NO	<1	0.3	15.49	142.24	11	10.0	3.3	18
57598	2	3	5	0	0	NO	<1	0.2	14.66	141.65	1	12.2	3.0	18

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
84284	2.17%	134	40	112
75378	1.3%	145	40	113
64860	0.99%	135	40	111
57598	0.92%	68	40	102

Lab No	Brand	Product	Grade	Recommendation
84284	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
75378	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64860	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57598	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF ISSAQUAH 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE	**Fuel Type:** BIODIESEL-B5	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: GE	**Oil Brand:** CHEVRON	
	Model: 7FDM-12	**Oil Type:** MREO DELO477CFO	
Customer No: 20386655	**Equip. Make:**	**Fluid Grade:** 40	**End User:**
Unit No: ISSAQUAH	**Equip. Model:**	**Ser.No:** 100464466	**End Loc:**

Lab No / Condition	Date Taken / Tested	Time on_Oil / on_Unit	WEAR METALS (ppm): IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES: SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
57598 Normal	08/01/08 08/07/08	1488 31517	5	0	0	0	0	2	0	0	0	0	5	23	5361	0	4	4	111	2
48901 Normal	07/01/08 07/08/08	897 30347	4	0	0	0	0	2	0	0	0	0	6	21	5689	0	0	3	103	2
40419 Normal	05/31/08 06/05/08	______	7	0	0	0	0	2	0	0	0	0	5	23	4845	0	0	3	124	2
32497 Abnormal	04/30/08 05/05/08	______ 29743	7	0	0	0	0	3	0	0	0	0	6	21	5919	0	0	5	114	1

Lab No	CONTAMINATION: Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES: Visc100	Visc40	Oxidation	TBN	TAN	Nitration
57598	2	3	5	0	0	NO	<1	0.2	14.66	141.65	1	12.2	3.0	18
48901	2	3	6	0	0	NO	<1	0.1	15.59	139.06	8	12.4	1.2	15
40419	2	2	5	0	0	NO	<1	0.1	14.70	132.93	4	14.2	1.8	9
32497	3	3	6	0	0	NO	<1	0.	15.59	156.13	14	9.9	5.7	22 A

Lab No	ADDITIONAL: LMOA	OILADD	SAE	VI
57598	0.92%	68	40	102
48901	0.74%	158	40	115
40419	0.20%	N/A	40	111
32497	1.7%	N/A	40	101

Lab No	Brand	Product	Grade	Recommendation
57598	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48901	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
40419	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
32497	CHEVRON	MREO DELO477CFO	40	MODERATE LEVEL OF NITRATION PRODUCTS DETECTED. NO RECOMMENDED ACTION AT THIS TIME. RESAMPLE AT NORMAL INTERVALS.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF ISSAQUAH 2901 3RD AVE SUITE 500 SEATTLE, WA 98121-3104 USA	**Comp. Descr.:** #2 MAIN ENGINE	**Fuel Type:** BIODIESEL-B5	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: GE	**Oil Brand:** CHEVRON	
	Model: 7FDM-12	**Oil Type:** MREO DELO477CFO	
Customer No: 20386655	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: ISSAQUAH	**Equip. Model:**	**Ser.No:** 100015244 464467	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm)										ADDITIVES							
			IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
64861 Normal	09/01/08 09/04/08	1990 32117	5	0	0	0	0	3	0	0	0	0	6	28	5987	0	1	5	140	3
57599 Normal	08/01/08 08/07/08	1389 31516	5	0	0	0	0	2	0	0	0	0	6	25	5469	0	1	5	106	2
48902 Normal	07/01/08 07/08/08	796 30344	4	0	0	0	0	2	0	0	0	0	6	22	5816	0	0	5	97	2
40420 Normal	05/31/08 06/05/08	______	3	0	0	0	0	2	0	0	0	0	5	23	4773	0	0	4	112	2

Lab No	CONTAMINATION								PHYSICAL PROPERTIES					
	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TBN	TAN	Nitration
64861	3	3	6	0	0	NO	<1	0.3	15.99	149.02	12	10.1	3.4	18
57599	2	2	6	0	0	NO	<1	0.2	15.52	147.49	12	12.0	3.4	18
48902	2	2	6	0	0	NO	<1	0.2	15.25	144.80	10	12.0	1.3	17
40420	2	2	5	0	0	NO	<1	0.1	14.62	108.06	5	14.4	2.0	9

Lab No	ADDITIONAL			
	LMOA	OILADD	SAE	VI
64861	1.6%	201	40	111
57599	1.26%	105	40	109
48902	1.20%	204	40	107
40420	0.12%	N/A	40	140

Lab No	Brand	Product	Grade	Recommendation
64861	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57599	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48902	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
40420	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF ISSAQUAH 2901 3RD AVE SUITE 500 SEATTLE, WA 98121-3104 USA	**Comp. Descr.:** #2 MAIN ENGINE **Make:** GE **Model:** 7FDM-12	**Fuel Type:** BIODIESEL-B5 **Oil Brand:** CHEVRON **Oil Type:** MREO DELO477CFO	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
Customer No: 20386655	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: ISSAQUAH	**Equip. Model:**	**Ser.No:** 100015244 464467	**End Loc:**

			WEAR METALS (ppm)										ADDITIVES							
Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
84285 Normal	10/31/08 11/06/08	2662 33291	5	0	0	0	0	2	0	0	0	0	5	25	5398	0	6	3	123	2
75379 Normal	10/01/08 10/08/08	2066 32695	5	0	0	0	0	3	0	0	0	0	5	27	5933	0	5	5	123	3
64861 Normal	09/01/08 09/04/08	1990 32117	5	0	0	0	0	3	0	0	0	0	6	28	5987	0	1	5	140	3
57599 Normal	08/01/08 08/07/08	1389 31516	5	0	0	0	0	2	0	0	0	0	6	25	5469	0	1	5	106	2

Lab No	CONTAMINATION								PHYSICAL PROPERTIES					
	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TBN	TAN	Nitration
84285	2	2	5	0	0	NO	<1	0.2	15.14	150.08	13	9.7	2.7	19
75379	3	2	5	0	0	NO	<1	0.2	15.72	148.88	12	10.6	3.8	18
64861	3	3	6	0	0	NO	<1	0.3	15.99	149.02	12	10.1	3.4	18
57599	2	2	6	0	0	NO	<1	0.2	15.52	147.49	12	12.0	3.4	18

Lab No	ADDITIONAL			
	LMOA	OILADD	SAE	VI
84285	2.17%	191	40	102
75379	1.9%	209	40	110
64861	1.6%	201	40	111
57599	1.26%	105	40	109

Lab No	Brand	Product	Grade	Recommendation
84285	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
75379	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64861	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57599	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as requir

Appendix H

M. V. Tillikum Main Engines Lubricant Analysis Results

Company: WSF TILLIKUM 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE	**Fuel Type:** Diesel	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
Customer No: 20386661	**Make:** EMD	**Oil Brand:** CHEVRON	
	Model: 12-645F7B	**Oil Type:** MREO DELO477CFO	
	Equip. Make:	**Fluid Grade:** 20W40	**End User:**

Lab No Condition	Date Taken Tested	Time on Oil on_Unit	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
			WEAR METALS (ppm)										ADDITIVES							
84289 Abnormal	11/01/08 11/06/08	3302 3299	12	0	10	31 A	0	3	0	0	0	0	5	33	6663	0	8	3	160	3
75370 Normal	10/01/08 10/08/08	2775 2772	11	0	8	24	0	2	0	0	0	0	5	29	6071	0	0	3	128	3
64867 Normal	09/01/08 09/04/08	2256	11	0	8	21	0	3	0	0	0	0	5	28	5700	0	2	3	120	3
57594 Normal	08/01/08 08/07/08	1698 1695	12	0	8	20	0	2	0	0	0	0	4	27	5875	0	0	3	124	2

Lab No	CONTAMINATION								PHYSICAL PROPERTIES					
	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TBN	TAN	Nitration
84289	3	4	5	0	0	NO	<1	0.1	15.10	141.95	8	10.6	2.8	16
75370	2	2	5	0	0	NO	<1	0.1	15.76	145.42	8	11.2	2.9	16
64867	3	3	5	0	0	NO	<1	0.2	18.14	141.91	8	10.3	3.0	16
57594	2	3	4	0	0	NO	<1	0.1	15.55	141.65	8	12.8	2.8	16

Lab No	ADDITIONAL			
	LMOA	OILADD	SAE	VI
84289	1.41%	1795	40	108
75370	0.66%	1543	40	112
64867	1.0%	245	50	143
57594	0.95%	337	40	113

Lab No	Brand	Product	Grade	Recommendation
84289	CHEVRON	MREO DELO477CFO	20W40	COPPER LEVEL HAS INCREASED SINCE LAST SAMPLE. RECOMMEND RESAMPLE TO MONITOR/ESTABLISH WEAR TREND.
75370	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64867	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57594	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF TILLIKUM 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE **Make:** EMD **Model:** 12-645F7B	**Fuel Type:** Diesel **Oil Brand:** CHEVRON **Oil Type:** MREO DELO477CFO	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
Customer No: 20386661	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: TILLIKUM	**Equip. Model:**	**Ser.No:** 100015154	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
57594 Normal	08/01/08 08/07/08	1698 1695	12	0	8	20	0	2	0	0	0	0	4	27	5875	0	0	3	124	2
48897 Normal	07/01/08 07/08/08	1159 1162	10	0	7	17	2	2	0	0	0	0	5	24	5814	0	0	4	105	2
40424 Normal	06/01/08 06/05/08	639 639	12	0	8	14	0	2	0	0	0	0	5	27	4905	0	0	8	117	3
27012 Normal	04/01/08 04/16/08	47 47	8	0	8	16	0	2	0	0	0	0	6	25	5511	0	0	6	107	2

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
57594	2	3	4	0	0	NO	<1	0.1	15.55	141.65	8	12.8	2.8	16
48897	2	4	5	0	0	NO	<1	0.1	15.49	141.94	8	12.0	3.2	16
40424	2	6	5	0	0	NO	<1	0.1	14.33	137.10	7	13.4	2.7	13
27012	2	4	6	0	0	NO	<1	0.1	14.82	135.90	4	13.5	1.5	8

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
57594	0.95%	337	40	113
48897	1.15%	603	40	111
40424	0.58%	328	40	103
27012	0.21%	0	40	111

Lab No	Brand	Product	Grade	Recommendation
57594	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48897	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
40424	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
27012	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company:	Comp. Descr.: #2 MAIN ENGINE	Fuel Type: Diesel	Lab:
WSF TILLIKUM 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	Make: EMD Model: 12-645F7B	Oil Brand: CHEVRON Oil Type: MREO DELO477CFO	4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
Customer No: 20386661	Equip. Make:	Fluid Grade: 20W40	End User:

Lab No Condition	Date Taken Tested	Time on Oil on_Unit	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
			WEAR METALS (ppm)										ADDITIVES							
84290 Abnormal	11/01/08 11/06/08	3303 3300	13	0	11	33 A	2	3	0	0	0	0	5	30	6122	0	2	3	137	3
75371 Normal	10/01/08 10/08/08	2775 2772	13	0	10	27	0	2	0	0	0	0	5	29	5641	0	1	3	121	3
64868 Normal	09/01/08 09/04/08	2256	14	0	9	26	0	2	0	0	0	0	4	28	5891	0	0	3	120	3
57595 Normal	08/01/08 08/07/08	1698 1695	14	0	9	23	0	2	0	0	0	0	5	27	5997	0	0	3	116	2

Lab No	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TBN	TAN	Nitration
	CONTAMINATION								PHYSICAL PROPERTIES					
84290	3	4	5	0	0	NO	<1	0.1	14.88	141.68	8	10.9	2.7	15
75371	2	2	5	0	0	NO	<1	0.1	15.40	144.65	8	11.3	2.6	15
64868	2	4	4	0	0	NO	<1	0.2	15.47	143.19	8	11.1	2.7	15
57595	2	4	5	0	0	NO	<1	0.1	15.54	144.81	8	12.8	3.2	15

Lab No	LMOA	OILADD	SAE	VI
	ADDITIONAL			
84290	1.22%	1613	40	105
75371	0.60%	1363	40	109
64868	0.84%	298	40	110
57595	0.90%	305	40	111

Lab No	Brand	Product	Grade	Recommendation
84290	CHEVRON	MREO DELO477CFO	20W40	COPPER LEVEL HAS INCREASED SINCE LAST SAMPLE. RECOMMEND RESAMPLE TO MONITOR/ESTABLISH WEAR TREND.
75371	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64868	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57595	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company:	Comp. Descr.: #2 MAIN ENGINE	Fuel Type: Diesel	Lab:
WSF TILLIKUM 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	Make: EMD	Oil Brand: CHEVRON	4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Model: 12-645F7B	Oil Type: MREO DELO477CFO	
Customer No: 20386661	Equip. Make:	Fluid Grade: 20W40	End User:

			WEAR METALS (ppm)										ADDITIVES							
Lab No Condition	Date Taken Tested	Time on Oil on_Unit	IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
57595 Normal	08/01/08 08/07/08	1698 1695	14	0	9	23	0	2	0	0	0	0	5	27	5997	0	0	3	116	2
48898 Normal	07/01/08 07/08/08	1159 1162	14	0	8	22	0	2	0	0	0	0	5	25	6475	0	0	5	115	2
40425 Normal	06/01/08 06/05/08	640 640	13	0	9	15	0	2	0	0	0	0	4	25	4730	0	0	4	112	2
27013 Normal	04/01/08 04/16/08	47 47	9	0	8	15	0	2	0	0	0	0	7	25	5618	0	0	6	115	2

Lab No	CONTAMINATION								PHYSICAL PROPERTIES					
	Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	Visc100	Visc40	Oxidation	TBN	TAN	Nitration
57595	2	4	5	0	0	NO	<1	0.1	15.54	144.81	8	12.8	3.2	15
48898	2	4	5	0	0	NO	<1	0.1	15.27	140.67	9	12.3	3.0	17
40425	2	3	4	0	0	NO	<1	0.1	15.20	139.40	7	13.3	2.7	13
27013	2	5	7	0	0	NO	<1	0.1	15.38	134.97	4	13.9	1.4	7

Lab No	ADDITIONAL			
	LMOA	OILADD	SAE	VI
57595	0.90%	305	40	111
48898	0.91%	502	40	110
40425	0.49%	250	40	111
27013	0.39%	0	40	117

Lab No	Brand	Product	Grade	Recommendation
57595	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48898	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
40425	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
27013	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF KLAHOWYA 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE	**Fuel Type:** Diesel	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: EMD	**Oil Brand:** CHEVRON	
	Model: 12-645F7B	**Oil Type:** MREO DELO477CFO	
Customer No: 20386660	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: KLAHOWYA	**Equip. Model:**	**Ser.No:** 100221312	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
85698 Normal	10/31/08 11/10/08	3506 3506	16	3	14	27	4	2	0	0	0	0	6	26	5790	0	0	7	115	7
75374 Normal	10/01/08 10/08/08	2957 2957	18	3	13	25	4	2	0	0	0	0	5	28	5652	0	0	6	114	7
64858 Normal	09/01/08 09/04/08	2346 2346	15	2	9	21	0	2	0	0	0	0	5	26	5430	0	2	5	121	6
57592 Normal	08/01/08 08/07/08	1771 1771	14	2	8	19	0	2	0	0	0	0	6	25	5780	0	0	5	115	5

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
85698	2	1	6	0	0	NO	<1	0.1	14.34	136.40	11	10.2	3.6	18
75374	2	2	5	0	0	NO	<1	0.1	14.69	138.84	9	9.7	5.2	17
64858	2	3	5	0	0	NO	<1	0.1	15.02	199.82	9	9.7	3.3	16
57592	2	2	6	0	0	NO	<1	0.1	14.50	127.86	8	11.8	4.0	16

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
85698	0.92%	584	40	104
75374	0.66%	511	40	105
64858	0.61%	442	40	67
57592	0.82%	356	40	114

Lab No	Brand	Product	Grade	Recommendation
85698	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
75374	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64858	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57592	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

as required

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF KLAHOWYA 2901 3RD AVE SUITE 500 SEATTLE WA 98121-3104	**Comp. Descr.:** #1 MAIN ENGINE	**Fuel Type:** Diesel	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: EMD	**Oil Brand:** CHEVRON	
	Model: 12-645F7B	**Oil Type:** MREO DELO477CFO	
Customer No: 20386660	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: KLAHOWYA	**Equip. Model:**	**Ser.No:** 100221312	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
57592 Normal	08/01/08 08/07/08	1771 1771	14	2	8	19	0	2	0	0	0	0	6	25	5780	0	0	5	115	5
48893 Normal	06/30/08 07/08/08	1079 1350	11	1	5	15	1	2	0	0	0	0	7	21	5406	0	0	6	95	4
42457 Normal	06/08/08 06/11/08	772 772	11	0	5	12	0	2	0	0	0	0	7	24	5160	0	0	5	112	4
32503 Normal	05/01/08 05/05/08	271 271	5	0	2	5	0	2	0	0	0	0	6	22	5534	0	0	6	116	2

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
57592	2	2	6	0	0	NO	<1	0.1	14.50	127.86	8	11.8	4.0	16
48893	2	3	7	0	0	NO	<1	0.1	14.79	135.59	7	11.8	2.9	15
42457	2	3	7	0	0	NO	<1	0.1	14.65	127.38	6	12.8	2.3	12
32503	2	2	6	0	0	NO	<1	0.1	14.28	131.59	3	14.1	2.6	5

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
57592	0.82%	356	40	114
48893	0.95%	102	40	109
42457	0.49%	151	40	116
32503	0.12	%	40	106

Lab No	Brand	Product	Grade	Recommendation
57592	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48893	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
42457	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
32503	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF KLAHOWYA 2901 3RD AVE SUITE 500 SEATTLE, WA 98121-3104 USA	**Comp. Descr.:** #2 MAIN ENGINE	**Fuel Type:** Diesel	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: EMD	**Oil Brand:** CHEVRON	
	Model: 12-645F7B	**Oil Type:** MREO DELO477CFO	
Customer No: 20386660	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: KLAHOWYA	**Equip. Model:**	**Ser.No:** 100221313	**End Loc:**

Lab No Condition	Date Taken Tested	Time on_Oil on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
85699 Normal	10/31/08 11/10/08	3510 3510	17	3	15	32	7	2	0	0	0	0	8	24	5517	0	0	6	110	7
75375 Normal	10/01/08 10/08/08	2962 2962	17	2	13	30	7	3	0	0	0	0	7	28	5905	0	2	6	126	7
64859 Normal	09/01/08 09/04/08	2368 2368	17	1	11	26	4	3	0	0	0	0	7	27	5958	0	6	6	135	7
57593 Normal	08/01/08 08/07/08	1802 1802	16	0	10	23	5	2	0	0	0	0	9	25	5564	0	0	7	117	5

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
85699	2	3	8	0	0	NO	<1	0.1	14.70	138.74	10	10.5	3.5	16
75375	3	2	7	0	0	NO	<1	0.2	15.10	141.03	8	10.1	2.7	15
64859	3	4	7	0	0	NO	<1	0.1	15.01	140.73	8	9.8	3.0	15
57593	2	4	9	0	0	NO	<1	0.1	15.15	138.15	8	11.9	3.6	15

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
85699	0.77%	567	40	106
75375	0.59%	507	40	109
64859	0.64%	435	40	108
57593	0.69%	317	40	112

Lab No	Brand	Product	Grade	Recommendation
85699	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
75375	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
64859	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
57593	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix H: Main Engines Lubricant Analysis Results

Company: WSF KLAHOWYA 2901 3RD AVE SUITE 500 SEATTLE, WA 98121-3104 USA	**Comp. Descr.:** #2 MAIN ENGINE	**Fuel Type:** Diesel	**Lab:** 4943 NW FRONT AVENUE PORTLAND, OR 97210 (800-770-4128, FAX (503)286-1562
	Make: EMD	**Oil Brand:** CHEVRON	
	Model: 12-645F7B	**Oil Type:** MREO DELO477CFO	
Customer No: 20386660	**Equip. Make:**	**Fluid Grade:** 20W40	**End User:**
Unit No: KLAHOWYA	**Equip. Model:**	**Ser.No:** 100221313	**End Loc:**

Lab No / Condition	Date Taken / Tested	Time on_Oil / on_Unit	WEAR METALS (ppm) IRON	CHROMIUM	LEAD	COPPER	TIN	ALUMINUM	NICKEL	SILVER	TITANIUM	VANADIUM	ADDITIVES SODIUM	MAGNESIUM	CALCIUM	BARIUM	PHOSPHORUS	ZINC	MOLYBDENUM	BORON
57593 Normal	08/01/08 08/07/08	1802 1802	16	0	10	23	5	2	0	0	0	0	9	25	5564	0	0	7	117	5
48894 Normal	06/30/08 07/08/08	1080 1350	12	1	8	20	7	2	0	0	0	0	11	22	5715	0	0	8	102	4
42458 Normal	06/08/08 06/11/08	908 908	11	0	8	16	3	2	0	0	0	0	10	24	5026	0	0	7	109	4
32504 Normal	05/01/08 05/05/08	274 274	6	0	4	10	4	3	0	0	0	0	8	20	6074	0	0	8	114	3

Lab No	CONTAMINATION Aluminum	Silicon	Sodium	Potassium	Water	Coolant	Fuel *	Solids/Soot	PHYSICAL PROPERTIES Visc100	Visc40	Oxidation	TBN	TAN	Nitration
57593	2	4	9	0	0	NO	<1	0.1	15.15	138.15	8	11.9	3.6	15
48894	2	3	11	0	0	NO	<1	0.1	14.61	135.98	7	12.1	2.6	13
42458	2	3	10	0	0	NO	<1	0.1	14.10	135.44	6	12.8	2.1	11
32504	3	1	8	0	0	NO	<1	0.1	13.46	132.78	4	15.2	2.9	7

Lab No	ADDITIONAL LMOA	OILADD	SAE	VI
57593	0.69%	317	40	112
48894	0.74%	123	40	108
42458	0.48%	114	40	101
32504	0.04%	34	40	96

Lab No	Brand	Product	Grade	Recommendation
57593	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
48894	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
42458	CHEVRON	MREO DELO477CFO	20W40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.
32504	CHEVRON	MREO DELO477CFO	40	RESULTS OF TEST PERFORMED INDICATE NO CORRECTIVE ACTION REQUIRED.

* Fuel results reported as "<" may have been determined by inference from viscosity measurements and may have been confirmed by instrument specific analysis as required.

Appendix I
MV Tillikum – Operational Details

To: Paul Brodeur, Director of Maintenance
From: Scott Calhoun, Staff Chief, MV Tillikum
Date: February 18, 2009
Subject: Biodiesel Final Report – MV Tillikum
Attachments: #1 – Biodiesel Timeline Chart
#2 – Injector Problem Report

Paul,

I will address your questions with my comments below. Please note that I've submitted a couple of attachments which address some of your questions.

1) Feedstock used during the testing?
   a) Canola

2) Identify any issues that you experienced and at what percentage those issues appeared, e.g. 5%, 10%, or 20%?
   a) We experienced in September, 2008, while at B10 concentration, bugs in the purifier causing heavy sludge buildup. Humbug tests of samples taken from both main fuel tanks and day tank were negative. We applied maintenance dosages of Biobor at each fueling during the month of September, which cleared up the bugs. We have had no reoccurrence and have not used Biobor since.
   b) We experienced severe sticking and stuck injectors. We first noticed the problem at B10 concentration levels. We are currently on the third complete set of injectors since the start of biodiesel testing. See Attachment #2 which details injector change-out intervals back to year 2005.

3) What did you find was an adequate cleaning frequency for your fuel purifier? How does that frequency differ from normal operations—e.g. 100% petroleum fuel?
   a) Cleaning frequency has been twice weekly throughout biodiesel testing and going back to when we first stopped using high sulfur fuels. Cleaning once per week was the norm prior to alternative and low sulfur fuels.

4) What did you find was the average filter life? How does that life differ from normal operations—e.g. 100% petroleum fuel?
   a) Filter life was not an issue with the canola product at any concentration level.

5) In your opinion, was fuel tank cleaning necessary at the start of the project?
   a) During the Tillikum's previous test periods on soy feedstock we found thick slime on internals of fuel tanks at the end of testing. I feel it was a good idea to clean the tanks as we had never tried the canola before. We will be opening the tanks for inspection during our Eagle Harbor layup, which is currently scheduled for late March or early April, 2009. We will be able to compare with what we have seen in the past.

6) Did you experience any leaking / weeping seals or gaskets on any fuel related components?
   a) We had to replace o-ring seals on the purifier on two occasions due to swelling and material breakdown.

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MV Tillikum – Operational Details

7) Did you notice any differences in the exhaust gas stack emissions?
   a) No.

8) Did you notice any differences in the exhaust gas stack temperatures?
   a) No.

9) Did you notice any loss of power or did you burn more fuel due to the less energy content of biodiesel? If yes, can you estimate how much, e.g. 1%, 2%?
   a) No, not a noticeable amount. We do not have fuel monitoring equipment like some other vessels which would show burn rates at comparable load levels.

10) Do you have any other observations / recommendations looking back / going forward?

Observations:

Canola Feedstock

1) The Tillikum's experience with this product has been favorable as far as filter life is concerned. The purifier is doing the job as filter life is comparable to pre-alternative fuel days.
2) The injector problems encountered on the Tillikum is a big issue. We sent out three injectors a couple months ago to VDDA for teardown and analysis. The report I finally received today states that what they saw was normal wear, however, this is not anything close to normal wear based on my 30+ years of experience. This past weekend I sent three more injectors with Chevron representatives Tom Kiernes and Peter VanSlyke, who will also do teardowns. One theory is that fuel residue is oxidizing on the barrel and plunger when engines are secured and hot.

High Cloud Point Feedstock

1) According to the Staff Chief of the Klahowya, they are changing racor filters on a weekly basis at 10 psi differential pressures. In the past on the Tillikum while testing soy feedstock, we changed racor filters frequently at 5 psi differential. I also know that the Klahowya has had boiler flame failures much the same as the Tillikum did during prior test periods on soy. Racor filters are not installed on Tillikum/Klahowya boiler fuel supplies. The filter plugging material is getting by the purifier and plugging filters.
2) The Klahowya does maintenance dosages of biobor at all fuelings, which is and has been vessel policy for a long time. I feel it would have been a good opportunity to know if this is necessary with this product.

Soy Feedstock

1) I haven't had any conversations with the Staff Chief of the Issaquah. I did have one conversation with an Oiler who stated that they had some bug infestation issues in the main fuel tanks. He also stated that the material that plugs filters is getting by the purifier, which is what the Tillikum experienced with the soy product in the past. I read in the Operations Log a few weeks back that an auxiliary engine shutdown due

to a plugged fuel filter. As with the Tillikum/Klahowya boilers and the Issaquah engines, there is no Racor primary filtration in the supply lines.

Recommendations looking back / going forward

1) Looking back I feel that this was a valuable endeavor. We have gathered a lot of data that can be used in the future. Unfortunately there are still a lot of unknowns out there, both short term and especially long term.
2) Going forward I think the idea of a long term test of five years on a single vessel would be a good idea. I do not feel that we have enough information and data to commit the whole fleet to biodiesel. If the lawmakers stick to their mandate and the entire fleet has to switch to biofuel I strongly recommend that two micron filtration with differential psi alarm and monitoring be installed in the fuel supply to all critical machinery. There is potential for engine shutdown do to filter plugging, which needs to be avoided at any cost.

It has been a pleasure working with "The Team." Thanks for all the support provided. Let me know if I can be of further assistance.

Scott Calhoun
Staff Chief, MV Tillikum

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MV Tillikum – Operational Details

BIODIESEL TIMELINE CHART – MV TILLIKUM

Date	Primary Racor Filters Changed		Secondary Spin-on Filters Changed		Purifier Cleaned	Comments
	#1 M/E	#2 M/E	#1 M/E	#2 M/E		
3/3/08			X	X		Normal Maintenance
3/31/08	X	X				Start of biodiesel testing
4/1/08 thru 7/30/08					Twice Weekly	B5 Canola / ULSD Blend
4/24/08		X				5 PSI Differential
4/28/08 thru 5/16/08						Dry-Dock @ Todd's
5/22/08	X					5 PSI Differential
5/23/08			X	X		Normal Maintenance
7/25/08		X				5 PSI Differential
8/1/08 thru 8/31/08					Twice Weekly	B10 Canola / ULSD Blend
8/9/08						Changed o-ring, purifier bowl hood due to swelling
9/1/08 thru 9/30/08					Twice Weekly	B10 Canola / ULSD Blend, Maintenance dosage of biobor at each fueling due to heavy sludge buildup in purifier (BUGS)
9/6/08						Changed 1 ea. stuck injector on #2 main engine
9/13/08			X	X		Normal Maintenance
9/27/08	X					5 PSI Differential

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10/1/08 thru 1/31/09					Twice Weekly	B20 Canola / ULSD Blend
11/8/08						Changed all injectors, both main engines due to sticking
12/6/08		X				5 PSI Differential
1/3/09	X					5 PSI Differential
1/7/09						Changed o-ring, purifier bowl hood due to swelling
1/17/09						15 of 24 injectors found to be stuck at shutdown.
1/30/09						Changed all injectors, both main engines due to sticking

Appendix I
MV Tillikum – Operational Details

To: Paul Brodeur, Director of Vessel Maintenance
From: Scott Calhoun, Staff Chief, MV Tillikum
Date: February 18, 2009
Subject: MV Tillikum M/E Injector Problem Report

DATE	MAIN ENGINE #	MAIN ENGINE HOURS	COMMENTS
06/18/05	#1	55,700	Changed all injectors after two years service – normal change-out interval, fuel racks all free.
06/21/05	#2	55,700	Changed all injectors after two years service – normal change-out interval, fuel racks all free.
06/11/07	#1	66,074	Changed all injectors after two years service – normal change-out interval, fuel racks all free after 10,374 running hours.
06/12/07	#2	66,074	Changed all injectors after two years service – normal change-out interval, fuel racks all free after 10,374 running hours.
04/01/08	Both	70,726	First load of B5 Canola / ULSD.
08/01/08	Both	72,375	First load of B10 Canola / ULSD.
10/06/08	Both	73,552	Found several stuck injector racks when engines are secured. The fuel racks free up after engines are started.
10/07/08	Both	73,576	First load of B20 Canola / ULSD.
11/08/08	Both	74,129	Changed all injectors (24 total) on both main engines due to most racks being stuck, engines are hard to start. 17 months & 8,055 hrs. of service from this set of injectors.
12/20/08	Both	74,774	Top deck inspections of both main engines. Checked one bank of injectors (6 total), none of the checked injector racks were stuck.
01/17/09	Both	75,247	Found that 15 out of 24 injectors are sticking when engines are secured, the racks free up once the engines are running. 1,118 total engine hours on these injectors. Very abnormal!

1/30/09	Both	75,480	Changed all injectors (24 total) on both main engines due to most racks being stuck, engines are hard to start. Less than 3 months & 1,351 hrs. of service from this set of injectors.

At this point the above data indicates that the problem is tied to the use of the canola feed stock product. This problem was not observed when the vessel was running on soy feed stock during the two previous test periods or at any time while running on low and ultra low sulfur fuels.

Scott Calhoun
Staff Chief, MV Tillikum

Appendix I
MV Tillikum – Fuel Injector Report

Feb 2, 2009

Valley Power Systems
P/N 40079006 (05J20286, 05C22300, 06B22243)
Ref. Biofuel (Canola base) B20 blend ULSF injector failure analysis
(Injectors have been in operation from 11-06-07 until 11-08-08 with 8,055 hours)
All units were tested for the following:

Performance
Rack Freeness
One unit had a smooth operating rack and the other two had sluggish racks. There was evidence of corrosion and carbon contaminates in the gear and rack teeth.

Atomization
All units displayed good atomization of the test oil during both fast and slow stroking of the plunger regardless of rack position. (Tested at full fuel through idle rack position)

Leakage Rate
All units were tested and found to be well within specification for leakage. (Specification used for leakage is identical to that of a newly remanufactured injector.)

Calibration
The three units were calibrated at standard conditions and delivery was at the midpoint of the calibration specification for newly remanufactured injectors.

Physical condition of major components
Plunger & Bushing assembly
Plungers are in good condition, no visible signs of seizure (intermittent or full). Helices are in good condition with no indication of chipping or erosion. Short and slight scratches above the helices indicate occasional hard contaminants entering through the bushing port holes and rapidly diminishing in size. Any visible marks observed on the plunger and bushing are minor in nature and do not appear to be different from those found on units tested previously with straight ULSF.

Nozzle assembly
Nozzle bodies are in good condition; seating areas are free from chipping, erosion, or abrasion. Needles are likewise in good condition and show no signs of scuffing or scoring on the quill bearing surfaces. Spray holes do not exhibit any uneven or excessive wear patterns.

Conclusions
Internal components all indicate normal wear patterns. No evidence of a manufacturing defect was found which would cause the complaint that the injectors would stick at cold start. Excessively high viscosity of the fuel or lube oil during cold start can cause a "sticking" (plunger no-follow) condition.

EL/JAJ 2-2-09

Appendix I
MV Tillikum – Operational Details

To:	Paul Brodeur, Director of Maintenance
From:	Scott L. Calhoun, SCE, MV Tillikum
Date:	April 5, 2009
Subject:	Condition Report, Fuel Oil Day Tank

The following will describe what you are looking at on the following pictures.

D001.jpg	Tank Overhead
D002.jpg	Tank Bulkhead, Frame-0
D003.jpg	Tank Bulkhead, Inboard
D004.jpg	Tank Bulkhead, Frame-2
D006.jpg	Tank Bottom

The Fuel Oil Day Tank was very clean. There is no real buildup on any surface in the tank. This is consistent with what we were seeing in operation while testing the B20 Canola product. With this product the purifier does the job of separating the solids from the fuel which keeps the Primary 2 Micron Racor Filters from plugging up.

Scott Calhoun
Staff Chief, MV Tillikum


Day Tank Overhead (D001.jpg)


Day Tank Bulkhead, Frame-0 (D002.jpg)

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Day Tank Bulkhead, Inboard (D003.jpg)


Day Tank Bulkhead, Frame-2 (D004.jpg)


Day Tank Bottom (D006.jpg)

To: Paul Brodeur, Director of Maintenance

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MV Tillikum – Operational Details

From:	Scott L. Calhoun, SCE, MV Tillikum
Date:	April 5, 2009
Subject:	Condition Report, Starboard Main Fuel Tank

The following will describe what you are looking at on the following pictures.

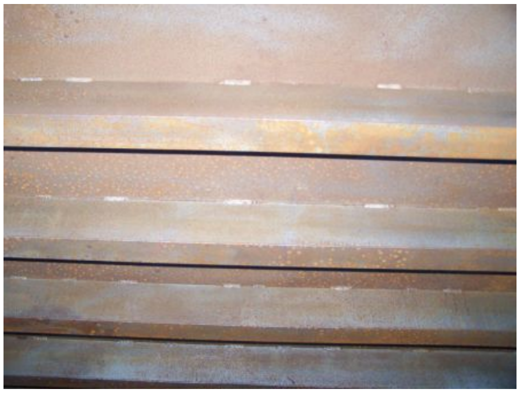
S002.jpg	Tank Overhead
S003.jpg	Tank Bulkhead, #2 End, Frame-6, Top
S004.jpg	Tank Bulkhead, #2 End, Frame-6, Bottom
S005.jpg	Tank Bulkhead, Inboard, Top
S006.jpg	Tank Bulkhead, Inboard, Bottom
S009.jpg	Tank Bottom, Lower
S010.jpg	Tank Bottom, Longitudinal Divider
S011.jpg	Tank Overhead, Rub-rail, and Bottom, Outboard At Top Of Tank
S012.jpg	Tank Bottom Above Suction Line
S013.jpg	Tank Bottom Above Suction Line

Overall the tank internals are quite clean. There is no buildup on the top or sides of the tank. On the tank bottom there is a small amount of buildup (black in color) which is mostly in the bottom portion of the tank. Pictures S009.jpg, S012.jpg, and S013.jpg show black and brown colored streaking. The brown color is the skin of the tank and the black is the small amount of buildup. We did not go into the tank or get the remaining fuel out of the tank to expose the vee at the bottom.

We received our last load of B20 Canola January 27, 2009. To date the Tillikum has taken approximately 94,700 gallons of Ultra Low Sulfur Diesel. I don’t know if the buildup was worse at the end of the biodiesel test period.

Scott Calhoun
Staff Chief, MV Tillikum

Appendix I
MV Tillikum – Operational Details


Storage Tank Overhead (S002.jpg)


Storage Tank Bulkhead, #2 End Frame-6, Top (S003.jpg)


Storage Tank Bulkhead, #2 End Frame-6, Bottom (S004.jpg)

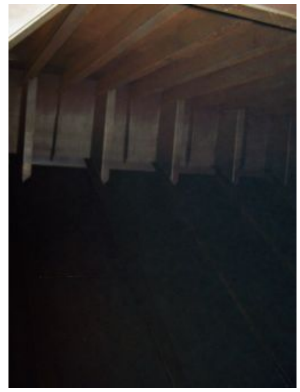

Storage Tank, Inboard, Top (S005.jpg)


Storage Tank, Inboard, Bottom (S006.jpg)


Storage Tank Bottom, Lower (S009.jpg)

Appendix I
MV Tillikum – Operational Details

Storage Tank Bottom
Longitudinal Divider (S010.jpg)



Storage Tank Overhead, Rub-rail
and Bottom, Outboard At Top (S011.jpg)

Storage Tank Bottom Above Suction Line
(S012.jpg)

Storage Tank Bottom Above Suction Line
(S013.jpg)

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

INSTRUCTIONS: Type required information in the green fields and then save the file. Type comments in as necessary. Email the file to lnrenehan@glosten.com weekly
IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell)

Week #	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
1	2	1-Apr-08							B05	V2-W05-040508-D		1	Fuel Delivery sample					
1	2	7-Apr-08	Scott Calhoun	Transfer Pump Sample		X		12:00 AM	B05	V2-W05-040708-1		2	Record Fuel Temp and Filter Pressure Drop at right	80 F.	53 F.	50 F.	2.1 psi diff.	2.5 psi diff.
1	2	7-Apr-08	Bill Schweyen	Transfer Pump Sample			X	2155	B05	V2-W05-040708-2		3						
1	2	8-Apr-08	Scott Calhoun	Transfer Pump Sample			X	12:00 AM	B05	V2-W05-040808-1		4	Record Fuel Temp and Filter Pressure Drop at right	80 F.	55 F.	60 F.	2.2 psi diff.	2.8 psi diff.
1	2	8-Apr-08	Rick Reinertsen	Transfer Pump Sample			X	2100	B05	V2-W05-040808-2		5						
1	2	9-Apr-08	Erik Hansen	Transfer Pump Sample		X		1000	B05	V2-W05-040908-1		6	Record Fuel Temp and Filter Pressure Drop at right	80	54	70	2.3	2.9
1	2	9-Apr-08	Rick Reinertsen	Transfer Pump Sample		X		2200	B05	V2-W05-040908-2		7						
1	2	10-Apr-08	Erik Hansen	Transfer Pump Sample			X	1000	B05	V2-W05-041008-1		8	Record Fuel Temp and Filter Pressure Drop at right	82	64	64	2.4	3
1	2	10-Apr-08	Rick Reinertsen	Transfer Pump Sample		X		2200	B05	V2-W05-041008-2		9						
1	2	11-Apr-08							B05	V2-W05-041108-D		10	Fuel Delivery sample					
1	2	11-Apr-08	Erik Hansen	Transfer Pump Sample		X		1030	B05	V2-W05-041108-1		11	Record Fuel Temp and Filter Pressure Drop at right	80	59	70	2.5	3.2
1	2	11-Apr-08	Rick Reinertsen	Transfer Pump Sample			X	2100	B05	V2-W05-041108-2		12						
1	2	12-Apr-08	Erik Hansen	Transfer Pump Sample			X	1030	B05	V2-W05-041208-1		13	Record Fuel Temp and Filter Pressure Drop at right	70	64	60	2.8	3.7
1	2	12-Apr-08	Rick Reinertsen	Transfer Pump Sample	X			2200	B05	V2-W05-041208-2		14						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
2	2	13-Apr-08	Erik Hansen	Transfer Pump Sample		X		1445	B05	V2-W06-041308-1		15	Record Fuel Temp and Filter Pressure Drop at right	63	63	58	2.8	3.6
2	2	13-Apr-08	Rick Reinertsen	Transfer Pump Sample		X		2200	B05	V2-W06-041308-2		16						
2	2	14-Apr-08	Erik Hansen	Transfer Pump Sample		X		1000	B05	V2-W06-041408-1		17	Record Fuel Temp and Filter Pressure Drop at right	80	58	70	2.7	3.5
2	2	14-Apr-08	Rick Reinertsen	Transfer Pump Sample	X			pm	B05	V2-W06-041408-2		18						
2	2	15-Apr-08							B05	V2-W06-041508-D		19	Fuel Delivery sample					
2	2	15-Apr-08	Erik Hansen	Transfer Pump Sample			X	1000	B05	V2-W06-041508-1		20	Record Fuel Temp and Filter Pressure Drop at right	78	64	60	2.8	3.6
2	2	15-Apr-08	Bill Schweyen	Transfer Pump Sample		X		1830	B05	V2-W06-041508-2		21						
2	2	16-Apr-08	Erik Hansen	Transfer Pump Sample		X		1000	B05	V2-W06-041608-1		22	Record Fuel Temp and Filter Pressure Drop at right	78	58	70	2.8	3.7
2	2	16-Apr-08	Eric Winge	Transfer Pump Sample		X		2000	B05	V2-W06-041608-2		23						
2	2	17-Apr-08	Scott Calhoun	Transfer Pump Sample		X		1045	B05	V2-W06-041708-1		24	Record Fuel Temp and Filter Pressure Drop at right	80	60	74	2.9	3.8
2	2	17-Apr-08	Eric Winge	Transfer Pump Sample			X	1945	B05	V2-W06-041708-2		25						
2	2	18-Apr-08	Erik Hansen	Transfer Pump Sample			X	1000	B05	V2-W06-041808-1		26	Record Fuel Temp and Filter Pressure Drop at right	80	64	62	3	3.9
2	2	18-Apr-08	Eric Winge	Transfer Pump Sample			X	2100	B05	V2-W06-041808-2		27						
2	2	19-Apr-08	Scott Calhoun	Transfer Pump Sample			X	1030	B05	V2-W06-041908-1		28	Record Fuel Temp and Filter Pressure Drop at right	76	61	59	3.1	4.1

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
2	2	19-Apr-08	Eric Winge	Transfer Pump Sample			X	2100	B05	V2-W06-041908-2		29						
3	2	20-Apr-08	Scott Calhoun	Transfer Pump Sample		X		1120	B05	V2-W07-042008-1		30						
3	2	21-Apr-08	Scott Calhoun	Transfer Pump Sample		X		1100	B05	V2-W07-042108-1		31	Record Fuel Temp and Filter Pressure Drop at right	78	56	67	3.2	4.3
3	2	22-Apr-08							B05	V2-W07-042208-D		32	Fuel Delivery sample					
3	2	22-Apr-08	Scott Calhoun	Transfer Pump Sample			X	1020	B05	V2-W07-042208-1		33						
3	2	23-Apr-08	Rick Reinertsen	Transfer Pump Sample		X		1030	B05	V2-W07-042308-1		34						
3	2	24-Apr-08	Rick Reinertsen	Transfer Pump Sample			X	1020	B05	V2-W07-042408-1		35	Record Fuel Temp and Filter Pressure Drop at right	81	60	66	3.4	1.9
3	2	25-Apr-08							B05	V2-W07-042508-D		36	Fuel Delivery sample					
3	2	25-Apr-08	Rick Reinertsen	Transfer Pump Sample			X	1020	B05	V2-W07-042508-1		37						
3	2	26-Apr-08	Rick Reinertsen	Transfer Pump Sample		X		1020	B05	V2-W07-042608-1	V2-W05-040708-1, V2-W05-040808-1, V2-W05-040908-1, V2-W05-041008-1, V2-W05-041108-1, V2-W05-041208-1, V2-W06-041308-1	31						
4	2	27-Apr-08		Transfer Pump Sample					B05	V2-W08-042708-1		32						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
6	2	16-May-08		Transfer Pump Sample Day [ ] Stbd [ ] Port [ ]		B05	V2-W10-051608-1		33						
6	2	17-May-08		Transfer Pump Sample Day [ ] Stbd [ ] Port [ ]		B05	V2-W10-051708-1		34						
6	2	17-May-08				B05	V2-W10-051708-D		35	Fuel Delivery sample					
7	2	18-May-08	Bill Dubose	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	1740	B05	V2-W11-051808-1		36						
7	2	19-May-08	Bill Dubose	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1620	B05	V2-W11-051908-1		37	Record Fuel Temp and Filter Pressure Drop at right	93	79	70	3.9	2
7	2	20-May-08	Bill Dubose	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	1230	B05	V2-W11-052008-1		38						
7	2	21-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1200	B05	V2-W11-052108-1		39						
7	2	22-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	820	B05	V2-W11-052208-1		40	Record Fuel Temp and Filter Pressure Drop at right	84	62	72	1.2	2.2
7	2	23-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	940	B05	V2-W11-052308-1		41						
7	2	24-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1035	B05	V2-W11-052408-1	V2-W06-041408-1, V2-W06-041508-1, V2-W06-041608-1, V2-W06-041708-1, V2-W06-041808-1, V2-W06-041908-1 Samples discarded	36	Record Fuel Temp and Filter Pressure Drop at right	74	70	66	1.2	2.2
7	2	24-May-08	Erik Hansen	Car deck fuel manifold	300	B05	V2-W11-052408-D		37	Fuel Delivery sample					
8	2	25-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1535	B05	V2-W12-052508-1		38						
8	2	26-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	900	B05	V2-W12-052608-1		39	Record Fuel Temp and Filter Pressure Drop at right	84	64	74	1.2	2
8	2	27-May-08	Bill Leonard	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1000	B05	V2-W12-052708-1		40						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Vessel	Date	Collected By	Location			Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
8	2	28-May-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X 	1000	B05	V2-W12-052808-1		41						
8	2	29-May-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X	1000	B05	V2-W12-052908-1		42	Record Fuel Temp and Filter Pressure Drop at right	84	76	68	2	2.5
8	2	30-May-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X 	1000	B05	V2-W12-053008-1		43						
8	2	31-May-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X	1000	B05	V2-W12-053108-1	V2-W05-040508-D, V2-W05-040708-2, V2-W05-040808-2, V2-W05-040908-2, V2-W05-041008-2, V2-W05-041108-D, V2-W05-041108-2, V2-W05-041208-2	36	(All Tillikum Week 1 samples discarded) Samples discarded					
8	2	27-May-08	Scott Calhoun	Delivery Truck			1930	B05	V2-W12-053108-D		37	Fuel Delivery sample					
9	2	1-Jun-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X 	1000	B05	V2-W13-060108-1		38						
9	2	2-Jun-08	Wayne Naysnerski	Purifier Discharge	Day Stbd Port	 X	1000	B05	V2-W13-060208-1		39	Record Fuel Temp and Filter Pressure Drop at right	84	67	68	2	2.7
9	2	3-Jun-08	Scott Calhoun	Delivery Truck			300	B05	V2-W13-060308-D		37	Fuel Delivery sample					
9	2	3-Jun-08	Wayne Naysnerski	Transfer Pump Sample	Day Stbd Port	 X 	1230	B05	V2-W13-060308-1		40						
9	2	4-Jun-08	Peter Kinda	Transfer Pump Sample	Day Stbd Port	 X	915	B05	V2-W13-060408-1		41						
9	2	5-Jun-08	Peter Kinda	Transfer Pump Sample	Day Stbd Port	 X	1000	B05	V2-W13-060508-1		42	Record Fuel Temp and Filter Pressure Drop at right	84	72	66	2.1	2.8
9	2	6-Jun-08	Peter Kinda	Transfer Pump Sample	Day Stbd Port	 X	1030	B05	V2-W13-060608-1		43						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
9	2	7-Jun-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1115	B05	V2-W13-060708-1	V2-W06-041308-2, V2-W06-041408-2, V2-W06-041508-D, V2-W06-041508-2, V2-W06-041608-2, V2-W06-041708-2, V2-W06-041808-2, V2-W06-041908-2	36	(All Tillikum Week 2 samples discarded) Samples discarded					
9	2	6-Jun-08		Delivery Truck	3:00am	B05	V2-W13-060608-D		37	Fuel Delivery sample					
10	2	8-Jun-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	am	B05	V2-W14-060808-1		38	Record Fuel Temp and Filter Pressure Drop at right	67	65	63	2.4	3.3
10	2	9-Jun-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1200	B05	V2-W14-060908-1		40	Record Fuel Temp and Filter Pressure Drop at right	82	70	66	2.2	2.9
10	2	10-Jun-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1015	B05	V2-W14-061008-1		42	Record Fuel Temp and Filter Pressure Drop at right	82	62	64	2.2	2.9
10	2	11-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1350	B05	V2-W14-061108-1		44	Record Fuel Temp and Filter Pressure Drop at right	84	62	76	2.2	3
10	2	12-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1400	B05	V2-W14-061208-1		46	Record Fuel Temp and Filter Pressure Drop at right	87	73	69	2.2	3.1
10	2	13-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1000	B05	V2-W14-061308-1		48	Record Fuel Temp and Filter Pressure Drop at right	84	63	74	2.2	3
10	2	14-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1015	B05	V2-W14-061408-1	Disposed of all Tillikum Week 3 Samples	50	Record Fuel Temp and Filter Pressure Drop at right	82	66	68	2.2	3
11	2	15-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1030	B05	V2-W15-061508-1		45	Record Fuel Temp and Filter Pressure Drop at right	86	70	69	2.2	3
11	2	16-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1015	B05	V2-W15-061608-1		47	Record Fuel Temp and Filter Pressure Drop at right	87	65	77	2.2	3
11	2	17-Jun-08	Bill Schweyen	Delivery Truck	3:00am	B05	V2-W14-061708-D		44	Fuel Delivery sample					
11	2	17-Jun-08	Bill Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1230	B05	V2-W15-061708-1		49	Record Fuel Temp and Filter Pressure Drop at right	86	65	77	2.2	3
11	2	18-Jun-08	Eric Ortwein	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1230	B05	V2-W15-061808-1		51	Record Fuel Temp and Filter Pressure Drop at right	90	75	71	2.1	2.9

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Vessel	Date	Collected By	Location		Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
11	2	19-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1230	B05	V2-W15-061908-1		53	Record Fuel Temp and Filter Pressure Drop at right	88	80	61	2.1	3
11	2	20-Jun-08	Erik Hansen	Delivery Truck		3:00am	B05	V2-W14-062008-D		44	Fuel Delivery sample					
11	2	20-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1030	B05	V2-W15-062008-1		55	Record Fuel Temp and Filter Pressure Drop at right	84	64	79	2.2	3
11	2	21-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1120	B05	V2-W15-062108-1		57	Record Fuel Temp and Filter Pressure Drop at right	79	71	69	2.3	3
12	2	22-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1200	B05	V2-W16-062208-1		48						
12	2	23-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1030	B05	V2-W16-062308-1		49	Record Fuel Temp and Filter Pressure Drop at right	84	71	61	2.1	3
12	2	24-Jun-08	Eric Ortwein	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1130	B05	V2-W16-062408-1		50						
12	2	25-Jun-08	Mike Tietz	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1000	B05	V2-W16-062508-1		51						
12	2	26-Jun-08	Mike Tietz	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1000	B05	V2-W16-062608-1		52	Record Fuel Temp and Filter Pressure Drop at right	85	69	70	2.2	3
12	2	27-Jun-08	Mike Tietz	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1015	B05	V2-W16-062708-1		53						
12	2	28-Jun-08	Mike Tietz	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1200	B05	V2-W16-062808-1	V2-W12-052508-1, V2-W12-052608-1, V2-W12-052708-1, V2-W12-052808-1, V2-W12-052908-1, V2-W12-053008-1, V2-W12-053108-1, V2-W12-053108-D, V2-W14-060808-1, V2-W14-060908-1, V2-W14-061008-1, V2-W14-061108-1, V2-W14-061208-1, V2-W14-061308-1, V2-W14-061408-1	39	SAMPLES DISCARDED (All Tillikum Week 8 samples discarded)					

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
17	13	2	29-Jun-08	Mike Tietz	Transfer Pump Sample			X	1030	B05	V2-W17-062908-1		41						
17	13	2	30-Jun-08	Mike Tietz	Transfer Pump Sample		X		1100	B05	V2-W17-063008-1		42	Record Fuel Temp and Filter Pressure Drop at right	92	70	82	2.1	3
17	13	2	1-Jul-08	Eric Winge	Truck				300	B05	V2-W17-070108-D		43	Fuel Delivery sample					
17	13	2	1-Jul-08	Mike Tietz	Transfer Pump Sample			X	1030	B05	V2-W17-070108-1		44						
17	13	2	2-Jul-08	Peter Kinda	Transfer Pump Sample		X		1030	B05	V2-W17-070208-1		45						
17	13	2	3-Jul-08	Keith Newton	Truck				300	B05	V2-W17-070308-D		46	Fuel Delivery sample					
17	13	2	3-Jul-08	Peter Kinda	Transfer Pump Sample			X	1030	B05	V2-W17-070308-1		47	Record Fuel Temp and Filter Pressure Drop at right	89	80	67	2.3	3.3
17	13	2	4-Jul-08	Peter Kinda	Transfer Pump Sample		X		930	B05	V2-W17-070408-1		48						
17	13	2	5-Jul-08	Peter Kinda	Transfer Pump Sample			X	1030	B05	V2-W17-070508-1	V2-W13-060108-1, V2-W13-060208-1, V2-W13-060308-1, V2-W13-060408-1, V2-W13-060508-1, V2-W13-060608-1, V2-W13-060708-1, V2-W13-060708-D, V2-W15-061508-1, V2-W15-061608-1, V2-W15-061708-1, V2-W15-061808-1, V2-W15-061908-1, V2-W15-062008-1, V2-W15-062108-1	34	DONE 7/10/08(All Tillikum Week 9 samples discarded)					
18	14	2	6-Jul-08	Peter Kinda	Transfer Pump Sample		X		1130	B05	V2-W18-070608-1		35						
18	14	2	7-Jul-08	Peter Kinda	Transfer Pump Sample		X		830	B05	V2-W18-070708-1		36	Record Fuel Temp and Filter Pressure Drop at right	84	64	76	2.4	3.4
18	14	2	8-Jul-08	Bill Schweyen	Truck/Trailer				1945	B05	V2-W18-070808-D		37	Fuel Delivery sample					
18	14	2	8-Jul-08	Peter Kinda	Transfer Pump Sample			X	1000	B05	V2-W18-070808-1		38						
18	14	2	9-Jul-08	Thomas Timmerman	Transfer Pump Sample		X		1130	B05	V2-W18-070908-1		39						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location		Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
18	14	2	10-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	930	B05	V2-W18-071008-1		40	Record Fuel Temp and Filter Pressure Drop at right	86	65	78	2.4	3.5
18	14	2	11-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1145	B05	V2-W18-071108-1		41						
18	14	2	12-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1650	B05	V2-W18-071208-1	V2-W13-060708-D, V2-W14-060808-2, V2-W14-060908-2, V2-W14-061008-2, V2-W14-061108-2, V2-W14-061208-2, V2-W14-061308-2, V2-W14-061408-2, V2-W14-061408-D	33	DONE 7/14/08(All Tillikum Week 10 samples discarded)					
19	15	2	13-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1435	B05	V2-W19-071308-1		34						
19	15	2	14-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1105	B05	V2-W19-071408-1		35	Record Fuel Temp and Filter Pressure Drop at right	90	69	82	2.4	3.5
19	15	2	15-Jul-08	Bill Schweyen	Trailer		305	B05	V2-W19-071508-D		36	Fuel Delivery sample					
19	15	2	15-Jul-08	Bill Dubose	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	945	B05	V2-W19-071508-1		37						
19	15	2	16-Jul-08		Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B05	V2-W19-071608-1		38						
19	15	2	17-Jul-08		Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B05	V2-W19-071708-1		39	Record Fuel Temp and Filter Pressure Drop at right					
19	15	2	18-Jul-08					B05	V2-W19-071808-D		40	Fuel Delivery sample					
19	15	2	18-Jul-08		Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B05	V2-W19-071808-1		41						
19	15	2	19-Jul-08		Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B05	V2-W19-071908-1	V2-W14-061408-D, V2-W15-061508-2, V2-W15-061608-2, V2-W15-061708-2, V2-W15-061808-2, V2-W15-061908-2, V2-W15-062008-2, V2-W15-062108-2, V2-W15-062108-D	33	(All Tillikum Week 11 samples discarded)					
20	16	2	20-Jul-08		Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B05	V2-W20-072008-1		34						

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
21	17	2	1-Aug-08	Reinertsen	Truck				3:00 AM	B10	V2-W21-080108-D		39	Fuel Delivery sample **1/2 GALLON BIOBOR ADDED TO EACH PORT & STARBOARD STORAGE TANKS AS PER**					
21	17	2	1-Aug-08	**BROWN**	Transfer Pump Sample		X		1000	B-10	V2-W21-080108-1		40						
21	17	2	1-Aug-08	**LEONARD**	Transfer Pump Sample			X	1936	B10	V2-W21-080108-2		41						
21	17	2	2-Aug-08	**BROWN**	Transfer Pump Sample		X		1020	B10	V2-W21-080208-1		42						
21	17	2	2-Aug-08	**NO SAMPLE TAKE**	Transfer Pump Sample					B10	V2-W21-080208-2	V2-W17-062908-1, V2-W17-063008-1, V2-W17-070108-D, V2-W17-070108-1, V2-W17-070208-1, V2-W17-070308-D, V2-W17-070308-1, V2-W17-070408-1, V2-W17-070508-1	34	**DISCARDED ALL SAMPLES LISTED**					
22	18	2	3-Aug-08	Richard Brown	Transfer Pump Sample			X	1125	B10	V2-W22-080308-1		35						
22	18	2	3-Aug-08	Eric Ortwein	Transfer Pump Sample			X	2000	B10	V2-W22-080308-2		36						
22	18	2	4-Aug-08	Richard Brown	Transfer Pump Sample			X	1032	B10	V2-W22-080408-1		37	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	88	72	70	2.9	2.2
22	18	2	4-Aug-08	Eric Ortwein	Transfer Pump Sample			X	1930	B10	V2-W22-080408-2		38						
22	18	2	5-Aug-08	Bill Schweyen	Truck					B10	V2-W22-080508-D		39	Fuel Delivery sample **NO BIOBOR ADDED**					
22	18	2	5-Aug-08	Richard Brown	Transfer Pump Sample			X	1020	B10	V2-W22-080508-1		40						
22	18	2	5-Aug-08	Mike Tietz	Transfer Pump Sample			X	1850	B10	V2-W22-080508-2		41						
22	18	2	6-Aug-08	Bill Dubose	Transfer Pump Sample		X		1145	B10	V2-W22-080608-1		42						
22	18	2	6-Aug-08	Mike Tietz	Transfer Pump Sample		X		1930	B10	V2-W22-080608-2		43						
22	18	2	7-Aug-08	Bill Dubose	Transfer Pump Sample			X	8:45 AM	B10	V2-W22-080708-1		44	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	86	71	69	2.9	2.2

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
22	18	2	7-Aug-08		Transfer Pump Sample				pm	B10	V2-W22-080708-2		45	**NO SAMPLE COLLECTED**					
22	18	2	8-Aug-08	Bill Dubose	Transfer Pump Sample		X		1042	B10	V2-W22-080808-1		46						
22	18	2	8-Aug-08	Mike Tietz	Transfer Pump Sample		X		1930	B10	V2-W22-080808-2		47						
22	18	2	9-Aug-08	Bill Dubose	Transfer Pump Sample			X	1115	B10	V2-W22-080908-1		40						
22	18	2	9-Aug-08	Mike Tietz	Transfer Pump Sample			X	2000	B10	V2-W22-080908-2	V2-W18-070608-1, V2-W18-070708-1, V2-W18-070808-D, V2-W18-070808-1, V2-W18-070908-1, V2-W18-071008-1, V2-W18-071108-1, V2-W18-071208-1	33	(All Tillikum Week 14 samples discarded) **ALL SAMPLES DISCARDED AS DIRECTED**					
23	19	2	10-Aug-08	Bill Dubose	Transfer Pump Sample		X		1159	B10	V2-W23-081008-1		34						
23	19	2	10-Aug-08	Mike Tietz	Transfer Pump Sample		X		1930	B10	V2-W23-081008-2		35						
23	19	2	11-Aug-08	Bill Dubose	Transfer Pump Sample		X		9:32 AM	B10	V2-W23-081108-1		36	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	90	68	80	2.9	2.2
23	19	2	11-Aug-08	Wayne Naysnerski	Transfer Pump Sample			X	2000	B10	V2-W23-081008-2		37						
23	19	2	12-Aug-08	Bill Schweyen	Truck				3:20 AM	B10	V2-W23-081208-D		38	Fuel Delivery sample **1/2 GALLON BIOBOR ADDED TO EACH PORT & STARBOARD STORAGE TANKS AS PER**					
23	19	2	12-Aug-08	Bill Dubose	Transfer Pump Sample			X	9:07 AM	B10	V2-W23-081208-1		39						
23	19	2	12-Aug-08		Transfer Pump Sample				pm	B10	V2-W23-081208-2		40	**NO SAMPLE COLLECTED**					
23	19	2	13-Aug-08	Bill Leonard	Transfer Pump Sample		X		8:55 AM	B10	V2-W23-081308-1		41						
23	19	2	13-Aug-08	Peter Kinda	Transfer Pump Sample			X	2030	B10	V2-W23-081308-2		42						
23	19	2	14-Aug-08	Bill Leonard	Transfer Pump Sample			X	7:53 AM	B10	V2-W23-081408-1		43	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	90	80	73	2.9	2.1

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
23	19	2	14-Aug-08	Peter Kinda	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	2150	B10	V2-W23-081408-2		44						
23	19	2	15-Aug-08	Erik Hansen	Truck	3:00 AM	B10	V2-W23-081508-D		45	Fuel Delivery sample **1/2 GALLON BIOBOR ADDED TO EACH PORT & STARBOARD STORAGE TANKS AS PER**					
23	19	2	15-Aug-08	Eric Ortwein	Transfer Pump Sample – Day [ ] Stbd [X] Port [ ]	1500	B10	V2-W23-081508-1		46						
23	19	2	15-Aug-08	Peter Kinda	Transfer Pump Sample – Day [ ] Stbd [X] Port [ ]	2100	B10	V2-W23-081508-2		47						
23	19	2	16-Aug-08	Eric Ortwein	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	1300	B10	V2-W23-081608-1		48						
23	19	2	16-Aug-08	Peter Kinda	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	2000	B10	V2-W23-081608-2	V2-W19-071308-1, V2-W19-071408-1, V2-W19-071508-D, V2-W19-071508-1, V2-W19-071608-1, V2-W19-071708-1, V2-W19-071808-D, V2-W19-071808-1, V2-W19-071908-1	40	(All Tillikum Week 15 samples discarded) ALL SAMPLES DISCARDED AS DIRECTED					
24	20	2	17-Aug-08	Eric Ortwein	Transfer Pump Sample – Day [ ] Stbd [X] Port [ ]	1600	B10	V2-W24-081708-1		41						
24	20	2	18-Aug-08	Panaris	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	1000	B10	V2-W24-081808-1		42	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	92	75	80	3	2.2
24	20	2	19-Aug-08	Eric Ortwein	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	1000	B10	V2-W24-081908-1		43						
24	20	2	19-Aug-08	Scott Calhoun	Fill Station	1940		V2-W24-081908-D		44	Fuel Delivery sample **1/2 GALLON BIOBOR ADDED TO EACH PORT & STARBOARD STORAGE TANKS AS PER**					
24	20	2	20-Aug-08	Wayne Naysnerski	Transfer Pump Sample – Day [ ] Stbd [X] Port [ ]	1400	B10	V2-W24-082008-1		45						
24	20	2	21-Aug-08	Todd Ogdahl	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	1000	B10	V2-W24-082108-1		46	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	84	73	70	3.2	2.3
24	20	2	22-Aug-08	Mike Tietz	Transfer Pump Sample – Day [ ] Stbd [X] Port [ ]	1300	B10	V2-W24-082208-1		47						
24	20	2	23-Aug-08	Mike Tietz	Transfer Pump Sample – Day [ ] Stbd [ ] Port [X]	1300	B10	V2-W24-082308-1	V2-W20-072008-1, V2-W20-072108-1, V2-W20-072208-1, V2-W20-072308-1, V2-W20-072408-1, V2-W20-072508-1, V2-W20-072608-1, V2-W21-080108-1, V2-W21-080208-1, V2-W22-080308-1, V2-W22-080408-1, V2-W22-080508-1, V2-W22-080608-1, V2-W22-080708-1, V2-W22-080808-1, V2-W22-080908-1	32	(All Tillikum Week 16 samples discarded. All morning B10 samples through Tillikum Week 18 discarded.) ALL SAMPLES DISCARDED AS DIRECTED					

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
24	20	2	23-Aug-08	Mike Tietz	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1300	B10	V2-W24-082308-1	V2-W20-072008-1, V2-W20-072108-1, V2-W20-072208-1, V2-W20-072308-1, V2-W20-072408-1, V2-W20-072508-1, V2-W20-072608-1, V2-W21-080108-1, V2-W21-080208-1, V2-W22-080308-1, V2-W22-080408-1, V2-W22-080508-1, V2-W22-080608-1, V2-W22-080708-1, V2-W22-080808-1, V2-W22-080908-1	32	(All Tillikum Week 16 samples discarded. All morning B10 samples through Tillikum Week 18 discarded.) ALL SAMPLES DISCARDED AS DIRECTED					
21	17	2	24-Aug-08	Mike Tietz	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	900	B10	V2-W25-082408-1		33						
21	17	2	25-Aug-08	Mike Tietz	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1015	B10	V2-W25-082508-1		34	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	90	67	70	3.2	2.2
22	18	2	26-Aug-08	Scott Calhoun	Fill Station	300	B10	V2-W25-082608-D		35	Fuel Delivery sample **1/2 GALLON BIOBOR ADDED TO EACH PORT & STARBOARD STORAGE TANKS AS PER**					
22	18	2	26-Aug-08	NO SAMPLE TAKEN	Transfer Pump Sample: Day [ ] Stbd [ ] Port [ ]	NA	B10	V2-W25-082608-1		36						
22	18	2	27-Aug-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	915	B10	V2-W25-082708-1		37						
22	18	2	28-Aug-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1015	B10	V2-W25-082808-1		38	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	90	76	72	3.3	2.3
22	18	2	29-Aug-08	Keith Newton	Fill Station	300	B10	V2-W25-082908-D		39	1/2 Gallon Biobor added to ea. Fuel Storage Tank before fuelling					
22	18	2	29-Aug-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	900	B10	V2-W25-082908-1		40	Purifier cleaned twice ea. Week, sludge very minimal in bowl.					
22	18	2	30-Aug-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1000	B10	V2-W25-083008-1	V2-W21-072708-1, V2-W21-072808-1, V2-W21-072908-D, V2-W21-072908-1, V2-W21-073008-1, V2-W21-073108-1, V2-W21-080108-D, V2-W23-081008-1, V2-W23-081108-1, V2-W23-081208-1, V2-W23-081308-1, V2-W23-081408-1, V2-W23-081508-1, V2-W23-081608-1	27	(All B5 samples discarded. 8/1/08 delivery sample discarded. All morning B10 samples through Tillikum Week 19 discarded.)					
22	18	2	31-Aug-08	Peter Kinda	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1100	B10	V2-W26-083108-1		28						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Day	Stbd	Port	Time	Fuel Type	Serial Number	Samples to Discard	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
26	22	2	1-Sep-08	KINDA	Transfer Pump Sample		X		930	B10	V2-W26-090108-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	84	64	76	3.7	2.4
26	22	2	2-Sep-08	KINDA	Transfer Pump Sample		X		830	B10	V2-W26-090208-1							
26	22	2	3-Sep-08	DUBOSE	Transfer Pump Sample			X	1150	B10	V2-W26-090308-1							
26	22	2	4-Sep-08	DUBOSE	Transfer Pump Sample		X		830	B10	V2-W26-090408-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	85	65	76	3.9	2.4
26	22	2	5-Sep-08	DUBOSE	Transfer Pump Sample		X		630	B10	V2-W26-090508-1							
26	22	2	6-Sep-08	DUBOSE	Transfer Pump Sample		X		930	B10	V2-W26-090608-1	V2-W22-080508-D, V2-W21-080108-2, V2-W21-080208-2, V2-W22-080308-2, V2-W22-080408-2, V2-W22-080608-1, V2-W22-080608-2, V2-W22-080708-1, V2-W22-080708-2, V2-W22-080808-1, V2-W22-080808-2, V2-W22-080908-1, V2-W22-080908-2	SAMPLES DISCARDED AS DIRECTED (All samples from Tillikum Week 18 and before discarded.)					
27	23	2	7-Sep-08	DUBOSE	Transfer Pump Sample			X	1315	B10	V2-W27-090708-1							
27	23	2	8-Sep-08	DUBOSE	Transfer Pump Sample			X	910	B10	V2-W27-090808-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	90	73	72	3.8	2.3
27	23	2	9-Sep-08	HANSEN	PORT DECK FILL STATION				2000	B10	V2-W27-090908-D		Fuel Delivery sample INVOICE #0316679					
27	23	2	9-Sep-08	DUBOSE	Transfer Pump Sample		X		920	B10	V2-W27-090908-1							
27	23	2	10-Sep-08	ORTWEIN	Transfer Pump Sample		X		1300	B10	V2-W27-091008-1							
27	23	2	11-Sep-08	ORTWEIN	Transfer Pump Sample			X	1300	B10	V2-W27-091108-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	92	80	78	3.8	2.4
27	23	2	12-Sep-08	HANSEN	PORT DECK FILL STATION				300	B10	V2-W27-091208-D		Fuel Delivery sample INVOICE #0316710					
27	23	2	12-Sep-08	ORTWEIN	Transfer Pump Sample		X		1300	B10	V2-W27-091208-1							

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
27	23	2	13-Sep-08	ORTWEIN	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1500	B10	V2-W27-091308-1	V2-W23-081008-2, V2-W23-081108-1, V2-W23-081108-2, V2-W23-081208-D, V2-W23-081208-1, V2-W23-081208-2, V2-W23-081308-1, V2-W23-081308-2, V2-W23-081408-1, V2-W23-081408-2, V2-W23-081508-D, V2-W23-081508-1, V2-W23-081508-2, V2-W23-081608-1, V2-W23-081608-2	SAMPLES DISCARDED AS DIRECTED (All samples from Tillikum Week 19 and before discarded.)					
28	24	2	14-Sep-08	ORTWEIN	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1300	B10	V2-W28-091408-1							
28	24	2	15-Sep-08	LEONARD	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	900	B10	V2-W28-091508-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	88	72	92	3.5	2
28	24	2	16-Sep-08	LEONARD	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	900	B10	V2-W28-091608-1							
28	24	2	16-Sep-08	CALHOUN	PORT DECK FILL STATION	1935	B10	V2-W28-091608-D		Fuel Delivery sample INVOICE #0316780					
28	24	2	17-Sep-08		Transfer Pump Sample Day [ ] Stbd [ ] Port [ ]		B10	V2-W28-091708-1		NO SAMPLE TAKEN					
28	24	2	18-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	920	B10	V2-W28-091808-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	83	65	67	4.2	2.5
28	24	2	19-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	815	B10	V2-W28-091908-1							
28	24	2	20-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	920	B10	V2-W28-092008-1	V2-W24-081708-1, V2-W24-081808-1, V2-W24-081908-1, V2-W24-081908-D, V2-W24-082008-1, V2-W24-082108-1, V2-W24-082208-1, V2-W24-082308-1	SAMPLES DISCARDED AS DIRECTED (All samples from Tillikum Week 20 and before discarded.)					
29	25	2	21-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	1300	B10	V2-W29-092108-1							
29	25	2	22-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	830	B10	V2-W29-092208-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	84	64	75	4	2.5
29	25	2	23-Sep-08	ORTWEIN	PORT DECK FILL STATION	300	B10	V2-W29-092308-D		Fuel Delivery sample					
29	25	2	23-Sep-08	NAYSNERSKI	Transfer Pump Sample Day [ ] Stbd [ ] Port [X]	930	B10	V2-W29-092308-1							
29	25	2	24-Sep-08	KINDA	Transfer Pump Sample Day [ ] Stbd [X] Port [ ]	900	B10	V2-W29-092408-1							

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
29	25	2	25-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd / Port [X]	840	B10	V2-W29-092508-1		Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	89	74	70	4.3	2.6
29	25	2	26-Sep-08	ORTWEIN	PORT DECK FILL STATION	300	B10	V2-W29-092608-D		Fuel Delivery sample					
29	25	2	26-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd / Port [X]	1330	B10	V2-W29-092608-1							
29	25	2	27-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd / Port [X]	1015	B10	V2-W29-092708-1	V2-W25-082408-1, V2-W25-082508-1, V2-W25-082608-D, V2-W25-082608-1, V2-W25-082708-1, V2-W25-082808-1, V2-W25-082908-D, V2-W25-082908-1, V2-W25-083008-1	(All samples from Tillikum Week 21 and before discarded.) CHANGED BOTH RACOR FUEL FILTERS ON #1 MAIN ENGINE. (APPROX. 4 MONTHS SINCE LAST CHANGE)					
30	26	2	28-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd [X] / Port	1330	B10	V2-W30-092808-1							
30	26	2	29-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd [X] / Port	1000	B10	V2-W30-092908-1							
30	26	2	30-Sep-08	KINDA	Transfer Pump Sample: Day / Stbd / Port [X]	840	B10	V2-W30-093008-1							

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
30	26	2	3-Oct-08	Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	930	B10	V2-W30-100308-1	V2-W26-083108-1, V2-W26-090108-1, V2-W26-090208-1, V2-W26-090308-1, V2-W26-090408-1, V2-W26-090508-1,	33	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from Tillikum Week 22 and before discarded.)	88	67	80	1.9	2.7
30	26	2	7-Oct-08	Winge	Port Fill Station	300	B20	V2-W30-100708-D		36	Fuel Delivery sample Invoice #0317084					
31	27	2	7-Oct-08	Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	945	B20	V2-W31-100708-1		37	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	87	63	78	1.9	2.7
31	27	2	10-Oct-08	Hansen	Port Fill Station	300	B20	V2-W31-101008-D		40	Fuel Delivery sample Invoice #0317119					
31	27	2	10-Oct-08	Ortwein	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1300	B20	V2-W31-101008-1	V2-W27-090708-1, V2-W27-090808-1, V2-W27-090908-D, V2-W27-090908-1, V2-W27-091008-1, V2-W27-091108-1, V2-W27-091208-D, V2-W27-	33	Fuel Temp Day Tank: Samples discarded Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from Tillikum Week 23 and before discarded.)	84	71	70	2	2.8
32	28	2	14-Oct-08	Ortwein	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	1500	B20	V2-W32-101408-1		34	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	81	66	74	2	2.8
32	28	2	17-Oct-08	Tietz	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	745	B20	V2-W32-101708-1	V2-W28-091408-1, V2-W28-091508-1, V2-W28-091608-1, V2-W28-091608-D, V2-W28-091708-1, V2-W28-091808-1, V2-W28-091908-1, V2-W28-	35	Fuel Temp Day Tank: Samples discarded Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from Tillikum Week 24 and before discarded.)	84	71	69	2	2.8
33	29	2	21-Oct-08	Calhoun	Port Fill Station	315	B20	V2-W33-102108-D		37	Fuel Delivery sample Invoice #0317287					
33	29	2	21-Oct-08		Transfer Pump Sample: Day [ ] Stbd [ ] Port [ ]		B20	V2-W33-102108-1		38	Fuel Temp Day Tank: NO SAMPLE TAKEN Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:					
33	29	2	24-Oct-08	Reinertsin	Port Fill Station	300	B20	V2-W33-102408-D		36	Fuel Delivery sample Invoice #0317355					
34	30	2	28-Oct-08	Payne	Port Fill Station	1930	B20	V2-W34-102808-D		40	Fuel Delivery sample Invoice #0317426					
34	30	2	28-Oct-08	Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	800	B20	V2-W34-102808-1	V2-W29-092108-1, V2-W29-092208-1, V2-W29-092308-D, V2-W29-092308-1, V2-W29-092408-1, V2-W29-092508-1, V2-W29-092608-D, V2-W29-	33	Fuel Temp Day Tank: Samples discarded Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from Tillikum Week 25 and before discarded.)	81	63	70	2	2.8

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location		Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
35	31	2	4-Nov-08	Payne	Port Fill Station		300	B20	V2-W35-110408-D			Fuel Delivery sample INVOICE #0317511					
35	31	2	4-Nov-08	NO SAMPLE TAKEN TODAY	Transfer Pump Sample	Day [ ] Stbd [ ] Port [ ]		B20	V2-W35-110408-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:					
35	31	2	7-Nov-08	Hansen	Port Fill Station		300	B20	V2-W35-110708-D			Fuel Delivery sample INVOICE #0317578					
36	32	2	11-Nov-08	Brown	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]		B20	V2-W36-111108-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	87	68	67	2	2.1
37	33	2	19-Nov-08	Ortwein	Port Fill Station		300	B20	V2-W37-111908-D			Fuel Delivery sample INVOICE #0317744					
37	33	2	18-Nov-08	Tietz	Transfer Pump Sample	Day [ ] Stbd [ ] Port [X]	1420	B20	V2-W37-111808-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	87	70	68		
37	33	2	21-Nov-08	Ortwein	Port Fill Station		315	B20	V2-W37-112108-D			Fuel Delivery sample INVOICE #0317789					
38	34	2	25-Nov-08	Winge	Port Fill Station		1930	B20	V2-W38-112508-D			Fuel Delivery sample INVOICE #0317852					
38	34	2	25-Nov-08	Kinda	Transfer Pump Sample	Day [ ] Stbd [X] Port [ ]	1440	B20	V2-W38-112508-1	V2-W30-092808-1, V2-W30-092908-1, V2-W30-093008-1, V2-W30-100308-1, V2-W30-100708-D, V2-W31-100708-1, V2-W31-101008-D, V2-W31-101008-1, V2-W32-101408-1, V2-W32-101708-1, V2-W33-102108-D, V2-	9	Fuel Temp Day Tank: ALL SAMPLES DISCARDED Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from 10/28/08 and before discarded.)					

WSF Biodiesel Test Samples
Vessel 2 - Tillikum

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Week #	Tillikum Test Week#	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp Day Tank	Fuel Temp Stbd Wing Tank	Fuel Temp Port Wing Tank	Filter Pressure Drop #1 Main	Filter Pressure Drop #2 Main
39	35	2	2-Dec-08	Winge	Port Fill Station	300	B20	V2-W39-120208-D			Fuel Delivery sample INVOICE # 0317926					
39	35	2	2-Dec-08	Dubose	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	920	B20	V2-W39-120208-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	???	???	???	???	???
39	35	2	5-Dec-08	Kinda	Port Fill Station	300	B20	V2-W39-120508-D			Fuel Delivery sample INVOICE # ???					
40	36	2	10-Dec-08	Tietz	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	???	B20	V2-W40-120908-1			Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: NOTE THAT RACOR FILTERS WERE CHANGED 12/6/08 ON #2 MAIN ENGINE	69	68	68	2	1.5
40	36	2	10-Dec-08	Winge	Port Fill Station	1940	B20	V2-W40-120908-D			Fuel Delivery sample INVOICE # 0318080					
41	37	2	19-Dec-08	Hansen	Port Fill Station [ ] [ ] [ ]	1000	ULSD	V2-W41-121608-1			Fuel Delivery Sample INVOICE # 0318240 (NOTE THAT NO BIODIESEL DELIVERED DUE TO SUPPLIER NOT ABLE TO ACCESS THE STORAGE TANK - SNOW STORM					
42	38	2	23-Dec-08	Kinda	Transfer Pump Sample: Day [ ] Stbd [X] Port [ ]	730	B20	V2-W42-122308-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:	77	36	65	3.8	2.7
42	38	2	25-Dec-08	Jarman	Port Fill Station	1945	ULSD	V2-W42-122308-D			Fuel Delivery sample INVOICE # 0318297 (NOTE THAT NO BIODIESEL DELIVERED DUE TO SUPPLIER NOT ABLE TO ACCESS THE STORAGE TANK - SNOW STORM					
43	39	2	30-Dec-08	Jarman	Port Fill Station	355	B20	V2-W43-123008-D			Fuel Delivery sample INVOICE # 0318339					
43	39	2	30-Dec-08	Timmerman	Transfer Pump Sample: Day [ ] Stbd [ ] Port [X]	1300	B20	V2-W43-123008-1	V2-W35-110408-D, V2-W35-110408-1, V2-W35-110708-D, V2-W36-111108-1, V2-W37-111808-D, V2-W37-111808-1, V2-W37-112108-D, V2-W38-	10	Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng: (All samples from 11/30/08 and before discarded.)	78	62	60	4.1	2.8
43	39	2	31-Dec-08		Transfer Pump Sample: Day [ ] Stbd [ ] Port [ ]		B20	V2-W43-123108-1		11						

WSF Biodiesel Test Samples
Vessel 2 - Tillikum (Revised)

JANUARY, 2009

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
	2									Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:
	2	1-2-09	Kinda	Deck Fill	0300	B20	318392			Fuel Delivery sample
	2	1-6-09	[illegible]	X-Fer pump	1030	B20	0106091			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: 2.0 Filter Pressure Drop #2 Main Eng: 2.3
	2	1-6-09	CALHOUN	PORT FILL STATION	1935	B20 CANOLA	V2-W?-010609			FUEL DELIVERY SAMPLE
	2	1-13-09	TIETZ	PURIFIER DISCHARGE	1530	B20 CANOLA	V2-W39 011309-1			Fuel Temp Day Tank: Fuel Temp Stbd Wing Tank: Fuel Temp Port Wing Tank: Filter Pressure Drop #1 Main Eng: Filter Pressure Drop #2 Main Eng:
	2	1-13-09	CALHOUN	PORT FILL STATION	0305	B20	V2-W?-011309			Fuel Delivery sample INV.#0318563
	2	1-16-09	ORTWEIN	PORT FILL STATION	0300	B-20	V2-011609 D			FUEL DIVERY SAMPLE
	2	1-20-09	Kinda	F.O. XFER Pump	0630	B20	V2-012009-1			Fuel Temp Day Tank: 72 Fuel Temp Stbd Wing Tank: 60 Fuel Temp Port Wing Tank: 58 Filter Pressure Drop #1 Main Eng: 2.2 Filter Pressure Drop #2 Main Eng: 3.4
	2	1-27-09	TIMMERMAN	F.O. XFER Pump	1100	B20	V2-012709-1			Fuel Temp Day Tank: 76 Fuel Temp Stbd Wing Tank: 52 Fuel Temp Port Wing Tank: 64 Filter Pressure Drop #1 Main Eng: 2.2 Filter Pressure Drop #2 Main Eng: 3.3
	2	1-27-09	TIETZ	PORT FILL STA.	0300	B20	V2-012709-D			Fuel Delivery sample INV.#0318778
	2	1-30-09		P. Fill Sta. ULSD only	0300	ULSD	V2-013009-D			FUEL DELIVERY SAMPLE

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
1	1	8-Mar-08	Justin	Eagle Harbor Fill pipe	1045	B05	V1-W01-030808-D	NONE	1	Fuel Delivery sample
1	1	9-Mar-08	Justin	Eagle Harbor	1045	B05	V1-W01-030908-D	NONE	2	Fuel Delivery sample
1	1	9-Mar-08	No fuel		am	B05	V1-W01-030908-1		3	:
1	1	9-Mar-08	Justin	Fill Pipe Vashon	1745 pm	B05	V1-W01-030908-2	NONE	4	Fuel Delivery Sample
1	1	10-Mar-08			am	B05	V1-W01-031008-1		5	Fuel Temp: Filter Pressure Drop:
1	1	10-Mar-08	Justin	Purifier Issaquah	1200 pm	B05	V1-W01-031008-2	NONE	6	Manifold Temp 55°F Engine temp@ L6 84°F
1	1	11-Mar-08	Alex	Purifier Issaquah	2130 tie up pm ~~am~~	B05	V1-W01-031108-1	NONE	7	Manifold temp 55°F Engine temp@ L6 86.5F
1	1	11-Mar-08	Justin	Purifier	1200 pm	B05	V1-W01-031108-2	NONE	8	Manifold temp 53°F Engine Temp @ L6 87.7
1	1	12-Mar-08	Joe	Purifier	1200 AM am	B05	V1-W01-031208-1	N/A	9	MANIFOLD TEMP 71°F ENGINE TEMP 96.4°
1	1	12-Mar-08	MATT	Purifier	1200 pm	B05	V1-W01-031208-2	None	10	Manifold 52°F Engine 84.4°F
1	1	13-Mar-08	~~MATT~~ Joe	Purifier	1200 am	B05	V1-W01-031308-1	None	11	Fuel Temp: Manifold ~~[illegible]~~ 71°F Filter Pressure Drop: Engine 91.4°F
1	1	13-Mar-08	MATT	Purifier	1200 pm	B05	V1-W01-031308-2	None	12	Manifold 54°F Engine 90°F
~~1~~	~~1~~	~~14 MAR 08~~	~~Eric~~	~~VASHON~~	~~0010~~	~~B05~~	~~V1-W01-031408-D~~	~~NONE~~	~~Additional~~	~~Fuel delivery sample~~
1	1	14-Mar-08	Eric	Purifier	0000 am	B05	V1-W01-031408-1	None	13	Manifold 56°F Eng 105°F
1	1	14-Mar-08	MATT	PURIFIER	1200 (pm)	B05	V1-W01-031408-2	⊖	14	MANIFOLD 54°F ENG 93°F
1	1	15-Mar-08	Joe	purifier	0000 am	B05	V1-W01-031508-1	None	15	Manifold 54°F Engine 102.2°F
1	1	15-Mar-08	MATT	PURIFIER	1200 (pm)	B05	V1-W01-031508-2	⊖	16	MANIFOLD 54°F ENG 97°F
2	1	15-Mar-08	Eric	SW fill pipe	0300AM	B05	V1-W02-031508-D	None	17	Fuel Delivery sample
2	1	16-Mar-08	Eric	SW Fillpipe	0300AM	B05	V1-W02-031608-D	None	18	Fuel Delivery sample
2	1	16-Mar-08	Collazo	Purifier	12:01 am	B05	V1-W02-031608-1	N/A	19	Manifold 65° Eng Temp 88.3
2	1	16-Mar-08	WEITHMAN	PURIFIER	1200 (pm)	B05	V1-W02-031608-2	⊖	20	MANIFOLD 55°F ENGINE 106°
2	1	17-Mar-08	Collazo	Purifier	12:08 am	B05	V1-W02-031708-1	N/A	21	Fuel Temp: Filter Pressure Drop:

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
2	1	17-Mar-08	Darling	Purifier	1200 pm	B05	V1-W02-031708-2	None	22	Manifold 68° LG - 105° LED 48°
2	1	18-Mar-08	Collazo	Purifier	1207 am	B05	V1-W02-031808-1	N/A	23	Manifold 73° Eng temp 87.4°
2	1	18-Mar-08	Darling	Purifier	1200 pm	B05	V1-W02-031808-2	N/A	24	Manifold 60°F LG - 120.7°F
2	1	19-Mar-08	Psillos	Purifier	1203 am	B05	V1-W02-031908-1	None	25	Temp 52
2	1	19-Mar-08	Milne	Purifier	1205 pm	B05	V1-W02-031908-2	None	26	Man. 60° Engine 87
2	1	20-Mar-08	Psillos	Purifier	11:58 am	B05	V1-W02-032008-1	None	27	Fuel Temp: Filter Pressure Drop:
2	1	20-Mar-08	Milne	Purifier	12:06 pm	B05	V1-W02-032008-2	None	28	Temp 58° manifold 88° Eng
2	1	21-Mar-08	Psillos	Purifier	1$:56 am	B05	V1-W02-032108-1	None	29	Temp 58° manifold 75 Eng
2	1	21-Mar-08	Sheldon	Purifier	12:00 pm	B05	V1-W02-032108-2	None	30	Temp 68° Manifold 90° Engine
2	1	22-Mar-08	Dinsmore	Purifier	00:30 am	B05	V1-W02-032208-1	None	31	Temp 62 manifold 74 Eng
2	1	22-Mar-08	Milne	Purifier	12:04 pm	B05	V1-W02-032208-2	None	32	temp Man. 54° Eng. 90°
3	1	22-Mar-08	Dinsmore	Purifier	08 06	B05	V1-W03-032208-D	None	33	Fuel Delivery sample
3	1	23-Mar-08	Dinsmore	Truck	03:00	B05	V1-W03-032308-D	None	34	Fuel Delivery sample
3	1	23-Mar-08	Dinsmore	Purifier	1258	B05	V1-W03-032308-1	None	35	Manifold 72° Engine 73
3	1	24-Mar-08	Milne	Purifier	12:35 P	B05	V1-W03-032408-1	None	36	Fuel Temp: Man. 56° Filter Pressure Drop: Eng. 88°
3	1	25-Mar-08	Villar	Purifier	23:25	B05	V1-W03-032508-1	None	37	Man. 68.2° Temp. 155.5°
3	1	26-Mar-08	Dinsmore	Purifier	11:48	B05	V1-W03-032608-1	None	38	Eng 76° Manifold
3	1	~~26 MAR~~ 27-Mar-08	~~Collazo~~ Collazo	~~Purifier~~ Purifier	~~13:30~~ 12:15	B05	~~Man 56 Eng 88 None~~ V1-W03-032708-1	None	39	Fuel Temp: 58° Filter Pressure Drop: 89.2°
3	1	28-Mar-08	Collazo	Purifier	11:30	B05	V1-W03-032808-1	None	40	Fuel 58° Eng 86.2°
		29 Mar-08	Collazo	Purifier	12:30			〃		Manifold fuel Temp 52° Eng fuel Temp 90.1°

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

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IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell)												
Week #	**Vessel**	**Date**	**Collected By**	**Location**	**Time**	**Fuel Type**	**Serial Number**	**Samples to Discard**	**Samples in Storage**	**Comments/Observations**	**Fuel Temp**	**Filter Pressure Drop**
4	1	29-Mar-08	Darling	~~T~~ TRUCK	03:00	B05	V1-W04-032908-D		35	Fuel Delivery sample		
4	1	30-Mar-08	~~Darling~~	~~Truck~~	~~[illegible]~~ 0230	B05	V1-W04-033008-D		36	Fuel Delivery sample	~~70/89~~	
4	1	30-Mar-08	Collazo	Pur	[illegible]:25	B05	V1-W04-033008-1		37		70/91	
4	1	31-Mar-08	Collazo	Pur	14:27	B05	V1-W04-033108-1		38	Record Fuel Temp and Filter Pressure Drop at right	70/92	
4	1	1-Apr-08	Collazo	Pur	14:07	B05	V1-W04-040108-1		39		60/81	
4	1	2-Apr-08	Blair	Purifier	1200	B05	V1-W04-040208-1		40		55/83	
4	1	3-Apr-08	Blair	Purifier	1200	B05	V1-W04-040308-1		41	Record Fuel Temp and Filter Pressure Drop at right	60/87	
4	1	4-Apr-08	Blair	Purifier	1200	B05	V1-W04-040408-1		42		57/84	
4	1	5-Apr-08	Blair	Purifier	1200	B05	V1-W04-040508-1	V1-W02-031608-1, V1-W02-031708-1, V1-W02-031808-1, V1-W02-031908-1, V1-W02-032008-1, V1-W02-032108-1, V1-W02-032208-1	36		65/90 ~~57/84~~	
5	1	5-Apr-08				B10	V1-W05-040508-D		37	Fuel Delivery sample		
5	1	6-Apr-08	~~Haars~~	~~Purifier~~	~~1250~~	~~B10~~	~~V1-W05-040608-D~~		~~38~~	~~Fuel Delivery sample~~	~~72/100~~	
5	1	6-Apr-08	Haars	Purifier	1250 am	B10	V1-W05-040608-1		39		72/100	
5	1	6-Apr-08			pm	B10	V1-W05-040608-2		40			
5	1	7-Apr-08			am	B10	V1-W05-040708-1		41	Record Fuel Temp and Filter Pressure Drop at right		
5	1	7-Apr-08	Blair	Purifier	1230 pm	B10	V1-W05-040708-2		42		72/87	
5	1	8-Apr-08			am	B10	V1-W05-040808-1		43			
5	1	8-Apr-08	Blair	Purifier	1300 pm	B10	V1-W05-040808-2		44		70/80	
5	1	9-Apr-08	~~[illegible]~~	~~Purifier~~	~~12~~ am	B10	V1-W05-040908-1		45			
5	1	9-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W05-040908-2		46			
5	1	10-Apr-08	~~DARLING~~	~~PURIFIER~~	~~1200~~ am	B10	V1-W05-041008-1		47	Record Fuel Temp and Filter Pressure Drop at right		
5	1	10-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W05-041008-2		48			
5	1	11-Apr-08			am	B10	V1-W05-041108-1		49			
5	1	11-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W05-041108-2		50			
5	1	12-Apr-08			am	B10	V1-W05-041208-1		51			
5	1	12-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W05-041208-2	V1-W01-030808-D, V1-W01-030908-D, V1-W01-030908-2, V1-W01-031008-2, V1-W01-031108-2, V1-W01-031208-2, V1-W01-031308-2, V1-W01-031408-2, V1-W01-031508-2	43	(All Week 1 samples discarded)		

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Manifold Fuel Temp	Engine ~~Filter Pressure Drop~~ Temp
6	1	12-Apr-08				B10	V1-W06-041208-D		44	Fuel Delivery sample		
6	1	13-Apr-08				B10	V1-W06-041308-D		45	Fuel Delivery sample		
6	1	13-Apr-08			am	B10	V1-W06-041308-1		46			
6	1	13-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W06-041308-2		47			
6	1	14-Apr-08			am	B10	V1-W06-041408-1		48	Record Fuel Temp and Filter Pressure Drop at right		
6	1	14-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W06-041408-2		49			
6	1	15-Apr-08			am	B10	V1-W06-041508-1		50			
6	1	15-Apr-08	DARLING	PURIFIER	1200 pm	B10	V1-W06-041508-2		51			
6	1	16-Apr-08	Blair	Purifier	1145 am	B10	V1-W06-041608-1		52		~~64°~~	N/A
6	1	16-Apr-08	SEIDMAN	PUR.	1200 pm	B10	V1-W06-041608-2		53		61°	
6	1	17-Apr-08	Blair	Purifier	1225 am	B10	V1-W06-041708-1		54	Record Fuel Temp and Filter Pressure Drop at right	59°	N/A
6	1	17-Apr-08	SEIDMAN	PUR.	0000 pm	B10	V1-W06-041708-2		55		~~100~~ 54	100°
6	1	18-Apr-08	Blair	Purifier	0000 am	B10	V1-W06-041808-1		56		58°	N/A
6	1	18-Apr-08	SEIDMAN	PUR.	1130 pm	B10	V1-W06-041808-2		57		52°	89
6	1	19-Apr-08	Blair	Purifier	1205 am	B10	V1-W06-041908-1		58		54	84
6	1	19-Apr-08	SEIDMAN	PUR.	1220 pm	B10	V1-W06-041908-2	V1-W02-031508-D, V1-W02-031608-D, V1-W02-031608-2, V1-W02-031708-2, V1-W02-031808-2, V1-W02-031908-2, V1-W02-032008-2, V1-W02-032108-2, V1-W02-032208-2	50	(All Week 2 samples discarded)	50°	87°
7	1	19-Apr-08	Blair	Fill Pipe ~~Purifier~~	0337	B10	V1-W07-041908-D		51	Fuel Delivery sample	N/A	N/A
7	1	20-Apr-08	Blair	Fill Pipe		B10	V1-W07-042008-D		52	Fuel Delivery sample	N/A	N/A
7	1	20-Apr-08	Blair	Purifier		B10	V1-W07-042008-1		53		64°	85°
7	1	21-Apr-08	SEIDMAN	PUR.	1220	B10	V1-W07-042108-1		54	Record Fuel Temp and Filter Pressure Drop at right	~~87~~ 57	87°
7	1	22-Apr-08	SEIDMAN	PUR	1230	B10	V1-W07-042208-1		55		57	83
7	1	23-Apr-08	Collazo	Purifier	11:33	B10	V1-W07-042308-1		56		60	85.5
7	1	24-Apr-08	Collazo	Purifier	1300	B10	V1-W07-042408-1		57	Record Fuel Temp and Filter Pressure Drop at right	56	84.6
7	1	25-Apr-08	Collazo	Purifier	12:30	B10	V1-W07-042508-1		58		70	83.7

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	MANNEY ENG TEMP Fuel Temp	Filter Pressure Drop
7	1	26-Apr-08	KJH	Purifier	NOON	B10	V1-W07-042608-1	V1-W03-032208-D, V1-W03-032308-D, V1-W03-032308-1, V1-W03-032408-1, V1-W03-032508-1, V1-W03-032608-1, V1-W03-032708-1, V1-W03-032808-1, V1-W03-032908-1, V1-W05-040608-1, V1-W05-040708-1, V1-W05-040808-1, V1-W05-040908-1, V1-W05-041008-1, V1-W05-041108-1, V1-W05-041208-1	43	(All Week 3 samples discarded)	68/100	
~~8~~	~~1~~	~~26-Apr-08~~				~~B10~~	~~V1-W08-042608-D~~		~~44~~	~~Fuel Delivery sample~~		
8	1	27-Apr-08	[illegible]	TRUCK	TRUCKS M[illegible]	B10	V1-W08-042708-D		45	Fuel Delivery sample		
8	1	27-Apr-08	[illegible]	PUR	11:38	B10	V1-W08-042708-1		46		67	91
8	1	28-Apr-08				B10	V1-W08-042808-1		47	Record Fuel Temp and Filter Pressure Drop at right		
8	1	29-Apr-08				B10	V1-W08-042908-1		48			
8	1	30-Apr-08				B10	V1-W08-043008-1		49			
8	1	1-May-08				B10	V1-W08-050108-1		50	Record Fuel Temp and Filter Pressure Drop at right		
8	1	2-May-08				B10	V1-W08-050208-1		51			
8	1	3-May-08				B10	V1-W08-050308-1	V1-W04-032908-D, V1-W04-033008-D, V1-W04-033008-1, V1-W04-033108-1, V1-W04-040108-1, V1-W04-040208-1, V1-W04-040308-1, V1-W04-040408-1, V1-W04-040508-1, V1-W06-041308-1, V1-W06-041408-1, V1-W06-041508-1, V1-W06-041608-1, V1-W06-041708-1, V1-W06-041808-1, V1-W06-041908-1	36	(All Week 4 samples discarded)		

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time		Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
9	1	3-May-08					B20	V1-W09-050308-D		37	Fuel Delivery sample
9	1	4-May-08					B20	V1-W09-050408-D		38	Fuel Delivery sample
9	1	4-May-08				am	B20	V1-W09-050408-1		39	
9	1	4-May-08	Blair	Purifier	1230	pm	B20	V1-W09-050408-2	59°/89°	40	
9	1	5-May-08				am	B20	V1-W09-050508-1		41	Fuel Temp: Filter Pressure Drop:
9	1	5-May-08	Blair	Purifier	1400	pm	B20	V1-W09-050508-2		42	59°/86°
9	1	6-May-08				am	B20	V1-W09-050608-1		43	59° /88°
9	1	6-May-08	Blair	Purifier	1200	pm	B20	V1-W09-050608-2		44	
9	1	7-May-08				am	B20	V1-W09-050708-1		45	
9	1	7-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W09-050708-2	60/93.6	46	
9	1	8-May-08				am	B20	V1-W09-050808-1		47	Fuel Temp: Filter Pressure Drop:
9	1	8-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W09-050808-2	57/89	48	
9	1	9-May-08				am	B20	V1-W09-050908-1		49	
9	1	9-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W09-050908-2	60 91	50	
9	1	10-May-08				am	B20	V1-W09-051008-1		51	
9	1	10-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W09-051008-2	V1-W05-040508-D, V1-W05-040608-D, V1-W05-040608-2, V1-W05-040708-2, V1-W05-040808-2, V1-W05-040908-2, V1-W05-041008-2, V1-W05-041108-2, V1-W05-041208-2	43	60°/95° (All Week 5 samples discarded)
10	1	10-May-08					B20	V1-W10-051008-D		44	Fuel Delivery sample

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time		Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
10	1	11-May-08					B20	V1-W10-051108-D		45	Fuel Delivery sample
10	1	11-May-08				am	B20	V1-W10-051108-1		46	
10	1	11-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W10-051108-2	60 / 89	47	
10	1	12-May-08				am	B20	V1-W10-051208-1		48	Fuel Temp: Filter Pressure Drop:
10	1	12-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W10-051208-2		49	60 / 92
10	1	13-May-08				am	B20	V1-W10-051308-1		50	
10	1	13-May-08	DARLING	PURIFIER	1200	pm	B20	V1-W10-051308-2		51	60/88
10	1	14-May-08				am	B20	V1-W10-051408-1		52	
10	1	14-May-08	MILNE	Purifier	1200	pm	B20	V1-W10-051408-2		53	62/89
10	1	15-May-08				am	B20	V1-W10-051508-1		54	Fuel Temp: Filter Pressure Drop:
10	1	15-May-08	MILNE	Purifier	1200	pm	B20	V1-W10-051508-2		55	70/91
10	1	16-May-08				am	B20	V1-W10-051608-1		56	
10	1	16-May-08	MILNE	Purifier	1200	pm	B20	V1-W10-051608-2		57	64/93
10	1	17-May-08	Blair	Fill Pipe		am	B20	V1-W10-051708-1		58	
10	1	17-May-08	MILNE	Purifier	1200	pm	B20	V1-W10-051708-2	V1-W06-041208-D, V1-W06-041308-D, V1-W06-041308-2, V1-W06-041408-2, V1-W06-041508-2, V1-W06-041608-2, V1-W06-041708-2, V1-W06-041808-2, V1-W06-041908-2	50	66/100 (All Week 6 samples discarded)
11	1	17-May-08	Blair	Fill Pipe			B20	V1-W11-051708-D		51	Fuel Delivery sample
11	1	18-May-08					B20	V1-W11-051808-D		52	Fuel Delivery sample

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
11	1	18-May-08	Milne	Purifier	1200	B20	V1-W11-051808-1		53	63/102
11	1	19-May-08	Milne	Purifier	1230	B20	V1-W11-051908-1		54	Fuel Temp: 65/102 Filter Pressure Drop:
11	1	20-May-08	Milne	Purifier	1200	B20	V1-W11-052008-1		55	56/97
11	1	21-May-08	Collazo	Purifier	12:01	B20	V1-W11-052108-1		56	70/88.7
11	1	22-May-08	Collazo	Purifier	11:30	B20	V1-W11-052208-1		57	Fuel Temp: 58 Filter Pressure Drop: 80
11	1	23-May-08	Collazo	Purifier	11:35	B20	V1-W11-052308-1		58	79/90
11	1	24-May-08	Collazo	Purifier	12:05	B20	V1-W11-052408-1	V1-W07-041908-D, V1-W07-042008-D, V1-W07-042008-1, V1-W07-042108-1, V1-W07-042208-1, V1-W07-042308-1, V1-W07-042408-1, ~~V1-W07-042508-1,~~ ~~V1-W07-042608-1,~~ V1-W09-050408-1, V1-W09-050508-1, V1-W09-050608-1, V1-W09-050708-1, V1-W09-050808-1, V1-W09-050908-1, V1-W09-051008-1	43	60/98 (All Week 7 samples discarded)
12	~~1~~	~~25 24-May-08~~	~~Collazo~~	~~Purifier~~	~~12:05~~	~~B20~~	~~V1-W12-052408-D~~		~~44~~	~~Fuel Delivery sample~~
12	1	25-May-08				B20	V1-W12-052508-D		45	Fuel Delivery sample
12	1	25-May-08	Collazo	Purifier	12:07	B20	V1-W12-052508-1		46	60/~~98~~ 93
12	1	26-May-08	Collazo	Purifier	12:15	B20	V1-W12-052608-1		47	Fuel Temp: 62 Filter Pressure Drop: 96
12	1	27-May-08				B20	V1-W12-052708-1		48	
12	1	28-May-08	Blair	Purifier	1300	B20	V1-W12-052808-1		49	63/90

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
12	1	29-May-08	Blair	Purifier	1275	B20	V1-W12-052908-1		50	Fuel Temp: 73/90 Filter Pressure Drop: N/A
12	1	30-May-08	Blair	Purifier	1145	B20	V1-W12-053008-1		51	69/88
12	1	May-08 31-May-08	Blair	Purifier	1300	B20	V1-W12-053108-1	V1-W08-042608-D, V1-W08-042708-D, ~~V1-W08-042708-1~~, ~~V1-W08-042808-1~~, ~~V1-W08-042908-1~~, ~~V1-W08-043008-1~~, ~~V1-W08-050108-1~~, ~~V1-W08-050208-1~~, ~~V1-W08-050308-1~~, ~~V1-W10-051108-1~~, ~~V1-W10-051208-1~~, ~~V1-W10-051308-1~~, ~~V1-W10-051408-1~~, ~~V1-W10-051508-1~~, ~~V1-W10-051608-1~~, ~~V1-W10-051708-1~~	36	(All Week 8 samples discarded)
13	1	31-May-08	Emery	Fill Pipe		B20	V1-W13-053108-D		37	Fuel Delivery sample
13	1	1-Jun-08	Emery	Fill Pipe		B20	V1-W13-060108-D		38	Fuel Delivery sample
13	1	1-Jun-08	Blair	Purifier	1245	B20	V1-W13-060108-1		39	62/92
13	1	2-Jun-08	Blair	Purifier	1230	B20	V1-W13-060208-1		40	Fuel Temp: 71/92 Filter Pressure Drop:
13	1	3-Jun-08	Blair	Purifier	1255	B20	V1-W13-060308-1		41	72/91
13	1	4-Jun-08	DARLING	PURIFIER	1200	B20	V1-W13-060408-1		42	60°/106.9
13	1	5-Jun-08	DARLING	PURIFIER	1200	B20	V1-W13-060508-1		43	Fuel Temp: Filter Pressure Drop: 60/89
13	1	6-Jun-08	DARLING	PURIFIER	1200	B20	V1-W13-060608-1		44	60 / 96

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
13	1	7-Jun-08	DARLING	PURIFIER	1200	B20	V1-W13-060708-1	V1-W09-050308-D, V1-W09-050408-D, V1-W09-050408-2, V1-W09-050508-2, V1-W09-050608-2, V1-W09-050708-2, V1-W09-050808-2, V1-W09-050908-2, V1-W09-051008-2	36	60 / 89 (All Week 9 samples discarded)
14	1	7-Jun-08	~~DARLING~~	~~PURIFIER~~	~~1200~~	B20	V1-W14-060708-D		37	Fuel Delivery sample
14	1	8-Jun-08	[illegible]			B20	V1-W14-060808-D		38	Fuel Delivery sample
14	1	8-Jun-08	DARLING	PURIFIER	1200	B20	V1-W14-060808-1		39	60 / 92
14	1	9-Jun-08	DARLING	PURIFIER	1200	B20	V1-W14-060908-1		40	Fuel Temp: Filter Pressure Drop: 60/96
14	1	10-Jun-08	DARLING	PURIFIER	1200	B20	V1-W14-061008-1		41	62 / 95
14	1	11-Jun-08	White	Purifier	~~[illegible]~~ 1700	B20	V1-W14-061108-1		42	60 / 118
14	1	12-Jun-08	White	Purifier	1200	B20	V1-W14-061208-1		43	Fuel Temp: Filter Pressure Drop: 59/118
14	1	13-Jun-08	White	Purifier	1200	B20	V1-W14-061308-1		44	61/118
14	1	14-Jun-08	White	Purifier	1200	B20	V1-W14-061408-1	V1-W10-051008-D, V1-W10-051108-D, V1-W10-051108-2, V1-W10-051208-2, V1-W10-051308-2, V1-W10-051408-2, V1-W10-051508-2, V1-W10-051608-2, V1-W10-051708-2	36	51/124 (All Week 10 samples discarded)
15	1	14-Jun-08	Blair	Fill Pipe	0300	B20	V1-W15-061408-D		37	Fuel Delivery sample
15	1	15-Jun-08				B20	V1-W15-061503-D		38	Fuel Delivery sample
15	1	15-Jun-08	White	Purifier	1200	B20	V1-W15-061508-1		39	65/127

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
15	1	16-Jun-08	White	Purifier	12:00	B20	V1-W15-061608-1		40	Fuel Temp: Filter Pressure Drop: 58/117
15	1	17-Jun-08	Milne	Purifier	1200	B20	V1-W15-061708-1		41	62/96
15	1	18-Jun-08	Collazo	Purifier	12:00	B20	V1-W15-061808-1		42	74/93.7
15	1	19-Jun-08	Collazo	Purifier	11:55	B20	V1-W15-061908-1		43	Fuel Temp: Filter Pressure Drop: 60/96.7
15	1	20-Jun-08	Collazo	Purifier	12:12	B20	V1-W15-062008-1		44	68/89
15	1	21-Jun-08	Collazo	Purifier	12:04	B20	V1-W15-062108-1	V1-W11-051708-D, V1-W11-051808-D, V1-W11-051808-1, V1-W11-051908-1, V1-W11-052008-1, V1-W11-052108-1, V1-W11-052208-1, V1-W11-052308-1, V1-W11-052408-1	36	62/98 (All Week 11 samples discarded)
16	1	21-Jun-08	K. Irish	Truck	0300	B20	V1-W16-062108-D		37	Fuel Delivery sample
16	1	22-Jun-08	Collazo	Purifier	12:07	B20	V1-W16-062208-D		38	Fuel Delivery sample 72/92
16	1	22-Jun-08	[illegible]	[illegible]	[illegible]	B20	V1-W16-062208-1		39	[illegible]
16	1	23-Jun-08				B20	V1-W16-062308-1		40	Fuel Temp: Filter Pressure Drop:
16	1	24-Jun-08				B20	V1-W16-062408-1		41	
16	1	25-Jun-08	Blair	Purifier	1215	B20	V1-W16-062508-1		42	76/95
16	1	26-Jun-08	Blair	Purifier	1200	B20	V1-W16-062608-1		43	Fuel Temp: Filter Pressure Drop: 86/68
16	1	27-Jun-08	Blair	Purifier	1200	B20	V1-W16-062708-1		44	94/64

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
16	1	28-Jun-08	Blair	Purifier	1200	B20	V1-W16-062808-1	V1-W12-052408-D, V1-W12-052508-D, V1-W12-052508-1, V1-W12-052608-1, V1-W12-052708-1, V1-W12-052808-1, V1-W12-052908-1, V1-W12-053008-1, V1-W12-053108-1	36	94°/72° (All Week 12 samples discarded)

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
16	1	28-Jun-08				B20	V1-W16-062808-D		37	Fuel Delivery sample
17	1	29-Jun-08				B20	V1-W17-062908-D		38	Fuel Delivery sample
17	1	29-Jun-08	Blair	Purifier	1200	B20	V1-W17-062908-1		39	99°/80°
17	1	30-Jun-08	Blair	Purifier	1200	B20	V1-W17-063008-1		40	Fuel Temp: Filter Pressure Drop: 97/71
17	1	1-Jul-08	?	?	?	B20	V1-W17-070108-1		41	
17	1	2-Jul-08	DARLING	PURIFIER	1200	B20	V1-W17-070208-1		42	~~[illegible]~~ 68/98
17	1	3-Jul-08	DARLING	PURIFIER	1200	B20	V1-W17-070308-1		43	Fuel Temp: Filter Pressure Drop: 69/90
17	1	4-Jul-08	DARLING	PURIFIER	1200	B20	V1-W17-070408-1		44	64 / 103.6
17	1	5-Jul-08	DARLING		1200	B20	V1-W17-070508-1	V1-W13-053108-D, V1-W13-060108-D, V1-W13-060108-1, V1-W13-060208-1, V1-W13-060308-1, V1-W13-060408-1, V1-W13-060508-1, V1-W13-060608-1, V1-W13-060708-1	36	69 / 102.5 (All Week 13 samples discarded)
17	1	5-Jul-08	Lin	Refill	0315	B20	V1-W17-070508-D		37	Fuel Delivery sample
18	1	6-Jul-08				B20	V1-W18-070608-D		38	Fuel Delivery sample
18	1	6-Jul-08	DARLING	PURIFIER	1200	B20	V1-W18-070608-1		39	68 100.3
18	1	7-Jul-08	Dudley	Purifier	1200	B20	V1-W18-070708-1		40	Fuel Temp: Filter Pressure Drop: 57 89.6 °F
18	1	8-Jul-08	Dudley	Purifier	1200	B20	V1-W18-070808-1		41	62F 95.6

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
18	1	9-Jul-08	Haars	Purifier	1240	B20	V1-W18-070908-1		42	68°/ 118.6
18	1	10-Jul-08	Milne	Purifier	1210	B20	V1-W18-071008-1		43	Fuel Temp: Filter Pressure Drop: 64/99.7
18	1	11-Jul-08	Milne	Purifier	1200	B20	V1-W18-071108-1		44	68/95
18	1	12-Jul-08	Milne	Purifier	1205	B20	V1-W18-071208-1	V1-W14-060708-D, V1-W14-060808-D, V1-W14-060808-1, V1-W14-060908-1, V1-W14-061008-1, V1-W14-061108-1, V1-W14-061208-1, V1-W14-061308-1, V1-W14-061408-1	36	67/103.5 (All Week 14 samples discarded)
18	1	12-Jul-08				B20	V1-W18-071208-D		37	Fuel Delivery sample
19	1	13-Jul-08				B20	V1-W19-071308-D		38	Fuel Delivery sample
19	1	13-Jul-08	Milne	Purifier	1210	B20	V1-W19-071308-1		39	68/97.6
19	1	14-Jul-08	Milne	Purifier	1215	B20	V1-W19-071408-1		40	Fuel Temp: Filter Pressure Drop: 68/101.5
19	1	15-Jul-08	Scott	Purifier	1210	B20	V1-W19-071508-1		41	68/100.2
19	1	16-Jul-08	Collazo	Purifier	1221	B20	V1-W19-071608-1		42	66/90.1
19	1	17-Jul-08	Scott	Purifier	1200	B20	V1-W19-071708-1		43	Fuel Temp: 68 Filter Pressure Drop: 110.3
19	1	18-Jul-08	Collazo	Purifier	1207	B20	V1-W19-071808-1		44	66/90

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
19	1	19-Jul-08	Darway	TURK	3AM	B20	V1-W19-071908-1	V1-W15-061408-D, V1-W15-061508-D, V1-W15-061508-1, V1-W15-061608-1, V1-W15-061708-1, V1-W15-061808-1, V1-W15-061908-1, V1-W15-062008-1, V1-W15-062108-1	36	(All Week 15 samples discarded)
19	1	19-Jul-08	CollAzo	Purifier	1207	B20	V1-W19-071908-D		37	Fuel Delivery sample 78/96
20	1	20-Jul-08	CollAzo	Purifier	1200	B20	V1-W20-072008-D		38	Fuel Delivery sample 64/93
20	1	20-Jul-08				B20	V1-W20-072008-1		39	
20	1	21-Jul-08	CollAzo	Purifier	1217	B20	V1-W20-072108-1		40	Fuel Temp: Filter Pressure Drop: 78/93
20	1	22-Jul-08	CollAzo	Purifier	1220	B20	V1-W20-072208-1		41	68/93
20	1	23-Jul-08				B20	V1-W20-072308-1		42	
20	1	24-Jul-08				B20	V1-W20-072408-1		43	Fuel Temp: Filter Pressure Drop:
20	1	25-Jul-08				B20	V1-W20-072508-1		44	
20	1	26-Jul-08	Blair	Purifier	1215	B20	V1-W20-072608-1	V1-W16-062108-D, V1-W16-062208-D, V1-W16-062208-1, V1-W16-062308-1, V1-W16-062408-1, V1-W16-062508-1, V1-W16-062608-1, V1-W16-062708-1, V1-W16-062808-1	36	68/95 (All Week 16 samples discarded)
20	1	26-Jul-08	Milne	Purifier	0015	B20	V1-W20-072608-D		37	Fuel Delivery sample 72/96.5

WSF Biodiesel Test Samples
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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
21	1	27-Jul-08	Milne	S/W	0300	B20	V1-W21-072708-D		38	Fuel Delivery sample
21	1	27-Jul-08	Blair	Purifier	1207	B20	V1-W21-072708-1		39	65/96
21	1	28-Jul-08	Blair	Purifier	1209	B20	V1-W21-072808-1		40	Fuel Temp: Filter Pressure Drop:
21	1	29-Jul-08	DARLING	PURIFIER	1200	B20	V1-W21-072908-1		41	68/98
21	1	30-Jul-08	DARLING	PURIFIER	1200	B20	V1-W21-073008-1		42	67/100
21	1	31-Jul-08	DARLING	PURIFIER	1200	B20	V1-W21-073108-1		43	Fuel Temp: 65/95 Filter Pressure Drop:
21	1	1-Aug-08	DARLING	PURIFIER	1200	B20	V1-W21-080108-1		44	70/102.9
21	1	2-Aug-08	SCOTT	Purifier	1200	B20	V1-W21-080208-1	V1-W16-062808-D, V1-W17-062908-D, V1-W17-062908-1, V1-W17-063008-1, V1-W17-070108-1, V1-W17-070208-1, V1-W17-070308-1, V1-W17-070408-1, V1-W17-070508-1	36	(All Week 17 samples discarded)

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
21	1	1-Aug-08	Darling	Purifier	1200	B20	V1-W21-080108-1		43	65/96°F 78/103°F
21	1	2-Aug-08				B20	V1-W21-080208-D		44	Fuel Delivery sample
21	1	2-Aug-08	Scott	Purifier	1200	B20	V1-W21-080208-1	V1-W17-062908-D, V1-W17-062908-1, V1-W17-063008-1, V1-W17-070108-1, V1-W17-070208-1, V1-W17-070308-1, V1-W17-070408-1, V1-W17-070508-1, V1-W17-070508-D	36	62°/113.2° (All Week 17 samples discarded)
22	1	3-Aug-08	Collazo	Truck	220	B20	V1-W22-080308-D		37	Fuel Delivery sample
22	1	3-Aug-08	DARLING	PURIFIER	1200	B20	V1-W22-080308-1		38	63 /110.5
22	1	4-Aug-08	DARLING	PURIFIER	1200	B20	V1-W22-080408-1		39	Fuel Temp: Filter Pressure Drop:
22	1	5-Aug-08	DARLING	PURIFIER	1200	B20	V1-W22-080508-1		40	65 /111.4
22	1	6-Aug-08	Milne	Purifier		B20	V1-W22-080608-1		41	70 /98.6
22	1	7-Aug-08	White	Purifier	300	B20	V1-W22-080708-1		42	Fuel Temp: Filter Pressure Drop: 66/120.9
22	1	8-Aug-08	White	Purifier	1200	B20	V1-W22-080808-1		43	64 / 126.4
22	1	9-Aug-08	White	Purifier	1200	B20	V1-W22-080908-D		44	Fuel Delivery sample 60 / 130.3
22	1	9-Aug-08				B20	V1-W22-080908-1	V1-W18-070608-D, V1-W18-070608-1, V1-W18-070708-1, V1-W18-070808-1, V1-W18-070908-1, V1-W18-071008-1, V1-W18-071108-1, V1-W18-071208-1, V1-W18-071208-D	36	(All Week 18 samples discarded)

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
23	1	10-Aug-08	White	Purifier	1400	B20	V1-W23-081008-1		37	69/113.6
23	1	11-Aug-08	White	Purfier	1400	B20	V1-W23-081108-1		38	Fuel Temp: Filter Pressure Drop: 63/110.1
23	1	12-Aug-08				B20	V1-W23-081208-1		39	
23	1	13-Aug-08	Collazo	Purifier	12:02	B20	V1-W23-081308-1		40	66/92
23	1	14-Aug-08	Collazo	Purifier	12:07	B20	V1-W23-081408-1		41	Fuel Temp: Filter Pressure Drop: 66/92
23	1	15-Aug-08	Collazo	Purifier	12:00	B20	V1-W23-081508-1		42	75/90
23	1	16-Aug-08	Darling	Truck	300AM	B20	V1-W23-081608-D		43	Fuel Delivery sample
23	1	16-Aug-08	Collazo	Purifier	1300	B20	V1-W23-081608-1	V1-W19-071308-D, V1-W19-071308-1, V1-W19-071408-1, V1-W19-071508-1, V1-W19-071608-1, V1-W19-071708-1, V1-W19-071808-1, V1-W19-071908-1, V1-W19-071908-D	35	78/94 (All Week 19 samples discarded)
24	1	17-Aug-08	Darling	Truck	300AM	B20	V1-W24-081708-D		36	Fuel Delivery sample
24	1	17-Aug-08	Collazo	Purifier	12:09	B20	V1-W24-081708-1		37	66/94
24	1	18-Aug-08	Collazo	Purifier	12:00	B20	V1-W24-081808-1		38	Fuel Temp: Filter Pressure Drop: 64/90
24	1	19-Aug-08	Collazo	Purifier	1207	B20	V1-W24-081908-1		39	~~[illegible]~~ 78/97
24	1	20-Aug-08	Blair	Purifier	1200	B20	V1-W24-082008-1		40	65/95
24	1	21-Aug-08	Blair	Purifier	1230	B20	V1-W24-082108-1		41	Fuel Temp: Filter Pressure Drop: 67/94.6°
24	1	22-Aug-08				B20	V1-W24-082208-1		42	
24	1	23-Aug-08				B20	V1-W24-082308-D		43	Fuel Delivery sample

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
24	1	23-Aug-08	FLEMMER	PURIFIER	1205	B20	V1-W24-082308-1	V1-W20-072008-D, V1-W20-072008-1, V1-W20-072108-1, V1-W20-072208-1, V1-W20-072308-1, V1-W20-072408-1, V1-W20-072508-1, V1-W20-072608-1, V1-W20-072608-D	35	(All Week 20 samples discarded)
25	1	24-Aug-08	Blair	Purifier	1220	B20	V1-W25-082408-1		36	70 198
25	1	25-Aug-08	Blair	Purifier	1220	B20	V1-W25-082508-1		37	77/94
25	1	26-Aug-08	Blair	Purifier	1300	B20	V1-W25-082608-1		38	75/95
25	1	27-Aug-08	Dudley	"	1230	B20	V1-W25-082708-1		39	Fuel Temp: Filter Pressure Drop:
25	1	28-Aug-08	Dudley	"	1200	B20	V1-W25-082808-1		40	65°/105°
25	1	29-Aug-08	Dudley	"	1200	B20	V1-W25-082908-1		41	70°/95°
~~25~~	1	30-Aug-08	~~Dudley~~	~~"~~	~~1340~~	B20	V1-W25-083008-D		42	~~61/96.8~~ Fuel Delivery sample
25	1	30-Aug-08	Dudley	Purifier	1340	B20	V1-W25-083008-1	V1-W21-072708-D, V1-W21-072708-1, V1-W21-072808-1, V1-W21-072908-1, V1-W21-073008-1, V1-W21-073108-1, V1-W21-080108-1, V1-W21-080208-D, V1-W21-080208-1	34	61°/95° (All Week 21 samples discarded)
~~26~~	1	31-Aug-08	—	—	—	B20	V1-W26-083108-D	—	35	Fuel Delivery sample
26	1	31-Aug-08	Dudley	Purifier	1200	B20	V1-W26-083108-1		36	56°/106°

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
26	1	1-Sep-08	Dudley	Purifier	1200	B20	V1-W26-090108-1		37	60°/90°
26	1	2-Sep-08	Dudley	Purifier	1200	B20	V1-W26-090208-1		38	59°/101°
26	1	3-Sep-08	LeBlanc	Purifier	1220	B20	V1-W26-090308-1		39	Fuel Temp: 67°/ 91.8° Filter Pressure Drop:
26	1	4-Sep-08	Haars	Purifier	12 10	B20	V1-W26-090408-1		40	64°/113.5°
26	1	5-Sep-08	Haars	Purifier	1155 am	B20	V1-W26-090508-1		41	72°/115.5°
26	1	6-Sep-08	Ivey	Fill Pipe	0530	B20	V1-W26-090608-D		42	Fuel Delivery sample
26	1	6-Sep-08	Milne	Purifier	1210	B20	V1-W26-090608-1	V1-W22-080308-D, V1-W22-080308-1, V1-W22-080408-1, V1-W22-080508-1, V1-W22-080608-1, V1-W22-080708-1, V1-W22-080808-1, V1-W22-080908-1	34	63/101 (All Week 22 samples discarded)
27	1	7-Sep-08				B20	V1-W27-090708-D		35	Fuel Delivery sample
27	1	7-Sep-08	Milne	Purifier	1200	B20	V1-W27-090708-1		36	66/108
27	1	8-Sep-08	Milne	Purifier	1155	B20	V1-W27-090808-1		37	66/103
27	1	9-Sep-08	White	Purifier	1200	B20	V1-W27-090908-1		38	65/ 117
27	1	10-Sep-08	Collazo	Purifier	1200	B20	V1-W27-091008-1		39	Fuel Temp: 72/107 Filter Pressure Drop:
27	1	11-Sep-08	Collazo	Purifier	12:17	B20	V1-W27-091108-1		40	74 96
27	1	12-Sep-08	Collazo	Purifier	12:01	B20	V1-W27-091208-1		41	68/102
27	1	13-Sep-08	Parlwa	Truck	3:30	B20	V1-W27-091308-D		42	Fuel Delivery sample

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
27	1	13-Sep-08	Collazo	Purifier	1200	B20	V1-W27-091308-1	V1-W22-080908-D, V1-W23-081008-1, V1-W23-081108-1, V1-W23-081208-1, V1-W23-081308-1, V1-W23-081408-1, V1-W23-081508-1, V1-W23-081608-D, V1-W23-081608-1	34	64/92 (All Week 23 samples discarded)
28	1	14-Sep-08	Collazo	Purifier	12:07	B20	V1-W28-091408-1		35	80/94
28	1	15-Sep-08	Collazo	Purifier	12:15	B20	V1-W28-091508-1		36	78/94
28	1	16-Sep-08	Collazo	Purifier	11:57	B20	V1-W28-091608-1		37	66/93
28	1	17-Sep-08	Blair	Purifier	1130	B20	V1-W28-091708-1		38	Fuel Temp: 65/115 Filter Pressure Drop:
28	1	18-Sep-08	Blair	Purifier	1230	B20	V1-W28-091808-1		39	67/94
28	1	19-Sep-08	Blair	Purifier	1230	B20	V1-W28-091908-1		40	65/92
28	1	20-Sep-08	Tapler	Fill Pipe	0300	B20	V1-W28-092008-D		41	Fuel Delivery sample
28	1	20-Sep-08	Blair	Purifier	1200	B20	V1-W28-092008-1	V1-W24-081708-D, V1-W24-081708-1, V1-W24-081808-1, V1-W24-081908-1, V1-W24-082008-1, V1-W24-082108-1, V1-W24-082208-1, V1-W24-082308-D, V1-W24-082308-1	32	66/94 (All Week 24 samples discarded)
29	1	21-Sep-08				B20	V1-W29-092108-D		33	Fuel Delivery sample
29	1	21-Sep-08	Blair	Purifier	1300	B20	V1-W29-092108-1		34	69/98
29	1	22-Sep-08	Blair	Purifier	1145	B20	V1-W29-092208-1		35	62/98
29	1	23-Sep-08	Blair	Purifier	1300	B20	V1-W29-092308-1		36	69/97

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
29	1	24-Sep-08	DARLING	PURIFIER	1200	B20	V1-W29-092408-1		37	Fuel Temp: 62/101.2 Filter Pressure Drop:
29	1	25-Sep-08	DARLING	PURIFIER	1200	B20	V1-W29-092508-1		38	64/119.1
29	1	26-Sep-08	DARLING	PURIFIER	1200	B20	V1-W29-092608-1		39	65/108.1
29	1	27-Sep-08				B20	V1-W29-092708-D		40	Fuel Delivery sample
29	1	27-Sep-08	DARLING	PURIFIER	1200	B20	V1-W29-092708-1	V1-W25-082408-1, V1-W25-082508-1, V1-W25-082608-1, V1-W25-082708-1, V1-W25-082808-1, V1-W25-082908-1, V1-W25-083008-D, V1-W25-083008-1	33	65 / 99 (All Week 25 samples discarded)
30	1	28-Sep-08	DARLING	PURIFIER	B20	B20	V1-W30-092808-1		34	
30	1	29-Sep-08				B20	V1-W30-092908-1		35	
30	1	30-Sep-08				B20	V1-W30-093008-1		36	
	1	1 Oct 08	milne	Purifier	~~B20~~ 1230	B20				75/101.5

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
30	1	4-Oct-08	Ivey	Fill	0300	B20	V1-W30-100408-D		38	Fuel Delivery sample
31	1	5-Oct-08				B20	V1-W31-100508-D		39	Fuel Delivery sample
31	1	7-Oct-08	Milne	Purifier	1200	B20	V1-W31-100708-1	V1-W26-083108-D, V1-W26-083108-1, V1-W26-090108-1, V1-W26-090208-1, V1-W26-090308-1, V1-W26-090408-1, V1-W26-090508-1, V1-W26-090608-D, V1-W26-090608-1	31	75/98.5 Fuel Temp: Filter Pressure Drop: (All Week 26 samples discarded)
31	1	11-Oct-08	Behnke	Truck	0310	B20	V1-W31-101108-D		32	Fuel Delivery sample
32	1	~~12-Oct-08~~ 14-Oct-08 15-oct-08	~~Weytham~~ Collazo Tapley	~~"~~ Purifier Purifier	~~0315~~ 12:00 12:00	~~B20~~ B20	V1-W32-101408-1	V1-W27-090708-D, V1-W27-090708-1, V1-W27-090808-1, V1-W27-090908-1, V1-W27-091008-1, V1-W27-091108-1, V1-W27-091208-1, V1-W27-091308-D, V1-W27-091308-1	24	~~" " "~~ 60/61 Fuel Temp: Filter Pressure Drop: (All Week 27 samples discarded)
32	1	16-oct-08 18-Oct-08	Tapley	Purifier	12:00	B20	V1-W32-101808-D		25	Fuel Delivery sample
33	1	19-Oct-08				B20	V1-W33-101908-D		26	Fuel Delivery sample
33	1	21-Oct-08				B20	V1-W33-102108-1	V1-W28-091408-1, V1-W28-091508-1, V1-W28-091608-1, V1-W28-091708-1, V1-W28-091808-1, V1-W28-091908-1, V1-W28-092008-D, V1-W28-092008-1	19	Fuel Temp: Filter Pressure Drop: (All Week 28 samples discarded)
33	1	25-Oct-08				B20	V1-W33-102508-D		20	Fuel Delivery sample

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
34	1	28-Oct-08	Dxllng	Pur.	1200	B20	V1-W34-102808-1	V1-W29-092108-D, V1-W29-092108-1, V1-W29-092208-1, V1-W29-092308-1, V1-W29-092408-1, V1-W29-092508-1, V1-W29-092608-1, V1-W29-092708-D, V1-W29-092708-1	12	64/98.6 Fuel Temp: Filter Pressure Drop: (All Week 29 samples discarded)

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

INSTRUCTIONS: Type required information in the green fields and then save the file. Type comments in as necessary. Email the file to lnrenehan@glosten.com weekly
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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
34	1	1-Nov-08	Blair	Fill Pipe	0300	B20	V1-W34-110108-D			Fuel Delivery sample
35	1	4-Nov-08	Milne	Purifier	1200	B20	V1-W35-110408-1			
35	1	8-Nov-08				B20	V1-W35-110808-D			Fuel Delivery sample
36	1	11-Nov-08				B20	V1-W36-111108-1			
37	1	18-Nov-08				B20	V1-W37-111808-1			
37	1	22-Nov-08				B20	V1-W37-112208-D			Fuel Delivery sample
38	1	24-Nov-08				B20	V1-W38-112408-D			Fuel Delivery sample
38	1	25-Nov-08				B20	V1-W38-112508-1	V1-W30-092808-1, V1-W30-092908-1, V1-W30-093008-1, V1-W30-100408-D, V1-W31-100508-D, V1-W31-100708-1, V1-W31-101108-D, V1-W32-101408-1, V1-W32-101808-D, V1-W33-101908-D, V1-W33-102108-1, V1-W33-102508-D, V1-W33-102508-D, V1-W34-102808-1	8	Fuel Temp: Filter Pressure Drop: (All samples from 10/28/08 and before discarded)
38	1	29-Nov-08				B20	V1-W38-112908-D			Fuel Delivery sample

WSF Biodiesel Test Samples
Vessel 1 - Issaquah

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations
39	1	1-Dec-08	Milne	Purifier	1700	B20	V1-W39-120108-D			Fuel Delivery sample
39	1	2-Dec-08	WATSON	PURIFIER	1500	B20	V1-W39-120208-1			Fuel Temp: Filter Pressure Drop:
39	1	6-Dec-08	Armstrong	Purifier	2400	B20	V1-W39-120608-D			Fuel Delivery sample
40	1	8-Dec-08	Armstrong	Purifier	0227	B20	V1-W40-120808-D			Fuel Delivery sample
40	1	9-Dec-08	Collazo	PurifieR	0714	B20	V1-W40-120908-1			Fuel Temp: 60 Filter Pressure Drop:
40	1	13-Dec-08				B20	V1-W40-121308-D			Fuel Delivery sample
41	1	16-Dec-08	Blair	Purifier	1300	B20	V1-W41-121608-1			Fuel Temp: Filter Pressure Drop:
41	1	20-Dec-08	Liu	Truck	0315	B20	V1-W41-122008-D			Fuel Delivery sample
42	1	22-Dec-08	LIU	Truck	2215	B20	V1-W42-122208-D			Fuel Delivery sample
42	1	23-Dec-08	WEYTHMAN	Purifier	0900	B20	V1-W42-122308-1			Fuel Temp: 63°F 110°F Filter Pressure Drop:
42	1	27-Dec-08				B20	V1-W42-122708-D			Fuel Delivery sample
43	1	30-Dec-08	MILNE	Purifier	1700	B20	V1-W43-123008-1	V1-W34-110108-D, V1-W35-110408-1, V1-W35-110808-D, V1-W36-111108-1, V1-W37-111808-1, V1-W37-112208-D, V1-W38-112408-D, V1-W38-112508-1, V1-W38-112908-D	12	72 103.5 Fuel Temp: Filter Pressure Drop: (All samples from 11/29/08 and before discarded)

WSF Biodiesel Test Samples - Vessel 1 - Issaquah

Vessel	Date	Collected By	Location	Time	Fuel Type	Comments/Observations
Issaquah	Jan-09	Milne	Fill pipe	0300	B20	fuel delivery **Note if weekly sample or if fuel delivery sample**
Issaquah	1-12-09	Blair	Purifier	1200	B200	57°
" "	1/14/09	White	Purifier	1500	B200	53°
" "	1/15/09	White	Purifier	1300	B200	54°
Issaquah	1/22/09	Milne	Purifier	1200	B20	68°
ISSAQUAH	1-24-09	Blair	Fill Pipe	0300	B20	Fuel Delivery
"	1-31-09	ARMSTRONG	TRUCK	0300	B20	FUEL DELIVERY

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

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Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
19	3	18-Jul-08	Connor White	Fuel Station	1815	B05	V3-W19-071808-D		1	Fuel Delivery sample		
19	3	18-Jul-08			pm	B05	V3-W19-071808-2		2			
19	3	19-Jul-08	Brenno	purifier suction	1030 hrs	B05	V3-W19-071908-1		3	From Port Storage Tank		
19	3	19-Jul-08			pm	B05	V3-W19-071908-2		4			
20	3	20-Jul-08	Brenno	purifier suction	1130 Hrs	B05	V3-W20-072008-1		5	From Stbd Storage Tank		
20	3	20-Jul-08	Hanson	purifier suction	2100 hrs	B05	V3-W20-072008-2		6			
20	3	21-Jul-08	Brenno	purifier suction	1030 hrs	B05	V3-W20-072108-1		7	Record Fuel Temp and Filter Pressure Drop at right	71 F	0.5/-0.5
20	3	21-Jul-08	Hanson	purifier suction	2030 hrs	B05	V3-W20-072108-2		8	From Stbd Storage Tank		
20	3	22-Jul-08	G. Steele	Fuel Station	0320 hrs	B05	V1-W02-031508-D		9	Fuel Delivery sample		
20	3	22-Jul-08	Brenno	purifier suction	1030 hrs	B05	V3-W20-072208-1		10	From Stbd Storage Tank		
20	3	22-Jul-08	Nelson	purifier suction	2350 hrs	B05	V3-W20-072208-2		11	From Stbd Storage Tank		
20	3	23-Jul-08			am	B05	V3-W20-072308-1		12			
20	3	23-Jul-08	Nelson	purifier suction	pm	B05	V3-W20-072308-2		13	From Port Storage Tank		
20	3	24-Jul-08			am	B05	V3-W20-072408-1		14	Record Fuel Temp and Filter Pressure Drop at right		
20	3	24-Jul-08	Nelson	purifier suction	pm	B05	V3-W20-072408-2		15	From Stbd Storage Tank		
20	3	25-Jul-08	Nelson	Fuel Station	0300 hrs	B05	V3-W20-072508-D		16	Fuel Delivery sample		
20	3	25-Jul-08			am	B05	V3-W20-072508-1		17			
20	3	25-Jul-08	Nelson	purifier suction	2100 hrs	B05	V3-W20-072508-2		18	From Port Storage Tank		
20	3	26-Jul-08			am	B05	V3-W20-072608-1		19			
20	3	26-Jul-08	Nelson	purifier suction	2400 hrs	B05	V3-W20-072608-2		20	From Stbd Storage Tank		
21	3	27-Jul-08			am	B05	V3-W21-072708-1		21			
21	3	27-Jul-08	Nelson	purifier suction	2100 hrs	B05	V3-W21-072708-2		22	From Port Storage Tank		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
21	3	28-Jul-08	Grall	purifier suction	0915 hrs	B05	V3-W21-072808-1		23	Record Fuel Temp and Filter Pressure Drop at right (STBD)	86 F	0.0/0.5
21	3	28-Jul-08	Nelson	purifier suction	2100 hrs	B05	V3-W21-072808-2		24			
21	3	29-Jul-08	Grall	purifier suction	0750 hrs	B05	V3-W21-072908-1		25	From Stbd Storage Tank		
21	3	29-Jul-08	Brenno	purifier suction	2250 hrs	B05	V3-W21-072908-2		26	From Stbd Storage Tank		
21	3	29-Jul-08	Pinion	Fuel Station	1945 hrs	B05	V3-W21-072908-D		27	Actually fueled on 31st Aug		
21	3	30-Jul-08	Bylund	purifier suction	1030 hrs	B05	V3-W21-073008-1		28	From Stbd Storage Tank		
21	3	30-Jul-08	Brenno	purifier suction	2130 hrs	B05	V3-W21-073008-2		29	From Port Storage Tank		
21	3	31-Jul-08	Bylund	purifier suction	1100 hrs	B05	V3-W21-073108-1		30	From Stbd Storage Tank	86 F	missed
21	3	31-Jul-08	Brenno	purifier suction	2215 hrs	B05	V3-W21-073108-2		31	From Stbd Storage Tank		
21	3	1-Aug-08	Bylund	purifier suction	1130 hrs	B05	V3-W21-080108-1		32	From Stbd Storage Tank		
21	3	1-Aug-08	Brenno	purifier suction	2300 hrs	B05	V3-W21-080108-2		33	From Port Storage Tank		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

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Week #	**Vessel**	**Date**	**Collected By**	**Location**	**Time**	**Fuel Type**	**Serial Number**	**Samples to Discard**	**Samples in Storage**	**Comments/Observations**	**Fuel Temp**	**Filter Pressure Drop**
21	3	1-Aug-08	Bylund	purifier suction	1130 hrs	B05	V3-W21-080108-1		32	From Stbd Storage Tank		
21	3	1-Aug-08	Brenno	purifier suction	2300 hrs	B05	V3-W21-080108-2		33	From Port Storage Tank		
21	3	2-Aug-08	Bylund	purifier suction	1130 hrs	B05	V3-W21-080208-1		34	From Stbd Storage Tank		
22	3	3-Aug-08	Bylund	purifier suction	1200 hrs	B05	V3-W22-080308-1		35	From Stbd Storage Tank		
22	3	4-Aug-08	Bylund	purifier suction	1100 hrs	B05	V3-W22-080408-1		36	Record Fuel Temp and Filter Pressure Drop at right	70 F	0.6/-0.5
22	3	5-Aug-08	Curley	purifier suction	0220 hrs	B05	V3-W22-080508-D		37	Fuel Delivery sample		
22	3	5-Aug-08	Bylund	purifier suction	1030 hrs	B05	V3-W22-080508-1		38	From Port Storage Tank		
22	3	6-Aug-08	Nelson	purifier suction	1000 hrs	B05	V3-W22-080608-1		39	From Port Storage Tank		
22	3	7-Aug-08	Nelson	purifier suction	0800 hrs	B05	V3-W22-080708-1		40	Record Fuel Temp and Filter Pressure Drop at right (STBD)	88 F	0.6/0.5
22	3	8-Aug-08	Grall	Fuel Station	0300 hrs	B05	V3-W22-080808-D		41	Fuel Delivery sample		
22	3	8-Aug-08	Nelson	purifier suction	1030 hrs	B05	V3-W22-080808-1	V3-W19-071908-1, V3-W20-072008-1, V3-W20-072108-1, V3-W20-072208-1, V3-W20-072308-1, V3-W20-072408-1	36	(All morning samples from 1st week of B5 discarded.)		
22	3	9-Aug-08	Nelson	purifier suction	1000 hrs	B05	V3-W22-080908-1		37	From Port Storage Tank		
23	3	10-Aug-08	Nelson	purifier suction	1000 hrs	B05	V3-W23-081008-1		38	From Stbd Storage Tank		
23	3	11-Aug-08	Nelson	purifier suction	0900 hrs	B05	V3-W23-081108-1		39	Record Fuel Temp and Filter Pressure Drop at right	88 F	0.6/0.6
23	3	12-Aug-08	Nelson	purifier suction	1000 hrs	B05	V3-W23-081208-1		40	From Stbd Storage Tank		
23	3	12-Aug-08	Newton	Fuel Station	1800 Hrs	B05	V3-W23-081208-D		41	Fuel Delivery sample		
23	3	13-Aug-08	Brenno	purifier suction	1015 hrs	B05	V3-W23-081308-1		42	From Stbd Storage Tank		
23	3	14-Aug-08	Brenno	purifier suction	1220 hrs	B05	V3-W23-081408-1		43	Record Fuel Temp and Filter Pressure Drop at right	70 F	0.8/-0.7

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
23	3	15-Aug-08	Brenno	purifier suction	1215 hrs	B05	V3-W23-081508-1	V3-W20-072508-1, V3-W20-072608-1, V3-W21-072708-1, V3-W21-072808-1, V3-W21-072908-1, V3-W21-073008-1, V3-W21-073108-1, V3-W21-080108-1	36	(All morning samples from 2nd week of B5 discarded.)		
23	3	16-Aug-08	Brenno	purifier suction	1200 hrs	B05	V3-W23-081608-1		37	From Port Storage Tank		
24	3	17-Aug-08	Brenno	purifier suction	1130 hrs	B05	V3-W24-081708-1		38	From Port Storage Tank		
24	3	18-Aug-08	Brenno	purifier suction	1130 hrs	B05	V3-W24-081808-1		39	Record Fuel Temp and Filter Pressure Drop at right	68 F	0.9/-0.9
24	3	19-Aug-08	Brenno	purifier suction	1130 hrs	B05	V3-W24-081908-1		40	From Stbd Storage Tank		
24	3	19-Aug-08	Newton	Fuel Station	0250 hrs	B05	V3-W24-081908-D		41	Fuel Delivery sample		
24	3	20-Aug-08	Alward	Fuel Station	0900 hrs	B05	V3-W24-082008-1		42	From Port Storage Tank		
24	3	21-Aug-08	Grall	purifier suction	1140 hrs	B05	V3-W24-082108-1		43	Record Fuel Temp and Filter Pressure Drop at right (STBD)	80 F	1.0/0.8
24	3	22-Aug-08	Grall	purifier suction	1030 hrs	B05	V3-W24-082208-1	V3-W19-071808-D, V3-W19-071808-2, V3-W19-071908-2, V3-W20-072008-2, V3-W20-072108-2, V1-W02-031508-D, V3-W20-072208-2, V3-W20-072308-2, V3-W20-072408-2, V3-W20-072508-D, V3-W20-072508-2, V3-W20-072608-2	32	(All Week 20 samples discarded)		
24	3	22-Aug-08	Nelson	Fuel Station	0300 hrs	B05	V3-W24-082208-D		33	Fuel Delivery sample		
24	3	23-Aug-08	Ryf	purifier suction	1105 hrs	B05	V3-W24-082308-1		34	From Port Storage Tank		
25	3	24-Aug-08	Grall	purifier suction	1215 hrs	B05	V3-W25-082408-1		35	From Port Storage Tank		
25	3	25-Aug-08	Brenno	purifier suction	1000 hrs	B05	V3-W25-082508-1		36	Record Fuel Temp and Filter Pressure Drop at right	87 F	0.7/0.7
25	3	26-Aug-08	Grall	purifier suction	0905 hrs	B05	V3-W25-082608-1		37	From Port Storage Tank		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
25	3	26-Aug-08	Brenno	Fuel Station	1940 hrs	B05	V3-W25-082608-D		38	Fuel Delivery on 27-Aug 08		
25	3	27-Aug-08	Bylund	purifier suction	1100 hrs	B05	V3-W25-082708-1		39	From Stbd Storage Tank		
25	3	28-Aug-08	Bylund	purifier suction	0800 hrs	B05	V3-W25-082808-1		40	Record Fuel Temp and Filter Pressure Drop at right (PORT)	68 F	
25	3	29-Aug-08	Bylund	purifier suction	1300 hrs	B05	V3-W25-082908-1	V3-W20-072508-D, V3-W20-072508-2, V3-W20-072608-2, V3-W21-072708-2, V3-W21-072808-2, V3-W21-072908-2, V3-W21-072908-D, V3-W21-073008-2, V3-W21-073108-2, V3-W21-080108-2, V3-W21-080208-1	30	From Port Storage Tank 71 F		
25	3	30-Aug-08	Bylund	purifier suction	1030 hrs	B05	V3-W25-083008-1		31	From Port Storage Tank 70 F		
26	3	31-Aug-08	Bylund	purifier suction	1130 hrs	B05	V3-W26-083108-1		32	From Stbd Storage Tank 68 F		
26	3	1-Sep-08	Bylund	purifier suction	1100 hrs	B10	V3-W26-090108-1		33	Record Fuel Temp and Filter Pressure Drop at right (PORT)	68 F	

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

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Week #	**Vessel**	**Date**	**Collected By**	**Location**	**Time**	**Fuel Type**	**Serial Number**	**Samples to Discard**	**Samples in Storage**	**Comments/Observations**	**Fuel Temp**	**Filter Pressure Drop**
26	3	1-Sep-08	Bylund	purifier suction	1100 hrs	B10	V3-W26-090108-1		36	Fuel Temp: Filter Pressure Drop:	68 F	
26	3	2-Sep-08	Grall	Fuel Station	0300 hrs	B10	V3-W26-090208-D		37	Fuel Delivery (B-5 on 3 Sept 08)		
26	3	2-Sep-08	Bylund	purifier suction	1140 hrs	B10	V3-W26-090208-1		38	From Stbd Storage Tank 70 F		
26	3	3-Sep-08	Nelson	purifier suction	0800 hrs	B10	V3-W26-090308-1		39	From Stbd Storage Tank 80 F		
26	3	4-Sep-08	Nelson	purifier suction	0800 hrs	B10	V3-W26-090408-1		40	From Port Storage Tank	80 F	0.5/0.5
26	3	5-Sep-08	Grall	Fuel Station	0300 hrs	B10	V3-W26-090508-D		41	Fuel Delivery sample		
26	3	5-Sep-08	Nelson	purifier suction	0800 hrs	B10	V3-W26-090508-1	V3-W22-080308-1, V3-W22-080408-1, V3-W22-080508-D, V3-W22-080508-1, V3-W22-080608-1, V3-W22-080708-1, V3-W22-080808-D, V3-W22-080808-1, V3-W22-080908-1	33	(Wk 22 samples discarded) STBD		
26	3	6-Sep-08	Nelson	purifier suction	1400 hrs	B10	V3-W26-090608-1		34	From Port Storage Tank 88 F		
27	3	7-Sep-08	Nelson	purifier suction	0930 hrs	B10	V3-W27-090708-1		35	From Starboard Tank, 65 F		
27	3	8-Sep-08	Nelson	purifier suction	0910 hrs	B10	V3-W27-090808-1		36	Fuel Temp: Filter Pressure Drop:	62 F (STBD)	0.5/0.6
27	3	9-Sep-08	Cobb	purifier suction	1045 hrs	B10	V3-W27-090908-1		37	From Port Storage Tank 64 F		
27	3	9-Sep-08	Brenno/Curley	Fuel Station	0300 hrs	B10	V3-W27-090908-D		38	Fuel Delivery sample (9/10/08)		
27	3	10-Sep-08	Brenno	purifier suction	1100 hrs	B10	V3-W27-091008-1		39	From Stbd Storage Tank		
27	3	11-Sep-08	Brenno	purifier suction	1100 hrs	B10	V3-W27-091108-1		40	Fuel Temp: Filter Pressure Drop:	65 F(PORT)	0.8/1.0
27	3	12-Sep-08	Brenno	purifier suction	1100 hrs	B10	V3-W27-091208-1	V3-W23-081008-1, V3-W23-081108-1, V3-W23-081208-1, V3-W23-081208-D, V3-W23-081308-1, V3-W23-081408-1, V3-W23-081508-1, V3-W23-081608-1	33	From Starboard Tank, 72 F		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
27	3	13-Sep-08	Brenno	purifier suction	1045 hrs	B10	V3-W27-091308-1		34	From Port Tank		
28	3	14-Sep-08	Brenno	purifier suction	1100 hrs	B10	V3-W28-091408-1		35	From Starboard Tank		
28	3	15-Sep-08	Brenno	purifier suction	1200 hrs	B10	V3-W28-091508-1		36	From Port Tank	68 F	1.0/1.0
28	3	16-Sep-08	Bylund	Fuel Station	0300 hrs	B10	V3-W28-091608-D		37	Fuel Delivery sample		
28	3	16-Sep-08	Mielke	purifier suction	1130 hrs	B10	V3-W28-091608-1		38	From Starboard Tank		
28	3	17-Sep-08	Grall	purifier suction	0925 hrs	B10	V3-W28-091708-1		39	From Port Tank		
28	3	18-Sep-08	Ryf	purifier suction	0930 hrs	B10	V3-W28-091808-1		40	Fuel Temp: Filter Pressure Drop:	84 F	0.6/0.7
28	3	19-Sep-08	Nelson	Fuel Station	0300 hrs	B10	V3-W28-091908-D		41	Fuel Delivery sample		
28	3	19-Sep-08	Grall	purifier suction	0845 hrs	B10	V3-W28-091908-1	V3-W24-081708-1, V3-W24-081808-1, V3-W24-081908-1, V3-W24-081908-D, V3-W24-082008-1, V3-W24-082108-1, V3-W24-082208-1, V3-W24-082208-D, V3-W24-082308-1	33	From Starboard Tank)		
28	3	20-Sep-08	Williams	purifier suction	0800 hrs	B10	V3-W28-092008-1		34	From Day Tank		
29	3	21-Sep-08	Grall	purifier suction	1150 hrs	B10	V3-W29-092108-1		35	From Starboard Tank		
29	3	22-Sep-08	Williams	purifier suction	0925 hrs	B10	V3-W29-092208-1		36	Fuel Temp:(Recirc from Day Tank) Filter Pressure Drop:	85 F	2.0/4.0
29	3	23-Sep-08	Williams	purifier suction	0845 hrs	B10	V3-W29-092308-1		37	From Port Storage Tank		
29	3	23-Sep-08	Brenno	Fuel Station	1940 Hrs	B10	V3-W29-092308-D		38	Fuel Delivery sample		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
29	3	23-Sep-08	Williams	purifier suction	0845 hrs	B10	V3-W29-092308-1		37	From Port Storage Tank		
29	3	23-Sep-08	Brenno	Fuel Station	1940 Hrs	B10	V3-W29-092308-D		38	Fuel Delivery sample		
29	3	24-Sep-08	Connor	purifier suction	0800 Hrs	B10	V3-W29-092408-1		39	From Port Storage Tank		
29	3	25-Sep-08	Connor	purifier suction	0800 Hrs	B10	V3-W29-092508-1		40	Fuel Temp: (STBD tank) Filter Pressure Drop:	58 F	2.0/2.0
29	3	26-Sep-08	Bylund	purifier suction	1315 Hrs	B10	V3-W29-092608-1	V3-W25-082608-D, V3-W25-082408-1, V3-W25-082508-1, V3-W25-082608-1, V3-W25-082708-1, V3-W25-082808-1, V3-W25-082908-1, V3-W25-083008-1	33	Port Tank (Wk 25 Smpls Discrdd)		
29	3	27-Sep-08	Bylund	Stbd Tank	1300 Hrs	B10	V3-W29-092708-1		34			
30	3	28-Sep-08	Williams	Stbd Tank	0810 Hrs	B10	V3-W30-092808-1		35			
30	3	29-Sep-08	Bylund	Port Tank	1000 Hrs	B10	V3-W30-092908-1		36	Fuel Temp: Filter Pressure Drop:		
30	3	30-Sep-08	Brenno	Fuel Station	0300 Hrs	B10	V3-W30-093008-D		37	Fuel Delivery sample		
30	3	30-Sep-08	Bylund	Port Tank	1130 Hrs	B10	V3-W30-093008-1		38			
30	3	1-Oct-08	Williams	Stbd Tank	2359 Hrs	B20	V3-W30-100108-1		39			
30	3	2-Oct-08	Nelson	purifier suction	0800 Hrs	B20	V3-W30-100208-1		40	Fuel Temp: Filter Pressure Drop:	85 F	5.0/5.0

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell)

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
30	3	3-Oct-08	Grall	Fuel Station	0300 Hrs	B20	V3-W30-100308-D		39	Fuel Delivery sample		
30	3	3-Oct-08	Cobb	Stbd Tank	0700 Hrs	B20	V3-W30-100308-1		40	Fuel Temp: Filter Pressure Drop:	67 F	3.0/3.0
31	3	7-Oct-08	Wakefield	Fuel Station	1940 Hrs	B20	V3-W31-100708-D		41	Fuel Delivery sample		
31	3	7-Oct-08	Brenno	Port Tank	1100 Hrs	B20	V3-W31-100708-1	V3-W26-083108-1, V3-W26-090108-1, V3-W26-090208-D, V3-W26-090208-1, V3-W26-090308-1, V3-W26-090408-1, V3-W26-090508-D, V3-W26-090508-1, V3-W26-090608-1	33	Fuel Temp: Filter Pressure Drop: SAMPLE TAKEN 10/08/08	65 F	Lapsed !
31	3	10-Oct-08				B20	V3-W31-101008-D		34	Fuel Delivery CANCELLED		
31	3	10-Oct-08	Brenno	Port Tank	0950 Hrs	B20	V3-W31-101008-1		35	TAKEN ON 11th OCT		
32	3	14-Oct-08	Brenno	Stbd Tank	1145 Hrs	B20	V3-W32-101408-1	V3-W27-090708-1, V3-W27-090808-1, V3-W27-090908-1, V3-W27-090908-D, V3-W27-091008-1, V3-W27-091108-1, V3-W27-091208-1, V3-W27-091308-1	28	Fuel Temp: Filter Pressure Drop: (All Week 27 samples discarded)	68 F	1.0/1.0
32	3	14-Oct-08	Bylund	Fuel Station	0300 Hrs	B20	V3-W32-101408-D		29	Fuel Delivery sample		
33	3	21-Oct-08	Brenno	Fuel Station	1950 Hrs	B20	V3-W33-102108-D		30	Fuel Delivery sample		
33	3	21-Oct-08	Grall	Stbd Tank	0600 Hrs	B20	V3-W33-102108-1	V3-W28-091408-1, V3-W28-091508-1, V3-W28-091608-D, V3-W28-091608-1, V3-W28-091708-1, V3-W28-091808-1, V3-W28-091908-D, V3-W28-091908-1, V3-W28-092008-1	22	Fuel Temp: Filter Pressure Drop: (All Week 28 samples discarded)	64 F	0.0/0.5
33	3	24-Oct-08	Cancelled	Cancelled	Cancelled	B20	V3-W33-102408-D		23	Cancelled		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell)												
Week #	**Vessel**	**Date**	**Collected By**	**Location**	**Time**	**Fuel Type**	**Serial Number**	**Samples to Discard**	**Samples in Storage**	**Comments/Observations**	**Fuel Temp**	**Filter Pressure Drop**
35	3	4-Nov-08	Bylund	Fuel Station	1940 Hrs	B20	V3-W35-110408-D			Fuel Delivery sample	N/A	N/A
36	3	11-Nov-08	Bylund	Fuel Station	0300 Hrs	B20	V3-W36-111108-D			Fuel Delivery sample	N/A	N/A
36	3	11-Nov-08	Brenno	Port Tank	1300 Hrs	B20	V3-W36-111108-1			Fuel Temp: Filter Pressure Drop:	68 F	1.0/1.0
36	3	14-Nov-08	Wolfe	Fuel Station	0300 Hrs	B20	V3-W36-111408-D			Fuel Delivery sample		
37	3	18-Nov-08	Bylund	Stbd Tank		B20	V3-W37-111808-1			Sample Taken 11/24/08	60 F	
37	3	18-Nov-08	Curley	Fuel Station	1940 Hrs	B20	V3-W37-111808-D			Fuel Delivered 11/19/08		
38	3	25-Nov-08	Brenno	Fuel Station	0300 Hrs	B20	V3-W38-112508-D			Fuel Delivery sample		
38	3	25-Nov-08				B20	V3-W38-112508-1	V3-W30-092808-1, V3-W30-092908-1, V3-W30-093008-D, V3-W30-093008-1, V3-W30-100308-D, V3-W30-100308-1, V3-W31-100708-D, V3-W31-100708-1, V3-W31-101008-D, V3-W31-101008-1, V3-W32-101408-1, V3-W32-101408-D, V3-W33-102108-D, V3-W33-102108-1, V3-W33-102408-D, V3-W34-102808-1, V3-W34-102808-D	9	Fuel Temp: Filter Pressure Drop: (All samples from 10/28/08 and before discarded)		

WSF Biodiesel Test Samples
Vessel 3 - Klahowya

IN CASE OF EMERGENCY: Engineering Responders are David Larsen, 206-624-7850 (office) 206-579-5350 (cell) or Paul Smith, 206-624-7850 (office) 425-356-9418 (cell)

Week #	Vessel	Date	Collected By	Location	Time	Fuel Type	Serial Number	Samples to Discard	Samples in Storage	Comments/Observations	Fuel Temp	Filter Pressure Drop
39	3	2-Dec-08	Williams	Stbd Tank	0100 hrs	B20	V3-W39-120208-1			Fuel Temp: Filter Pressure Drop:	62 F	0.5/1.0
39	3	2-Dec-08	Bylund	Fuel Station	2000 Hrs	B20	V3-W39-120208-D			Fuel Delivery sample		
40	3	9-Dec-08	Bylund	Fuel Station	0300 Hrs	B20	V3-W40-120908-D			Fuel Delivery sample		
40	3	9-Dec-08	Brenno	Stbd Tank	0755 Hrs	B20	V3-W40-120908-1			Fuel Temp: Filter Pressure Drop:	61 F	1.0/1.0
40	3	12-Dec-08	Wolfe	Fuel Station	0300 Hrs	B20	V3-W40-121208-D			Fuel Delivery sample		
41	3	16-Dec-08	Ryf	Port Tank	1435 Hrs	B20	V3-W41-121608-1			Fuel Temp: Filter Pressure Drop:	53 F	3.0/3.5
41	3	16-Dec-08	Brenno	Truck	1945 Hrs	B20	V3-W41-121608-D			Fuel Delivery sample (100%ULSD)		
42	3	23-Dec-08	Brenno	Truck	0300 Hrs	B20	V3-W42-122308-D			Fuel Delivery sample (100%ULSD)		
42	3	23-Dec-08	Bylund	Stbd Tank	0945 Hrs	B20	V3-W42-122308-1			Fuel Temp: Filter Pressure Drop:	54 F	4.5/4.5
42	3	26-Dec-08				B20	V3-W42-122608-D			Fuel Delivery sample		
43	3	30-Dec-08				B20	V3-W43-123008-1	V3-W35-110408-1, V3-W35-110408-D, V3-W36-111108-D, V3-W36-111108-1, V3-W36-111408-D, V3-W37-111808-1, V3-W37-111808-D, V3-W38-112508-D, V3-W38-112508-1, V3-W38-112808-D	11	Fuel Temp: Filter Pressure Drop: (All samples from 11/28/08 and before discarded)		
43	3	30-Dec-08				B20	V3-W43-123008-D			Fuel Delivery sample		

Appendix K: Sludge Characterization and Microbial Identification

Sludge Characterization and Microbial Identification

Washington State University (WSU) focused on investigation of the excess sludge formation in the purifiers of the vessels. Several methods, such as pyrolysis-GC/MS (Py-GC/MS), thermogravimetic analysis (TGA), ion chromatography (IC), and microbial identification were used to characterize the sludge samples obtained during the pilot test. A main cause responsible for the sludge formation was identified in order to make recommendations for preventing the excess sludge formation.

1. Organic materials in the sludge

Organic materials in the sludge were characterized using two methods, pyrolysis-GC/MS (Py-GC/MS) and thermogravimetic analysis (TGA).

1.1 Py-GC/MS analysis

Py-GC/MS analysis was carried out using a CDS pyroprobe 5000 with an Aglient GC-MS. Samples were loaded into a quartz tube and kept the oven (210 ^{o}C) to ensure adequate removal of oxygen prior to pyrolysis. Samples were pyrolyzed by heating to 500 ^{o}C, and the resulting pyrolysis vapors were separated by a (5% phenyl)-methylpolysiloxane non-polar column. The gas flow rate was 1 ml/min and helium was used as the carrier gas. The gas was then sent into a mass spectrometer (Aglient Technologies Inert XL MSD). The mass spectrometer conditions were as follows: transfer line at 150 ^{o}C, ion source 230 ^{o}C, and electron energy 70 eV. The mass spectra of predominant peaks were then compared to a mass spectra library to determine the compounds in a given peak.

Figure 1 shows the result of the sludge sample. The highest peak in the figure was at 31.5 min. Figure 2 suggests that the MS pattern of this peak was 8-Octadecenoic acid methyl ester ($C_{19}H_{36}O_2$), based on data from the library of standard chemicals. Thus, the sludge contains an 8-Octadecenoic acid methyl ester fraction.

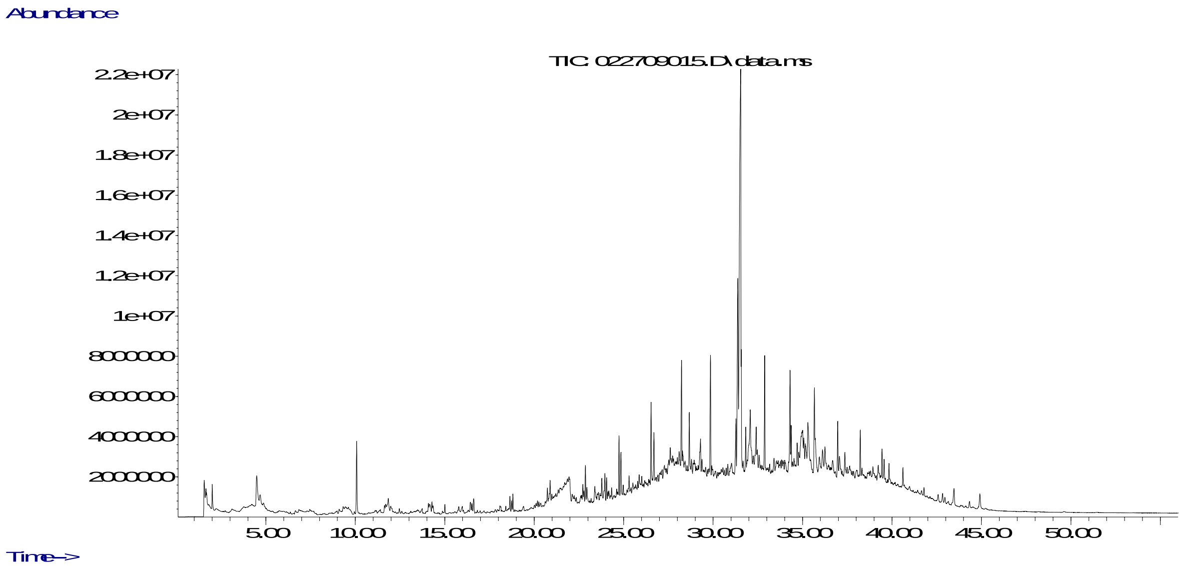

Figure 1. Py-GC/MS chromatograph of the sludge sample (May 30, 2008)

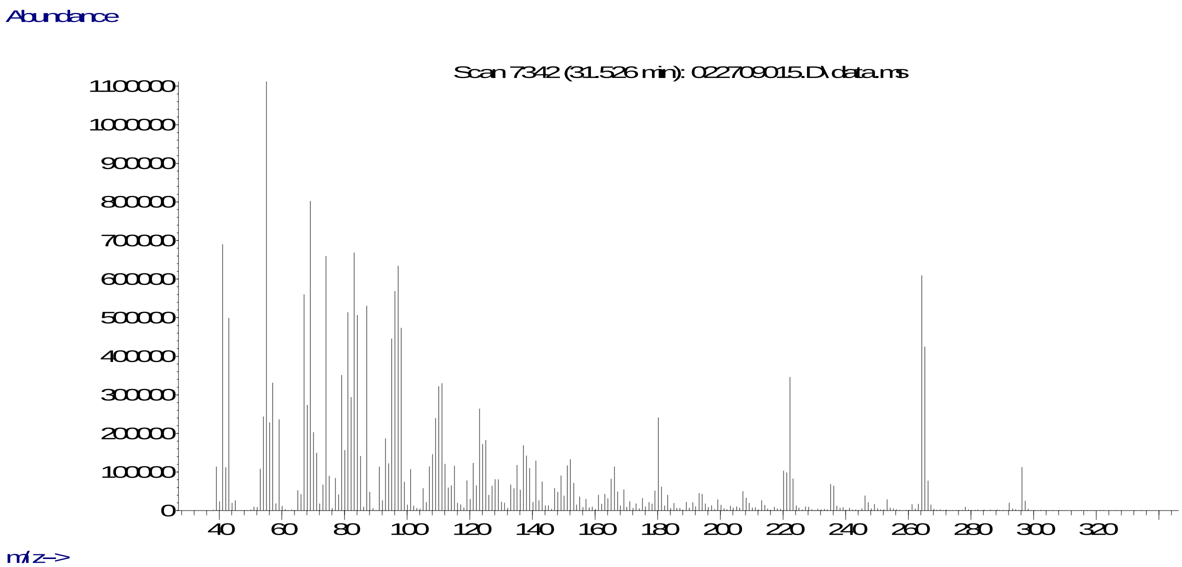

Figure 2. The MS pattern of 8-Octadecenoic acid, methyl ester (31.5 min)

1.2 TGA analysis

TGA analysis was also used to characterize the organic materials in this sludge sample. TGA analysis was conducted using a Mettler-Toledo TGA/SDTA851. Approximately 5-10 mg of sample was loaded into an aluminum pan and vaporized at a temperature range of 25-600 ^{o}C and a rate of 10 ^{o}C/min. The samples were run under nitrogen atmosphere at flow rate of 20 ml/min.

Figure 3 shows a derivative thermogravimetric (DTG) curve converted from the TGA. DTG demonstrates the rate of weight change of the sample with temperature change. There were two distinctive peaks in the Figure 3, suggesting that the sludge consisted of two major fractions with different properties. One fraction was within temperature range between 430-490 ^oC. This fraction may contain heavy components. However, this was a small fraction, about 6% of the sludge. A large fraction of the sludge material evaporated within the temperature range below 250 ^oC. This temperature range suggests light compounds with low molecular weight including water. It is interesting that three subpeaks at 125, 130, and 136 ^oC were present. It is not clear what specific compounds these subpeaks relate to. Further research is required to determine specific compounds in this fraction, as it was the major part of the sludge sample.

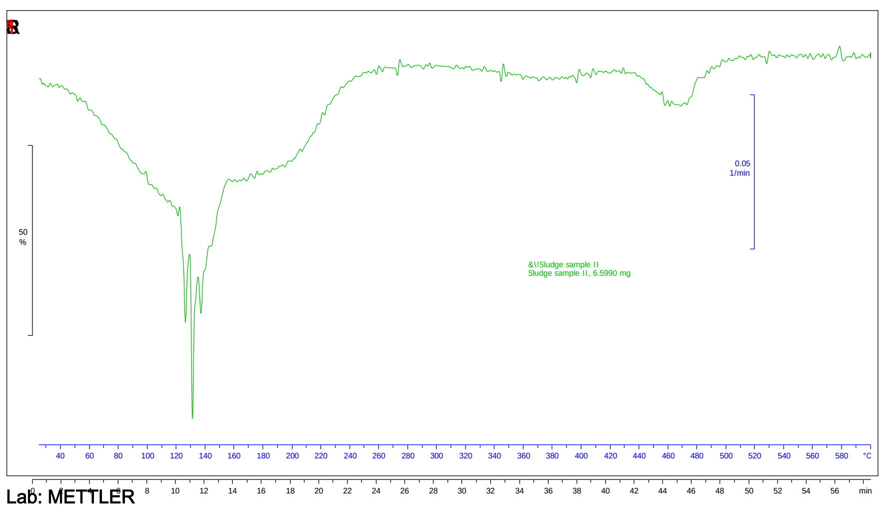

Figure 3. Derivative thermogravimetric (DTG) curve of the sludge sample (temperature change rate at 10.00°C/min within 25.0-600.0°C)

2. Water content in the sludge samples

Water content in the wet sludge was determined using the K-F titration method with a Titroline KF Titrator from Schott Instruments GmbH. Before the titration, the wet sludge samples at final concentration of 2.7% (w/v) were dispersed in organic solvents either chloroform ($CHCl_3$) or pyridine. These two solvents were chosen because the sludge appeared to be dispersed well in the solvents. The water content in the wet sludge was calculated by the content of sludge in solvents and K-F titration.

Table 1 shows the results of water content in the wet sludge samples. Water content in the solvent chloroform was 0.315 % (w/v), as obtained by K-F titration. As water solubility in chloroform was 0.795% (w/w), which is higher than the water content determined in the chloroform, water in the sludge sample did not saturate in the chloroform. Thus the K-F titration could estimate water content in the sludge from the chloroform sample. Water content in the wet sludge was approximately 11.7 % (w/w) determined from the solvent chloroform as the sludge content was 2.7 % (w/v) in the chloroform. Another solvent used was pyridine which is miscible with water. Water in the sludge could dissolve in solvent pyridine. Water content in the wet sludge was approximately17.2 % (w/w). Therefore water is a fraction of the wet sludge in the range of 11-17 % (w/w).

Table 1. Water content in the wet sludge

Solvent	Chloroform	Pyridine
H_2O in wet sludge % (w/w)	11.7 ± 1.1	17.2 ± 2.2

3. Microbial role in the sludge formation

The objectives of this effort were to investigate the presence of active microbes in the sludge, isolation of microbes from the sludge, and biocide influence on microbial growth,

3.1 Observation of the sludge samples under a microscope

A sludge sample from the purifier of the *Tillikum* was collected on July 15, 2008. In order to look at the micro structure and microbial presence, this sludge sample was observed under a microscope. A typical image of the sludge is shown in Figure 4. It appears that some separated micro domains were present in this sample. Sizes of the micro domains typically ranged from 30-150 μm. In addition, a great number of active bacteria were found in the micro domains, as shown in Figure 5. Some had a round shape and others had a rod shape. It appears that there were several bacteria species present in the samples. No yeast or fungi were observed in this sludge sample.

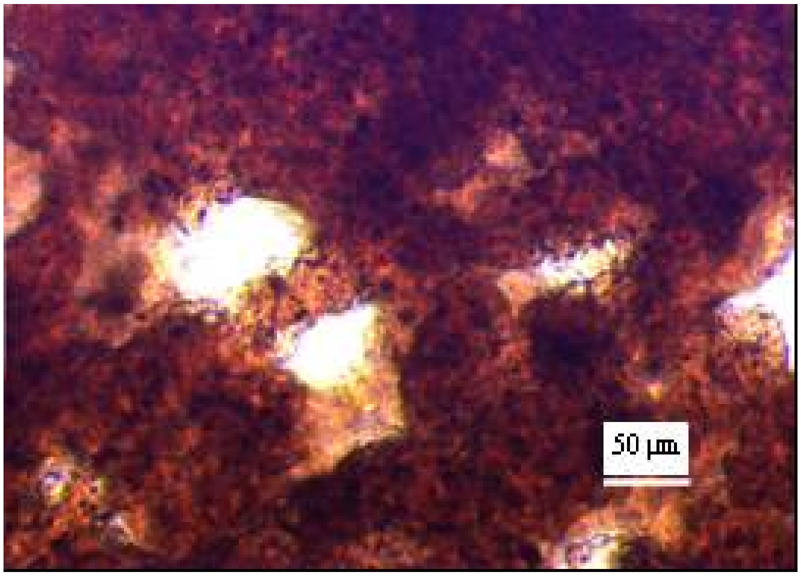

Figure 4. Image of sludge from the purifier of the *Tillikum*
(Separated micro domains appear white)

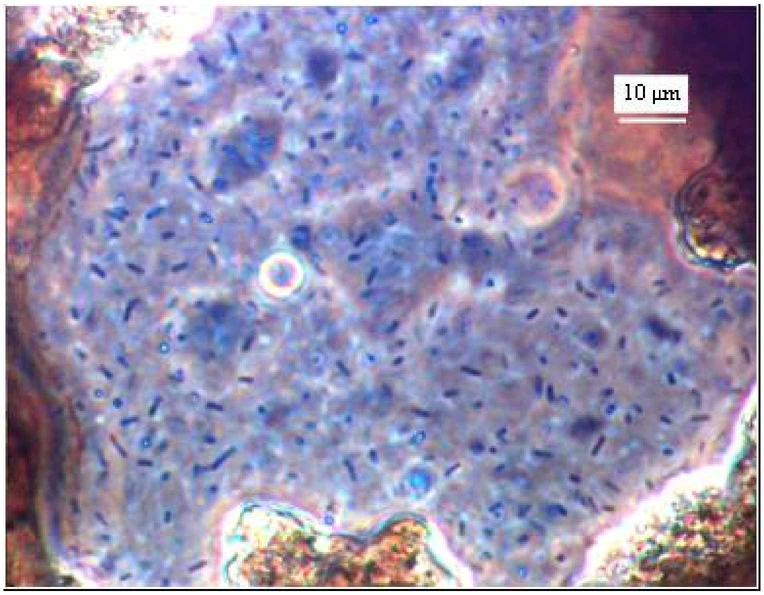

Figure 5. Images of bacteria in the sludge from the purifier of the *Tillikum*
(Active bacteria appear blue and are rod and round in shape)

Another sludge sample from the purifier of the *Issaquah* collected July 30, 2008, was also observed under a microscope. Again, many active bacteria were found in the sludge.

The microbial tests on the sludge were conducted with test kits. The results were shown to be microbial positive, which further confirms that active microbes were present in the sludge samples. However, the B5 fuel samples tested negative, so it did not appear that the microbes were coming from the fuel supplier

3.2 Isolation of microbes from the sludge of the Tillikum purifier

To identify microbes from the sludge of the *Tillikum* purifier collected on July 15, 2008, four types of solid media for microbial growth were applied. Plate count agar (PCA) was designed for detection of bacteria, potato dextran agar (PDA) was used for cultivation of fungi possibly present in the sludge, malt extract agar (MEA) was used mainly for cultivation of potential yeasts grown in the sludge, and anaerobic agar (AA) was designated for observation of microorganisms that could grow under anaerobic conditions. PCA contained pancreatic digest of casein, yeast extract, dextrose, and agar; PDA contained potato starch, dextrose, and agar; MEA contained maltose, dextrose, glycerol, peptone, and agar; and AA contained agar with casein Peptone, sodium chloride, dextrose, sodium thioglycollate, soy Peptone, L-cystine, agar, sodium sulfoxyl formaldehyde, and methylene blue.

In order to obtain a microbial count in the sludge, 0.10 grams of wet sludge was weighed under sterile conditions and then suspended in 1.0 mL of deionized water (DI water). The samples were then mixed by vortexing for ten minutes. 10 μL of the suspension samples were diluted into 50 mL DI water and shaken by hand for approximately two minutes. 100 μL of the diluted samples were spread onto culture plates and incubated at 30 ^{o}C for two days.

Large numbers of bacterial colonies grew on each type of medium. However, no fungi or yeast colonies were found on the plates. Thus, bacteria were the dominant microorganisms in the sludge. Table 2 shows the results of quantitative analysis by cell count. The number of bacteria in the sludge from three types of culture attained a level of 10^8 per gram of wet sludge. The bacteria also grew well in both anaerobic and aerobic conditions without a significant difference.

Table 2. Bactria numbers in the sludge on the cultural media

Medium type	Culture condition	Microbial number per gram of wet sludge (mean value in triplicate samples)
Anaerobic agar	anaerobic	5.28×10^7
PCA	aerobic	2.43×10^8
Two-layers of PCA	anaerobic aerobic	1.44×10^8 1.51×10^8

3.3 Isolation of viscous material from aqueous solution from the Tillikum purifier

High viscosity in the aqueous solution was observed in presence of excess sludge in the *Tillikum* purifier. It was speculated that polysaccharides were produced by the microbes and that provided high viscosity in the solution. Isolation of the viscous material from the water was attempted.

The water sample from the purifier of the *Tillikum* was centrifuged at 10,000 rpm for 20 minutes. Any insoluble materials were removed from the sample. Ethanol at a final concentration of 50% (v/v) was added into the supernatant of the aqueous solution. Some precipitates were formed and obtained after centrifugation. This procedure was repeated one more time, dissolving the precipitates with deionized water to precipitate the materials with ethanol and to obtain the materials by centrifugation. Finally, a small amount of solid material was obtained after drying at 105 ^oC overnight.

Ion chromatography (IC) analysis was used to identify monosaccharides from the sample. Samples were hydrolyzed in 1.0 M H_2SO_4 at 100 ^oC for 2 hours and diluted to obtain monosaccharide before the IC analysis. The measurement concentrations of five sugars, including arabinose, galactose, glucose, xylose, and fructose, were used in a standard addition protocol. All samples, including standard solutions of sugars, were filtered through 0.25 μm pore polycarbonate membranes (Nuclepore Corp., Pleasanton, CA). High-grade deionized water (18 Mohm/cm) passed through an organics removal cartridge (Unipure I system; Solution Consultants Inc., Marietta, GA) was employed throughout.

All sugar analysis was carried out using a Dionex ICS-3000 reagent free dual ion chromatography (IC) system (Sunnyvale, CA, USA), which was comprised of a DP dual gradient pump module, an EG dual eluent generator (with one KOH reservoir cartridge in use for this work) and a DC detector/chromatography module with three programmable high-pressure six-port injector valves. Briefly, the mobile phase, at a flow rate of 1.0 mL min^{-1}, consisted of ultrapure water (0.015 $\mu S\ cm^{-1}$; eluent A) and 250 mM NaOH (eluent B), with the following gradient: 0.0 min: 87% A, 13% B; 20.0 min: 87% A, 13% B; 40.0 min: 15% A, 85% B; 41.0 min: 100% B; 49.0 min: 100% B; 50.0 min: 87% A, 13% B; and 65.0 min: 87% A, 13% B. Due to matrix interference, quantification was carried out with standard addition.

Table 3 shows the results of the monosaccharide composition in the aqueous solution. Galactose and glucose were found in this sample. The detection of two sugars supported the presence of polysaccharides which are typically produced by bacteria. However, further research is needed to understand the role of the polysaccharides in the sludge formation

Table 3. Monosaccharide composition analysis in the aqueous solution by IC

Sample	Arabinose	Galactose	Glucose	Xylose	Fructose
Sludge Liquid	-	+	+	-	-

Note: "-" indicated no sugar was detected; "+" indicated sugar was detected.

3.4 Effect of biocide application on the microbial growth

Appendix K: Sludge Characterization and Microbial Identification

In order to simulate ferry conditions, biodiesel blend (canola based B5) was used in this batch culture. Table 4 shows the compositions of seven samples tested. The canola B5 was made by blending canola B100 from Imperium Renewable and ultra low sulfur diesel purchased on the local market. Deionized water was autoclaved at 121 ^{o}C for 15 minutes. The phase ratio of the oil to aqueous solution was 2:1 for all samples. In addition, biocide obtained from WSF at four different levels was added into some samples (samples #15 though #18). The biocide dose in sample #17 was the maintenance level used in the WSF test. Thus, sample #15 and sample #16 have higher levels of dosages, while sample #18 has a lower level of the dosage. All samples (except Sample #10) were inoculated with the WSF sludge. The seven samples described above were shaken at 190 rpm at 30 ^{o}C for four days to obtain microbial growth.

Table 4. Effect of biocide addition on bacteria growth

Sample ID	#10	#11	#13	#15	#16	#17	#18
Canola B5 (mL)	60	60	60	60	60	60	60
Water (mL)	30	30	30	30	30	30	30
Biocide concentration based on B5 (ml/L)	0	0	0	0.5	0.2	0.1	0.05
Sludge inoculation	NO	YES [a]	YES [b]	YES [b]	YES [b]	YES [b]	YES [b]

a: Sludge collected on May 30, 2008

b: Sludge used for all other samples collected on July 15, 2008

Figure 6 shows a photo of the seven samples after the liquid culture. Microbial growth appeared in all of the samples, except sample #10, which was a blank. Biofilm at the interface between oil and water phases was formed in the samples inoculated with the sludge. Bacteria in the biofilm were observed under a microscope. There appeared to be less biofilm at the higher levels of biocide in samples #15 and #16. However, microbial growth occurred in the four samples from samples #15 through #18 in the presence of the biocide. Thus, the biocide used here could not stop microbial growth under certain conditions, although it might inhibit microbial growth to some extent.

Appendix K: Sludge Characterization and Microbial Identification

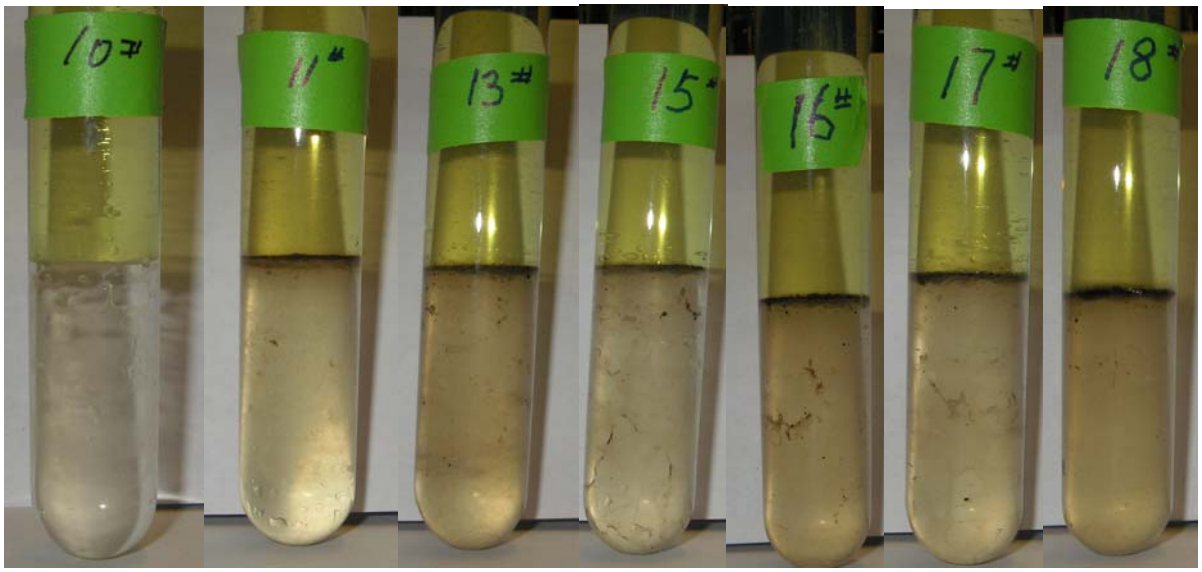

Figure 6. Microbial culture inoculated with sludge

In summary, lab research results showed that the sludge samples contained metal, microbes, water, and oil fractions (such as 8-Octadecenoic acid methyl ester) from canola biodiesel and light compounds possibly from diesel. Active bacteria were present in the sludge samples from the purifiers. The bacteria can grow in the presence of the B5 fuel and water. The bacterial contamination is one of major causes of the excess sludge formation. Thus, biocide application was recommended for inhibition of microbial growth in the pilot test. The biocide studied inhibited bacterial growth but did not stop bacterial growth in laboratory conditions. Thus, this biocide might not be the optimal choice for this ferry application.

4. **Microbial identification**

It is noted that the bacteria in the sludge could contain several types of strains. Isolation of the bacteria was conducted using plate streaking and gradient dilution methods. Five types of bacterial strains which could be dominant in the sludge sample were obtained after the isolation. They are designated as P1, P2, P4, P8, and P8-2. Identification of these five strains was done using molecular biological methods, including DNA extraction, 16s rRNA amplification, 16s rRNA gene clone, and DNA sequencing and sequence analysis. While three of the strains were identified, the rest of two are still being investigated.

Appendix K: Sludge Characterization and Microbial Identification

4.1 DNA extraction, 16s rRNA amplification and sequencing

The isolates were cultured in liquid Luria-Bertani medium at 37 °C overnight. The cells in mid-log phase were harvested by centrifugation at 12,000 rpm for 2 min. DNA was extracted using the Wizard genomic DNA purification kit (Promega, USA).

Internal fragments of 16s rRNA were amplified from genomic DNA using universal primers 8f and 926r (based on E.coli 16s rRNA positions). Amplification was performed in 50 µl (total volume) reactions that contained 20 ng (1 µl) of sample DNA, 1 U of AmpliTaq DNA polymerase, 1× AmpliTaq reaction buffer, 1.5 mM $MaCl_2$, 100 mM dNTP, 5% DMSO and 0.05 mM of each primer. Initial DNA was denaturated at 94 °C in a PTC-100 Programmable Thermal Controller for 5 min, followed by 35 cycles of denaturation at 94 °C for 1 min and annealing at 72 °C for 2 min, which was followed by a final extension at 72 °C for 10 min.

The recombinant plasmids contained the 16s rRNA insert were sequenced with bacterial 926r and 8f primers. The insert sequences were determined using Big Dye ver. 3 cycles of sequencing reactions, and resolved using an automatic sequencer (3100 PRISM Genetic Analyzer). Sequences were trimmed to exclude the PCR primer sites corrected with Chromas 2 (Chromas Version 2.22; http:// www.technelysium.com.au/chromas.heml). For identification with the closet relatives, inserted sequences were compared to those available GenBank (http://www.ncbi.nlm.nih.gov) databases. The CLUSTAL X program (version 1.83) was used to align the target sequences with reference sequences, and phylogenetic trees were constructed based on neighbor-joining method by the software package MEGA.

4.2 16srDNA identification and characteristics of the isolates

Phylogenetic positions of the three stains were shown in Figure 7. By analyzing the partial 16sRNA gene sequences with reference sequences of related genus, phylogenetic trees were constructed as mentioned in the methods. P1 was found to show 99% homogeneity with *Klebsiella oxytoca*. Thus it was tentatively referred to as *Klebsiella* *oxytoca* strain P1. P2 showed 98% of homogeneity with *Klebsiella pneumonia*, and also displayed different biochemical and physiological characteristics than *Klebsiella pneumonia*. For example, the cell surface of P2 was not as rough as the reference. Most importantly, P2 did not produce any exopolysaccharides, while *Klebsiella pneumonia* commonly does. Thus, it was tentatively assigned as *Klebsiella* novel species strain P2. The coccus P8-2 showed 99% homogeneity with *Staphylococcus epidermidis*, therefore it was referred to as *Staphylococcus epidermidis* strain P8-2.

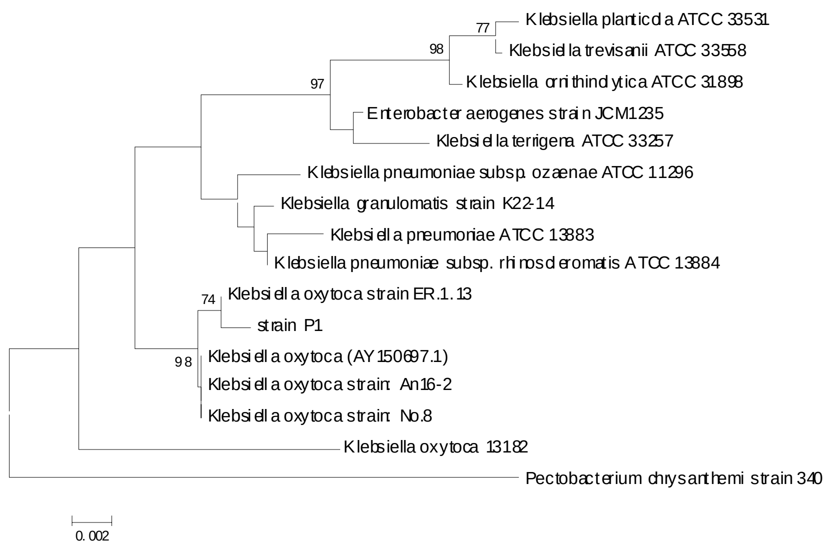

Figure 7. (A) Phylogenetic positions of the strain P1

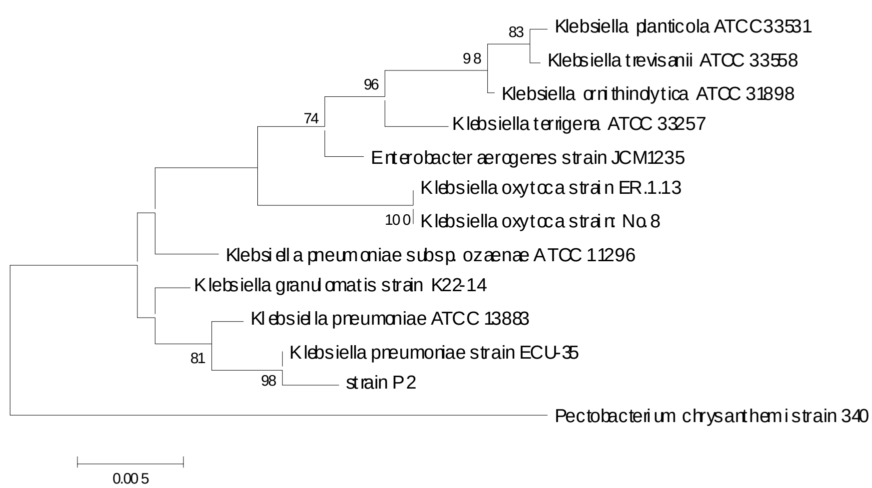

Figure 7. (B) Phylogenetic positions of the strain P2

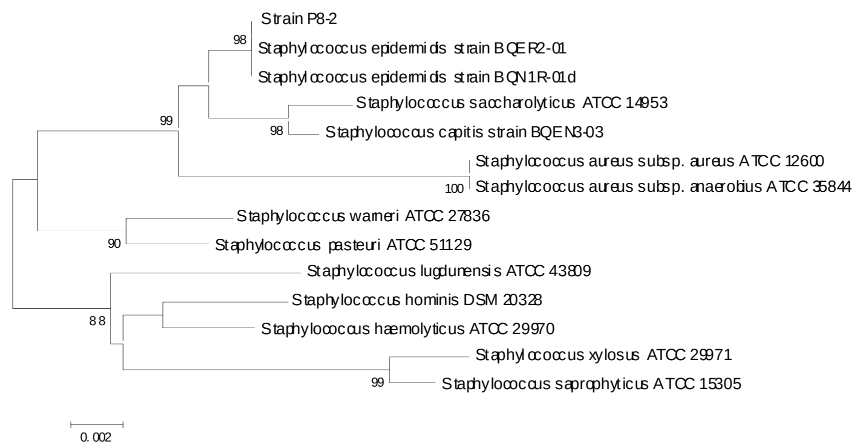

Figure 7. (C) Phylogenetic positions of the strain P8-2

In summary, three bacteria of the five strains were identified as *Staphylococcus epidermidis*, *Klebsiella oxytoca,* and a potentially novel strain of *Klebsilla* . The three identified bacteria are opportunistic disease-causing microorganisms. It appeared that none of these three microbes had been reported in contaminated diesel fuel or soil environments. Identification of the other two strains will require further research. Possible reasons that the strains could not be identified are that single colonies were not isolated from the samples and that high viscosity in these two samples made purifying the strains difficult.

5. Conclusions

Excess sludge was formed in the purifier of the *Tillikum* when the vessel burned the canola-based B5. The sludge sample studied contained metal (~11% ash), water (11-17%), major fractions of organic materials including 8-Octadecenoic acid methyl ester from canola biodiesel, and bacteria. The number of bacteria in the sludge attained a level of 10^8 per gram of wet sludge. Bacteria in the sludge could be grown in both anaerobic and aerobic conditions in the culture media. Galactose and glucose were detected in the aqueous solution from the purifier, suggesting the presence of viscous polysaccharides produced by the bacteria. Three bacteria of the five dominant strains were identified as

Appendix K: Sludge Characterization and Microbial Identification

Staphylococcus epidermidis, *Klebsiella oxytoca,* and a potentially novel strain of *Klebsilla*. The bacteria played a key role in the sludge formation. While microbial growth in the ferry fuel vessel tanks is one of the major causes for excessive sludge formation resulting in filter clogging, the problem of excess sludge was solved by application of biocide in the fuel during the testing period. Biocide application is strongly recommended when biodiesel blend fuels are used in marine ferry conditions.