



Lab Manual

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Introduction to Biodiesel Fuel

**K. Walz, K. Cadwell,
A. Hoffman, and P. Morschauser**



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Lab Manual Contents

ASTM Biodiesel Fuel Specifications - D6751	3
Biodiesel Test Lab Student Data Sheet	4
Titration of Used Oil Feedstocks	5
Pensky Martens Flash Point Test	6
Cloud Point Test	9
Shell Cup Viscosity Test	10
Copper Corrosion Test	13
Rancimat Oxidative Stability Test	14
3/27 Glyceride Intermediate Test	17
pHLIP Test	18
Centrifuge Water and Sediment Test	20
Sandy Brae Water Test	21
Cold Soak Filtration Test	24
Conradson Carbon Residue Test	25
Paradigm Sensor Impedance Spectroscopy Test	26
WI Biodiesel Production and Retail Station Lists	29
WI Small Scale Biofuel Producer Program	30
DOE Alternative Fuel Comparison Chart	32

Standard Test Methods and Specification for Biodiesel Fuel



SPECIFICATION FOR BIODIESEL (B100) – ASTM D6751-09

Nov. 2008

Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from vegetable oils or animal fats, for use in compression-ignition (diesel) engines. This specification is for pure (100%) biodiesel prior to use or blending with diesel fuel. #

Property	ASTM Method	Limits	Units
Calcium & Magnesium, combined	EN 14538	5 maximum	ppm (ug/g)
Flash Point (closed cup)	D 93	93 minimum	degrees C
Alcohol Control (One of the following must be met)			
1. Methanol Content	EN14110	0.2 maximum	% mass
2. Flash Point	D93	130 minimum	Degrees C
Water & Sediment	D 2709	0.05 maximum	% vol.
Kinematic Viscosity, 40 C	D 445	1.9 - 6.0	mm ² /sec.
Sulfated Ash	D 874	0.02 maximum	% mass
Sulfur			
S 15 Grade	D 5453	0.0015 max. (15)	% mass (ppm)
S 500 Grade	D 5453	0.05 max. (500)	% mass (ppm)
Copper Strip Corrosion	D 130	No. 3 maximum	
Cetane	D 613	47 minimum	
Cloud Point	D 2500	report	degrees C
Carbon Residue 100% sample	D 4530*	0.05 maximum	% mass
Acid Number	D 664	0.50 maximum	mg KOH/g
Free Glycerin	D 6584	0.020 maximum	% mass
Total Glycerin	D 6584	0.240 maximum	% mass
Phosphorus Content	D 4951	0.001 maximum	% mass
Distillation, T90 AET	D 1160	360 maximum	degrees C
Sodium/Potassium, combined	EN 14538	5 maximum	ppm
Oxidation Stability	EN 14112	3 minimum	hours
Cold Soak Filtration	Annex to D6751	360 maximum	seconds
For use in temperatures below -12 C	Annex to D6751	200 maximum	seconds

BOLD = BQ-9000 Critical Specification Testing Once Production Process Under Control

* The carbon residue shall be run on the 100% sample.

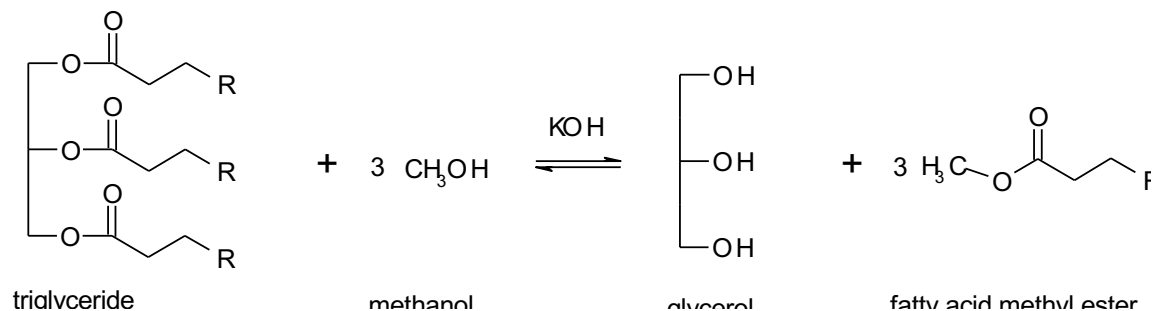
A considerable amount of experience exists in the US with a 20% blend of biodiesel with 80% diesel fuel (B20). Although biodiesel (B100) can be used, blends of over 20% biodiesel with diesel fuel should be evaluated on a case-by-case basis until further experience is available.

Biodiesel Lab Test Data Sheet

Property	Test Method	Apparatus/Procedure	units	limits	measured value	result
Water content	D2709	Sandy Brae Test Kit	% vol	.050 max		pass or fail
Water/Sediment	D2709	Centrifuge	% vol	Separation Layer?	yes or no	pass or fail
Carbon Residue (10 g sample)	D4530	Conradson flame test	% mass	.050 max		pass or fail
FlashPoint, closed cup	D93	Pensky Martens Flash Cup	°C	130 min		pass or fail
Kinematic Viscosity (at 40 °C)	D445	Viscometer Shell Viscosity Cups	mm ² /sec (cStokes)	1.9-6.0		pass or fail
Oxidative Stability (at 110 °C)	EN 14112	Rancimat	hrs	3 hrs min.		pass or fail
Copper Strip Corrosion	D130	Copper strips and heater	class	No 3. max		pass or fail
Glyceride Intermediates	3-27 Test	Solubility in methanol	NA	Cloudy Emulsion or Insoluble liquid	yes or no	pass or fail
Free and Total glycerin	pHLip	pHLip assay	NA	Haze or emulsion	yes or no	pass or fail
FFA (pH)	pHLip	pHLip assay	NA	yellow indicator	yes or no	pass or fail
Residual Catalyst (pH)	pHLip	pHLip assay	NA	purple indicator	yes or no	pass or fail
Specific gravity	D1250	hygrometer	NA	report		NA
Cloud Point	D2500	cloud point bath	°C	report		NA
Cold Soak Filtration	D7501	Vacuum Filtration	seconds	360 sec max		Pass or fail
Total Glycerin (TG)	D6584 Ispec Q100	Paradigm Sensor Impedance Spectrometer	% mass	0.25% max		pass or fail
% Methanol (MT)	EN14110 Ispec Q100	Paradigm Sensor Impedance Spectrometer	% mass	0.20% max		pass or fail
Acid Number (AN)	D664 Ispec Q100	Paradigm Sensor Impedance Spectrometer	mg KOH/ g fuel	0.50 max		pass or fail

Fatty Acid Determination of Used Oil Feedstocks for Biodiesel Production

Background: Biodiesel fuel is made by mixing vegetable oil (triglycerides) with methyl alcohol (aka methanol) in the presence of a basic catalyst (KOH). This produces glycerol (a byproduct) and fatty acid methyl esters (the biodiesel fuel).



BASIC BIODIESEL RECIPE FOR VIRGIN VEGETABLE OIL

Catalyst Mixture:

20 g of KOH per gallon of oil (*recommended by Josh Tickell, known to be too little*)

26 g of KOH per gallon of oil (*recommended by Piedmont Biofuels*)

36 g of KOH per gallon of oil (*recommended by Jon Van Gerpen, known to be excess*)

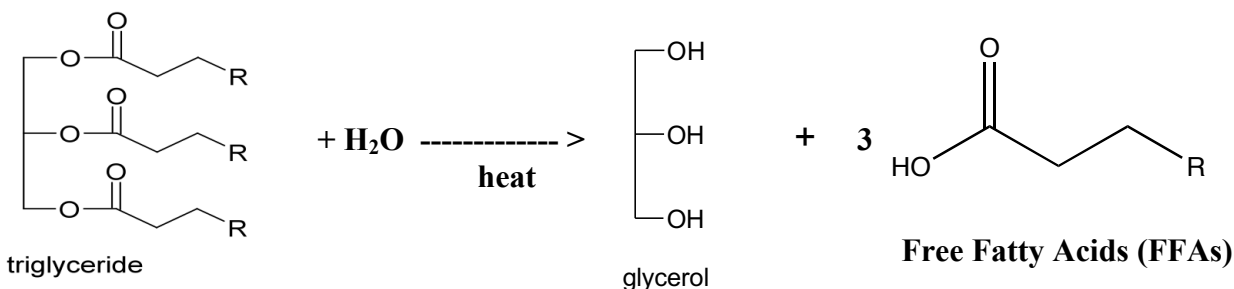
Reaction Mixture: 1 gallon of methanol/KOH catalyst for every 5 gallons of oil

Reaction Temp: Recommend between 55 and 60 °C (methanol BP = 64.7 °C)

Reaction should take from 60 to 120 min at 60 °C,

Depending on feedstock quality (van Gerpen et al.)

Problem: When vegetable oil is used for cooking purposes (especially for frozen foods), some of the triglyceride oil molecules break down to create free fatty acids (FFAs). The FFAs lower the pH of the oil, and unfortunately will neutralize the basic catalyst (KOH) that is normally added to speed the reaction up.



Solution: By doing a titration test before processing the fuel, we can measure the concentration of FFAs in the used cooking oil. We will then add additional extra KOH to our reaction to account for the neutralization of the FFAs.

DETERMINEING EXCESS KOH CATALYST REQUIRED BY TITRATION

- 1) Mix 10 mL of oil with 100 mL of isopropyl alcohol. Add 10 drops of phenothalien indicator. Note that the indicator is colorless in an acidic solution of FFAs.
- 2) Using a buret, slowly add 0.10% (w/v) KOH solution until you observe the titration endpoint color change from clear to pink. At this point, all of the FFA's have been neutralized by the KOH solution.
- 3) Record the volume of 0.10% (w/v) KOH that was used _____ mL of 0.1% KOH.
- 4) Determine the amount of extra KOH that must be added to the methanol using the following equation:

$$\text{_____ mL of 0.1\% KOH soln used} \times 0.3785 = \text{_____ g of extra KOH needed per gallon of oil}$$

- 5) Determine the total amount of KOH required based on the basic recipe for biodiesel fuel, plus the extra KOH required from the titration:

$$\left(\frac{\text{_____ g KOH}}{\text{per gal of oil (basic recipe)}} + \frac{\text{_____ g of extra KOH}}{\text{per gal of oil (titration)}} \right) \times \text{_____ gal of oil} = \text{_____ g KOH}$$

Pensky-Martens Closed Cup Flash Point Test

A fuel's flashpoint is the minimum temperature at which there is a sufficient concentration of evaporated fuel vapor for combustion to propagate after an ignition source (spark or flame) has been introduced. The concentration of fuel vapor is directly related to the fuel's vapor pressure, which in turn is dependent on temperature (see figure 1 below). Different fuels require different vapor concentrations to initiate combustion, thus flash point varies significantly between fuels (see Figure 2). In fact, the flash point differences between gasoline and diesel fuels are integral factors in the function of spark ignition versus compression ignition engines.

Figure 1. Vapor Pressure as a function of temperature for ethanol and biodiesel fuel.

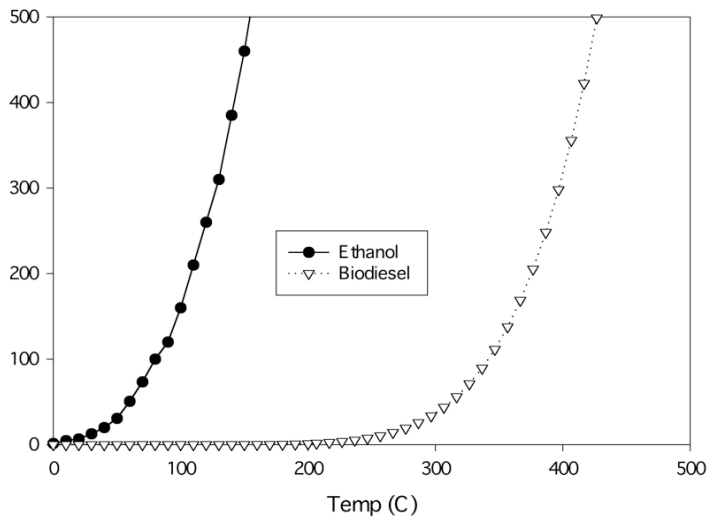


Figure 2. Flashpoints of several common fuels. Fuels marked with * indicate this value is the minimum allowed by ASTM.

Fuel	Flashpoint (°C)	Flashpoint (°F)
Gasoline	-43*	-45*
Acetone	-18	0
Methanol	10	50
Ethanol	12	54
Isopropanol	12	54
Octane	13	55
Butanol	35	95
#1 (winter) diesel	38*	100*
#2 (summer) diesel	52*	126*
#4 (marine) diesel	55*	131*
#6 bunker fuel	66*	151*
Methyl stearate	110	230
Methyl laurate	113	235
Biodiesel	130*	266*
Cetane	135	275
Methyl oleate	180	356
Methyl linoleate	186	367
Canola oil	192	378

The Department of Transportation uses flashpoint to determine shipping and safety regulations. The DOT classifies substances as either flammable or combustible using the following criteria:

	Flashpoint (°C)	Boiling Point (°C)
Flammable		
Class IA	< 22.8°C	< 37.8°C
Class 1B	< 22.8°C	> 37.8°C
Class IC	22.8°C - 37.8°C	N/A
Combustible		
II	37.8°C - 60°C	N/A
IIIA	60°C - 93°C	N/A
IIIB	> 93°C	N/A

Your instructor will assign you and your lab partner(s) a fuel sample to measure the flashpoint. Data may be combined to obtain class averages and to draw comparisons.

- 1) Inspect the flash point tester to ensure sample test cup is clean, the fluke digital thermometer is in place, and propane supply is turned on.
- 2) Making sure test cup and specimen are at least 18°C (32°F) below the expected flash point. Fill the test cup between 50% and 85% full with the fuel sample, place lid on cup and set cup inside the stove, making sure grooves are properly aligned.
- 3) Adjust the valve screw on the burner block starting with it all the way closed, then open it only 1/10 of a turn. Using the lighter provided light the test flame and adjust the screw if necessary to attain a flame size of ~ 1/8 inches in diameter (use the bead on the burner block for comparison).
- 5) Your instructor will suggest a preheat temperature and heat rate setting for your sample. Using the variable heat rate dial, adjust the rate assigned to you (either 25, 50, 75 or 100).
- 6) Stir sample using the mechanism on the top of the flash point instrument. WEAR A GLOVE DURING THIS PROCESS. The top sections of the instrument will get very hot to the touch.
- 7) Stop stirring (do this each time you apply the test flame). Lower the flame for half a second, leave it for 1 second, and then quickly raise the flame back to the test position.
- 8) Test the flashpoint at 5 °C temperature intervals as the sample heats. Stir between each test.
- 9) Record the flash point for your fuel. The sample is deemed to have flashed when "*a large flame appears and instantaneously propagates itself over the entire surface of the test specimen*". You should see a flash, which sometimes is accompanied by a whoosh or popping noise as well.
- 10) Turn the temperature dial down to zero and allow the instrument to cool. Only remove and clean test cup once the temperature have decreased to safe handling temperatures of less than 55°C (130°F). If yours is the last sample that will be tested for the day, turn off the propane tank.
- 11) The instructor may assist you in the use of compressed air to cool the flashpoint apparatus.

Cloud point measurement of biodiesel

The cloud point of a fuel is the temperature at which solids (waxes) begin to crystallize in the fuel as it is cooled. Because the solidified particles can gel and clog the fuel filter, the cloud point is commonly used to determine the lowest temperature at which a fuel can be used during cold/winter conditions.

Biodiesel has a higher cloud point than No. 2 diesel (that is, it begins to cloud/gel at higher temperatures), and so B100 (pure) biodiesel is not appropriate for cold weather applications. However, B20 biodiesel blends have a cloud point similar to No. 2 diesel. It is common to use cold weather additives in both No. 2 diesel and biodiesel blends in colder climates.

The cloud point of biodiesel depends upon the feedstock used. In general, biodiesel produced from animal fats tends to have a higher cloud point than that produced from vegetable oil. Biodiesel from recycled waste oil products also tends to have a higher cloud point. Biodiesel contaminants such as un-reacted feedstock, monoglyceride and diglyceride intermediates, and residual free glycerol can also have adverse effects elevating the fuel's cloud point.

Materials & Equipment:

Cloud point jar with biodiesel filled to the indicated line

Thermometer (placed in the fuel sample jar)

Sample jar holder and ice bath

Refrigerator/Freezer (optional)

Procedure:

1. Place the filled cloud point jar into the holder within the ice bath.
2. Observe the temperature indicated by the thermometer. Periodically remove the jar at intervals of roughly 2°C, and observe the biodiesel for any cloudiness (the biodiesel will begin to warm up when you remove it from the holder, so replace it quickly if cloudiness is not apparent).
3. Record the temperature at which you observe the biodiesel to become cloudy.
4. If time is available, allow the biodiesel to warm up until the cloudiness clears, and repeat for a total of 3 measurements. Take the average of these values and report this as your cloud point.

Measurement #1: _____ °C

#2: _____ °C

#3: _____ °C

Average cloud point: _____ °C

Shell Cup Viscosity Test

Viscosity is an important factor in determining the suitability of biodiesel for use in engines. If the fuel viscosity is too high, the injection pump will not be able to supply sufficient fuel into the cylinder. If the viscosity is too low, it may provide insufficient lubrication for fuel pumps and injectors and in extreme cases, may cause fuel injector nozzles to leak/drip.

High viscosity may be caused by:

- a) Presence of unreacted feedstock oil and/or monoglyceride and diglyceride intermediates in the biodiesel fuel (symptomatic of an incomplete transesterification process).
- b) Presence of glycerol byproduct in the biodiesel fuel (symptomatic of incomplete separation).

Low viscosity may be caused by:

- a) Presence of methanol in the biodiesel fuel. Note that this will also be indicated by a low fuel flashpoint (symptomatic of an incomplete washing process).
- b) Presence of water in the biodiesel fuel. Note that this will also be indicated by the centrifuge water and sediment test (symptomatic of an incomplete drying process).

There are two types of viscosity: kinematic viscosity measures the resistance of a liquid to flowing under gravity and has units of mm^2/s or centiStokes; dynamic viscosity is the ratio of the applied shear stress to the rate of shear of a material and has units of $\text{mPa}\cdot\text{s}$ or centiPoise. The kinematic and dynamic viscosity of a fluid are related by its density. The density of biodiesel is about 0.88 g/cm^3 .

$$\text{kinematic viscosity (in centiStokes)} = \text{dynamic viscosity (in centiPoise)} \div \text{density (in g/cm}^3\text{)}$$

$$1 \text{ centiPoise} = 1 \text{ cP} = 1 \text{ mPa}\cdot\text{s} \quad \text{and} \quad 1 \text{ centiStoke} = 1 \text{ cS} = 1 \text{ mm}^2/\text{s}$$

The tables below list the kinematic viscosity (in cS) of several pure liquids and common fuels.

Pure Liquids	Viscosity
ethanol	1.2
hexadecane	2.0
soy oil	35.4
palm oil	47.8
rapeseed oil	54.1
lard	62.1
glycerol	176.0

Fuel	Min	Max
#1 Diesel	1.3	2.4
#2 Diesel	1.9	4.1
#4 Diesel	NA	29.8
Biodiesel (B100)	1.9	6.0

The viscometer you will be using measures the dynamic viscosity of fluids, but the ASTM 6751 standard for B100 (pure biodiesel) specifies a kinematic viscosity in the range of 1.9 – 6.0 cS at 40°C (104°F). You will measure the dynamic viscosity of your biodiesel and use the equation above or the attached table to convert its dynamic viscosity value to a kinematic viscosity value.

Materials & Equipment:

Shell Viscosity Cups #1&3

Digital Thermometer

Temperature Bath

Procedure:

1. Set up a water incubator bath to warm your feedstock and biodiesel samples. Place the probe tip of the digital thermometer into the sample liquid to be tested. The temperature should read between 38°C and 42°C. If it does not, slightly adjust the bath setting and wait a few minutes for the temperature to change.
2. When the liquid is in the desired temperature range, remove the thermometer from the sample cup. Use the Shell cups to measure the drain time for the liquids to be sampled. The Shell cups must be immersed in ~120 mL of liquid so that the cup is completely filled. Stop the timer when the line of fluid draining from the cup first breaks. If instructed, repeat this measure 2 or 3 times and calculate an average.
3. Use the calibration curves provided for each of the Shell Cups to determine the viscosity of each liquid in centiPoise (cP). Mark points and label the drain times for each of the liquids tested on the graphs provided.

Feedstock Dynamic viscosity: _____ cP Kinematic Viscosity: _____ cS

Biodiesel Dynamic viscosity: _____ cP Kinematic Viscosity: _____ cS

4. Calculate the kinematic viscosity of each liquid in centistokes. OR use the table below to find the nearest dynamic viscosity value to the one you measured and read across to find the corresponding kinematic viscosity value and record it above. *Note the density of biodiesel is ~ 0.88 g/cm³*

$$\text{Dynamic viscosity (in cP)} \div \text{density (in g/cm}^3\text{)} = \text{Kinematic viscosity (in cS or mm}^2\text{/s)}$$

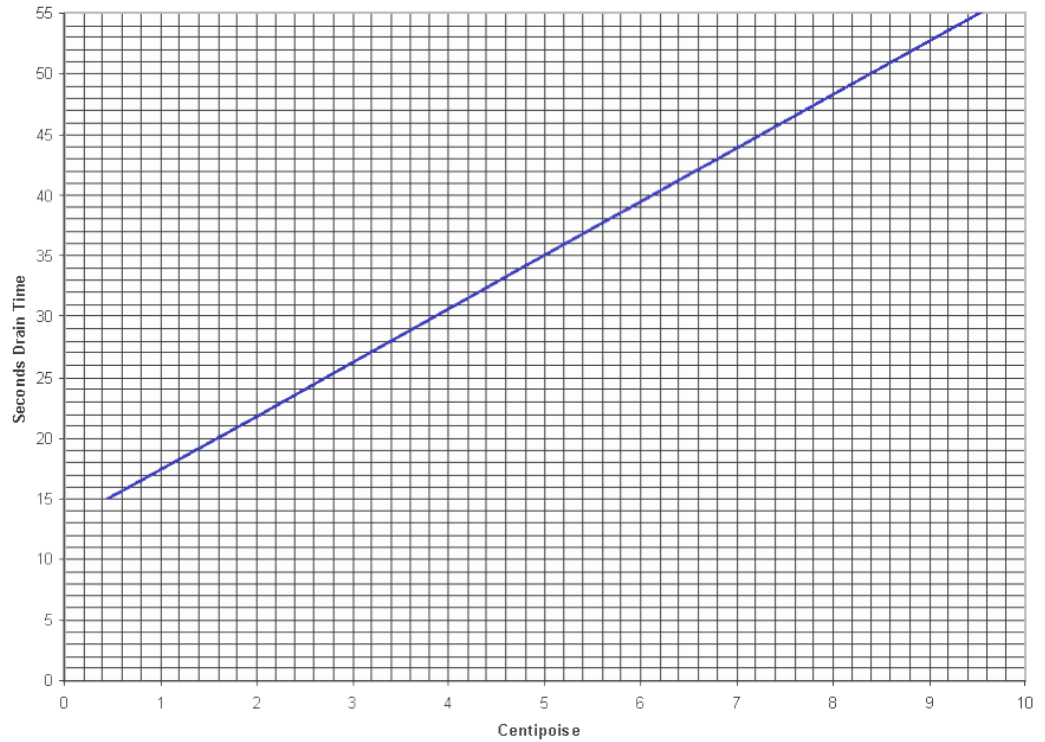
Dynamic viscosity (meter measures mPa*s aka cP)	Density of Biodiesel (g/cm ³)	Kinematic Viscosity (mm ² /s aka cS)
1.00	0.88	1.14
1.50	0.88	1.70
1.75	0.88	1.99
2.00	0.88	2.27
2.50	0.88	2.84
3.00	0.88	3.41
3.50	0.88	3.98
4.00	0.88	4.55
4.50	0.88	5.11
5.00	0.88	5.68
5.25	0.88	5.97
5.50	0.88	6.25
6.00	0.88	6.82
6.50	0.88	7.39
7.00	0.88	7.95
7.50	0.88	8.52
8.00	0.88	9.09
8.50	0.88	9.66
9.00	0.88	10.23
9.50	0.88	10.80
10.00	0.88	11.36

5. Is the kinematic viscosity of your biodiesel within the ASTM specification of 1.9 – 6.0 cS ? If not, what processing conditions might have caused your fuel to be off-spec?

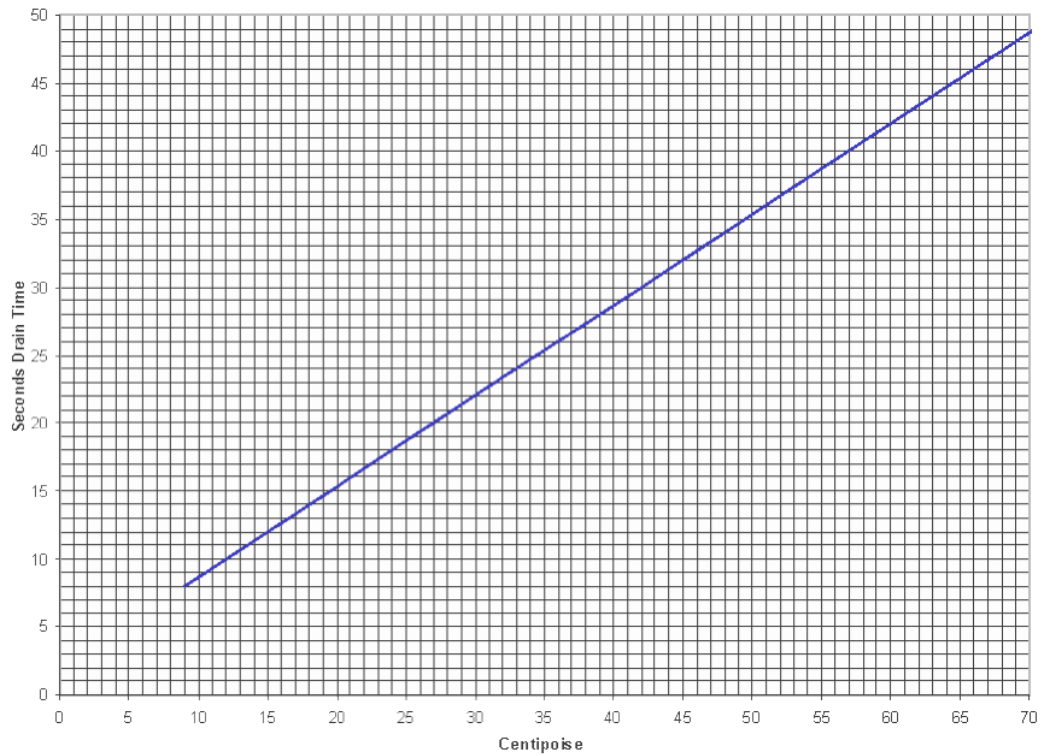
Shell Cup drain time (in S) as a function of Fluid Viscosity (in cP)

Use Shell Cup #1 for Biodiesel, and #3 for Feedstocks

Shell Cup #1
A-2481-TAW



Shell Cup #3
A-2483-TAW



Copper Strip Corrosion Test

Sulfur and other acidic/basic compounds in diesel fuels can have corrosive action on various metals (especially copper and brass which are often used in fuel line systems and). The copper strip test measures the relative corrosiveness of a fuel sample.

Excessive copper corrosion may be caused by:

- a) Presence of sulfur compounds in the fuel (possibly for biodiesel blends with petroleum).
- b) Presence of residual KOH catalyst in the biodiesel fuel (symptomatic of an incomplete neutralization/washing process).
- c) Presence of free fatty acids in the biodiesel fuel (symptomatic of aged fuel that has oxidized).
- d) Presence of water in the biodiesel fuel. Note that this will also be indicated by the centrifuge water and sediment test (symptomatic of an incomplete drying process).

Materials & Equipment:

Copper strip (3" x 1/2" x 1/16")	Steel wool and ethanol to clean copper surface
Constant temperature bath/block (50 °C)	Reaction vessel with biodiesel fuel

Procedure:

1. Clean the surface of the copper strip by polishing with steel wool. Use ethanol to help remove any oil deposits from your fingers. Verify the clean surface with a white cotton swab before proceeding.
2. Preheat a constant temperature bath/block to receive the sample chamber at 50 °C.
3. Immerse the copper strip in the sample chamber, seal and heat for 3 hours.
4. After 4 hours, remove the copper strips from the sample chamber. Clean the strip with ethanol and classify according to the following descriptions:

Slight Tarnish	1	a. Light orange, almost the same as freshly polished strip
		b. dark orange
Moderate Tarnish	2	a. Claret red
		b. Lavendar
		c. Multicolored with lavender, blue, or silver overlaid on claret red
		d. Silvery
		e. Brassy or gold
Dark Tarnish	3	a. Magenta Overcast on Brassy Strip
		b. Multicolored with red and green showing (peacock), but not gray
Corrosion	4	a. Transparent black, grey, or brown with peacock green barely showing
		b. Graphite or lusterless black
		c. Glossy or jet black

Rancimat Oxidative Stability Test

Over time, fuels can degrade by reaction with oxygen from the air. The rate at which biodiesel oxidizes depends on both the feedstock and processing conditions used to make the fuel. The oxidation process typically occurs over time scales of weeks to months, and is accelerated by factors such as aeration, light, and temperature. In some cases, the oxidation process may be slowed/inhibited through use of fuel additives (e.g. antioxidants, preservatives, etc.).

The Rancimat oxidative stability test measures the rate at which biodiesel fuel decomposes when subjected to elevated temperatures and vigorous aeration. These conditions allow for a rapid measure of fuel stability that has been shown to correlate to the slower oxidative process that occurs under normal storage conditions.

Preparing the Instrument

Do this step a few days before the measurement is to be made:

1. Regenerate the intake air molecular sieve by removing the canister and heating it in a drying oven at 140–180 °C for 48 hours.
2. Inspect the intake air filter and replace if necessary.

Cleaning the Instrument

The cleanness of instruments and accessories is an absolute necessity for achieving reliable, reproducible and correct analytical results. Even minute contamination can catalytically accelerate the oxidative decomposition and lead to completely false results.

1. Check whether the openings for the glass reaction tubes are clean and empty. Blow out any dust in the openings with nitrogen.
2. Clean conductivity measuring vessels several times with alcohol and distilled water (do not use acetone!).
3. Rinse the measuring vessel cover complete with electrodes several times with distilled water. If necessary, remove the protective ring for better access to the electrodes.
4. Rinse the connection tubing between reaction tube and measuring vessel several times with distilled water and alcohol or acetone.
5. It is recommended to use new glass reaction tubes and air tubes for each determination.
6. Used and not too strongly contaminated reaction tubes and air tubes can be cleaned by immersion in boiling RBS solution or a similar laboratory flushing agent for 1 h. They must then be thoroughly rinsed with distilled water and acetone.
7. Remove the air tube from the reaction tube cover and rinse it several times with distilled water and acetone. Dry the cover at 80°C in a drying oven.
8. *Note: Reaction tubes and tube covers which have not been dried properly can contaminate the sample with water and falsify the results.*

Preparing the Conductivity Measuring Vessels

1. Ensure that the conductivity measuring vessels are clean.
2. Fill each cleaned conductivity measuring vessel with 60 mL distilled water.
3. Place the conductivity measuring vessel cover fitted with a gas inlet tube on the conductivity measuring vessel. Ensure that the air tube will not bubble air directly on the conductivity probe.
4. Place the conductivity measuring vessel with its cover on the 743 Rancimat and connect the electrode connections on the cover to the corresponding sockets.

Preparing the Sample Reaction Tubes

1. Clean the used reaction tube covers.
2. Measure 8.5 mL of biodiesel into each of the reaction tubes to be used.
3. Take the upper rim of the reaction tube in your hand (e.g. in the space between thumb and index finger) and rotate the glass through 360°. This provides the degreased glass with a thin grease film, without which it is very difficult to remove the cover from the tube after the determination.
4. Insert an air inlet tube into the reaction tube cover and fasten it by screwing down the connection nipple.
5. Place the reaction tube cover on the reaction tube. Rotate the cover so that the air tube is as close as possible to the vessel wall.
6. Fasten the white connection tube from the conductivity measuring vessel to the corresponding nipple on the reaction tube cover.
7. Place the prepared reaction tubes into the tube rack until the heating block is ready to receive the samples.

Pre-heating the block

1. The two blocks A and B can be set to different temperatures and switched on individually for each block by clicking on the button in the software.
2. As soon as the heating is switched on, the color of the button switches to red. At the same time the TEMPERATURE LED on the Rancimat starts to blink. If the button is clicked again during the heating phase then the block will switch off.
3. The actual temperature is shown digitally beside the button.
4. When the selected temperature has been reached the color of the frame of the button switches to green. At the same time the TEMPERATURE LED stops blinking and the LED remains lit up. The block is now ready for receiving the samples and starting the determination.

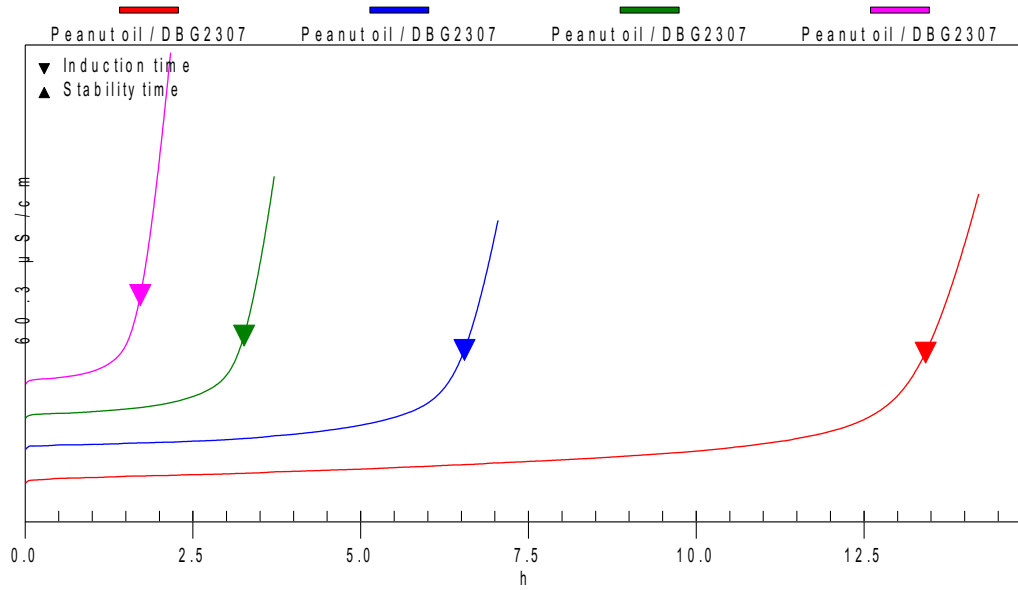
Data Analysis

A typical data set includes measurements of the oxidative induction time of the sample at several temperatures. Examples for peanut oil are shown on the following page.

NOTE: The prEN and ASTM standards only require a single test of a 7.5 g sample performed at 110°C, with a gas flow of 10L/h and Delta T of 0.9 °C.

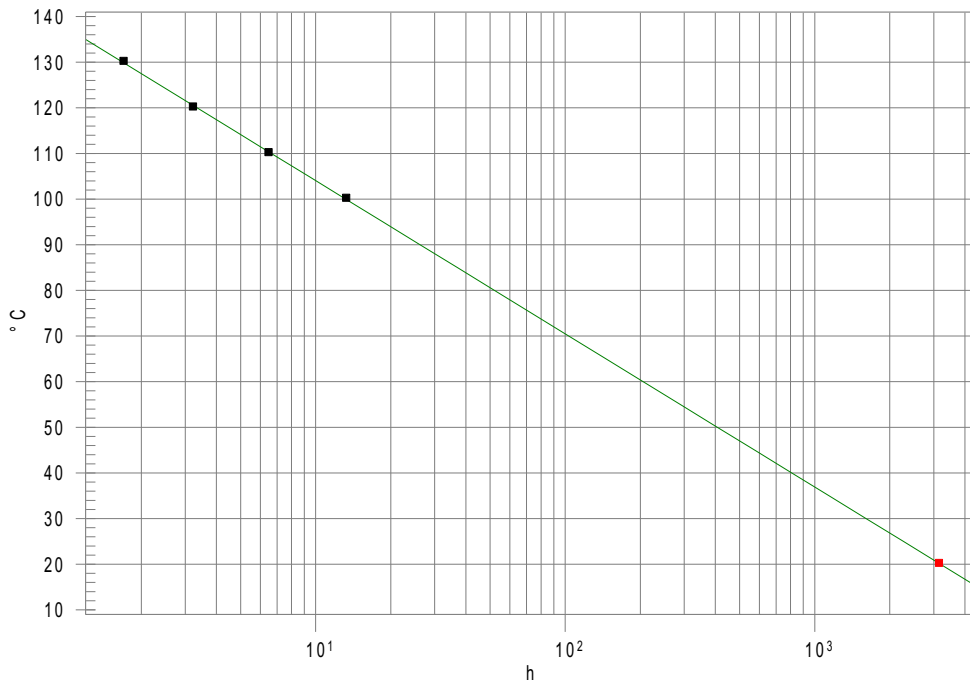
Oxidative Stability and Induction Times for Peanut Oil at 130, 120, 110, and 100 C

Conductivity (uS/cm) versus time (hours)



Log-Linear Extrapolation of Oxidative Stability for Peanut oil

Temperature (C) versus Time (h)



The “3/27” Glyceride Intermediate Test (Mono, Di, and Triglyceride content)

1. For the glycerides test add 27 ml of methanol to a glass vial. Using a disposable beral pipette, add 3 ml of commercial biodiesel. Cap the vial to seal.
2. Shake vigorously for a minute, and allow the mixture to settle in a test tube rack.

Biodiesel that meets ASTM specs should dissolve in the methanol solvent resulting in a single phase of clear liquid. Biodiesel that is out of spec will result in a cloudy emulsion of glyceride and methyl ester droplets suspended in the methanol.

4. After 5 minutes observe the bottom of the vial.

Biodiesel that meets ASTM specs for free and total glycerol should remain dissolved in the methanol solvent as a single phase of clear liquid. After settling, biodiesel that is out of spec will typically exhibit an insoluble glyceride liquid layer at the bottom of the tube in addition to the cloudy emulsion suspended in the methanol.

For video footage, see
<http://www.youtube.com/watch?v=R3jGvefA4OI>

pHLIP test for glycerin, soap, and pH

ASTM D6751 defines maximum limits in biodiesel for free glycerin (also called glycerol, a byproduct of the transesterification reaction) and for total glycerin (glycerol plus monoglyceride and diglyceride intermediates) impurities. Free glycerin in biodiesel can increase the biodiesel viscosity, settle at the bottom of storage tanks, and attract moisture. High total glycerin values can lead to carbon build-up and fuel system fouling in diesel engines.

Measuring the glycerin content to ASTM standards requires access to either a gas chromatograph (GC) or a high performance liquid chromatograph (HPLC). This equipment is not commonly available outside of specialized chemical laboratories. However, qualitative indicator tests are commercially available to provide a quick assay for biodiesel glycerol content. The indicator test you will be using today will allow you to detect if any residual basic catalyst is present in the biodiesel and will provide a quick check of the fuels pH.

An excessively high pH is caused by the presence of residual alkaline catalyst in the fuel. Alkaline biodiesel is corrosive to engine components and indicates that the fuel was not sufficiently washed.

An excessively low pH may be caused by free fatty acids from the original feedstock oil, or by the aging (oxidation) of the biodiesel fuel over time. High acid numbers are associated with fuel system deposits, filter clogging and engine component corrosion.

Materials & Equipment:

pHLip test vial containing indicator solution
Squeeze bulb
~10 – 15 mL biodiesel

Procedure:

1. Transfer enough biodiesel into the test vial to almost fill the vial, leaving a small air space.
2. Tighten cap and **gently** flip the vial over 10 times. Allow contents to stand for 10 minutes (if you mix the biodiesel and indicator too vigorously, a much longer time will be necessary). The vial contents will separate into two layers: the top biodiesel layer and the bottom indicator layer.
3. Observe the top biodiesel layer: is it clear and bright or cloudy?

4. Observe the bottom indicator layer: is it clear or cloudy? What color is it (red, orange, yellow, purple)?

5. Observe the interface between the two layers: is it smooth and “mirror-like” or does it appear that there is a middle layer present?

6. Interpret the quality of your biodiesel with respect to glycerin and catalyst contamination and acid number using the guidelines and photos below (excerpted from the manufacturer’s instructions).

High quality biodiesel is indicated by:

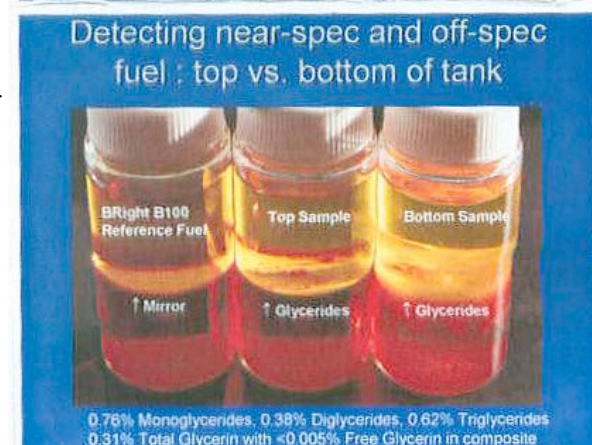
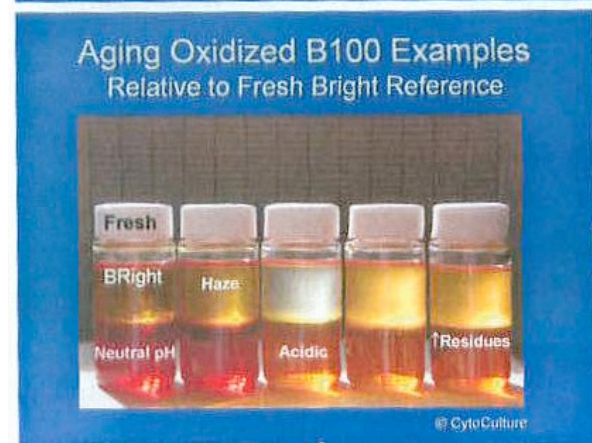
- Clear biodiesel layer
- Clear, “cherry red” indicator layer
- Smooth, “mirror-like” interface

A cloudy biodiesel layer combined with a clear, red indicator layer is characteristic of excess free or total glycerin or free fatty acids (in aged fuel). The glycerin/glycerides may also form a middle emulsion layer between the fuel and the indicator.

A cloudy lower layer is likely due to soap contamination. Soap may be formed by a combination of water, free fatty acids and catalyst.

A purple lower layer indicates a high pH. This results from residual alkaline catalyst (KOH, NaOH, etc.) in the fuel.

An orange or yellow lower layer indicates a low pH. This results either from high free fatty acid content of the feedstock or aging of the fuel.



Centrifuge Test for Water and Sediment

Water and sediment can cause problems with fuel line icing and filter plugging. In order to meet ASTM specifications, biodiesel must contain $< 0.050\%$ water and sediment by volume. Failure to meet this specification usually is attributable to poor separation processes during the biodiesel synthesis or washing stages.

Materials & Equipment:

Centrifuge, Centrifuge tubes, biodiesel fuel

Procedure:

1. Check all of the slots available on the centrifuge and inspect for the presence of weights or stoppers in the bottom of the slots. It is critical to ensure that the centrifuge rotor is balanced.
2. Obtain two matched centrifuge tubes of similar manufacture (same shape, mass, etc.) Fill both tubes with equal quantities of biodiesel so that they contain an equal mass of fuel.
3. Place the tubes in centrifuge slots located directly opposite one another to maintain balance on the rotor.
4. Spin the samples at 800 rcf (relative centrifugal force) for a period of 10 minutes.
5. When the centrifuge has stopped, remove the tubes and report the % water and sediment.

Note: ASTM D2709 requires specialized centrifuge tubes to obtain the desired accuracy for this test. If performing the test to these standards, the taper bottom tubes must accommodate 100 mL fuel samples and be marked with graduations to the nearest 0.01 mL.

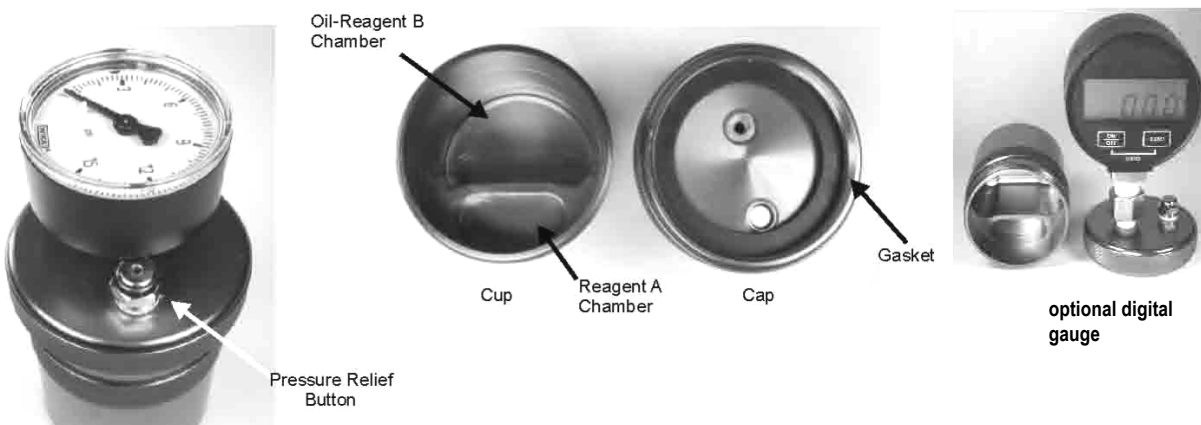
Sandy Brae Test for Water Content

CAUTION: The reagents used in the Sandy Brae Kit include Calcium Hydride (reagent A) and a mixed anhydrous solvent (Reagent B). These materials are capable of causing chemical burns. Wear gloves and safety goggles when handling these materials.

Principle of Operation

Calcium hydride reacts with water to produce hydrogen gas. By reacting calcium hydride with a fuel sample of interest, and measuring the pressure of the hydrogen gas that is produced, one can measure the water content of any liquid fuel mixture. Note that the pressure gage included in the Sandy Brae Instrument has a maximum pressure rating of 15 PSI. If the pressure exceeds 14 PSI during the course of a test, the pressure relief valve should be immediately opened to release the gas and avoid damaging the gauge. Testing then can be repeated using the protocol for a higher water content range.

1. If using a digital pressure gauge, turn the Pressure Gauge On. To zero display, release pressure, then press and hold the zero button until the LCD displays “----”, then release. Check that the gauge is set to read in PSI. To change units, press both the on and zero buttons simultaneously until desired (PSI) units are displayed.



2. Using a syringe, measure a quantity of sample oil according to the table below and add it to the Oil & Reagent B Chamber. Using a second syringe, measure a quantity of Reagent B (mixed anhydrous solvent) and add it to the Oil & Reagent B Chamber.

Test Range (max H ₂ O %)	0.15%	1.50%	3.00%	6.00%	12.00%
Fuel Sample Volume (mL)	30	4	2	1	0.5
Reagent B Volume (mL)	10	16	18	19	19.5

3. Use a scissors and a pencil tip to open a packet of reagent A. Empty the packet into the Reagent A Chamber, being careful to avoid getting any of the reagent in the oil/solvent mix.
4. Keeping the cup vertical to avoid spilling reagents, tightly screw on the cap to obtain a tight seal. **NOTE: DO NOT USE THE GAGE TO TIGHTEN THE CAP.**

5. Shake the vessel vigorously for 20 seconds. Check the pressure gauge to insure that the pressure has not exceeded 14 PSI. If the pressure approaches or exceeds 14 PSI, abort the test by pressing the relief valve, or by unscrewing the cap. Repeat this step twice more (performing it a total of three times). Then let the vessel rest for one minute
6. Shake the vessel for 10 seconds, then rest for 50 seconds. Repeat this step four times, then take the final pressure reading.
7. Use the Pressure Gage Charts to determine the % water in the fuel sample. If necessary, you can also measure the temperature of the fuel and use the temperature compensation charts to adjust for this variable.
8. Use any dry petroleum solvent (e.g. mineral spirits, petroleum distillates, pentane, hexane, etc.) to clean the reaction vessel. ***Do not use water or alcohol for cleaning, since these will leave behind H₂O in the apparatus. Also do not use acetone to clean the vessel since this will dissolve the plastic body and lens of the pressure gage.***

Tables to Convert Sandy Brae Gauge Reading (in PSI) to % Water and ppm

Gage Reading in PSI = GR

**Range .15%
GR X .01**

GR	% Water	PPM
1	0.01%	100
2	0.02%	200
3	0.03%	300
4	0.04%	400
5	0.05%	500
6	0.06%	600
7	0.07%	700
8	0.08%	800
9	0.09%	900
10	0.10%	1000
11	0.11%	1100
12	0.12%	1200
13	0.13%	1300
14	0.14%	1400
15	0.15%	1500

**Range 1.5%
GR X .1**

GR	% Water	PPM
1	0.1%	1000
2	0.2%	2000
3	0.3%	3000
4	0.4%	4000
5	0.5%	5000
6	0.6%	6000
7	0.7%	7000
8	0.8%	8000
9	0.9%	9000
10	1.0%	10000
11	1.1%	11000
12	1.2%	12000
13	1.3%	13000
14	1.4%	14000
15	1.5%	15000

**Range 3%
GR X .2**

GR	% Water	PPM
1	0.2%	2000
2	0.4%	4000
3	0.6%	6000
4	0.8%	8000
5	1.0%	10000
6	1.2%	12000
7	1.4%	14000
8	1.6%	16000
9	1.8%	18000
10	2.0%	20000
11	2.2%	22000
12	2.4%	24000
13	2.6%	26000
14	2.8%	28000
15	3.0%	30000

**Range 6%
GR X .4**

GR	% Water	PPM
1	0.4%	4000
2	0.8%	8000
3	1.2%	12000
4	1.6%	16000
5	2.0%	20000
6	2.4%	24000
7	2.8%	28000
8	3.2%	32000
9	3.6%	36000
10	4.0%	40000
11	4.4%	44000
12	4.8%	48000
13	5.2%	52000
14	5.6%	56000
15	6.0%	60000

**Range 12%
GR X .8**

GR	% Water	PPM
1	0.8%	8000
2	1.6%	16000
3	2.4%	24000
4	3.2%	32000
5	4.0%	40000
6	4.8%	48000
7	5.6%	56000
8	6.4%	64000
9	7.2%	72000
10	8.0%	80000
11	8.8%	88000
12	9.6%	96000
13	10.4%	104000
14	11.2%	112000
15	12.0%	120000

Sandy Brae Temperature Compensation Factors

Degrees F	Factor	Degrees F	Factor	Degrees F	Factor	Degrees F	Factor
32	1.0916	54	1.0448	76	1.0019	98	0.9623
33	1.0894	55	1.0428	77	1.0000	99	0.9606
34	1.0872	56	1.0407	78	0.9981	100	0.9589
35	1.0850	57	1.0387	79	0.9963	101	0.9572
36	1.0828	58	1.0367	80	0.9944	102	0.9555
37	1.0806	59	1.0347	81	0.9926	103	0.9538
38	1.0784	60	1.0327	82	0.9908	104	0.9521
39	1.0762	61	1.0307	83	0.9889	105	0.9504
40	1.0741	62	1.0288	84	0.9871	106	0.9487
41	1.0719	63	1.0268	85	0.9853	107	0.9470
42	1.0698	64	1.0248	86	0.9835	108	0.9454
43	1.0677	65	1.0229	87	0.9817	109	0.9437
44	1.0656	66	1.0209	88	0.9799	110	0.9420
45	1.0634	67	1.0190	89	0.9781	111	0.9404
46	1.0613	68	1.0171	90	0.9763	112	0.9387
47	1.0592	69	1.0151	91	0.9746	113	0.9371
48	1.0572	70	1.0132	92	0.9728	114	0.9355
49	1.0551	71	1.0113	93	0.9710	115	0.9338
50	1.0530	72	1.0094	94	0.9693	116	0.9322
51	1.0509	73	1.0075	95	0.9675	117	0.9306
52	1.0489	74	1.0056	96	0.9658	118	0.9290
53	1.0468	75	1.0037	97	0.9641	119	0.9274
						120	0.9258

Degrees C	Factor	Degrees C	Factor	Degrees C	Factor	Degrees C	Factor	Degrees C	Factor
0	1.0916	10	1.0530	20	1.0171	30	0.9835	40	0.9521
1	1.0876	11	1.0493	21	1.0136	31	0.9803	41	0.9490
2	1.0836	12	1.0456	22	1.0102	32	0.9770	42	0.9460
3	1.0797	13	1.0420	23	1.0068	33	0.9739	43	0.9430
4	1.0758	14	1.0383	24	1.0034	34	0.9707	44	0.9401
5	1.0719	15	1.0347	25	1.0000	35	0.9675	45	0.9371
6	1.0681	16	1.0311	26	0.9967	36	0.9644	46	0.9342
7	1.0643	17	1.0276	27	0.9933	37	0.9613	47	0.9313
8	1.0605	18	1.0241	28	0.9900	38	0.9582	48	0.9283
9	1.0567	19	1.0205	29	0.9868	39	0.9551	49	0.9255

Instructions: For temperature compensation, multiply the above factor times the gauge reading for the the temperature of the sample in the test vessel. The product is the corrected percent water.

Cold Soak Filtration Test

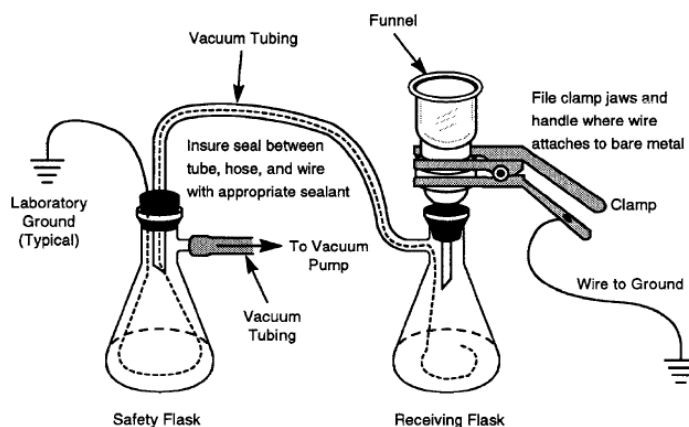
Some impurities commonly found in plant oils (eg. phospholipids, sterol glucosides, etc) can cause problems with off spec biodiesel causing filter plugging in cold weather conditions. This test was added to the specification for ASTM biodiesel to insure that commercially sold fuel will not exhibit such problems.

SAFETY NOTE:

Measure the flash point of your fuel sample BEFORE attempting this test. ***If your fuel has a LOW flashpoint, DO NOT conduct the cold flow filtration test.*** Vacuum filtering fuel samples with a low flashpoint can cause vapors to off-gas from the fuel and enter the vacuum pump. These vapors contaminate the pump oil, causing premature damage/wear. They also can present a fire hazard if there is a source of ignition present.

Materials & Equipment:

Two 1L vacuum filtration flask
Vaccum Pump & hose
Refrigerator for chilling fuel
Stopwatch
47 mm diameter, 0.7 micron glass microfiber filter (whatman GF/F)



Procedure:

1. Place a 300 mL sample of biodiesel in a refrigerator at 40 degrees F for 16 hours.
2. Allow the sample to warm to room temperature (75-79 degrees F)
3. Assemble the vacuum filtration apparatus, being sure that the ground wire is appropriately positioned.
4. Vaccum Filter through a the glass microfiber filter and record the filtration time in seconds.
5. If the filtration time exceeds 720 seconds, stop the test and report the volume of fuel that was filtered before the test was stopped.

Conradson Test for Carbon Residue

This test determines the amount of carbon residue left after evaporation and pyrolysis of the fuel and is intended to provide some indication of the relative coke-forming propensities of the sample. Fuels that produce high amounts of carbon residue can form deposits on the insides of cylinder walls, rings, and valves, and seats and may compromise engine performance.

High measures of biodiesel carbon residue may be caused by:

- a) Presence of unreacted feedstock oil and/or monoglyceride and diglyceride intermediates in the biodiesel fuel (symptomatic of an incomplete transesterification process).
- b) Presence of glycerol byproduct in the fuel (symptomatic of incomplete separation process).

Equipment:

Conradson test assembly (see following page)	Analytical balance
Natural gas supply	Sand

Procedure:

1. Clean a porcelain crucible and determine its mass. Add exactly 10 grams of the sample to the crucible.
2. Place the porcelain crucible in the center of the skidmore crucible.
3. Add ~ ½ inch of clean dry leveled sand in the bottom of the large nickel crucible.
4. Place the skidmore crucible into the large nickel crucible and place the covers on each of them.
5. Place the wire triangle on the stand, with the ceramic insulator on top with grooves facing upward.
6. Place the crucible onto the wire triangle at the center of the insulator.
7. Apply a strong flame to preheat the sample for 10 minutes and evaporate off all volatile components. Use care not to overheat the sample which can cause foaming. When smoke appears above the chimney, this indicates that pyrolysis of the sample has begun. Immediately move the burner so that the flame plays on the sides of the crucible and ignites the vapors.
8. After igniting the smoke above the chimney, remove the burner temporarily and adjust the flame so that *the ignited vapors burn uniformly above the chimney but not above the wire bridge*. Heat can be increased if necessary to keep the flame above the chimney, but avoid foaming due to overheating. *Continue for a total burning time of 13 minutes.*
9. When vapors cease to burn, and no further blue smoke is observed, readjust the burner to a strong flame and heat until the bottom of the nickel crucible is a cherry red. *Maintain this heat for 7 minutes.*
10. Remove the burner and allow the apparatus to cool. Use tongs to remove the porcelain crucible and place in a dessicator to cool. When the sample has reached room temperature, mass the crucible and determine the percent carbon residue

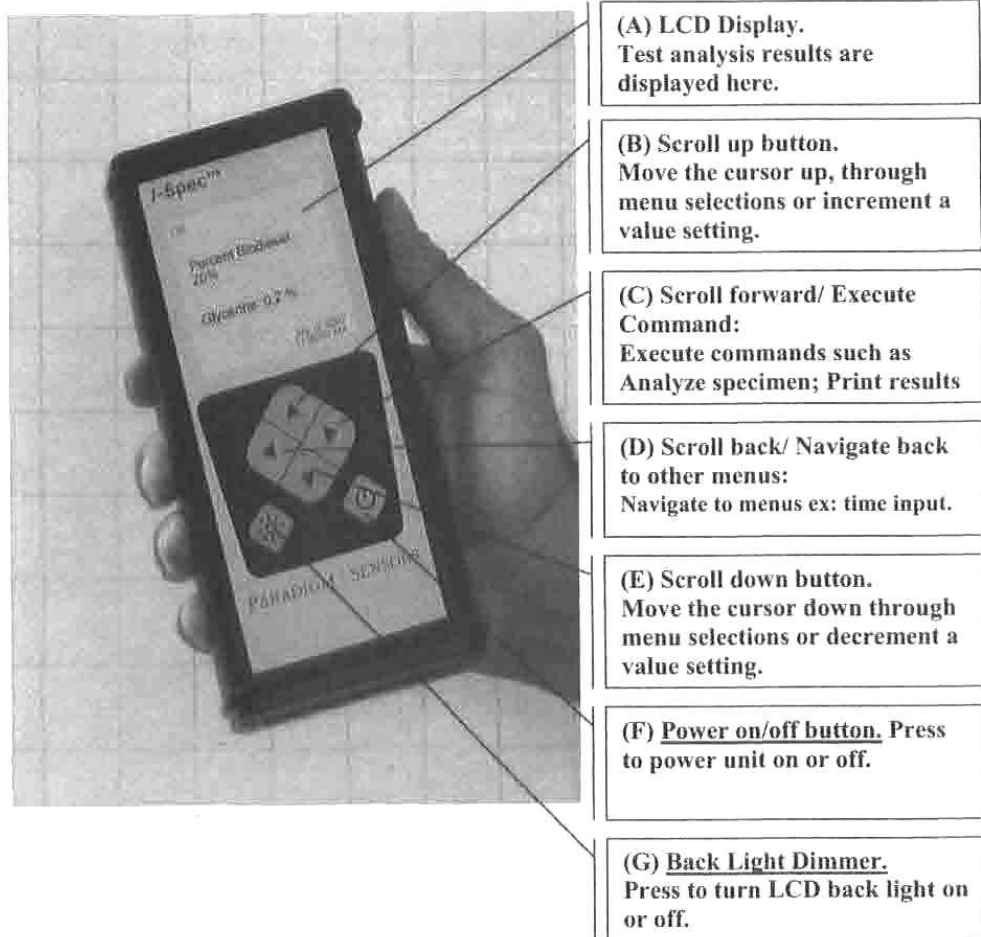
Paradigm Sensor Impedance Spectroscopy Test for Total Glycerin, Methanol, and Acid Number

i-SPEC[®] Q 100
Handheld Biodiesel Analyzer
REFERENCE GUIDE

FIRST TIME OPERATION

The i-SPEC[®] Q100 may be used virtually anywhere. It is important that you allow the sample temperature to stabilize before starting your test.









Below is a guide to the functions of the i-SPEC[®] Keys:



To begin, please follow the steps on the back of this page:

R10.2.1

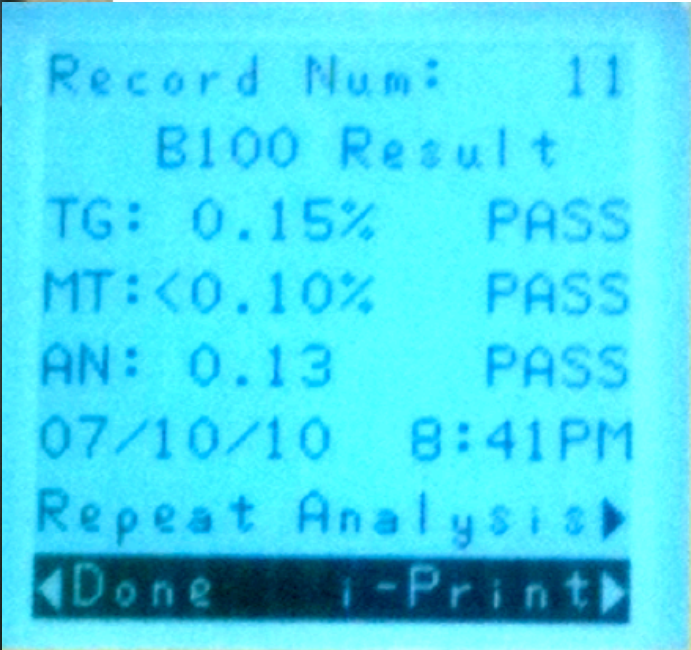
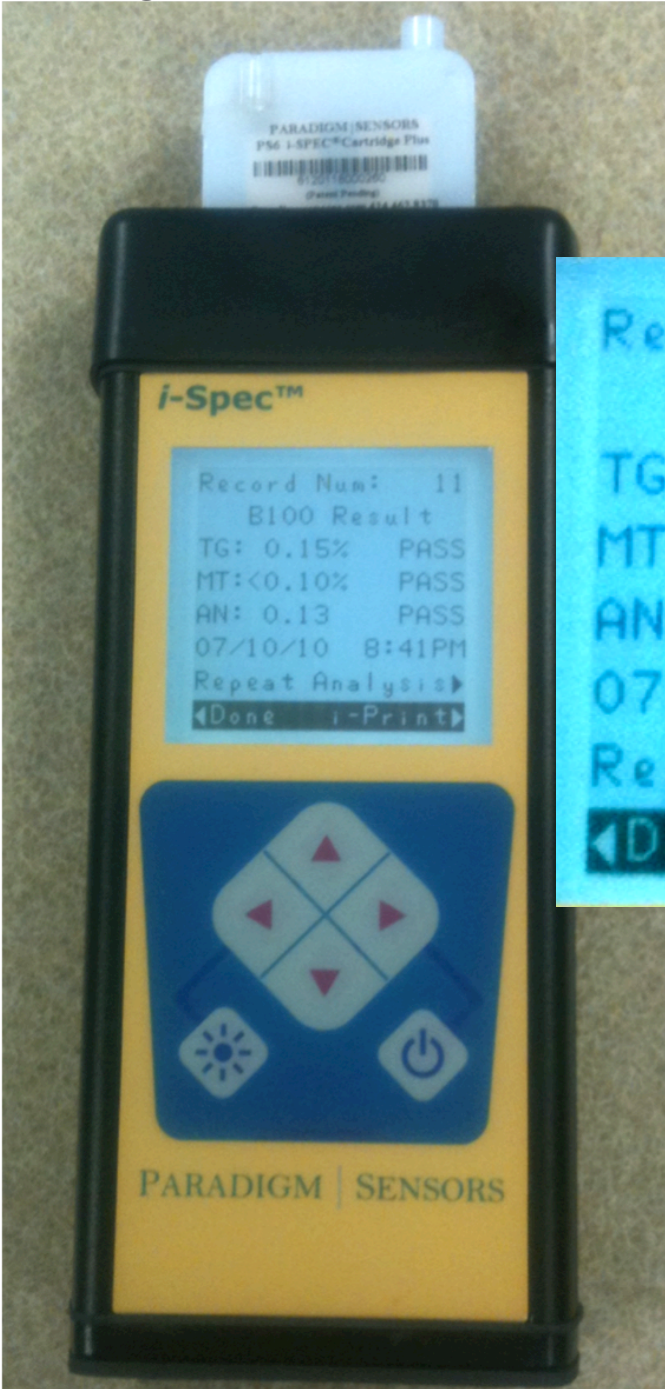
To Analyze a Sample:

1. For first time use, connect the AC adapter into the back of the docking station, then into the wall outlet. Place unit in docking station. Charge the handheld unit overnight or until *Charging Done* is displayed on LCD.
2. Remove handheld from docking station. Turn on the handheld with  button at bottom right. Wait until self diagnostic completes and *Insert Sample* appears.
3. For field calibration, select cartridge, remove black cap, and completely insert the cartridge into the top of the handheld. Wait for *Cell Calibrated* to appear.
4. Only use disposable syringe provided. Remove cartridge from unit, remove red cap, and insert approximately 0.4ml biodiesel sample. Fill is complete when fluid fills half of reservoir opposite fill port. To assure all air is out of cartridge, it is recommended to overflow the reservoir (hold a cloth to reservoir to assure fluid does not wet outside of cartridge). Check to make sure any excess biodiesel present on the exterior of the cartridge is wiped off before insertion into the handheld.
5. Completely insert the cartridge into the top of the handheld. Wait for *Analyze Sample* to appear.
6. When *press to start* is indicated push  button. *Analyzing Step 1* will appear on the screen. *Analyzing Step 2* will follow.
7. Wait several minutes for the analysis to appear on the LCD display. Results display includes *B* for blend, *GLY* for glycerin (TG for B98-100), *AN* for Acid Number (B98-100 only) and *MT* for methanol (B98-100 only) as well as pass/limit/fail indications next to *TG*, *AN* and *MT*. If *Sample is Beyond the Instrument Range* appears, one result is skewing the results of all parameters and the sample may be out of spec.
8. If *Temperature Change More than 2°C* appears, the temperature varied too much during the test. Simply press the  button to go back to analysis page. Press  button again to restart analysis (as above in 6)
9. Repeat analysis is possible if you do not remove the cartridge. If you wish to repeat the analysis, with *repeat analysis* highlighted, press the  button to go back to analysis page. Press  button again to restart analysis. Data for both samples will be saved in handheld.
10. Print the results if you have the optional printer by highlighting *i-print* and press  button. (Keep the top of handheld pointed toward the printer)
11. Exit by highlighting *Done* and press  button
12. Remove cartridge and insert in plastic zipper sealed bag to return to Paradigm Sensors. Dispose of syringe; do not reuse syringes.

Safety Information

- Do not drop or shock the instrument
- Do not pour biodiesel into the top of the handheld. Use syringe to inject biodiesel into cartridges.
- Be sure not to exceed the 16 volt d.c. input power. Only use Paradigm Sensors' approved chargers and adapters to power the docking station.
- Do not immerse handheld or charger base in water. To clean, refer to instructions in the user manual.

Paradigm Sensor Results from May 2012



WISCONSIN BIODIESEL PRODUCTION FACILITIES
Updated July 21, 2009

	Production Start Date	Production Capacity (MGY)	Address	City	Zip	Phone	Web
OPERATING							
BEST Biodiesel	2007	10	111 Eagle Dr.	Cashton	54619	(608) 654-6115	www.bestenergies.com
Midwest Biofuel, LLC	2007	5	125 Industrial Dr.	Clinton	53525	(866) 565-0297	www.midwest-biofuel.com
Walsh Bio Fuels, LLC	2007	5	N3092 Hwy 12 & 16	Mauston	53948	(608) 847-6869	
Sun Power Biodiesel, LLC	2008	3	1690 Elm Street	Cumberland	54829	(715) 822-2415 x201	
Pepin Biotech – 25 Small Producers	2008	3	Various Locations	Pepin		(651) 565-2000	http://www.pepinbiotech.com/
Bio Blend Fuels, Inc.	2009	2.6	2817 Basswood Dr.	Manitowoc	54220	(920) 686-1997	www.bioblendfuels.com
IDLE							
Sanimax Energy	2006	20	605 Bassett St.	De Forest	53532	(519) 824-2381	www.sanimax.com
Badger Biodiesel, Inc.	2006	3.5	PO Box 247	Clyman	53016	(888) 558-9611 x106	
PROPOSED							
Innovation Fuels	-	100	1626 S. Harbor Dr.	Milwaukee	53051	(414) 486-1513	www.innovationfuels.com
Western Wisconsin Biodiesel	-	10	PO Box 185	Whitehall	54773	(715) 538-4371	
ACP Environmental Fuels	-	4	125 Anderson St.	Shell Lake	54870	(715) 416-2719	
Sun Power Biodiesel, LLC	-	5		Ashland	54806	(715) 822.2415 x 201	
Mid-Wisconsin Biodiesel, LLC	-	1	W19085 Cedar St	Eland	54427	(715) 253-2100	

Biodiesel Refueling Stations in Wisconsin
Updated July 21, 2009

Business Name	Address	City	Zip	Phone	Blend	Notes
New Horizons Cenex Convenience Store	401 Elm St.	Boscobel	53085	(608) 375-4801	B5	Business Hours: 4am - 11pm, 24/7 pumps
BP Highway Hop	665 E Ave	Lomira	53048	(920) 269-7621	B5	Business Hours: 5 am - 11pm, 24/7 pumps
Lyndon Station BP	470 Cty Hwy HH, Exit 79/190-94	Lyndon Station	53944	(608) 666-3771	B5	Open 24/7
PrairieFire BioFuels Cooperative	1894 E. Washington Ave.	Madison	53704	(608) 441-5454	B99.9	Business Hours: Mon, Wed, Fri 3pm-7pm, Sat 10am-4pm. Also by Appt.
Bio Blend Fuels Inc	2817 Basswood Rd	Manitowoc	54220	(920) 686-1997	B99,B50,B20	open to the public 24/7
Smart Station	1637 4th Ave. W.	Monroe	53566	(608) 329-3900	B5, B20	Unmanned fuel station, 24/7 pumps, Seasonal Blends
Blanchardville Coop Oil Assn.	1401 Hwy 69 S.	New Glarus	53516	(608) 527-2112	B5	24/7 pumps, offered April 1–October 31
Cenex Express Pump 24	401 Marshview Dr.	Sun Prairie	53590	(800) 236-3276	B5	24/7 pumps
190 Cenex	341 E. Jefferson St.	West Salem	54669	(608) 786-1108	B5	Offered April 1–October 31

See also: <http://www.altfuelprices.com/>

Wisconsin Small Scale Biofuel Producer Program

<http://fs18.formsite.com/RenewableInstallers/form060565323/index.html>

6/2/2010

Biofuel Registration

Producer Registration Form

*** First Name** *** Last Name**

Company Name

*** Address 1**

Address 2

*** City** *** State** *** Zip Code**

*** Phone Number** *** eMail Address**

Biofuel Production and Use Information

*** Production Type (Check all that apply)**

Ethanol

Biodiesel

Other

*** How is finished product used? (Check all that apply)**

Personal/Business use off-road (farm equipment, lawn care, etc.)

Personal/Business use on-road

Personal/Business use heating/electricity generation

Resale

Educational use only

Educational use off-road (lawn care, maintenance, etc.)

Educational use on-road

Educational use heating/electricity generation

Other

*** Annual Production Capacity/Design Capacity (\$)**

*** Production Method**

- Batch
- Continuous

*** Production Method (Describe)**

*** Feedstock**

- Corn
- Agri-based Virgin Oil
- Waste Vegetable Oil
- Rendered Fat
- Other

Storage/Waste

*** Storage Method (Indicate container contents, type and amounts)**

*** Waste/Co-Products**

- Spent Grain/Meal
- Carbon Dioxide
- Glycerin
- Water Wash
- Methanol
- Other

*** How do you handle your waste/co-products?**

The Small Producers website has an area available to show your name, address, telephone and email address. Please check your preference below.

*

- Yes - Publish my contact information on the website.
- Please do NOT publish any of my information on the website

<p>Environmental impacts of Burning the Fuel</p>	<p>Produces harmful emissions, however, gasoline and gasoline vehicles are rapidly improving and emissions are being reduced.</p>	<p>Produces harmful emissions, however, diesel and diesel vehicles are rapidly improving and emissions are being reduced especially with after-treatment devices.</p>	<p>Reduces particulate matter and global warming gas emissions compared to conventional diesel, however, NO_x emissions may be increased.</p>	<p>CNG vehicles can demonstrate a reduction in ozone-forming emissions compared to some conventional fuels, however, HC emissions may be increased.</p>	<p>EVs have zero tailpipe emissions, however, some amount of emissions can be contributed to power generation.</p>	<p>E-85 vehicles can demonstrate a 25% reduction in ozone-forming emissions compared to reformulated gasoline.</p>	<p>Zero regulated emissions for fuel cell-powered vehicles, and only NO_x emissions possible for internal combustion engines operating on hydrogen.</p>	<p>LNG vehicles can demonstrate a reduction in ozone-forming emissions compared to some conventional fuels, however, HC emissions may be increased.</p>	<p>LPG vehicles can demonstrate a 60% reduction in ozone-forming emissions compared to reformulated gasoline.</p>	<p>M-85 vehicles can demonstrate a 40% reduction in ozone-forming emissions compared to reformulated gasoline.</p>
<p>Energy Security impacts</p>	<p>Manufactured using mostly imported oil, which is not an energy secure option.</p>	<p>Manufactured using imported oil, which is not an energy secure option.</p>	<p>Biodiesel is domestically produced and has a fossil energy ratio of 3.3 to 1, which means that its fossil energy inputs are similar to those of petroleum.</p>	<p>CNG is domestically produced. The United States has vast natural gas reserves.</p>	<p>Electricity is generated mainly through coal fired power plants. Coal is the United States' most plentiful fossil energy resource and coal is our most economical and price stable fossil fuel.</p>	<p>Ethanol is produced domestically and it is renewable.</p>	<p>Hydrogen can help reduce U.S. dependence on foreign oil by being produced from renewable resources.</p>	<p>LNG is domestically produced and its typically costs less than gasoline and diesel fuels.</p>	<p>LPG is the most widely available alternative fuel with an estimated 3,400 refueling sites nationwide. The disadvantage of LPG is that 45% of the fuel in the U.S. is derived from oil.</p>	<p>Methanol can be domestically produced from renewable resources.</p>
<p>Fuel Availability</p>	<p>Available at all fueling stations.</p>	<p>Available at select fueling stations.</p>	<p>Available in bulk from an increasing number of suppliers. There are 22 states that have some biodiesel stations available to the public.</p>	<p>More than 1,100 CNG stations can be found across the country. California has the highest concentration of CNG stations. Home fueling will be available in the fall of 2005.</p>	<p>Most homes, government facilities, fleet garages, and businesses have adequate electrical capacity for charging, but, special hookup or upgrades may be required. More than 600 electric charging stations are available in California and Arizona.</p>	<p>Most of the E-85 fueling stations are located in the Midwest, but in all, approximately 150 stations are available in 23 states.</p>	<p>There are only a small number of hydrogen stations across the country. Most are available for private use only.</p>	<p>Public LNG stations are limited (only 35 nationally). LNG is available through several suppliers of cryogenic liquids.</p>	<p>LPG is the most accessible alternative fuel in the U.S. There are more than 3,300 stations nationwide.</p>	<p>Methanol remains a qualified alternative fuel as defined by EPA act, but it is not commonly used.</p>
<p>AFV Fueling Station Locations</p>	<p>N/A</p>	<p>N/A</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>	<p>Visit the AFDC Web Site's AFV Fueling Station Locator (http://www.afdc.doe.gov/refueling_mapsite.shtml) to search for stations near you.</p>
<p>Infrastructure Information</p>	<p>N/A</p>	<p>N/A</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>	<p>Visit the AFDC Web Site's "Infrastructure Development Information and Resources Page"</p>

