BIODIESEL

COLD WEATHER BLENDING STUDY

COLD FLOW BLENDING CONSORTIUM

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Executive Summary

Increased use of biodiesel has created some handling challenges for bringing blended fuels to the consumer. The most immediate handling concern for blenders is assurance that diesel fuels and biodiesel can be blended uniformly and in a single phase. More specifically, blenders need guidelines and parameters for blending diesel fuel and biodiesel in colder climates. Neat biodiesel has a much higher cloud point than conventional diesel fuels and this can impact handling procedures. This concern became a priority following the passage of a bill in Minnesota that required all on-highway diesel fuels to contain at least 2% biodiesel as early as July 1, 2005.

In response to the need in Minnesota, the National Biodiesel Board established a Biodiesel Cold Flow Consortium to study the blending properties of biodiesel. Members of the consortium included petroleum marketers, biodiesel producers, fuel blenders, and other experts and interested parties. The members designed a project to investigate this cold flow problem. The project goal was to define operating parameters for blending biodiesel with diesel fuel at a variety of temperatures, including those seen in the wintertime in Minnesota.

To achieve this goal, a small blending test rig was designed to simulate splash and proportional blending at the terminal. Unadditized No. 1 and No. 2 diesel fuels were selected, along with three biodiesels with a range of cold flow properties. The test temperatures were determined using Minnesota winter climate data. All testing focused on preparing 2 volume percent biodiesel blends.

Splash blending tests were based on visual observation of wax crystal formation and are thus qualitative. To ensure quantitative data was obtained, differential pressure drop measurements were collected. These measurements compared the pressure drop of neat diesel fuel through a filter with the pressure drop created by B2 blends at various temperatures.

Results from the testing showed that the biodiesel must be kept at least 10ºF above its cloud point to successfully blend with diesel fuels in cold climates. Because generic, unadditized fuels were used in this project, the actual temperatures of the fuels will need to be determined on an individual basis.

Table of Contents

Introduction

In response to the recent passage of Minnesota's bill requiring 2% biodiesel in all diesel fuels starting as early as July 1, 2005, the National Biodiesel Board convened a Cold Flow Consortium. The Consortium was tasked with investigating the blending of biodiesel into diesel fuel at temperatures similar to those experienced in the Minnesota winter, with the objective of defining parameters for successfully preparing homogeneous single-phase blends. The Consortium was composed of fuel providers, marketers, blenders, and other interested parties. Each member had an equal voice in the Consortium.

Scope

This study was designed to accurately determine the temperature where biodiesel and No. 1 and No. 2 diesel could be blended at 2 volume percent (2%) biodiesel, while meeting standards for blend precision and homogeneity. The approach taken was to fabricate a small scale blending system to simulate splash and proportional blending. The system has the capability to blend biodiesel at different rates with different grades of diesel fuel at different temperatures. This study focused on preparing 2% biodiesel (B2) blends exclusively. The blending system was self-contained to include tanks, pumps, motors, and necessary appurtenances. The system included the ability to heat and/or cool the biodiesel as needed and cool the diesel as needed.

Experimental Apparatus

The test unit was designed to be totally portable to allow for future testing at various locations. The design of the test skid was specifically sized for testing B2 as mandated in the state of Minnesota. The test skid included an environmental chilling chamber, capable of cooling fuel to near -60ºF in a reasonably short period of time. A photograph of the blending unit is in Figure 1. Each process and test was recorded manually and with video equipment along with the blending equipment records of volume amounts. To assist in recording the results of these tests, the finished product tank included interior lighting, viewing ports, and sample ports. The finished product tank was manufactured of a clear material to offer the best possible opportunity for evaluating the formation of crystals.

The design for the first series of testing simulated splash blending into a clear blending container maintained at ambient temperature. A process and instrumentation diagram (P&ID) of this test bench configuration is contained in Appendix A. For proportional blending, a flow loop was created to allow the fuels to circulate through the piping while inside the cooling chamber. The piping loop included a filter and differential pressure across the filter was employed to monitor fuel viscosity changes and determine if the fuels were plugging the filters or strainers. Large increases in viscosity or filter plugging would indicate the formation of wax or biodiesel crystals. A P&ID of this configuration is shown in Appendix B.

Figure 1. Photograph of Small Scale Test Unit for Blending Biodiesel and Diesel Fuel

Test Procedures

Sequential Blending into Visible Container. These tests simulated splash blending. Four scenarios were tested:

1. Cold No. 1 diesel was loaded into the container. The first type of biodiesel was added to the top to create a B2 blend. This procedure was repeated for each type of biodiesel.
2. Cold No. 2 diesel was loaded into the container. The first type of biodiesel was added to the top to create a B2 blend. This procedure was repeated for each type of biodiesel.
3. Biodiesel was loaded into the container first. The No. 1 diesel fuel was loaded on top to create the B2 blend. This scenario was repeated for each type of biodiesel.
4. Biodiesel was loaded into the container first. The No. 2 diesel fuel was loaded on top to create the B2 blend. This scenario was repeated for each type of biodiesel.

Proportional Blending. The biodiesel and diesel fuels were blended through proportional blending. To accomplish this, four gallons of cold No. 1 or No. 2 diesel fuel were circulated through the filters and the pressure drop across the filters measured. Biodiesel was then proportionally blended at 2% and any change in the filter pressure drop monitored. This procedure was repeated with each of the three biodiesels. Step-by-step procedures are given in Appendix C.

Test Fuels

A local truck rack operator provided the diesel fuels for this project. The fuels were unadditized commercial grades of No. 1 and No. 2 diesel fuels. The certificates of analysis are in Appendix D and E, respectively. The biodiesels were soy-, yellow grease-, and tallow-derived fuels. The certificates of analysis are in Appendices F, G, and H, respectively. West Central Soy provided the soy biodiesel. Rothsay/Laurenco provided the yellow grease and tallow biodiesels.

The biodiesels were sent to a test facility to measure the cloud and pour points of the neat biodiesels and the B2 blends. Because the unadditized diesel fuel (Appendices D and E) was not available, a typical no. 2 diesel was used to make the blends for cloud point and pour point determination. The results of this testing are shown in Table 1.

Table 1. Measured Low Temperature Properties of Fuels Used in this Study

Fuel	Cloud Point		Pour Point	
	°C	°F	°C	°F
No. 2 Diesel	-23	-9	-27	-17
Soy Biodiesel	2	35	0	32
Yellow Grease Biodiesel	5	41	3	37
Tallow Biodiesel	14	57	18	64
2% Soy Biodiesel	-21	-5	-27	-17
2% Yellow Grease Biodiesel	-21	-5	-27	-17
2% Tallow Biodiesel	-20	-4	-27	-17

Results and Discussion

The initial testing used visual observation to determine if shock crystallization occurred. Testing revealed several drawbacks with this method. First, the fuel was pushed through the apparatus with nitrogen gas. Bubbles of nitrogen remained suspended in the fuels impeding visual observation. To allow for visual observation, the clear blending vessel was exposed to ambient temperatures. Although the fuel was preconditioned to the test temperatures and the plumbing was insulated, the ambient air warmed the fuels and the test temperature was unknown. Due to the qualitative nature of the data, no conclusions could be drawn from the visual data, however they are included in Appendix I.

To resolve these issues, vane pumps were used to push the fuel rather than nitrogen gas. Temperature monitoring was used to ensure the pumps were not heating the fuels. The clear blending vessel was replaced with a steel blending vessel. The steel blending vessel was placed in an environmental chamber designed to keep the apparatus at the desired temperature. These changes no longer allowed for visual observation of the blending results.

A quantitative measure of changes in the blend was needed. Swagelok SS-8TF2 filters of varying porosities were used in conjunction with differential pressure gauges to indicate changes in viscosity or solid formation. The diesel fuels were circulated through a 15 micron filter to determine the baseline pressure drop. Results of this baseline testing are listed in Table 2. The duration is the amount of time needed to dispense 1 gallon of fuel.

Table 3 shows the results of testing with the three biodiesels. The fuels were circulated through the pump rig for 180 seconds. The differential pressure was measured at various intervals throughout the testing. For the low and middle cloud point fuels, the 100 mesh strainer was clean at the end of the circulation period. For the high cloud point fuel, the strainer was 50% plugged with solids. The 15 micron filter did not allow for usable data, as the biodiesels exceeded the gauge range and bypassed the loop through the relief valve.

Table 2. Baseline Testing with Fuels to Determine Pressure Drop Across Various Size Filters and Strainers

Fuel	Strainer	Flow Rate, GPM	Temperature, ºF	Duration, sec	Differential Pressure, PSI
#2	None	1	64	60	0
#2	None	3.3	64	18	0
#2	100 mesh	3.3	68	18	7.5
#2	15 micron	1.9	68	31	82
#2	100 mesh	1.4	68	42	1
#2	15 micron	0.85	68	71	35
#1	100 mesh	3.3	50	18	3
#1	15 micron	2.1	50	29	not measured
#1	100 mesh	1.5	51	39	not measured
#1	15 micron	1.1	51	37	not measured

Table 3. Baseline Testing with Biodiesel Fuels to Determine Pressure Drop Across 100 Mesh Filter. Shaded lines indicate biodiesel was at or below its cloud point.

Biodiesel Cloud Point, ºF	Flow Rate, GPM	Temperature, ºF	Test Time, sec	Differential Pressure, PSI
32	3.3	50	60	5
32	3.3	51	90	5
32	3.3	51	120	5
32	3.3	51	150	5
32	3.3	51	180	5
43	3.3	50	60	6
43	3.3	51	90	6
43	3.3	51	120	6
43	3.3	51	150	6
43	3.3	51	180	6
58	3.3	51	60	17
58	3.3	51	90	16
58	3.3	51	120	16
58	3.3	51	150	16
58	3.3	52	180	14

The diesel fuel was filtered through the 15 micron filter then switched to the 100 mesh strainer. The differential pressure was measured before, during, and after blending with biodiesel at a constant temperature. The final differential pressure reading was taken through the 15 micron filter and compared to the diesel baseline results to determine the rise in pressure of the blend (Table 4).

Table 4. Differential Pressure Results of Biodiesel Blending into Diesel Fuels

The shaded lines indicate that the biodiesel temperature is at or below its cloud point.

Test	Type of Diesel Fuel	Diesel Fuel Temp. F	Biodiesel Cloud Point, F	Biodiesel Temp. F	% Biodiesel in Test Sample	Unblended Fuel DP PSI	B2 DP PSI	DP Rise in PSI	Comments
1RR	#2	10	32	58	1.7	70	75	5	
2	Kerosene	10	32	50	2	40	40	0	
3	# 2	10	43	50	1.9	75	80	5	
4	Kerosene	10	43	50	1.9	45	45	0	
5	#2	10	58	56	1.8	75	82	7	
6	Kerosene	10	58	58	1.7	40	42	2	
7	Kerosene	0	32	50	1.7	33	35	2	
8	Kerosene	-10	32	50	1.8	50	55	5	
9	Kerosene	-10	43	50	1.8	45	45	0	
10	Kerosene	0	43	50	1.9	32	35	3	
11	Kerosene	0	58	53	1.9	40	45	5	
12	Kerosene	-10	58	53	2	35	45	10	Blend Unsuccessful

All above tests were performed using a 15 micron Filter and 2% Biodiesel Blends. All samples were top samples.

Under the conditions used in this study, researchers determined that the biodiesel must be at least 10ºF warmer than its cloud point when it is blended in cold diesel fuel. Although some testing was conducted below the cloud point of the biodiesels, there is not enough data to draw definite conclusions and the recommendation above is a conservative estimate. Unadditized diesel fuels were deliberately chosen for this study. Due to various fuel properties encountered in the real world, the target temperatures will need to be determined on an individual basis based on the fuels in use.

The results were shared with the Consortium members. A record of their comments is in Appendix J.

Conclusions

This study was designed to simulate different types of blending for biodiesel and diesel fuels. A small test rig was constructed to simulate real world blending scenarios. The original tests used visual observation to determine when the blends were successful. This method did not provide objective data. A modification to the test methodology was made – filters and differential pressure gauges were used to determine the change in differential pressure between the base fuel and the B2 blends.

Based on tests with the fuels described above, the study findings are:

- Qualitative visual observations of sequential blending with diesel and biodiesel fuels showed clouding and possible crystallization of the fuel.
  - This may be a concern in Northern and Midwest states where biodiesel will be blended into colder diesel fuel that *may* result in crystal formation without adequate mixing.

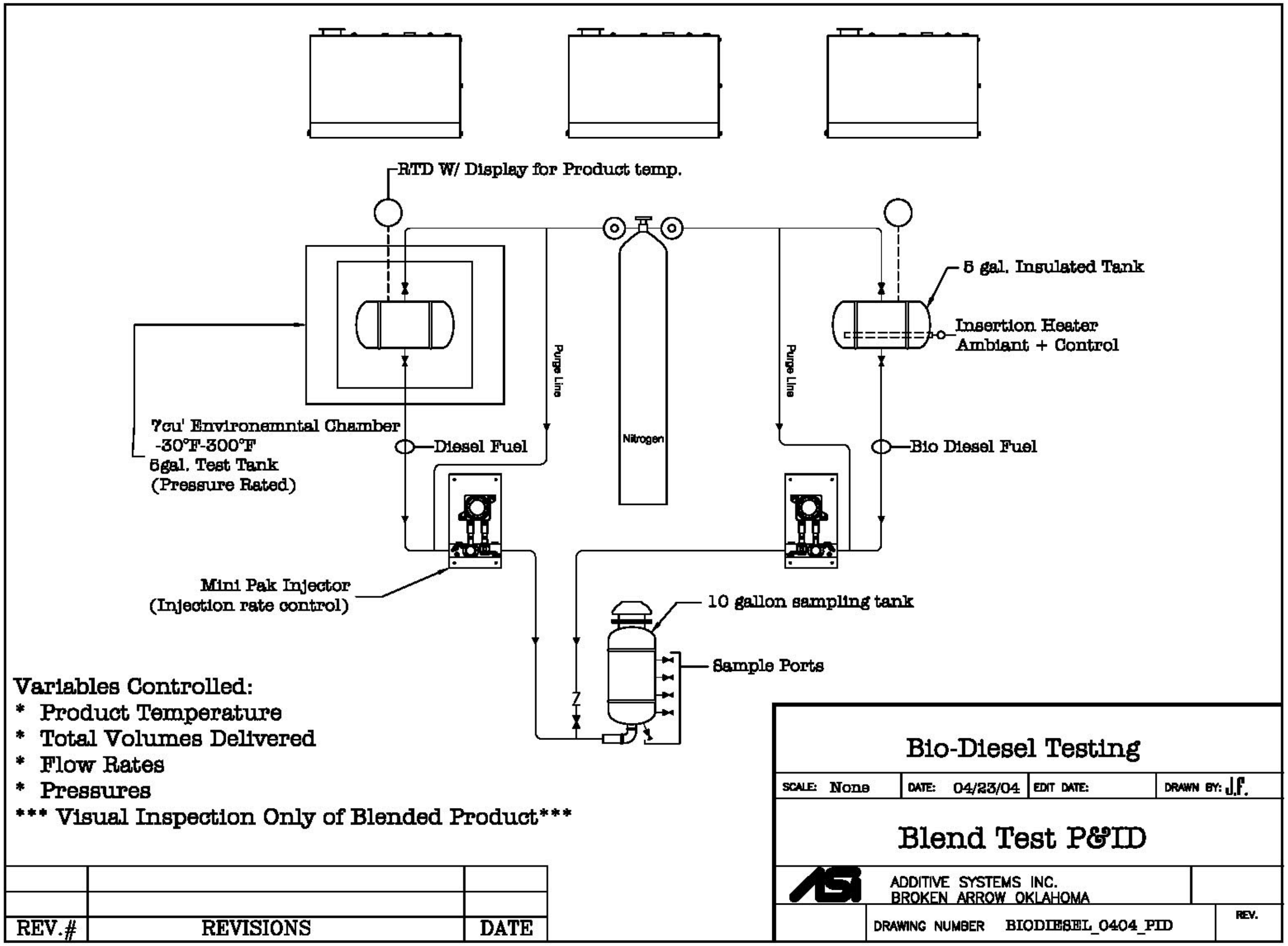
- A typical rack blending system is “once through only” without circulation through a pump.
  - Circulating diesel or biodiesel fuels through a pump does not match up with real world rack blending systems.
  - In this study, test run blending used circulation through a pump that *may* have provided additional shearing and mixing that helped to eliminate “shock” or wax crystallization.

In this study, successful B2 blends were made when the biodiesel was 10°F above its cloud point. Unadditized diesel fuel was deliberately chosen for this study and the three biodiesels were selected to span a range of cloud points and are not meant to be representative of all fuels encountered. Because of the variety of fuel properties, the target temperatures for blending will need to be determined on an individual basis based on the fuels and actual winter temperatures at the terminal. It will be important for blenders to request cloud point information from suppliers for cold weather considerations.

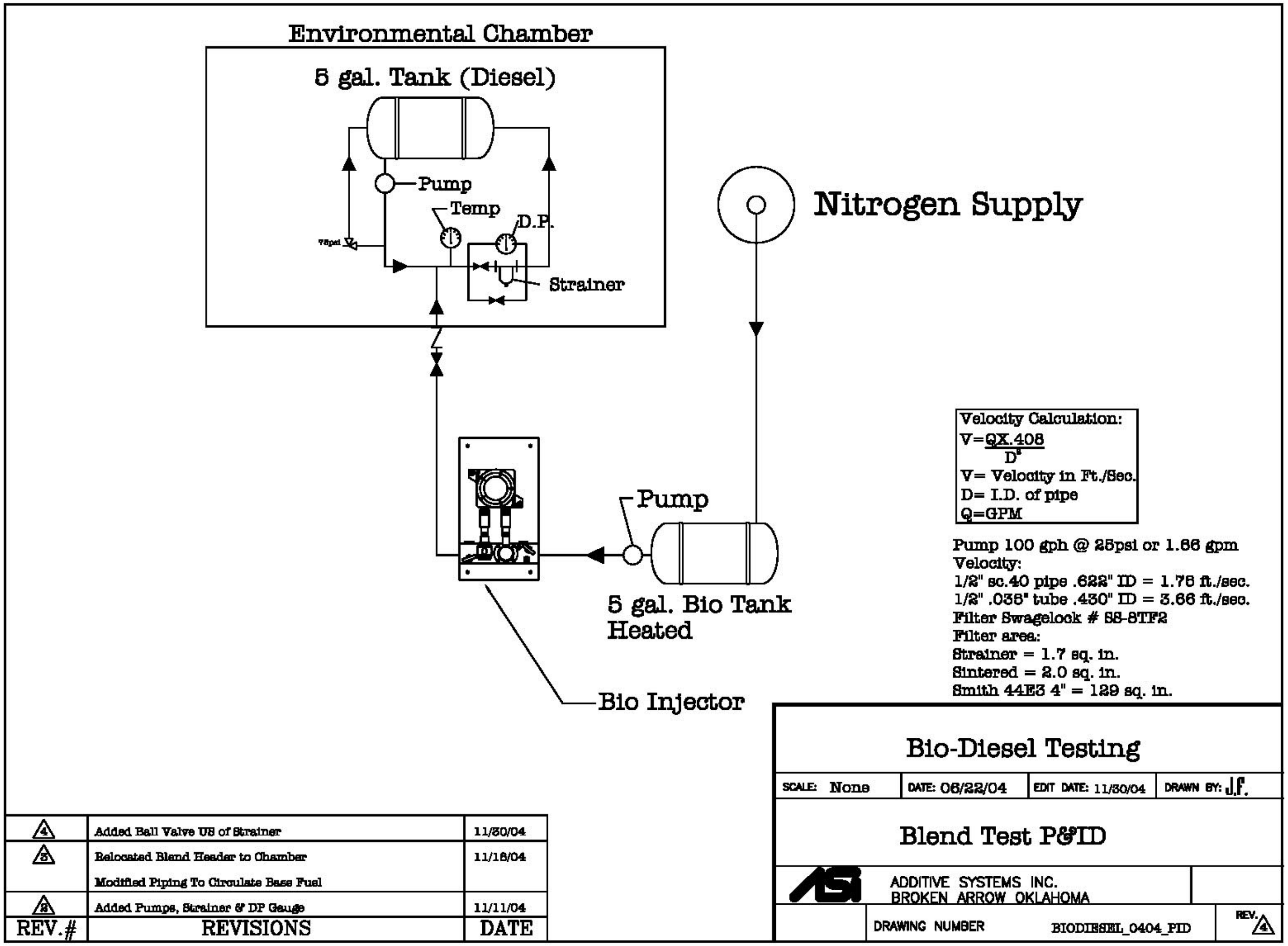
Small Group Steering Committee Members

Steve Howell-Marc IV Consulting Group
Paul Nazzaro-Advanced Fuel Systems
Charley Selvedge-Flint Hills Resources
Rick Stanko-Marathon Ashland Petroleum Company
Rod Lawrence- Magellan Midstream LP

Appendix A. P&ID of Splash Blending Rig.



Appendix B. P&IF of Modified Test Rig



Velocity Calculation:
$V=\frac{QX.408}{D^2}$
V= Velocity in Ft./Sec.
D= I.D. of pipe
Q=GPM

Pump 100 gph @ 25psi or 1.66 gpm
Velocity:
1/2" sc.40 pipe .622" ID = 1.76 ft./sec.
1/2" .035" tube .430" ID = 3.66 ft./sec.
Filter Swagelock # SS-8TF2
Filter area:
Strainer = 1.7 sq. in.
Sintered = 2.0 sq. in.
Smith 44E3 4" = 129 sq. in.

REV.#	REVISIONS	DATE
4	Added Ball Valve US of Strainer	11/30/04
3	Relocated Blend Header to Chamber Modified Piping To Circulate Base Fuel	11/16/04
2	Added Pumps, Strainer & DP Gauge	11/11/04

Appendix C. Step-by-step Analytical Procedures

The step-by-step analytical procedures follow.

Baseline Determination

1. Turn on the diesel fuel pump. Set the temperature controller to the test temperature.
2. Assure that Flow Control Valve #1 (FCV1) is closed, i.e. no fuel is passing through the Differential Pressure Gauge (DPG).
3. Allow the system to run for XX minutes. (Calculated value based on the volume of diesel fuel in the tank and the flow rate; volume pumped > volume in the tank.)
4. Assure the temperature has stabilized. Record the temperature.
5. Open FCV1 and start timer.
6. At 1 minute intervals record the reading on the DPG.
7. If the DP increases to over 10? mm Hg, record the time and turn off the pump.
8. At 10 min record the reading on the DPG as the Final Differential Pressure (FDP).
9. Repeat steps 1 – 8.
10. Record the results from the two runs and report the average.

Biodiesel Blend Filterability Determination

1. Turn on the diesel fuel pump. Set the controller to the test temperature.
2. Assure that FCV1 is closed.
3. Allow the system to run for XX minutes
4. Load the desired amount of biodiesel into the injector.
5. Record the injector temperature.
6. Assure the diesel fuel temperature has stabilized. Record the temperature.
7. Open FCV1 and allow the diesel fuel to flow through the DPG for 1 minute.
8. Record the DP.
9. Inject the biodiesel
10. If the DP increases to over 10? mm Hg, record the time and turn off the pump.
11. At 10 minutes record the reading on the DPG as the FDP.
12. Repeat steps 1 – 11, with new diesel fuel and biodiesel.
13. Record the results from the two runs and report the average.

Biodiesel Solubility Determination

1. Turn on diesel fuel pump. Set the temperature controller to the test temperature.
2. Assure that FCV1 is closed.
3. Allow the system to run for XX minutes
4. Load the desired amount of biodiesel into the injector.
5. Record the injector temperature.
6. Assure the diesel fuel temperature has stabilized. Record the temperature.
7. Inject the biodiesel
8. Circulate the blended fuel for 10 minutes.
9. Open FCV1 and allow the blended fuel to flow through the DPG.
10. Record the DP every one minute.
11. If the DP increases to over 10? mm Hg, record the time and turn off the pump.
12. At 10 minutes record the reading on the DPG as the FDP.
13. Repeat steps 1 – 11, with new diesel fuel and biodiesel.
14. Record the results from the two runs and report the average.

The ability to use the rig and the procedures above to assess the cold temperature properties of blends below the cloud point of diesel fuel depends on the repeatability of the rate of filter plugging, because at these temperatures, the filter is going to plug.

Appendix D. Certificate of Analysis for #1 Diesel Fuel

Laboratory Analysis Report

Date Printed: 5/20/2005

Report To:
Rod Lawrence
Magellan Analytical Services
1090-A Sunshine Rd
Kansas City KS 66115 -

Submitted By:
Paul Hinkle
Additive Systems Inc
407 S Main
Broken Arrow OK 74012

cc:

Sample ID: KS04100778

Type of Sample: Diesel Fuel

Tank:

Sample Description: Jet Fuel

Sample Notes: D9

Method	Results
D 86 - Distillation	
	165.6 °C IBP
	185.8 °C 10%
	191.8 °C 20%
	210.9 °C 50%
	250.0 °C 90%
	272.9 °C FBP
	97.6 mL Volume
	1.0 mL Loss
	1.4 mL Residue
D 93 - Flash-Point by Pensky-Martens Closed Cup Tester	
	37 °C
D 5453 - Total Sulfur by Ultraviolet Fluorescence	
	920 ppm (wt/wt)
D 4737 - Cetane Index	
	44.9
D 5773 - Cloud Point	
	-54 °F
D 5949 - Pour Point	
	-70 °F

10/20/2004

Results in boxes do not meet ASTM D975 specifications.

Appendix E. Certificate of Analysis for #2 Diesel Fuel

Laboratory Analysis Report

Date Printed: 5/20/2005

Report To:
Rod Lawrence
Magellan Analytical Services
1090-A Sunshine Rd
Kansas City KS 66115 -

Submitted By:
Paul Hinkle
Additive Systems Inc
407 S Main
Broken Arrow OK 74012

cc:

Sample ID: KS04100777

Type of Sample: Diesel Fuel

Tank:

Sample Description: # 2 LSD

Sample Notes: D9

Method **Results**

D 86 - Distillation

181.8 °C IBP
213.3 °C 10%
224.2 °C 20%
262.1 °C 50%
324.6 °C 90%
351.8 °C FBP
97.8 mL Volume
1.0 mL Loss
1.2 mL Residue

D 93 - Flash-Point by Pensky-Martens Closed Cup Tester

50 °C

D 5453 - Total Sulfur by Ultraviolet Fluorescence

292 ppm (wt/wt)

D 4737 - Cetane Index

47.3

D 5773 - Cloud Point

6 °F

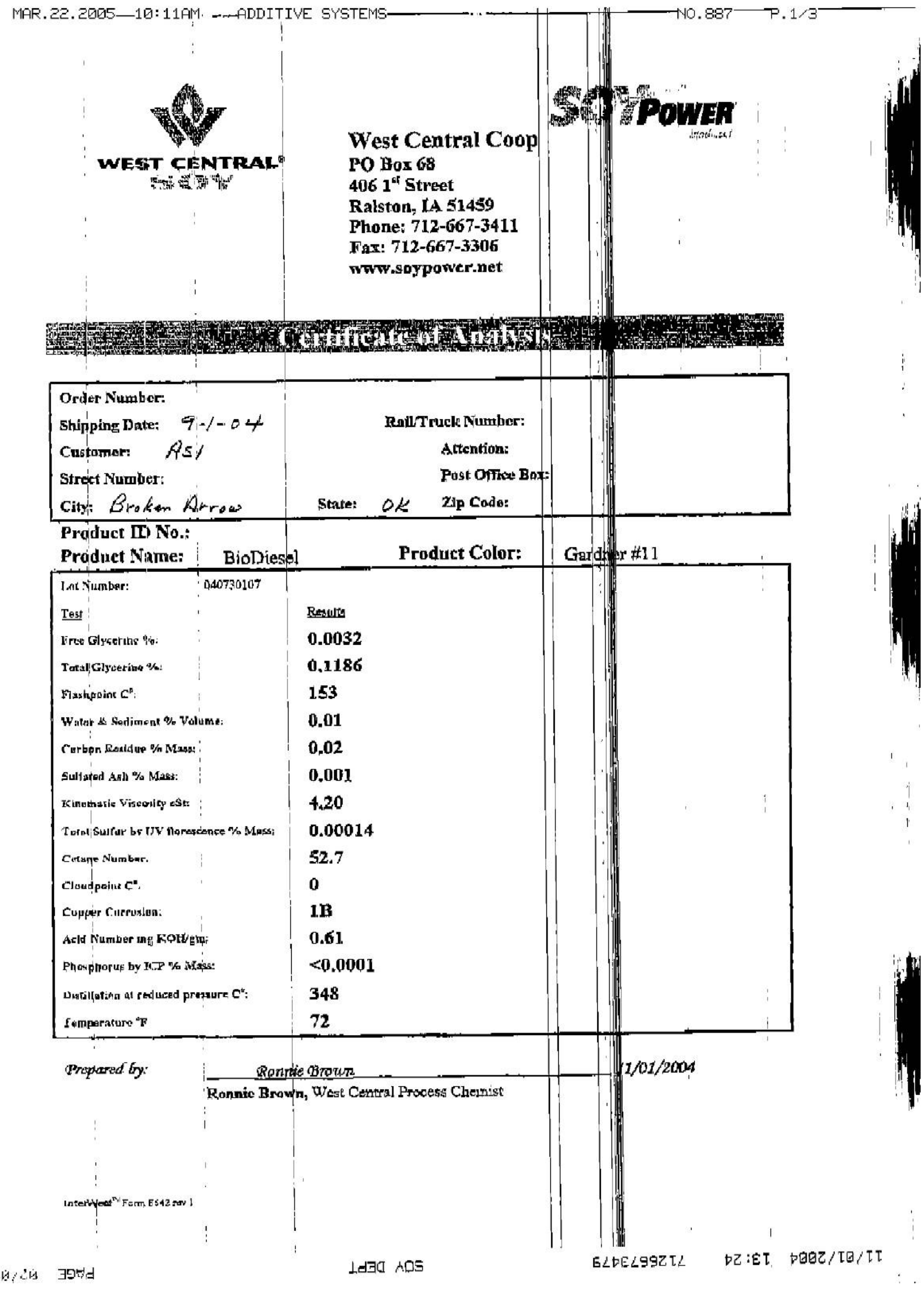
D 5949 - Pour Point

-10 °F

10/20/2004

Results in boxes do not meet ASTM D975 specifications.

Appendix F. Certificate of Analysis for Soy Biodiesel



MAR.22.2005 10:11AM ADDITIVE SYSTEMS NO.887 P.1/3

WEST CENTRAL®

SOY POWER

West Central Coop
PO Box 68
406 1st Street
Ralston, IA 51459
Phone: 712-667-3411
Fax: 712-667-3306
www.soypower.net

Certificate of Analysis

Order Number:
Shipping Date: 9-1-04
Rail/Truck Number:
Customer: ASI
Attention:
Street Number:
Post Office Box:
City: Broken Arrow
State: OK
Zip Code:

Product ID No.:
Product Name: BioDiesel
Product Color: Gardner #11

Lot Number: 040730107

Test	Results
Free Glycerine %:	0.0032
Total Glycerine %:	0.1186
Flashpoint C°:	153
Water & Sediment % Volume:	0.01
Carbon Residue % Mass:	0.02
Sulfated Ash % Mass:	0.001
Kinematic Viscosity cSt:	4.20
Total Sulfur by UV florescence % Mass:	0.00014
Cetane Number:	52.7
Cloudpoint C°:	0
Copper Corrosion:	1B
Acid Number mg KOH/gm:	0.61
Phosphorus by ICP % Mass:	<0.0001
Distillation at reduced pressure C°:	348
Temperature °F	72

Prepared by: Ronnie Brown 11/01/2004
Ronnie Brown, West Central Process Chemist

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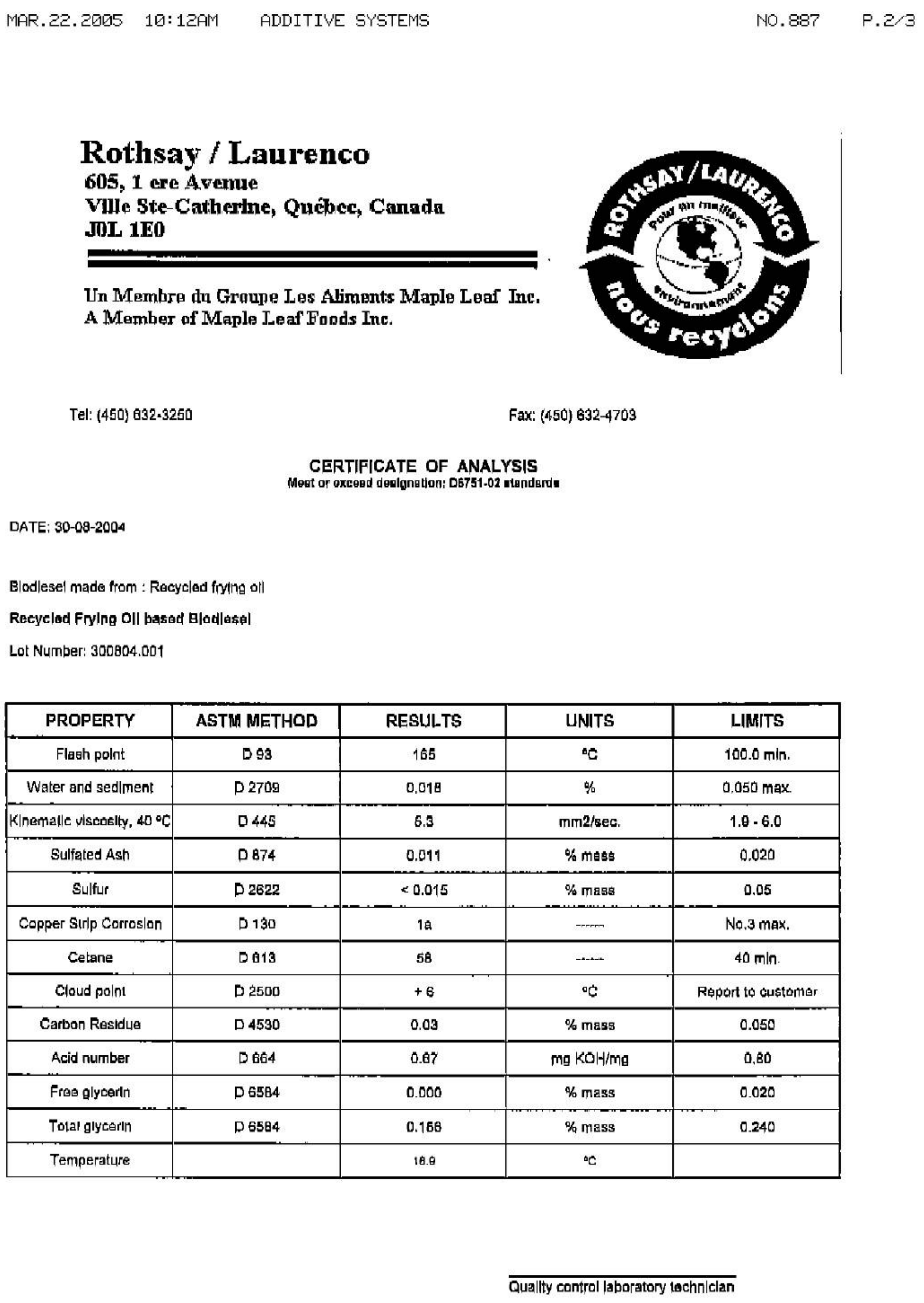
Appendix G. Certificate of Analysis for Yellow Grease Biodiesel



MAR.22.2005 10:12AM ADDITIVE SYSTEMS NO.887 P.2/3

Rothsay / Laurenco
605, 1 ere Avenue
Ville Ste-Catherine, Québec, Canada
J0L 1E0

Un Membre du Groupe Les Aliments Maple Leaf Inc.
A Member of Maple Leaf Foods Inc.

Tel: (450) 632-3250 Fax: (450) 632-4703

CERTIFICATE OF ANALYSIS

Meet or exceed designation: D6751-02 standards

DATE: 30-08-2004

Biodiesel made from : Recycled frying oil

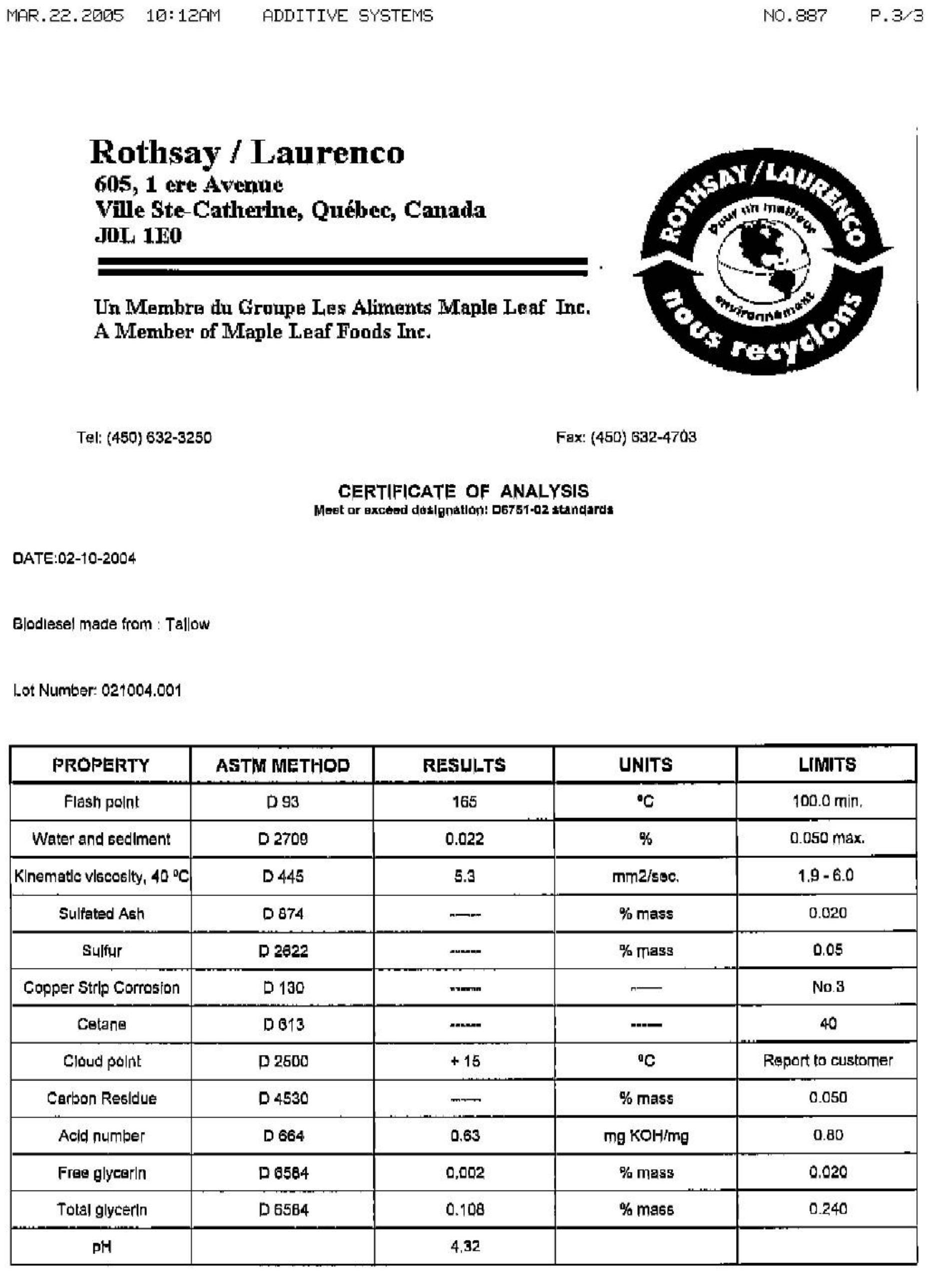
Recycled Frying Oil based Biodiesel

Lot Number: 300804.001

PROPERTY	ASTM METHOD	RESULTS	UNITS	LIMITS
Flash point	D 93	165	°C	100.0 min.
Water and sediment	D 2709	0.018	%	0.050 max.
Kinematic viscosity, 40 °C	D 445	5.3	mm2/sec.	1.9 - 6.0
Sulfated Ash	D 874	0.011	% mass	0.020
Sulfur	D 2622	< 0.015	% mass	0.05
Copper Strip Corrosion	D 130	1a	------	No.3 max.
Cetane	D 613	58	-----	40 min.
Cloud point	D 2500	+ 6	°C	Report to customer
Carbon Residue	D 4530	0.03	% mass	0.050
Acid number	D 664	0.67	mg KOH/mg	0.80
Free glycerin	D 6584	0.000	% mass	0.020
Total glycerin	D 6584	0.166	% mass	0.240
Temperature		18.9	°C	

Quality control laboratory technician

Appendix H. Certificate of Analysis for Tallow Biodiesel



MAR.22.2005 10:12AM ADDITIVE SYSTEMS NO.887 P.3/3

Rothsay / Laurenco
605, 1 ere Avenue
Ville Ste-Catherine, Québec, Canada
J0L 1E0

Un Membre du Groupe Les Aliments Maple Leaf Inc.
A Member of Maple Leaf Foods Inc.

Tel: (450) 632-3250 Fax: (450) 632-4703

CERTIFICATE OF ANALYSIS
Meet or exceed designation: D6751-02 standards

DATE:02-10-2004

Biodiesel made from : Tallow

Lot Number: 021004.001

PROPERTY	ASTM METHOD	RESULTS	UNITS	LIMITS
Flash point	D 93	165	°C	100.0 min.
Water and sediment	D 2709	0.022	%	0.050 max.
Kinematic viscosity, 40 °C	D 445	5.3	mm2/sec.	1.9 - 6.0
Sulfated Ash	D 874	------	% mass	0.020
Sulfur	D 2622	------	% mass	0.05
Copper Strip Corrosion	D 130	------	------	No 3
Cetane	D 613	------	------	40
Cloud point	D 2500	+ 15	°C	Report to customer
Carbon Residue	D 4530	------	% mass	0.050
Acid number	D 664	0.63	mg KOH/mg	0.80
Free glycerin	D 6584	0.002	% mass	0.020
Total glycerin	D 6584	0.108	% mass	0.240
pH		4.32		

Appendix I. Qualitative Blending Data

Blend Type	Diesel Type	Diesel Temp, F	Biodiesel Cloud Point, F	Biodiesel Temp, F	Temp Differential	Comments
Ratio	No. 2	40	32	72	32	Mixed well
Ratio	No. 2	30	32	72	42	Mixed well
Ratio	No. 2	20	32	72	52	Mixed well
Ratio	No. 2	10	32	72	62	Mixed well
Ratio	No. 2	0	32	72	72	Mixed well, Signs of icing revealed paraffin dropout, clogged 80 M strainers on #2 Fuel. Removed strainers and retest.
Ratio	No. 2	-5	32	72	77	Mixed well
Ratio	No. 2	-5	32	72	77	Mixed Well, No icing
Ratio	No. 2	-10	32	72	82	Mixed Well, No icing
Ratio	No. 2	-10	32	72	82	Mixed Well, No icing
Ratio	No. 2	-15	32	72	87	Mixed Well, Some icing
Ratio	No. 2	-17	32	72	89	#2 slushy. Bio blended throughout though.
Ratio	No. 2	-20	32	72	92	#2 slushy, Partially frozen. Bio did not blend throughout
Ratio	No. 2	-25	32	72	97	#2 Froze
Ratio	No. 2	-10	32	55	65	Mixed Well, No icing
Ratio	No. 2	-10	32	50	60	Mixed Well, No icing
Ratio	No. 2	-10	32	45	55	Bio Crystallizing on contact, Mixing but not blending.
Ratio	No. 2	-15	32	50	65	Small amounts of bio Crystallizing on contact, Mixing but not blending.
Ratio	No. 2	-15	32	55	70	Mixed Well, No icing
Ratio	No. 2	0	43	60	60	Mixed Well
Ratio	No. 2	-5	43	60	65	Mixed well
Ratio	No. 2	-5	43	55	60	Mixed Well, No Crystals
Ratio	No. 2	-10	43	55	65	Mixed Well, No Crystals
Ratio	No. 2	-10	43	50	60	Mixed Well, No Crystals, Hazy Fuel
Ratio	No. 2	-15	43	45	60	Mixed Well, No Crystals, Hazy Fuel
Ratio	No. 2	-15	43	40	55	Mixed thoroughly, Very Cloudy
Ratio	No. 2	-15	43	35	50	Bio icing, Creating large crystals, Did not Blend
Ratio	No. 2	-15	43	30	45	Bio icing, Solids Present, Did not Blend
Ratio	No. 2	-5	43	35	40	Mixed Thoroughly, Crystals forming on contact.
Ratio	No. 2	-5	43	40	45	Mixed Well, No icing
Ratio	No. 2	0	43	35	35	Mixed well but stayed hazy, cloudy

Blend Type	Diesel Type	Diesel Temp, F	Biodiesel Cloud Point, F	Biodiesel Temp, F	Temp Differential	Comments
Ratio	No. 1	-30	32	45	75	Icing, mixed fair
Ratio	No. 1	-30	32	50	80	Icing, mixed fair
Ratio	No. 1	-30	32	60	90	Icing, mixed fair
Ratio	No. 1	-25	32	60	85	Icing, mixed fair
Ratio	No. 1	-20	32	60	80	Mixed well
Ratio	No. 1	-20	32	55	75	Icing, mixed fair
Ratio	No. 1	-15	32	55	70	Mixed Well
Ratio	No. 1	-15	32	50	65	Icing, mixed fair
Ratio	No. 1	-15	32	53	68	Mixed well
Ratio	No. 1	-10	32	50	60	Mixed Well
Ratio	No. 1	-10	32	45	55	Mixed Well, No icing
Ratio	No. 1	-10	32	50	60	Mixed Well, No icing
Ratio	No. 1	-5	32	45	50	Blended well
Ratio	No. 1	-5	32	40	45	Blended well
Ratio	No. 1	0	32	35	35	Icing, mixed fair
Ratio	No. 1	-15	43	40	55	Mixed well
Ratio	No. 1	-20	43	40	60	Mixed well
Ratio	No. 1	-25	43	40	65	Slight Icing of bio
Ratio	No. 1	-30	43	40	70	Icing of bio
Ratio	No. 1	-15	43	35	50	Blended well
Ratio	No. 1	-10	43	35	45	Icing of bio
Ratio	No. 1	-25	43	45	70	Mixed Well, No icing
Ratio	No. 1	-30	43	45	75	Icing
Ratio	No. 1	-30	43	50	80	Icing
Ratio	No. 1	-25	43	50	75	Blended well
Ratio	No. 1	-30	43	55	85	Blended well
Ratio	No. 1	-35	43	55	90	Icing
Ratio	No. 1	-35	43	60	95	Blended

Blend Type	Diesel Type	Diesel Temp, F	Biodiesel Cloud Point, F	Biodiesel Temp, F	Temp Differential	First Product: Comments
Sequential	No. 2	0	32	50	50	Bio: Mixed Well
Sequential	No. 2	0	32	50	50	No. 2:Mixed Well
Sequential	No. 2	-5	32	45	50	Bio: Mixed Well
Sequential	No. 2	-5	32	45	50	No. 2:Mixed Well
Sequential	No. 2	-10	32	45	55	Bio: Mixed Well
Sequential	No. 2	-10	32	45	55	No. 2:Mixed Well
Sequential	No. 2	-10	32	40	50	Bio: Icing
Sequential	No. 2	-10	32	40	50	No. 2: Mixed Well
Sequential	No. 2	-10	32	45	55	Bio: Mixed Well
Sequential	No. 2	-15	32	55	70	Bio: Mixed Well
Sequential	No. 2	-15	32	55	70	No. 2: Mixed Well
Sequential	No. 2	-15	32	50	65	Bio: Mixed Well
Sequential	No. 2	-15	32	50	65	No. 2: Mixed Well
Sequential	No. 2	-15	32	45	60	Bio: Mixed Fair/ Slower Dispersing
Sequential	No. 2	-15	32	40	55	Bio: Icing/ Still mixed fair
Sequential	No. 2	0	32	45	45	No. 2: Slight Icing
Sequential	No. 2	0	43	50	50	Bio: Mixed Well
Sequential	No. 2	0	43	50	50	No. 2:Mixed Well
Sequential	No. 2	-5	43	45	50	Bio: Mixed Well
Sequential	No. 2	-5	43	45	50	No. 2:Mixed Poorly
Sequential	No. 2	-10	43	45	55	Bio: Mixed Well
Sequential	No. 2	-10	43	45	55	No. 2:Mixed Poorly
Sequential	No. 2	-10	43	40	50	Bio: Icing
Sequential	No. 2	-10	43	40	50	No. 2: Bio blobbing, no blending at all
Sequential	No. 2	-10	43	45	55	Bio: Mixed Well
Sequential	No. 2	-15	43	55	70	Bio: Mixed Well
Sequential	No. 2	-15	43	55	70	No. 2: Slow to blend but did mix with agitation.
Sequential	No. 2	-15	43	50	65	Bio: Mixed Well
Sequential	No. 2	-15	43	40	55	No. 2: Bio blobbing, no blending at all
Sequential	No. 2	-15	43	45	60	Bio: Blended well
Sequential	No. 2	-15	43	40	55	Bio: Blended Well, but Crystals Forming
Sequential	No. 2	0	43	45	45	No. 2: Slow to blend but did mix.

Blend Type	Diesel Type	Diesel Temp, F	Biodiesel Cloud Point, F	Biodiesel Temp, F	Temp Differential	First Product: Comments
Sequential	Kerosene	-20	32	60	80	Kerosene: Mixed Well
Sequential	Kerosene	-15	32	55	70	Bio: Mixed Well
Sequential	Kerosene	-15	32	55	70	Kerosene: Mixed Well
Sequential	Kerosene	-10	32	50	60	Bio: Mixed Well
Sequential	Kerosene	-10	32	50	60	Kerosene: Not Blending
Sequential	Kerosene	-10	32	40	50	Bio: Mixed Well
Sequential	Kerosene	-10	32	45	55	Bio: Mixed Well
Sequential	Kerosene	-5	32	55	60	Bio: Mixed Well
Sequential	Kerosene	-5	32	55	60	Kerosene: Mixed Well
Sequential	Kerosene	-5	32	50	55	Bio: Mixed Well
Sequential	Kerosene	0	32	50	50	Kerosene: Mixed Well
Sequential	Kerosene	0	32	45	45	Kerosene: Icing
Sequential	Kerosene	0	32	40	40	Bio: Blended Well
Sequential	Kerosene	0	32	40	40	Kerosene: Not Blending, Icing
Sequential	Kerosene	-30	43	40	70	Bio: Slight icing of bio
Sequential	Kerosene	-30	43	40	70	Kerosene: Icing of bio. Poor Mix
Sequential	Kerosene	-25	43	40	65	Bio: Minor icing of bio. Mix Well
Sequential	Kerosene	-25	43	40	65	Kerosene: Minor icing of bio. Mix Poor
Sequential	Kerosene	-20	43	40	60	Bio: Mix well, no icing
Sequential	Kerosene	-25	43	45	70	Bio: Mix well, no icing
Sequential	Kerosene	-30	43	45	75	Bio: Icing
Sequential	Kerosene	-20	43	40	60	Kerosene: Icing of bio. Poor Mix
Sequential	Kerosene	-15	43	35	50	Bio: Mixed well
Sequential	Kerosene	-15	43	35	50	Kerosene: Did not blend well.
Sequential	Kerosene	-25	43	50	75	Bio: Mixed Well
Sequential	Kerosene	0	43	50	50	Kerosene: Blended well
Sequential	Kerosene	-30	43	55	85	Bio: Blended Well
Sequential	Kerosene	-30	43	50	80	Bio: Icing
Sequential	Kerosene	-35	43	55	90	Bio: Icing
Sequential	Kerosene	-40	43	60	100	Bio: Icing
Sequential	Kerosene	-35	43	60	95	Bio: Blended Well

Appendix J. Listing of Consortium Members Comments

Contributors of the Consortium have offered the following statements for consideration:

- Optimal biodiesel blending is dependant on accurate knowledge of B100 and Petroleum diesel cold flow properties to help determine parameters.
- The impact of blending method type (splash, ratio, and sequential blending) and mechanical mixing on B2 blend homogeneity was not evaluated in this study.
- The impact of B2 biodiesel blends on D975 test parameters was not evaluated in test runs completed and documented in this report.
- The impact of water contamination on wax/ice crystallization was not evaluated within this study although desiccant filters were used to help prevent moisture contamination of the B100 and fuels for testing.
- In many cases the pressure drop of the B2 blend was greater than that of the base diesel fuel. In no case was the B2 blend a lower pressure drop than the base diesel fuel. The potential implications of this for users of B2 blends made during cold weather blending are not known.
- In several cases the bottoms samples had slightly higher biodiesel concentrations than the “bulk” samples. This might indicate the existence of not completely homogenous mixtures for these test conditions.