Naval Facilities Engineering Command
ENGINEERING AND EXPEDITIONARY WARFARE CENTER

# Technical Report
# TR-NAVFAC-EXWC-EV-1305
# February 2013

# Demonstration of Biodiesel in Ground Tactical Vehicles and Equipment

# Version 1
# ESTCP Project WP-200728

David Chavez

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**ESTCP Project WP-200728**

**David Chavez**
**Naval Facilities Engineering Command**

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## ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| AFB | Air Force Base |
| AFPET | Air Force Petroleum Agency |
| AFV | Alternative Fuel Vehicle |
| API | American Petroleum Institute |
| ASN I&E | Assistant Secretary of the Navy Installations and Environment |
| ASTM International | American Society for Testing and Materials |
| ATR | Attenuated Total Reflectance |
| AVGP | Armored Vehicle General Purpose |
| BHD | Bio Hydro-Fined Diesel |
| CAA | Clean Air Act |
| CE | Construction Engineering |
| CONUS | Continental United States |
| CTC | Concurrent Technologies Corporation |
| DASA | Deputy Assistant Secretary of the Army |
| DF | Diesel Fuel |
| DF-2 | Diesel Fuel grade #2 (ASTM D975 Grade 2-D) |
| DI | Deionized |
| DoD | Department of Defense |
| DOE | Department of Energy |
| DLA | Defense Logistics Agency |
| DS1 | ULDSF Grade 1 (ASTM D975 Grade 1-D S15) |
| DS2 | ULDSF Grade 2 (ASTM D975 Grade 2-D S15) |
| ECRA | Energy Conservation Reauthorization Act |
| EMA | Truck and Engine Manufacturers Association |
| EO | Executive Order |
| EPA | Environmental Protection Agency |
| EPAct | Energy Policy Act |
| ESTCP | Environmental Security Technology Certification Program |
| FTIR | Fourier Transform Infrared Spectroscopy |
| GC | Gas Chromatograph |
| HEMTT | Heavy Expanded Mobility Tactical Truck |
| HMMWV | High Mobility Multipurpose Wheeled Vehicle (aka HUMVEE) |
| ICP | Inductively Coupled Plasma |
| ICP/AES | Inductively Coupled Plasma/Atomic Emission Spectrometer |
| ICP/OES | Inductively Coupled Plasma/Optical Emission Spectrometer |
| ID | Identification |
| JG-PP | Joint Group on Pollution Prevention |
| JOAP | Joint Oil Analysis Program |
| LMTV | Light Medium Tactical Vehicle |
| LSDF | Low Sulfur Diesel Fuel |
| MCAGCC | Marine Corps Air Ground Combat Center |
| MCAS | Marine Corps Air Station |
| MCBH | Marine Corps Base Hawaii |
| MTV | Medium Tactical Vehicle |

| | |
|---|---|
| MTVR | Medium Tactical Vehicle Replacement |
| NBB | National Biodiesel Board |
| NBVC | Naval Base Ventura County |
| NDCEE | National Defense Center for Energy and Environment |
| NAVFAC ESC | Naval Facilities Engineering Service Center |
| NAVFAC EXWC | Naval Facilities Engineering and Expeditionary Warfare Center |
| NFELC | Naval Facilities Expeditionary Logistics Center |
| NREL | National Renewable Energy Laboratory |
| NSWC | Naval Surface Warfare Center |
| OEM | Original Equipment Manufacturer |
| OCONUS | Outside Continental United States |
| OSMIS | Operating and Support Management Information System |
| POC | Point of Contact |
| POL | Petroleum, Oil, Lubricant |
| POP | Period of Performance |
| PLS | Palletized Load System |
| QA/QC | Quality Assurance/Quality Control |
| RDECOM | Research, Development and Engineering Command |
| RFS | Renewable Fuel Standard |
| RPM | Revolutions per Minute |
| SERDP | Strategic Environmental Research and Development Program |
| SME | Subject Matter Expert |
| SOW | Statement of Work |
| SRG | Seabee Readiness Group |
| SwRI | Southwest Research Institute |
| TARDEC | Tank-Automotive Research, Development and Engineering Center |
| TRAM | Tractor, Rubber Tired, Articulated Steering, Multi-Purpose |
| U.S. | United States |
| USAF | United States Air Force |
| USDA | U.S. Department of Agriculture |

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## Executive Summary

The major objective of this project was to demonstrate and validate the use of B20 in tactical vehicles by addressing users concerns as stated in The Tri-Service Petroleum, Oil, and Lubricant (POL) Users Group, comprising representatives from the Army, Navy, and Air Force, March 2006 Position Statement.

Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) investigated biodiesel as usable green technology in military ground tactical vehicles. Biodiesel is a clean-burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel fuel to create a biodiesel blend and it can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (i.e., B20 is 20% biodiesel, 80% petroleum diesel fuel). The purpose of this investigation was to analyze and compare fuel samples and oil samples from vehicles using biofuels, specifically a B20 blend, against vehicles using standard petroleum diesel or JP-8 fuels, located at five military facilities across the United States (U.S.). Oil analysis data was received from U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) and fuel analysis was conducted by Concurrent Technology Corporation (CTC).

Three types of fuel samples were collected and analyzed from each location. The first type, delivery samples, was taken from any new shipment of fuel to the test location. At some locations, the initial storage tank fill was the only delivery sample taken for that location. The delivery samples received more extensive testing than the other samples in order to assess the quality of the fuel against the B20 specification. The second type of sample collected was the storage tank or nozzle sample. These samples were taken on a monthly basis from the storage tank, generally through the nozzle that was used to fill the vehicle fuel tank. The third and final type of fuel sample was the vehicle tank sample. This sample was also taken on a monthly basis, directly from the test vehicle's fuel tank. Engine oil was also sampled on a monthly basis. Engine oil analysis data included measurements according to the procedures outlined in the Joint Oil Analysis Program (JOAP) Manual. Testing results for both fuel and oil samples, and weather data from each location was loaded into a database for project team and stakeholder access and review. Each location was requested to report any unscheduled maintenance.

This report provides a brief overview of the five participating military installations including seasonal temperature variations, climate classification (if available) and the number of fuel and oil samples that were taken at each site. This report also presents the step-by-step fuel and oil sampling plan that was provided to each location to ensure that accurate and uniform sampling and sample labeling was conducted across the five installations. Additionally, fuel and oil sample laboratory analysis, charts, quality assurance/quality control (QA/QC) data, and weather data are included in the Appendices.

DoD does not currently authorize B20 use in Tactical Fleets. During this demonstration, Medium Tactical Vehicle Replacement (MTVR) or 7-Ton Trucks, High Mobility Multipurpose Wheeled Vehicles (HMMWVs), HUMVEES, Tractor, Rubber Tired, Articulated Steering, Multi-Purpose (TRAMs), and 2 of the 3 vehicles at Moody AFB (2008 Bobtail and a Refueler Truck) did not

experience maintenance breakdowns. One vehicle at Moody AFB, a 1997 Bobtail, needed its fuel tank cleaned and the fuel sending unit rebuilt and cleaned at the end of the demonstration due to fuel breakdown.

The data gathered by this demonstration validates the March 2006 Tri-Service Biodiesel Position Paper, although it has been demonstrated that under certain circumstances (higher Rancimat, high vehicle usage) vehicles running on B20 did not have vehicle maintenance issues that were different than vehicles running on JP-8. The Tri-Service POL membership and DLA Energy have also stated that increasing the oxidative requirement for biodiesel is not feasible and limiting the use of B20 to a limited number of CONUS operations is logistically impossible. Another important fact to consider is OEM will not honor warranties on engine breakdowns for vehicles running on biodiesel blends above 5%, so even if the engine breakdown cannot be directly tied to the use of B20, warranties on DoD vehicles will be voided due to use of B20.

Blanket approval for the use of B20 in all tactical vehicles would not be advised because the potential for problems over and above those typically encountered with petroleum fuels is higher with the use of biodiesel. The annual fuel savings and diverted oil based fuel only make a tiny impact on overall DoD fuel usage, and the fuel cost savings are quickly negated by a small percentage of vehicles having maintenance issues.

The maximum annual DoD fuel cost saving for switching from JP-8 to B20 is calculated to be $3,385,051 and the amount of fuel diverted from oil based to renewable is 5,207,771 gallons. The overall impact to DoD would be is less than 1% of the total use of JP-8 in DoD. Also, any cost saving derived from the difference in fuel cost between B20 and JP-8 can be quickly consumed by maintenance costs.

To reduce maintenance cost issues, a conversion from JP-8 to B20 in ground tactical fleets requires adding additional requirements to the current ASTM D7467 B20 specification to improve the fuel quality. Adding additional requirements may not be possible under the current acquisition process and would raise the cost of B20. This additional cost would probably negate any cost savings calculated using the current acquisition process. B20 should only be used in CONUS training operations that run continuously, so that B20 is not left in storage and vehicle tanks for more than one month. These additional requirements will be difficult and according to the DoD POL Users Group, non-implementable, but necessary to reduce the occurrences of maintenance issues if DoD activities decide to implement B20 in tactical fleets.

# 1.0 INTRODUCTION

## 7.1 BACKGROUND

Biodiesel is a clean-burning alternative fuel, produced from domestic, renewable resources. Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel fuel to create a biodiesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is made through the chemical process of transesterification of fats and oils from numerous sources. The process leaves behind two products – fatty acid methyl esters (the chemical name for biodiesel) and glycerin (a valuable byproduct usually sold for use in soaps, cosmetics, and other products). Biodiesel is defined as “mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats” that conform to the ASTM International D6751 biodiesel blend stock specification. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (i.e., B20 is 20% biodiesel, 80% petroleum diesel fuel). Biodiesel must be produced to strict industry specifications (ASTM D6751) in order to ensure proper performance. Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the 1990 Clean Air Act (CAA) Amendments. Biodiesel that meets ASTM D6751 and is legally registered with the Environmental Protection Agency (EPA) is a legal motor fuel for sale and distribution. Research conducted in the United States (U.S.) shows biodiesel emissions have decreased levels of all target polycyclic aromatic hydrocarbons (PAH) and nitrated PAH (nPAH) compounds, as compared to petroleum diesel fuel exhaust. PAH and nPAH compounds have been identified as potential cancer causing compounds. Targeted PAH compounds were reduced by 13 percent. Target nPAH compounds were also reduced dramatically with biodiesel fuel, with 2-nitrofluorene and 1-nitropyrene reduced by 50 percent, and the rest of the nPAH compounds reduced to trace levels. All of these reductions are due to the fact the biodiesel fuel contains no aromatic compounds.

Damage to the Nation’s petroleum infrastructure from hurricanes Katrina and Rita were major wakeup calls for sustainability of fuel production. This damage showed just how vulnerable our Nation was to even minor disruptions to petroleum production and highlighted the need to develop alternatives to petroleum for private, commercial, and military energy supplies. On 13 September 2005, the Deputy Secretary of Defense issued a memorandum requiring that Military Departments take measures that will ultimately save fuel. This requirement was driven by a Presidential Memorandum seeking to reduce both short and long-term petroleum consumption to address projected shortages due to damage to petroleum production and refining capacity caused by Hurricane Katrina. On 14 November 2005, the Assistant Secretary of the Navy (ASN I&E) issued policy guidance restating that B20 be used in all non-deployable, non-emergency, diesel vehicles. The policy also called for testing of B20 in non-deployed tactical fleet vehicles and support equipment beginning in 2007. This policy clearly articulated the ASN I&E goal of switching non-deployed tactical fleet to B20 as soon as sufficient information was available to ensure a relatively trouble free conversion. Because of the need for consistent fuels and fueling policies between services, it was appropriate to address these issues using the Environmental Security Technology Certification Program (ESTCP). The sustainable fuel concern was further highlighted by President Bush during his 2006 State of the Union address when he stated, "America is addicted to oil, which is often imported from unstable parts of the world,"…"The best way to break this addiction is through technology."

Federal agencies must also comply with E.O. 13423, which was issued by President Bush in January 2007 and revoked E.O. 13149. Under E.O. 13423, agencies are required to:

- Reduce petroleum consumption by 2% annually through fiscal year (FY) 2015 compared to their FY 2005 baseline value.
- Increase alternative fuel use by at least 10% compounded annually through FY 2015 compared to their FY 2005 baseline value.

The Energy Independence and Security Act of 2007 was established to "move the United States toward greater energy independence and security, to increase the production of clean renewable fuels, to protect consumers, to increase the efficiency of products, buildings, and vehicles, to promote research on and deploy greenhouse gas capture and storage options, and to improve the energy performance of the Federal Government, and for other purposes." Preamble, Pub. L. 110–140, December 19, 2007. Section 526, Procurement and Acquisition of Alternative Fuels, provides as follows:

> "No Federal agency shall enter into a contract for procurement of an alternative or synthetic fuel, including a fuel produced from nonconventional petroleum sources, for any mobility-related use, other than for research or testing, unless the contract specifies that the lifecycle greenhouse gas emissions associated with the production and combustion of the fuel supplied under the contract must, on an ongoing basis, be less than or equal to such emissions from the equivalent conventional fuel produced from conventional petroleum sources."

Although numerous Department of Defense (DoD) activities have implemented biodiesel-fueling programs for their non-tactical on-road diesel vehicle fleets, a number of organizations have been reluctant to implement B20 on tactical systems and stationary engines due to technical and logistical concerns. Using B20 in tactical equipment would require a change in policy. Existing policy designated a Single Fuel on the Battlefield policy for tactical vehicles. These military fuels included jet propellant fuels (JP-8/JP-5/Jet A-1). JP-8 is used both in training and tactical operations in the Continental U.S. (CONUS) and Outside CONUS (OCONUS) to ensure the military's operational readiness is secure. All of these military fuels were produced primarily from conventional petroleum resources (crude oil) and dependent on the supply of foreign oil. Although a switch to one fuel is the ultimate goal, many installations operate ground vehicles that are non-deployed assets (vehicles and equipment that only operate in CONUS) on petroleum diesel fuel, instead of JP-8.

Biodiesel was the only alternative fuel to voluntarily perform and pass EPA Tier I and Tier II testing to quantify emission characteristics and health effects. That study found that B20 (20% biodiesel blended with 80% conventional diesel fuel) reduced total hydrocarbons by up to 20%, Carbon Monoxide up to 12%, and total particulate matter up to 12%.

The Tri-Service Petroleum, Oils and Lubricants (POL) Users Group, comprising representatives from the Army, Navy, and Air Force, issued a position statement in March 2006 supporting the current prohibition against the use of B20 for tactical applications. It identified the following critical issues associated with the use of B20 in such applications:

1. Stability
2. High temperature properties
3. Low temperature properties
4. Water affinity
5. Material compatibility
6. Solvency

## 7.2 OBJECTIVE OF THE DEMONSTRATION

The major objective of this project was to demonstrate and validate the use of B20 in tactical vehicles by addressing users concerns as stated in The Tri-Service POL Users Group, March 2006 Position Statement. The group's concerns were the stability of the biodiesel, accelerated deterioration of the biodiesel during periods of storage at higher ambient temperatures, vehicle operation and gelling of the biodiesel in low-temperature environments, water affinity, and possible increased fuel contamination caused by biodiesel-dissolution of contaminants and sludge.

Subset objectives were also identified to further support the initial concerns. These additional objectives included:

- Developing and demonstrating tri-service operational parameters for using B20 in DoD ground tactical vehicles and equipment:
  - fuel quality
  - vehicle age
  - vehicle usage rate
  - maximum fuel storage limits, and
  - climate conditions
- Determining if DoDs existing fuel management infrastructure and handling procedures can satisfy user requirements
- Establishing a minimum set of fuel quality tests for use by tactical fleet end users,
- Establishing B20 operational parameters, procedures, validated technologies (e.g. testing methods), and
- Summarizing lessons learned within a fleet user's guide published for existing administrative (non-deployable, non-emergency) vehicle and equipment use.

## 7.3 REGULATORY DRIVERS

The Energy Policy Act (EPAct) of 2005 amended the Clean Air Act to establish a Renewable Fuel Standard (RFS) program. The U.S. Congress gave EPA the responsibility to coordinate with the U.S. Department of Energy (DOE), the U.S. Department of Agriculture (USDA), and stakeholders, to design and implement this first-of-its-kind program.

President Bush signed H.R. 6, the Energy Independence and Security Act of 2007, into law. The measure provided for a significant increase in the RFS. The expansion of the RFS as provided for in H.R. 6 significantly increased the use of biodiesel in the U.S.

The Energy Independence and Security Act expanded the minimum amount of biofuels that will be used in the U.S. to 36 billion gallons by 2022. Within the expanded RFS, the measure contains specific provisions that, for the first time, implemented a renewable requirement for diesel fuel. The Act also required each agency to develop fueling infrastructure. At least one renewable fuel pump must have been installed at each Federal fleet-fueling center. DoD provided an exemption for sites using less than 100,000 gallons of fuel per year.

To get a renewable component in diesel fuel, the Energy Independence and Security Act specifically required the use of biomass-based diesel fuel. Biodiesel qualifies as a biomass-based diesel fuel. The usage requirements for biomass-based diesel began at 500 million gallons per year in 2009 and will expand to 1 billion gallons in 2012. Beyond 2012, a minimum of 1 billion gallons must be used, and the amount can be set higher by the Administrator of the EPA, in consultation with the Secretary of the USDA and the Secretary of the DOE.

A renewable fuel was defined by the EPA as a motor vehicle fuel that is produced from plant or animal products or wastes, as opposed to fossil fuel sources. Renewable fuels included ethanol, biodiesel and other motor vehicle fuels made from renewable sources. The Act also required that alternative fuel procurements have lower lifecycle greenhouse gas emissions than petroleum. The program grants credit for both renewable fuels blended into conventional gasoline or diesel and those used in their neat (unblended) form as motor vehicle fuel.

# 2.0 TECHNOLOGY DESCRIPTION

## 2.1 TECHNOLOGY OVERVIEW

Biodiesel production is a mature technology with broad commercial use. Biodiesel can be made from a variety of animal or plant sources. For further details on biodiesel production methodologies reference the National Renewable Energy Laboratory (NREL) publication NREL/SR-510-36244 “Biodiesel Production Technology”.

ASTM International is a consensus based-standards group comprised of engine and fuel injection equipment companies, fuel producers, fuel users, Government representatives (both Federal and State), and other groups. Their standards are recognized in the United States by most government entities, including states, charged with the responsibility of ensuring fuel quality. The specification for biodiesel (B100) is ASTM D6751. This specification is intended to ensure the quality of biodiesel to be used as a blend stock with diesel fuel at 20% and lower blend levels. Any biodiesel used in the United States for blending should meet ASTM D6751 requirements. ASTM developed a standard specification for B6 to B20 biodiesel blends, ASTM D7467 Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20).

The Truck and Engine Manufacturers Association (EMA) has developed a test specification for biodiesel blends up to B20. An important aspect of the EMA specification is that it contains minimum standards for fuel stability. The OEM specification for biodiesel blends is more stringent than ASTM.

B20 was mandated for use in administrative diesel vehicles (non-deployable non-emergency) that represent a small percentage of the vehicles used by the DoD in CONUS. Biodiesel blend use is common throughout the United States and throughout the world.

B20 blends have a recommended storage life of 6 months maximum. The actual useful life of a biodiesel blend is dependent upon the fuel quality and storage tank management. The storage life of the biodiesel blends is rarely a factor in commercial use. Commercial biodiesel blends are typically consumed quickly, rarely allowing the fuel to remain in storage longer than a month or two. Expended fuel is typically restocked within a week. Though the use of biodiesel blend fuels is common throughout the U.S., few applications are similar to military operations. For example, military training operations utilize fuel in an intermittent fashion, unlike the more steady use rate for non-military users. Military use rates are also dependent upon the scope of the training operation.

Figure 1 shows the path that biodiesel takes from B100 producer to end user. The B100 is usually tested by the producer to confirm specification compliance. The blender may also perform minimal testing to confirm the quality of the B100. From the blenders’ facility, the blend is usually trucked to the installation storage tank before it is delivered to the vehicle.

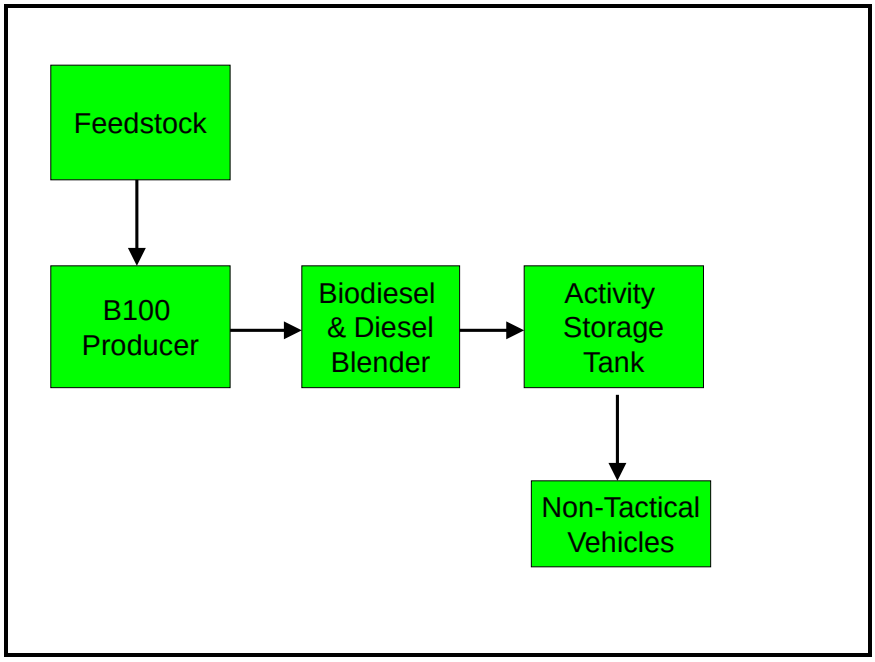


**Figure 1.** Typical Biodiesel Production, Delivery, and Use Chain

A 1995 Biodiesel Fuel Evaluation for U.S. Army Tactical Wheeled Vehicles compared vehicle system performance for vehicles operating with an 80/20 percent JP-8/Biodiesel fuel blend instead of neat (or 100%) JP-8 fuel. The vehicles also operated on Diesel Fuel grade #2 (DF-2). The results of the evaluation were mixed. Vehicles generally operated equally well during acceleration and pull-bar tests. During the endurance testing some vehicle engines were running poorly shortly after the biodiesel blend was introduced into the fuel system. Plugged fuel filters were the cause of incidents. The report concluded that increased solvency of the biodiesel blend dissolved dirt deposits left behind from when the vehicles were running on DF-2. The suspended dirt became trapped in the filters, restricting fuel flow, and making the engines run inadequately. After changing the fuel filters, either as a corrective or preventive measure, the engines ran normally.

A comprehensive vehicle study examining the benefits of using a 20% soy biodiesel blend (B20) in a commercial, over-the-road trucking company is the “2 Million Mile Haul”. The study had a goal to demonstrate that a biodiesel blend can be successfully used year-round, even during winter driving conditions. The study was sponsored by the Soy Iowa Central Community College and Decker Truck Line, Inc. They have collaborated together with Renewable Energy Group, Caterpillar Engine Company, the Iowa Soybean Association, the National Biodiesel Board (NBB), and the USDA. The preliminary result of the study found that B20 can be used effectively year round, although fuel filter plugging did increase in the winter, between October 2006 and April 2007.

A NREL 2006 study, “100,000 Mile Evaluation of Transit Buses Operated on Biodiesel Blends (B20)” evaluated the emissions, fuel economy, and maintenance of five 40-foot transit buses operated on B20, compared to four buses operated on petroleum diesel fuel. In the 100,000-mile

evaluation of transit buses operated on B20, the following operational differences were found related:

- The fuel economy for both petroleum diesel fuel and B20 groups was 4.41 mpg based on in-use fleet data. An approximately 2% reduction in fuel economy for B20 was measured in laboratory emission testing.

- Total maintenance costs per mile were $0.54 for the diesel group and $0.51 for the B20 group, and maintenance costs specific to the engine and fuel systems were $0.05 and $0.07 per mile, respectively. Because of high variability in maintenance costs between vehicles, the engine and fuel system maintenance costs for the two groups were not significantly different.

- Miles between road calls averaged 3,197 for the diesel group and 3,632 for the B20 group. There was no evidence in the data to suggest this difference is related to fuel use.

- Fuel filter plugging on the B20 buses caused road calls, and required extra filter replacements in the B20 group. Although the additional maintenance cost was small, adding only $1,054.81 to the B20 group or $0.002 per mile, the events were significant to the transit district because of resulting disruptions to normal bus service. Fuel filter plugging may have been caused by the presence of high levels of plant sterols in the B20 or other fuel quality issues.

- Measurement of biodiesel blend level showed erratic biodiesel content for delivery load samples. Vehicle samples, however, were consistently at or near B20 indicating complete blending had occurred during delivery and offloading of the fuel.

- Oil analysis results indicated no additional metal accumulation due to wear (wear metals) from the use of B20, with similar rates of decay, oxidation, fuel dilution, and viscosity. Soot levels in the lubricant were significantly lower for the B20 vehicles.

- Laboratory chassis testing on the City-Suburban Heavy-Vehicle Cycle using the in-use fuels found that B20 reduced emissions of all regulated pollutants and caused a small fuel economy decrease.

A 1995 study, “An Alternative Fuel For Urban Buses - Biodiesel Blends”, conducted by NREL, the University of West Virginia Department of Energy, and the University of Missouri, enabled transit operators to conduct a real-world comparison of B20 and low sulfur diesel fuel (LSDF; sulfur level is less than 500 ppm by mass). Performance and operational data were collected from urban mass transit buses at Bi-State Development Agency in St. Louis, Missouri. The report studied the real-world impact of a biodiesel blend on maintenance, reliability, cost, fuel economy and safety compared to LSDF. The study concluded that the buses experienced small but observable differences in fuel economy and maintenance costs. Emergency road calls were few in number for both B20 and diesel fuel control buses. An analysis of the engine lubricating oil indicated that the wear metals normally found in the B20 fueled buses were similar to the diesel control buses.

Biodiesel is the first and only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the U.S. EPA under the CAA Section 211(b). These programs include the most stringent emissions testing protocols ever required by EPA for certification of fuels or fuel additives. The data collected under these programs are the most thorough inventory of the environmental and human health effects attributes that current technology will allow.

## 2.2 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

B20 remains one of the few alternative fuels that can be implemented into DoD CONUS operations with little or no cost increases related to infrastructure changes and fuel cost, since the mandate to use B20 in non-tactical fleets has been established, most DoD facilities have access to the fuel. However, additional handling concerns for tactical training operations that often use tanker trucks, make the implementation for tactical fleets difficult and would increase off-road training costs. The ability to use B20 in selected tactical vehicles and equipment would improve overall fuel supply security, reduce greenhouse gas and regulated air emissions, and potentially reduce long-term fuel costs. Most tactical fleets use JP-8, which cost $0.11 per gallon more than B20. Petroleum diesel costs the same as biodiesel. Worldwide, DoD consumed 26 million barrels of JP-8 petroleum in 2010. Implementation of B20 into CONUS training operations would be a step towards developing an environmentally sustainable fueling option for tactical vehicles. Figure lists the fuel prices for petroleum diesel, B20, and JP-8 for FY11 and FY12.

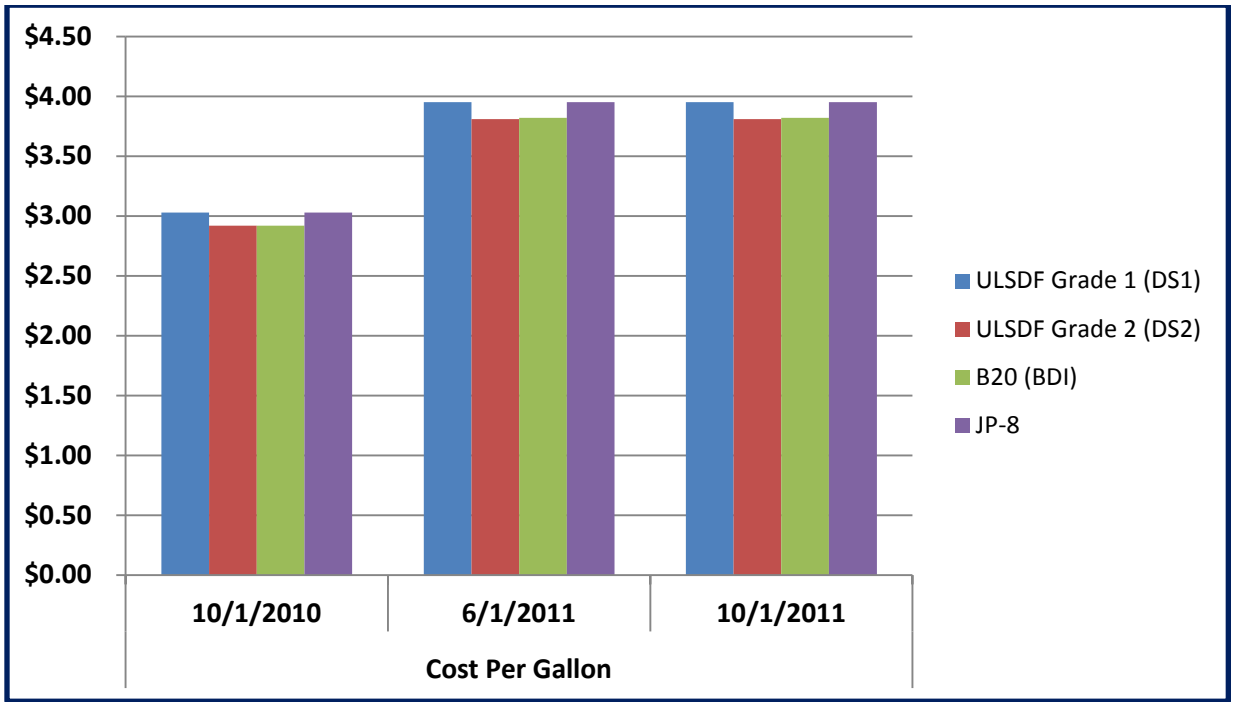


**Figure 2. Fuel Price per Gallon over time**

The cost of B20 is highly dependent on the cost of DS2, since DS2 is 80% of the blend. Any cost savings garnered by switching from JP-8 to B20, can also be achieved by switching from JP-8 to DS2, without the risk presented by using B20.

B20 has combustion properties very similar to diesel and can generally be used in existing fuel dispensing systems with little or no additional modifications, although it is highly recommended that tanks be cleaned prior to conversion to B20. The use of B20 in cold weather requires additional considerations B20 typically has poorer low-temperature properties compared to petroleum diesel fuel. Under extreme cold conditions, B20 is normally not used.

The differences between B100 and B20 are reflected in the stability requirements in the respective fuel specifications. B100 must have a minimum induction period of 3 hours for oxidation stability using the Rancimat test. B6 to B20 blends must have a minimum induction period of 6 hours per ASTM D7467. The oxidation stability of biodiesel usually does not reach the level of stability of petroleum fuel. Also, B100 oxidation stability varies with the feedstock used to produce it. Highly saturated feedstocks, such as palm or tallow, tend to be more oxidatively stable than less saturated feedstocks, such as soy. It can be argued that increased use of antioxidants in B100 accounts for most of the increased stability; although, some of the increase is undoubtedly due to increase use of feedstocks with higher inherent oxidation stability.

The biodiesel industry has grown exponentially in recent years. The conventional feedstocks are somewhat limited. The availability of acceptable feedstocks may ultimately limit future growth. Research to identify new feedstocks is increasing. As discussed earlier, the specific animal or plant fats used to manufacture B100 may significantly alter its characteristics and usability from region to region. New feedstock sources such as algae are promising, but the existing technology to produce biodiesel is limited to the most economically available feedstock in any specific region of the world.

Since the introduction of the $1-per-gallon biodiesel tax credit in 2005, U.S. biodiesel production climbed steadily until 2010, when Congress allowed it to lapse temporarily as the health care debate overshadowed other issues. Production immediately plummeted from a record of about 700 million gallons in 2008 to about 315 million gallons in 2010.

The industry bounced back quickly in 2011, after Congress reinstated the tax incentive in December 2010 and the EPA included biodiesel as an Advanced Biofuel in its new Renewable Fuels Program (RFS2), requiring minimum volumes of biodiesel use in U.S. diesel fuels. In the first six months of 2011, U.S. biodiesel production exceeded 375 million gallons.

# 3.0 PERFORMANCE OBJECTIVES

This project was designed to address the Tri-Service POL Users Group concerns with the use of B20 in tactical vehicles and equipment including: 1) fuel stability, 2) high temperature properties, 3) low temperature properties, 4) water affinity, 5) material compatibility, and 6) solvency. The project has attempted to address these concerns by running field tests that can possibly lead to the development of specific parameters (fuel quality, fuel storage limits, vehicle usage and load, climate conditions, fuel handling, and fuel storage conditions) for using B20 in tactical vehicles. The B20 used for this demonstration was no different from the B20 currently used in DoD military installations for non-tactical vehicles and equipment. This B20 represented the fuel presently being purchased for the DoD: it may have included B20 from BQ-9000 certified facilities, B20 which is state certified, or B20 from states where no oversight exists. Fuel quality is a key factor to the successful use of B20 in tactical vehicles. To ensure quality, the fuel used was tested against ASTM D7467 and must have met B20 requirements for the duration of the demonstration as defined in Section 5.3. Joint Oil Analysis Program (JOAP) tests and specifications for used engine oil were also performed to determine engine component wear and any impact caused by using B20.

The primary performance criteria that were used to demonstrate success of this project are listed in **Error! Reference source not found.**, Performance Objectives.

## 3.1 PERFORMANCE OBJECTIVES

**Table 1. Performance Criteria**

| Type of Performance Objective | Primary Performance Criteria | Expected Performance (Metric) | Actual Performance Objective Met? |
|---|---|---|---|
| Quantitative | | | |
| | 1. Fuel Stability | Storage time meets or exceeds 6 Month storage limit for B20 | Mixed (See Section 6.0) |
| | 2. High Temperature Properties | Storage time meets or exceeds 6 Month storage limit for B20 in hot, dry climate | Mixed |
| | 3. Low Temperature Properties | Storage time meets or exceeds 6 Month storage limit for B20 in cold climate | Yes* |
| | 4. Water Affinity | Storage time meets or exceeds 6 Month storage limit for B20 in damp environment (climate and operation) | Mixed (See Section 6.0) |
| | 5. Acid Number | Meets or exceeds 6 Month storage limit | Yes |

| Type of Performance Objective | Primary Performance Criteria | Expected Performance (Metric) | Actual Performance Objective Met? |
|---|---|---|---|
| | | for B20 | |
| | 6. Kinematic Viscosity | Meets or exceeds 6 Month storage limit for B20 | Yes |
| Qualitative | 7. Material Compatibility | No material incompatibility experienced | Mixed (See Section 6.0, JOAP did not predict or show 1997 Bobtail fuel sending unit incompatibility) |
| | 8. Solvency | When B20 is stable (established in quantitative tests) will pass visual appearance and sediment tests | Mixed (See Section 6.0) |

**B20 used at cold site installation was automatically switched to B10 in the winter months, however only one test vehicle received B10 fuel. Switching to B10 was done outside approved procurement through DLA and obtained no energy credits. Low temperature properties of Biodiesel improved during the ESTCP investigation by the addition of the Cold Soak Filtration Test to the ASTM International D6751 for B100 specification.*

# 4.0 SITE DESCRIPTION

This section of the report describes each of the participating locations and how the sampling was conducted. Sections 4.1.1 through 4.1.5 provide a brief background of each location, the operational groups located on site, the vehicles that participated in the program, and the general climate at each location.

## 4.1 TEST FACILITIES

Moody Air Force Base (AFB), Marine Corps Air Ground Combat Center (MCAGCC) 29 Palms, Naval Base Ventura County (NBVC) Port Hueneme, Naval Surface Warfare Center (NSWC) Crane, and Marine Corps Base Hawaii (MCBH) Kaneohe Bay were selected to participate in this task due to the varying vehicle usage, climate conditions and the potential effects of running bio-based fuels in tactical ground vehicles. Each site participated in this program for a 6 to12 month Period of Performance (POP) during which fuel and oil samples were drawn monthly and shipped to the National Defense Center for Energy and Environment (NDCEE) and Tank Automotive Research and Development Engineering Center (TARDEC), respectively, for analysis. Fuel samples were taken from test vehicles and fuel storage tanks. Oil samples were taken from both the test and control vehicles.

Since there is a mandate to use B20 in the administrative fleets at DoD installations, many CONUS installations have installed B20 pumps at existing fuel dispensing facilities. At NSWC Crane, B20 distribution is available, but a system to deliver JP-8 was set up to deliver JP-8 to control vehicles. No additional cost was incurred by the project for the installation of the B20 pumps.

The exact type of B20 feedstock varied from site to site. The project used available B20 that was already being purchased to run administrative fleets. The exception to this rule was MCB Hawaii, which did not have a B20 tank for administrative fleet vehicles. A temporary 400 gallon tote dispenser was set up for the duration of the test at this site. The feedstock for the NSWC Crane was soybean oil. The feedstock for the NBVC vehicles could not be determined as several biodiesel providers contributed to the B20 blend. The feedstock for the 29 Palms vehicles was primarily soybean oil, but the biodiesel producer also stated that used vegetable oil was also used occasionally. Soybean oil was the feedstock of the primary biodiesel producer for the B20 used at Moody AFB, but AFPA also reported some spot buys that may have included peanut oil as a feedstock. The biodiesel used at MCB Hawaii was produced using waste vegetable oil as the feedstock.

### 4.1.1 MOODY AIR FORCE BASE

Moody AFB is a U.S. Air Force (USAF) installation located in southern Georgia. Moody AFB is home to the 23$^{rd}$ Wing and the 93$^{rd}$ Air Ground Operations Wing which provide worldwide air support, perform combat search and rescue, and train forces to support the war on terrorism. Moody AFB experiences warm summer months (average high of 93°F (34°C)) and mild winters (average low of 38°F (3°C)). For this task, B20 fuel samples were taken from 3 vehicles of different makes, years, and mileage and from a fuel dispenser (tank or nozzle sample) located on

base. A 2008 Bobtail, a 1997 Bobtail, and an R-11 Refueler were the vehicles selected for this task.

### 4.1.2 U.S. MARINE CORPS 29 PALMS

As the world's largest Marine Corps Base, MCAGCC 29 Palms, California, is the premier training facility for Marine operations worldwide. It is essential for maintaining high levels of readiness within the U.S. Marine Corps. Each year, roughly 50,000 marines participate in the base's training exercise programs. 29 Palms is classified as having an arid, upland desert climate with high summer month temperatures (summer highs of 120°F (49°C)) and freezing winter temperature (as low as 15°F (-9°C)). B20 fuel samples were drawn from a High Mobility Multipurpose Wheeled Vehicle (HMMWV) and a B20 fuel storage tank, located on base, servicing commercial vehicles.

### 4.1.3 NBVC PORT HUENEME

Naval Base Ventura County (NBVC) is a U.S. Naval installation located in Southern California. As the only deepwater harbor between Los Angeles and San Francisco, NBVC Port Hueneme supports the current DoD logistics pre-positioning strategy, storage and deployment of heavy construction equipment. Port Hueneme experiences mild summer and winter conditions with temperatures in the 70s and mid 40s (°F respectively). For this task, Port Hueneme personnel drew B20 fuel samples from a Medium Tactical Vehicle Replacement (MTVR) and a B20 fuel storage tank. Oil samples from a MTVR running on JP-8 were used as a control variable when testing oil samples from the MTVR running on B20.

### 4.1.4 NSWC CRANE

Located in Crane, Indiana, Naval Surface Warfare Center (NSWC) Crane is a shore command of the U.S. Navy under the Naval Sea Systems Command. With employees deployed around the world, Crane specializes in full lifecycle support of Special Missions, Strategic Missions, and Electronic Warfare/Information Operations. Crane, Indiana experiences hot summers (average July of 88°F (31°C)) with several months at freezing temperature or below (average January low of 21°F (-6°C)). NSWC Crane employees took fuel samples from two Armored Vehicle General Purpose (AVGP) vehicles running on B20, and one B20 fuel storage tank. Oil samples drawn from two AVGP vehicles running on JP-8 were used as control vehicles against the two vehicles running on B20.

### 4.1.5 MCBH KANEOHE BAY

Marine Corps Base Hawaii (MCBH) Kaneohe Bay is located approximately 12 miles northeast of Honolulu and is home to the U.S. Marine Corps Pacific, 3rd Marine Regiment, 1st Radio Battalion, and the Marine Corps Air Facility. Kaneohe Bay experiences relatively little fluctuation in temperatures with summers averaging 80 to 85°F (27 to 29°C) and winters ranging from 70 to 76°F (21 to 24°C) . B20 fuel samples were analyzed from one Tractor, Rubber Tired, Articulated Steering, Multi-Purpose (TRAM), one HMMWV, and one fuel storage tank. Oil samples were analyzed from one TRAM and HMMWV running on B20 and one TRAM and HMMWV running on JP-8.

## 4.2 WEATHER DATA

Monthly weather data was gathered through the National Oceanic and Atmospheric Administration's National Climatic Data Center Quality Controlled Local Climatological Data database. Weather stations with available monthly data were selected by geographical proximity to the sampling site installations. Weather stations include: Palm Springs International Airport (29 Palms), Kaneohe Marine Corp Air Station (MCAS) (MCBH Kaneohe Bay), Valdosta Regional Airport (Moody AFB), Monroe County Airport (NSWC Crane), and Oxnard Airport (NBVC Port Hueneme). Data collected during the sampling period from May 2009 until December 2010 included, but is not limited to, high and low temperatures; average wet bulb temperature, average dew point, precipitation, and pressure. Please see Appendix E, Weather Data, for all data collected.

## 4.3 SITE-RELATED PERMITS AND REGULATIONS

Additional site-related permits and regulations were not required at any test site. B20 was already available for GSA white fleet vehicles, so not additional requirements were necessary to use the fuel in tactical vehicles.

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# 5.0 TEST DESIGN

Tactical vehicles in military training operations do not run consistently over a long time period, as many commercial fleets do. Much of the data previously collected and analyzed has been on fleet vehicles that have a consistent, steady mileage output. Prior tests on B20-powered fleet vehicles have provided positive results, with statistically insignificant maintenance and operational cost differences compared to vehicles using petroleum diesel fuel**Error! Bookmark ot defined.**, **Error! Bookmark not defined.**. These results have been compared to the results of this demonstration to determine how important vehicle usage rates are.

Maintenance shop personnel use work order sheets to record maintenance data from vehicles using petroleum diesel fuel. An installation may have several maintenance shops that are responsible for different vehicles. Installations also have motor pools, where vehicles are stored and inspected for use. It is not common practice for maintenance and vehicle records to be computerized, they generally are hand written and stored as paper files.

## 5.1 CONCEPTUAL TEST DESIGN

As stated earlier in the plan, several studies have shown an improvement in engine emissions for B20-powered vehicles compared to vehicles powered by petroleum diesel fuel**Error! Bookmark ot defined.**. This demonstration has helped to determine a set of parameters to increase the overall use of B20 in DoD CONUS installations. By collecting data to help set guidelines and measure costs for implementation, installations will be better able to determine whether their operations are suitable for B20 use. Additionally, administrative fleets will be able to expand B20 use and reduce the risk of vehicles being adversely affected by poor quality B20.

## 5.2 SAMPLING PROTOCOL

### 5.2.1 OIL SAMPLING PROCEDURE

A sample of the fresh engine oil was taken and sent to TARDEC for analysis. *CTC* procured 4-ounce plastic oil sample bottles and had them delivered to each sampling location. New samples were taken from the engines of both the control vehicle(s) and test vehicle(s) on a monthly basis and also sent to TARDEC for analysis. Each sample was labeled with: the location of the vehicle, date the sample was taken, supplier name (where applicable), name of the individual who took the sample and the vehicle identification (ID).

### 5.2.2 FUEL SAMPLING PROCEDURE

A sample of the B100 biodiesel that was used for blending with diesel to formulate the B20 used at each location was sent to TARDEC when a new shipment of B20 was received during the study period. A sample of the B20 was also taken from each location at the beginning of the study and if a new shipment was received. These samples were referred to as delivery samples and received more extensive testing in order to compare the as-delivered B20 to ASTM D7467. These samples were sent for analysis. One-gallon tight head, 24-gauge grey epoxy phenolic lined steel cans, with ¾” bung opening and a handle (part #HMS-60390) were procured from All-Pak and delivered to each of the test sites. The sample containers were determined to be clean and

dry before use, and a volume of the sample was used to rinse the container to remove any previous contamination.

Storage tank samples were taken on a monthly basis, and whenever a new delivery of B20 was received. The sample was taken from a service hose because the storage tanks/trucks had no manhole or sampling hatch/valve. In order to get a representative sample, the fuel was allowed to flow until about two times the length of the sample apparatus was flushed, and then the one gallon can was filled and immediately capped.

The test vehicle was filled with the B20 fuel and samples were taken by removing the plug in the fuel tank and allowing the fuel to flow into the one gallon sample can. Where applicable, a nozzle or dispenser sample was also taken at the time of fueling.

All samples were labeled with: the location of the vehicle, date the sample was taken, the quantity and type of fuel received, supplier name (where applicable), name of the individual who took the sample, the vehicle ID, and the sampling point (nozzle, dispenser, etc.).

## 5.3 ANALYSIS OF FUEL SAMPLE

Table 2 and Table 3 list the testing methods used to analyze the B20 delivery samples. Much of the testing and acceptance criteria listed in the table are derived from a compilation of testing methods listed in the B20 specification (A-A-59693) and the B6-B20 blend specification (ASTM D7467). Any deviations from the standard test method or comments required are also listed in Table 5.

**Table 2. Delivery Sample Testing Methods**

| Test Name | Test Method | Acceptance Criteria | Deviations/Comments |
|---|---|---|---|
| Appearance | ASTM D4176 | Clear, bright, visually free from un-dissolved water, sediment, and suspended matter | Temperature was also measured to ensure it was near ambient prior to testing. |
| Acid Number | ASTM D664 | 0.2 mg KOH/g, max | NA |
| Viscosity at 40°C | ASTM D445 | 1.9 – 4.1 $mm^2$/sec | NA |
| Flash Point | ASTM D93 | 52°C, min | NA |
| Low Temperature Properties | ASTM D2500 (Cloud Point) | Report | Dry ice was used to cool the samples, with temperature recorded using a calibrated digital thermometer that measured to 0.1°C. |
| Sulfur Content | ASTM D2622 | 0.0015 mass %, max | NA |
| Distillation Temp, 90% Evaporated | ASTM D86 | 343°C, max | NA |
| Ramsbottom Carbon Residue | ASTM D524 | 0.35 mass %, max | NA |

| Test Name | Test Method | Acceptance Criteria | Deviations/Comments |
|---|---|---|---|
| (10% bottoms) | | | |
| Cetane Index | ASTM D976 | 40, min | NA |
| Ash content | ASTM D482 | 0.01 mass %, max | An open coil burner was used in place of the open flame burner and the samples were heated to the point of smoke evolution, not flames, to avoid splattering of the sample. |
| Water & sediment | ASTM D2709 | 0.05 vol %, max | NA |
| Copper strip corrosion | ASTM D130 | No. 3, max | NA |
| API Gravity | ASTM D1298 | Report | NA |
| Biodiesel content | ASTM D7371 | 20 ± 1% (by volume) | NA |
| Oxidation stability, Rancimat | EN 14112 Modified (equivalent to EN 15751, which was not yet a published method when the test plan for this project was written) | 6 hours, min | NA |
| Density at 15°C | ASTM D4052 | Report (kg/L) | NA |
| Aromaticity | ASTM D1319 | 35 vol%, max | NA |
| Color | ASTM D1500 | Rating 3, max | NA |
| Particulate Contamination | ASTM D6217 | 10 mg/L, max | NA |
| Stability | Modified ASTM D2274 (equivalent to ASTM D7462, which was not yet a published method when the test plan for this project was written) | 1. Total insolubles, mg/100 mL<br>2. Iso-octane insolubles, mg/100 mL<br>3. Acid number, mg KOH/g | Two Whatman glass microfiber filters were used in place of the cellulose ester membrane filters, which conforms to the ASTM D7462 oxidative stability test. Also, three washes with 50 mL of trisolvent each were used for total insolubles instead of 75 mL. |
| Trace Metals (Ca, Mg, Na, K) | EN14538 | Not detectable | NA |
| Total water content | ASTM D6304 | Report (mg/kg) | A pyridine-free reagent, |

| Test Name | Test Method | Acceptance Criteria | Deviations/Comments |
|---|---|---|---|
| | | | Composite 5, was used with an autotitrator, given the health concerns. The reagent was standardized and a known standard was evaluated prior to conducting sample titrations. |

Table 6 lists the testing that was performed on the monthly storage tank and vehicle samples. These testing methods and acceptance criteria are an abbreviated list of the testing conducted on the delivery samples, focusing on key physical properties of the fuels that could be affected by climate, storage conditions, and length of storage time.

**Table 3. Testing for Monthly Storage and Vehicle Tank Samples**

| Test Name | Test Method | Acceptance Criteria |
|---|---|---|
| Appearance | ASTM D4176 | Clear, bright, visually free from un-dissolved water, sediment, and suspended matter |
| Acid Number | ASTM D664 | 0.2 mg KOH/g, max |
| Viscosity at 40°C | ASTM D445 | 1.9 – 4.1 $mm^2$/sec |
| Water & sediment | ASTM D2709 | 0.05 vol %, max |
| Total water content | ASTM D6304 | Report (mg/kg) |
| Color | ASTM D1500 | 3, max |
| Particulate Contamination | ASTM D6217 | 10 mg/L, max |
| Oxidation Stability, Rancimat | Modified EN14112 (Equivalent to EN 15751, which was not yet a published method when the test plan for this project was written) | 6 hours, min |
| Stability | Modified ASTM D2274 (equivalent to ASTM D7462, which was not yet a published method when the test plan for this project was written) | 1. Total insolubles, mg/100 mL<br>2. Iso-octane insolubles, mg/100 mL<br>3. Acid number, mg KOH/g |

The testing procedures use to analyze the fuel samples are located in Appendix B.

## 5.4 ANALYSIS OF OIL SAMPLES

Table 4 lists oil testing methods used to analyze the oil samples from the test and control vehicles at each location. The oil testing methods are based on the methodology contained in the JOAP Manual. The testing procedures utilized by TARDEC to analyze the oil samples are located in Appendix B.

**Table 4. Oil Testing Methods**

| Test Name | Test Methods |
|---|---|
| Wear Metals | ASTM D5185 |
| Total Acid Number | ASTM D664 |
| Total Base Number | ASTM D4739 |
| Kinematic Viscosity at 40°C and 100°C | ASTM D445 |
| Viscosity Index | ASTM D2270 |
| Soot Content | ASTM D7686 |
| Percent Fuel Dilution | ASTM D3524 |
| Water Content | ASTM D6304, Procedure C |

## 5.5 OPERATIONAL TESTING

### 5.5.1 VEHICLE PREPARATION

Across each base, a variety of vehicles were used to conduct the study. At least one vehicle on each base was used as the control, using either JP-8 or diesel as the fuel. Also, there was at least one vehicle identified at each location as the test vehicle, running on B20. Each of the vehicles used for this program, both control and test, had maintenance performed prior to initiating the testing. This maintenance included replacing both the oil and fuel filters and changing the engine oil. At NBVC, each vehicle was also fitted with a new fuel pump, fuel pump gasket, fuel injectors, fuel injector o-rings, and fuel lines. These components were to be examined at the end of the study for signs of degradation, scorching, scarring, and deposits.

## 5.6 VEHICLE USAGE

Both control and test vehicles were run at each location, in varying time increments on a monthly basis, as outlined in Table 5. The amount of hours of operation for each vehicle is listed in Appendix F. Vehicle operators were also asked to record observations regarding the negative performance of each vehicle such as engine knocks, tailpipe emissions, stalls, or slow starts.

**Table 5. Vehicle Usage Plan by Base Location**

| Military Base | Vehicle usage |
|---|---|
| NSWC Crane | One test and control Armored Vehicle General Purpose (AVGP) vehicle run for four hours per month, One test and control Armored Vehicle General Purpose (AVGP) vehicle run for 15 minutes per month |
| NBVC Port Hueneme | One test and control Medium Tactical Vehicle Replacement (MTVR, or 7-ton Truck) vehicle run according to the regular Construction Engineering (CE) training schedule |
| Moody AFB | One test and control for two Bobtail trucks and one Refueler truck vehicle run on regular operations schedule |
| 29 Palms | One test and control High Mobility Multipurpose Wheeled Vehicle (HMMWV, aka HUMVEE) vehicle run one day every 4 weeks |
| MCBH Kaneohe Bay | One test and control vehicle (TRAM) run on regular operations schedule, and one test and control vehicle (HMMWV) run on regular operations schedule |

# 6.0 PERFORMANCE ASSESSMENT

## 6.1 B20 DATA

The analytical methods used to analyze the quality of the fuel were derived from CID A-A-59693 (Commercial Item Description for Diesel Fuel, Biodiesel [B20] Blend), ASTM D6751, and ASTM D7467. The biodiesel blend samples were analyzed for storage stability and quality on a monthly basis using the test methods outlined in Section 5.3 of this report. If there were any new deliveries of B20 or changes to the feedstock by the manufacturer, additional samples were taken and a more in depth analysis was performed. These test methods are also outlined in Section 5.3.

Individual fuel sampling kits were prepared, distributed, collected, and tracked for each demonstration site for collecting the requisite fuel specimens for analysis. Samples were sent via pre-addressed sampling packages to the laboratory for testing as outlined in Tables 2 and 3. A laboratory analysis report was provided after analysis of each batch of samples and was recorded in a collective fuel results spreadsheet, corresponding graphs, and a database. Figure 3 shows a portion of Moody AFB fuel analysis as completed by the laboratory.

It should be noted that no test limits have been established for fuel in vehicle tanks. The methods used should not be construed as a pass/fail test but rather should be used for comparison.

| Test Name | Test Method | Acceptance Criteria | Sample Name | | |
|---|---|---|---|---|---|
| | | | Moody AFB; Sampled week of 9/14/09 | Moody AFB Vehicle Sample - #08C00265, 243 hours; Sampled 10/7/09 | Moody AFB Vehicle Sample - #05L00156, 335 hours; Sampled 10/7/09 |
| CTC Lab Sample ID | | | 09-04782-C | 09-5075-C | 09-5076-C |
| Appearance | ASTM D4176 | Report | Fail - haze rating = 2 | Clear & bright; haze rating = 1 | Clear & bright; haze rating = 1 |
| Acid Number | ASTM D664 | 0.3 mg KOH/g, max | 0.102 mg KOH/g | 0.063 mg KOH/g | 0.098 mg KOH/g |
| Viscosity at 40°C | ASTM D445 | 1.9-4.1 $mm^2/sec$ | 2.92 $mm^2/sec$ | 2.93 $mm^2/sec$ | 2.91 $mm^2/sec$ |
| Water and Sediment | ASTM D2709 | 0.05%, max | 0.05 | <0.005 | 0.005 |
| Total Water Content | ASTM E1064 | Report | 0.02% | 0.02% | 0.02% |
| Color | ASTM D1500 | L3.0, max | L0.5 | L0.5 | L1.0 |
| Particulate Contamination | ASTM D6217 | 10 mg/L, max | 12.9 mg/L | 1.8 mg/L | 2.9 mg/L |
| Oxidation Stability - Rancimat | EN14112 | 6 hours, max | 5.68 hours | 5.51 hours | 5.95 hours |
| Oxidation Stability | modified ASTM D2274 | Report | | | |
| Total Insolubles | | | 1.0 mg/100mL | 2.26 mg/100mL | 0.286 mg/100mL |
| Iso-Octane Insolubles | | | 0.57 mg/100 mL | 1.26 mg/100 mL | 0.143 mg/100 mL |
| Total Acid Number | | | 0.36 mg KOH/g | 0.128 mg KOH/g | 0.127 mg KOH/g |

**Figure 3. Example Fuel Data Set from Moody AFB**

Please see Appendix C, Biodiesel Fuel Data, for all raw fuel testing results. The following sections summarize, in chart format , the monthly storage tank and vehicle tank test results from each location. Since Moody AFB was the one site to have significant fuel break down in one vehicle, more charts are included for explanation.

### 6.1.1 MOODY AFB FUEL TESTING RESULTS

**Visual Appearance:** The first testing method performed on the monthly storage and vehicle tank samples was appearance. The results of the appearance test for all samples are located below, in Table 9.

**Table 6. Appearance Results for Moody AFB Samples**

| Sample Name | Appearance Result |
|---|---|
| **Storage Tank Samples** | |
| Moody AFB;<br>Sampled week of 9/14/09 | Fail; haze rating = 2 |
| Moody AFB Dispenser; Sampled-10/16/09 | Fail; haze rating = 2 |
| Moody AFB Seminole Nozzle Sample; Sampled 12/08/09 | Clear & bright; haze rating = 1 |
| Moody AFB Seminole Dispensing Nozzle; Sampled 01/20/10 | Clear & bright; haze rating = 1 |
| Moody AFB Seminole Biodiesel Receipt Sample; Sampled 01/26/10 | Clear & bright; haze rating = 1 |
| Moody AFB Dispenser Nozzle; Sampled 2/10/10 | Clear & bright; haze rating = 1 |
| **R-11 Refueler Samples** | |
| Moody AFB<br>Vehicle Sample - #05L00156, 3355 hours;<br>Sampled 10/07/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 11/03/09 | Clear & bright; haze rating = 1 |

| Sample Name | Appearance Result |
|---|---|
| Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 12/15/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 05L00156, 3542 hours; Sampled 01/05/10 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 05L00156, 3667 hours; Sampled 02/04/10 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 05L00156, 3726 hours; Sampled 03/10/10 | Fail; haze rating = 3 |
| Moody AFB Vehicle 05L00156, 3736 hours; Sampled 04/09/10 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 05L00156, 3744 hours; Sampled 05/10/10 | Fail; haze rating = 4 |
| Moody AFB, Vehicle 05L00156, 3810 hours, Sampled 06/10/10 | Fail; haze rating = 2 |
| Moody AFB, Vehicle 05L00156, 3878 hours, Sampled 07/08/10 | Fail; haze rating = 3 |
| **2008 Bobtail Samples** | |
| Moody AFB<br>Vehicle Sample - #08C00265, 243 hours; Sampled 10/7/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle Sample-#08C00265, 284 hours; Sampled 11/03/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle Sample-#08C00265, 342 hours; Sampled 12/15/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 08C00265, 342 hours; Sampled 01/05/10 | Clear & bright; haze rating = 1 |

| Sample Name | Appearance Result |
|---|---|
| Moody AFB Vehicle 08C00265, 447 hours; Sampled 02/04/10 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 08C00265, 528 hours; Sampled 03/17/10 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 08C00265, 574 hours; Sampled 04/09/10 | Fail; haze rating = 6 |
| Moody AFB Vehicle 08C00265, 612 hours; Sampled 05/10/10 | Clear & bright; haze rating = 1 |
| Moody AFB, Vehicle 08C00265, 659 hours, Sampled 06/10/10 | Clear & bright; haze rating = 1 |
| Moody AFB, Vehicle 08C00265, 716 hours, Sampled 07/08/10 | Clear & bright; haze rating = 1 |
| **1997 Bobtail Samples** | |
| Moody AFB Vehicle Sample - #97C00410, 2706 hours; Sampled 10/7/09 | Fail-haze rating = 6 Sample was cloudy |
| Moody AFB Vehicle Sample-#97C00410, 2711 hours; Sampled 11/03/09 | Fail-haze rating = 5 |
| Moody AFB Vehicle Sample-#97C00410, 2714 hours; Sampled 12/15/09 | Clear & bright; haze rating = 1 |
| Moody AFB Vehicle 97C00410, 2718 hours; Sampled 01/05/10 | Failed; haze rating = 5 |
| Moody AFB Vehicle 97C00410, 2723.5 hours; Sampled 02/04/10 | Fail; haze rating = 3 |

| Sample Name | Appearance Result |
|---|---|
| Moody AFB Vehicle 97C00410, 2734 hours; Sampled 03/17/10 | Fail; haze rating = 2 |
| Moody AFB Vehicle 97C00410, 2736 hours; Sampled 04/09/10 | Fail; haze rating = 6 |
| Moody AFB Vehicle 97C00410, 2740 hours; Sampled 05/10/10 | Clear & bright; haze rating = 1 |
| Moody AFB, Vehicle 97C00410, 2748 hours; Sample 06/10/10 | Fail; haze rating = 3 |
| Moody AFB, Vehicle 97C00410, 2753 hours; Sample 07/08/10 | Clear & bright; haze rating = 1 |

The results in Table 6 show that, initially, the storage tank samples contained some haze but had cleared by the December 2009 sampling event. The R-11 Refueler tank samples were clear until the last few months of sampling. The first two samples from the storage tank samples failed the visual appearance test; all subsequent samples passed. Note that once the fuel in the storage tank tested as clear and bright, it remained such throughout the remainder of the samples.

Four of the ten Refueler samples failed the visual appearance test. One of the failed samples was taken on the same day as the last storage tank sample (which passed); and, the remaining three failed samples were taken after the date of the last storage tank sample.

The samples from the two Bobtails had mixed results. The 2008 Bobtail maintained clear samples throughout the test. The 1997 Bobtail, however, had most samples failing the appearance test, at various levels of haze. If we assume that the passing samples for the 2008 Bobtail means that the dispensing filters on the above-ground storage tank were cleaning the fuel sufficiently, then the failed samples from the 1997 Bobtail suggest fuel breakdown occurred in the 1997 Bobtail, but not the 2008 Bobtail even though they used the same fuel. This was confirmed by a visual inspection of the vehicle fuel tank.

A new fuel tank was installed on the 1997 Bobtail B20 vehicle at the beginning of the project. One year later, the fuel tank was heavily coated with orange/brown deposits. Analysis by the AFPA determined that these deposits were made up of oxidative stability breakdown products from the biodiesel. Figure 4 show the interior of the1997 Bobtail fuel tank.

**Figure 4. Test Vehicle: 1997 Bobtail Fuel Tank**

Figure 5 shows the fuel sending unit from the 1997 Bobtail B20 vehicle is heavily coated with oxidative stability breakdown products from the biodiesel. Note that the red fuel screen has fallen off the fuel sending unit due to material incompatibility with the degraded biodiesel. The B20 as received, and in bulk storage at Moody AFB, was of high quality, clear and bright, and free of sediments. This formation of solids occurs in vehicle tanks as a result of high temperatures and high humidity which causes the biodiesel to degrade, some design deficiencies in the vehicles fuel tank, and the lack of use of the 1997 Bobtail.

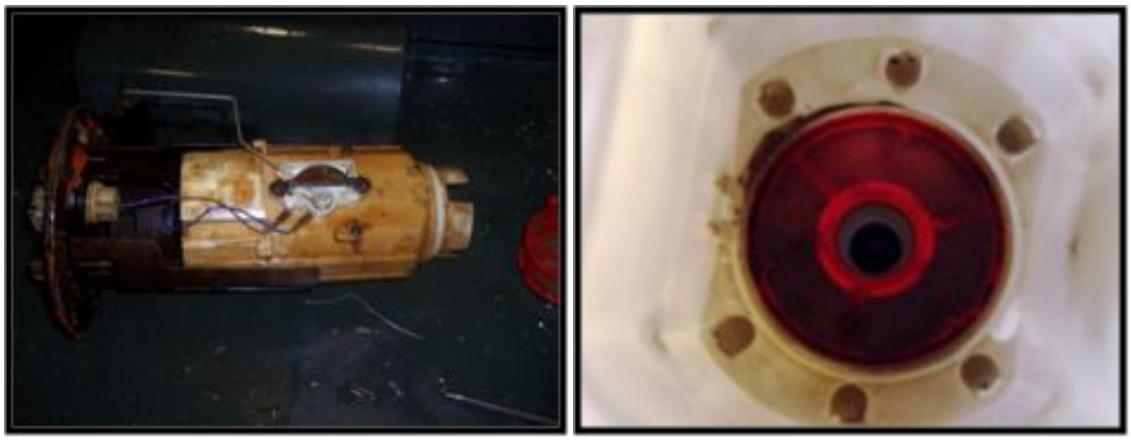

**Figure 5. Test Vehicle: 1997 Bobtail Fuel Sending Unit**

Figure 6 displays the fuel sending unit from the 1997 Bobtail diesel fuel control vehicle. The sending unit is clean and free of deposits and the red fuel screen is securely in place.

**Figure 6. Control Vehicle: 1997 Bobtail Sending Unit**

Fewer B20 maintenance issues and occurrences of B20 tank solids have been reported with the newer 2008 Bobtails. Changes to vehicle design may play a role as displayed in Figure 7.

- Fuel tank covered, less exposed to the sunshine/heat
- Fuel cap more appropriate and robust
- Due to recess, less chance of getting water/rain into the fuel tank during refueling

**Figure 7. Comparison of Exterior of 1997 and 2008 Bobtail**

Another important factor is the number of hours the vehicles operated over the duration of the demonstration:

- 1997 Bobtail – 47 hours
- 2008 Bobtail – 473 hours

The 1997 Bobtail was operated 90% less than the 2008 Bobtail. The 2008 Bobtail, as displayed in Figure 8, did not have the same breakdown of fuel as the 1997 Bobtail.

**Figure 8. Test Vehicle: 2008 Bobtail Fuel Tank**

**Acid Number:** The acid number results can be viewed in Figure 9. The acceptance criterion for this testing method was a value of 0.2 mg KOH/g, as a maximum limit. All acid values met this requirement.

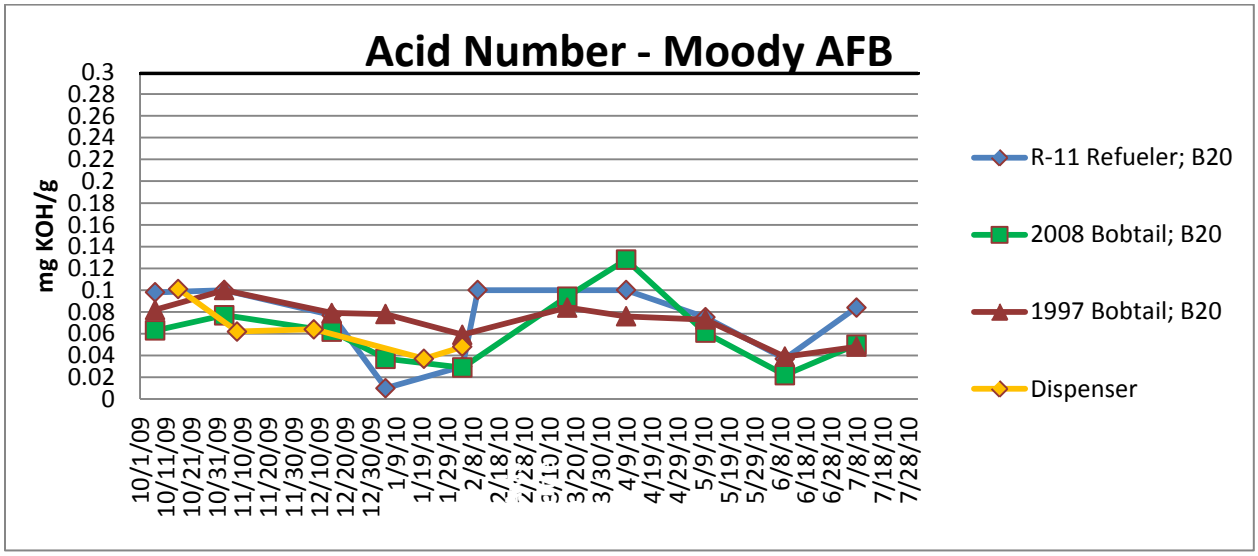


**Figure 9. Acid Values for Moody AFB Samples**

**Kinematic Viscosity:** All samples passed viscosity measurement at 40°C, with results in the range from 2.5 to 3.0 $mm^2$/sec. The specification limits for this requirement are 1.9 to 4.1 $mm^2$/sec.

**Water and sediment**: The specification for this requirement is a maximum water and sediment content of 0.05 volume percent. Two samples failed to meet this requirement. Both samples also had elevated total water content values, as seen in Figure 10, below. Although there is no

acceptance criterion for total water content, some discussion of the results is possible. Petroleum diesel fuel typically holds up to a maximum of about 150 – 200 parts per million (by mass) of total water. All of the samples shown in Figure 10 have at least 200 ppm (by mass) or more of total water. These results demonstrate the tendency of biodiesel blends to emulsify water at levels above petroleum diesel fuel alone. It should also be noted that the high reading for the 2008 Bobtail on 4/9/2009 is not consistent with the rest of the data. The same sample seems inconsistent in Figure 10, Particulate Contamination. This may be due to an analytical error, or possibly a mis-labeled sample.

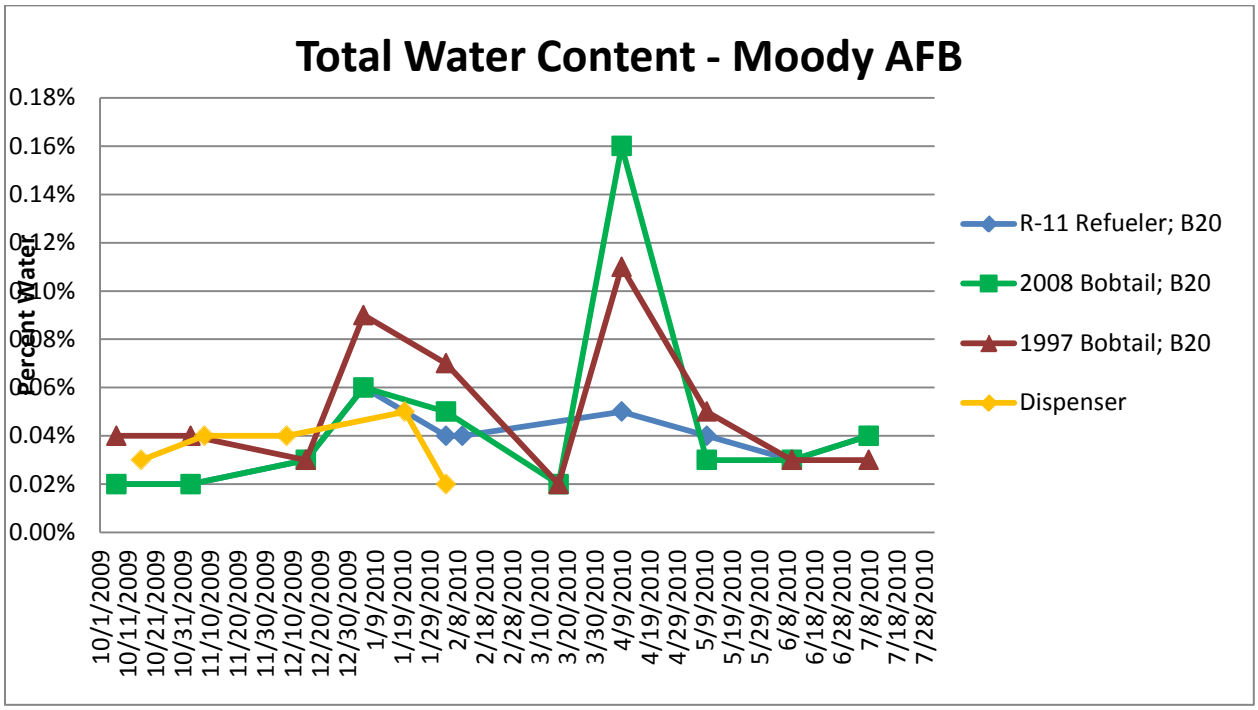


**Figure 10. Total Water Content Results for Moody AFB Samples**

**Color:** Determination of color was also conducted on the samples. These measurements were performed using a colorimeter, with values to be reported at 0.5 increments. If the sample was lighter than the value at that increment but darker than the next lower increment, the higher value was reported with an "L" indication. The acceptance criterion for this test is a color number of 3, maximum. All samples, with the exception of a few of the 1997 Bobtail vehicle samples, passed this requirement. The failing samples for the 1997 Bobtail were also the same samples that failed appearance.

**Particulate Contamination:** Results of this test are charted in Figure 11. There were two vehicle samples that did not meet the test requirement of less than 10 mg/L particulate content for new fuel. Note that the samples that did not meet this level also had failures in appearance, had higher acid values, and had elevated water and sediment and total water content values.

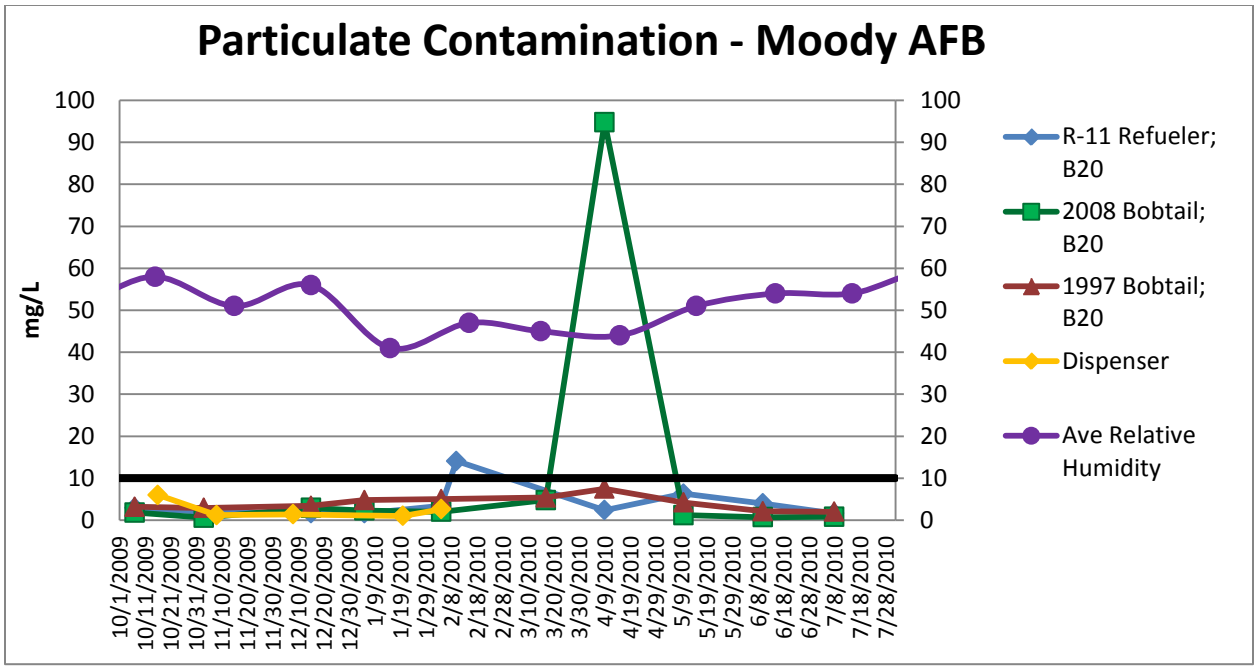


**Figure 11. Particulate Contamination Results for Moody AFB**

**Oxidation Stability (Rancimat and D2274, modified):** The Rancimat test results are plotted in Figure 12. All of the storage tank samples met specification limits. The Refueler and the two Bobtail trucks each had at least one sample that failed the specification requirements; all the samples from the 1997 Bobtail failed.

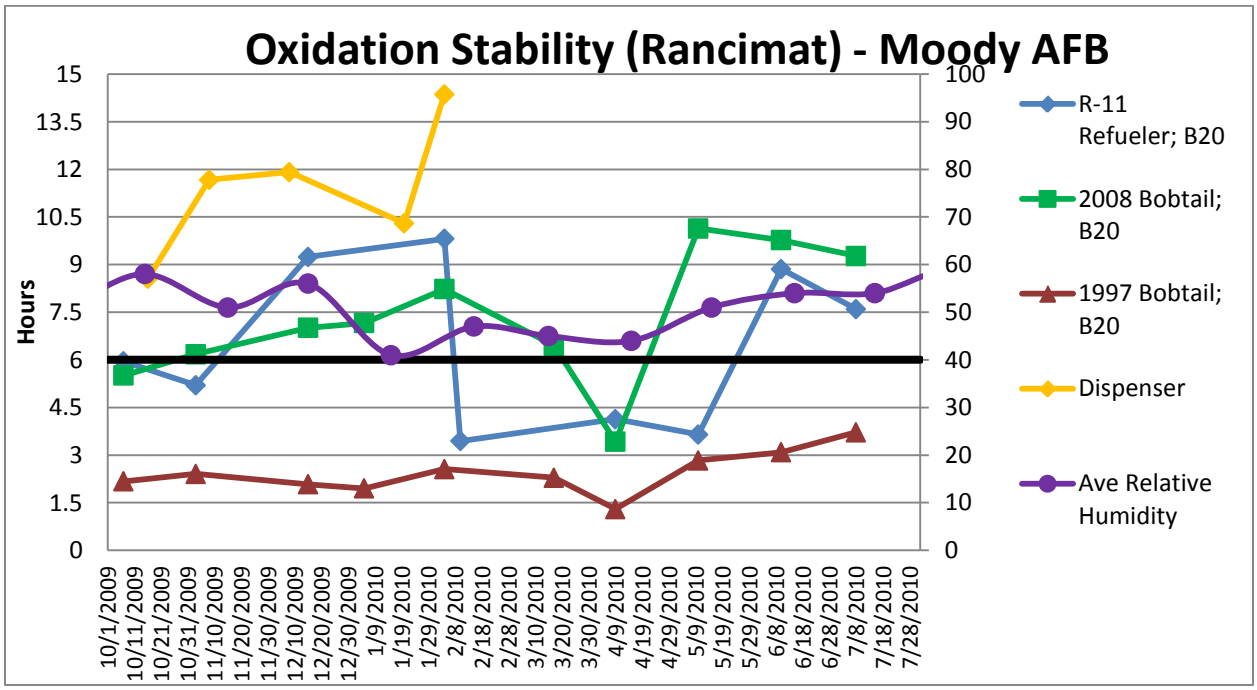


**Figure 12. Rancimat Oxidation Stability Results for Moody AFB Samples**

The results of the modified D2274 oxidation stability test are listed in Table 7 and shown graphically in Figure 13. There are no widely recognized acceptance criteria for this testing method but 2.5 mg of total insolubles per 100 mL is often cited as an acceptable pass/fail limit. As with the Rancimat results, the D2274 (modified) test results were mixed. The storage tank samples all passed, the Refueler and vehicles each had at least one failing sample. Overall, the worst results were for the 1997 Bobtail. The iso-octane insolubles and acid value results had trends similar to the total insolubles results.

The fuel in storage tank was not sampled for the duration of the test by local personnel as instructed. This oversight left a gap of data missing from the charts. This lack of data for the storage tanks is unfortunate since the breakdown occurring in the vehicles cannot be traced back to the quality of the fuel going into the vehicle.

**Table 7. D2274, Modified, Oxidation Stability Results for Moody AFB Samples**

| Sample Name | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| **Storage Tank Samples** | | | |
| Moody AFB; Sampled week of 9/14/09 | 1.0 | 0.57 | 0.36 |
| Moody AFB Dispenser; Sampled-10/16/09 | 0.22 | 0.11 | 0.085 |
| Moody AFB Seminole Nozzle Sample; Sampled 12/08/09 | 0.14 | 0.14 | 0.074 |
| Moody AFB Seminole Nozzle Sample; Sampled 12/08/09 | < 0.1 | < 0.1 | 0.084 |
| Moody AFB Seminole Nozzle Sample; Sampled 01/20/10 | 0.17 | <0.1 | 0.05 |
| Moody AFB Seminole Biodiesel Receipt Sample; Sampled 01/26/10 | 0.14 | 0.14 | 0.049 |
| Moody AFB Seminole Nozzle Sample; Sampled 2/10/10 | 0.83 | 0.14 | 0.07 |
| **R-11 Refueler Samples** | | | |
| Moody AFB Vehicle Sample - #05L00156, 3355 hours; Sampled 10/7/09 | 0.29 | 0.14 | 0.127 |

| Sample Name | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 11/03/09 | 1.77 | 0.37 | 0.014 |
| Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 12/15/09 | 0.97 | 0.20 | 0.071 |
| Moody AFB Vehicle 05L00156, 3542 hours; Sampled 01/05/10 | 0.14 | 0.14 | 0.008 |
| Moody AFB Vehicle 05L00156, 3667 hours; Sampled 02/04/10 | 3.29 | < 0.1 | 0.075 |
| Moody AFB Vehicle 05L00156, 3726 hours; Sampled 02/10/10 | No data | No data | No data |
| Moody AFB Vehicle 05L00156, 3936 hours; Sampled 04/09/10 | 10.5 | 6.1 | 0.012 |
| Moody AFB Vehicle 05L00156, 3724 hours; Sampled 05/10/10 | 8.2 | 6.7 | < 0.005 |
| Moody AFB, Vehicle 05L00156, 3810 hours, Sampled 06/10/10 | 2.5 | 0.6 | 0.054 |
| Moody AFB, Vehicle 05L00156, 3878 hours, Sampled 07/08/10 | 2.2 | 0.1 | 0.086 |
| **2008 Bobtail Samples** | | | |
| Moody AFB Vehicle Sample - #08C00265, 243 hours; Sampled 10/7/09 | 2.26 | 1.26 | 0.128 |
| Moody AFB Vehicle Sample-#08C00265, 4840 hours; Sampled 11/03/09 | 1.71 | 0.77 | 0.131 |
| Moody AFB Vehicle Sample-#08C00265, 342 hours; Sampled 12/15/09 | 0.68 | 0.34 | 0.086 |
| Moody AFB Vehicle 08C00265, 342 hours; Sampled 01/05/10 | 0.23 | 0.23 | 0.048 |

| Sample Name | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| Moody AFB Vehicle 08C00265, 447 hours; Sampled 02/04/10 | 1.61 | 0.31 | 0.078 |
| Moody AFB Vehicle 08C00265, 528 hours; Sampled 03/17/10 | No data | No data | No data |
| Moody AFB Vehicle 08C00265, 574 hours; Sampled 04/09/10 | 8.43 | 5.8 | 0.015 |
| Moody AFB Vehicle 08C00265, 612 hours; Sampled 05/10/10 | 3.2 | 0.1 | <0.005 |
| Moody AFB, Vehicle 08C00265, 659 hours, Sampled 06/10/10 | 2.0 | 0.4 | 0.041 |
| Moody AFB, Vehicle 08C00265, 716 hours, Sampled 07/08/10 | 1.5 | 1.4 | 0.074 |
| **1997 Bobtail Samples** | | | |
| Moody AFB Vehicle Sample - #97C00410, 2706 hours; Sampled 10/7/09 | 143.2 | 118.7 | 0.008 |
| Moody AFB Vehicle Sample- #97C00410, 2711 hours; Sampled 11/03/09 | 0.83 | < 0.1 | 0.162 |
| Moody AFB Vehicle Sample- #97C00410, 2714 hours; Sampled 12/15/09 | 1.0 | 0.40 | 0.085 |
| | | | |
| Moody AFB Vehicle 97C00410, 2718 hours; Sampled 01/05/10 | 86.4 | 57.9 | 0.026 |
| Moody AFB Vehicle 97C00410, 2723.5 hours; Sampled 02/04/10 | 66.4 | 56.9 | 0.008 |
| Moody AFB Vehicle 97C00410, 2734 hours; Sampled 03/17/10 | No data (not enough volume) | No data | No data |
| Moody AFB Vehicle 97C00410, 2736 hours; Sampled 04/09/10 | 107.1 | 24.0 | 0.016 |

| Sample Name | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| Moody AFB Vehicle 97C00410, 2740 hours; Sampled 05/10/10 | 37.5 | 13.4 | 0.005 |
| Moody AFB, Vehicle 97C00410, 2748 hours; Sample 06/10/10 | 52.5 | 41.5 | <0.005 |
| Moody AFB, Vehicle 97C00410, 2753 hours; Sample 07/08/10 | 70.1 | 13.7 | <0.005 |

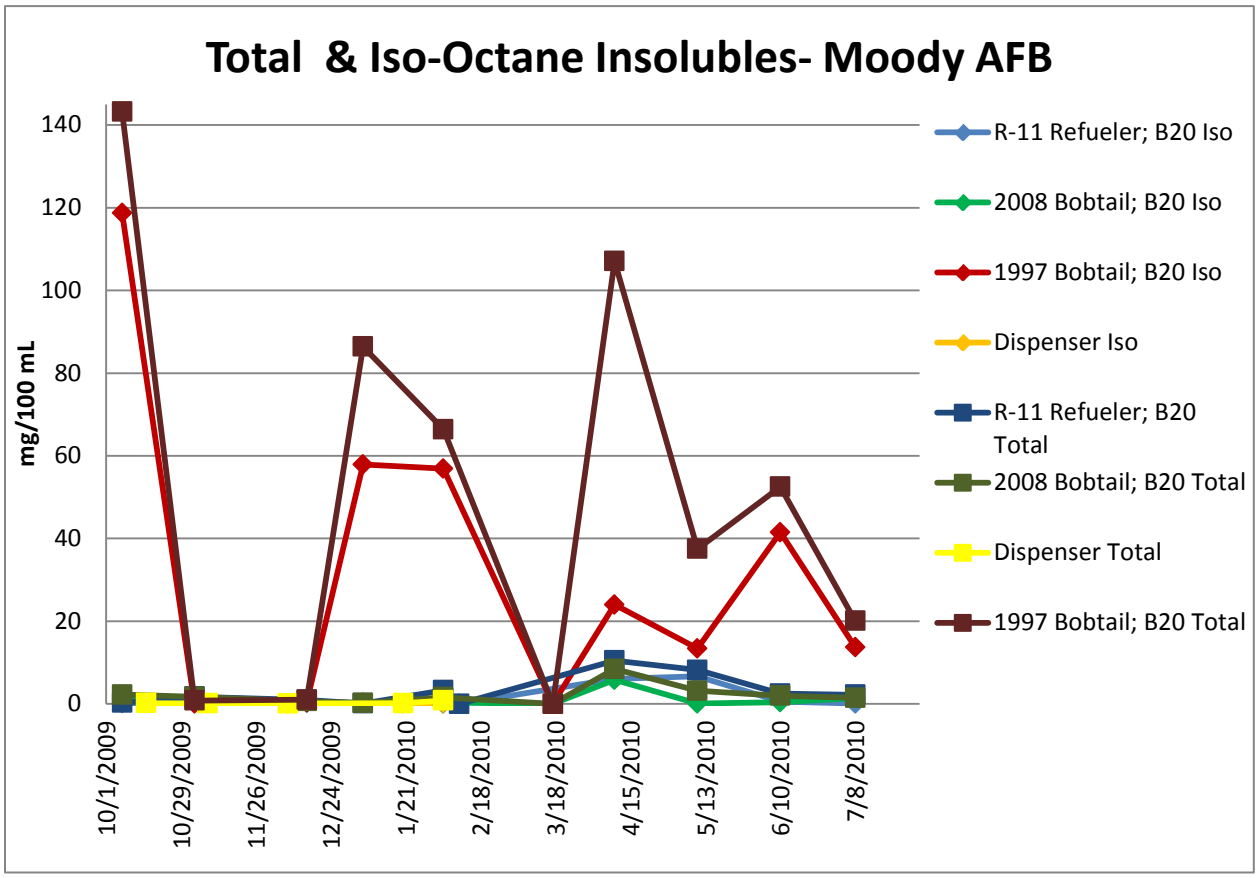


**Figure 13. D2274, Modified, Oxidation Stability Results for Moody AFB Samples**

### 6.1.2 MARINE CORPS BASE 29 PALMS FUEL TESTING RESULTS

Results of the fuel testing for this location were very consistent throughout the sampling period. The storage tank and vehicle tank samples trended very similarly for most testing methods. All

appearance results throughout the trial were "clear and bright with a haze rating of 1". In addition, all acid values were below the acceptance criterion of 0.2 mg KOH/g, generally tracking near 0.1 mg KOH/g or less. The fuel viscosity values were generally between 2.8 and 3.0 $mm^2$/sec, which is well within the requirements for this property. Water and sediment values were all < 0.005 volume percent, total water content was generally less than 100 ppm and color was lighter than 1.5. Particulate contamination was generally less than 5 mg/L and three vehicle samples failed Rancimat oxidation stability. Figure 14 shows the results of that testing.

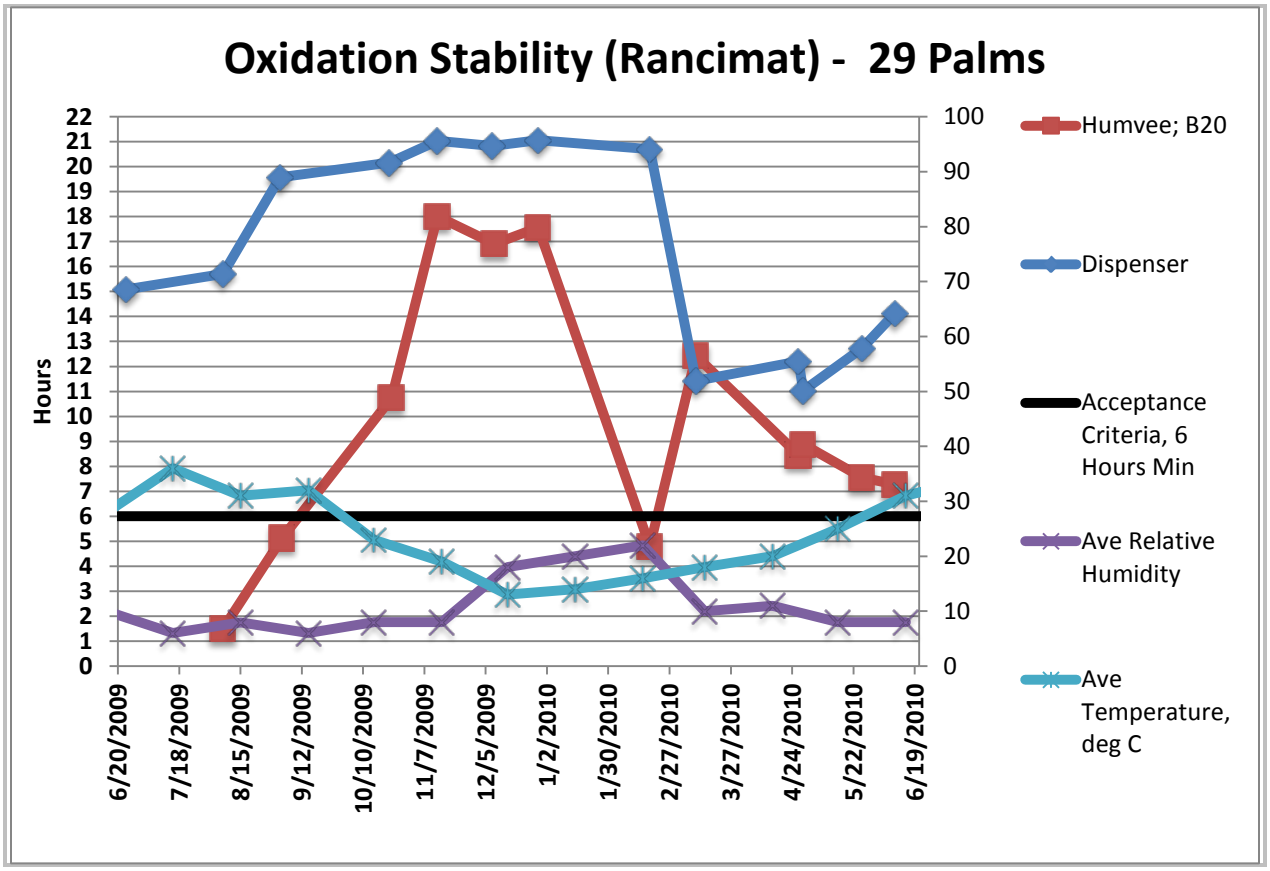


**Figure 14. Rancimat Stability Results for 29 Palms**

The modified D2274 oxidation stability results listed in Table 8, and shown graphically in Figure 15, also trended similarly between storage tank and vehicle tank samples, with total insoluble results generally running less than 5 mg/100 mL. The only outlier was the original vehicle sample, which could have resulted from residual contamination in the fuel tank or fuel lines.

**Table 8. D2274, Modified, Oxidation Stability Results for 29 Palms Samples**

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| **Storage Tank Samples** | | | |
| 6/24/09 | 0.4 | 0.1 | 0.091 |
| 8/7/09 | 2.43 | 0.943 | 0.078 |
| 9/2/09 | 0.537 | 0.1 | 0.085 |
| 10/22/09 | 0.6 | 0.11 | 0.097 |
| 11/13/09 | 0.26 | 0.1 | 0.102 |
| 12/8/09 | 0.11 | 0.11 | 0.08 |
| 12/29/09 | 0.11 | 0.11 | 0.101 |
| 2/18/10 | 0.14 | 0.14 | 0.096 |
| 3/11/10 | 5.57 | 0.1 | 0.098 |
| 4/27/10 | 0.5 | 0.2 | 0.091 |
| 4/29/10 | 0.2 | 0.2 | 0.092 |
| 5/26/10 | 1.69 | 0.23 | 0.061 |
| 6/10/10 | 0.2 | 0.2 | 0.059 |
| **Vehicle Tank** | | | |
| 8/7/09 | 235.6 | 36.1 | 0.125 |
| 9/3/09 | 2.43 | 0.943 | 0.088 |
| 10/23/09 | 0.85 | 0.51 | 0.1 |
| 11/13/09 | 0.25 | 0.14 | 0.103 |
| 12/9/09 | 2.0 | 0.14 | 0.081 |
| 12/29/09 | 0.11 | 0.11 | 0.092 |
| 2/18/10 | Not Detected (ND) | ND | 0.1 |
| 3/11/10 | 5.56 | 0.26 | 0.099 |
| 4/27/10 | 0.3 | 0.2 | 0.091 |

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| 4/29/10 | 0.1 | 0.3 | 0.091 |
| 5/26/10 | 2.6 | 0.49 | 0.2 |
| 6/10/10 | 1.1 | 0.2 | 0.061 |

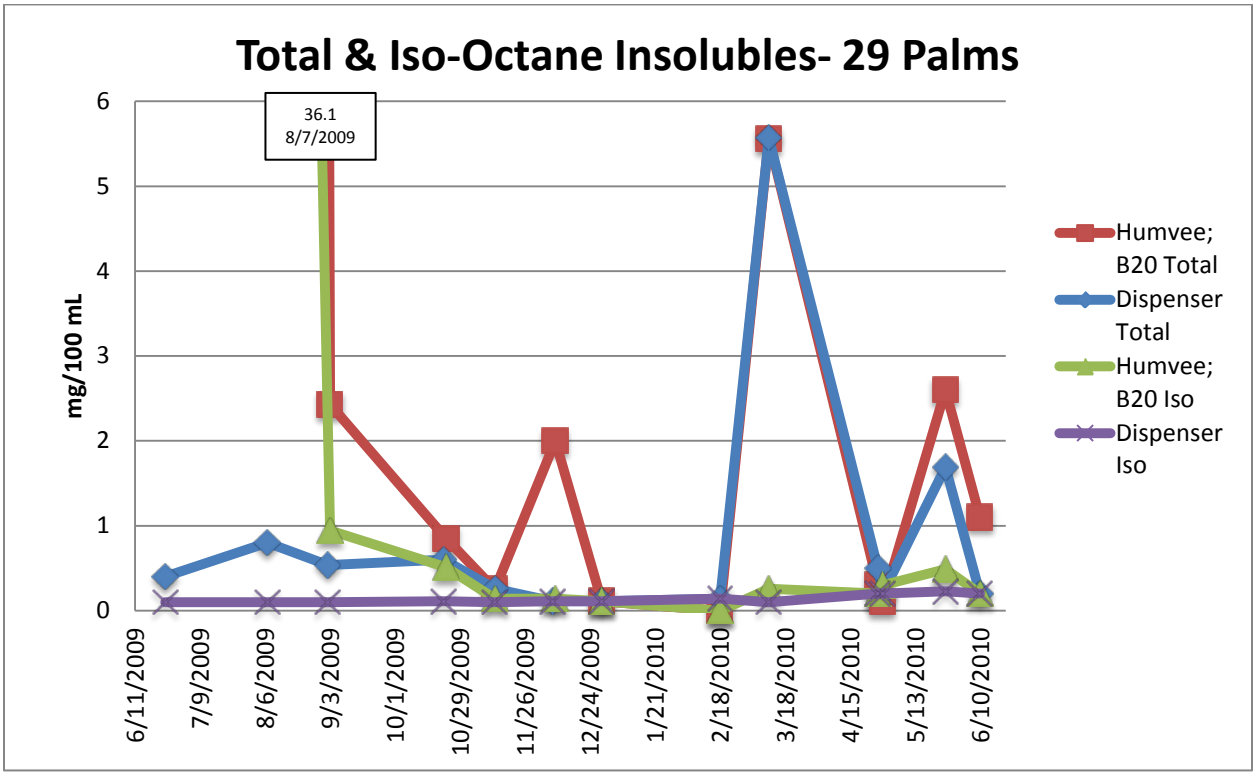


**Figure 15. D2274, Modified, Oxidation Stability Results for 29 Palms Samples**

The fuel filters for the test and control HMMWV vehicles are displayed in Figure 16.

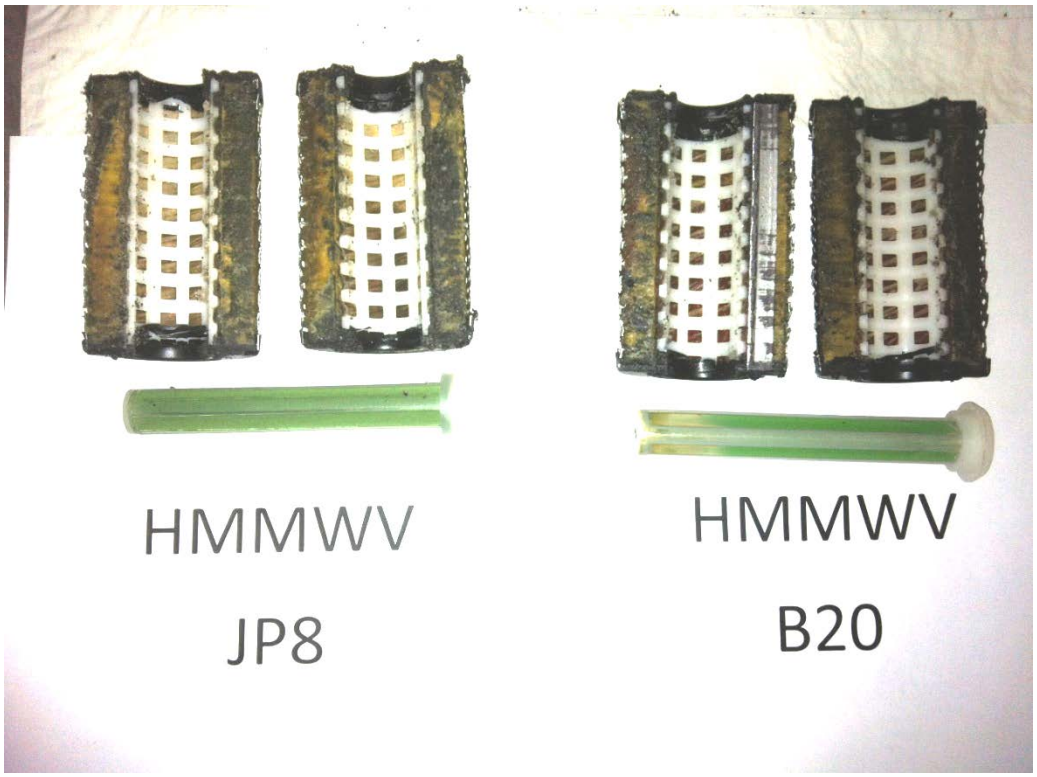


**Figure 16. Fuel Filters taken from Control and Test HMMWVs**

The fuel filters were taken from the test MTVR vehicle running on B20 did not display any visual difference when compared to the control MTVR vehicle fuel filters.

### 6.1.3 NBVC PORT HUENEME FUEL TESTING RESULTS

As with the samples from 29 Palms, the storage and vehicle tank samples tracked closely. First, all samples had an appearance rating of clear and bright with a haze rating of 1. Total acid numbers for all samples were less than 0.1 mg KOH/g. Viscosity values were lower than the previous two locations, but still within specification limits, with the readings all between 2.25 and 2.45 $mm^2$/sec. Water and sediment, total water content, and color values were all low, and well below the established acceptance criteria. Particulate contamination was below the required level for all but one storage tank sample, which was the last sample taken at NBVC for this trial.

Even though all of the other physical property data met the acceptance criteria, the oxidation stability test results showed that there were issues with fuel stability immediately after the start of the trial. The initial storage tank sample barely met the Rancimat requirement of a minimum of 6 hours and had minimal filterable insolubles present from the modified D2274 oxidation stability test. After this point, all vehicle and storage tank sample results for Rancimat stability dipped below 6 hours and the filtered insolubles increased more than one hundred fold. See Figure 17 for a graph of the Rancimat results and for the modified D2274 oxidation stability results.

A couple of factors were unique to the NBVC site. First, there was only one delivery of fuel for the duration of the demonstration. The fuel exceeded, by a full year, the recommended storage life of 6 months. Second, it is the only site that contained fuel in the vehicle that was always the same age as the fuel in the storage tank, since fuel was never replenished.

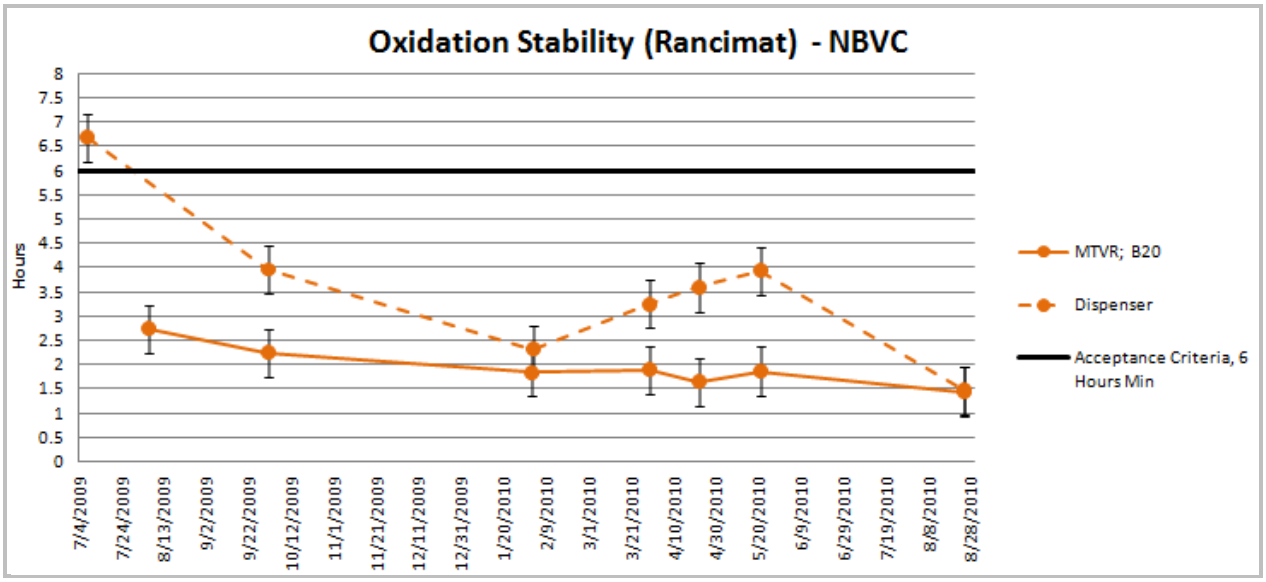


**Figure 17. Rancimat Stability Results for NBVC Port Hueneme Samples**

**Table 9. D2274, Modified, Oxidation Stability Results for the NBVC Samples**

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| **Storage Tank** | | | |
| Dispenser Sample, Sampled 07/08/09 | 0.5 | 0.5 | 0.080 |
| Nozzle Sample, Sampled 10/01/09 | 269.4 | 154.1 | 0.080 |
| Dispenser Sample, Sampled 02/03/10 | 550.5 | 472.7 | 0.014 |
| Storage Tank, Sampled 03/30/10 | 85.1 | 81.4 | 0.010 |

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| From Station; Sampled 04/22/10 | 247.7 | 39.0 | <0.005 |
| From Station; Sampled 05/21/10 | 58.3 | 2.9 | 0.025 |
| From Fill Station, Sampled 08/25/10 | 628.1 | 413.7 | <0.005 |
| **Vehicle Tank** | | | |
| Vehicle Sample, Sampled 08/06/09 | 648 | 177 | 0.080 |
| Vehicle Sample, Sampled 10/01/09 | 280.3 | 208 | 0.007 |
| Vehicle Sample, Sampled 02/02/10 | 576.4 | 747.7 | 0.009 |
| Vehicle Sample, Sampled 03/30/10 | 503.6 | 325.8 | 0.009 |
| Vehicle Sample, Sampled 04/22/10 | 672.9 | 460.7 | <0.005 |
| Vehicle Sample, Sampled 05/21/10 | 618.6 | 447.6 | 0.034 |
| Vehicle Sample, Sampled 08/25/10 | 687.8 | 483.4 | <0.005 |

Table 12 shows that the Total and Iso-octane insolubles were each higher in the vehicle tank than the storage tank. This follows since the fuel in the vehicle tank is exposed to higher temperatures. **Error! Reference source not found.** The table also shows that the Total and Iso-octane Insolubles for the B20 in the dispenser and MTVR at NBVC was high. One explanation is that the location only had one fuel delivery, so the fuel was never refreshed with new fuel. The amount of insolubles remained in a diminishing volume of fuel so the concentration rose over time. As shown in Figure 19, the biodiesel in the MTVR eventually broke down.

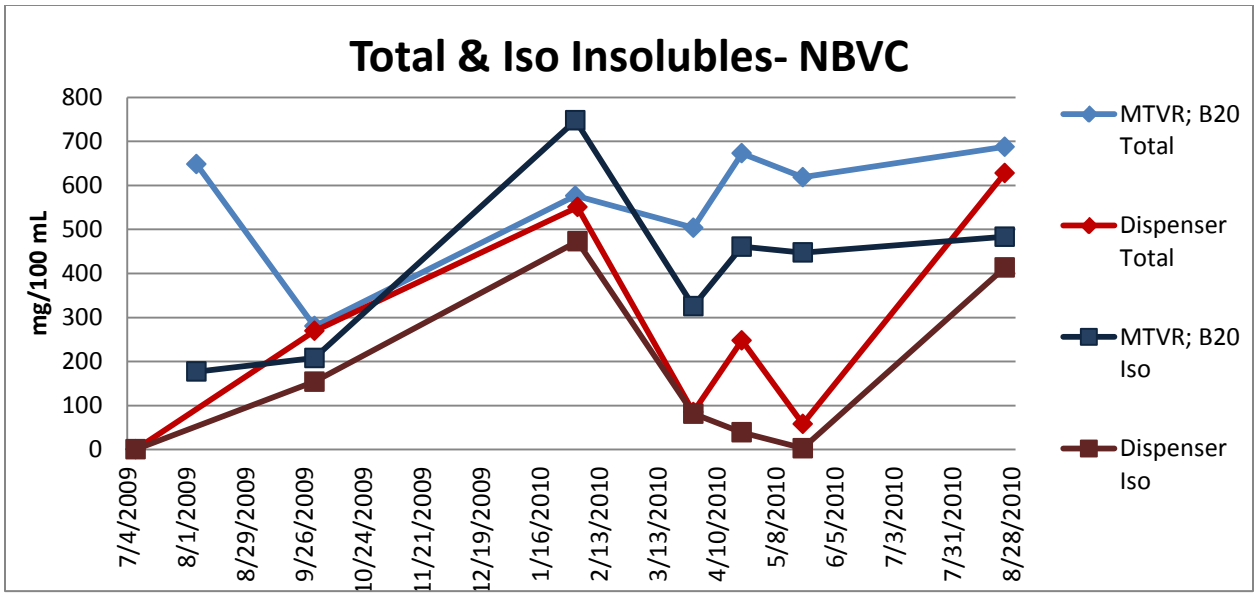


**Figure 18. Total and Iso-octane Insolubles for NBVC**

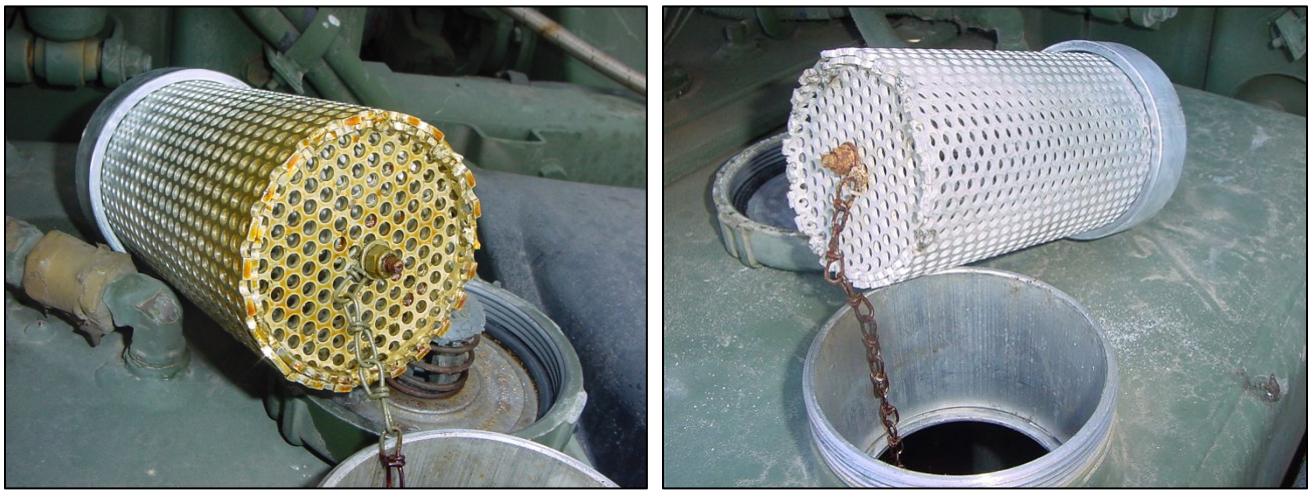

**Figure 19. Fuel Strainer for Test and Control MTVR**

The sampling team did not note any breakdown for the first part of the sampling which began on July 8th, 2009 and ended August 25th 2010. The visible breakdown occurred between the last sample date, August 25, 2010 and October 2011 (when pictures were taken). B20 had been in the MTVR tank for 14 months.

Fuel filters taken from control and test MTVRs are shown in Figure 20 and Figure 21.

**Figure 20. Fuel Filter taken from Test and Control MTVR Vehicles**

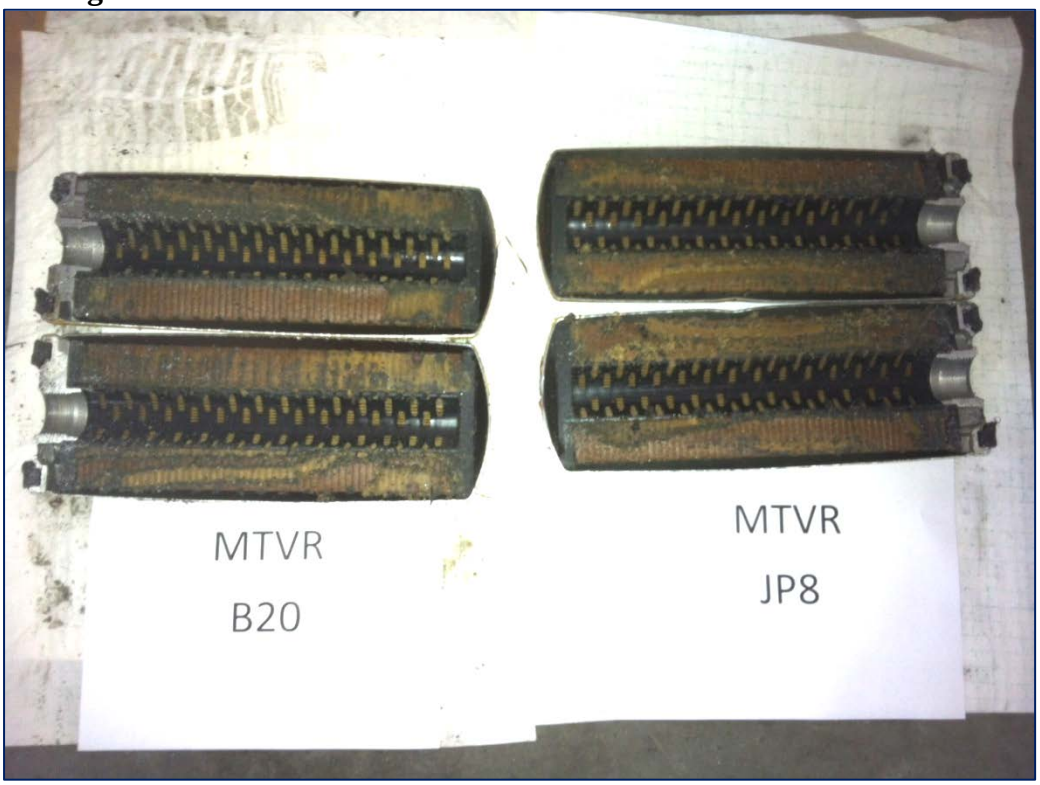


**Figure 21. Fuel Filter taken from Test and Control MTVR Vehicles**

The fuel filters were taken from the test MTVR vehicle running on B20 did not display any visual difference when compared to the control MTVR vehicle fuel filters.

### 6.1.4 NSWC CRANE FUEL TESTING RESULTS

For the vehicle and storage tank samples at NSWC Crane, the physical property data all trended similarly and met the acceptance criteria established for appearance (one failure on a vehicle sample), acid number, viscosity, water and sediment, total water content, color, and particulate contamination. However, as with the NBVC samples, fuel stability was the issue. As shown in Figure 22, most of the vehicle fuel samples did not pass Rancimat stability and the D2274, modified, oxidation stability results for the vehicle samples, though falling below the acceptance criteria, it cannot be concluded that the fuel is doing harm to the engine components, since the test is designed for acceptance, not for fuel use during operation.

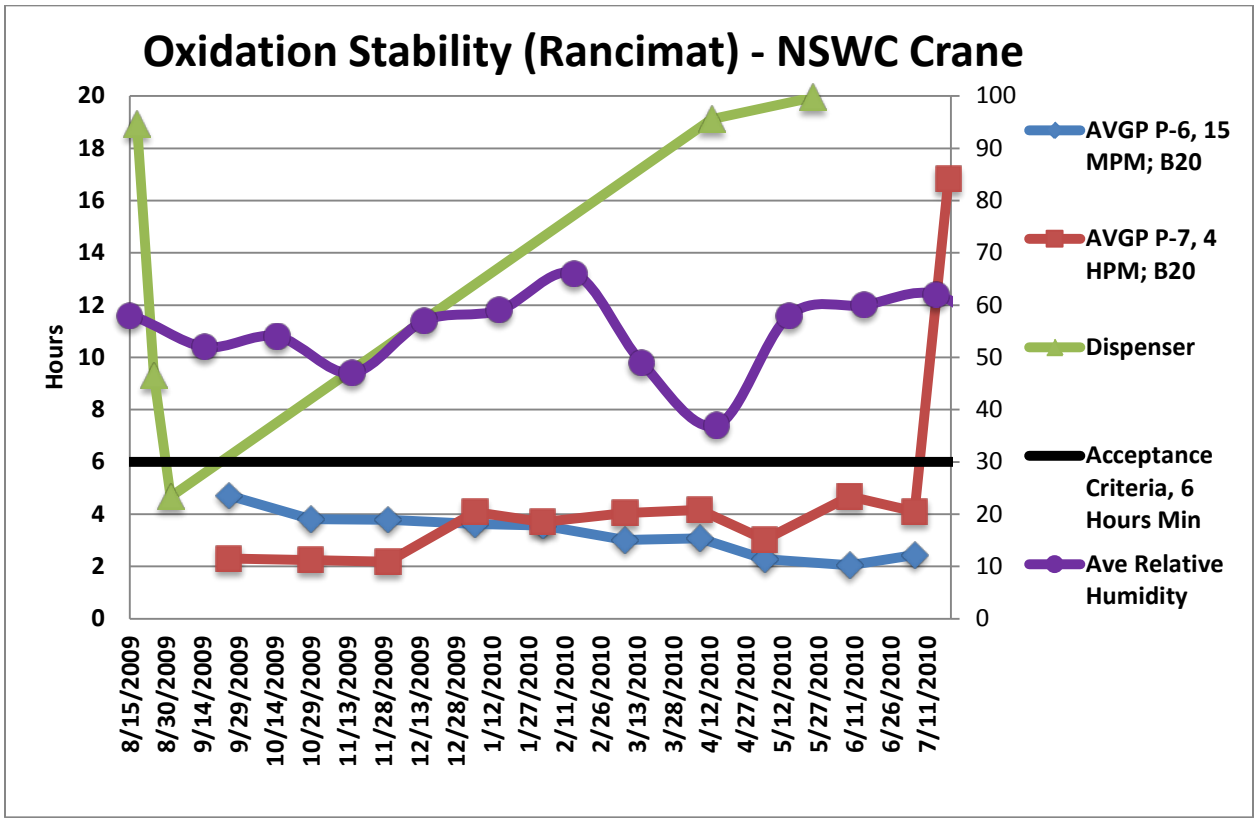


**Figure 22. Rancimat Stability Results for NSWC Crane**

The storage tank samples had passing results for both Rancimat and oxidation stability. Table 10 shows that the initial B20 placed into the AVGPs contained high insoluble levels. During refueling cycles, the level of insoluble dropped as fresh fuel replaced old fuel in the vehicle tanks.

**Table 10. D2274, Modified, Oxidation Stability Results for the NSWC Samples**

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| **Storage Tank** | | | |
| Fuel Tank Sample, Sampled 09/01/09 | 4.83 | 3.66 | 0.006 |
| Dispenser Sample, Sampled 08/18/09 | 0.13 | <0.1 | 0.34 |
| Fuel Truck Sample, Sampled 08/25/09 | 0.94 | <0.1 | 0.35 |
| Dispenser Sample, Sampled 04/13/10 | 1.15 | <0.1 | 1.15 |
| Dispenser Sample Sampled 05/25/10 | 1.4 | 0.3 | 0.063 |
| **Vehicle Tank (AVGP P-6, Run 15 Min/Month)** | | | |
| 09/25/09 | 434.4 | 292.7 | 0.006 |
| 10/29/08 | 8.43 | 6.69 | 0.019 |
| 11/30/09 | 52.3 | 48.9 | <0.005 |
| 01/005/10 | 22.4 | 16.8 | <0.005 |
| 02/02/10 | 51.9 | 45.8 | 0.034 |
| 03/08/10 | 50.1 | 46.8 | 0.045 |
| 04/08/10 | 34 | 22.8 | <0.005 |
| 05/05/10 | 61.1 | 24.9 | 0.006 |
| 06/09/10 | 478.2 | 353.3 | <0.005 |
| 07/06/10 | 381.2 | 331.1 | <0.005 |
| **Vehicle Tank (AVGP P-7, Run 4 Hrs/month)** | | | |
| 09/25/09 | 456.6 | 292.7 | 0.006 |
| 10/29/08 | 206.6 | 164 | 0.018 |
| 11/30/09 | 443.3 | 353.1 | <0.005 |

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| 01/05/10 | 65.4 | 61.7 | <0.005 |
| 02/02/10 | 121 | 51.1 | <0.005 |
| 03/08/10 | 44.7 | 35 | <0.005 |
| 04/08/10 | 30.1 | 19.3 | <0.005 |
| 05/05/10 | 594.3 | 485.1 | <0.005 |
| 06/09/10 | 68.1 | 63 | <0.005 |
| 07/06/10 | 52.3 | 35.6 | <0.005 |

Figures 23-26 show no visible evidence of fuel breakdown in the fuel filters. The fuel filters that were in the test AVGPs running on B20 look identical to the fuel filters that were pulled out of the control AVGPs running on JP-8.

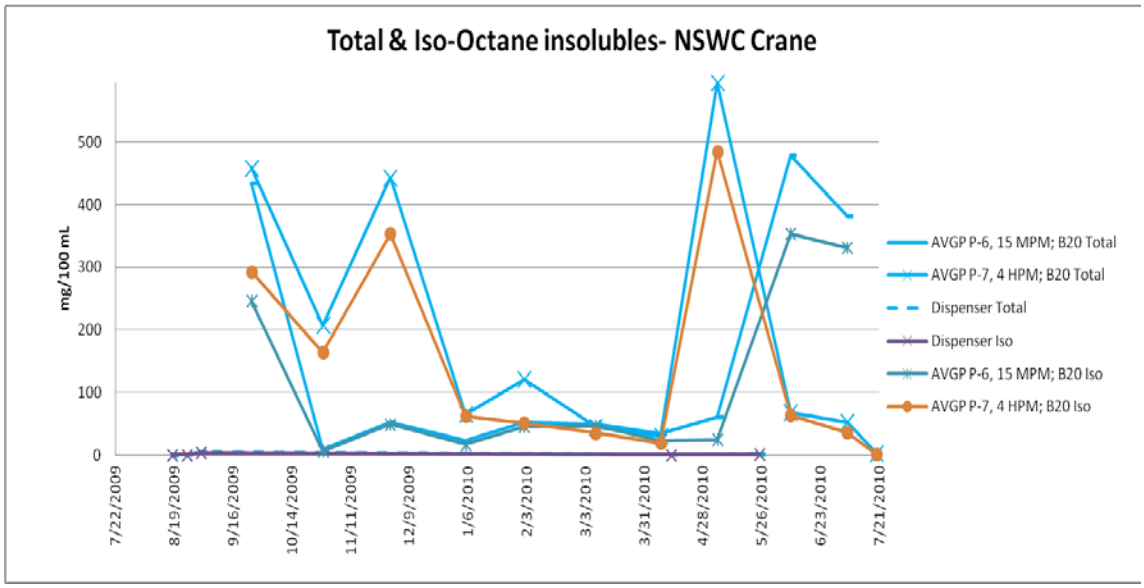


**Figure 23. Modified, Oxidation Stability Results for NSWC Crane**

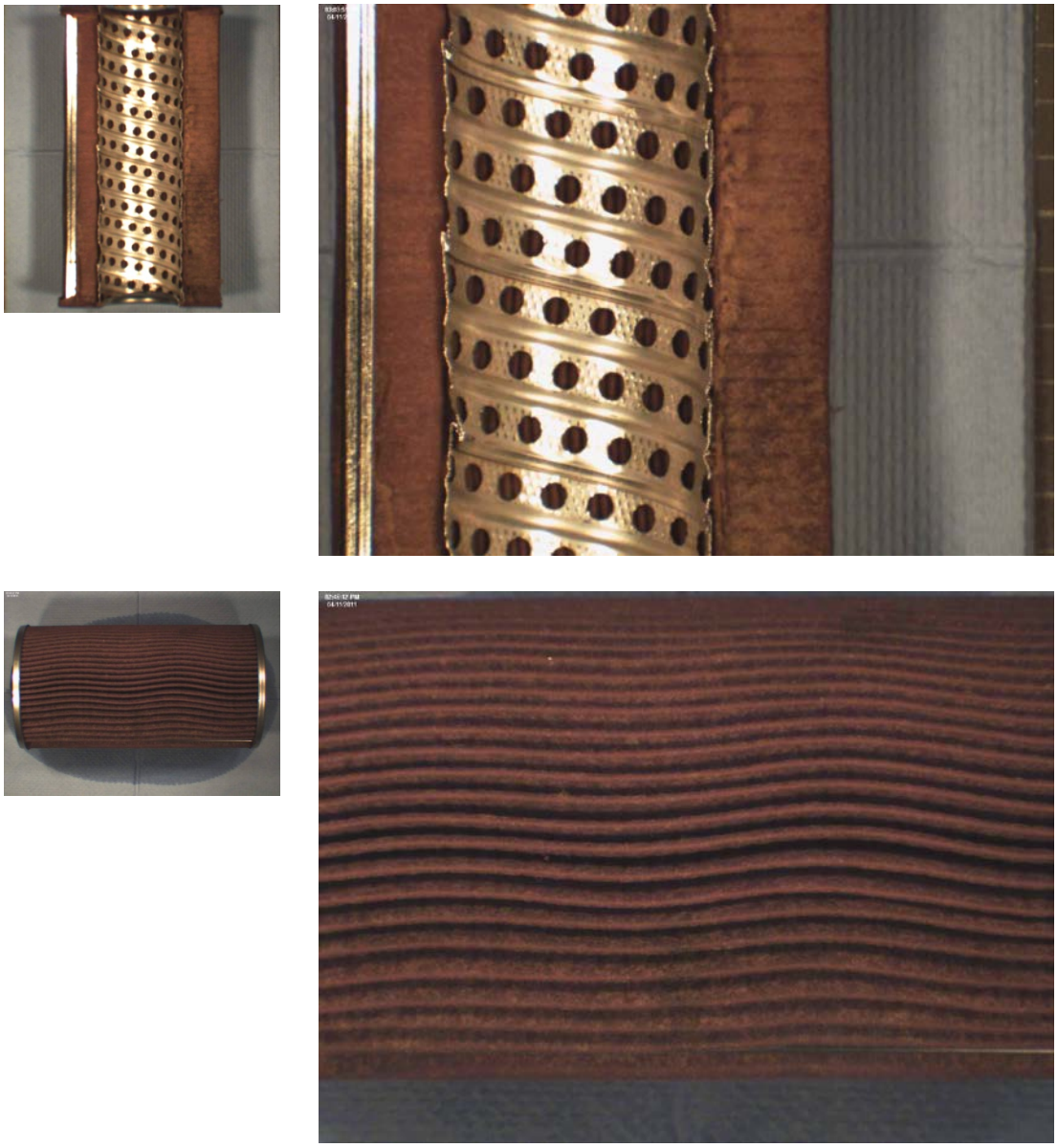

**Figure 24. Fuel Filter for Control AVGP Vehicles on JP-8 for 4 hours per month**

**Figure 25. Fuel Filter for Test AVGP Vehicle on B20 for 4 hours per month**

**Figure 26. Fuel Filter for Control AVGP Vehicles on JP-8 for 15 minutes per month**

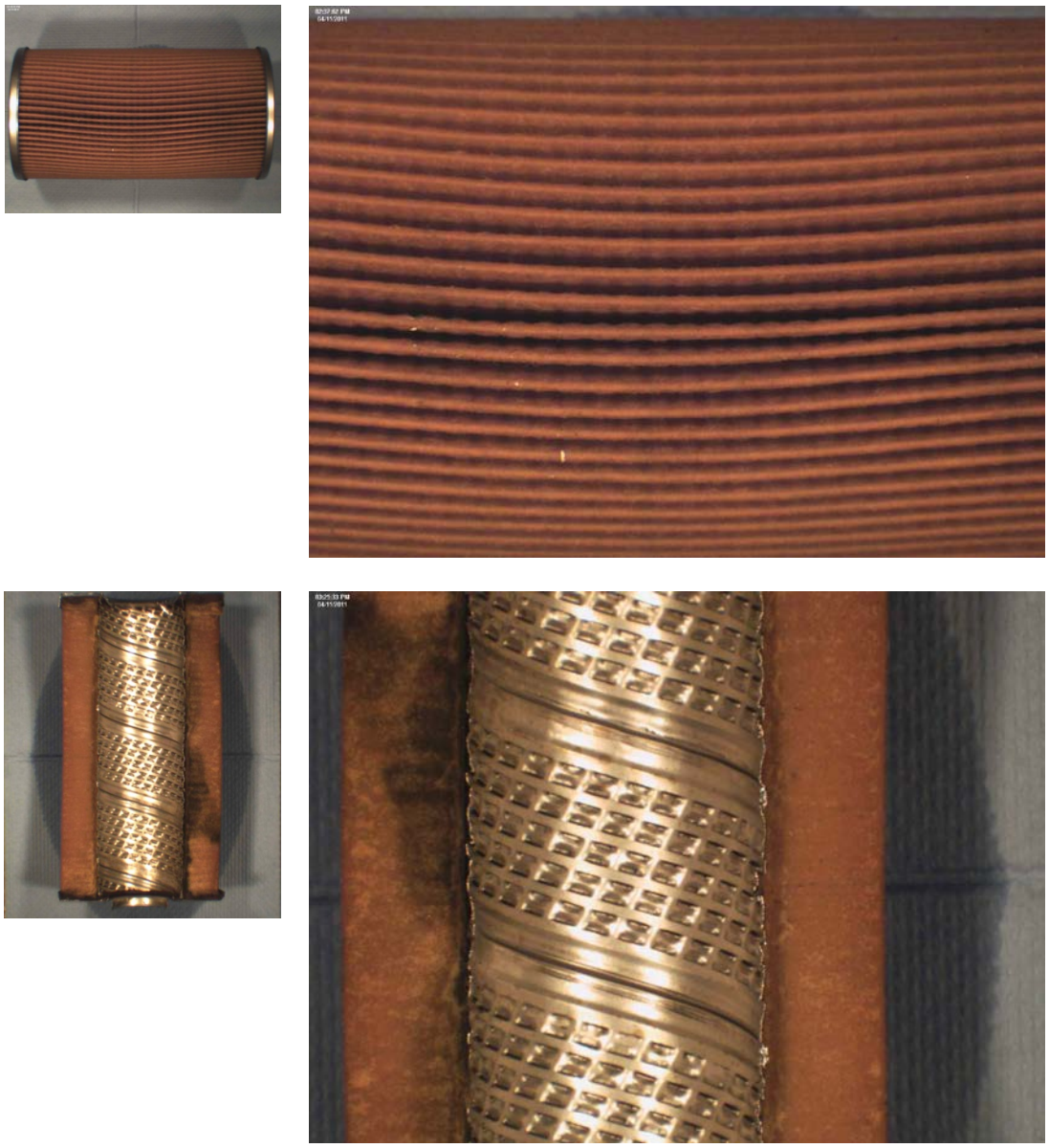

**Figure 27. Fuel Filter for Test AVGP Vehicle on B20 for 15 minutes per month**

The fuel filters for each of the test AVGP vehicles running on B20 at NSWC Crane do not display any visual difference from the control AVGP vehicles running on JP-8.

### 6.1.5 MCBH KANEOHE BAY FUEL TESTING RESULTS

Test results for the vehicle and storage tank samples from MCBH met acceptance criteria for appearance (except initial delivered sample), acid number, viscosity, water and sediment, total water content, and color. Two of the vehicle tank samples failed particulate contamination, with levels of particulate greater than 10 mg/L. For these samples as well, stability was an issue. See Figure 27 for the Rancimat stability results.

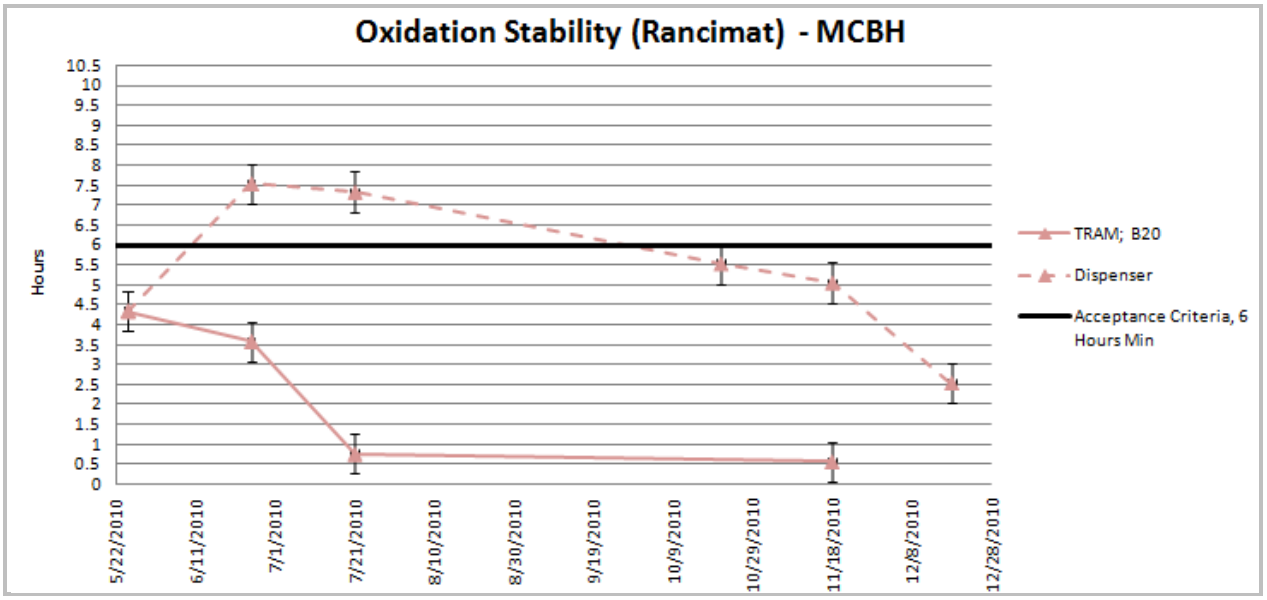


**Figure 28. Rancimat Stability for MCBH Samples**

The D2274, modified, oxidation stability listed in Table 11 and shown graphically in Figure 28 trended in a similar fashion, where the storage tank samples maintained low filterable solids values until the last storage tank sample.

**Table 11. D2274, Modified, Oxidation Stability Results for the MCBH Samples**

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| **Storage Tank** | | | |
| Delivery Sample, 5/27/10 | 19.5 | 14.9 | 0.01 |
| Storage Tank, 6/25/10 | 3.9 | 1.2 | 0.045 |
| Storage Tank, 7/21/10 | 5.3 | 0.1 | 0.039 |
| Storage Tank, 10/21/10 | 2.3 | 0.6 | 0.038 |

| Sample Date | Total Insolubles (mg/100 mL) | Iso-octane Insolubles (mg/100 mL) | Acid Value (mg KOH/g) |
|---|---|---|---|
| Storage Tank; 11/18/10 | 0.5 | 0.5 | 0.07 |
| Storage Tank; 12/18/10 | 465.1 | 388.2 | 0.077 |
| **Vehicle Tank** | | | |
| Vehicle Sample, 5/27/10 | 648 | 177 | 0.080 |
| Vehicle Sample 6/25/10 | 280.3 | 208 | 0.007 |
| Vehicle Sample, 7/21/10 | 576.4 | 747.7 | 0.009 |
| Vehicle Sample, 11/18/10 | 503.6 | 325.8 | 0.009 |

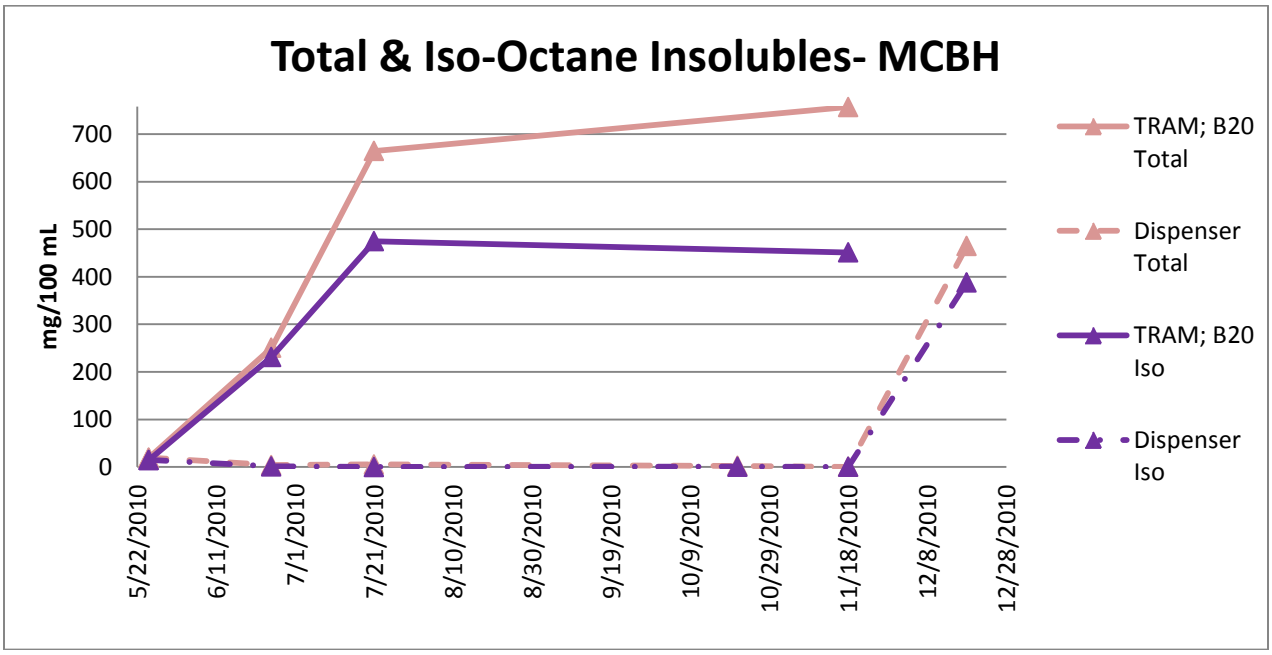


**Figure 29. D2274, Modified, Oxidation Stability Results for MCBH Samples**

The vehicle sample had one hundred times the level of filterable insoluble as the storage tank samples throughout the trial to date. The Total and Iso-octane insolubles were each higher in the vehicle tank than the storage tank. This follows since the fuel in the vehicle tank is exposed to higher temperatures. **Error! Reference source not found.** The table also shows that the Total

and Iso-octane Insolubles for the B20 in the vehicle at MCBH was much higher than the storage tank, the increased insoluables in the vehicles is probably due to thermal stress. See Appendix C for the all the oxidation stability test results.

## 6.2 ENGINE OIL DATA

The used engine oil samples were analyzed according to the ASTM methods, as outlined in Table 12. Monthly samples were taken, and sent to TARDEC for analysis. The results were compiled and reported to the NDCEE, where the data was used as an indicator to determine if the engines/components showed signs of wear or degradation. These results were also used in comparison to the corresponding B20 samples, to determine if any noticeable trends developed between the two samples.

**Table 12. Engine Oil Testing Methods**

| Type of Performance Objective | Primary Performance Testing Method |
|---|---|
| Wear Metals | ASTM D5185 |
| Total Acid Number | ASTM D664 |
| Total Base Number | ASTM D4739 |
| Kinematic Viscosity at 40°C | ASTM D445 |
| Kinematic Viscosity at 100°C | ASTM D445 |
| Viscosity Index | ASTM D2270 |
| Total Water Content | ASTM D6304 |
| Soot Content | ASTM D7686 |
| % Fuel Dilution | ASTM D3524 |

Figure 30 shows a portion of Moody AFB oil testing completed by TARDEC. Areas highlighted in yellow indicate potential abnormalities in the oil.

| Used Engine Oil Analysis – JP8 and B20 used in engines | | 8/20/2009 | 8/20/2009 | 8/20/2009 | 8/20/2009 | 8/20/2009 | 8/20/2009 |
|---|---|---|---|---|---|---|---|
| | | --- | 2008 Bobtail; Ford; FLTT350 | 2008 Bobtail; Ford; FLTT350 | 1997 Bobtail; Dodge; Ram 2500; | R-11 Refueler; INT; 7400 | R-11 Refueler; INT; 7401 |
| Work Order | | WO#00654 | WO#00654 | WO#00654 | WO#00654 | WO#00654 | WO#00654 |
| Sample Number | QPL | FL-13267-09 | FL-13268-09 | FL-13269-09 | FL-13270-09 | FL-13271-09 | FL-13272-09 |
| Description | | Baseline Oil | B20 used | Diesel used | B20 used | Diesel used | B20 used |
| ASTM D 5185 – Wear Metals by ICP (ppm) | | | | | | | |
| Ag | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Al | | 1.7 | 2.9 | 3.4 | 2.4 | 2.2 | 1.1 |
| B | 0 | 3.0 | 10.3 | 10.3 | 5.3 | 2.5 | 2.0 |
| Ba | 0 | <0.5 | 1.6 | 1.1 | <0.5 | <0.5 | <0.5 |
| Ca | 2810 | 2477.0 | 2392.0 | 2413.0 | 2438.0 | 2354.2 | 1864.9 |
| Cd | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Cr | | <0.5 | 0.8 | 0.6 | 1.5 | 0.5 | <0.5 |
| Cu | 0 | <0.5 | 4.5 | 5.2 | 2.2 | 2.4 | 0.6 |
| Fe | | 1.9 | 15.9 | 19.5 | 9.3 | 6.6 | 3.3 |
| K | 0 | 2.0 | 4.3 | 9.4 | <0.5 | <0.5 | <0.5 |
| Mg | 10 | 7.3 | 6.5 | 6.7 | 8.2 | 541.1 | 494.3 |
| Mn | | <0.5 | 0.6 | 0.6 | 0.5 | <0.5 | <0.5 |
| Mo | | 1.4 | <0.5 | 0.5 | 0.6 | 0.7 | <0.5 |
| Na | 0 | 5.5 | 13.1 | 12 | 3.5 | 4.6 | 3.7 |
| Ni | | <0.5 | <0.5 | 0.8 | 0.5 | <0.5 | <0.5 |
| P | 1140 | 1128.0 | 1095.0 | 1133.0 | 1159.0 | 1379.0 | 1209.0 |
| Pb | | <0.5 | 1.5 | 2.0 | 0.7 | 2.4 | 0.7 |
| Si | 10 | 6.5 | 13.7 | 12.4 | 3.9 | 4.6 | 4.0 |
| Sn | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Ti | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| V | | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 | <0.5 |
| Zn | 1300 | 1230.0 | 1195.0 | 1214.0 | 1219.0 | 1505.0 | 1275.0 |
| ASTM D 664 – Total Acid Number (mgKOH/g) | | 2.210 | 2.420 | 2.460 | 2.300 | 2.670 | 2.825 |
| ASTM D 4739 – Total Base Number | | 7.631 | 7.318 | 7.219 | 7.631 | 6.918 | 7.710 |
| ASTM D 445 – Kin. Visc. @ 40C (cSt) | | 109.60 | 102.45 | 103.40 | 105.00 | 67.52 | 97.96 |
| ASTM D 445 – Kin. Visc. @ 100C | | 14.88 | 14.13 | 14.25 | 14.40 | 10.32 | 13.45 |
| ASTM D 2270 – Viscosity Index | | 140.6 | 140.5 | 140.9 | 140.7 | 139.3 | 137.1 |
| ASTM D 6304 – Water Content (%) | | 0.064 | 0.077 | 0.073 | 0.072 | 0.105 | 0.098 |
| Soot Content by Soot Meter | | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ASTM D 3524 – Fuel Dilution (%) | | 0.000 | 0.000 | 0.000 | 0.000 | 6.801 | 1.461 |

**Figure 30. Example Oil Data Set from Moody AFB**

Updated spreadsheets were submitted by TARDEC to the NDCEE on a quarterly basis. As with the biodiesel results, an oil results spreadsheet, graphs, and database were updated by the NDCEE staff. See Appendix D, B20 Oil Data for raw oil testing results submitted by TARDEC.

### 6.2.1 MOODY AFB OIL TESTING RESULTS

The oil test results for Moody AFB showed that the test and control vehicles trended similarly for each type of vehicle. There were no significant findings in the wear metals test results. However, there were some trends identified with the Refueler vehicles as opposed to the other two vehicle sets. See Figure 31, 31, and 32 below to view the trends in fuel dilution and viscosity.

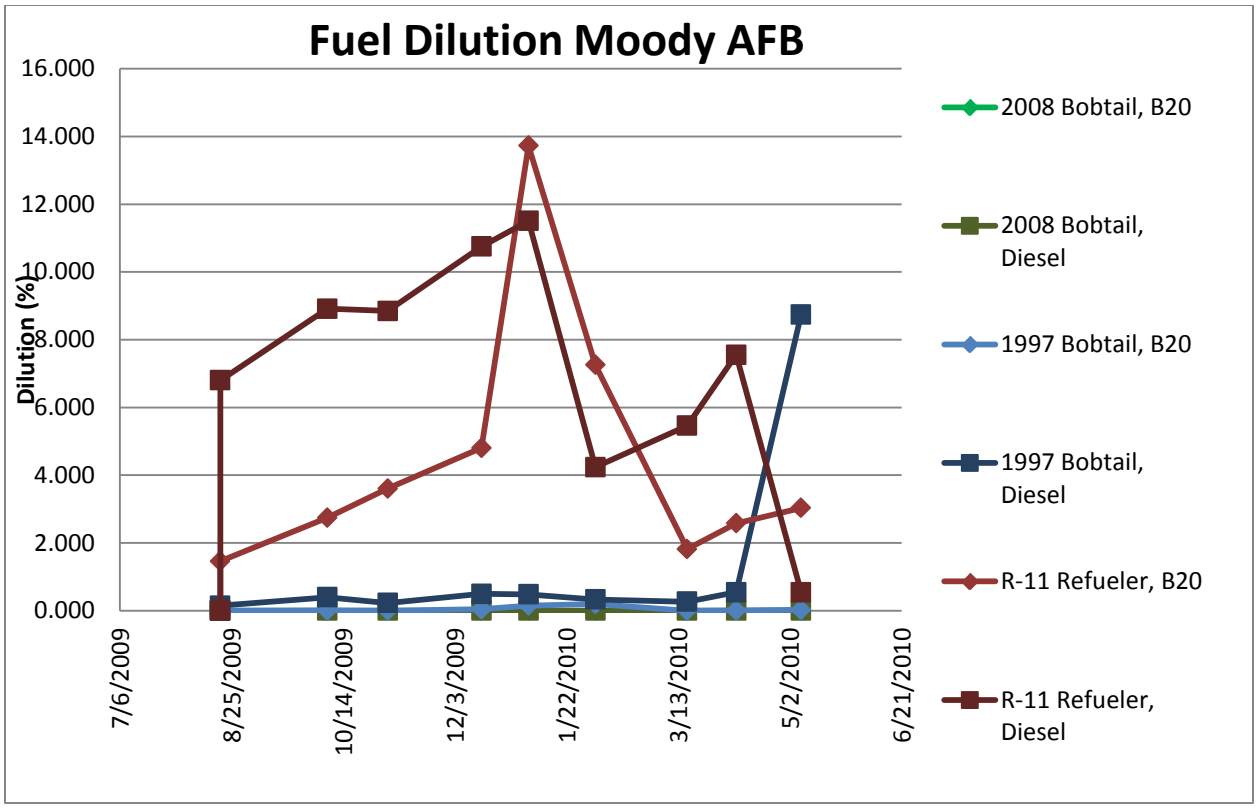


**Figure 31. Fuel Dilution Results for Moody AFB Oil Samples**

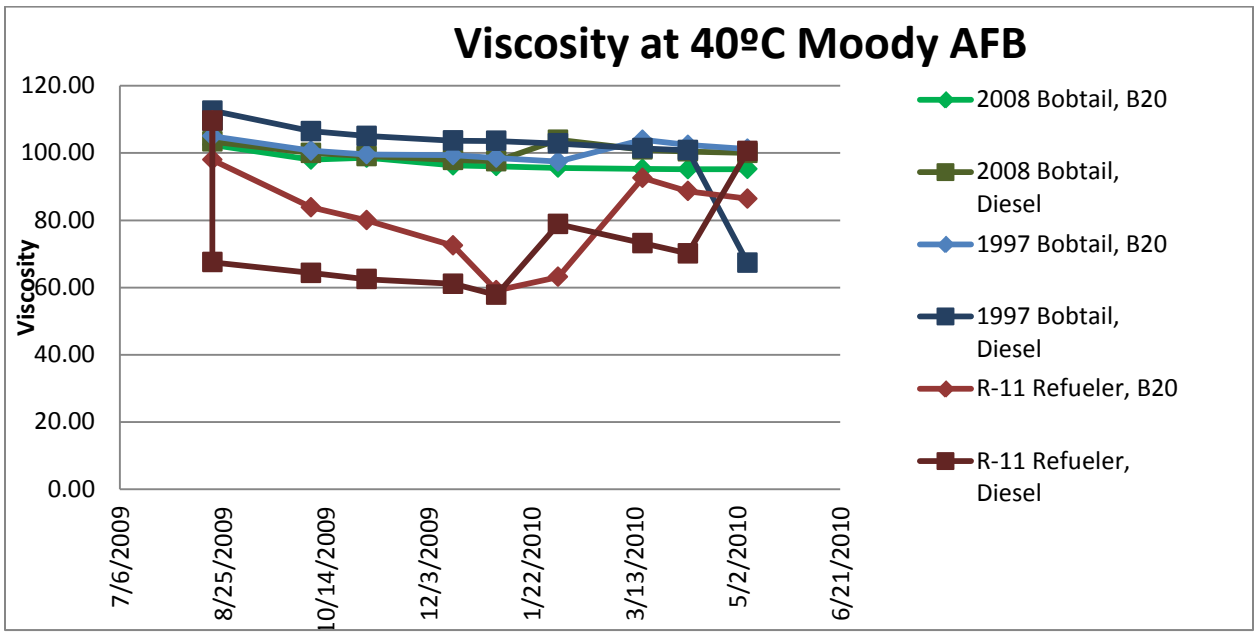


**Figure 32. Engine Oil Viscosity at 40°C for Moody AFB Oil Samples**

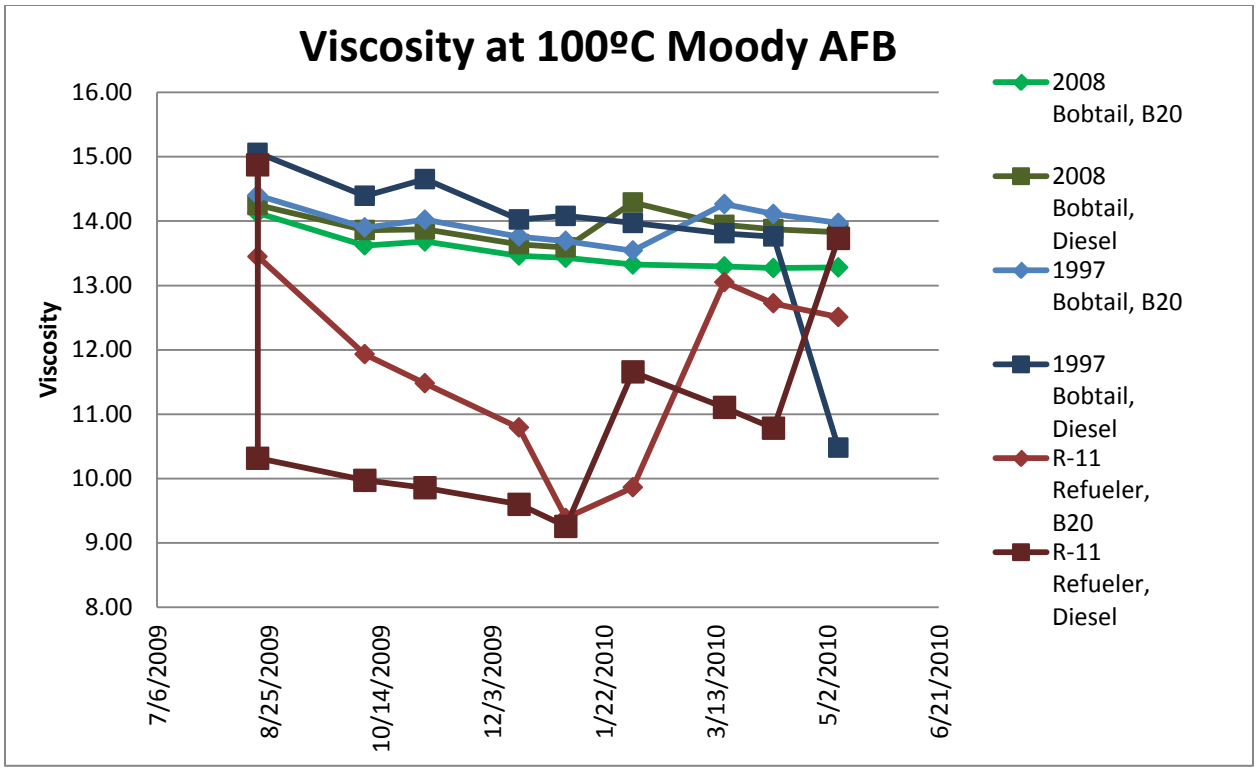


**Figure 33. Engine Oil Viscosity at 100°C for Moody AFB Oil Samples**

From the Figures, it appears that there is potential fuel contamination in the oil for the Refueler, whether running on diesel fuel or B20 blend. This contamination also causes a decrease in engine oil viscosity. Overall, there does not appear to be any effect from B20 on the vehicle engines at Moody AFB.

### 6.2.2 29 PALMS OIL TESTING RESULTS

The test results for 29 Palms showed that the vehicles trended the same throughout the test. The only anomalies in the wear metals data were increased concentrations of molybdenum and magnesium in the oil samples from both vehicles and increasing lead levels in the vehicle operating on JP-8. The only oil analysis property that appeared to change over time with respect to the vehicles was viscosity. The viscosity of the oil from the vehicle operating on JP-8 increased over time while the viscosity of the oil from the vehicle running on B20 blend remained fairly constant. Please see Figure 34  34 and 35.

The 12/09/09 test sample appears to be an anomaly. The test sample may have been contaminated or not drawn correctly. The sample, WO#00693 was labeled “sample would not run” for ASTM D 445). It does not match the pattern for viscosity results for previous or later oil samples.

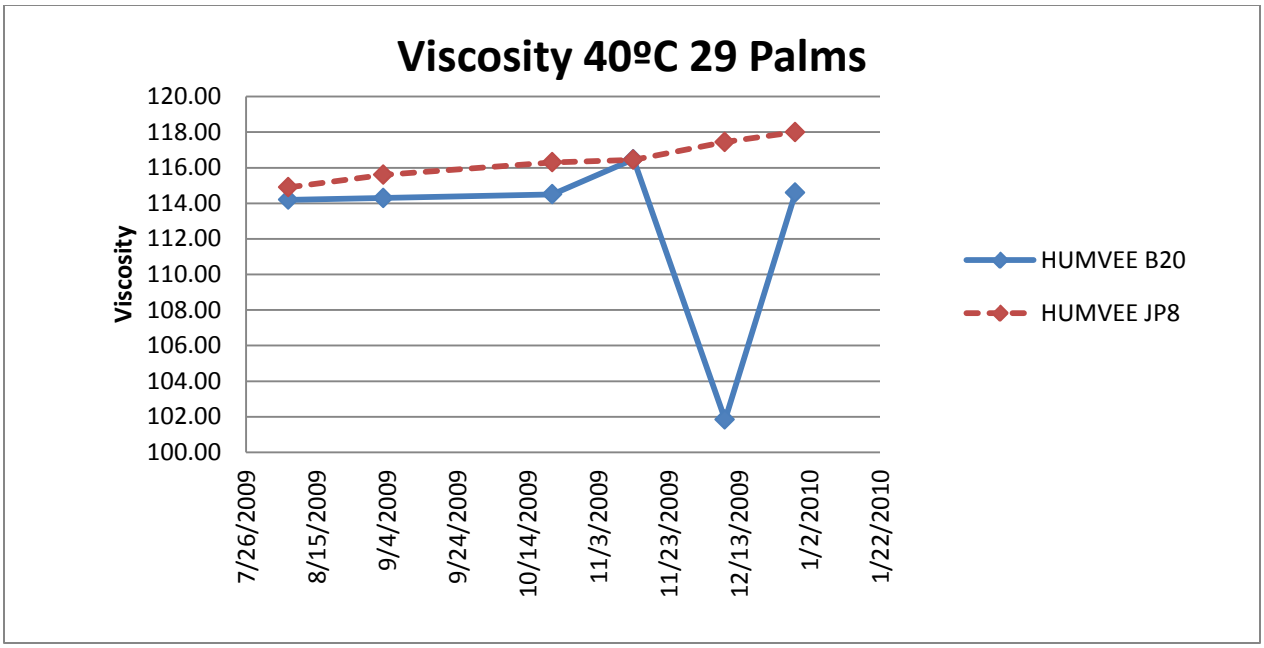


**Figure 34. Engine Oil Viscosity at 40°C for 29 Palms Oil Samples**

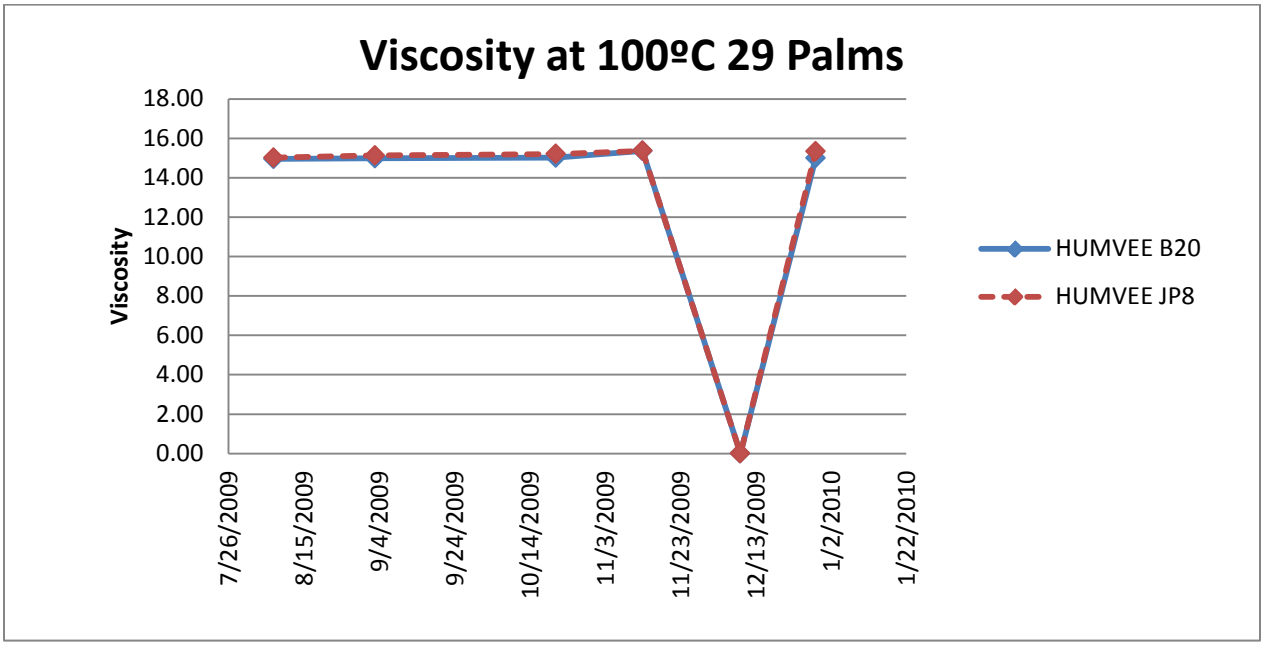


**Figure 35. Engine Oil Viscosity at 100°C for 29 Palms Oil Samples**

### 6.2.3 NBVC PORT HUENEME OIL TESTING RESULTS

The wear metals results for the NBVC samples trended very consistently, with higher levels of silver, calcium, and copper detected in these samples when compared to the other locations.

There were no significant changes or differences between the vehicles for any of the oil physical properties tests.

### 6.2.4 NSWC CRANE OIL TESTING RESULTS

For the vehicles operated at NSWC Crane, there were similar trends in the data between the test and control vehicles. There were no anomalies in the wear metals data, with the exception that the barium content was higher for all Crane vehicles when compared to the vehicles from other locations. There were some noticeable trends in the physical properties over time. For all vehicles, the engine oil viscosity decreased, while the fuel dilution increased for three of the four vehicles in the study. Water content and total base number remained relatively stable throughout the trial. Please see Figure 36, 36, and 37 for the fuel dilution and viscosity charts.

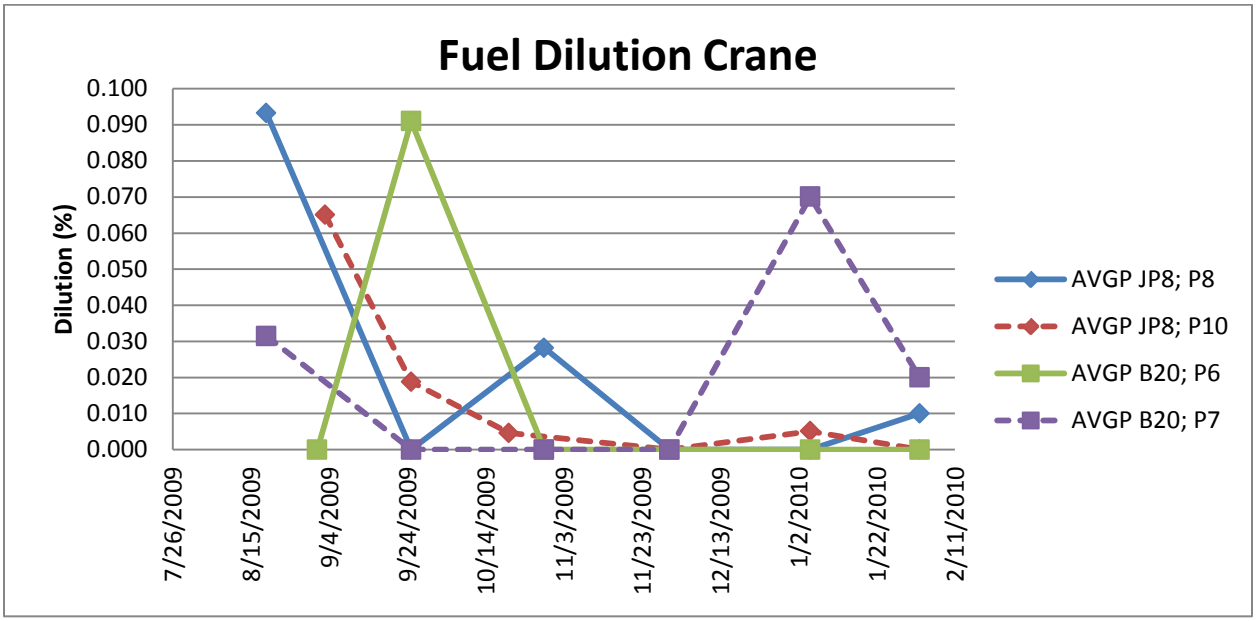


**Figure 36. Fuel Dilution Results for NSWC Crane Oil Samples**

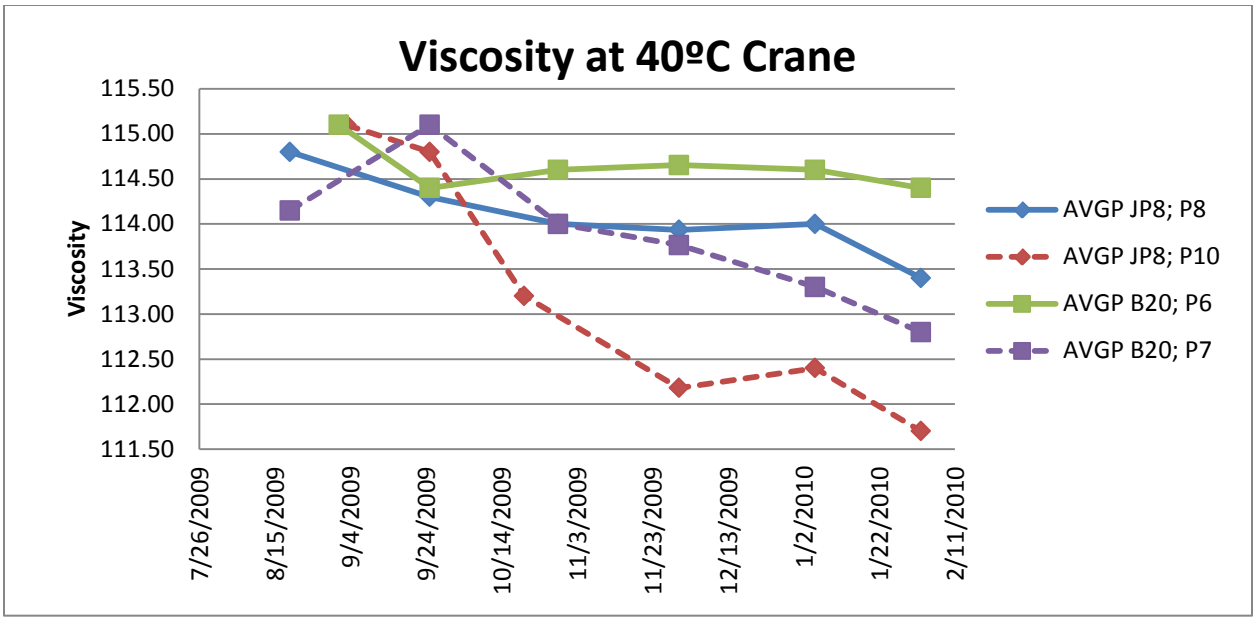


**Figure 37. Engine Oil Viscosity at 40°C for NSWC Crane Oil Samples**

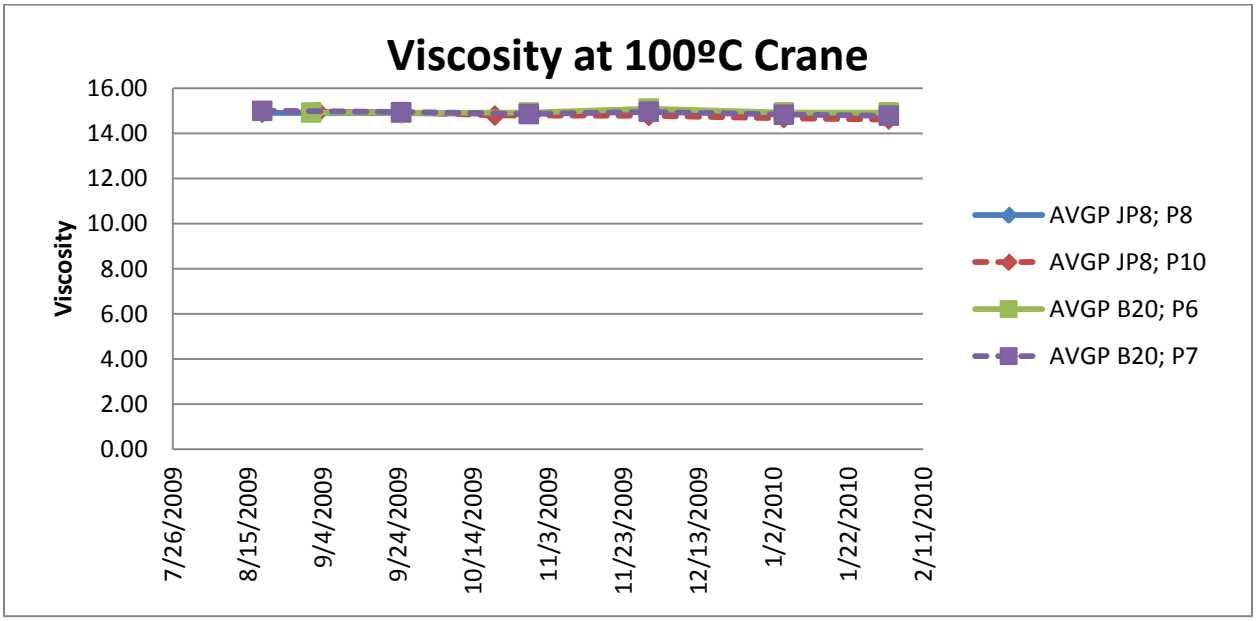


**Figure 38. Engine Oil Viscosity at 100°C for NSWC Crane Oil Samples**

### 6.2.5 MCBH KANEOHE BAY OIL TESTING RESULTS

For the engine oil samples received from the test and control vehicles at MCBH, the wear metals results showed some spikes in manganese, sodium, and nickel concentrations, but the results are not consistent with the limited number of data points. The same is true for the physical property data. There are currently only two data points for each vehicle, so trending and comparison of data is not possible.

## 6.3 SUMMARY OF RESULTS

### 6.3.1 FUEL DATA

**Visual Appearance and Water and Sediment:** For the appearance test, the visual appearance of the fuel was recorded for each sample. This data cannot be trended in chart form so a brief description of the results will be provided. First, for the vehicles and storage tank at Moody AFB, vehicle # 97C00410, the 1997 Bobtail, consistently had failures in appearance due to haze or cloudiness. Then, beginning with the February 2010 samples, approximately at the half-way point in the study, the samples from the other two vehicles began to show failures due to cloudiness. These results varied from month to month. All samples received from NBVC and 29 Palms passed appearance, as well as the vehicle and storage sample from MCBH. For the vehicle and storage samples from NSWC Crane, two of the vehicle samples, for the AVGP P-7 vehicle, failed appearance during the year-long trial.

All samples received had water and sediment values less than the acceptance criteria of 0.05 volume percent, max. See the data listed in Appendix C.

**Acid Number:** As shown in Figure 39 and 39, all samples passed acid number testing, having results less than the acceptance criteria of 0.2 mg KOH/g.

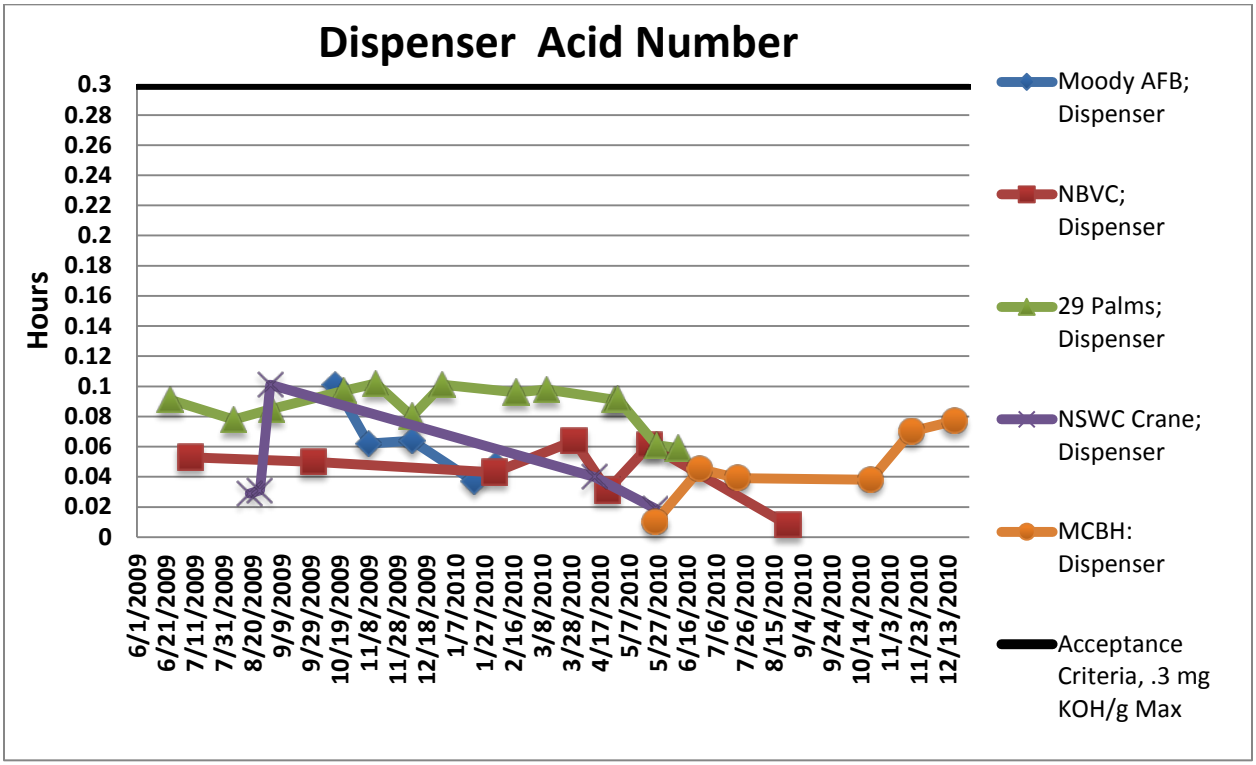


**Figure 39. B20 Acid Number Results for the Storage Tank Samples**

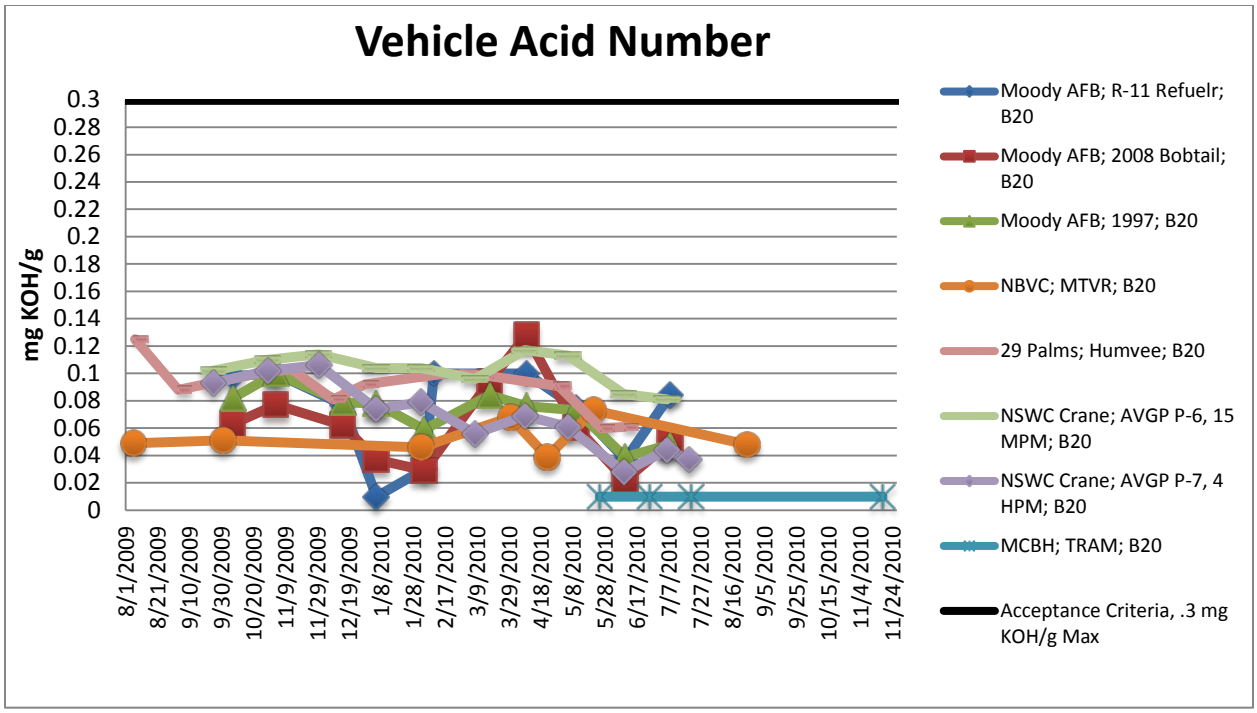


**Figure 40. B20 Acid Number Results for Vehicle Samples**

**Kinematic Viscosity at 40°C:** All samples from all locations were within the viscosity range of the acceptance criteria of 1.9 to 4.1 $mm^2$/sec.

**Total Water:** Figure 41 and 41 present the summarized results for total water content. As discussed earlier in this report, since the majority of the samples contained 0.02% total water, or more, these results demonstrate the tendency of biodiesel blends to hold more water than petroleum diesel fuel. Often the water is picked up in the fuel delivery and storage system; other times the water is in the vehicle storage tank. The fact that all of the samples passed the water and sediment test means that most of the water in these samples was likely either dissolved or highly emulsified because of the biodiesel. This emulsified water may account for the numerous failed haze ratings for visual appearance. This means an increased possibility that water will move into the vehicle fuel system and aid in the corrosion of metal surfaces. For these reasons, keeping the system as dry as possible has to be a priority when using biodiesel.

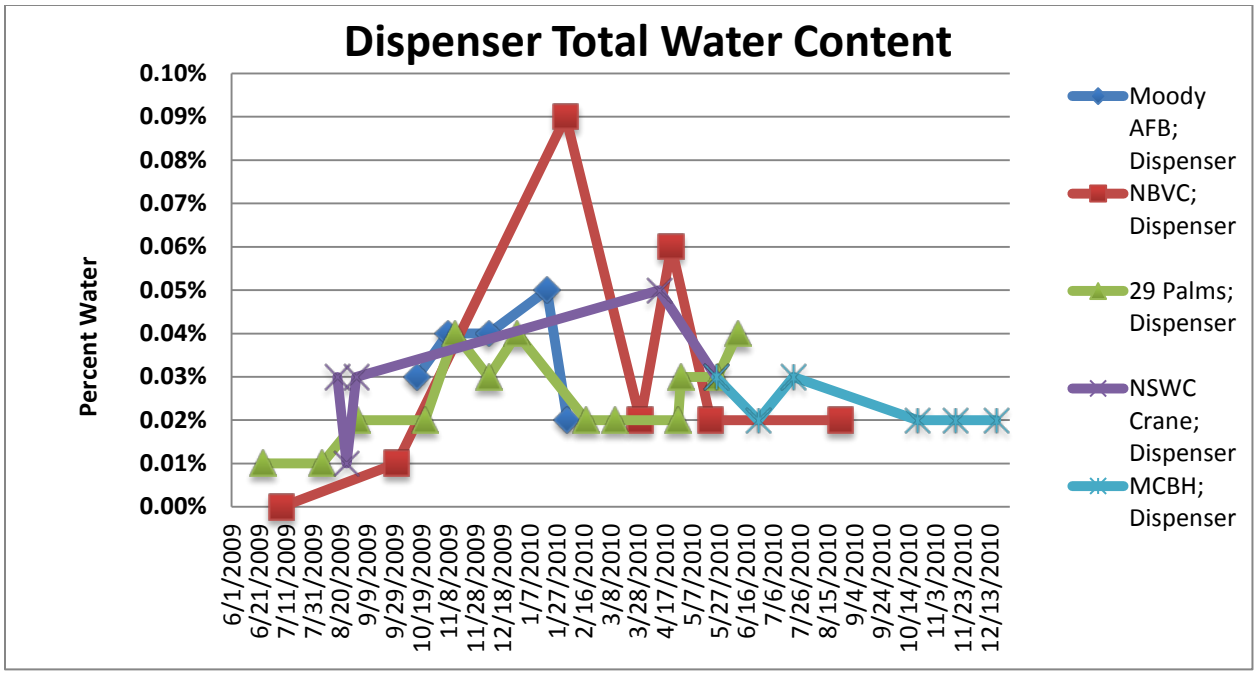


**Figure 41. Total Water Content for Dispenser Samples**

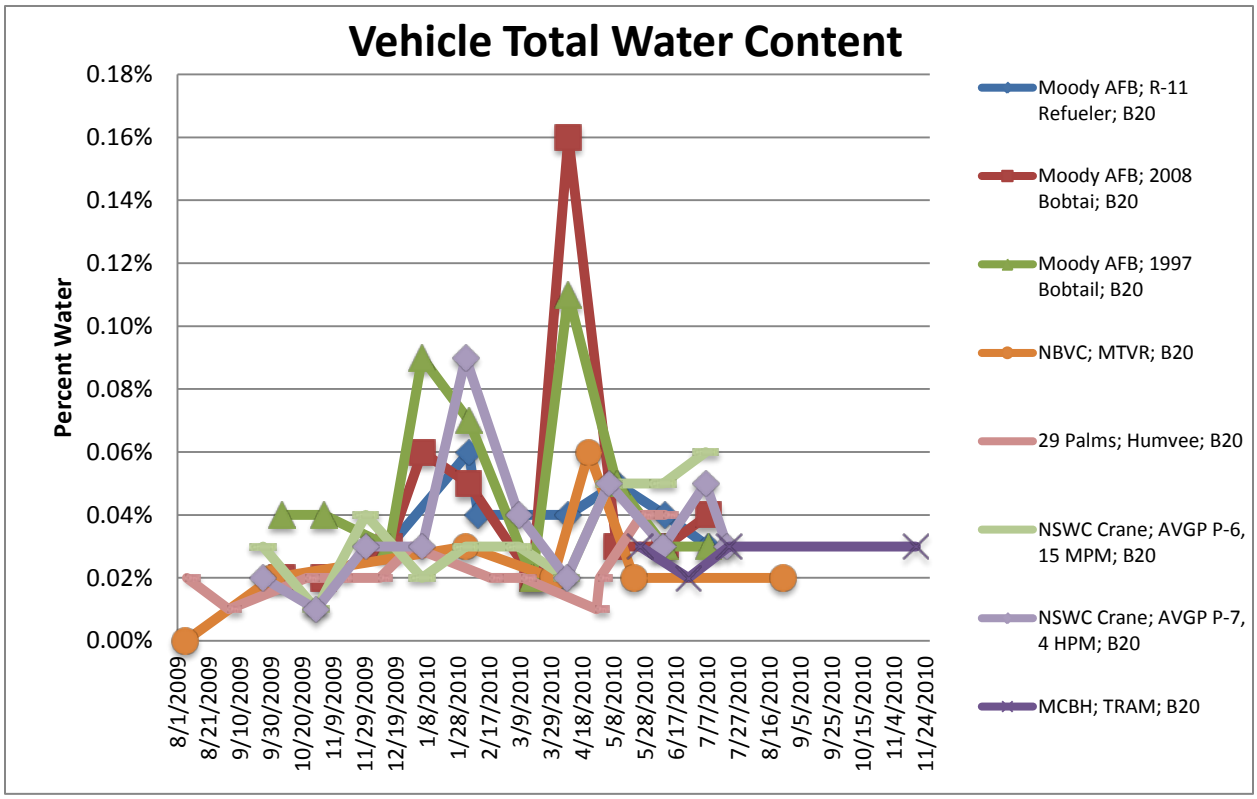


**Figure 42. Total Water Content Results for the Vehicle Samples**

**Color:** The pass/fail limit for this test is a color rating of 3 or less. All samples tested, both fuel tank and storage tank, met this requirement. In almost all instances, sample results were less than 1.5. Test results for each sample are located in tables in Appendix C.

**Particulate Content:** Figure 43 and 43 show the results of the particulate content test for the vehicle and storage tank samples. The acceptance criterion for this test is 10 mg/L, maximum. All storage tank samples met the test criterion, which is indication that the fuel, as delivered, and during storage, was clean. However, two locations had incidences where the vehicle samples did not meet the test requirements. Moody AFB had two vehicles, during two different sampling events, fall outside the limits of the test. Both vehicles had results for the next month's samples within the testing limits. The periodic increases in particulates may have been caused by increased contaminants (dirt, etc.) in the fuel tanks, materials incompatibility, or they may represent anomalies in the testing process. Since fuel is filtered before passing from storage tank to vehicle, another cause of contaminates is through fuel break down in the vehicle. In general, the particulate content results show that the storage tanks and vehicle fuel tanks were relatively clean and tended to stay that way throughout the program.

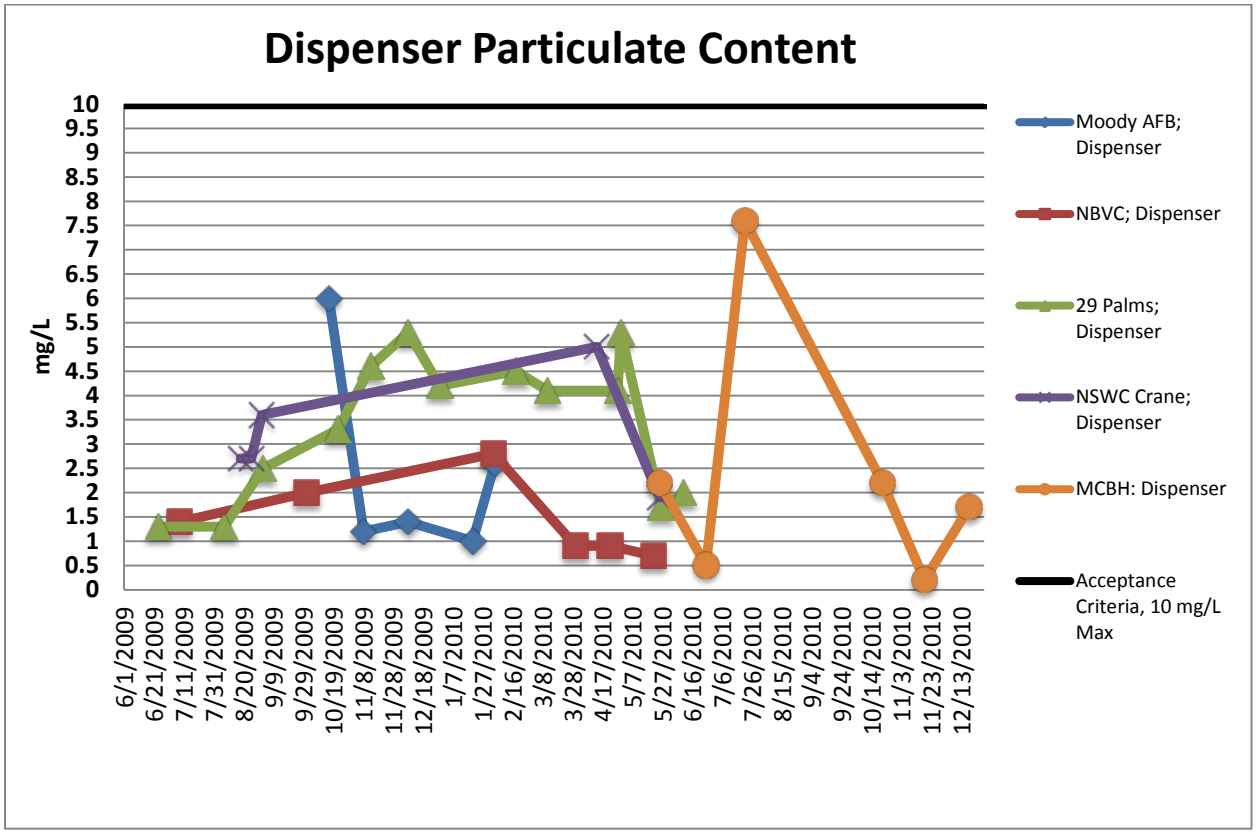


**Figure 43. B20 Particulate Content Results for Storage Tank Samples**

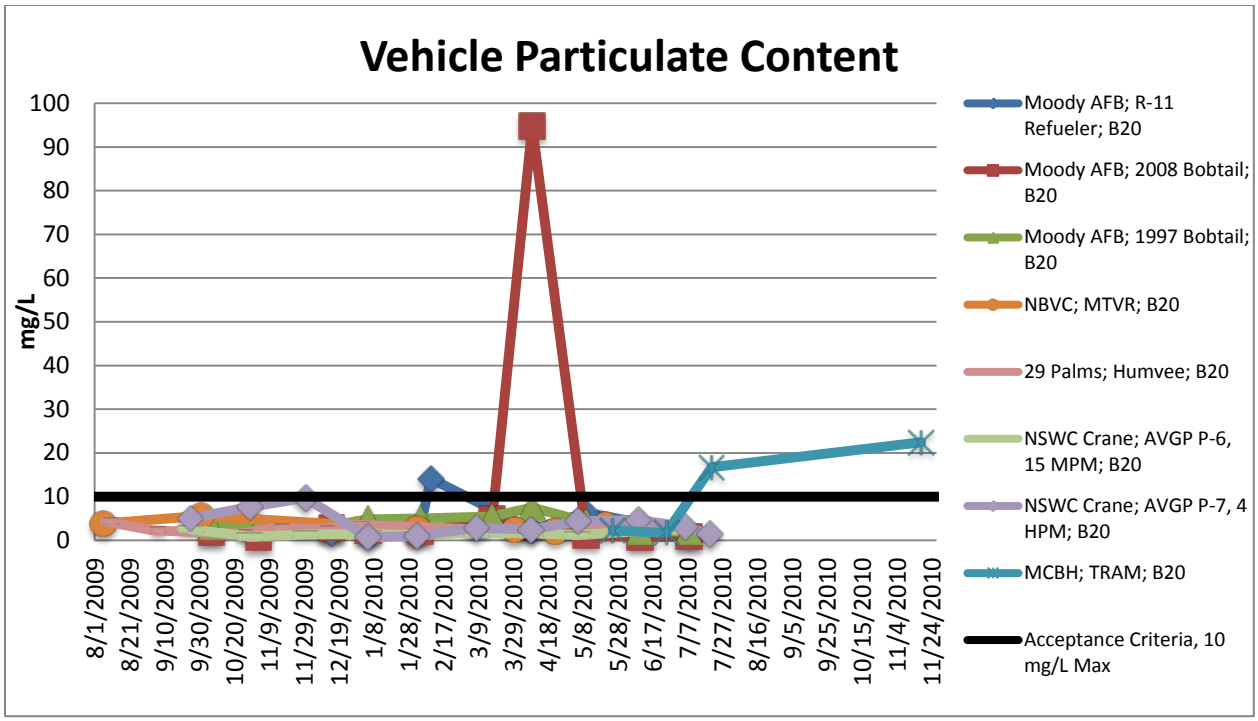


**Figure 44. B20 Particulate Content Results for Vehicle Samples**

**Rancimat Oxidation Stability:** The summarized stability test results are shown in Figure 45 and Figure 46. This test measures the rate at which volatile compounds (mostly acids and peroxides) are formed during the oxidation of the test sample. The oxidation of the sample is caused by blowing air over the surface of the sample while it is heated to 110°C. The volatile compounds are collected in a vessel of water; and, the conductivity of the water is measured throughout the test. When the rate of change of the conductivity reaches a certain point, the algorithm that controls the test determines that the fuel has reached its induction period. When evaluating the results of this test, it is important to remember that the 6-hour minimum is a specification requirement. Based upon test measurements in the vehicle fuel tanks in this study, blends with less than 6-hour induction periods are still useful fuels that will likely cause no problem if used in the near future. A reduction in the measured induction period of fuel in storage means that the fuel has been oxidized to some degree; but, that oxidation may have caused no appreciable degradation to the fuel. In some cases, oxidation of biodiesel causes an increase of particulates, acid number, or water shedding characteristics. Only measurement of these properties will determine if such changes have indeed occurred. So, it should be remembered that changes in Rancimat induction period do indicate some change in the fuel but do not necessarily mean the fuel is no longer usable.

In general, the vehicle samples as shown in Figure 44 failed to meet the minimum acceptance requirement in a number of cases, as compared with their respective storage tank samples. These reductions in induction period may be the result of storage time, or storage conditions (heat, water, contaminants, etc.), or both. The reductions in the induction periods of the vehicle sample could be mitigated by quicker turnover of the fuel in the vehicle, diluting contaminants and/or addition of antioxidants to the blend. Note in Figure 45 and Figure 46 that many of the samples

showed varying results throughout the program. The longer induction periods tended to be in the colder times of the year. Replenishing fuel in vehicles with fresh fuel will also improve the oxidation stability of the fuel in the tank.

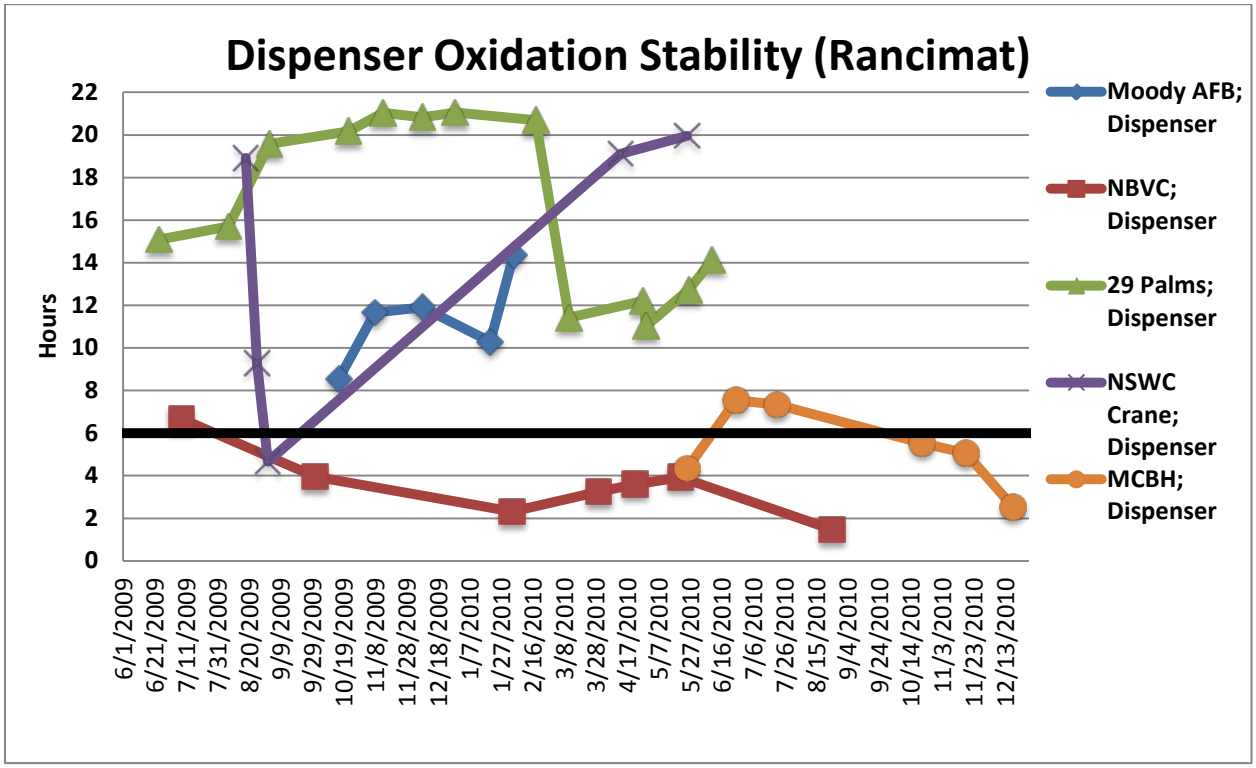


**Figure 45. B20 Rancimat Oxidation Stability Results for Storage Tank Samples**

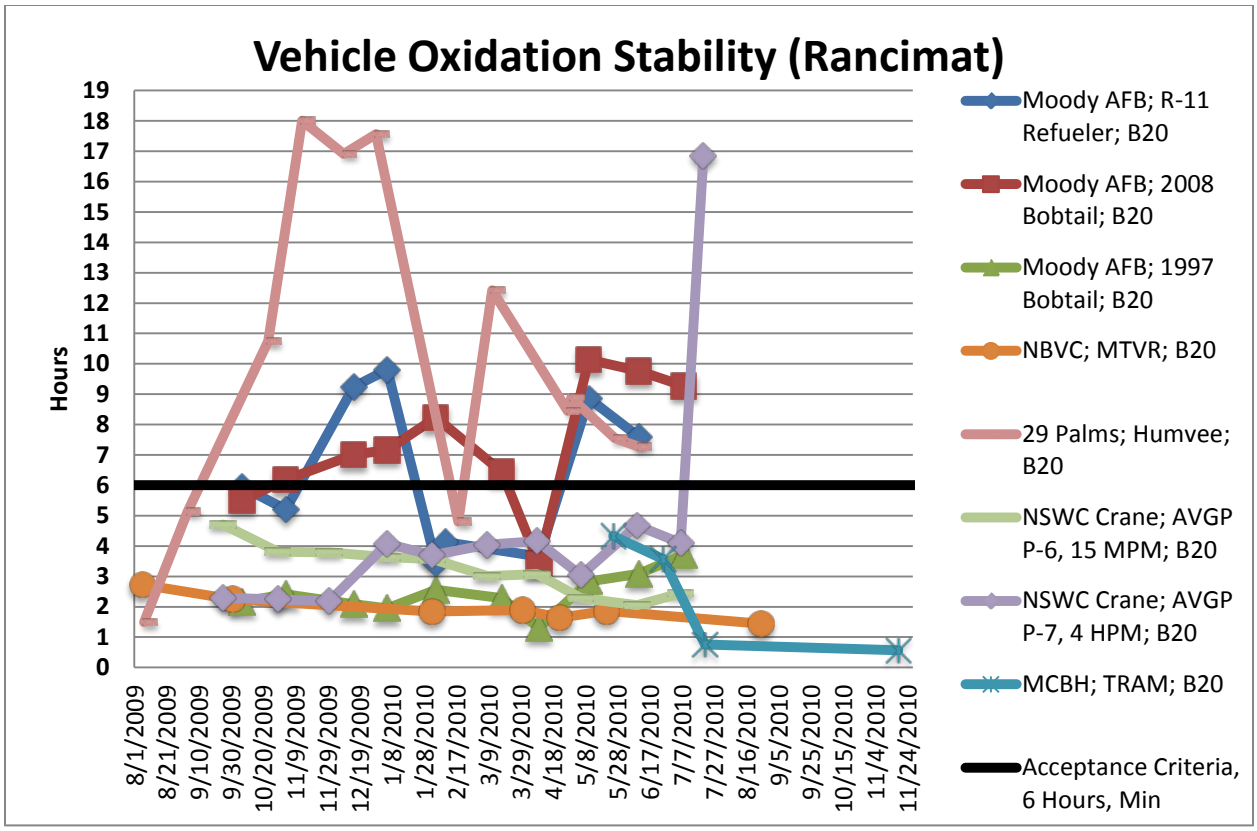


**Figure 46. B20 Rancimat Oxidation Stability Results for the Vehicle Samples**

**Modified ASTM D2274 Oxidation Stability Test:** By the time of this writing, this procedure has been published at ASTM D7462. The reader is invited to read D7462 for a complete description of the test. The summary of the test, as found in D7462, is located in Appendix C.

This test method has no generally-accepted pass/fail limits. It is most useful as an indicator of the tendency of a given biodiesel/biodiesel blend to form insoluble material during oxidation. Review of the data located in Appendix C shows a number of potential trends. As the samples from Moody AFB show, the 1997 Bobtail consistently had the highest concentrations of filterable materials throughout the trial. This is the same vehicle that had high water content and failing Rancimat stability results. The other two vehicles at Moody and the storage tank samples all had comparable results. For the 29 Palms vehicle and storage tank samples, the initial vehicle sample had high results for insoluble content, but then all remaining samples were consistently low. However, both the storage tank and vehicles samples for NBVC showed very high levels of insolubles, which match the trends of failing Rancimat oxidation stability values for these same samples. For NSWC Crane, the storage tank samples all had low results for concentrations of filterable solids. However, the samples from the two vehicles had consistently higher results, being at least one order of magnitude higher in insoluble content than the storage tank samples. This large change in stability between the storage tank and the vehicle tank may be due to residual contamination or water in the vehicle tank that could assist with premature breakdown of the biodiesel component of the fuel, but the fuel may break down even in the absence of water

or residual contamination. One thing is clear: the fuel does break down faster in the vehicle tank than in the storage tank.

An overall summary of the fuel results shows that, in most cases, the B20 with good initial stability (as shown by Rancimat results) does not deteriorate over time in the storage tanks. Generally, the fuel properties remained consistent throughout the test, with some locations, such as 29 Palms, having consistently high-performing fuel, while other locations had a lesser-performing blend. Also, it appears that, in some instances, the fuel sitting in the vehicle tanks did deteriorate. For the locations that measured very high Rancimat results (Crane and 29 Palms), the fuel in the vehicles did not have visible breakdown during the duration of the demonstration. Two locations, Port Hueneme and Kaneohe Bay, had only one delivery during the total & iso-octane insolubles fuel test. Consequently the fuel tests showed more deterioration (more insoluables), including very high counts in the vehicle.

### 6.3.2 WEATHER DATA

**Relative Humidity:** When the temperature is high and the relative humidity is low, evaporation of water is rapid; soil dries, wet clothes hung on a line or rack dry quickly, and perspiration readily evaporates from the skin.

When the temperature is high and the relative humidity is high, evaporation of water is slow. When relative humidity approaches 100 percent, condensation can occur on surfaces, leading to problems with mold, corrosion, decay, and other moisture-related deterioration. Figure 47 and Figure 48 show the average humidity and temperature for each site.

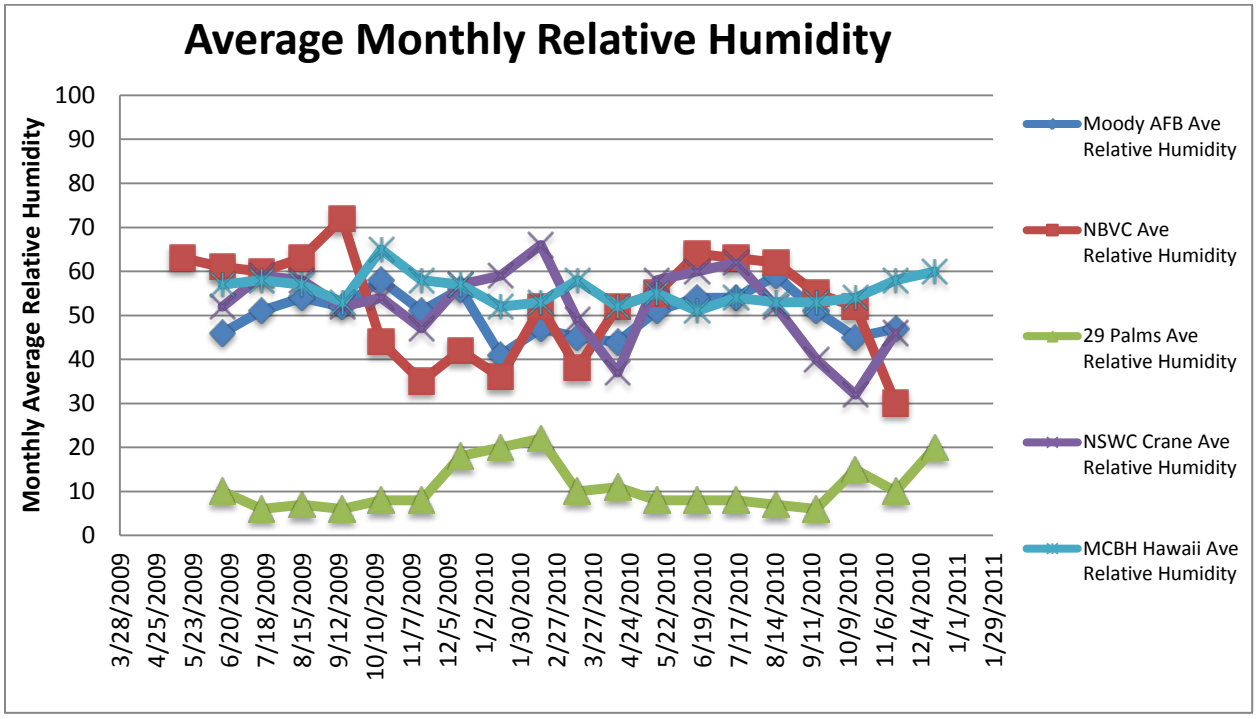


**Figure 47. Average Monthly Relative Humidity per Site**

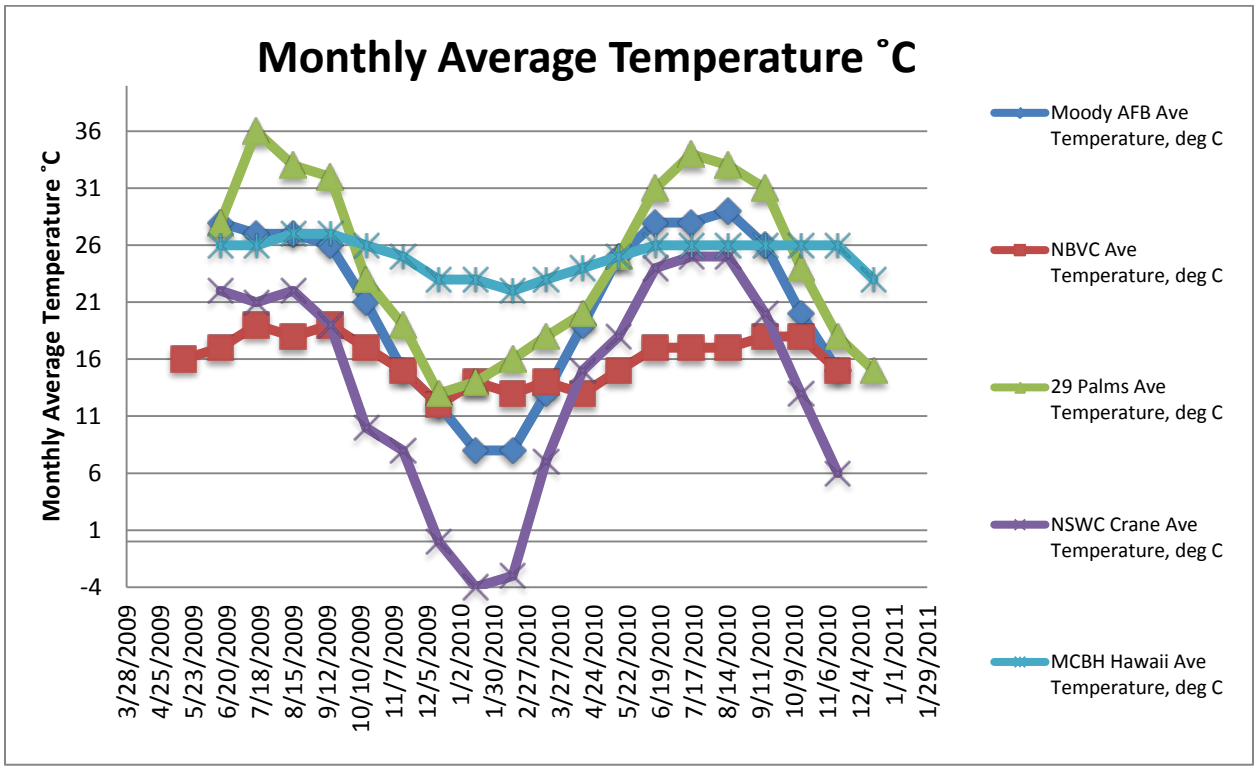


**Figure 48. Average Monthly Temperature (˚C) per Site**

Figure 47 shows that 29 Palms had a relative humidity level much lower than the rest of the sites. The remaining sites each had comparable levels of relative humidity throughout the year.

Figure 48 shows that temperature range was the most diverse in NSWC Crane. The average temperature was below freezing between December and February.

### 6.3.3 OIL DATA

Please see Appendix D for raw oil data submitted by TARDEC. As noted in the test methodology section, there were no acceptance criteria listed for the oil analyses. Testing was conducted for comparison purposes only.

The first testing results reviewed and compared were wear metals. There were a few trends noted when comparing results between the locations. First, vehicles from 29 Palms had consistently higher levels of boron, magnesium, molybdenum, zinc, and silicon than the other locations. And, samples from NSWC Crane had the highest boron content, while the NBVC samples had the highest silver and copper content. There were no significant trends or differences between test and control vehicles at any of the locations, with the exception of the HMMWVs at 29 Palms. The control vehicle running on JP-8 had consistently higher levels of zinc, silicon, and sodium than the test vehicle. Some of the charts of the wear metals results are listed in Figure 49 to 53.

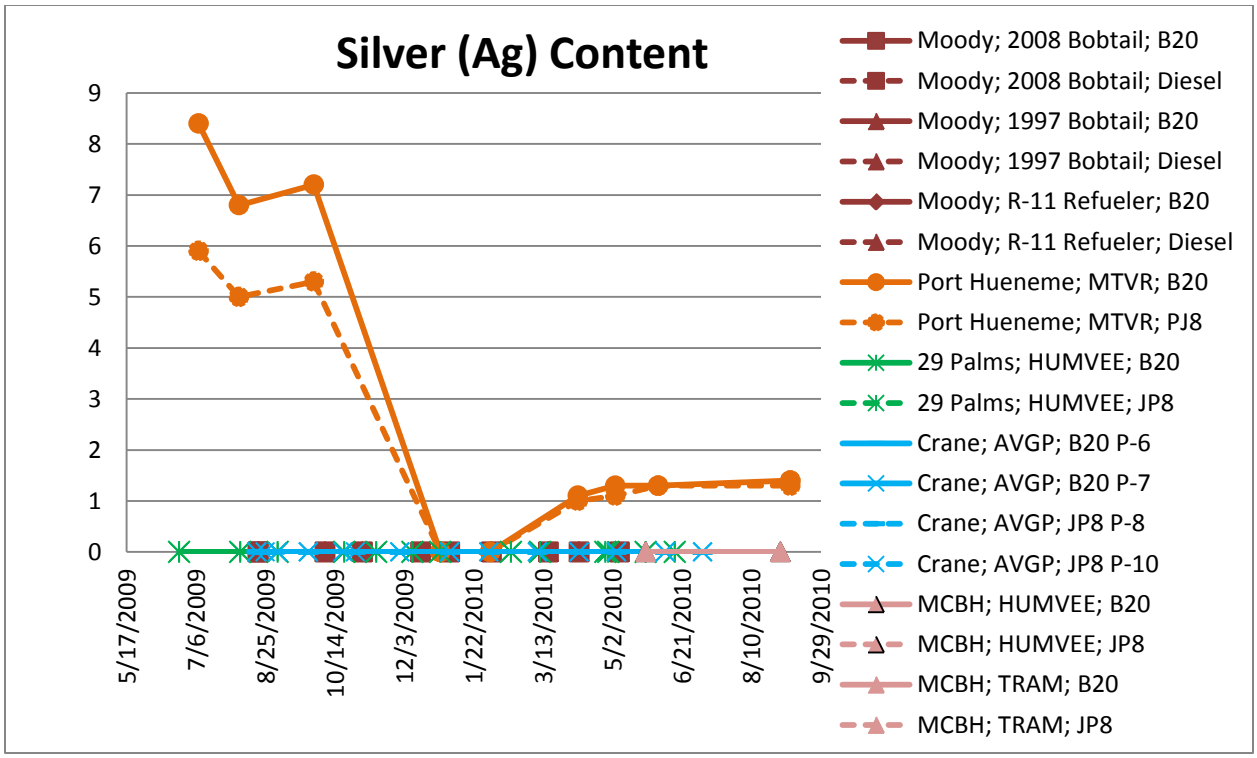


**Figure 49. Wear Metals Results for Silver Content**

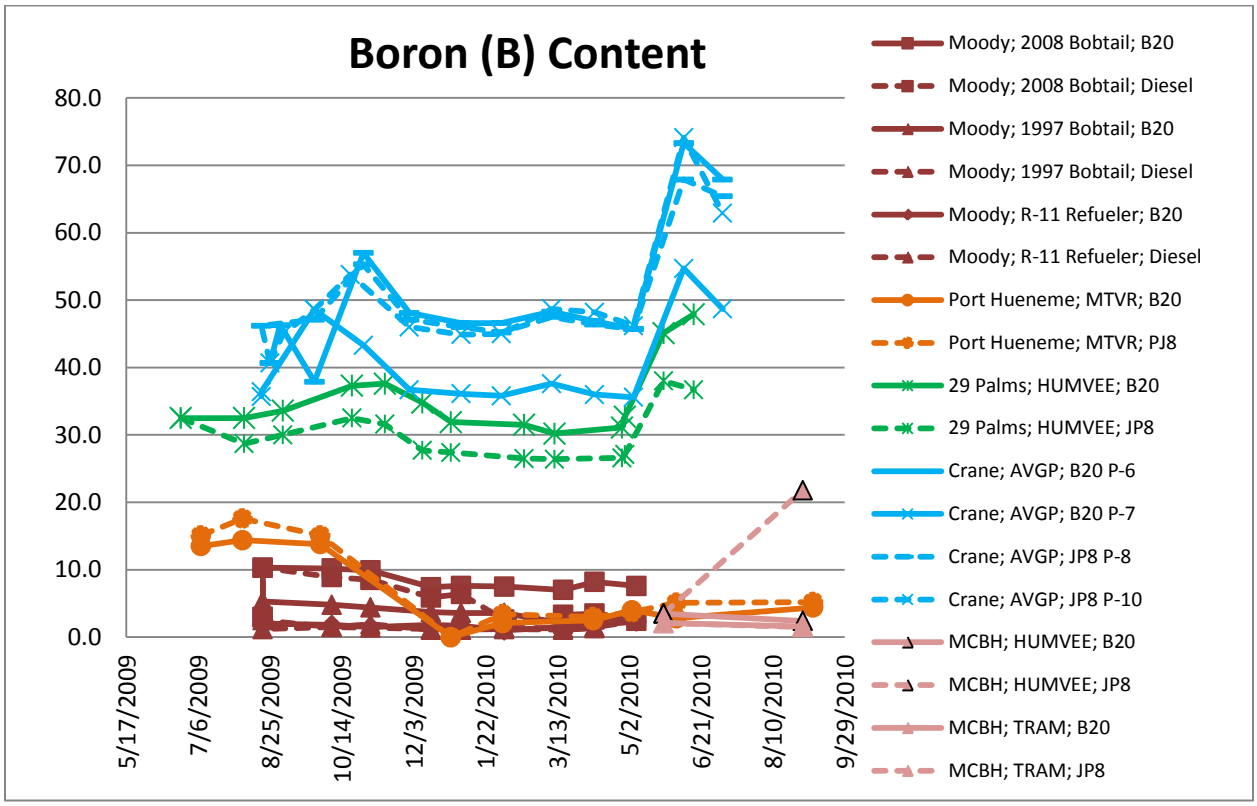


**Figure 50. Wear Metals Results for Boron Content**

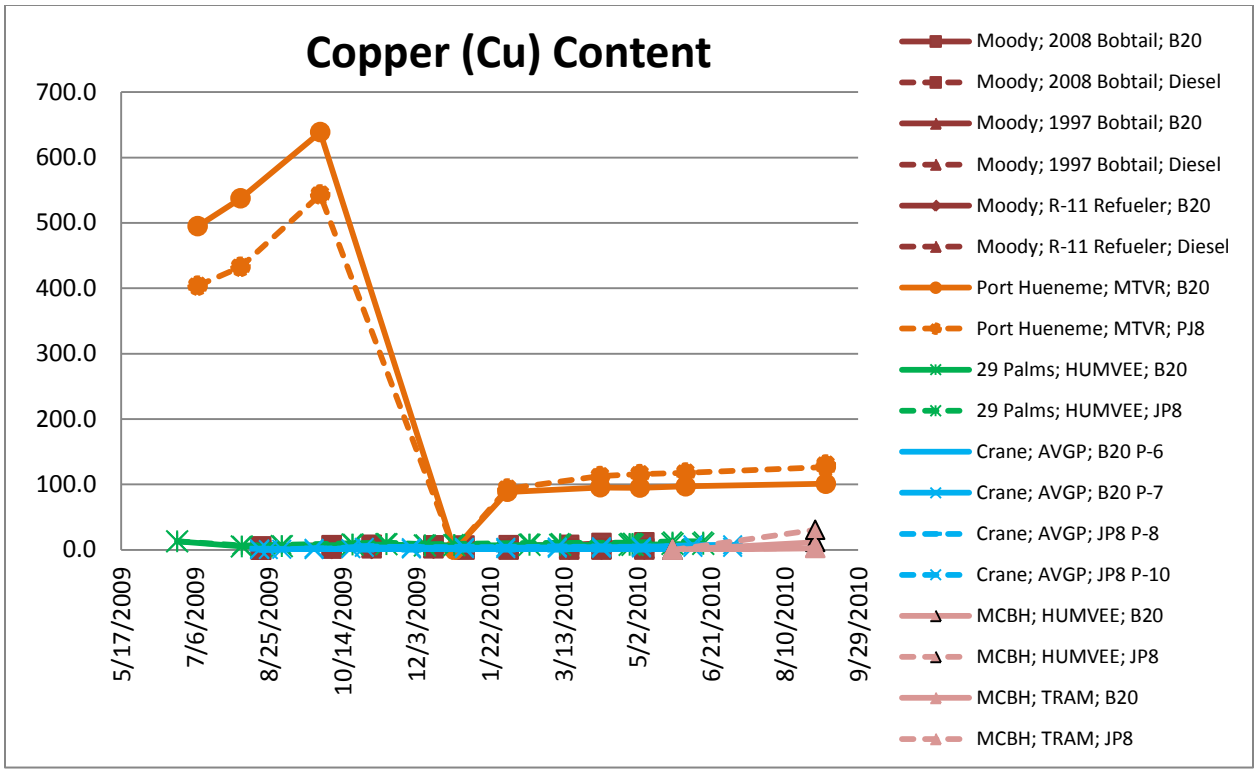


**Figure 51. Wear Metals Results for Copper Content**

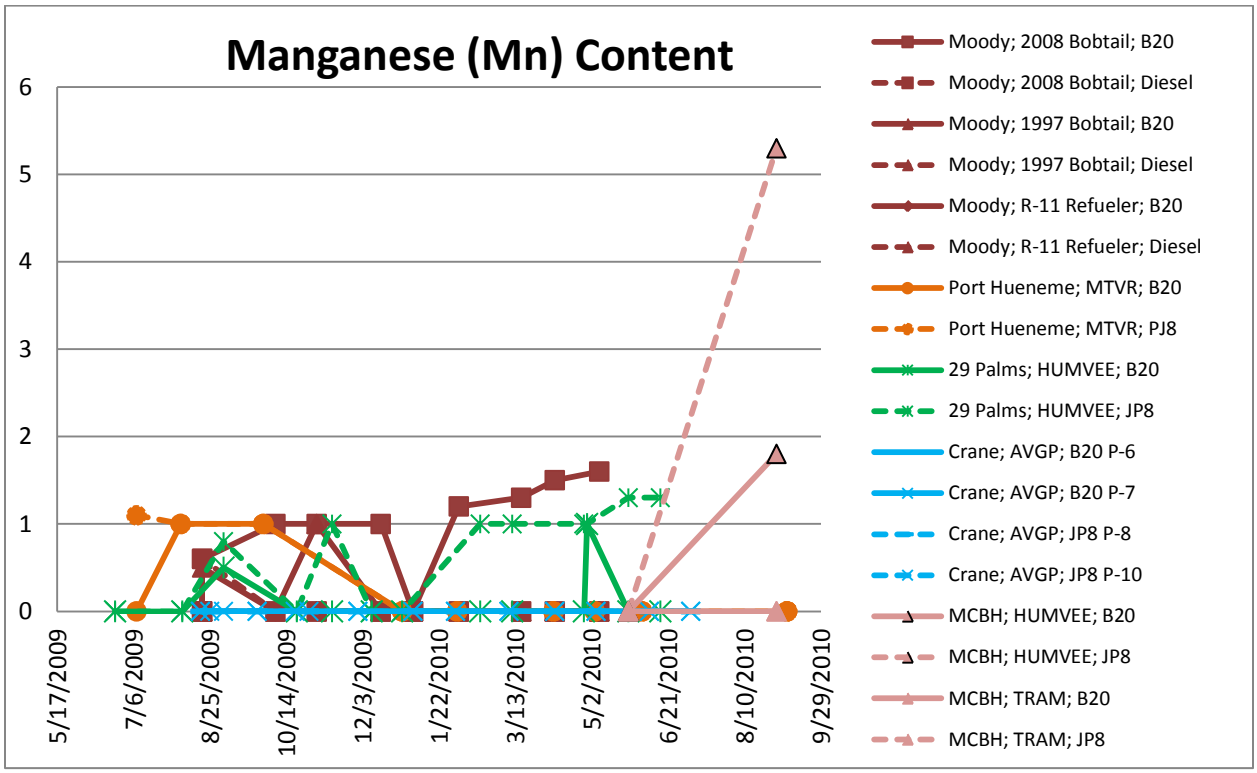


**Figure 52. Wear Metals Results for Magnesium Content**

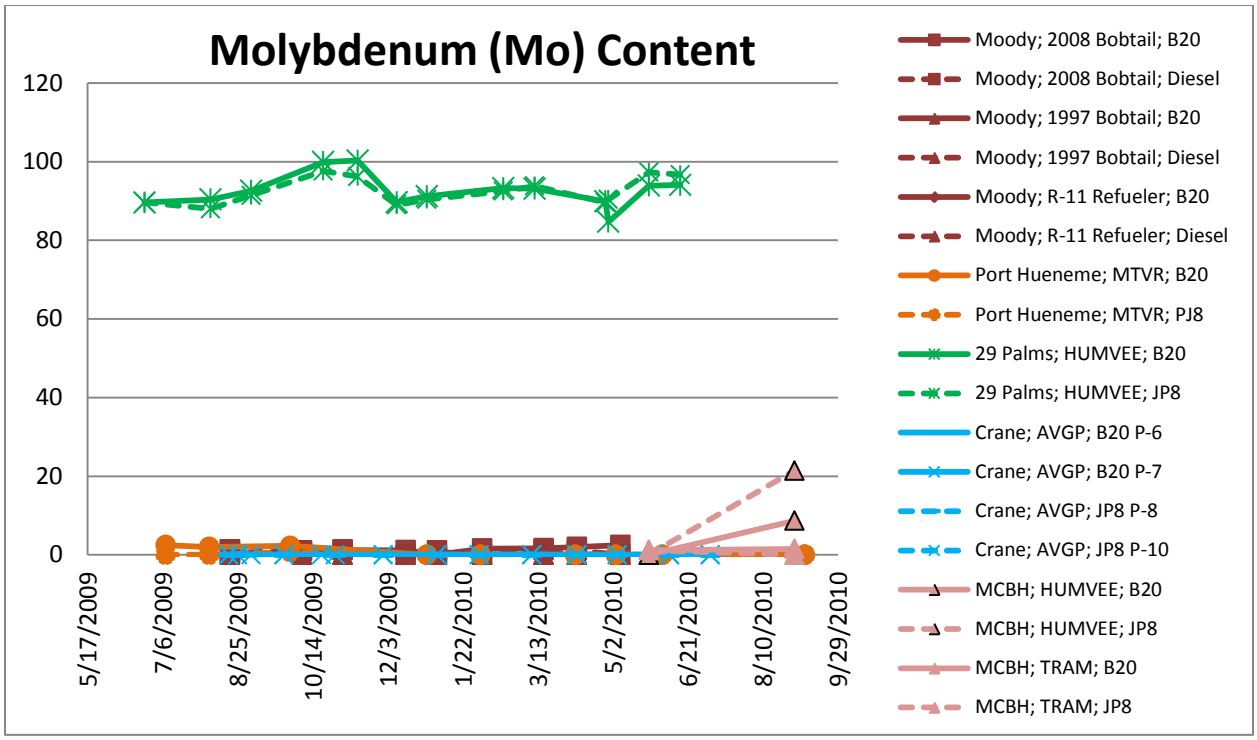


**Figure 53. Wear Metals Results for Molybdenum Content**

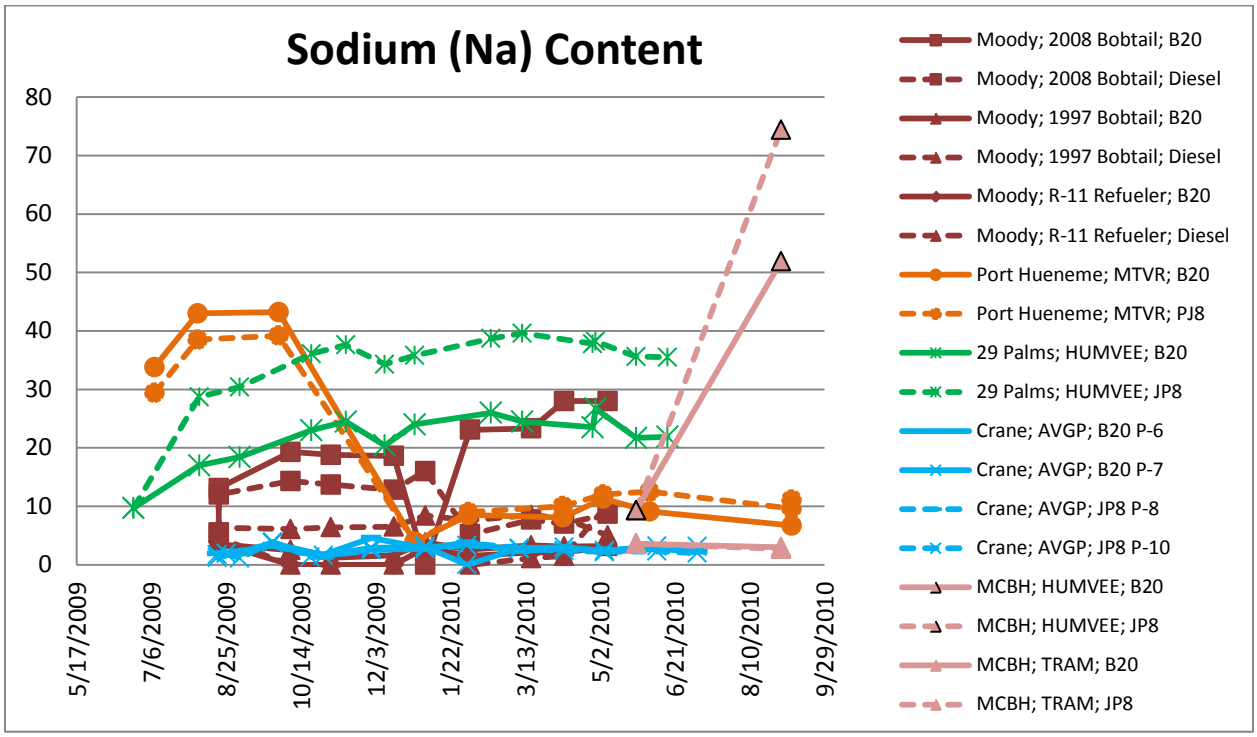


**Figure 54. Wear Metals Results for Sodium Content**

Other trends noted for each of the locations is as follows. First, at Moody AFB, the R-11 Refueler and both the control and test vehicles had consistently lower viscosity values and higher fuel dilution percentages than the Bobtail vehicles at that location. In fact, the control Refueler running on diesel generally had lower viscosity and higher fuel dilution values than the test vehicle operating on B20. Otherwise, the testing results for the Bobtail control and test vehicles were comparable.

At 29 Palms, the test and control vehicles had comparable engine oil test results with the exception of one outlier for the test vehicle, potentially due to water contamination in that particular sample.

For NBVC, the test and control vehicle results were very comparable, especially toward the end of the trial. There were increased fuel dilution percentages in the test vehicle engine oil at the beginning of the trial.

For the NSWC Crane vehicles, all results trended similarly, with viscosity decreasing as water content and fuel dilution increased. Figure 55 and Figure 56 below show the trends for these samples.

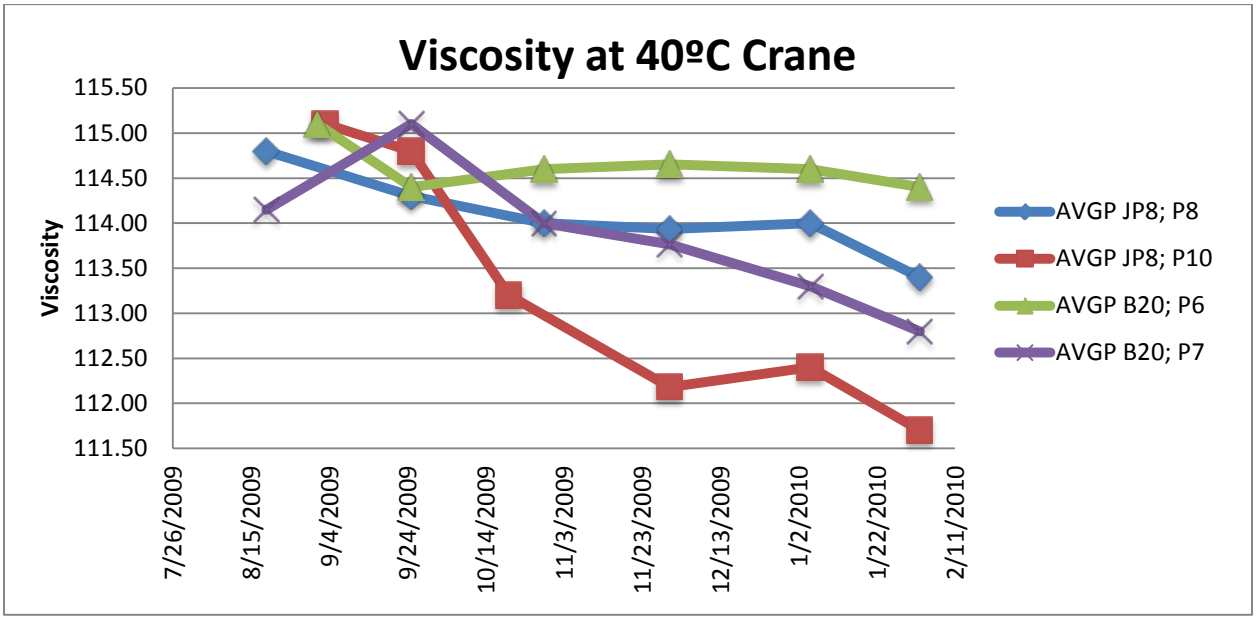


**Figure 55. Engine Oil Viscosity Results for NSWC Crane Vehicles**

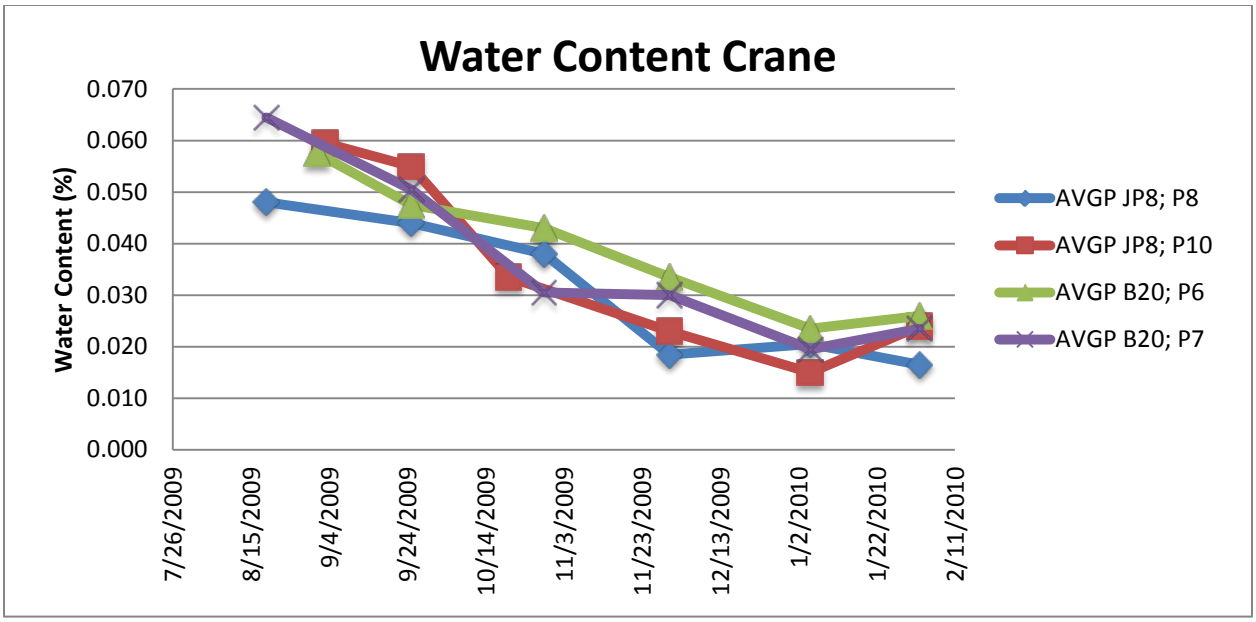


**Figure 56. Engine Oil Water Content Results for NSWC Crane Vehicles**

Limited sampling conducted at MCBH does not show any significant trend. Only two data points are currently available for each vehicle.

The overall conclusion from review of the summarized engine oil data shows that B20 does not have an effect on the engine, as can be seen in changes in the engine oil itself. Generally, the test and control vehicle data trended similarly.

### 6.3.4 TACTICAL BIODIESEL DATABASE

All B20 biodiesel, engine oil, and weather data tested or collected was entered into the Tactical Biodiesel Database developed for easy data extraction and trend analysis. The database is located at https://tacticalbiodieseluse.ctc.com/. For access to the data, a user name and password can be obtained at this website. See deliverables "Draft Biofuels Database Layout and Overview" and "Draft Technical Data Package (Database Systems and Operation Manual)" for additional database resources. Figure 57 through 58, below, are examples of biodiesel fuel analysis results (Figure 57), oil analysis results (Figure 58), and weather data (Figure 59) that can be extracted from the database and analyzed for correlations among the three. The examples below show actual results from 29 Palms.

View samples by Report: 29 Palms

Look up existing by sample id: 09-4420-C Delete

| | Report Name | Sample ID | Sample Source | Description | Reviewed |
|---|---|---|---|---|---|
| Edit | 29 Palms | 09-4420-C | 29 Palms: Dispenser | 29 Palms Dispenser Sample (#18) B20 6/24/09 | ☐ |

| | Test Name | Test Result | Acceptance Criteria | Method | Date | Analyst | Passed |
|---|---|---|---|---|---|---|---|
| Edit | Acid Number | 0.091 mg KOH/g | 0.2 mg KOH/g, max | ASTM D664 | 9/5/2009 12:00:00 AM | AB | ☐ |
| Edit | Appearance | Clear and Bright with a Haze Rating of 1 | Clear, bright, visually free from undissolved water, sediment, and suspended matter | ASTM D4176 | 9/3/2009 12:00:00 AM | AM | ☐ |
| Edit | Color | L1.5 ASTM Color | 3, max | ASTM D1500 | 9/9/2009 12:00:00 AM | TK | ☐ |
| Edit | Oxidation stability, Rancimat | 15.09 Hours | 6 hours, min | EN 14112 | 9/9/2009 12:00:00 AM | TK | ☐ |
| Edit | Particulate Contamination | 1.3 mg/L | 10 mg/L, max | ASTM D6217 | 9/4/2009 12:00:00 AM | AM | ☐ |
| Edit | Viscosity at 40°C | 2.90 mm2/sec | 1.9 – 4.1 mm2/sec | ASTM D445 | 9/1/2009 12:00:00 AM | AB | ☐ |
| Edit | Water & sediment | <0.1% Sediment | 0.05 vol %, max | ASTM D2709 | 8/27/2009 12:00:00 AM | AM | ☐ |
| Edit | % Water by Karl Fischer | 0.08 mg/ml | 0.02% | ASTM D6304 | 8/28/2009 12:00:00 AM | AB | ☐ |
| Edit | Oxidation Stability - Total Insolubles | 0.4 mg/100 ml | 0.1 mg/100 ml | Modified ASTM D2274 | 9/9/2009 12:00:00 AM | TK | ☐ |
| Edit | Oxidation Stability - Iso-Octane Insolubles | 0.1 mg/100 ml | 0.1 mg/100 ml | Modified ASTM D2274 | 9/9/2009 12:00:00 AM | TK | ☐ |
| Edit | Oxidation Stability – Acid Value | 0.084 mg KOH/g | 0.005 mg KOH/g | Modified ASTM D2274 | 9/9/2009 12:00:00 AM | TK | ☐ |

**Figure 57. Biodiesel Fuel Analysis Database Screenshot**

| Sample Details | |
|---|---|
| WO_Num | WO#00639 |
| FLTT_Sample_Num | FL-13199-09 |
| Vehicle | 29 Palms Humvee Test |
| Description | Used Oil; HUMVEE, B20 Used; 8/7/2009 |
| Ag | <1 |
| B | 32.5 |
| Al | 2.9 |
| Ba | <1 |
| Ca | 1384.0 |
| K | 5.7 |
| Cd | <1 |
| Cu | 5.1 |
| Cr | <1 |
| Fe | 11.1 |
| Mg | 772.3 |
| Mn | <1 |
| Mo | 90.4 |
| Na | 17.0 |
| Ni | <1 |
| P | 1238.0 |
| Pb | 2.1 |
| Si | 20.3 |
| Sn | <1 |
| Ti | <1 |
| V | <1 |
| Zn | 1287.0 |
| Total Acid Number mgKOH/g | 2.810 |
| Total Base Number | 8.788 |
| Kinematic Viscosity @40C (cSt) | 114.20 |
| Kinematic Viscosity @100C (cSt) | 14.95 |
| Viscosity Index | 135.6 |
| Water Content (%) | 0.049 |
| Soot Content by Soot Meter | 0.00 |
| Fuel Dilution (%) | 0.000 |
| Edit Delete | |

**Figure 58. Biodiesel Oil Analysis Database Screenshot**

Choose a location: 29 Palms

| Low Temp | High Temp | Avg Dew Point | Avg Wet Bulb | Date | |
|---|---|---|---|---|---|
| 68 | 99 | 50 | 64 | 6/1/2009 | Edit Delete |
| 69 | 100 | 36 | 60 | 6/2/2009 | Edit Delete |
| 74 | 96 | 31 | 57 | 6/3/2009 | Edit Delete |
| 70 | 91 | 42 | 59 | 6/4/2009 | Edit Delete |
| 64 | 85 | 41 | 56 | 6/5/2009 | Edit Delete |
| 60 | 86 | 44 | 57 | 6/6/2009 | Edit Delete |
| 62 | 88 | 48 | 60 | 6/7/2009 | Edit Delete |
| 67 | 89 | 49 | 61 | 6/8/2009 | Edit Delete |
| 65 | 86 | 48 | 60 | 6/9/2009 | Edit Delete |
| 63 | 84 | 50 | 60 | 6/10/2009 | Edit Delete |

1 2 3 4 5 6 7 8 9 10 ...

**Figure 59. Biodiesel Weather Data Database Screenshot**

### 6.3.5 VEHICLE OPERATOR OBSERVATIONS

Vehicle operators from each of the demonstration sites reported no performance differences between test and control vehicles.

# 7.0 COST ASSESSMENT

Biodiesel prices are directly proportional to the costs of raw materials (natural fats/oils and methanol), production, and distribution. Since B20 is composed of largely diesel fuel derived from petroleum, it was expected that its cost would parallel that of petroleum crude and diesel. However, Congress had provided a biodiesel excise tax credit of up to $1.00/per gallon per percentage of biodiesel in the fuel blend. DLA Energy costs for the last few years indicate that DoD pays the same for DS2 and B20.

Biodiesel quality has a direct impact on maintenance and operational costs. Biodiesel that falls outside of ASTM specifications have led to an increase in engine component breakdown. Improved quality of biodiesel through more stringent specifications may be required to expand the use of biodiesel to tactical fleets. This will increase the cost of the fuel but will reduce the risk of maintenance issues. Biodiesel also provides superior lubricity versus petroleum diesel, particularly Ultra-Low Sulfur Diesel (ULSD), which was mandated to replace commercial diesel fuel in the United States by 2010. Lubricity is defined as the ability to reduce friction of solid surfaces in relative motion. The process of hydro-treating diesel fuel to reduce sulfur may alter the natural lubricants found in fuel. Lower lubricity in ULSD fuels may cause premature failure of engine components, particularly fuel injector pumps, as demonstrated in multiple iterations of independent testing. Biodiesel maintains a high level of lubricity as an engine fuel. Biodiesel is also proven to increase lubricity of ULSD fuels when mixed in any percentage of fuel blends, even as low as 1 percent. The greater lubricity properties of biodiesel fuel contribute to improved engine longevity by reducing wear on fuel delivery and internal engine components.

In addition to fuel quality, vehicle performance may be affected by vehicle age, accumulated vehicle mileage and a history of diesel use. Vehicles built prior to 1994 may have components that are not compatible with B20, such as rubber hoses or gaskets. Vehicles that have run diesel for many years may have deposits that act as a seal on engine components. The solvency of B20 causes these deposits to break down leading to leaks. As stated earlier, this breakdown of diesel deposits also occurs when switching from diesel to JP-8.

## 7.1 COST MODEL

The FY12 Rates for Fuel (per gallon) listed by DLA Energy are:

B20 – $3.69
DS1 – $3.82
DS2 – $3.69
JP-8 - $3.82

There is no fuel cost saving switching vehicles currently running on DS2 to B20, and there would be an adverse economic effect, since maintenance costs and storage tank maintenance would rise.

But for vehicles currently running on JP-8 or DS1, there could be a fuel cost saving based upon the number of vehicles that could be switched over. After subtracting out the cost for storage tank maintenance and vehicle maintenance costs, there may be a cost savings.

The total cost is calculated by multiplying the total fuel used by the type of vehicles tested in the study by the cost of the fuel. Comparison is made between B20 and JP8, since it is already determined that there is no difference in price between B20 and DS2.

## 7.2 COST ANALYSIS AND COMPARISON

The cost analysis and comparison is broken out into section by branch and total DoD.

The Army is the largest DoD owner of ground tactical vehicles and would have the largest economic outcome switching from JP-8 to B20. According to the Army Operating and Support Management Information System (OSMIS), the Army operates 387,981 CONUS ground tactical vehicles that use 23 million gallons of JP-8. Of these vehicles, HMMWVs constitute 49.6% of the total, although it is not the largest ground tactical fuel user. The Heavy Expanded Mobility Tactical Truck (HEMTT) series uses 25% of all the fuel used by ground tactical vehicles for the Army, or 5.9 million gallons of fuel even though it makes up only 10% of the CONUS ground tactical fleet. The HMMWVs use 21% of all fuel used. Table 13 lists the Top 5 Army CONUS ground tactical vehicles and the amount of fuel used by each series (not including the HEMTT). These vehicles make up 88.3% of all Army CONUS ground tactical vehicles and use 62.4% of fuel used by Army CONUS ground tactical vehicles.

**Table 13. Army CONUS Ground Tactical Vehicles and Fuel Use**

| Ground Tactical Vehicle | Number of Ground Tactical Vehicle Series | Percentage Of Total Ground Tactical Vehicles | Amount Of Fuel (JP-8) Used | Percentage Of Total Fuel Used |
|---|---|---|---|---|
| HMMWV | 192,608 | 49.6% | 5,018,946 | 21.2% |
| LMTV | 47,625 | 12.2% | 3,559,232 | 15.0% |
| “M” Series Truck | 38,347 | 9.9% | 2,433,063 | 10.3% |
| MTV | 51,630 | 13.3% | 3,763,572 | 15.9% |
| PLS | 12,813 | 3.3% | 2,368,414 | 10.0% |

The annual fuel cost savings of switching from JP-8 to B20 for HMMWV series in the Army is calculated to be $770,917 based upon the difference in cost per gallon, $0.13, between JP-8 and B20. The HMMWVs tested in this program did not produce any maintenance issues that could be differentiated from the control vehicles running on JP-8. The annual amount of fuel diverted from an oil based fuel to a renewable fuel is 1,186,025 gallons.

Although the different series of vehicles were not specifically tested in this program we can still calculate the fuel cost saving and amount of fuel diverted for all CONUS Army vehicles. The

annual fuel cost savings of switching from JP-8 to B20 for all Army CONUS ground tactical vehicles is calculated to be $2,999,536 and the amount of oil based fuel diverted is calculated to be 4,614,671 gallons each year.

The impact of switching from JP-8 to B20 for HMMWVs and MTVRs in the Navy and Marine Corps would not have the amount of fuel savings as the Army since they drive fewer CONUS ground tactical vehicles. The estimated annual amount of JP-8 consumed by ground tactical vehicles for the Navy and Marine Corps is 2,965,500 gallons.

The Marine Corps owns approximately 42,000 ground tactical vehicles; 24,000 of these are HMMWVs and 9,000 are MTVRs. This makes up 79% of the ground tactical fleet. If these vehicles switched to B20 the annual fuel cost saving would be $304,557 with 486,549 gallons of oil based fuel diverted.

The overall impact of switching CONUS Air Force ground tactical vehicles from JP-8 to B20 would be minimal for a couple of reasons. First, the Air Force defines a Tactical Vehicle differently than the other services. Every vehicle on the flight line is considered tactical. The Army, Navy, and Marines generally define tactical as transport vehicles such as MTVRs and Humvees. Additionally, a vast majority of the CONUS Air Force bases already use B20 for the vehicles that they consider appropriate for use. Air Force provides the following technical requirements for users:

Definition of Acceptable B20
Seasonal Change Outs Requirements
Maintenance Guidance
Vehicle Use Guidance
Fuel Testing Guidance

Since the Air Force has already defined which of their tactical vehicles should and should not use B20, a DoD change in policy for B20 would not increase the amount of biodiesel purchased and consumed.

The total annual DoD fuel cost saving for switching from JP-8 to B20 is calculated to be $3,385,051 and the amount of fuel diverted from oil based to renewable is 5,207,771 gallons.

The overall impact to DoD would be very small considering that DoD consumes nearly 5 trillion gallons of fuel each year. Of this total, JP-8 makes up 64%. The percentage of fuel diverted from JP-8 oil based fuel to renewable biodiesel would be just 0.17%.

The cost for an increase in maintenance when switching from JP-8 to B20 is difficult to estimate since only one vehicle had unusual maintenance costs associated with it. At best it can be calculated at which point the fuel savings cost would equal the maintenance cost.

The cost to repair the gas tank and replacement unit for 1997 Bobtail was $917. Although this vehicle would not be defined as a ground tactical for the other services, it does provide a data

point for repair cost. The number of vehicles that would need to have this service done to equal the amount of fuel cost savings is 3,691 or 1% of the total vehicles.

The cost to change the oil and replace a fuel filter for a MTVR is $502. The number of MTVRs that would need to have this service done to equal the amount of fuel cost savings is 6,743 vehicles or 11% of the total MTV and MTVRs in DoD.

The cost to change the oil and replace a fuel filter for a HMMWV is $147. The number of HMMWVs that would need to have this service done to equal the amount of fuel cost savings is 23,028 vehicles or 11% of the total number of HMMWVs in DoD.

# 8.0 IMPLEMENTATION ISSUES

Critical issues for stakeholders and end users include fuel stability and its use in extreme climates. The Tri-Service POL Users Group, comprising representatives from the Army, Navy, and Air Force, issued a position statement in March 2006 supporting the current prohibition against the use of B20 for tactical applications. It identified the following critical issues associated with the use of B20 in such applications:

1. *Stability.* B20 is susceptible to storage instability that may adversely affect vehicles or vessel performance. The resulting oxidation and deterioration of the fuel may cause corrosion, filter plugging, and high temperature deposit formation, reducing the ability of the tactical vehicles or equipment to be stored short- (as in travel for a combat mission) or long-term. European Committee for Standardization or Comité Européen de Normalisation (CEN) has a draft method in development to determine stability of biodiesel blends. The draft method is a modified Rancimat test. (EN 15751 has since been published.)
2. *High temperature properties*. B20 instability is accelerated by high temperatures, which may cause the fuel to degrade in days or weeks. The resulting oxidation and deterioration of the fuel may cause corrosion, filter plugging, and high temperature deposit formation, adversely affecting vehicle or vessel performance.
3. *Low temperature properties*. Biodiesel blends with diesel fuel (DF) have poor cold-weather properties, including higher cloud and pour points. This may adversely affect readiness for low-temperature operations.
4. *Water affinity.* In the presence of water, acids are formed in B20 that may lead to increased corrosion and maintenance of fuel systems that contain steel. In addition, B20 promotes microbial growth, resulting in fuel system corrosion and fuel filter plugging. Biodiesel does not shed water nearly as readily as its petroleum fuel counterparts. This leads to many of the problems experienced with using biodiesel blends, including fuel water emulsions. Fuel water emulsions are associated with, and can encourage, microbial growth.
5. *Material compatibility and solvency.* B20 may react adversely with certain plastics, metals, and elastomers, causing operational failure and increased maintenance requirements. The solvency effect of B20 may lead to increased filter requirements and leaks in the fuel system.

The Tri-Service POL Users Group concluded that these issues must be addressed before B20 can be used in tactical vehicles. Tactical vehicles must be capable of deployment immediately and of performing mission-critical tasks with minimal fuel-related maintenance and related risks. This demonstration resulted in the following responses to each of the Tri-Service POL Users Group issues:

1. *Stability*. B20 oxidation stability, as measured by the Rancimat test, is a property that changes during storage. The rate of oxidation of any given blend will depend on numerous factors including the feedstock used to make the B100, the amount of exposure to oxygen, storage temperatures, storage conditions, and others. Because of these factors, it is difficult to predict the expected useful time period (storage life) of

any given B20 in storage. [This is also true for petroleum fuels but to a much lesser degree.] For this reason, the storage of B20 in tanks and the use of B20 in any vehicle, either non-tactical or tactical, must include steps to:

a. Try to ensure a high Rancimat level at the start; this may require increased stringency in the SOW for the purchase of B20. (Based on the test results which show that vehicles running on B20 with Rancimat measurements exceeding 12 hours (Crane and 29 Palms) had no fuel breakdown in vehicle tanks. Vehicles running on B20 that just met the required Rancimat measured minimum of 6 hours (Moody and NBVC) each had evidence of fuel breakdown). This will increase the cost of the fuel substantially.
b. Avoid high humidity climate zones, minimize exposure to high and low temperatures as much as possible.
c. Avoid using B20 in vehicles that consume less than one tank of fuel per month, particularly in climate with high relative humidity.

2. *High Temperature Properties.* Based on our test observations, problems arose only when the B20 is exposed to both high temperatures and high relative humidity conditions which can affect oxidative stability. The 29 Palms Test Vehicle, running in high temperature, low relative humidity conditions did not have the same rate of oxidative breakdown and particulate contamination as vehicles running in a high temperature, high relative humidity climate.
3. *Low Temperature Properties.* As with stability, the low-temperature properties of biodiesel are very dependent on the feedstock and processing of the biodiesel. Most fuel suppliers are cognizant of the needed low-temperature properties of a fuel to be used in a given region during a given time of the year. They typically use a variety of methods to ensure that the fuel they sell will meet the near-term requirements regarding low-temperature operability. Most problems arise when ambient temperatures are lower than expected or when fuel is purchased during warm weather and not used until colder times of the year. [This can also happen with petroleum fuels.] Any user of B20 should be cognizant of these potential problems and take steps to avoid them. B20 used at a cold site installation (NSWC Crane) was automatically switched to B10 in the winter months, however only one test vehicle received B10 fuel. The vehicle running 15 minutes per month, AVGP P-6, filled with B20 at the start of the demonstration, used the same fuel for the duration of the test. This seems to indicate that B20 exceeding the Rancimat specification of 6 hours, is a better indication that the fuel will not breakdown than the climate zone that the vehicle operates in. Low temperature properties of biodiesel improved during the demonstration by the addition of the Cold Soak Filtration Test to the ASTM International D6751 for B100 specification in 2008.
4. *Water Affinity.* Biodiesel is known to be more susceptible to water emulsification to a much higher degree than petroleum diesel fuel. For this reason, any user of B20 should strive to keep fuel storage tanks and vehicle tanks as dry as possible. The test data does indicate that B20 in vehicles will degrade faster in a humid climate than a dry climate.
5. *Material Compatibility and Solvency.* Addition of B20 to fuel systems that have high levels of contamination and deposits will likely increase the occurrence of problems in the near term. This is because biodiesel will help loosen and suspend contaminants

into the fuel. Maintaining clean fuel storage systems is the best method to prevent this potential problem. Some increase in filter usage rate may be encountered when biodiesel is first introduced into a given storage/vehicle tank. No additional maintenance costs occurred during the demonstration period that would be found during the duration of this test in general maintenance records, but there were costs associated with cleaning the tank and repairing the sending unit. Additionally, the incompatibility of the 1997 Bobtail fuel sending units is an indication that B20 fuel that becomes instable will cause damage to components within the fuel tank and it can be assumed, eventually downstream to the fuel filters and fuel injectors.

Based on the results of this demonstration project, the use of B20 in selected locations can be recommended for expanded testing only under certain conditions:

- Use B20 fuel that meets or exceeds ASTM International Specifications. The fuels used by successful test vehicles significantly exceeded the oxidation stability requirement by Rancimat (6 hours) at Crane (Average 14.4hours) and 29 Palms (Average 16.6 hours). This may not be implementable.
- Use vehicles that are refueled at least once a month. The one failure in the test was a vehicle that was used only 1/10$^{th}$ the amount of time as another test vehicle at the same location with the same fuel.

Blanket approval for the use of B20 in all tactical vehicles would not be advised because the potential for problems over and above those typically encountered with petroleum fuels is higher with the use of biodiesel. The annual fuel savings and diverted oil based fuel only make a tiny impact on overall DoD fuel usage, and the fuel cost savings are quickly negated by a small percentage of vehicles having maintenance issues. Major engine manufacturers may require certification of the fuel blend percentage to honor the warranty of the vehicle. OEM will not honor warranty for vehicles that use a biodiesel blend of greater that 5%.

Finally, system performance as documented in Table 14 is a critical aspect affecting user acceptance. Technologies that offer environmental advantages must also be capable of meeting the user's performance acceptance criteria. Most end-users expect high reliability from fueling stations with minimal maintenance and operator attention. Liquid fuel dispensing systems are relatively simple in design with few moving parts. Although B20 can use existing fuel storage tanks and pumps, there may be additional requirements such as a periodic visual inspection of fueling facilities to ensure storage tanks do not contain deposits, contaminants, or materials compatibility degradation that may be carried into vehicle fuel systems.

**Table 14. Performance of Vehicles at the Five Installations**

| **Performance Criteria** | **Expected Performance Metric (pre demo)** *Examples* | **Performance Confirmation Method** *Examples* | **Actual Performance (post demo)** *Future* |
|---|---|---|---|
| **PRIMARY CRITERIA (Performance Objectives) (Quantitative)** | | | |
| **Vehicle Component Testing (**fuel pump, fuel pump gasket, fuel injector, fuel injector o-ring, fuel lines, and fuel filter)<br>• Scorching<br>• Deposits<br>• Scarring | No difference between vehicles run on B20 and vehicles run on petroleum diesel fuel | Visible observation of component with the naked eye and under microscope | Moody AFB 1997 Bobtail resulted in heavy deposits in the fuel tank. Although the fuel tank and fuel sending unit were not cleaned and repaired during the demonstration, maintenance action would be required to prevent these solids from moving downstream affecting the fuel injectors and other fuel wetted parts. |
| **Performance Criteria** | **Expected Performance Metric (pre demo)** *Examples* | **Performance Confirmation Method** *Examples* | **Actual Performance (post demo)** *Future* |
| **Vehicle Oil Inspection** | Within JOAP specification | Laboratory testing | Initial NBVC test vehicle oil was OEM off spec oil from a rebuild. Oil was changed and further testing met all JOAP standards. |
| **PRIMARY CRITERIA (Performance Objectives) (Qualitative)** | | | |
| **Reliability** | No statistically significant change in engine failure (failure a major engine component such as a connecting rod which causes the engine to cease or to run in a debilitated manner) related to fuel system for vehicles running on B20 versus vehicles running on diesel or JP-8 | Record keeping | At MCBH, the test TRAM required a new fuel filter; however a definitive cause for replacement was not determined.<br><br>No variation in standard maintenance in other vehicles occurred.<br><br>No vehicle failure, although it is expected that the 1997 Bobtail would have eventually had a major engine problem. |

| **Performance Criteria** | **Expected Performance Metric (pre demo)** *Examples* | **Performance Confirmation Method** *Examples* | **Actual Performance (post demo)** *Future* |
|---|---|---|---|
| | | | |

Initiating the use of B20 at military installations should appear seamless for the end user and should not create any changes in the fueling process. This demonstration showed an increase in the cost of fleet tactical vehicle maintenance and operation when using B20 within specific fuel quality and operational parameters. In addition, tri-service operational parameters (fuel quality, vehicle age, vehicle usage rate, maximum fuel storage limits, and climate conditions) for using B20 in DoD ground tactical vehicles and equipment were investigated, and validated.

The vehicle that had significant problems while using B20 is the 1997 Bobtail. This vehicle has a history of problems at Moody AFB. The low use rate (75 hours/year), the climate (high temperature/high humidity), and the vehicle age and design contributed to a faster breakdown of fuel then the other vehicles operating on the same fuel in the same conditions. Climate did seem to play a role in fuel breakdown the fuel breakdown in the 1997 Bobtail, but not as much as the initial fuel quality and vehicle usage. The initial sample of the fuel going into the 1997 Bobtail had a Rancimat of 8.5 hours, which met the specification, but was well below the initial Rancimat readings for Crane (18.92 hours). The operation times for the Crane test vehicles (54.6 hours and 6.4 hours) were run the same or less than the Moody vehicle (47 hours) but did not have the same fuel breakdown, even though the relative humidity was virtually the same. The 2008 Bobtail used the same fuel in the same climate, but did not have the same breakdown because the vehicle was used 10 times more frequently than the 1997 Bobtail.

The data gathered by this demonstration validates the March 2006 Tri-Service Biodiesel Position Paper, although it has been demonstrated that under certain circumstances (higher Rancimat, high vehicle usage) vehicles running on B20 did not have vehicle maintenance issues that were different than vehicles running on JP-8. The Tri-Service POL membership and DLA Energy have also stated that increasing the oxidative requirement for biodiesel is not feasible and limiting the use of B20 to a limited number of CONUS operations is logistically impossible. Another important fact to consider is OEM will not honor warranties on engine breakdowns for vehicles running on biodiesel blends above 5%, so even if the engine breakdown cannot be directly tied to the use of B20, warranties on DoD vehicles will be voided due to use of B20.

Any cost savings calculated in this demonstration could also be achieved by switching from JP-8 to DS2 without any of the risks associated with B20 use. Cost savings should not be a factor when determining if CONUS operations should be switched from JP-8 to B20.

Demonstration results will be distributed to the Tri-Service POL Users Group, the Joint Group on Pollution Prevention (JG-PP) and shared with the National Renewable Energy Laboratory for nationwide distribution. The Tri-Service POL Users Group consists of fuels experts from each of the armed services. POL members set standards for fuel procurement for their respective

branches. The JG-PP will host demonstration information on the JG-PP website to facilitate program awareness, communications and technology transfer.

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**APPENDICES**

# APPENDIX A Points of Contact

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| | | | |
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| | | | |
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# APPENDIX B Biodiesel Test Methods

## Appearance

Test Description

Immediately upon drawing a 1-L sample into a clear glass container having a diameter of 100 mm, the sample was visually checked for evidence of water or particulate contamination. The sample was held up to a light and visually examined for haze or lack of clarity. The sample was then swirled to produce a vortex and the bottom of the vortex examined for particulate matter. The visual clarity was recorded as clear and bright or not clear and bright. Whether particulate matter or water was or was not viewed at the bottom of the vortex was also recorded.

Test Methodology

| | |
|---|---|
| **Parameters** | Add sample to clear container; visually examine for haze, particulate matter, and water |
| **Acceptance Criteria** | Clear, bright, visually free from undissolved water, sediment, and suspended matter |
| **Reference Document** | ASTM D4176 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Bar chart/Photographs | ASTM | N/A | N/A |

Deviations from or Interpretation of Test Method

The temperature of the fuel was checked to ensure that it was at or around the ambient temperature. Fuel that is taken from relatively warm storage (i.e., underground storage) and tested at a colder ambient temperature may develop water haze as dissolved water drops out of solution. Also, fuel tested at its cloud point temperature, or lower, may have wax crystals that could be erroneously identified as particulate contamination.

## Acid Number

Test Description

The buret of the automatic titrator was filled with a 0.1 mol/L (N) alcoholic KOH solution, and this solution was standardized. A titration blank was also performed, by placing 125 mL of the titration solvent into a 250 mL beaker, and then titrating the solution. A weighed quantity of sample was added to a 250 mL beaker according to Table 1 of ASTM D664. A quantity of 125 mL of titration solvent was then added to the beaker. The beaker was placed on the titration stand, the combination solvotrode electrode and buret tip were both lowered into the sample and the stir plate was activated. The automatic titrator was programmed to deliver 0.05 mL/min of titrant through the region of the inflection points. The potentiometric/derivative curves were recorded and

the titration was continued until the potential became constant, changing less than 5 mV/0.1 mL. The volume of titrant, normality, volume required for blank titration, and mass of sample were used to calculate the acid number.

Test Methodology

| | |
|---|---|
| **Parameters** | Set an autotitrator to deliver 0.05 mL/min of alcoholic KOH during a potentiometric titration until the potential changes by less than 5 mV/0.1 mL; calculate acid number |
| **Experimental Control** | Standardization of KOH, and Titrant blank |
| **Acceptance Criteria** | 0.2 mg KOH/g, max |
| **Reference Document** | ASTM D664 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Autotitrator | Brinkmann Instruments/Metrohm USA | 836 Titrando | 1836002010117 |
| Analytical Balance | A&D | N/A | 10400184 |

Deviations from or Interpretation of Test Method
None

**Kinematic Viscosity at 40°C**

Test Description

The Cannon-Fenske routine viscometer was charged in the manner dictated by the design of the viscometer (See ASTM D446, Annex A1). If the sample contained solid particles or fibers, it was filtered either prior to or during charging through a 75 micron filter. The charged viscometer was placed in the temperature-controlled bath long enough for the fuel to reach the test temperature, and then allowed to equilibrate for an additional 30 minutes. Suction was used to adjust the head level of the sample to a position in the capillary arm of the instrument about 7 mm above the first timing mark. With the sample flowing freely, the time required for the meniscus to pass from the first to the second timing mark was measured (in seconds to within 0.1 second). If this flow time was less than 200 seconds, a viscometer with a capillary of smaller diameter was selected and the analysis repeated. The above measurement procedure was repeated a second time and both measurements were recorded. The average of the two readings was used to calculate kinematic viscosity.

Test Methodology

| | |
|---|---|
| **Parameters** | Determine the viscosity of the sample at specified temperatures by recording the time required for the sample to flow from the first to |

| | |
|---|---|
| | the second timing mark and then using this value to calculate viscosity. |
| **Acceptance Criteria** | 1.9-4.1 $mm^2$/sec |
| **Reference Document** | ASTM D445, ASTM D446 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Cannon-Fenske Routine Viscometer | Cannon Instruments | Recorded with each test | Recorded with each test |
| Constant Temperature Bath | Cannon Instruments | CT-500 | 1505-A2107 |

Deviations from or Interpretation of Test Method
None

**Flash Point**

Test Description

A brass test cup was filled with the test specimen to the filling mark inside the test cup. The temperature of the test cup and sample was at least 18 °C below the expected flash point. The test cover was placed on the test cup and the assembly placed into the apparatus. The locking device was engaged and the thermometer added. The test flame was lit and adjusted to a diameter of 3.2 to 4.8 mm. Heat was applied at such a rate that the temperature increased at a rate of 5 to 6 °C/min. The stirring device was set at 90 to 120 revolutions per minute (rpm). When the temperature of the test specimen was 23 ± 5° C below the expected flash point, the ignition source was applied, and each time thereafter at a temperature reading that is a multiple of 1 °C. The observed flash point was recorded as the reading on the thermometer at the time ignition source application caused a distinct flash in the interior of the test cup. The sample was deemed to have flashed when a large flame appeared and instantaneously propagated itself over the entire surface of the test specimen.

Test Methodology

| | |
|---|---|
| **Parameters** | Add at least 75 mL of sample to the sample cup and cover; the cup was heated and stirred; an ignition source was directed into the test cup at specified temperature intervals until a flash was detected. |
| **Acceptance Criteria** | 52°C, min |
| **Reference Document** | ASTM D93 |

Test Equipment

| Lab Equipment Required for Test | Manufacturer | Model # | Serial # |
|---|---|---|---|
| Closed Cup Tester | Pensky-Martens | N/A | N/A |
| Thermocouple | Fluke | Various | Various |

Deviations from or Interpretation of Test Method

None

## Cloud Point

Test Description

The sample to be tested was brought to a temperature at least 14°C above the expected cloud point. The sample was poured into the test jar and closed tightly with the cork that contains the test thermocouple. The thermocouple was adjusted so that it was coaxial to the jar and the bulb rested on the bottom of the jar. The jar test jacket was inserted into the cooling medium approximately 10 minutes before placing the test jar. A gasket was placed around the test jar and inserted into the cooled jacket. The temperature of the cooling bath was maintained at 0 ± 1.5°C. At each thermometer reading that is a multiple of 1°C, the test jar was removed from the jacket quickly and inspected for cloud, then placed back in the jacket. The complete operation required no more than 3 seconds. The jacket and test jar were placed in different baths, as needed, to lower the sample temperature. The cloud point was reported (to the nearest 1°C), as the temperature where any cloud was observed at the bottom of the test jar, which was confirmed by continued cooling.

Test Methodology

| | |
|---|---|
| **Parameters** | Cool the sample and periodically examine for clouding at the bottom of the test jar. |
| **Acceptance Criteria** | Report |
| **Reference Document** | ASTM D2500 |

Test Equipment

| Lab Equipment Required for Test | Manufacturer | Model # | Serial # |
|---|---|---|---|
| Low Temperature Bath | Koehler | N/A | N/A |
| Thermocouple | Fluke | Various | Various |

Deviations from or Interpretation of Test Method

Dry ice was used to cool the samples, so only one bath was necessary.

## Sulfur Content

Test Description

Wavelength dispersive X-ray fluorescence spectrometry was utilized to determine the percent mass sulfur for this testing method. The sample was placed in the X-ray beam, and the peak intensity of the sulfur Kα line at 5.373 Å was measured. The background intensity, measured at a recommended wavelength of 5.190 Å (5.437 Å for an Rh target tube) was subtracted from the peak intensity. The resulting net counting rate was then compared to a previously prepared calibration curve or equation to obtain the concentration of sulfur in mass %.

Test Methodology

| | |
|---|---|
| **Parameters** | The sample was loaded into a clean sample cell and placed in the X-ray beam; the counting rate was compared to a calibration curve to determine mass percent sulfur. |
| **Acceptance Criteria** | 0.0015 mass %, max |
| **Reference Document** | ASTM D2622 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| XRF Spectrometer | Oxford Instruments | Twin X ULS | 46839-TNX0524 |

Deviations from or Interpretation of Test Method

None

**Distillation Temperature**

Test Description

Based on the sample's composition, vapor pressure, and initial boiling point or expected end point, or combination thereof, the sample was placed in one of five groups (Group 0 to 4). Apparatus arrangement, condenser temperature, and other operational variables were defined by the group in which the sample fell. A 100-mL specimen of the sample was distilled under the prescribed conditions for the group in which the sample fell. The distillation was performed in a laboratory batch distillation unit at ambient pressure under conditions that were designed to provide approximately one theoretical plate fractionation. Systematic observations of temperature readings and volumes of condensate were made, depending on the requirements of the specifications. The volume of the residue and the losses were also recorded. At the conclusion of the distillation, the observed vapor temperatures were corrected for barometric pressure and the data were examined for conformance to procedural requirements, such as distillation rates. The test was repeated if any specified condition had not been met. Test results were expressed as percent evaporated or percent recovered versus corresponding temperature.

Test Methodology

| | |
|---|---|
| **Parameters** | A 100-mL specimen was distilled at prescribed conditions, based upon the group in which it fell in the ASTM procedure. Results were reported as the percent evaporated or percent recovered versus temperature. |
| **Acceptance Criteria** | 343°C at 90% evaporated, max |
| **Reference Document** | ASTM D86 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Heating Element | N/A | N/A | N/A |
| Thermocouple | Fluke | Various | Various |

Deviations from or Interpretation of Test Method

None

**Ramsbottom Carbon Residue (10% Bottoms)**

Test Description

The sample was weighed (0.5 to 4.0 grams of sample, depending on the expected % residue) into a special glass bulb having a capillary opening, and was placed in a metal furnace maintained at approximately 550°C. The sample was thus quickly heated to the point at which all volatile matter was evaporated out of the bulb with or without decomposition while the heavier residue that remained in the bulb underwent cracking and coking reactions. During the latter portion of the heating period, the coke or carbon residue was subjected to further slow decomposition or slight oxidation due to the possibility of breathing air into the bulb. After an approximate 20 minute heating period, the bulb was removed from the bath, cooled in a desiccator, and again weighed. The residue remaining was calculated as a percentage of the original sample, and reported as carbon residue.

Test Methodology

| | |
|---|---|
| **Parameters** | Sample + coking bulb were weighed, and then placed in a 550°C furnace for 20 minutes; bulb was removed from furnace and cooled in desiccator; bulb was reweighed to determine carbon residue. |
| **Acceptance Criteria** | 0.35%, max |
| **Reference Document** | ASTM D524 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Analytical Balance | A&D | N/A | 10400184 |
| Carbon Residue Furnace | Koehler | N/A | R03179058 |

Deviations from or Interpretation of Test Method

None

## Calculated Cetane Index

Test Description

Data was collected from either density or American Petroleum Institute (API) gravity and distillation temperature (specifically the mid-boiling temperature, in ºC or ºF) in order to perform the calculation to estimate Cetane Index. The following equation was used to calculate the Cetane Index:

$$\text{Calculated cetane index} = -420.34 + 0.016G^2 + 0.192\,G \log M + 65.01(\log M^2) - 0.0001809\,M^2$$

Or

$$\text{Calculated cetane index} = 454.74 - 1641.416D + 774.74D^2 - 0.554B + 97.803(\log B)^2$$

Where:
$G$ = API gravity, determined by ASTM D287 or ASTM D1298
$M$ = mid-boiling temperature, ºF, determined by ASTM D86 and corrected to standard barometric pressure

$D$ = density at 15°C, g/mL, determined by ASTM D1298
$B$ = mid-boiling temperature, °C, determined by ASTM D86 and corrected to standard barometric pressure

Test Methodology

| | |
|---|---|
| **Parameters** | Determine API gravity, or density and mid-boiling temperature, then perform calculation. |
| **Acceptance Criteria** | 40, min |
| **Reference Document** | ASTM D976 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| N/A | | | |

Deviations from or Interpretation of Test Method
None; however, it should be noted that calculated cetane index methods, such as D976, are not valid with B100 or biodiesel blends.

## Ash Content

Test Description

The crucible to be used for the test was conditioned by heating at 700 to 800 °C for a minimum of 10 minutes, cooled to room temperature, and weighed to the nearest 0.1 mg. The sample was mixed by 10 minutes of manual or mechanical shaking and examined for homogeneity. Once homogeneous, a specified amount (see Table 1 in ASTM D482) of fuel was weighed into the crucible and recorded. The crucible was carefully heated with a burner until the contents could be ignited by the flame. The crucible was maintained at such a temperature that the sample continued to burn at a uniform rate, leaving only a carbonaceous residue when the burning ceased. The residue was heated in the muffle furnace at 775 ± 25 °C until all carbonaceous material has disappeared. The crucible was cooled to room temperature and weighed to the nearest 0.1 mg. The crucible was again heated at 775 °C for 20 to 30 minutes, cooled, and reweighed. The heating and weighing was repeated until constant weight (defined as: two consecutive weighing that differ by not more than 0.5 mg) was achieved. The mass percent of the ash was calculated as a percentage of the original sample.___

Test Methodology

| | |
|---|---|
| **Parameters** | Weighed out test specimen into a crucible; ignited the sample by heating with a burner, then placed the sample in a muffle furnace to completely reduce the sample to ash; reweighed specimen. |
| **Acceptance Criteria** | 0.01 mass %, max |
| **Reference Document** | ASTM D482 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Analytical Balance | A&D | N/A | 10400184 |
| Muffle Furnace | Thermolyne | N/A | 1276070664285 |

Deviations from or Interpretation of Test Method

An open coil burner was used in place of the open flame burner, due to the flammable nature of the test samples. Also, the sample and crucible were heated to the point where smoke evolved and the sample was evaporating volatile components, rather than to the point of flames due to the splattering nature of the sample, and the resulting erroneous results.

## Water and Sediment

Test Description

With the sample container equilibrated to ambient lab temperature, the fuel sample was agitated by hand, for 10 minutes to ensure homogeneity. As soon as possible, to prevent losing any water or sediment, the centrifuge tube was filled to the 100-mL mark directly from the container. The tube was then stoppered and placed in the centrifuge opposite another filled tube, for balance. The samples were whirled for 10 minutes at a speed to produce an rcf (relative centrifugal force) of 800 ± 60 at the tip of the whirling tubes. The combined water and sediment at the bottom of the tube was reported to the nearest 0.005 mL.

Test Methodology

| | |
|---|---|
| **Parameters** | Fill centrifuge tube with 100 mL of well-mixed sample; place in centrifuge and spin for 10 minutes at a speed to achieve 800 for rcf; record the amount of combined water and sediment at the bottom of the tube |
| **Experimental Control** | N/A |
| **Acceptance Criteria** | 0.05%, max |
| **Reference Document** | ASTM D2709 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Centrifuge | Koehler | K60002-PT | R09050013-A |

Deviations from or Interpretation of Test Method

None

## Copper Strip Corrosion

Test Description

A 30 mL sample that is free of any suspended or entrained water was placed into a chemically cleaned and dry 25 mm by 150 mm test tube. A polished copper strip was added to the test tube within one minute of completing the final strip preparation. The tube was stoppered with a vented cork and placed in a bath maintained at 50 ± 1°C (122 ± 2°F). The contents of the tube were protected from strong light during the test. After 3 hours ± 5 minutes in the bath, the strip was examined and rated as described below.

After the test was complete, the contents of the test tube were poured in to a 150-mL tall-form beaker. The strip was immediately removed from the beaker with stainless steel forceps and immersed in wash solvent (isooctane or other sulfur-free hydrocarbon solvent). After the immersion, the strip was blotted dry with quantitative filter paper, and inspected for evidence of tarnishing or corrosion (by comparison with the Copper Strip Corrosion Standards). In order to make an accurate comparison, both the test strip and the standard strip plaque were held in such a manner that light reflected from them at an angle of approximately 45°. A description of strip characteristics and ratings is listed in Table 4 below.

**Table 4. Copper Strip Classifications**

| **Classification** | **Designation** | **Description** |
|---|---|---|
| Freshly polished strip | -- | -- |

| | | |
|---|---|---|
| 1 | Slight tarnish | a. light orange, almost the same as freshly polished |
| | | b. dark orange |
| 2 | Moderate tarnish | a. claret red |
| | | b. lavender |
| | | c. multicolored with lavender blue or silver, overlaid on claret red |
| | | d. silvery |
| | | e. brassy or gold |
| 3 | Dark tarnish | a. magenta overcast on brassy strip |
| | | b. multicolored with red and green showing (peacock), but no gray |
| 4 | Corrosion | a. transparent black, dark gray or brown with peacock green barely showing |
| | | b. graphite or lusterless black |
| | | c. glossy or jet black |

Test Methodology

| | |
|---|---|
| **Parameters** | Prepared test strips were placed in test solution inside a bomb and submerged in a water bath for the designated time and temperature; the strips were then removed and rated. |
| **Acceptance Criteria** | No. 3 max |
| **Reference Document** | ASTM D130 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Copper Strip Bath | Koehler | N/A | N/A |

Deviations from or Interpretation of Test Method

None

**Biodiesel Content**

Test Description

The biodiesel content of fuel samples were measured using a Fourier Transform Infrared (FTIR) Spectrometer with an attenuated total reflectance (ATR) fixture that uses a diamond as the ATR crystal. A new calibration curve was built for each set of samples run on the instrument. The calibration samples covered a concentration of biodiesel ranging from 1% to 20%. After collecting a baseline scan of the equipment, a spectrum was gathered on each standard as well as the sample. The spectrum of the sample was

compared against the standards at various select wavelengths to determine the sample biodiesel content.

Test Methodology

| | |
|---|---|
| **Parameters** | A baseline scan, calibration standards scans, and a sample scan were used to determine the % biodiesel content in a fuel sample. |
| **Acceptance Criteria** | 20 +/- 1 % (V/V) |
| **Reference Document** | ASTM D7371 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| FTIR | Mattson | Genesis II | 990715 |
| ATR | SENSIR Technologies | N/A | 625 |

Deviations from or Interpretation of Test Method

None

**Oxidation Stability-Rancimat**

Test Description

A measured volume of sample was introduced into the reaction vessel. Aeration tubes were attached, and the top of the vessel was assembled. The assembly includes connection to the measuring vessel and conductivity probe. The sealed reaction vessel was then placed in the heater block and allowed to reach 110°C. Air flow was initiated and the test was started. The test proceeded until there was a conductivity shift in the measuring vessel, which indicated that all the primary compounds had been converted (fatty acid methyl esters converted to peroxides) and the secondary products were being transferred to the reaction vessel. The test was automatically ended by the conductivity shift. The time for the test was recorded as the induction time.

Test Methodology

| | |
|---|---|
| **Parameters** | Introduce sample into the reaction vessel and assemble. Once the sample is at temperature, begin the test. Record the induction time. |
| **Acceptance Criteria** | B100: 3 hours, min<br>Blends: 6 hours, min |
| **Reference Document** | EN14112 |

Test Equipment

| Lab Equipment Required for Test | Manufacturer | Model # | Serial # |
|---|---|---|---|
| Biodiesel Rancimat | Brinkmann Instruments/Metrohm USA | 873 Rancimat | 18730015 |
| Analytical Balance | A&D | N/A | 10400184 |

Deviations from or Interpretation of Test Method

None

**Density at 15°C**

Test Description

A 0.7 mL volume of sample was siphoned into the tube of the digital density meter. The sample was examined in the tube, ensuring that no air bubbles were trapped. The change in oscillating frequency caused by the change in the mass of the tube was used in conjunction with calibration data to determine the density of the sample. The digital reading was recorded once the reading had stabilized to four significant figures.

Test Methodology

| | |
|---|---|
| **Parameters** | Introduced the sample into the density meter and recorded the stable reading and temperature. |
| **Acceptance Criteria** | Report |
| **Reference Document** | ASTM D4052 |

Test Equipment

| Lab Equipment Required for Test | Manufacturer | Model # | Serial # |
|---|---|---|---|
| Digital Density Meter | Anton Parr | DMA 35N | 80207955 |
| Thermocouple | Fluke | Various | Various |

Deviations from or Interpretation of Test Method

None

**ASTM Color**

Test Description

A blank standard was obtained by filling a glass cuvette to a depth of at least 50mm with deionized water, and placed in the colorimeter. The color was automatically detected by the instrument, and stored. The test sample was run by filling a second glass cuvette to a depth of at least 50mm, and also placed in the colorimeter. The test sample was analyzed

three times, and the average was reported. The colorimeter has a range from lighter than 0.5 to 8.0. Also, if the average value was not a whole number, the number was rounded up to the nearest standard reading.

Test Methodology

| | |
|---|---|
| **Parameters** | Analyze a DI water blank, then analyze the sample three times and report the average result. |
| **Acceptance Criteria** | 3.0, max |
| **Reference Document** | ASTM D1500 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Colorimiter | Hach/Lange | LICO 100 | 1209242 |

Deviations from or Interpretation of Test Method

The colorimeter used by *CTC* only has one sample position, unlike the model called out in ASTM D1500. Therefore, only one cuvette may be analyzed at any given time.

## Particulate Contamination

Test Description

A 1L sample of fuel, measured into a glass container, was vacuum filtered through one or more sets of 0.8 micron membrane filters. Each membrane filter set consisted of a tared nylon test membrane and a tared, nylon 66, control membrane. The membrane filters were prepared by placing the test and control membranes in a glass Petri dish (lid ajar), in a drying oven at 90 ± 5°CºC for 30 minutes. The Petri dish was removed from the oven and the membrane filters were equilibrated in lab air for 30 minutes prior to measuring the mass of each filter on an analytical balance. Next the control membrane was placed into the filtration system and the test membrane was placed on top of the control. When the level of particulate contamination is low, a single set of filters will usually suffice; when the contamination is high or of a nature that induces slow filtration rates, two or more sets may be required to complete filtration in a reasonable time.

The fuel sample was then added to the filtration apparatus, at 100 mL increments, until the entire liter of sample was filtered or until the filtration of 100 mL required longer than 10 minutes. If the filters needed to be changed due to poor filtration, the filtrate was poured into a clean graduated cylinder to record the volume. The filters were washed with flushing fluid (heptane/isooctane) and then removed. Filtration was continued with a new set of filters. After the filtration was completed, the membrane filters were washed with flushing fluid, dried, and weighed. The particulate contamination level was

determined from the increase in the mass of the test membranes relative to the control membranes, and was reported in units of mg/L.

Test Methodology

| | |
|---|---|
| **Parameters** | 1L of fuel sample was filtered through a series of 0.8 micron, pre-weighed filters (control and test per set); after filtration, the filters were washed, dried, and weighed; the weights of the control and test membranes before and after filtration were used to calculate particulate contamination |
| **Acceptance Criteria** | 10 mg/L, max |
| **Reference Document** | ASTM D6217 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Analytical Balance | A&D | N/A | 10400184 |
| Drying Oven | Lindberg/Blue | N/A | OV-1134 |

Deviations from or Interpretation of Test Method
None

**Oxidation Stability-Modified**

Test Description

A 400 mL volume of fuel was filtered and collected in a filter flask. A 350 mL volume of the filtered fuel was placed in a glass oxidation cell, and within one hour, the test cell was immersed in a bath at 95°C ± 0.2°C. A condenser connected to cooling water was placed over the oxidation cell, and connected to an oxygen supply at a rate of 3 ± 0.3 L/hour. The time the oxidation cell was placed in the bath was recorded, and the test was run for the duration of 16 ± 0.25 hours. The level of the fuel in the oxidation cell was below the level of the bath medium, so the fuel was protected from light for the duration of the test. After aging, the sample was removed from the bath and allowed to cool to approximately room temperature (but no longer than 4 hours). A set of matched filters (test and control) were placed in the filtration apparatus, suction was applied, and the cooled sample was poured through the filters. After filtration was complete, the oxidation cell and oxygen delivery tubes were rinsed with three 50 ± 5 mL volumes of isooctane, and the rinsate also poured through the filters. The two filters were then dried in an oven at 80°C for 30 minutes, cooled, and weighed on an analytical balance to the nearest 0.1mg. Adherent insolubles were then removed from the oxidation cell and oxygen delivery tube with three volumes of 75 ± 5mL of trisolvent, and the rinsates collected in a tared 200 mL beaker. The contents of the beaker were then evaporated at 135°C, and allowed to cool in a desiccator for one hour. The beaker was reweighed on an

analytical balance, and the weights recorded. The sum of the filterable and adherent insolubles, expressed as milligrams per 100 mL, was reported as total insolubles.

Test Methodology

| | |
|---|---|
| **Parameters** | Age a sample of fuel in an oxidation cell/heating bath for 16 hours at 95°C under 3L/h oxygen flow. Determine filterable insolubles through filtration with isooctane and adherent insolubles by rinsing with trisolvent. |
| **Acceptance Criteria** | Report total insolubles, iso-octane insolubles, and acid value |
| **Reference Document** | ASTM D2274, modified |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Constant Temperature Bath | Cannon Instruments | CT-500 | 1505-A2107 |
| Analytical Balance | A&D | N/A | 10400184 |

Deviations from or Interpretation of Test Method

Whatman glass microfiber filters (70 mm diameter, 1µm pore size) were used in place of the Cellulose ester membrane filters (47 mm diameter, 0.8 µm pore size) called out in ASTM D2274. Filters were dried at 90°C, as determined by laboratory staff. Also, three volumes of 50 ± 5 mL of trisolvent were used to rinse out adherent insolubles instead of 75.

## Trace Metals

Test Description

Standards of the analytes of interest, calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K), were prepared using oil based standards and suitable solvent. Mineral oil was added to each calibration standard to match the matrix of the subsequent standards. Samples were analyzed using an inductively couple plasma/optical emission spectrometer (ICP/OES) and compared to the intensities determined from the calibration standards. A correction factor was determined for each analyte and used to calculate the concentration in each sample. If the analyte concentration exceeded the high calibration standard, the sample was diluted to yield concentrations between the high and low calibration standard. Samples were diluted by weight with premisolv. An internal standard was added to the solutions to indicate variations of test specimen response. The solutions were introduced to the ICP/OES instrument by peristaltic pump.

Test Methodology

| | |
|---|---|
| **Parameters** | Sample was injected into the ICP/OES. Emission intensities were measured for samples and compared to the standards. Concentration was then calculated. |
| **Acceptance Criteria** | Not detected |
| **Reference Document** | ASTM D5185, modified |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| ICP/OES | Perkin Elmer | Optima 5300 DV | 077C8022002 |

Deviations from or Interpretation of Test Method

None

## Total Water Content

Test Description

Water content was measured utilizing an automatic titrator, with the buret primed with Composite 5 reagent, and the reaction vessel filled with anhydrous methanol. First, the Composite 5 solution was standardized by adding a water standard (Hydranal 10.0) to the reaction vessel which was then dehydrated with Composite 5 reagent. The normality for the Composite 5 reagent was then calculated and recorded. Following the determination of the normality, a known weight of fuel sample was added to the solvent and the titration of the sample started automatically. Composite 5 reagent was added until the millivolt reading stabilized and the volume was recorded. A second sample addition of known weight was made to the reaction vessel and titrated in the same manner. The percent

water in the sample was calculated automatically, and the two values were then averaged for reporting.

Test Methodology

| | |
|---|---|
| **Parameters** | A water standard is added to the reaction vessel and titrated to determine the reagent factor; a known weight of fuel sample is then added to the same reaction vessel and titrated, with the percent water automatically calculated. |
| **Acceptance Criteria** | Report |
| **Reference Document** | ASTM D6304, ASTM E1064, ASTM E203 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Autotitrator | Brinkmann Instruments/Metrohm USA | 836 Titrando | 1836002010117 |
| Analytical Balance | A&D | N/A | 10400184 |

Deviations from or Interpretation of Test Method

Pyridine is not used, nor is pure water. Instead, Composite 5 solution (Di ethyl ether, imidazole, sulfur dioxide, iodine, & 2-methylimidazole) was used in conjunction with anhydrous methanol, and a Hydranal water standard (xylene, n-butanol, and propylene carbonate). Changes in procedure due to these substitutions are listed above.

## API Gravity

Test Description

The sample was brought to a specified temperature (15°C for most specifications) and a test portion was transferred to a hydrometer cylinder that had been brought to approximately the same temperature. The appropriate hydrometer, also at a similar temperature, was lowered into the test portion and allowed to settle. After temperature equilibrium had been reached, the hydrometer scale was read, and the temperature of the sample was taken. The observed hydrometer reading was reduced to the reference temperature by means of the Petroleum Measurement Tables. If necessary, the hydrometer cylinder and its contents were placed in a constant temperature bath to avoid excessive temperature variation during the test.

Test Methodology

| | |
|---|---|
| **Parameters** | A glass hydrometer was used to measure the |

| | |
|---|---|
| | density or API gravity (by converting hydrometer reading using the Petroleum Measurement Table) at a specified temperature. |
| **Acceptance Criteria** | Report |
| **Reference Document** | ASTM D1298 |

Test Equipment

| **Lab Equipment Required for Test** | **Manufacturer** | **Model #** | **Serial #** |
|---|---|---|---|
| Thermocouple | Fluke | Various | Various |

Deviations from or Interpretation of Test Method

None

# APPENDIX C Oil Test Methods

## Wear Metals

Test Description

A weighed portion of the used engine oil was mixed thoroughly, and diluted tenfold by weight with either mixed xylenes or other suitable solvents. Standards were prepared in the same manner. An internal standard was added to the solutions to indicate variations of test specimen response. The solutions were introduced to the ICP instrument by peristaltic pump. Samples were run and compared to the intensities determined from the calibration standards. A correction factor was determined for each analyte and used to calculate the concentration in each sample. If the analyte concentration exceeded the high calibration standard, the sample was diluted to yield concentrations between the high and low calibration standard.

Test Methodology

| | |
|---|---|
| **Parameters** | Sample was injected and emission intensities were measured and compared to the standard. Sample concentration was then calculated. |
| **Reference Document** | ASTM D5185 |
| **Lab Equipment for Test** | Analytical balance capable of 0.001g, inductively-coupled plasma atomic emission spectrometer (ICP/AES), and a nebulizer. |

## Total Acid Number

Test Description

The buret was filled with 0.1 mol/L (M) alcoholic KOH solution to prepare for the titration. A weighed quantity of sample (see Table 1 of ASTM D664) was added to a 100mL beaker. Sixty (60) mL of titration solvent was then added to the beaker. The beaker was placed on the titration stand, the electrodes were lowered into the sample, the buret tip was also placed below the surface of the sample, and the stirrer was activated. The titrator delivered 0.05 mL/min of alcoholic KOH through the region of the inflection points. The potentiometric/derivative curves were recorded and the titration was continued until the potential became constant, changing less than 5 mV/0.1 mL. The volume of titrant, molarity, the volume of KOH required for blank titration, and mass of sample were used to calculate the acid number.

Test Methodology

| | |
|---|---|
| **Parameters** | Sample was titrated by delivering 0.05 mL/min of alcoholic KOH during a potentiometric titration until the potential changed by less than 5 mV/0.1 mL; acid number was then calculated. |

| | |
|---|---|
| **Reference Document** | ASTM D664 |
| **Lab Equipment for Test** | Either a manual or automatic titration apparatus, glass electrode, calomel reference electrode, mechanical stirrer, and glass burette |

## Total Base Number

Test Description

The buret was filled with 0.1 mol/L (M) alcoholic HCl solution to prepare for the titration. A weighed quantity of sample (see 11.1 of ASTM D4739) was added to a 100-mL beaker. Sixty (60) mL of titration solvent was then added to the beaker. The beaker was placed on the titration stand and the electrodes were lowered into the sample. The buret tip was also placed below the surface of the sample, and the stirrer was activated. The titration delivered 0.100 mL/min of alcoholic HCl every 90 seconds, until a well defined inflection point was clearly visible. The potentiometric/derivative curves were recorded. The volume of titrant, molarity, the volume of KOH required for blank titration, and mass of sample were used to calculate the base number.

Test Methodology

| | |
|---|---|
| **Parameters** | Sample was titrated by delivering 0.100 mL/min of alcoholic HCl every 90 seconds, for the duration of the potentiometric titration until the inflection is clearly visible, and then base number was calculated. |
| **Reference Document** | ASTM D4739 |
| **Lab Equipment for Test** | Either a manual or automatic titration apparatus, sensing pH electrode, Ag/AgCl reference electrode, mechanical stirrer, and glass burette |

## Kinematic Viscosity at 40°C and 100°C

Test Description

Automated viscometers were used for running ASTM D445 for kinematic viscosity. The glass capillary viscometer was charged in the manner dictated by the design of the viscometer (see ASTM D446). If the sample contained solid particles or fibers, it was filtered either prior to or during charging through a 75 micron filter. The charged viscometer was placed into the automated viscometer bath and allowed to equilibrate for 30 minutes. Suction pressure was used to adjust the head level of the sample to a position in the capillary arm of the instrument about 7 mm above the first timing mark. With the sample flowing freely, the time was measured (in seconds to within 0.1 second) that was required for the meniscus to pass from the first to the second timing mark. If this flow time was less than 200 seconds, a viscometer with a capillary of smaller diameter was selected and the analysis repeated. The above measurement procedure was repeated a

second time and both measurements were recorded. The average of the two readings was used to calculate kinematic viscosity.

Test Methodology

| | |
|---|---|
| **Parameters** | Determined the viscosity of the sample at specified temperatures by recording the time required for the sample to flow from the first to the second timing mark and then using this value to calculate viscosity. |
| **Reference Document** | ASTM D445, ASTM D446 |
| **Lab Equipment for Test** | Automated viscometer, temperature controlled bath, temperature measuring device, and a timing device. |

## Viscosity Index

Test Description

*Procedure A:* for oils with a viscosity index up to and including 100.
If the kinematic viscosity of the oil at 100°C was between 2.0 $mm^2$/sec and 70.0 $mm^2$/sec, the *L* and *H* values were extracted from Table 1 of ASTM D2270. These values were used to calculate viscosity index by the following equation:
$VI=[(L-U)/(L-H)x100]$ where
*L*=taken from Table 1
*H*=taken from Table 1
*U*=kinematic viscosity of the oil at 40°C

*Procedure B:* for oils with a viscosity index of 100 and greater.
If the kinematic viscosity of the oil at 100°C was between 2.0 $mm^2$/sec and 70.0 $mm^2$/sec, the *L* and *H* values were extracted from Table 1 of ASTM D2270. These values were used to calculate viscosity index by the following equation:
$VI=[((\text{antilog } N)-1)/0.00715]+100$ where
$N=(\log H-\log U)/\log Y$
*L*=taken from Table 1
*H*=taken from Table 1
Y=kinematic viscosity of the oil at 100°C
U=kinematic viscosity of the oil at 40°C

Test Methodology

| | |
|---|---|
| **Parameters** | Determine the viscosity index of the oil by performing the specified calculation using the kinematic viscosity of the oil at 40°C and 100°C. |
| **Reference Document** | ASTM D2270, ASTM D445, ASTM D446 |
| **Lab Equipment for Test** | N/A |

## Soot Content

Test Description

The cubic zirconia sample platform was coated with the oil sample. The soot meter used attenuated total reflection (ATR) transmission to measure the % of soot (carbon) in the sample in a matter of 30 seconds. The meter has a built in calibration curve, so no further calibration was necessary. *Note: This is a generic method derived from specifications of the manufacturer of the soot meter. A more detailed method will be available after the ASTM document has been approved and added.*

Test Methodology

| | |
|---|---|
| **Parameters** | Determined amount of suspended soot content in motor oils using attenuated total reflectance. |
| **Reference Document** | ASTM standard is pending (based on instrument-specific test method by Wilks Enterprise Inc.) |
| **Lab Equipment for Test** | Infracal soot meter |

## Percent Fuel Dilution

Test Description

A calibration curve was obtained by mixing a minimum of three mixtures of diesel fuel and engine oil, covering the range of the sample, up to a maximum of 12 mass percent diesel fuel. These mixtures were individually injected onto the gas chromatograph (GC), and the total areas noted. The oil sample was prepared by weighing 0.1 ±0.001g of *n*-decane into a vial, and then weighing 1.0 ±0.01g of the sample into the same vial. The vial was then filled, to a total of 10.00 + 0.01g with carbon disulfide. The vial was capped and mixed well before injecting 1µL of the mixture onto the column of the gas chromatograph. The total integrated area due to the fuel portion of the sample and the total integrated area due to *n*-decane were recorded. The ratio of these two areas was then calculated. The mass percent of the diesel fuel or B20 present in the oil was then determined by relating the ratio to the calibration curve.

Test Methodology

| | |
|---|---|
| **Parameters** | A calibration curve determined with internal standards was obtained by GC, then oil samples were run and compared with the standards, and mass % of diesel fuel or B20 in engine oil was determined. |
| **Reference Document** | ASTM D3524 |
| **Lab Equipment for Test** | Gas chromatograph |

## Water Content

Test Description

Water content was determined in accordance with ASTM D6304, Procedure C. A 1 mL sample of the used oil was injected into the evaporator assembly and an operating sequence was started. Once the end point was reached, the amount of water, in micrograms, was recorded from the readout on the instrument. To determine % water in the sample, the following equations were used:
ppm water = (amount of water (µg))/(sample weight (g))
% water = (ppm water)/10,000

Test Methodology

| | |
|---|---|
| **Parameters** | The used oil sample was heated in the water evaporator accessory and the vaporized water was carried into the titration cell by a dry, inert gas. |
| **Reference Document** | ASTM D6304, Procedure C |
| **Lab Equipment for Test** | Coulometric Karl Fischer Titration apparatus with water evaporator accessory |

# APPENDIX D Biodiesel Fuel Data

## Table 15. Biodiesel Fuel Data

| Test Name | | CTC Lab Sample ID | Appearance | Acid Number | Viscosity at 40°C | Water and Sediment | Total Water Content | Color | Particulate Contamination | Oxidation Stability - Rancimat | Total Insolubles | Iso-Octane Insolubles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Test Method | | | ASTM D4176 | ASTM D664 | ASTM D445 | ASTM D2709 | ASTM E1064 | ASTM D1500 | ASTM D6217 | EN14112 | | |
| Acceptance Criteria | | | Report | 0.3 mg KOH/g, max | 1.9-4.1 $mm^2/sec$ | 0.05%, max | Report | L3.0, max | 10 mg/L, max | 6 hours, max | | |
| Sample Name | Moody AFB; Sampled week of 9/14/09 | 09-04782-C | Fail - haze rating = 2 | 0.102 mg KOH/g | 2.92 $mm^2/sec$ | 0.05 | 0.02% | L0.5 | 12.9 mg/L | 5.68 hours | 1.0 mg/100mL | 0.57 mg/100 mL |
| | Moody AFB Vehicle Sample - #08C00265, 243 hours; Sampled 10/7/09 | 09-5075-C | Clear & bright; haze rating =1 | 0.063 mg KOH/g | 2.93 $mm^2/sec$ | <0.005 | 0.02% | L0.5 | 1.8 mg/L | 5.51 hours | 2.26 mg/100mL | 1.26 mg/100 mL |
| | Moody AFB Vehicle Sample - #05L00156, 3355 hours; Sampled 10/7/09 | 09-5076-C | Clear & bright; haze rating =1 | 0.098 mg KOH/g | 2.91 $mm^2/sec$ | 0.005 | 0.02% | L1.0 | 2.9 mg/L | 5.95 hours | 0.286 mg/100mL | 0.143 mg/100 mL |
| | Moody AFB Vehicle Sample - #97C00410, 2706 hours; Sampled 10/7/09 | 09-5077-C | Fail-haze rating =6. Sample was cloudy | 0.082 mg KOH/g | 2.92 $mm^2/sec$ | 0.005 | 0.04% | L5.0 | 3.2 mg/L | 2.17 hours | 143.2 mg/100mL | 118.7 mg/100 mL |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Moody AFB Dispenser Sample-10/16/09** | **09-5209-C** | **Fail-haze rating =2** | **0.101 mg KOH/g** | **2.84 $mm^2$/sec** | **0.005** | **0.03%** | **L0.5** | **6.0 mg/L** | **8.55 hours** | **0.22 mg/100 mL** | **0.11 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#97C00410, 2711 hours; Sampled 11/03/09** | **09-5485-C** | **Fail-haze rating =5** | **0.100 mg KOH/g** | **2.93 $mm^2$/sec** | **0.005** | **0.04%** | **L3.5** | **2.9 mg/L** | **2.41 hours** | **0.83 mg/100 mL** | **<0.1 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 11/03/09** | **09-5486-C** | **Clear & bright; haze rating =1** | **0.100 mg KOH/g** | **2.76 $mm^2$/sec** | **<0.1%*** | **<0.02%** | **L0.5** | **2.0 mg/L** | **5.20 hours** | **1.77 mg/100 mL** | **0.37 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#08C00265, 4840 hours; Sampled 11/03/09** | **09-5487-C** | **Clear & bright; haze rating =1** | **0.077 mg KOH/g** | **3.00 $mm^2$/sec** | **<0.1%*** | **<0.02%** | **L0.5** | **0.6 mg/L** | **6.18 hours** | **1.71 mg/100 mL** | **0.77 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#08C00265, 342 hours; Sampled 12/15/09** | **09-5781-C** | **Clear & bright; haze rating =1** | **0.062 mg KOH/g** | **2.9 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **2.9 mg/L** | **7.01 hours** | **0.68 mg/100 mL** | **0.34 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#97C00410, 2714 hours; Sampled 12/15/09** | **09-5782-C** | **Clear & bright; haze rating =1** | **0.079 mg KOH/g** | **2.9 $mm^2$/sec** | **<0.005** | **0.03%** | **L4.0** | **3.4 mg/L** | **2.08 hours** | **1.0 mg/100 mL** | **0.40 mg/100 mL** |
| | **Moody AFB Vehicle Sample-#05L00156, 3388 hours; Sampled 12/15/09** | **09-5783-C** | **Clear & bright; haze rating =1** | **0.077 mg KOH/g** | **2.9 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **1.6 mg/L** | **9.24 hours** | **0.97 mg/100 mL** | **0.20 mg/100 mL** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Moody AFB Seminole Nozzle Sample; Sampled 12/08/09** | **09-5784-C** | **Clear & bright; haze rating =1** | **0.062 mg KOH/g** | **3.1 $mm^2$/sec** | **<0.005** | **0.04%** | **L1.0** | **1.2 mg/L** | **11.67 hours** | **0.14 mg/100 mL** | **0.14 mg/100 mL** |
| | **Moody AFB Seminole Nozzle Sample; Sampled 12/08/09** | **09-5785-C** | **Clear & bright; haze rating =1** | **0.064 mg KOH/g** | **2.8 $mm^2$/sec** | **<0.005** | **0.04%** | **L1.0** | **1.4 mg/L** | **11.91 hours** | **<0.1 mg/100 mL** | **<0.1 mg/100 mL** |
| | **Moode AFB Vehicle 08C00265, 342 Hours; Sampled 01/05/10** | **10-00046-C** | **Clear & bright; haze rating =1** | **0.037 mg KOH/g** | **2.70 $mm^2$/sec** | **<0.005** | **0.06%** | **L0.5** | **2.3 mg/L** | **7.16 hours** | **0.23 mg/100 mL** | **0.23 mg/100 mL** |
| | **Moody AFB Vehicle 97C00410, 2718 Hours; Sampled 01/05/10** | **10-00047-C** | **Failed; haze rating =5** | **0.078 mg KOH/g** | **2.90 $mm^2$/sec** | **<0.005** | **0.09%** | **L4.0** | **4.8 mg/L** | **1.95 hours** | **86.4 mg/100 mL** | **57.9 mg/100 mL** |
| | **Moody AFB Vehicle 05L00156, 3542 Hours; Sampled 01/05/10** | **10-00048-C** | **Clear & bright; haze rating =1** | **<0.01 mg KOH/g** | **2.49 $mm^2$/sec** | **<0.005** | **0.06%** | **L0.5** | **1.6 mg/L** | ***Pending *** | **0.14 mg/100 mL** | **0.14 mg/100 mL** |
| | **Moody AFB Seminole Dispensing Nozzle; Sampled 01/20/10** | **10-00049-C** | **Clear & bright; haze rating =1** | **0.037 mg KOH/g** | **2.67 $mm^2$/sec** | **<0.005** | **0.05%** | **L0.5** | **1.0 mg/L** | **10.30 hours** | **0.17 mg/100 mL** | **<0.1 mg/100 mL** |
| | **Moody AFB Seminole Biodiesel Receipt Sample; Sampled 01/26/10** | **10-00060-C** | **Clear & bright; haze rating =1** | **0.030 mg KOH/g** | **2.83 $mm^2$/sec** | **<0.005** | **0.05%** | **L0.5** | **1.5 mg/L** | **12.51 hours** | **0.14 mg/100 mL** | **0.14 mg/100 mL** |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Moody AFB Vehicle 08C00265, 447 Hours; Sampled 02/04/10** | **10-00126-C** | **Clear & bright; haze rating =1** | **0.029 mg KOH/g** | **2.7 mm2/sec** | **<0.005** | **0.05%** | **L0.5** | **2 mg/L** | **8.23 hours** | **1.61 mg/100 mL** | **0.31 mg/100 mL** |
| | **Moody AFB Vehicle 97C00410, 2723.5 Hours; Sampled 02/04/10** | **10-00127-C** | **Clear & bright; haze rating =3** | **0.059 mg KOH/g** | **2.82 mm2/sec** | **<0.005** | **0.07%** | **L3.0** | **5 mg/L** | **2.56 hours** | **66.4 mg/100 mL** | **56.9 mg/100 mL** |
| | **Moody AFB Vehicle 05L00156, 3667 Hours; Sampled 02/04/10** | **10-00128-C** | **Clear & bright; haze rating =1** | **0.03 mg KOH/g** | **2.83 mm2/sec** | **<0.005** | **0.04%** | **L0.5** | **3.4 mg/L** | **9.81 hours** | **3.29 mg/100 mL** | **<0.1 mg/100 mL** |
| | **Moody AFB Dispenser Nozzle** | **10-00373-C** | **Clear & bright; haze rating =1** | **0.048 mg KOH/g** | **2.8 mm2/sec** | **<0.005** | **0.02%** | **L0.5** | **2.6 mg/L** | **14.36 hours** | **0.83 mg/100 mL** | **0.14 mg/100 mL** |
| | **Moody AFB Vehicle 05L00156, 3726 Hours; Sampled 02/10/10** | **10-00763-C** | **Fail; haze rating =3** | **0.1 mg KOH/g** | **2.97 mm2/sec** | **0.05%** | **0.04%** | **L2.0** | **14.1 mg/L** | **3.44 Hours** | **Needs to be rerun** | **Needs to be rerun** |
| | **Moody AFB Vehicle 08C00265, 528 hours; Sampled 03/17/10** | **10-00764-C** | **Clear & bright; haze rating =1** | **0.094 mg KOH/g** | **2.88 mm2/sec** | **<0.005%** | **0.02%** | **L1.0** | **4.8 mg/L** | **6.45 Hours** | **Needs to be rerun** | **Needs to be rerun** |
| | **Moody AFB Vehicle 97C00410, 2734 Hours; Sampled 03/17/10** | **10-00765-C** | **Fail; haze rating =2** | **0.084 mg KOH/g** | **2.85 mm2/sec** | **<0.005%** | **0.02%** | **L2.0** | **5.4 mg/L** | **2.29 Hours** | **Needs to be rerun** | **Needs to be rerun** |

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| | **Moody AFB Vehicle 08C00265, 574 hours; Sampled 04/09/10** | **10-01038-C** | **Fail; haze rating =6** | **0.128 mg KOH/g** | **3.0 mm2/sec** | **1.50%** | **0.16%** | **L1.0** | **94.8 mg/L** | **3.42 hours** | **8.43 mg/100 mL** | **5.8 mg/100 mL** |
| | **Moody AFB Vehicle 97C00410, 2736 Hours; Sampled 04/09/10** | **10-01039-C** | **Fail; haze rating =6** | **0.076 mg KOH/g** | **2.85 mm2/sec** | **0.10%** | **0.11%** | **L2.0** | **7.5 mg/L** | **1.3 hours** | **107.06 mg/100 mL** | **24 mg/100 mL** |
| | **Moody AFB Vehicle 05L00156, 3936 Hours; Sampled 04/09/10** | **10-01040-C** | **Clear & bright; haze rating=1** | **0.1 mg KOH/g** | **2.88 mm2/sec** | **<0.005%** | **0.05%** | **L1.0** | **2.4 mg/L** | **4.13 Hours** | **10.5 mg/100 mL** | **6.1 mg/100 mL** |
| | **Moody AFB Vehicle 08C00265, 612 Hours; Sampled 05/10/10** | **10-1217-C** | **Clear & bright; haze rating=1** | **0.061 mg KOH/g** | **3.0 mm2/sec** | **<0.005%** | **0.03%** | **L1.0** | **1.2 mg/L** | **10.14 hours** | **3.2 mg/100 mL** | **0.1 mg/100 mL** |
| | **Moody AFB Vehicle 97C00410, 2740 Hours; Sampled 05/10/10** | **10-1218-C** | **Clear & bright; haze rating=1** | **0.073 mg KOH/g** | **2.9 mm2/sec** | **<0.005%** | **0.05%** | **L2.0** | **4.2 mg/L** | **2.83 hours** | **37.5 mg/100 mL** | **13.4 mg/100 mL** |
| | **Moody AFB Vehicle 05L00156, 3724 Hours; Sampled 05/10/10** | **10-1219-C** | **Fail; haze rating =4** | **0.075 mg KOH/g** | **3.0 mm2/sec** | **0.01%** | **0.04%** | **L3.0** | **6.3 mg/L** | **3.65 hours** | **8.2 mg/100 mL** | **6.7 mg/100 mL** |
| | **Moody AFB, Vehicle 08C00265, 659 Hours, Sampled 06/10/10** | **10-1385-C** | **Clear & bright; haze rating=1** | **0.022 mg KOH/g** | **2.83 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **0.7 mg/L** | **9.77 Hours** | **2.0 mg/100 mL** | **0.4 mg/100 mL** |

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| | **Moody AFB, Vehicle 97C00410, 2748 Hours; Sample 06/10/10** | **10-1386-C** | **Fail; haze rating =3** | **0.039 mg KOH/g** | **2.88 mm2/sec** | **0.01%** | **0.03%** | **L3.0** | **2.1 mg/L** | **3.09 Hours** | **52.5 mg/100 mL** | **41.5 mg/100 mL** |
| | **Moody AFB, Vehicle 05L00156, 3810 Hours, Sampled 06/10/10** | **10-1387-C** | **Fail; haze rating =2** | **0.037 mg KOH/g** | **2.79 mm2/sec** | **0.01%** | **0.03%** | **L3.0** | **4.0 mg/L** | **8.86 Hours** | **2.5 mg/100 mL** | **0.6 mg/100 mL** |
| | **Moody AFB, Vehicle 08C00265, 716 Hours, Sampled 07/08/10** | **10-2917-C** | **Clear & bright; haze rating=1** | **0.05 mg KOH/g** | **2.78 mm2/sec** | **<0.005%** | **0.04%** | **L1.0** | **0.8 mg/L** | **9.27 Hours** | **1.5 mg/100 mL** | **1.4 mg/100 mL** |
| | **Moody AFB, Vehicle 05L00156, 3878 Hours, Sampled 07/08/10** | **10-2918-C** | **Fail; haze rating =3** | **0.084 mg KOH/g** | **2.78 mm2/sec** | **<0.005%** | **0.04%** | **L1.5** | **1.6 mg/L** | **7.60 Hours** | **2.2 mg/100 mL** | **0.1 mg/100 mL** |
| | **Moody AFB, Vehicle 97C00410, 2753 Hours; Sample 07/08/10** | **10-2919-C** | **Clear & bright; haze rating=1** | **0.048 mg KOH/g** | **2.84 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **2.0 mg/L** | **3.72 Hours** | **20.1 mg/100 mL** | **13.7 mg/100 mL** |
| | | | | | | | | | | | | |
| | | **Total Water Content** | **Particulate Contamination (mg/L)** | **Oxidation Stability - Rancimat (Hours)** | **Acid Number Values (mg KOH/g)** | **Date Sampled** | | | | | | |

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| | **Moody AFB Vehicle Sample - #05L00156, 3355 hours; Sampled 10/7/09** | **0.02%** | **2.9** | **5.95** | **0.098** | **10/7/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #05L00156, 3388 hours; Sampled 11/03/09** | **0.02%** | **2** | **5.2** | **0.1** | **11/3/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #05L00156, 3388 hours; Sampled 12/15/09** | **0.03%** | **1.6** | **9.24** | **0.077** | **12/15/2009** | | | | | | |
| | **Moody AFB Vehicle 05L00156, 3542 Hours; Sampled 01/05/10** | **0.06%** | **1.6** | ***Pending*** | **0.01** | **1/5/2010** | | | | | | |
| | **Moody AFB Vehicle 05L00156, 3667 Hours; Sampled 02/04/10** | **0.04%** | **3.4** | **9.81** | **0.03** | **2/4/2010** | | | | | | |
| | **Moody AFB Vehicle 05L00156 3726 hours 2/10/10** | **0.04%** | **14.1** | **3.44** | **0.1** | **2/10/2010** | | | | | | |
| | **Moody AFB Vehicle 05L00156 3936 hours 4/9/10** | **0.05%** | **2.4** | **4.13** | **0.1** | **4/9/2010** | | | | | | |

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| | **Moody AFB Vehicle 05L00156, 3724 Hours; Sampled 05/10/10** | **0.04%** | **6.3** | **3.65** | **0.075** | **5/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 05L00156, 3810 Hours, Sampled 06/10/10** | **0.03%** | **4** | **8.86** | **0.037** | **6/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 05L00156, 3878 Hours, Sampled 07/08/10** | **0.04%** | **1.6** | **7.6** | **0.084** | **7/8/2010** | | | | | | |
| | **Moody AFB Vehicle Sample - #08C00265, 243 hours; Sampled 10/7/09** | **0.02%** | **1.8** | **5.51** | **0.063** | **10/7/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #08C00265, 4840 hours; Sampled 11/03/09** | **0.02%** | **0.6** | **6.18** | **0.077** | **11/3/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #08C00265, 342 hours; Sampled 12/15/09** | **0.03%** | **2.9** | **7.01** | **0.062** | **12/15/2009** | | | | | | |

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| | **Moode AFB Vehicle 08C00265, 342 Hours; Sampled 01/05/10** | **0.06%** | **2.3** | **7.16** | **0.037** | **1/5/2010** | | | | | | |
| | **Moody AFB Vehicle 08C00265, 447 Hours; Sampled 02/04/10** | **0.05%** | **2** | **8.23** | **0.029** | **2/4/2010** | | | | | | |
| | **Moody AFB Vehicle 08C00265 528 hours 3/17/10** | **0.02%** | **4.8** | **6.45** | **0.094** | **3/17/2010** | | | | | | |
| | **Moody AFB Vehicle 08C00265 574 hours 4/9/10** | **0.16%** | **94.8** | **3.42** | **0.128** | **4/9/2010** | | | | | | |
| | **Moody AFB Vehicle 08C00265, 612 Hours; Sampled 05/10/10** | **0.03%** | **1.2** | **10.14** | **0.061** | **5/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 08C00265, 659 Hours, Sampled 06/10/10** | **0.03%** | **0.7** | **9.77** | **0.022** | **6/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 08C00265, 716 Hours, Sampled 07/08/10** | **0.04%** | **0.8** | **9.27** | **0.05** | **7/8/2010** | | | | | | |

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| | **Moody AFB Vehicle Sample - #97C00410, 2706 hours; Sampled 10/7/09** | **0.04%** | **3.2** | **2.17** | **0.082** | **10/7/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #97C00410, 2711 hours; Sampled 11/03/09** | **0.04%** | **2.9** | **2.41** | **0.1** | **11/3/2009** | | | | | | |
| | **Moody AFB Vehicle Sample- #97C00410, 2714 hours; Sampled 12/15/09** | **0.03%** | **3.4** | **2.08** | **0.079** | **12/15/2009** | | | | | | |
| | **Moody AFB Vehicle 97C00410, 2718 Hours; Sampled 01/05/10** | **0.09%** | **4.8** | **1.95** | **0.078** | **1/5/2010** | | | | | | |
| | **Moody AFB Vehicle 97C00410, 2723.5 Hours; Sampled 02/04/10** | **0.07%** | **5** | **2.56** | **0.059** | **2/4/2010** | | | | | | |
| | **Moody AFB Vehicle 97C00410 2734 hours 3/17/10** | **0.02%** | **5.4** | **2.29** | **0.084** | **3/17/2010** | | | | | | |
| | **Moody AFB Vehicle 97C00410 2736 hours 4/9/10** | **0.11%** | **7.5** | **1.3** | **0.076** | **4/9/2010** | | | | | | |

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| | **Moody AFB Vehicle 97C00410, 2740 Hours; Sampled 05/10/10** | **0.05%** | **4.2** | **2.83** | **0.073** | **5/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 97C00410, 2748 Hours; Sample 06/10/10** | **0.03%** | **2.1** | **3.09** | **0.039** | **6/10/2010** | | | | | | |
| | **Moody AFB, Vehicle 97C00410, 2753 Hours; Sample 07/08/10** | **0.03%** | **2** | **3.72** | **0.048** | **7/8/2010** | | | | | | |
| | **Moody AFB Dispenser Sample- 10/16/209** | **0.03%** | **6** | **8.55** | **0.101** | **10/16/2009** | | | | | | |
| | **Moody AFB Seminole Nozzle Sample; Sampled 12/08/09** | **0.04%** | **1.2** | **11.67** | **0.062** | **11/8/2009** | | | | | | |
| | **Moody AFB Seminole Nozzle Sample; Sampled 12/08/09** | **0.04%** | **1.4** | **11.91** | **0.064** | **12/8/2009** | | | | | | |
| | **Moody AFB Seminole Dispensing Nozzle; Sampled 01/20/10** | **0.05%** | **1** | **10.3** | **0.037** | **1/20/2010** | | | | | | |
| | **Moody AFB Dispenser** | **0.02%** | **2.61** | **14.36** | **0.048** | **2/4/2010** | | | | | | |

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| | **Nozzle** | | | | | | | | | | | |
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| **Test Name** | | **CTC Lab Sample ID** | **Appearance** | **Acid Number** | **Viscosity at 40°C** | **Water and Sediment** | **Total Water Content** | **Color** | **Particulate Contamination** | **Oxidation Stability - Rancimat** | **Iso-Octane Insolubles** | **Total Acid Number** |
| **Test Method** | | | **ASTM D4176** | **ASTM D664** | **ASTM D445** | **ASTM D2709** | **ASTM E1064** | **ASTM D1500** | **ASTM D6217** | **EN14112** | | |
| **Acceptance Criteria** | | | **Report** | **0.3 mg KOH/g, max** | **1.9-4.1 $mm^2/sec$** | **0.05%, max** | **Report** | **L3.0, max** | **10 mg/L, max** | **6 hours, max** | | |
| **Sample Name** | **29 Palms Dispenser Sample (#18); Sampled 6/24/09** | **09-4420-C** | **Clear & bright; haze rating = 1** | **0.091 mg KOH/g** | **2.90 $mm^2/sec$** | **<0.005** | **0.08 mg/mL** | **L1.5** | **1.3 mg/L** | **15.09 hours** | **0.1 mg/100 mL** | **0.084 mg KOH/g** |
| | **29 Palms Vehicle Sample; Sampled 8/7/09** | **09-4421-C** | **Clear & bright; haze rating = 1** | **0.125 mg KOH/g** | **2.91 $mm^2/sec$** | **<0.005** | **0.21 mg/mL** | **L1.0** | **4.3 mg/L** | **1.49 hours** | **36.1 mg/100 mL** | **0.017 mg KOH/g** |
| | **29 Palms Dispenser Sample; Sampled 8/7/09** | **09-4422-C** | **Clear & bright; haze rating = 1** | **0.078 mg KOH/g** | **2.80 $mm^2/sec$** | **<0.005** | **0.09 mg/mL** | **L1.5** | **1.3 mg/L** | **15.70 hours** | **0.1 mg/100 mL** | **0.089 mg KOH/g** |
| | **29 Palms HMMVW Vehicle Sample; Sampled 9/3/09** | **09-5044-C** | **Clear & bright; haze rating = 1** | **0.088 mg KOH/g** | **2.81 $mm^2/sec$** | **<0.005** | **< 0.01%** | **L1.5** | **2.3 mg/L** | **5.13 hours** | **0.943 mg/100 mL** | **0.008 mg KOH/g** |

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| | **29 Palms Fuel Station Dispenser Sample; Sampled 9/2/09** | **09-5045-C** | **Clear & bright; haze rating = 1** | **0.085 mg KOH/g** | **2.74 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.5** | **2.5 mg/L** | **19.58 hours** | **<0.1 mg/100 mL** | **0.091 mg KOH/g** |
| | **29 Palms Fuel Station 18 Nozzle Sample; Sampled 10/22/09** | **09-5483-C** | **Clear & bright; haze rating =1** | **0.097 mg KOH/g** | **2.87 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.5** | **3.3 mg/L** | **20.16 hours** | **0.11 mg/100 mL** | **0.094 mg KOH/g** |
| | **29 Palms HMMWV Vehicle Sample, 94-59514; Sampled 10/23/09** | **09-5484-C** | **Clear & bright; haze rating =1** | **0.100 mg KOH/g** | **2.87 $mm^2$/sec** | **<0.005** | **<0.02%** | **L1.5** | **1.5 mg/L** | **10.75 hours** | **0.51 mg/100 mL** | **0.104 mg KOH/g** |
| | **29 Palms MCAGCC, HMMWV, 94-59514; Sampled 11/13/09** | **09-5488-C** | **Clear & bright; haze rating =1** | **0.103 mg KOH/g** | **2.64 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.5** | **2.9 mg/L** | **18.01 hours** | **0.14 mg/100 mL** | **0.087 mg KOH/g** |
| | **29 Palms Fuel from Fuel Farm; Sampled 11/13/09** | **09-5489-C** | **Clear & bright; haze rating =1** | **0.102 mg KOH/g** | **2.87 $mm^2$/sec** | **<0.005** | **0.04%** | **L1.5** | **4.6 mg/L** | **21.04 hours** | **<0.1 mg/100 mL** | **0.087 mg KOH/g** |
| | **29 Palms HMMWV, 94-59514; Sampled 12/09/09** | **09-5779-C** | **Clear & bright; haze rating =1** | **0.081 mg KOH/g** | **2.9 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.5** | **2.5 mg/L** | **16.91 hours** | **0.14 mg/100 mL** | **0.091 mg KOH/g** |
| | **29 Palms Fuel Pump #17; Sampled 12/08/09** | **09-5780-C** | **Clear & bright; haze rating =1** | **0.080 mg KOH/g** | **2.9 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.5** | **5.3 mg/L** | **20.83 hours** | **0.11 mg/100 mL** | **0.094 mg KOH/g** |

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| **Dispenser** | | **Total Water Content** | **Particulate Contamination (mg/L)** | **Oxidation Stability - Rancimat (Hours)** | **Acid Number Values (mg KOH/g)** | **Date Sampled** | | | | | | |
| | **29 Palms Dispenser Sample (#18); Sampled 6/24/09** | **0.01%** | **1.3** | **15.09** | **0.091** | **6/24/2009** | | | | | | |
| | **29 Palms Dispenser Sample; Sampled 8/7/09** | **0.01%** | **1.3** | **15.7** | **0.078** | **8/7/2009** | | | | | | |
| | **29 Palms Fuel Station Dispenser Sample; Sampled 9/2/09** | **0.02%** | **2.5** | **19.58** | **0.085** | **9/2/2009** | | | | | | |
| | **29 Palms Fuel Station 18 Nozzle Sample; Sampled 10/22/09** | **0.02%** | **3.3** | **20.16** | **0.097** | **10/22/2009** | | | | | | |
| | **29 Palms Fuel from Fuel Farm; Sampled 11/13/09** | **0.04%** | **4.6** | **21.04** | **0.102** | **11/13/2009** | | | | | | |
| | **29 Palms Fuel Pump #17; Sampled 12/08/09** | **0.03%** | **5.3** | **20.83** | **0.08** | **12/8/2009** | | | | | | |

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| | **29 Palms Fuel Station; Sampled 12/29/09** | **0.04%** | **4.2** | **21.06** | **0.101** | **12/29/2009** | | | | | | |
| | **29 PalmsPump sample2/18/10** | **0.02%** | **4.5** | **20.7** | **0.096** | **2/18/2010** | | | | | | |
| | **HMMVR Location: Pump 3/11/10** | **0.02%** | **4.1** | **11.42** | **0.098** | **3/11/2010** | | | | | | |
| | **29 Palms 94-59514, VIC 69812; Sampled 04/27/10** | **0.02%** | **4.1** | **12.21** | **0.091** | **4/27/2010** | | | | | | |
| | **29 Palms From Pump 94-59514, VIC 69218; Sampled 04/29/10** | **0.03%** | **5.3** | **11.03** | **0.092** | **4/29/2010** | | | | | | |
| | **29 Palms from HMMWR Station; Sampled 05/26/10** | **0.03%** | **1.7** | **12.73** | **0.061** | **5/26/2010** | | | | | | |
| | **29 Palms from MCAGCC Pump 94-59514; Sampled 06/10/10** | **0.04%** | **2** | **14.13** | **0.059** | **6/10/2010** | | | | | | |

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| | **29 Palms Vehicle Sample; Sampled 8/7/09** | **0.02%** | **4.3** | **1.49** | **0.125** | **8/7/2009** | | | | | | |
| | **29 Palms HMMVW Vehicle Sample; Sampled 9/3/09** | **0.01%** | **2.3** | **5.13** | **0.088** | **9/3/2009** | | | | | | |
| | **29 Palms HMMWV Vehicle Sample, 94-59514; Sampled 10/23/09** | **0.02%** | **1.5** | **10.75** | **0.1** | **10/23/2009** | | | | | | |
| | **29 Palms MCAGCC, HMMWV, 94-59514; Sampled 11/13/09** | **0.02%** | **2.9** | **18.01** | **0.103** | **11/13/2009** | | | | | | |
| | **29 Palms HMMWV, 94-59514; Sampled 12/09/09** | **0.02%** | **2.5** | **16.91** | **0.081** | **12/9/2009** | | | | | | |
| | **29 Palms HMMWV; Sampled 12/29/09** | **0.03%** | **3.5** | **17.56** | **0.092** | **12/29/2009** | | | | | | |
| | **29 Palms Vehicle sample 2/18/10** | **0.02%** | **ND** | **4.8** | **0.1** | **2/18/2010** | | | | | | |
| | **HMMVR Location: Vehicle 3/11/10** | **0.02%** | **2.9** | **12.42** | **0.099** | **3/11/2010** | | | | | | |

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| | **29 Palms From Vehicle 94-59514; Sampled 04/27/10** | **0.01%** | **1.8** | **8.45** | **0.091** | **4/27/2010** | | | | | | |
| | **29 Palms From Vehicle HHMWR 94-95914; Sampled 04/29/10** | **0.02%** | **3.8** | **8.88** | **0.091** | **4/29/2010** | | | | | | |
| | **29 Palms from Vehicle HMMWR 94-59514; Sampled 05/26/10** | **0.04%** | **2** | **7.55** | **0.06** | **5/26/2010** | | | | | | |
| | **29 Palms from HMMWR 94-59514; Sampled 06/10/10** | **0.04%** | **2.1** | **7.27** | **0.061** | **6/10/2010** | | | | | | |
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| **Test Name** | **CTC Lab Sample ID** | **Appearance** | **Acid Number** | **Viscosity at 40°C** | **Water and Sediment** | **Total Water Content** | **Color** | **Particulate Contamination** | **Oxidation Stability - Rancimat** | **Oxidation Stability** | **Iso-Octane Insolubles** | **Total Acid Number** |
| **Test Method** | | **ASTM D4176** | **ASTM D664** | **ASTM D445** | **ASTM D2709** | **ASTM E1064** | **ASTM D1500** | **ASTM D6217** | **EN14112** | **modified ASTM D2274** | | |
| **Acceptance Criteria** | | **Report** | **0.3 mg KOH/g, max** | **1.9-4.1 $mm^2$/sec** | **0.05%, max** | **Report** | **L3.0, max** | **10 mg/L, max** | **6 hours, min** | **Report** | | |
| **NBVC Dispenser Sample; Sampled 7/8/09** | **09-4423-C** | **Clear & bright; haze rating = 1** | **0.053 mg KOH/g** | **2.36 $mm^2$/sec** | **<0.005** | **0.08 mg/mL** | **L0.5** | **1.4 mg/L** | **6.68 hours** | | **0.5 mg/100 mL** | **0.080 mg KOH/g** |

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| **NBVC Vehicle Sample; Sampled 8/6/09** | **09-4424-C** | **Clear & bright; haze rating = 1** | **0.049 mg KOH/g** | **2.27 $mm^2$/sec** | **0.005** | **0.24 mg/mL** | **L1.0** | **3.8 mg/L** | **2.73 hours** | | **177 mg/100 mL** | **0.080 mg KOH/g** |
| **NBVC Nozzle Sample; Sampled 10/1/09** | **09-5073-C** | **Clear & bright; haze rating = 1** | **0.050 mg KOH/g** | **2.35 $mm^2$/sec** | **<0.005** | **0.01%** | **L0.5** | **2.0 mg/L** | **3.96 hours** | | **154.1 mg/100 mL** | **0.080 mg KOH/g** |
| **NBVC Vehicle #USN-9647633; Sampled 10/1/09** | **09-5074-C** | **Clear & bright; haze rating = 1** | **0.051 mg KOH/g** | **2.25 $mm^2$/sec** | **<0.005** | **< 0.02%** | **L1.0** | **5.6 mg/L** | **2.24 hours** | | **208 mg/100 mL** | **0.007 mg KOH/g** |
| **NBVC Vehicle Sample, Sampled 02/02/10** | **10-00123-C** | **Clear & bright; haze rating = 1** | **0.046 mg KOH/g** | **2.33 mm2/sec** | **<0.005** | **0.03%** | **L1.0** | **2.6 mg/L** | **1.84 hours** | | **747.7 mg/100 mL** | **0.009 mg KOH/g** |
| **NBVC Dispenser Sample; Sampled 02/03/10** | **10-00124-C** | **Clear & bright; haze rating = 1** | **0.043 mg KOH/g** | **2.43 mm2/sec** | **<0.005** | **0.09%** | **L0.5** | **2.8 mg/L** | **2.31 hours** | | **472.7 mg/100 mL** | **0.014 mg KOH/g** |
| **NBVC Storage Tank; Sampled 03/30/10** | **10-00711-C** | **Clear & bright; haze rating = 1** | **0.064 mg KOH/g** | **2.36 mm2/sec** | **<0.005** | **<0.02%** | **L0.5** | **0.9 mg/L** | **3.25 Hours** | | **81.4 mg/100 mL** | **0.01 mg KOH/g** |
| **NBVC From MTVR; Sampled 03/30/10** | **10-00712-C** | **Clear & bright; haze rating = 1** | **0.068 mg KOH/g** | **2.40 mm2/sec** | **<0.005** | **<0.02%** | **L0.5** | **2.4 mg/L** | **1.89 Hours** | | **325.8 mg/100 mL** | **0.009 mg KOH/g** |
| **NBVC From Vehicle; Sampled 04/22/10** | **10-01069-C** | **Clear & bright; haze rating = 1** | **0.039 mg KOH/g** | **2.35 mm2/sec** | **<0.005** | **0.06%** | **L0.5** | **2.1 mg/L** | **1.64 hours** | | **460.7 mg/100 mL** | **<0.005 mg KOH/g** |

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| **NBVC From Station; Sampled 04/22/10** | **10-01070-C** | **Clear & bright; haze rating = 1** | **0.031 mg KOH/g** | **2.37 mm2/sec** | **<0.005** | **0.06%** | **L0.5** | **0.9 mg/L** | **3.59 hours** | | **39 mg/100 mL** | **<0.005 mg KOH/g** |
| **NBVC Vehicle Sample; Sampled 05/21/10** | **10-1327-C** | **Clear & bright; haze rating=1** | **0.073 mg KOH/g** | **2.3 mm2/sec** | **<0.005%** | **0.02%** | **L0.5** | **3.5 mg/L** | **1.86 hours** | | **447.6 mg/100 mL** | **0.034 mg KOH/g** |
| **NBVC Sample from Station; Sampled 05/21/10** | **10-1328-C** | **Clear & bright; haze rating=1** | **0.061 mg KOH/g** | **2.4 mm2/sec** | **<0.005%** | **0.02%** | **L0.6** | **0.7 mg/L** | **3.93 hours** | | **2.9 mg/100 mL** | **0.025 mg KOH/g** |
| **NBVC Sample from Fill Station; Sampled 08/25/10** | **10-3276-C** | **Clear & bright; haze rating=1** | **0.008 mg KOH/g** | **2.38 mm2/sec** | **0.02%** | **0.02%** | **L0.5** | **12.4 mg/L** | **1.47 Hours** | | **413.7 mg/100 mL** | **<0.005 mg KOH/g** |
| **NBVC Vehicle Sample 96-47633; Sampled 08/25/10** | **10-3277-C** | **Clear & bright; haze rating=1** | **0.048 mg KOH/g** | **2.37 mm2/sec** | **<0.005%** | **0.02%** | **L0.5** | **4.9 mg/L** | **1.44 Hours** | | **483.4 mg/100 mL** | **<0.005 mg KOH/g** |
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| | **Total Water Content** | **Particulate Contaminatio n (mg/L)** | **Oxidation Stability - Rancimat (Hours)** | **Acid Number Values (mg KOH/g)** | **Date Sampled** | | | | | | | |
| **NBVC Dispenser Sample; Sampled 7/8/09** | **0.00%** | **1.4** | **6.68** | **0.053** | **7/8/2009** | | | | | | | |
| **NBVC Nozzle Sample; Sampled** | **0.01%** | **2** | **3.96** | **0.05** | **10/1/2009** | | | | | | | |

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| **10/1/09** | | | | | | | | | | | | |
| **NBVS Dispenser Sample; Sampled 02/03/10** | **0.09%** | **2.8** | **2.31** | **0.043** | **2/3/2010** | | | | | | | |
| **NBVC Storage Tank 3/30/10** | **0.02%** | **0.9** | **3.25** | **0.064** | **3/30/2010** | | | | | | | |
| **NBVC From Station; Sampled 04/22/10** | **0.06%** | **0.9** | **3.59** | **0.031** | **4/22/2010** | | | | | | | |
| **NBVC Sample from Station; Sampled 05/21/10** | **0.02%** | **0.7** | **3.93** | **0.061** | **5/21/2010** | | | | | | | |
| **NBVC Sample from Fill Station; Sampled 08/25/10** | **0.02%** | **12.4** | **1.47** | **0.008** | **8/25/2010** | | | | | | | |
| **NBVC Vehicle Sample; Sampled 8/6/09** | **0.00%** | **3.8** | **2.73** | **0.049** | **8/6/2009** | | | | | | | |
| **NBVC Vehicle #USN-9647633; Sampled 10/1/09** | **0.02%** | **5.6** | **2.24** | **0.051** | **10/1/2009** | | | | | | | |

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| **NBVS Vehicle Sample, Sampled 02/02/10** | **0.03%** | **2.6** | **1.84** | **0.046** | **2/2/2010** | | | | | | | |
| **NBVC Vehicle (MTVR) 3/30/10** | **0.02%** | **2.4** | **1.89** | **0.068** | **3/30/2010** | | | | | | | |
| **NBVC From Vehicle; Sampled 04/22/10** | **0.06%** | **2.1** | **1.64** | **0.039** | **4/22/2010** | | | | | | | |
| **NBVC Vehicle Sample; Sampled 05/21/10** | **0.02%** | **3.5** | **1.86** | **0.073** | **5/21/2010** | | | | | | | |
| **NBVC Vehicle Sample 96-47633; Sampled 08/25/10** | **0.02%** | **4.9** | **1.44** | **0.048** | **8/25/2010** | | | | | | | |
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| **Test Name** | **CTC Lab Sample ID** | **Appearance** | **Acid Number** | **Viscosity at 40°C** | **Water and Sediment** | **Total Water Content** | **Color** | **Particulate Contamination** | **Oxidation Stability - Rancimat** | **Oxidation Stability** | **Iso-Octane Insolubles** | **Total Acid Number** |
| **Test Method** | | **ASTM D4176** | **ASTM D664** | **ASTM D445** | **ASTM D2709** | **ASTM E1064** | **ASTM D1500** | **ASTM D6217** | **EN14112** | **modified ASTM D2274** | | |
| **Acceptance Criteria** | | **Report** | **0.3 mg KOH/g, max** | **1.9-4.1 $mm^2$/sec** | **0.05%, max** | **Report** | **L3.0, max** | **10 mg/L, max** | **6 hours, max** | **Report** | | |
| **NSWC Crane Fuel Pump, P-6, Hasler Oil; Sampled 9/1/09** | **09-04779-C** | **Clear & bright; haze rating = 1** | **0.101 mg KOH/g** | **2.68 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **3.6 mg/L** | **4.66 hours** | | **3.66 mg/100 mL** | **0.006 mg KOH/g** |

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| **NSWC Crane Dispenser, P-7, Hasler Oil; Sampled 8/18/09** | **09-04780-C** | **Clear & bright; haze rating = 1** | **0.029 mg KOH/g** | **2.72 $mm^2$/sec** | **<0.005** | **0.03%** | **0.5** | **2.7 mg/L** | **18.92 hours** | | **< 0.1 mg/100 mL** | **0.34 mg KOH/g** |
| **NSWC Crane, Fuel Truck, Hasler Oil; Sampled 8/25/09** | **09-04781-C** | **Clear & bright; haze rating = 1** | **0.031mg KOH/g** | **2.82$mm^2$/sec** | **<0.005** | **0.01%** | **L0.5** | **2.7 mg/L** | **9.29 hours** | | **< 0.1 mg/100 mL** | **0.35 mg KOH/g** |
| **NSWC Crane Vehicle Tank, P-6, Hasler Oil; Sampled 9/25/09** | **09-04783-C** | **Clear & bright; haze rating = 1** | **0.102 mg KOH/g** | **2.70 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **2.5 mg/L** | **4.71 hours** | | **246.1 mg/100 mL** | **0.009 mg KOH/g** |
| **NSWC Crane Vehicle Tank, P-7, Hasler Oil; Sampled 9/25/09** | **09-04784-C** | **Fail - haze rating = 1 (particulate)** | **0.093 mg KOH/g** | **2.61 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.5** | **5.0 mg/L** | **2.30 hours** | | **292.7 mg/100 mL** | **0.006 mg KOH/g** |
| **NSWC Crane Vehicle Tank, P-6, Hasler Oil, 1 hour; sampled 10/29/09** | **09-5258-C** | **Clear & bright; haze rating =1** | **0.110 mg KOH/g** | **2.7 $mm^2$/sec** | **<0.005** | **<0.01%** | **L1.0** | **0.8 mg/L** | **3.81 hours** | | **6.69 mg/100 mL** | **0.019 mg KOH/g** |
| **NSWE Crane Vehicle Tank, P-7, Hasler Oil, 5.5 hours; sampled 10/29/09** | **09-5259-C** | **Clear & bright; haze rating =1** | **0.102 mg KOH/g** | **2.7 $mm^2$/sec** | **<0.005** | **<0.01%** | **L1.5** | **7.6 mg/L** | **2.24 hours** | | **164 mg/100 mL** | **0.018 mg KOH/g** |

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| **NSWE Crane Tank P-6, Hasler Oil, 0.25 hours; Sampled 11/30/09** | **09-5490-C** | **Clear & bright; haze rating =1** | **0.114 mg KOH/g** | **2.68 $mm^2$/sec** | **<0.005** | **0.04%** | **L1.0** | **1.3 mg/L** | **3.79 hours** | | **48.9 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWE Crane Tank P-7, Hasler Oil, 4.5 hours; Sampled 11/30/09** | **09-5491-C** | **Clear & bright; haze rating =1** | **0.106 mg KOH/g** | **2.80 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.5** | **9.7 mg/L** | **2.18 hours** | | **353.1 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Tank P-6, AVGP; Sampled 01/05/10** | **10-00031-C** | **Clear & bright; haze rating =1** | **0.104 mg KOH/g** | **2.60 $mm^2$/sec** | **<0.005** | **0.02%** | **L1.0** | **1.4 mg/L** | **3.63 hours** | | **16.8 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Tank P-7, AVGP; Sampled 01/05/10** | **10-00032-C** | **Clear & bright; haze rating =1** | **0.074 mg KOH/g** | **2.20 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **0.7 mg/L** | **4.08 hours** | | **61.7 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Fuel Tank P-6, 0.25 Run Hours, AVGP; Sampled 02/02/10** | **10-00083-C** | **Clear & bright; haze rating =1** | **0.104 mg KOH/g** | **2.69 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **1.2 mg/L** | **3.57 hours** | | **45.8 mg/100 mL** | **0.034mg KOH/g** |
| **NSWC Crane Hasler Oil, Fuel Tank P-7, 3.5 Run Hours, AVGP; Sampled 02/02/10** | **10-00084-C** | **Clear & bright; haze rating =1** | **0.079 mg KOH/g** | **2.26 $mm^2$/sec** | **<0.005** | **0.09%** | **L1.0** | **1 mg/L** | **3.70 hours** | | **51.1 mg/100 mL** | **<0.005 mg KOH/g** |

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| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 03/08/10** | **10-00374-C** | **Clear & bright; haze rating =1** | **0.096 mg KOH/g** | **1.9 $mm^2$/sec** | **<0.005** | **0.03%** | **L1.0** | **1.7 mg/L** | **3.01** | | **46.8 mg/100 mL** | **0.045 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 03/08/10** | **10-00375-C** | **Clear & bright; haze rating =1** | **0.056 mg KOH/g** | **3.8 $mm^2$/sec** | **<0.005** | **0.04%** | **L1.0** | **2.9 mg/L** | **4.04** | | **35 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP, 9 Hours; Sampled 04/08/10** | **10-00853-C** | **Fail; haze rating =1** | **0.069 mg KOH/g** | **2.15 mm2/sec** | **<0.005** | **0.02%** | **L1.0** | **2.4 mg/L** | **4.16 hours** | | **19.3 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP, 1 Hour; Sampled 04/08/10** | **10-00854-C** | **Clear & bright; haze rating =1** | **0.117 mg KOH/g** | **2.71 mm2/sec** | **<0.005** | **0.02%** | **L1.0** | **1.6 mg/L** | **3.08 hours** | | **22.8 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Pump Nozzle P-7 AVGP; Sampled 04/13/10** | **10-01037-C** | **Clear & bright; haze rating=1** | **0.04 mg KOH/g** | **2.69 mm2/sec** | **0.01%** | **0.05%** | **L1.0** | **5.0 mg/L** | **19.12 hours** | | **<0.1 mg/100 mL** | **0.06 mg KOH/g** |

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| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 05/05/10** | **10-01098-C** | **Clear & bright; haze rating =1** | **0.113 mg KOH/g** | **2.69 mm2/sec** | **<0.005** | **0.05%** | **L1.0** | **1.2 mg/L** | **2.28 hours** | | **24.9 mg/100 mL** | **0.006 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 05/05/10** | **10-01099-C** | **Clear & bright; haze rating =1** | **0.061 mg KOH/g** | **2.36 mm2/sec** | **<0.005** | **0.05%** | **L1.0** | **4.3 mg/L** | **3.03 hours** | | **485.1 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil Dispenser Nozzle P-7 AVGP; Sampled 05/25/10** | **10-1329-C** | **Clear & bright; haze rating=1** | **0.019 mg KOH/g** | **2.6 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **1.9 mg/L** | **19.95 hours** | | **0.3 mg/100 mL** | **0.063 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 06/09/10** | **10-01491-C** | **Clear & bright; haze rating=1** | **0.085 mg KOH/g** | **2.67 mm2/sec** | **<0.005%** | **0.05%** | **L1.0** | **2.1 mg/L** | **2.05 Hours** | | **353.3 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 06/09/11** | **10-01492-C** | **Clear & bright; haze rating=1** | **0.028 mg KOH/g** | **2.5 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **4.6 mg/L** | **4.68 Hours** | | **63 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6, 0.4 Hours; Sampled 07/06/10** | **10-2671-C** | **Clear & bright; haze rating=1** | **0.081 mh KOH/g** | **2.69 mm2/sec** | **<0.005%** | **0.06%** | **L1.0** | **2.5 mg/L** | **2.44 Hours** | | **331.1 mg/100 mL** | **<0.005 mg KOH/g** |

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| **NSWC Crane Hasler Oil, Vehicle Tank P-7, 4.9 Hours; Sampled 07/06/11** | **10-2672-C** | **Clear & bright; haze rating=1** | **0.044 mg KOH/g** | **2.48 mm2/sec** | **<0.005%** | **0.05%** | **L2.0** | **3.1 mg/L** | **4.10 Hours** | | **35.6 mg/100 mL** | **<0.005 mg KOH/g** |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7, 4.9 Hours** | **10-2920-C** | **Clear & bright; haze rating=1** | **0.037 mg KOH/g** | **2.74 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **1.4 mg/L** | **16.84 Hours** | | **1 mg/100 mL** | **0.038 mg KOH/g** |
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| | **Total Water Content** | **Particulate Contaminatio n (mg/L)** | **Oxidation Stability - Rancimat (Hours)** | **Acid Number Values (mg KOH/g)** | **Date Sampled** | | | | | | | |
| **NSWC Crane Vehicle Tank, P-6, Hasler Oil; Sampled 9/25/09** | **0.03%** | **2.5** | **4.71** | **0.102** | **9/25/2009** | | | | | | | |
| **NSWC Crane Vehicle Tank, P-6, Hasler Oil, 1 hour; sampled 10/29/09** | **0.01%** | **0.8** | **3.81** | **0.11** | **10/29/2009** | | | | | | | |
| **NSWE Crane Tank P-6, Hasler Oil, 0.25 hours; Sampled 11/30/09** | **0.04%** | **1.3** | **3.79** | **0.114** | **11/30/2009** | | | | | | | |

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| **NSWC Crane Hasler Oil, Tank P-6, AVGP; Sampled 01/05/10** | **0.02%** | **1.4** | **3.63** | **0.104** | **1/5/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Fuel Tank P-6, 0.25 Run Hours, AVGP; Sampled 02/02/10** | **0.03%** | **1.2** | **3.57** | **0.104** | **2/2/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 03/08/10** | **0.03%** | **1.7** | **3.01** | **0.096** | **3/8/2010** | | | | | | | |
| **NSWC Crane Hasler Oil Vehicle P6 AVGP 1 hours 4/8/10** | **0.02%** | **1.6** | **3.08** | **0.117** | **4/8/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 05/05/10** | **0.05%** | **1.2** | **2.28** | **0.113** | **5/5/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-6 AVGP; Sampled 06/09/10** | **0.05%** | **2.1** | **2.05** | **0.085** | **6/9/2010** | | | | | | | |

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| **NSWC Crane Hasler Oil, Vehicle Tank P-6, 0.4 Hours; Sampled 07/06/10** | **0.06%** | **2.5** | **2.44** | **0.081** | **7/6/2010** | | | | | | | |
| **NSWC Crane Vehicle Tank, P-7, Hasler Oil; Sampled 9/25/09** | **0.02%** | **5** | **2.3** | **0.093** | **9/25/2009** | | | | | | | |
| **NSWE Crane Vehicle Tank, P-7, Hasler Oil, 5.5 hours; sampled 10/29/09** | **0.01%** | **7.6** | **2.24** | **0.102** | **10/29/2009** | | | | | | | |
| **NSWE Crane Tank P-7, Hasler Oil, 4.5 hours; Sampled 11/30/09** | **0.03%** | **9.7** | **2.18** | **0.106** | **11/30/2009** | | | | | | | |
| **NSWC Crane Hasler Oil, Tank P-7, AVGP; Sampled 01/05/10** | **0.03%** | **0.7** | **4.08** | **0.074** | **1/5/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Fuel Tank P-7, 3.5 Run Hours, AVGP; Sampled 02/02/10** | **0.09%** | **1** | **3.7** | **0.079** | **2/2/2010** | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 03/08/10** | **0.04%** | **2.9** | **4.04** | **0.056** | **3/8/2010** | | | | | | | |
| **NSWC Crane Hasler Oil Vehicle P7 AVGP 9 hours 4/8/10** | **0.02%** | **2.4** | **4.16** | **0.069** | **4/8/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 05/05/10** | **0.05%** | **4.3** | **3.03** | **0.061** | **5/5/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7 AVGP; Sampled 06/09/11** | **0.03%** | **4.6** | **4.68** | **0.028** | **6/9/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7, 4.9 Hours; Sampled 07/06/11** | **0.05%** | **3.1** | **4.1** | **0.044** | **7/6/2010** | | | | | | | |
| **NSWC Crane Hasler Oil, Vehicle Tank P-7, 4.9 Hours** | **0.03%** | **1.4** | **16.84** | **0.037** | **7/20/2010** | | | | | | | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **NSWC Crane Dispenser, P-7, Hasler Oil; Sampled 8/18/09** | **0.03%** | **2.7** | **18.92** | **0.029** | **8/18/2009** | | | | | | | |
| **NSWC Crane, Fuel Truck, Hasler Oil; Sampled 8/25/09** | **0.01%** | **2.7** | **9.29** | **0.031** | **8/25/2009** | | | | | | | |
| **NSWC Crane Fuel Pump, P-6, Hasler Oil; Sampled 9/1/09** | **0.03%** | **3.6** | **4.66** | **0.101** | **9/1/2009** | | | | | | | |
| **NSWC CraneHasler OilVehicle P7 AVGPPump nozzle4/13/10** | **0.05%** | **5** | **19.12** | **0.04** | **4/13/2010** | | | | | | | |
| **NSWC Crane Hasler Oil Dispenser Nozzle P-7 AVGP; Sampled 05/25/10** | **0.03%** | **1.9** | **19.95** | **0.019** | **5/25/2010** | | | | | | | |
| | | | | | | | | | | | | |
| **Test Name** | **CTC Lab Sample ID** | **Appearance** | **Acid Number** | **Viscosity at 40°C** | **Water and Sediment** | **Total Water Content** | **Color** | **Particulate Contamination** | **Oxidation Stability - Rancimat** | **Oxidation Stability** | **Iso-Octane Insolubles** | **Total Acid Number** |
| **Test Method** | | **ASTM D4176** | **ASTM D664** | **ASTM D445** | **ASTM D2709** | **ASTM E1064** | **ASTM D1500** | **ASTM D6217** | **EN14112** | **modified ASTM D2274** | | |
| **Acceptance** | | **Report** | **0.3 mg KOH/g,** | **1.9-4.1** | **0.05%,** | **Report** | **L3.0,** | **10 mg/L, max** | **>6 hours** | **Report** | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | | | **max** | **$mm^2$/sec** | **max** | | **max** | | | | | |
| **MCBH Delivery Sample; Sampled 05/27/10** | | **Fail-Haze Rating = 1** | **0.034 mg KOH/g** | **2.67 $mm^2$/sec** | **<0.005%** | **0.03%** | **L1.5** | **2.2 mg/L** | **4.33 Hours** | | **14.9 mg/100 mL** | **<0.005 mg KOH/g** |
| **MCBH Diesel Fuel, TRAM 640437; Sampled 06/25/10** | **10-01489-C** | **Clear & Bright-Haze Rating = 1** | **<0.01 mg KOH/g** | **2.19 $mm^2$/sec** | **<0.005%** | **0.02%** | **L1.0** | **1.7 mg/L** | **3.57 hours** | | **231.5 mg/100 mL** | **0.001 mg KOH/g** |
| **MCBH Diesel Fuel, Biodiesel Storage Tank; Sampled 06/25/10** | **10-01490-C** | **Clear & Bright-Haze Rating = 1** | **0.045 mg KOH/g** | **2.68 $mm^2$/sec** | **<0.005%** | **0.02%** | **L1.0** | **0.5 mg/L** | **7.54 hours** | | **1.2 mg/100 mL** | **0.082 mg KOH/g** |
| **MCBH Diesel Fuel, TRAM 640437, Sampled 7/21/2010** | **10-4428-C** | **Clear & Bright-Haze Rating = 2** | **<0.01 mg KOH/g** | **2.5 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **16.7 mg/L** | **0.76 hours** | | **474.6 mg/100 mL** | **<0.005 mg KOH/g** |
| **MCBH Diesel Fuel, Biodiesel Storage Tank, Sampled 7/21/2010** | **10-4429-C** | **Clear & Bright-Haze Rating = 1** | **0.039 mg KOH/g** | **2.67 mm2/sec** | **<0.005%** | **0.03%** | **L1.0** | **7.6 mg/L** | **7.33 hours** | | **0.1 mg/100 mL** | **0.072 mg KOH/g** |
| **MCBH Diesel Fuel, Biodiesel Storage Tank, Sampled 10/21/2010** | **10-04732-C** | **Clear & Bright-Haze Rating = 1** | **0.038 mg KOH/g** | **2.7 mm2/sec** | **<0.005%** | **0.02%** | **L1.0** | **2.2 mg/L** | **5.53 hours** | | **0.6 mg/100 mL** | **0.031 mg KOH/g** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MCBH Diesel Fuel, Biodiesel Storage Tank; Sampled 11/18/10** | **10-5014-C** | **Clear & Bright-Haze Rating = 1** | **0.07 mg KOH/g** | **2.7 mm2/sec** | **<0.005%** | **0.02%** | **L1.0** | **0.2 mg/L** | **5.05 hours** | | **0.5 mg/100 mL** | **<0.005 mg KOH/g** |
| **MCBH Diesel Fuel, Truck M69009, Tank 640437; Sampled 11/18/10** | **10-5015-C** | **Clear & Bright-Haze Rating = 1** | **<0.01 mg KOH/g** | **2.69 mm2/sec** | **<0.005%** | **0.03%** | **L1.5** | **22.4 mg/L** | **0.57 hours** | | **451.1 mg/100 mL** | **<0.005 mg KOH/g** |
| **MCBH Diesel Fuel, Biodiesel Storage Tank, Sampled 12/18/2010** | **10-5100-C** | **Clear & Bright-Haze Rating = 1** | **0.077 mg KOH/g** | **2.7 mm2/sec** | **<0.005%** | **0.02%** | **L1.0** | **1.7 mg/L** | **2.53 hours** | | **388.2 mg/100 mL** | **<0.005 mg KOH/g** |
| | | | | | | | | | | | | |
| **Dispenser** | **Total Water Content** | **Particulate Contaminatio n (mg/L)** | **Oxidation Stability - Rancimat (Hours)** | **Acid Number Values (mg KOH/g)** | **Date Sampled** | | | | | | | |
| **MCBH Delivery Sample; Sampled 05/27/10** | **0.03%** | **2.2** | **4.33** | **0.01** | **5/25/2010** | | | | | | | |
| **MCBH Diesel Fuel, Biodiesel Storage Tank; Sampled 06/25/10** | **0.02%** | **0.5** | **7.54** | **0.045** | **6/25/2010** | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MCBH Diesel Fuel, Biodiesel Storage Tank, Sampled 7/21/2010** | **0.03%** | **7.6** | **7.33** | **0.039** | **7/21/2010** | | | | | | | |
| **MCBH Diesel Fuel, Biodiesel Storage Tank** | **0.02%** | **2.2** | **5.53** | **0.038** | **10/21/2010** | | | | | | | |
| **MCBH Diesel Fuel, Biodiesel Storage Tank; Sampled 11/18/10** | **0.02%** | **0.2** | **5.05** | **0.07** | **11/18/2010** | | | | | | | |
| **MCBH Diesel Fuel, Biodiesel Storage Tank** | **0.02%** | **1.7** | **2.53** | **0.077** | **12/18/2010** | | | | | | | |
| **MCBH Delivery Sample; Sampled 05/27/10** | **0.03%** | **2.2** | **4.33** | **0.01** | **5/25/2010** | | | | | | | |
| **MCBH Diesel Fuel, TRAM 640437; Sampled 06/25/10** | **0.02%** | **1.7** | **3.57** | **0.01** | **6/25/2010** | | | | | | | |
| **MCBH Diesel Fuel, TRAM 640437, Sampled 7/21/2010** | **0.03%** | **16.7** | **0.76** | **0.01** | **7/21/2010** | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **MCBH Diesel Fuel, Truck M69009, Tank 640437; Sampled 11/18/10** | **0.03%** | **22.4** | **0.57** | **0.01** | **11/18/2010** | | | | | | | |

# APPENDIX E Oil Data

## Table 16. Oil Data

| Moody | | ASTM D 5185 - Wear Metals by ICP (ppm) | | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Dated | Sample Number | Description | | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 |
| 8/20/2009 | FL-13267-09 | 2008 Bobtail | Baseline Oil | <0.5 | 1.7 | 3.0 | <0.5 | 2477.0 | <0.5 | <0.5 | <0.5 | 1.9 | 2.0 | 7.3 | <0.5 | 1.4 | 5.5 | <0.5 | 1128.0 | <0.5 | 6.5 | <0.5 | <0.5 | <0.5 | 1230.0 |
| 8/20/2009 | FL-13268-09 | 2008 Bobtail | B20 used | <0.5 | 2.9 | 10.3 | 1.6 | 2392.0 | <0.5 | 0.8 | 4.5 | 15.9 | 4.3 | 6.5 | 0.6 | <0.5 | 13.1 | <0.5 | 1095.0 | 1.5 | 13.7 | <0.5 | <0.5 | <0.5 | 1195.0 |
| 10/7/2009 | FL-13317-09 | 2008 Bobtail | B20 Used | <1 | 3.9 | 10.2 | 2.2 | 2451.0 | <1 | 1.6 | 6.4 | 41.1 | 7.3 | 8.9 | 1 | 1 | 19.3 | <1 | 1119.0 | 2.8 | 18.3 | <1 | <1 | <1 | 1215.0 |
| 11/3/2009 | FL-13338-09 | 2008 Bobtail | B20 used | <1 | 4.3 | 9.9 | 2 | 2365.0 | <1 | 1.7 | 7 | 43.7 | 7.0 | 9.3 | 1 | 1.2 | 18.8 | <1 | 1100.0 | 2.9 | 17.8 | <1 | <1 | <1 | 1228.0 |
| 12/15/2009 | FL-13379-10 | 2008 Bobtail | B20 used | <1 | 3.9 | 7.4 | 1.9 | 2309.0 | <1 | 1.9 | 6.3 | 56.8 | 6.6 | 7.1 | 1.0 | 1.2 | 18.6 | <1 | 1044.0 | 3.6 | 18.1 | <1 | <1 | <1 | 1194.0 |
| 1/5/2010 | FL-13409-10 | 2008 Bobtail | B20 used | <1 | 4.5 | 7.6 | <1 | 2337.0 | <1 | <1 | <1 | 68.0 | <1 | 7.1 | <1 | <1 | <1 | <1 | 1077.0 | <1 | 21.9 | <1 | <1 | <1 | 1190.0 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2/4/2010** | **FL-13475-10** | **2008 Bobtail** | **B20 used** | **<1** | **5.2** | **7.5** | **1.9** | **2227.0** | **<1** | **2.6** | **6.9** | **74.9** | **12.9** | **6.9** | **1.2** | **1.6** | **23.1** | **<1** | **994.0** | **4.8** | **22.3** | **<1** | **<1** | **<1** | **1075.0** |
| | **3/17/2010** | **FL-13484-10** | **2008 Bobtail** | **B20 used** | **<1** | **5.8** | **7.0** | **1.8** | **2112.0** | **<1** | **2.8** | **7.5** | **81.2** | **18.1** | **8.0** | **1.3** | **1.7** | **23.3** | **<1** | **933.0** | **5.2** | **23.2** | **<1** | **<1** | **<1** | **999.0** |
| | **4/8/2010** | **FL-13528-10** | **2008 Bobtail** | **B20 used** | **<1** | **6.5** | **8.2** | **2.2** | **2424.0** | **<1** | **3.4** | **10.3** | **102.9** | **18.3** | **7.4** | **1.5** | **2.0** | **28.0** | **1.0** | **1107.0** | **6.8** | **26.8** | **1.1** | **<1** | **<1** | **1208.0** |
| | **5/7/2010** | **FL-13546-10** | **2008 Bobtail** | **B20 used** | **<1** | **6.4** | **7.6** | **2.1** | **2259.0** | **<1** | **3.4** | **11.2** | **103.7** | **19.3** | **8.0** | **1.6** | **2.5** | **28.0** | **<1** | **1006.0** | **6.6** | **26.8** | **<1** | **<1** | **<1** | **1127.0** |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **8/20/2009** | **FL-13267-09** | **1997 Bobtail** | **Baseline Oil** | **<0.5** | **1.7** | **3.0** | **<0.5** | **2477.0** | **<0.5** | **<0.5** | **<0.5** | **1.9** | **2.0** | **7.3** | **<0.5** | **1.4** | **5.5** | **<0.5** | **1128.0** | **<0.5** | **6.5** | **<0.5** | **<0.5** | **<0.5** | **1230.0** |
| | **8/20/2009** | **FL-13270-09** | **1997 Bobtail** | **B20 used** | **<0.5** | **2.4** | **5.3** | **<0.5** | **2438.0** | **<0.5** | **1.5** | **2.2** | **9.3** | **<0.5** | **8.2** | **0.5** | **0.6** | **3.5** | **0.5** | **1159.0** | **0.7** | **3.9** | **<0.5** | **<0.5** | **<0.5** | **1219.0** |
| | **10/7/2009** | **FL-13318-09** | **1997 Bobtail** | **B20 Used** | **<1** | **3.2** | **4.8** | **<1** | **2548.0** | **<1** | **2.9** | **3.6** | **10.9** | **1.9** | **10** | **<1** | **<1** | **2.5** | **<1** | **1183.0** | **<1** | **2.8** | **<1** | **<1** | **<1** | **1244.0** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **11/3/2009** | **FL-13339-09** | **1997 Bobtail** | **B20 used** | **<1** | **3.6** | **4.4** | **<1** | **2369.0** | **<1** | **3.1** | **4** | **12.4** | **2.1** | **10.2** | **1** | **<1** | **1.2** | **<1** | **1121.0** | **<1** | **1.3** | **<1** | **<1** | **<1** | **1216.0** |
| | **12/15/2009** | **FL-13380-10** | **1997 Bobtail** | **B20 used** | **<1** | **2.9** | **3.7** | **<1** | **2331.0** | **<1** | **2.5** | **3.5** | **10.5** | **2.5** | **8.3** | **<1** | **<1** | **1.6** | **<1** | **1097.0** | **<1** | **1.8** | **<1** | **<1** | **<1** | **1202.0** |
| | **1/5/2010** | **FL-13410-10** | **1997 Bobtail** | **B20 used** | **<1** | **3.0** | **3.6** | **<1** | **2374.0** | **<1** | **<1** | **3.5** | **12.2** | **1.6** | **9.0** | **<1** | **0.8** | **3.8** | **<1** | **1128** | **<1** | **3.8** | **<1** | **<1** | **<1** | **1205.0** |
| | **2/4/2010** | **FL-13476-10** | **1997 Bobtail** | **B20 used** | **<1** | **3.1** | **3.6** | **<1** | **2225.0** | **<1** | **2.9** | **3.6** | **12.6** | **1.7** | **8.7** | **<1** | **<1** | **2.6** | **<1** | **1051.0** | **<1** | **2.8** | **<1** | **<1** | **<1** | **1083.0** |
| | **3/17/2010** | **FL-13485-10** | **1997 Bobtail** | **B20 used** | **<1** | **2.0** | **2.0** | **<1** | **2137.0** | **<1** | **<1** | **<1** | **4.9** | **2.7** | **7.3** | **<1** | **<1** | **3.3** | **<1** | **1001.0** | **<1** | **3.6** | **<1** | **<1** | **<1** | **1010.0** |
| | **4/8/2010** | **FL-13529-10** | **1997 Bobtail** | **B20 used** | **<1** | **1.8** | **2.6** | **<1** | **2313.0** | **0.0** | **<1** | **<1** | **5.7** | **2.5** | **7.4** | **<1** | **<1** | **3.1** | **<1** | **1129.0** | **<1** | **3.3** | **<1** | **<1** | **<1** | **1150.0** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5/7/2010 | FL-13545-10 | 1997 Bobtail | B20 used | <1 | 1.8 | 2.5 | <1 | 2252.0 | <1 | <1 | <1 | 5.8 | 2.4 | 8.3 | <1 | <1 | 3.2 | <1 | 1083.0 | <1 | 3.4 | <1 | <1 | <1 | 1137.0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8/20/2009 | FL-13267-09 | R-11 Refueler | Baseline Oil | <0.5 | 1.7 | 3.0 | <0.5 | 2477.0 | <0.5 | <0.5 | <0.5 | 1.9 | 2.0 | 7.3 | <0.5 | 1.4 | 5.5 | <0.5 | 1128.0 | <0.5 | 6.5 | <0.5 | <0.5 | <0.5 | 1230.0 |
| | 8/20/2009 | FL-13272-09 | R-11 Refueler | B20 used | <0.5 | 1.1 | 2.0 | <0.5 | 1864.9 | <0.5 | <0.5 | 0.6 | 3.3 | <0.5 | 494.3 | <0.5 | <0.5 | 3.7 | <0.5 | 1209.0 | 0.7 | 4.0 | <0.5 | <0.5 | <0.5 | 1275.0 |
| | 10/7/2009 | FL-13319-09 | R-11 Refueler | B20 Used | <1 | 1.4 | 1.8 | <1 | 1842.0 | <1 | <1 | 1 | 6.5 | 1.1 | 492.4 | <1 | <1 | <1 | <1 | 1169.0 | <1 | <1 | <1 | <1 | <1 | 1228.0 |
| | 11/3/2009 | FL-13340-09 | R-11 Refueler | B20 used | <1 | 1.7 | 1.5 | <1 | 1659.0 | <1 | <1 | 1.2 | 7.8 | 1.2 | 462.3 | <1 | <1 | <1 | <1 | 1061.0 | <1 | <1 | <1 | <1 | <1 | 1155.0 |
| | 12/15/2009 | FL-13378-10 | R-11 Refueler | B20 used | <1 | 1.8 | 1.8 | <1 | 1709.0 | <1 | <1 | 1.4 | 8.4 | 2.4 | 471.0 | <1 | <1 | <1 | <1 | 1065.0 | <1 | <1 | <1 | <1 | <1 | 1194.0 |
| | 1/5/2010 | FL-13411-10 | R-11 Refueler | B20 used | <1 | 1.9 | 1.7 | <1 | 1957.0 | <1 | <1 | 3.6 | 8.5 | <1 | 474.9 | <1 | <1 | 2.9 | <1 | 1041.0 | 3.4 | 3.1 | <1 | <1 | <1 | 1202.0 |
| | 2/4/2010 | FL-13477-10 | R-11 Refueler | B20 used | <1 | 2.5 | 1.0 | <1 | 1551.0 | <1 | <1 | 2.3 | 11.7 | 1.5 | 430.9 | <1 | <1 | 1.5 | <1 | 931.0 | 2.9 | 1.8 | <1 | <1 | <1 | 991.0 |
| | 3/17/2010 | FL-13486-10 | R-11 Refueler | B20 used | <1 | 1.6 | 1.5 | <1 | 1833.0 | <1 | <1 | <1 | 4.0 | 1.7 | 202.8 | <1 | <1 | 2.1 | <1 | 970.0 | <1 | 2.4 | <1 | <1 | <1 | 987.0 |
| | 4/8/2010 | FL-13530-10 | R-11 Refueler | B20 used | <1 | 2.1 | 1.8 | <1 | 1988.0 | <1 | <1 | <1 | 11.3 | 1.7 | 215.3 | <1 | <1 | 2.1 | <1 | 1097.0 | <1 | 2.3 | <1 | <1 | <1 | 1127.0 |
| | 5/7/2010 | FL-13544-10 | R-11 Refueler | B20 used | <1 | 2.3 | 2.3 | <1 | 1971.0 | <1 | <1 | <1 | 16.0 | 1.4 | 214.6 | <1 | <1 | 3.1 | <1 | 1073.0 | 1.1 | 3.4 | <1 | <1 | <1 | 1138.0 |
| | Dated | Sample Number | Description | | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **8/20/2009** | **FL-13267-09** | **2008 Bobtail** | **Baseline Oil** | **<0.5** | **1.7** | **3.0** | **<0.5** | **2477.0** | **<0.5** | **<0.5** | **<0.5** | **1.9** | **2.0** | **7.3** | **<0.5** | **1.4** | **5.5** | **<0.5** | **1128.0** | **<0.5** | **6.5** | **<0.5** | **<0.5** | **<0.5** | **1230.0** |
| | **8/20/2009** | **FL-13269-09** | **2008 Bobtail** | **Diesel used** | **<0.5** | **3.4** | **10.3** | **1.1** | **2413.0** | **<0.5** | **0.6** | **5.2** | **19.5** | **9.4** | **6.7** | **0.6** | **0.5** | **12** | **0.8** | **1133.0** | **2.0** | **12.4** | **<0.5** | **<0.5** | **<0.5** | **1214.0** |
| | **10/7/2009** | **FL-13320-09** | **2008 Bobtail** | **Diesel Used** | **<1** | **4.1** | **8.9** | **1.4** | **2504.0** | **<1** | **1** | **7** | **35.2** | **15.3** | **8.3** | **<1** | **1.1** | **14.3** | **<1** | **1139.0** | **3.0** | **13.7** | **<1** | **<1** | **<1** | **1227.0** |
| | **11/3/2009** | **FL-13335-09** | **2008 Bobtail** | **Diesel used** | **<1** | **4.3** | **8.5** | **1.3** | **2400.0** | **<1** | **1.1** | **7.3** | **37.8** | **15.9** | **13.8** | **<1** | **1.4** | **13.7** | **<1** | **1101.0** | **3.0** | **13.0** | **<1** | **<1** | **<1** | **1142.0** |
| | **12/15/2009** | **FL-13382-10** | **2008 Bobtail** | **Diesel used** | **<1** | **3.9** | **5.9** | **1.2** | **2250.0** | **<1** | **1.2** | **6.6** | **42.4** | **11.3** | **8.2** | **<1** | **<1** | **12.8** | **<1** | **1011.0** | **4.0** | **13.0** | **<1** | **<1** | **<1** | **1152.0** |
| | **1/5/2010** | **FL-13412-10** | **2008 Bobtail** | **Diesel used** | **<1** | **4.1** | **6.4** | **<1** | **2294.0** | **<1** | **<1** | **6.7** | **52.9** | **14.3** | **8.2** | **<1** | **1.1** | **16** | **<1** | **1055.0** | **4.9** | **15.3** | **<1** | **<1** | **<1** | **1153.0** |
| | **2/4/2010** | **FL-13478-10** | **2008 Bobtail** | **Diesel used** | **<1** | **2.5** | **2.6** | **<1** | **2194.0** | **<1** | **<1** | **1.3** | **17.4** | **8.0** | **9.5** | **<1** | **<1** | **5.2** | **<1** | **1027.0** | **1.5** | **5.3** | **<1** | **<1** | **<1** | **1057.0** |
| | **3/17/2010** | **FL-13481-10** | **2008 Bobtail** | **Diesel used** | **<1** | **3.2** | **3.3** | **<1** | **2211.0** | **<1** | **<1** | **1.7** | **25.4** | **12.6** | **8.0** | **<1** | **1.2** | **7.7** | **<1** | **1028.0** | **2.6** | **7.7** | **<1** | **<1** | **<1** | **1064.0** |
| | **4/8/2010** | **FL-13531-10** | **2008 Bobtail** | **Diesel Used** | **<1** | **3.1** | **3.5** | **<1** | **2262.0** | **<1** | **<1** | **1.7** | **27.1** | **12.6** | **8.0** | **<1** | **1.1** | **7.0** | **<1** | **1080.0** | **2.7** | **6.9** | **<1** | **<1** | **<1** | **1110.0** |
| | **5/7/2010** | **FL-13547-10** | **2008 Bobtail** | **Diesel Used** | **<1** | **3.6** | **2.8** | **<1** | **2233.0** | **<1** | **<1** | **2.0** | **33.6** | **15.8** | **7.0** | **<1** | **<1** | **8.7** | **<1** | **1043.0** | **3.5** | **8.6** | **<1** | **<1** | **<1** | **1107.0** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **8/20/2009** | **FL-13267-09** | **1997 Bobtail** | **Baseline Oil** | **<0.5** | **1.7** | **3.0** | **<0.5** | **2477.0** | **<0.5** | **<0.5** | **<0.5** | **1.9** | **2.0** | **7.3** | **<0.5** | **1.4** | **5.5** | **<0.5** | **1128.0** | **<0.5** | **6.5** | **<0.5** | **<0.5** | **<0.5** | **1230.0** |
| | **8/20/2009** | **FL-13273-09** | **1997 Bobtail** | **Diesel used** | **<0.5** | **1.8** | **1.2** | **<0.5** | **2288.3** | **<0.5** | **<0.5** | **0.7** | **3.4** | **<0.5** | **177** | **<0.5** | **<0.5** | **6.3** | **<0.5** | **1184.0** | **0.5** | **6.7** | **<0.5** | **<0.5** | **<0.5** | **1255.0** |
| | **10/7/2009** | **FL-13322-09** | **1997 Bobtail** | **Diesel Used** | **<1** | **2.3** | **1.5** | **<1** | **2452.0** | **<1** | **1.6** | **1.8** | **7.2** | **1.6** | **175.9** | **<1** | **<1** | **6.1** | **<1** | **1209.0** | **<1** | **6.2** | **<1** | **<1** | **<1** | **1279.0** |
| | **11/3/2009** | **FL-13337-09** | **1997 Bobtail** | **Diesel used** | **<1** | **2.5** | **1.4** | **<1** | **2361.0** | **<1** | **2** | **2** | **7.7** | **1.6** | **176.7** | **<1** | **<1** | **6.4** | **<1** | **1190.0** | **<1** | **6.2** | **<1** | **<1** | **<1** | **1318.0** |
| | **12/15/2009** | **FL-13383-10** | **1997 Bobtail** | **Diesel used** | **<1** | **2.4** | **1.2** | **<1** | **2188.0** | **<1** | **1.8** | **1.9** | **7.3** | **2.5** | **167.1** | **<1** | **<1** | **6.5** | **<1** | **1119.0** | **<1** | **6.9** | **<1** | **<1** | **<1** | **1225.0** |
| | **1/5/2010** | **FL-13414-10** | **1997 Bobtail** | **Diesel used** | **<1** | **2.2** | **1.1** | **<1** | **2226.0** | **<1** | **<1** | **1.8** | **8.0** | **<1** | **169.9** | **<1** | **<1** | **8.4** | **<1** | **1117.0** | **<1** | **8.2** | **<1** | **<1** | **<1** | **1196.0** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2/4/2010 | FL-13480-10 | 1997 Bobtail | Diesel used | <1 | 2.2 | 1.2 | <1 | 2098.0 | <1 | 1.8 | 1.9 | 8.1 | <1 | 159.6 | <1 | <1 | 7.6 | <1 | 1044.0 | <1 | 7.6 | <1 | <1 | <1 | 1087.0 |
| | 3/17/2010 | FL-13483-10 | 1997 Bobtail | Diesel used | <1 | 2.6 | 1.1 | <1 | 2110.0 | <1 | 2.0 | 2.1 | 9.3 | <1 | 159.9 | <1 | <1 | 8.5 | <1 | 1031.0 | <1 | 8.5 | <1 | <1 | <1 | 1069.0 |
| | 4/8/2010 | FL-13533-10 | 1997 Bobtail | Diesel used | <1 | 2.2 | 1.3 | <1 | 2162.0 | <1 | 1.9 | 2.0 | 9.1 | 1.8 | 163.1 | <1 | <1 | 7.9 | <1 | 1082.0 | <1 | 7.8 | <1 | <1 | <1 | 1122.0 |
| | 5/7/2010 | FL-13542-10 | 1997 Bobtail | Diesel used | <1 | 1.9 | 3.5 | <1 | 2110.0 | <1 | <1 | 1.6 | 6.3 | 1.2 | 66.0 | <1 | <1 | 5.0 | <1 | 1026.0 | 1.3 | 5.0 | <1 | <1 | <1 | 1125.0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8/20/2009 | FL-13267-09 | R-11 Refueler | Baseline Oil | <0.5 | 1.7 | 3.0 | <0.5 | 2477.0 | <0.5 | <0.5 | <0.5 | 1.9 | 2.0 | 7.3 | <0.5 | 1.4 | 5.5 | <0.5 | 1128.0 | <0.5 | 6.5 | <0.5 | <0.5 | <0.5 | 1230.0 |
| | 8/20/2009 | FL-13271-09 | R-11 Refueler | Diesel used | <0.5 | 2.2 | 2.5 | <0.5 | 2354.2 | <0.5 | 0.5 | 2.4 | 6.6 | <0.5 | 541.1 | <0.5 | 0.7 | 4.6 | <0.5 | 1379.0 | 2.4 | 4.6 | <0.5 | <0.5 | <0.5 | 1505.0 |
| | 10/7/2009 | FL-13321-09 | R-11 Refueler | Diesel Used | <1 | 1.8 | 1.5 | <1 | 1988.0 | <1 | <1 | 2.9 | 7.4 | 1.3 | 466.8 | <1 | <1 | <1 | <1 | 1187.0 | 1.7 | 1.1 | <1 | <1 | <1 | 1262.0 |
| | 11/3/2009 | FL-13336-09 | R-11 Refueler | Diesel used | <1 | 2 | 1.9 | <1 | 1901.0 | <1 | <1 | 3.4 | 7.6 | 1.5 | 458.6 | <1 | <1 | <1 | <1 | 1122.0 | 2.0 | <1 | <1 | <1 | <1 | 1281.0 |
| | 12/15/2009 | FL-13381-10 | R-11 Refueler | Diesel used | <1 | 1.8 | 1.1 | <1 | 1685.0 | <1 | <1 | 3.0 | 6.8 | 1.5 | 413.9 | <1 | <1 | <1 | <1 | 892.0 | 2.3 | <1 | <1 | <1 | <1 | 1057.0 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1/5/2010 | FL-13413-10 | R-11 Refueler | Diesel used | <1 | 1.9 | 1.1 | <1 | 1949.0 | <1 | <1 | 3.6 | 8.8 | 1.0 | 471.9 | <1 | <1 | 3.1 | <1 | 1034.0 | 3.5 | 3.3 | <1 | <1 | <1 | 1190.0 |
| | 2/4/2010 | FL-13479-10 | R-11 Refueler | Diesel used | <1 | 1.7 | 1.4 | <1 | 2012.0 | <1 | <1 | <1 | 4.1 | 1.6 | 63.0 | <1 | <1 | <1 | <1 | 977.0 | <1 | <1 | <1 | <1 | <1 | 1010.0 |
| | 3/17/2010 | FL-13482-10 | R-11 Refueler | Diesel used | <1 | 1.9 | 1.3 | <1 | 1979.0 | <1 | <1 | 1.1 | 5.1 | 1.9 | 61.6 | <1 | <1 | 1.1 | <1 | 943.0 | 1.0 | 1.4 | <1 | <1 | <1 | 977.0 |
| | 4/8/2010 | FL-13532-10 | R-11 Refueler | Diesel used | <1 | 1.9 | 1.5 | <1 | 2156.0 | <1 | <1 | 1.3 | 6.2 | 1.7 | 67.8 | <1 | <1 | 1.5 | <1 | 1043.0 | 1.1 | 1.7 | -1.0 | <1 | <1 | 1096.0 |
| | 5/7/2010 | FL-13543-10 | R-11 Refueler | Diesel used | <1 | 2.3 | 2.4 | <1 | 2219.0 | <1 | 2.0 | 2.1 | 9.6 | 1.2 | 165.6 | <1 | <1 | 10.3 | <1 | 1111.0 | <1 | 10.1 | <1 | <1 | <1 | 1197.0 |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Port Hueneme | | | ASTM D 5185 - Wear Metals by ICP (ppm) | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn | |
| | Dated | Sample Number | Description | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 | |
| | 7/8/2009 | FL-13122-09 | Baseline Oil, JP8 used | 5.9 | 2.6 | 15.1 | 2.9 | 2694.0 | <1 | <1 | 404.0 | 13.7 | 9.0 | 51.1 | 1.1 | <1 | 29.4 | <1 | 1084.0 | 8.0 | 26.7 | <1 | <1 | <1 | 1180.0 | |
| | 8/6/2009 | FL-13162-09 | Used Oil, MTVR, JP8 used | 5.0 | 2.4 | 17.6 | 2.4 | 2746.0 | <1 | <1 | 432.6 | 13.0 | 5.7 | 49.8 | 1.0 | <1 | 38.5 | <1 | 1126.0 | 7.0 | 37.7 | <1 | <1 | <1 | 1189.0 | |
| | 9/29/2009 | FL-13300-09 | Used Oil, MTVR, JP8 used | 5.3 | 2.8 | 15.1 | 2.4 | 2592.0 | <0.5 | 0.5 | 543.2 | 13.7 | 4.4 | 50.2 | 1.0 | 0.7 | 39.2 | <0.5 | 1069.0 | 7.6 | 38.5 | 0.7 | <0.5 | <0.5 | 1092.0 | |
| | 12/29/2009 | FL-13398-10 | New Oil, MTVR, JP8 used | <1 | 1.2 | <1 | <1 | 2806.0 | <1 | <1 | <1 | 2.1 | <1 | 9.0 | <1 | <1 | 3.9 | <1 | 1146.0 | <1 | 4.2 | <1 | <1 | <1 | 1185.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2/3/2010 | FL-13430-10 | Used Oil, MTVR, JP8 used | <1 | 1.4 | 3.4 | <1 | 2622.0 | <1 | <1 | 93.4 | 4.6 | 1.8 | 15.4 | <1 | <1 | 9.0 | <1 | 1057.0 | 1.2 | 9.1 | <1 | <1 | <1 | 1087.0 | |
| | 4/7/2010 | FL-13504-10 | Used Oil, MTVR, JP8 used | 1.0 | 1.5 | 3.0 | <1 | 2704.0 | <1 | <1 | 112.8 | 5.4 | 1.8 | 14.3 | <1 | <1 | 10.0 | <1 | 1108.0 | 1.4 | 10.2 | <1 | <1 | <1 | 1142.0 | |
| | 5/4/2010 | FL-13526-10 | Used Oil, MTVR, JP8, used | 1.1 | 1.4 | 3.7 | <1 | 2798.0 | <1 | <1 | 115.6 | 5.6 | 1.9 | 14.2 | <1 | <1 | 12.0 | <1 | 1157.0 | 1.3 | 11.7 | <1 | <1 | <1 | 1179.0 | |
| | 6/4/2010 | FL-13557-10 | Used Oil, MTVR, JP8 used | 1.3 | 1.6 | 5.1 | 1.2 | 2789.0 | <1 | <1 | 117.9 | 6.0 | 1.8 | 15.0 | <1 | <1 | 12.5 | <1 | 1134.0 | 2.0 | 12.5 | <1 | <1 | <1 | 1206.0 | |
| | 9/7/2010 | FL-13682-10 | Used Oil, MTVR, JP8 used | 1.3 | 2.5 | 5.2 | 1.2 | 2903.0 | <1 | <1 | 126.7 | 7.8 | 1.4 | 14.1 | <1 | <1 | 9.6 | <1 | 1189.0 | 3.2 | 9.4 | <1 | <1 | <1 | 1324.0 | |
| | 9/7/2010 | FL-13683-10 | Used Oil, MTVR, JP8 used | 1.4 | 2.5 | 4.5 | 1.3 | 3103.0 | <1 | <1 | 130.4 | 7.9 | 1.4 | 14.3 | <1 | <1 | 11.1 | <1 | 1257.0 | 3.5 | 11.2 | <1 | <1 | <1 | 1467.0 | |
| | | | ASTM D 5185 - Wear Metals by ICP (ppm) | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn | |
| | Dated | Sample Number | Description | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 | |
| | 7/8/2009 | FL-13121-09 | Baseline Oil, B20 used | 8.4 | 3.9 | 13.5 | 3.0 | 2534.0 | <1 | 1.0 | 495.0 | 19.0 | 9.0 | 106.7 | <1 | 2.5 | 33.8 | <1 | 1083.0 | 7.8 | 30.4 | 1.1 | <1 | <1 | 1183.0 | |
| | 8/6/2009 | FL-13163-09 | Used Oil, MTVR, B20 used | 6.8 | 3.5 | 14.4 | 2.5 | 2631.0 | <1 | <1 | 537.3 | 17.9 | 6.0 | 104.1 | 1.0 | 2.0 | 43.0 | <1 | 1136.0 | 7.1 | 41.9 | <1 | <1 | <1 | 1199.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 9/29/2009 | FL-13299-09 | Used Oil, MTVR, B20 used | 7.2 | 4.2 | 13.8 | 2.4 | 2444.0 | <0.5 | 0.7 | 638.5 | 17.5 | 4.7 | 104.0 | 1.0 | 2.3 | 43.2 | <0.5 | 1089.0 | 7.5 | 42.5 | 1.2 | <0.5 | <0.5 | 1099.0 | |
| | 12/29/2009 | FL-13397-10 | New Oil, MTVR, B20 used | <1 | 1.1 | <1 | <1 | 2841.0 | <1 | <1 | <1 | 2.1 | <1 | 9.0 | <1 | <1 | 3.9 | <1 | 1166.0 | <1 | 4.3 | <1 | <1 | <1 | 1218.0 | |
| | 2/3/2010 | FL-13431-10 | Used Oil, MTVR, B20 used | <1 | 1.5 | 2.1 | <1 | 2602.0 | <1 | <1 | 88.6 | 4.6 | 1.8 | 19.2 | <1 | <1 | 8.5 | <1 | 1043.0 | 1.0 | 8.6 | <1 | <1 | <1 | 1067.0 | |
| | 4/7/2010 | FL-13503-10 | Used Oil, MTVR, B20 used | 1.1 | 1.5 | 2.5 | <1 | 2705.0 | <1 | <1 | 95.3 | 5.3 | 1.7 | 25.4 | <1 | <1 | 8.1 | <1 | 1113.0 | 1.2 | 8.4 | <1 | <1 | <1 | 1144.0 | |
| | 5/4/2010 | FL-13525-10 | Used Oil, MTVR, B20, used | 1.3 | 1.5 | 4.0 | <1 | 2804.0 | <1 | <1 | 94.8 | 5.2 | 1.3 | 20.3 | <1 | <1 | 11.3 | <1 | 1184.0 | 1.0 | 10.8 | <1 | <1 | <1 | 1196.0 | |
| | 6/4/2010 | FL-13558-10 | Used Oil, MTVR, B20 used | 1.3 | 1.7 | 2.8 | 1.2 | 2787.0 | <1 | <1 | 97.0 | 5.3 | 1.5 | 20.1 | <1 | <1 | 9.1 | <1 | 1143.0 | 1.7 | 9.2 | <1 | <1 | <1 | 1205.0 | |
| | 9/7/2010 | FL-13684-10 | Used Oil, MTVR, B20 used | 1.4 | 2.3 | 4.4 | 1.2 | 2807.0 | <1 | <1 | 101.1 | 6.4 | 1.5 | 20.8 | <1 | <1 | 6.7 | <1 | 1162.0 | 3.1 | 6.6 | <1 | <1 | <1 | 1266.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 Palms | | | ASTM D 5185 - Wear Metals by ICP (ppm) | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn | |
| | Dated | Sample Number | Description | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 | |
| | 6/24/2009 | FL-13123-09 | New Oil, HUMVEE | <1 | 3.1 | 32.5 | <1 | ########## | <1 | <1 | 12.9 | 9.1 | 7.2 | 815.9 | <1 | 89.6 | 9.7 | <1 | 1193.0 | 2.4 | 11.0 | 2.4 | <1 | <1 | 1308.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8/7/2009 | FL-13199-09 | Used Oil, HUMVEE, B20 used | <1 | 2.9 | 32.5 | <1 | 1384.0 | <1 | <1 | 5.1 | 11.1 | 5.7 | 772.3 | <1 | 90.4 | 17.0 | <1 | 1238.0 | 2.1 | 20.3 | <1 | <1 | <1 | 1287.0 | |
| | 9/3/2009 | FL-13277-09 | Used Oil, Humvee, B20 used | <0.5 | 3.2 | 33.6 | <0.5 | 1448.0 | <0.5 | 0.7 | 5.7 | 12.9 | 3.7 | 801.5 | 0.5 | 92.6 | 18.4 | 0.6 | 1302.0 | 2.7 | 20.5 | 0.9 | <0.5 | <0.5 | 1368.0 | |
| | 10/21/2009 | FL-13334-09 | Used Oil; Engine running B20 | <1 | 4.8 | 37.3 | <1 | ########## | <1 | 1.0 | 7.7 | 17.2 | 9.6 | 901.8 | <1 | 99.9 | 23 | <1 | 1305.0 | 2.7 | 25.5 | 1.4 | <1 | <1 | 1344.0 | |
| | 11/13/2009 | FL-13347-09 | Used Oil; HMMWV; B20 used | <1 | 5.2 | 37.6 | <1 | 1472.0 | <1 | 1.1 | 8.4 | 18.8 | 10.0 | 907.5 | <1 | 100.3 | 24.5 | <1 | 1272.0 | 2.7 | 26.8 | 1.5 | <1 | <1 | 1402.0 | |
| | 12/9/2009 | FL-13375-09 | Used Oil, HMMVR, B20 used | <1 | 3.9 | 34.8 | <1 | 1288.0 | <1 | <1 | 6.5 | 16.4 | 24.1 | 804.1 | <1 | 89.7 | 20.4 | <1 | 1136.0 | 2.4 | 22.2 | 1.9 | <1 | <1 | 1207 | |
| | 12/29/2009 | FL-13416-10 | Used Oil; Engine running B20 | <1 | 4.3 | 31.9 | <1 | 1367.0 | <1 | 1.1 | 6.8 | 19.1 | 6.4 | 856.6 | <1 | 91.2 | 24.0 | <1 | 1190.0 | 2.9 | 25.8 | 1.5 | <1 | <1 | 1272.0 | |
| | 2/18/2010 | FL-13499-10 | Used Oil, HMMVR, B20 used | <1 | 4.3 | 31.5 | <1 | 1344.0 | <1 | 1.3 | 7.2 | 22.2 | 7.2 | 821.6 | <1 | 93.3 | 26.0 | <1 | 1164.0 | 3.0 | 27.7 | 1.1 | <1 | <1 | 1257.0 | |
| | 3/11/2010 | FL-13501-10 | Used Oil, HMMVR, B20 used | <1 | 4.6 | 30.2 | <1 | 1350.0 | <1 | 1.6 | 7.3 | 24.5 | 7.4 | 827.3 | <1 | 93.1 | 24.5 | <1 | 1161.0 | 3.2 | 26.2 | 1.4 | <1 | <1 | 1256.0 | |
| | 4/27/2010 | FL-13539-10 | Used Oil, HMMWV, B20, used | <1 | 4.7 | 31.1 | <1 | 1307.0 | <1 | 1.6 | 7.5 | 24.2 | 6.0 | 805.1 | <1 | 89.9 | 23.5 | <1 | 1141.0 | 2.9 | 25.3 | 2.3 | <1 | <1 | 1157.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/29/2010 | FL-13541-10 | Used Oil, HMMWR, B20, used | <1 | 5.3 | 32.7 | <1 | 1249.0 | <1 | 1.7 | 7.6 | 22.9 | 4.8 | 788.0 | 1.0 | 84.7 | 26.7 | 1.3 | 1107.0 | 3.2 | 27.9 | 2.3 | <1 | <1 | 1091.0 | |
| | 5/26/2010 | FL-13582-10 | Used oil; Engine running B20 | <1 | 4.7 | 45.1 | <1 | 1379.0 | 1.3 | 2.0 | 8.8 | 28.0 | 5.0 | 961.0 | <1 | 93.9 | 21.7 | 1.3 | 1148.0 | 3.7 | 23.3 | 3.7 | <1 | <1 | 13.2 | |
| | 6/16/2010 | FL-13581-10 | Used oil; Engine running B20 | <1 | 4.9 | 47.9 | <1 | 1386.0 | 1.5 | 2.0 | 9.1 | 29.1 | 5.0 | 961.0 | <1 | 94.1 | 21.9 | 1.2 | 1159.0 | 3.9 | 23.5 | 3.8 | <1 | <1 | 1300.0 | |
| | Dated | Sample Number | Description | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 | |
| | 6/24/2009 | FL-13123-09 | New Oil, HUMVEE | <1 | 3.1 | 32.5 | <1 | ########## | <1 | <1 | 12.9 | 9.1 | 7.2 | 815.9 | <1 | 89.6 | 9.7 | <1 | 1193.0 | 2.4 | 11.0 | 2.4 | <1 | <1 | 1308.0 | |
| | 8/7/2009 | FL-13198-09 | Used Oil, HUMVEE, JP8 used | <1 | 2.6 | 28.7 | <1 | 1382.0 | <1 | <1 | 6.5 | 10.8 | 3.4 | 780.7 | <1 | 88.0 | 28.7 | <1 | 1228.0 | 6.6 | 30.5 | 4.1 | <1 | <1 | 1292.0 | |
| | 9/3/2009 | FL-13276-09 | Used Oil, Humvee, JP8 used | <0.5 | 2.7 | 30.0 | <0.5 | 1454.0 | <0.5 | 0.7 | 7.5 | 12.9 | 1.1 | 817.3 | 0.8 | 91.4 | 30.4 | 0.5 | 1307.0 | 8.4 | 31.5 | 5.3 | <0.5 | <0.5 | 1380.0 | |
| | 10/21/2009 | FL-13333-09 | Used Oil; Engine running JP8 | <1 | 3.7 | 32.5 | <1 | ########## | <1 | <1 | 10.0 | 17.1 | 5.6 | 911.2 | <1 | 97.6 | 36.1 | <1 | 1297.0 | 9.2 | 37.6 | 6.4 | <1 | <1 | 1343.0 | |
| | 11/13/2009 | FL-13346-09 | Used Oil; HMMWV; JP8 used | <1 | 4.0 | 31.6 | <1 | 1449.0 | <1 | 1.0 | 10.9 | 18.7 | 5.8 | 899.5 | 1.0 | 96.2 | 37.6 | <1 | 1237.0 | 9.8 | 38.7 | 7.4 | <1 | <1 | 1372.0 | |
| | 12/9/2009 | FL-13374-09 | Used Oil, HMMVR, JP8 used | <1 | 3.1 | 27.7 | <1 | 1330.0 | <1 | <1 | 8.8 | 16.7 | 11.1 | 842.6 | <1 | 89.0 | 34.3 | <1 | 1145.0 | 9.6 | 35.2 | 6.4 | <1 | <1 | 1226 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 12/29/2009 | FL-13415-10 | Used Oil; Engine running JP8 | <1 | 3.4 | 27.4 | <1 | 1391.0 | <1 | 1.0 | 9.3 | 19.6 | 3.7 | 877.9 | <1 | 90.4 | 35.8 | <1 | 1191.0 | 10.7 | 37.0 | 7.3 | <1 | <1 | 1282.0 | |
| | 2/18/2010 | FL-13500-10 | Used Oil, HMMVR, JP8 used | <1 | 3.3 | 26.5 | <1 | 1373.0 | <1 | 1.1 | 10.4 | 24.4 | 4.3 | 851.5 | 1.0 | 92.5 | 38.7 | <1 | 1152.0 | 12.9 | 40.4 | 8.6 | <1 | <1 | 1263.0 | |
| | 3/11/2010 | FL-13502-10 | Used Oil, HMMVR, JP8 used | <1 | 3.5 | 26.4 | <1 | 1383.0 | <1 | 1.3 | 10.7 | 26.0 | 4.4 | 857.0 | 1.0 | 93.8 | 39.6 | <1 | 1155.0 | 13.9 | 41.2 | 9.6 | <1 | <1 | 1264.0 | |
| | 4/27/2010 | FL-13540-10 | Used Oil, HMMWr, JP8, used | <1 | 3.7 | 26.6 | <1 | 1305.0 | <1 | 1.3 | 11.3 | 25.3 | 3.0 | 828.8 | 1.0 | 89.6 | 37.8 | <1 | 1109.0 | 13.1 | 38.7 | 9.8 | <1 | <1 | 1126.0 | |
| | 4/29/2010 | FL-13538-10 | Used Oil, HHMWR, JP8, used | <1 | 3.7 | 27.1 | <1 | 1356.0 | <1 | 1.4 | 11.3 | 26.9 | 3.4 | 826.7 | 1.0 | 90.4 | 38.2 | <1 | 1140.0 | 13.8 | 39.2 | 10.8 | <1 | <1 | 1175.0 | |
| | 5/26/2010 | FL-13583-10 | Used oil; Engine running JP8 | <1 | 3.9 | 38.0 | <1 | 1436.0 | 1.0 | 1.8 | 13.1 | 31.2 | 3.0 | 1024.0 | 1.3 | 97.3 | 35.6 | 1.5 | 1142.0 | 17.5 | 36.4 | 12.8 | <1 | <1 | 1314.0 | |
| | 6/16/2010 | FL-13584-10 | Used oil; Engine running JP9 | <1 | 3.9 | 36.7 | <1 | 1425.0 | <1 | 1.8 | 13.3 | 31.5 | 3.0 | 1017.0 | 1.3 | 96.7 | 35.5 | 1.4 | 1127.0 | 17.6 | 36.3 | 12.8 | <1 | <1 | 1300.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Crane | | ASTM D 5185 - Wear Metals by ICP (ppm) | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn | |
| | Dated | Sample Number | Description | | | | 0 | 0 | 2810 | | | 0 | | 0 | 10 | | | 0 | | 1140 | | 10 | | | 1300 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 8/25/2009 | FL-13261-09 | New Oil; Hasler Oil; 15W-40 | <0.5 | 1.3 | 40.7 | 4.7 | 2253.0 | <0.5 | <0.5 | <0.5 | 1.9 | 9.9 | 6.5 | <0.5 | <0.5 | 1.9 | <0.5 | 1064.0 | <0.5 | 2.5 | <0.5 | <0.5 | <0.5 | 1149.0 | |
| | 8/19/2009 | FL-13263-09 | Used Oil; AVGP; JP8 used; P8 | <0.5 | 1.3 | 46.2 | <0.5 | 2286.0 | <0.5 | <0.5 | 1.4 | 3.1 | 10.0 | 12.5 | <0.5 | <0.5 | 1.9 | <0.5 | 1079.0 | 0.5 | 2.6 | <0.5 | <0.5 | <0.5 | 1155.0 | |
| | 9/25/2009 | FL-13295-09 | Used Oil; AVGP; JP8 used; P8 | <0.5 | 1.5 | 47.1 | <0.5 | 2356.0 | <0.5 | <0.5 | 1.0 | 4.1 | 4.0 | 18.4 | <0.5 | <0.5 | 3.2 | <0.5 | 1164.0 | 1.1 | 3.5 | <0.5 | <0.5 | <0.5 | 1213.0 | |
| | 10/29/2009 | FL-13331-09 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.9 | 55.3 | <1 | 2515.0 | <1 | <1 | 5.3 | 5.7 | 11.1 | 15.3 | <1 | <1 | 1.3 | <1 | 1207.0 | <1 | 1.7 | <1 | <1 | <1 | 1232 | |
| | 11/30/2009 | FL-13367-09 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.5 | 47.1 | <1 | 2265.0 | <1 | <1 | 4.3 | 4.9 | 8.7 | 14.1 | <1 | <1 | 2.6 | <1 | 1097.0 | <1 | 2.7 | <1 | <1 | <1 | 1178 | |
| | 1/5/2010 | FL-13395-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.6 | 46.0 | <1 | 2251.0 | <1 | <1 | 4.5 | 5.6 | 8.1 | 13.9 | <1 | <1 | 2.7 | <1 | 1061.0 | <1 | 3.1 | <1 | <1 | <1 | 1090.0 | |
| | 2/2/2010 | FL-13427-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.5 | 45.2 | <1 | 2189 | <1 | <1 | 4.5 | 6.9 | 7.9 | 14.0 | <1 | <1 | 3.7 | <1 | 1053.0 | 1.0 | 3.9 | <1 | <1 | <1 | 1101.0 | |
| | 3/9/2010 | FL-13452-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.5 | 47.5 | <1 | 2284.0 | <1 | <1 | 4.9 | 7.6 | 8.2 | 14.4 | <1 | <1 | 2.9 | <1 | 1105.0 | 1.0 | 3.0 | <1 | <1 | <1 | 1161.0 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/8/2010 | FL-13522-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.6 | 46.4 | <1 | 2326.0 | <1 | <1 | 4.9 | 8.1 | 4.7 | 14.8 | <1 | <1 | 2.7 | <1 | 1125.0 | 1.2 | 2.9 | <1 | <1 | <1 | 1192.0 | |
| | 5/5/2010 | FL-13579-10 | Used Oil; AVGP; JP8 used | <1 | 1.5 | 45.7 | <1 | 2139.0 | <1 | <1 | 4.9 | 7.3 | 7.6 | 14.4 | <1 | <1 | 2.6 | <1 | 1026.0 | <1 | 2.9 | <1 | <1 | <1 | 1038.0 | |
| | 6/9/2010 | FL-13579-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.7 | 67.9 | <1 | 2193.0 | 1.1 | <1 | 5.7 | 8.1 | 4.9 | 13.7 | <1 | <1 | 2.7 | <1 | 1019.0 | 1.7 | 2.8 | <1 | <1 | <1 | 1126.0 | |
| | 7/6/2010 | FL-13598-10 | Used Oil; AVGP; JP8 used; P8 | <1 | 1.7 | 65.4 | <1 | 2210.0 | <1 | <1 | 5.8 | 8.2 | 5.0 | 13.9 | <1 | <1 | 2.6 | <1 | 1030.0 | 1.5 | 2.7 | <1 | <1 | <1 | 1121.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8/25/2009 | FL-13261-09 | New Oil; Hasler Oil; 15W-40 | <0.5 | 1.3 | 40.7 | 4.7 | 2253.0 | <0.5 | <0.5 | <0.5 | 1.9 | 9.9 | 6.5 | <0.5 | <0.5 | 1.9 | <0.5 | 1064.0 | <0.5 | 2.5 | <0.5 | <0.5 | <0.5 | 1149.0 | |
| | 9/3/2009 | FL-13265-09 | Used Oil; AVGP ; JP8 used; P10 | <0.5 | 1.3 | 45.0 | <0.5 | 2243.0 | <0.5 | <0.5 | 0.7 | 3.0 | 11.0 | 13.9 | <0.5 | <0.5 | 1.1 | <0.5 | 1050.0 | 0.6 | 1.9 | <0.5 | <0.5 | <0.5 | 1125.0 | |
| | 9/25/2009 | FL-13296-09 | Used Oil; AVGP ; JP8 used; P10 | <0.5 | 1.6 | 48.6 | <0.5 | 2393.0 | <0.5 | <0.5 | 2.3 | 4.1 | 4.2 | 12.6 | <0.5 | <0.5 | 3.9 | <0.5 | 1176.0 | 1.2 | 4.2 | <0.5 | <0.5 | <0.5 | 1225.0 | |
| | 10/20/2009 | FL-13332-09 | Used Oil; AVGP ; JP8 used; P10 | <1 | 1.8 | 53.8 | <1 | 2527.0 | <1 | <1 | 1.6 | 6.2 | 11.4 | 17.4 | <1 | <1 | 1.3 | <1 | 1210.0 | <1 | 1.7 | <1 | <1 | <1 | 1236 | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **11/30/2009** | **FL-13368-09** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.4** | **46** | **<1** | **2244.0** | **<1** | **<1** | **1.3** | **5.2** | **9.1** | **15.2** | **<1** | **<1** | **2.5** | **<1** | **1084.0** | **1** | **2.6** | **<1** | **<1** | **<1** | **1168** | |
| | **1/5/2010** | **FL-13396-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.5** | **44.9** | **<1** | **2206.0** | **<1** | **<1** | **1.5** | **6.0** | **8.4** | **15.7** | **<1** | **<1** | **2.7** | **<1** | **1049.0** | **<2** | **3.0** | **<1** | **<1** | **<1** | **1077.0** | |
| | **2/2/2010** | **FL-13428-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.5** | **45** | **<1** | **2169** | **<1** | **<1** | **1.7** | **6.7** | **8.5** | **15.7** | **<1** | **<1** | **3.3** | **<1** | **1043.0** | **1.2** | **3.5** | **<1** | **<1** | **<1** | **1091.0** | |
| | **3/9/2010** | **FL-13453-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.5** | **48.7** | **<1** | **2319.0** | **<1** | **<1** | **2.0** | **8.2** | **9.2** | **17.2** | **<1** | **<1** | **2.7** | **<1** | **1117.0** | **1.5** | **2.9** | **<1** | **<1** | **<1** | **1179.0** | |
| | **4/8/2010** | **FL-13523-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.6** | **48.2** | **<1** | **2342.0** | **<1** | **<1** | **2.3** | **9.9** | **4.7** | **17.2** | **<1** | **<1** | **2.4** | **<1** | **1135.0** | **2.0** | **2.6** | **<1** | **<1** | **<1** | **1208.0** | |
| | **5/5/2010** | **FL-13580-10** | **Used Oil; AVGP; JP8 used** | **<1** | **1.5** | **46.2** | **<1** | **2166.0** | **<1** | **<1** | **2.4** | **9.4** | **6.6** | **16.1** | **<1** | **<1** | **2.2** | **<1** | **1058.0** | **1.6** | **2.5** | **<1** | **<1** | **<1** | **1064.0** | |
| | **6/9/2010** | **FL-13580-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.7** | **74.1** | **<1** | **2252.0** | **1.6** | **<1** | **3.4** | **11.7** | **5.5** | **16.6** | **<1** | **<1** | **2.3** | **<1** | **1053.0** | **2.7** | **2.6** | **<1** | **<1** | **<1** | **1157.0** | |
| | **7/6/2010** | **FL-13599-10** | **Used Oil; AVGP ; JP8 used; P10** | **<1** | **1.6** | **62.9** | **<1** | **2220.0** | **<1** | **<1** | **3.5** | **12.4** | **5.4** | **16.2** | **<1** | **<1** | **2.0** | **<1** | **1020.0** | **2.5** | **2.1** | **<1** | **<1** | **<1** | **1128.0** | |
| | **Dated** | **Sample Number** | **Description** | | | | **0** | **0** | **2810** | | | **0** | | **0** | **10** | | | **0** | | **1140** | | **10** | | | **1300** | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **8/25/2009** | **FL-13261-09** | **New Oil; Hasler Oil; 15W-40** | **<0.5** | **1.3** | **40.7** | **4.7** | **2253.0** | **<0.5** | **<0.5** | **<0.5** | **1.9** | **9.9** | **6.5** | **<0.5** | **<0.5** | **1.9** | **<0.5** | **1064.0** | **<0.5** | **2.5** | **<0.5** | **<0.5** | **<0.5** | **1149.0** | |
| | **9/1/2009** | **FL-13264-09** | **Used Oil; AVGP; B20 used; P-6** | **<0.5** | **1.3** | **46.3** | **<0.5** | **2260.0** | **<0.5** | **<0.5** | **<0.5** | **2.9** | **10.6** | **12.5** | **<0.5** | **<0.5** | **1.9** | **<0.5** | **1053.0** | **<0.5** | **2.6** | **<0.5** | **<0.5** | **<0.5** | **1135.0** | |
| | **9/25/2009** | **FL-13297-09** | **Used Oil; AVGP; B20 used; P-6** | **<0.5** | **1.6** | **37.9** | **<0.5** | **2239.0** | **0.8** | **<0.5** | **2.0** | **5.3** | **4.6** | **75.7** | **<0.5** | **<0.5** | **3.4** | **0.5** | **1151.0** | **1.2** | **3.7** | **<0.5** | **<0.5** | **<0.5** | **1178.0** | |
| | **10/29/2009** | **FL-13329-09** | **Used Oil; AVGP; B20 used; P-6** | **<1** | **1.8** | **57.0** | **<1** | **2614.0** | **<1** | **<1** | **<1** | **4.6** | **10.8** | **16.1** | **<1** | **<1** | **1.7** | **<1** | **1245.0** | **<1** | **2.2** | **<1** | **<1** | **<1** | **1290.0** | |
| | **11/30/2009** | **FL-13365-09** | **Used Oil; AVGP; B20 used; P-6** | **<1** | **1.4** | **48.1** | **<1** | **2257.0** | **<1** | **<1** | **<1** | **3.8** | **8.6** | **13.7** | **<1** | **<1** | **4.6** | **<1** | **1089.0** | **<1** | **4.6** | **<1** | **<1** | **<1** | **1181** | |
| | **1/5/2010** | **FL-13393-10** | **Used Oil; AVGP; B20 used; P-6** | **<1** | **1.5** | **46.6** | **<1** | **2232.0** | **<1** | **<1** | **<1** | **4.2** | **7.9** | **13.4** | **<1** | **<1** | **2.8** | **<1** | **1059.0** | **<1** | **3.1** | **<1** | **<1** | **<1** | **1092.0** | |
| | **2/2/2010** | **FL-13425-10** | **Used Oil; AVGP; B20 used; P-6** | **<1** | **1.5** | **46.6** | **<1** | **2219.0** | **<1** | **<1** | **<1** | **4.7** | **7.7** | **14.2** | **<1** | **<1** | **3.8** | **<1** | **1067.0** | **<1** | **4.1** | **<1** | **<1** | **<1** | **1119.0** | |
| | **3/9/2010** | **FL-13450-10** | **Used Oil; AVGP; B20 used; P-6** | **<1** | **1.4** | **48.3** | **<1** | **2283.0** | **<1** | **<1** | **<1** | **5.1** | **8.0** | **14.2** | **<1** | **<1** | **2.3** | **<1** | **1105.0** | **<1** | **2.5** | **<1** | **<1** | **<1** | **1166.0** | |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4/8/2010 | FL-13520-10 | Used Oil; AVGP; B20 used; P-6 | <1 | 1.5 | 46.9 | <1 | 2311.0 | <1 | <1 | <1 | 5.1 | 5.3 | 14.5 | <1 | <1 | 2.9 | <1 | 1109.0 | <1 | 3.1 | <1 | <1 | <1 | 1178.0 | |
| | 5/5/2010 | FL-13577-10 | Used Oil; AVGP; B20 used | <1 | 1.5 | 45.7 | <1 | 2181.0 | <1 | <1 | <1 | 4.7 | 8.4 | 14.8 | <1 | <1 | 2.2 | <1 | 1043.0 | <1 | 2.5 | <1 | <1 | <1 | 1070.0 | |
| | 6/9/2010 | FL-13577-10 | Used Oil; AVGP; B20 used; P-6 | <1 | 1.6 | 73.3 | <1 | 2257.0 | 1.2 | <1 | 1.3 | 5.9 | 4.9 | 13.6 | <1 | <1 | 2.7 | <1 | 1057.0 | 1.2 | 3.1 | <1 | <1 | <1 | 1156.0 | |
| | 7/6/2010 | FL-13596-10 | Used Oil; AVGP; B20 used; P-6 | <1 | 1.8 | 67.9 | <1 | 2220.0 | <1 | <1 | 1.2 | 5.7 | 4.9 | 13.6 | <1 | <1 | 2.2 | <1 | 1028.0 | 1.2 | 2.5 | <1 | <1 | <1 | 1119.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 8/19/2009 | FL-13262-09 | New Oil; Hasler Oil; 15W-40 | <0.5 | 1.3 | 35.7 | <0.5 | 2212.0 | <0.5 | <0.5 | <0.5 | 1.8 | 9.4 | 70.6 | <0.5 | <0.5 | 1.7 | <0.5 | 1079.0 | 1.0 | 2.5 | <0.5 | <0.5 | <0.5 | 1176.0 | |
| | 8/19/2009 | FL-13266-09 | Used Oil; AVGP; B20 used; P7 | <0.5 | 1.3 | 36.4 | <0.5 | 2162.0 | <0.5 | <0.5 | 1.1 | 3.4 | 10.9 | 72.3 | <0.5 | <0.5 | 1.2 | <0.5 | 1050.0 | 0.5 | 2.0 | <0.5 | <0.5 | <0.5 | 1123.0 | |
| | 9/25/2009 | FL-13298-09 | Used Oil; AVGP; B20 used; P7 | <0.5 | 1.7 | 48.6 | <0.5 | 2270.0 | <0.5 | <0.5 | <0.5 | 3.4 | 5.0 | 13.6 | <0.5 | <0.5 | 3.7 | <0.5 | 1130.0 | 0.8 | 4.0 | <0.5 | <0.5 | <0.5 | 1144.0 | |
| | 10/29/2009 | FL-13330-09 | Used Oil; AVGP; B20 used; P7 | <1 | 1.9 | 43.3 | <1 | 2440.0 | <1 | <1 | 3.6 | 7.6 | 10.1 | 81.3 | <1 | <1 | 1.6 | <1 | 1211.0 | 1 | 2.1 | <1 | <1 | <1 | 1250 | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11/30/2009 | FL-13366-09 | Used Oil; AVGP; B20 used; P7 | <1 | 1.5 | 36.7 | <1 | 2151.0 | <1 | <1 | 3.1 | 6.5 | 8.1 | 75.4 | <1 | <1 | 2.9 | <1 | 1084.0 | <1 | 3 | <1 | <1 | <1 | 1171 | |
| | 1/5/2010 | FL-13394-10 | Used Oil; AVGP; B20 used; P7 | <1 | 1.6 | 36.1 | <1 | 2154.0 | <1 | <1 | 3.5 | 7.1 | 7.5 | 74.9 | <1 | <1 | 3.1 | <1 | 1063.0 | 1.0 | 3.4 | <1 | <1 | <1 | 1092.0 | |
| | 2/2/2010 | FL-13426-10 | Used Oil; AVGP; B20 used; P7 | <1 | 1.6 | 35.8 | <1 | 2123 | <1 | <1 | 3.4 | 7.3 | 7.4 | 68.6 | <1 | <1 | <1 | <1 | 1054.0 | 1.0 | 4.1 | <1 | <1 | <1 | 1105.0 | |
| | 3/9/2010 | FL-13451-10 | Used Oil; AVGP; B20 used; P7 | <1 | 1.5 | 37.6 | <1 | 2218.0 | <1 | <1 | 4.0 | 8.7 | 7.7 | 69.6 | <1 | <1 | 2.8 | <1 | 1113.0 | 1.1 | 2.9 | <1 | <1 | <1 | 1171.0 | |
| | 4/8/2010 | FL-13521-10 | Used Oil; AVGP; B20 used; P7 | <1 | 1.7 | 36.0 | <1 | 2245.0 | 1.1 | <1 | 4.5 | 10.5 | 4.7 | 71.3 | <1 | <1 | 3.0 | <1 | 1128.0 | 1.5 | 3.1 | <1 | <1 | <1 | 1201.0 | |
| | 5/5/2010 | FL-13578-10 | Used Oil; AVGP; B20 used | <1 | 1.6 | 35.6 | <1 | 2118.0 | <1 | <1 | 4.5 | 9.6 | 8.2 | 63.5 | <1 | <1 | 2.4 | <1 | 1047.0 | 1.1 | 2.6 | <1 | <1 | <1 | 1070.0 | |
| | 6/9/2010 | FL-13578-10 | Used Oil; AVGP; B20 used; P7 | <1 | 2.0 | 54.7 | <1 | 2209.0 | 2.1 | <1 | 7.4 | 12.5 | 4.8 | 63.9 | <1 | <1 | 3.2 | <1 | 1056.0 | 2.5 | 3.5 | 1.4 | <1 | <1 | 1166.0 | |
| | 7/6/2010 | FL-13597-10 | Used Oil; AVGP; B20 used; P7 | <1 | 2.1 | 48.7 | <1 | 2157.0 | 1.7 | <1 | 7.5 | 13.5 | 4.8 | 63.6 | <1 | <1 | 3.1 | <1 | 1021.0 | 2.6 | 3.2 | 1.5 | <1 | <1 | 1126.0 | |
| | | | | | | | | | | | | | | | | | | | | | | | | | | |

| MCBH | | ASTM D 5185 - Wear Metals by ICP (ppm) | Ag | Al | B | Ba | Ca | Cd | Cr | Cu | Fe | K | Mg | Mn | Mo | Na | Ni | P | Pb | Si | Sn | Ti | V | Zn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dated** | **Sample Number** | **Description** | | | | **0** | **0** | **2810** | | | **0** | | **0** | **10** | | | **0** | | **1140** | | **10** | | | **1300** | |
| **5/26/2010** | **FL-13560-10** | **New Oil; TRAM** | **<1** | **1.5** | **2.1** | **<1** | **2857.0** | **<1** | **<1** | **<1** | **1.8** | **1.0** | **9.3** | **<1** | **1.2** | **3.6** | **<1** | **1167.0** | **<1** | **4.1** | **<1** | **<1** | **<1** | **1206.0** | |
| **8/31/2010** | **FL-13685-10** | **Used oil; TRAM; engine running JP8** | **<1** | **2.8** | **1.5** | **<1** | **2765.0** | **<1** | **<1** | **3.4** | **15.0** | **<1** | **8.4** | **<1** | **<1** | **2.7** | **<1** | **1183.0** | **2.1** | **2.6** | **<1** | **<1** | **<1** | **1277.0** | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |
| **5/26/2010** | **FL-13561-10** | **New Oil; Humvee** | **<1** | **2.3** | **3.5** | **<1** | **2241.0** | **<1** | **<1** | **<1** | **1.7** | **<1** | **7.2** | **<1** | **<1** | **9.3** | **<1** | **1074.0** | **<1** | **9.7** | **<1** | **<1** | **<1** | **1130.0** | |
| **8/31/2010** | **FL-13686-10** | **Used oil; HUMVEE; engine running JP8** | **<1** | **4.9** | **21.8** | **1.5** | **2602.0** | **11.8** | **3.1** | **30.6** | **105.9** | **9.5** | **217.1** | **5.3** | **21.4** | **74.4** | **2.1** | **1185.0** | **32.5** | **72.9** | **20.7** | **<1** | **<1** | **1316.0** | |
| **Dated** | **Sample Number** | **Description** | | | | **0** | **0** | **2810** | | | **0** | | **0** | **10** | | | **0** | | **1140** | | **10** | | | **1300** | |
| **5/26/2010** | **FL-13560-10** | **New Oil; TRAM** | **<1** | **1.5** | **2.1** | **<1** | **2857.0** | **<1** | **<1** | **<1** | **1.8** | **1.0** | **9.3** | **<1** | **1.2** | **3.6** | **<1** | **1167.0** | **<1** | **4.1** | **<1** | **<1** | **<1** | **1206.0** | |
| **8/31/2010** | **FL-13687-10** | **Used oil; TRAM; engine running B20** | **<1** | **2.4** | **1.6** | **<1** | **3011.0** | **<1** | **1.0** | **2.5** | **20.2** | **<1** | **9.5** | **<1** | **1.5** | **3.0** | **<1** | **1259.0** | **1.8** | **3.0** | **<1** | **<1** | **<1** | **1439.0** | |
| | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **5/26/2010** | **FL-13561-10** | **New Oil; Humvee** | **<1** | **2.3** | **3.5** | **<1** | **2241.0** | **<1** | **<1** | **<1** | **1.7** | **<1** | **7.2** | **<1** | **<1** | **9.3** | **<1** | **1074.0** | **<1** | **9.7** | **<1** | **<1** | **<1** | **1130.0** | |
| | **8/31/2010** | **FL-13688-10** | **Used oil; HUMVEE; engine running B20** | **<1** | **7.6** | **2.4** | **<1** | **2243.0** | **3.0** | **9.9** | **11.8** | **105.8** | **2.0** | **275.9** | **1.8** | **8.7** | **51.9** | **4.0** | **1154.0** | **8.6** | **50.6** | **<1** | **<1** | **<1** | **1249.0** | |

# APPENDIX F Weather Data

## Table 17. NOAA, National Climatic Data Center, PALM SPRINGS, CA

| | Temperature (Fahrenheit) | | | | | Precipitation (In) | | Pressure(inches of Hg) | |
|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Avg. | Avg. Dew pt. | Avg Wet Bulb | 2400 LST Snow Fall | 2400 LST Water Equiv | Avg. Station | Avg. Sea Level |
| **June-09** | 96.4 | 69.1 | 82.8 | 46.6 | 62.2 | M | 0 | 29.26 | 29.74 |
| **July-09** | 110.9s | 80.9s | 95.9s | 49.2 | 67.9 | M | 0 | 29.29 | 29.76 |
| **August-09** | M | M | M | 47.7 | 66.3 | | | | |
| **September-09** | 103.9 | 74.7 | 89.3 | 44.3 | 64.3 | M | 0 | 29.32 | 29.79 |
| **October-09** | 86.9 | 59.3 | 73.1 | 34 | 54.4 | M | 0 | 29.36 | 29.84 |
| **November-09** | 80.1 | 53.5 | 66.8 | 28.7 | 49.6 | M | 0.05s | 29.47 | 29.95 |
| **December-09** | 67 | 44.3 | 55.7 | 30.6 | 44.5 | M | 1.27s | 29.54 | 30.02 |
| **January-10** | 68.8 | 46.4 | 57.6 | 33.9 | 46.7 | M | 4.52s | 29.49 | 29.98 |
| **February-10** | 71.6 | 49.4 | 60.5 | 38 | 49.5 | M | 0.75s | 29.45 | 29.94 |
| **March-10** | 77.9 | 52 | 65 | 30 | 49.3 | M | T | 29.47 | 29.96 |
| **April-10** | 82.2 | 54.9 | 68.6 | 34.8 | 52.6 | M | 0.08s | 29.37 | 29.85 |
| **May-10** | 90.7 | 61.7 | 76.2 | 37.6 | 56.6 | M | T | 29.34 | 29.82 |
| **June-10** | 102.9 | 71.4 | 87.2 | 46.2 | 63.8 | M | 0 | 29.27 | 29.74 |
| **July-10** | 108.4 | 78.4 | 93.4s | M | M | M | 0 | 29.26 | 29.72 |
| **August-10** | 106.2 | 76.5 | 91.4s | 47.4 | 65.8 | M | 0 | 29.26 | 29.73 |
| **September-10** | 103.6 | 71.7 | 87.7 | 42.1 | 62.7 | M | 0.11s | 29.27 | 29.74 |
| **October-10** | 87.1 | 64.2 | 75.7 | 45.7 | 59.3 | M | 0.48s | 29.45 | 29.93 |
| **November-10** | 76.2 | 51.1 | 63.7 | 29.2 | 48.5 | M | 0.04s | 29.54 | 30.03 |
| **December-10** | 69.7 | 48.4 | 59.1 | 35.3 | 48.4 | M | 3.72s | 29.51 | 29.99 |

## Table 18. NOAA, National Climatic Data Center, VALDOSTA, GA

| | Temperature (Fahrenheit) | | | | | | Precipitation (In) | Pressure(inches of Hg) | |
|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Avg. | Dep From Normal | Avg. Dew pt. | Avg Wet Bulb | 2400 LST Water Equiv | Avg. Station | Avg. Sea Level |
| June-09 | 93.1 | 70.3 | 81.7 | | 68.7 | 72.5 | 3.29s | 29.68 | 29.92 |
| July-09 | 90.6 | 69.7 | 80.2 | | 69 | 72.1 | 6.76s | 29.8 | 30.03 |
| August-09 | 89.8 | 71 | 80.4 | | 70.1 | 72.8 | 4.00s | 29.82 | 30.06 |
| September-09 | 87.3 | 68.4 | 77.9 | | 67.1 | 70.4 | 2.13s | 29.78 | 30.02 |
| October-09 | 80.3 | 60.6 | 70.5 | | 61.6 | 64.7 | 1.43s | 29.8 | 30.03 |
| November-09 | 70.5 | 46.9 | 58.7 | | 48.5 | 53.1 | 1.63s | 29.84 | 30.11 |
| December-09 | 62.1 | 43.2 | 52.7 | | 44.1 | 48.5 | 5.28s | 29.87 | 30.11 |
| January-10 | 58.6 | 35.2 | 46.9 | | 34 | 41 | 3.41s | 29.89 | 30.13 |
| February-10 | 57.6 | 35.9 | 46.8 | | 36 | 41.9 | 1.20s | 29.78 | 30.02 |
| March-10 | 67.6 | 43.1 | 55.4 | | 43.3 | 49.2 | 2.06s | 29.73 | 29.97 |
| April-10 | 80.8 | 52.5 | 66.7 | | 53.6 | 59.3 | 3.57s | 29.82 | 30.05 |
| May-10 | 88.1 | 65 | 76.6 | | 65.6 | 69.2 | 4.32s | 29.8 | 30.03 |
| June-10 | 92.6 | 71.3 | 82 | | 71.7 | 74.4 | 4.01s | 29.8 | 30.03 |
| July-10 | 93.3 | 73 | 83.2 | | 72.8 | 75.6 | 5.06s | 29.82 | 30.05 |
| August-10 | 92.5 | 74.8 | 83.7 | | 74.6 | 76.7 | 5.06s | 29.75 | 29.98 |
| September-10 | 90.2 | 66.9 | 78.6 | | 67.4 | 70.9 | 4.19s | 29.76 | 29.99 |
| October-10 | 82.1 | 53.2 | 67.7 | | 55.2 | 60 | 0.39s | 29.81 | 30.05 |
| November-10 | 73.4 | 44.3 | 58.9 | | 47.5 | 52.1 | 0.84s | 29.9 | 30.13 |
| December-10 | 54.2 | 29.66667 | 42.07143 | | 27.4375 | 36.25 | M | 29.885 | 30.1338 |

## Table 19. NOAA, National Climatic Data Center, BLOOMINGTON, IN

| | Temperature (Fahrenheit) | | | | | | Precipitation (In) | | Pressure(inches of Hg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Avg. | Dep From Normal | Avg. Dew pt. | Avg Wet Bulb | 2400 LST Snow Fall | 2400 LST Water Equiv | Avg. Station | Avg. Sea Level |
| June-09 | 82.2 | 62.2 | 72.2 | | 61.7 | 65.6 | M | 5.65s | 28.97 | 29.86 |
| July-09 | 78.3 | 59.6 | 69 | | 60.4 | 63.8 | M | 6.02s | 29.06 | 29.95 |
| August-09 | 81.2 | 60.5 | 70.9 | | 62 | 65.2 | M | 3.39s | 29.13 | 30.02 |
| September-09 | 76.9 | 54.6 | 65.8 | | 55.6 | 59.6 | M | 2.20s | 29.15 | 30.05 |
| October-09 | 60.4 | 41.2 | 50.8 | | 41.8 | 46.6 | M | 8.10s | 29.08 | 29.98 |
| November-09 | 57.5 | 36 | 46.8 | | 36 | 41.9 | M | 1.07s | 29.18 | 30.09 |
| December-09 | 38.7 | 23.8 | 31.3 | | 23.6 | 28.8 | M | 3.41s | 29.13 | 30.05 |
| January-10 | 32.2 | 18.1 | 25.2 | | 18.2 | 22.5 | M | 1.46s | 29.18 | 30.11 |
| February-10 | 34.1 | 17.9 | 26 | | 20.4 | 24.5 | M | 1.34s | 29.08 | 30.01 |
| March-10 | 56.6 | 33.7 | 45.2 | | 34.8 | 40.4 | M | 3.62s | 29.02 | 29.92 |
| April-10 | 71.9 | 46.3 | 59.1 | | 43.9 | 51.5 | M | 4.58s | 29.03 | 29.92 |
| May-10 | 75.1 | 54.9 | 65 | | 56.5 | 60 | M | 6.99s | 29.07 | 29.96 |
| June-10 | 85.3 | 64.8 | 75.1 | | 66.7 | 69.6 | M | 8.17s | 29.05 | 29.94 |
| July-10 | 86.8 | 66.2 | 76.5 | | 68.5 | 71 | M | 3.28s | 29.1 | 29.99 |
| August-10 | 89.2 | 62.9 | 76.1 | | 65.4 | 69 | M | 0.68s | 29.08 | 29.97 |
| September-10 | 81.9 | 53.9 | 67.9 | | 53.5 | 59.5 | M | 0.87s | 29.1 | 29.99 |
| October-10 | 71.2 | 41.1 | 56.2 | | 39.2 | 47.8 | M | 0.76s | 29.11 | 30.01 |
| November-10 | 56.1 | 30.6 | 43.4 | | 32.3 | 38.5 | M | 6.56s | 29.15 | 30.1 |
| December-10 | M | M | M | | M | M | M | M | M | M |

## Table 20. NOAA, National Climatic Data Center, OXNARD, CA

| | Temperature (Fahrenheit) | | | | | | Precipitation (In) | | Pressure(inches of Hg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Avg. | Dep From Normal | Avg. Dew pt. | Avg Wet Bulb | 2400 LST Snow Fall | 2400 LST Water Equiv | Avg. Station | Avg. Sea Level |
| May-09 | 66.8 | 54.7 | 60.8 | | 53.5 | 56.4 | M | 0.10s | 29.85 | 29.93 |
| June-09 | 68.4 | 57.6 | 63 | | 55.3 | 58.4 | M | 0.14s | 29.83 | 29.9 |
| July-09 | 71.3 | 59.4 | 65.4 | | 57.3 | 59.9 | M | 0 | 29.85 | 29.92 |
| August-09 | 71.8 | 58 | 64.9 | | 57.6 | 60.1 | M | 0.02s | 29.85 | 29.92 |
| September-09 | 75 | 56 | 65.5 | | 60.3 | 62.5 | M | 0.00s | 29.87 | M |
| October-09 | 71.1 | 54.2 | 62.7 | | 50 | 56.1 | M | 0.93s | 29.85 | 29.92 |
| November-09 | 69 | 47.4 | 58.2 | | 42.5 | 50.5 | M | 0.01s | 29.91 | 29.98 |
| December-09 | 62 | 44.1 | 53.1 | | 40.3 | 46.7 | M | 2.59s | 29.96 | 30.04 |
| January-10 | 67.5 | 46.7 | 57.1 | | 41.9 | 49.5 | M | 6.13s | 29.9 | 29.97 |
| February-10 | 64 | 47.8 | 55.9 | | 46 | 50.8 | M | 4.44s | 29.9 | 29.97 |
| March-10 | 66.1 | 48.6 | 57.4 | | 43.0 | 50.2 | M | 0.57 | M | M |
| April-10 | 63.5 | 48.8 | 56.2 | | 46.3 | 51.4 | M | 1.26s | 29.88 | 29.96 |
| May-10 | 65.6 | 50.7 | 58.2 | | 49 | 53.3 | M | 0.19s | 29.88 | 29.96 |
| June-10 | 67 | 56.7 | 61.9 | | 55 | 57.6 | M | T | 29.85 | 29.93 |
| July-10 | 68.2 | 57.3 | 62.8 | | 55.6 | 58.2 | M | 0.00s | 29.83 | 29.9 |
| August-10 | 68.2 | 56.2 | 62.2 | | 54.7 | 57.5 | M | 0.04s | 29.8 | 29.88 |
| September-10 | 71.1 | 57.1 | 64.1 | | 54.8 | 58.3 | M | 0.08s | 29.79 | 29.86 |
| October-10 | 70 | 57.9 | 64 | | 53.7 | 58.4 | M | 2.39s | 29.93 | 30 |
| November-10 | 69.7 | 48.7 | 59.2 | | 41.1 | 50.2 | M | 0.94s | 29.99 | 30.1 |
| December-10 | 65 | 50.4 | 57.8571 | | 45.375 | 51.4375 | M | M | M | M |

## APPENDIX G Vehicle Operations Schedule

**Table 21. Mileage and Hours of Operation**

| Vehicles | Mileage | Hours |
|---|---|---|
| 94-59514 Hummer on B20 | 1271 | |
| 94-59513 Hummer on JP8 | 2131 | |
| USN 9647633 MTVR on B20 | 92.7 | 45.5 |
| USN 9647632 MTVR on JP8 | 142 | 41.0 |
| P-7 LAV Test on B20 | 1169 | 54.6 |
| P-6 LAV Test on B20 | 6 | 6.4 |
| P-8 LAV Control on JP8 | 6 | 8.0 |
| P-10 LAV Control on JP8 | 793 | 47.6 |
| 08C 2008 Bobtail | | 473.0 |
| 97C 1997 Bobtail | | 47.0 |
| 05L R-11 Refueler Truck | | 523.0 |