

**Work Plan for
Washington State Ferry
2008
Biodiesel Test**

February 5th, 2008

By

**Washington State University
The University of Idaho
The Glosten Associates, Inc.
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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.

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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 |

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| | |
|------------------------|---|
| | 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°C, favored the precipitates’ formation. However, the precipitate composition is not currently clear and requires further research.

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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

Prevention measures: (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.

Corrective actions if this problem occurs again: (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

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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 be 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.

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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)* |

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| | | | |
|---------------|-------------------|-------------------|----------------|
| | 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 |

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| | | | | |
|-----------------|--------------------------|-----|---|----|
| | 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

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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.

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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 if 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

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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

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- 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.

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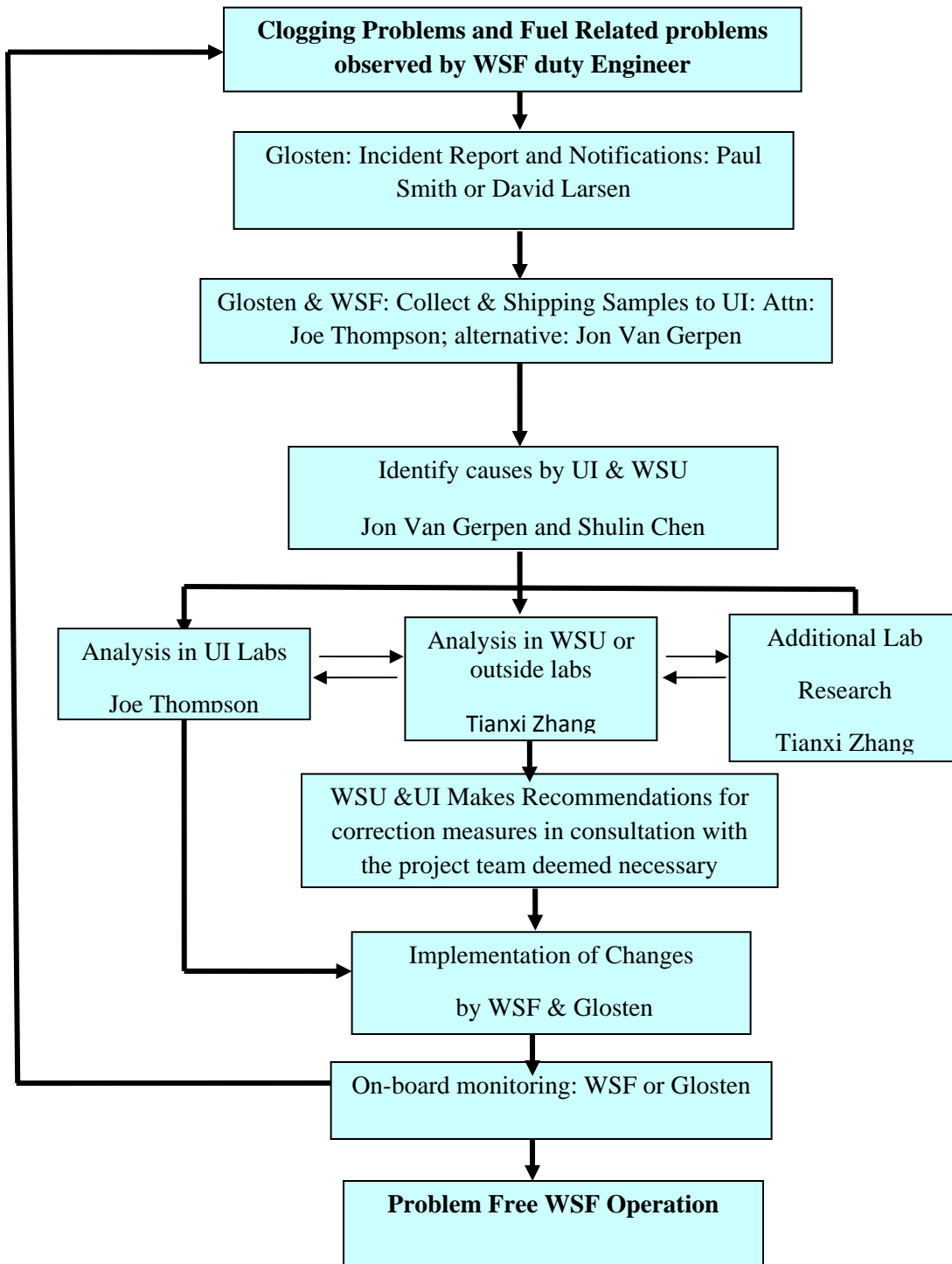


Figure 1. Flowchart for trouble-shooting with diagnosis and cause identification

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

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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

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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.

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Biodiesel (B20) shall be a blend consisting of 20% by volume (up to $\pm 1\%$ 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 |

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| | | |
|------------------------|-----------------------|-----------------|
| 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 lines and hoses are solely used for distillate fuel delivery. If storage and delivery tanks, lines, and equipment are not dedicated

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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.

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- 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

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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)

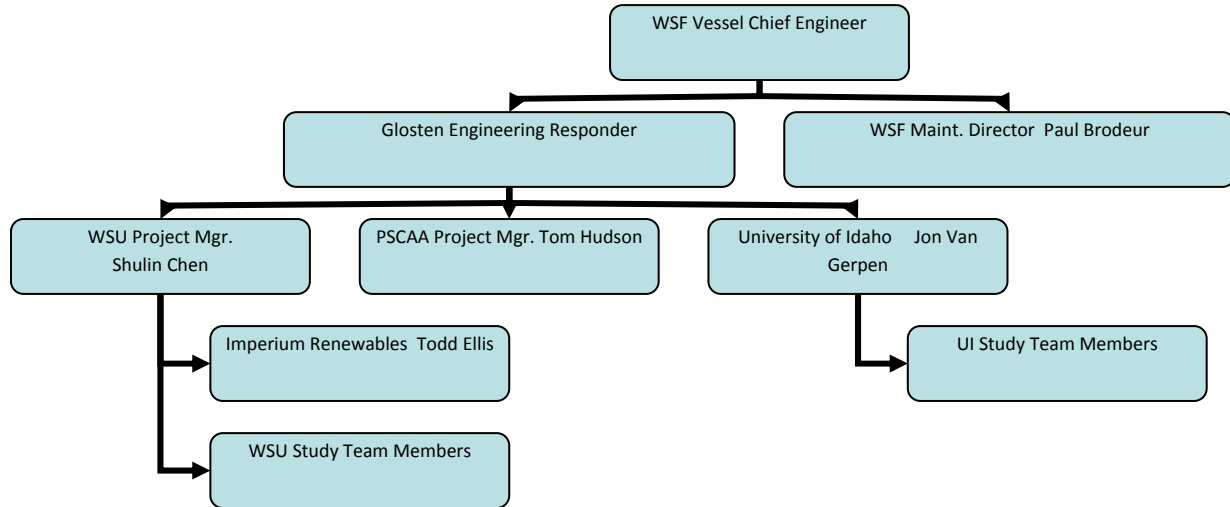
Appendix 4 -- 2008 WSF Biodiesel Trial Incident Report

| | |
|---|--|
| 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

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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 |
|---------------------|-------------------------------|
| Tom Hudson | Puget Sound Clean Air Council |
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| Tianxi Zhang | Washington State University |
| Joan Million | Washington State University |
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| Jon Van Gerpen | University of Idaho |
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