

# Additive Use and Cold Flow Performance of Biodiesel Blends in Tennessee



Tennessee Department of Agriculture  
Regulatory Services Division  
October 22, 2008

## Introduction:

The use of biodiesel blends during the winter months is one of the primary challenges for blenders, marketers and users of biodiesel blended fuel. Important work has been carried out and published on procedures for blending biodiesel with diesel fuel in cold weather conditions. This work has chiefly focused on creating biodiesel blends that will remain in liquid solution during cold weather blending. However, there is relatively little data available that is intended to predict the satisfactory performance of heavy-duty diesel vehicles in North America utilizing BXX blends. The State of Tennessee has emerged as a very desirable state to both produce and use biodiesel. This study will show that Tennessee's relatively mild winters, on average, make the use of blends up B20 practical throughout the year, provided that proper biodiesel blending stock and additives are selected for use during the coldest months.

## Protocol:

The Tennessee Department of Agriculture conducted a cold flow operability study on 34 samples of diesel fuel and biodiesel blends (14 samples of diesel fuel and 20 samples of BXX blends). Two base diesel fuels were used for this study. Each of the base diesel samples were analyzed for conformance with critical ASTM International D975 specification limits. One base B100 biodiesel blending stock fuel was used for this study, and the base biodiesel was analyzed for conformance with critical ASTM International D6751 limits.

Each diesel and BXX blend sample was analyzed for cold flow performance, both untreated and after being treated with additives that were supplied by three additive suppliers. The suppliers are identified by the letters A, B, and C in the data tables and charts that are included in this report. Supplier A offered two separate formulations, identified as A Formula 1 and A Formula 2. The base diesel samples were treated at various treat rates as recommended by the suppliers for the particular packages.

The cold flow performance methods utilized in this study were ASTM International D2500 Standard Test Method for Cloud Point of Petroleum Products and ASTM International D4539 Standard Test Method for Filterability of Diesel Fuels by Low-Temperature Flow Test (LTFT).

Cloud Point measures the temperature at which a cloud or haze of wax crystals first appear in the sample. A Cloud Point value that is less than the expected lowest temperature that the fuel will be exposed to is considered to be the closest thing to a fail-safe method available that will ensure vehicle performance. The

Low Temperature Flow Test (LTFT) was designed to correlate with the cold weather operability North American heavy duty trucks, and typically will be more responsive to cold flow additives than Cloud Point. With this method, a fuel sample is cooled very slowly to simulate typical over-night field conditions. At each 1° C interval, a specimen under vacuum is drawn through a specified screen. This is repeated until the sample will not pass through the screen in 60 seconds or less. The lowest temperature at which the sample will pass through the screen in the prescribed time limit is considered the LTFT Pass result.

The base diesel fuels and the biodiesel blending stock used in this study were subjected to tests to validate that those fuels each met the applicable ASTM International standards for each product. This test data can be found in Appendix A of this report.

## Results

### Base Diesel

The base diesel fuels used in this study had Cloud Points of 7.9 °F and 8.3 °F with corresponding LTFT Pass values of 6.8 °F and 5.0 °F. When treated with cold flow performance additives, the base diesel fuels had an average LTFT Pass value of 0.5 °F, indicating an average response to the additives of 5.4 °F. As you can see from *Table 1* below, the LTFT Pass results were found to be from -5.8 °F to 3.2 °F, for a range of 9.0 °F. Note that the diesel sample identified as 'Supreme' was recognized by the refiner as a high cetane number 'Supreme' grade of No. 2 Diesel; the sample noted as ULSD is a 'regular' grade of No. 2 Diesel. Also note that one set of ULSD samples were treated with an additional 'Premium Diesel Additive', listed as PDR in the table, in addition to the cold flow improver package. Premium diesel additives normally affect characteristics, including but not limited to, such as lubricity, thermal stability, fuel injector cleanliness, and cetane number (in addition to cold flow properties).

<i>Table 1 – Cold Flow Results of Base Diesel Fuel</i>								
Sample	Additive	Additive Supplier	Treat Rate mL/gal	Cloud Point, F	Pass LTFT, Deg C	Fail LTFT, Deg C	Pass LTFT, Deg F	Fail LTFT, Deg F
Supreme Base Fuel	No additives			7.9	-14.0	-15.0	6.8	5.0
Supreme	Cold Flow Improver	A, Formula 1	15.14		-17.0	-18.0	1.4	-0.4
Supreme	Cold Flow Improver	A, Formula 2	15.14		-16.0	-17.0	3.2	1.4
Supreme	Cold Flow Improver	B	10.41		-16.0	-17.0	3.2	1.4
Supreme	Cold Flow Improver	C	4.54		-16.0	-17.0	3.2	1.4
ULSD Base Fuel	No additives			8.3	-15.0	-16.0	5.0	3.2
ULSD	Cold Flow Improver	A, Formula 1	5.05		-16.0	-17.0	3.2	1.4
ULSD	Cold Flow Improver	A, Formula 2	3.79		-16.0	-17.0	3.2	1.4
ULSD	Cold Flow Improver	B	3.79		-16.0	-17.0	3.2	1.4
ULSD	Cold Flow Improver	C	2.65		-21.0	-22.0	-5.8	-7.6

ULSD	Cold Flow Improver PDR	A, Formula 1	5.05 11.37		-17.0	-17.0	1.4	1.4
ULSD	Cold Flow Improver PDR	A, Formula 2	3.79 9.46		-21.0	-22.0	-5.8	-7.6
ULSD	Cold Flow Improver PDR	B	3.79 7.57		-17.0	-18.0	1.4	-0.4
ULSD	Cold Flow Improver PDR	C	2.65 8.33		-21.0	-22.0	-5.8	-7.6

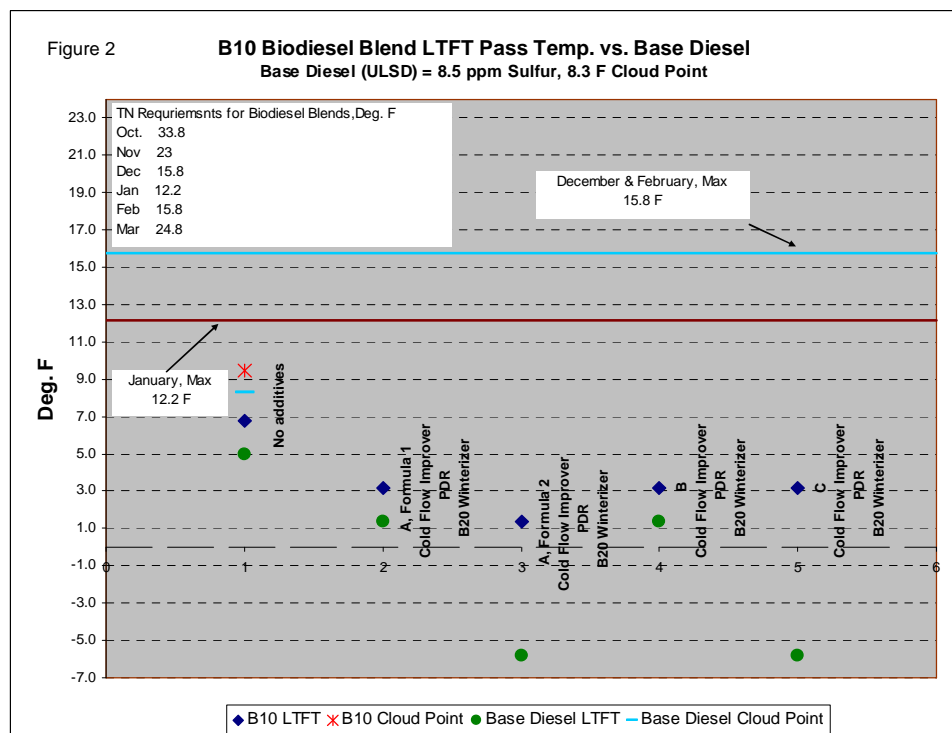
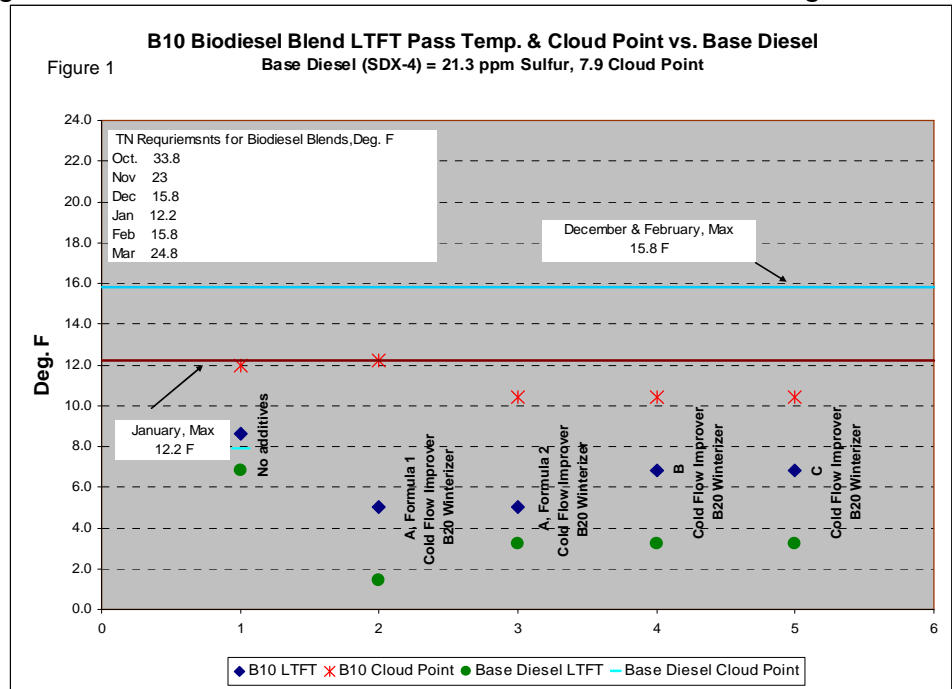
### B10 Blends:

The B10 samples derived from the base diesel fuels had cloud points of 12.0 °F and 9.5 °F. B10 Cloud points on the Supreme grade of base diesel exhibited a small overall response, with an average Cloud Point of 10.9 °F. There was insufficient sample retain to perform Cloud Point on the B10 blends made with base ULSD grade diesel. However, the B10 samples treated with cold flow additives did exhibit a measurable improvement in predicted performance versus the untreated B10 fuel when those samples were subjected to the LTFT test. The LTFT Pass results in *Table 2* below indicate that the Pass values on the two untreated B10 samples were 8.6 °F and 6.8 °F, while the average LTFT Pass results of the treated fuels were 4.3 °F, with results from 1.4 °F to 6.8 °F (range 5.4 °F).

<i>Table 2 – Cold Flow Results of B10 Blends</i>								
Sample	Additive	Additive Supplier	Treat Rate mL/gal	Cloud Point, F	Pass LTFT, Deg C	Fail LTFT, Deg C	Pass LTFT, Deg F	Fail LTFT, Deg F
B10/SDX-4 Base Fuel	No additives			12.0	-13.0	-14.0	8.6	6.8
B10/SDX-4	Cold Flow Improver B20 Winterizer	A, Formula 1	7.58 3.16	12.2	-15.0	-16.0	5.0	3.2
B10/SDX-4	Cold Flow Improver B20 Winterizer	A, Formula 2	7.58 3.16	10.4	-15.0	-16.0	5.0	3.2
B10/SDX-4	Cold Flow Improver B20 Winterizer	B	5.21 3.79	10.4	-14.0	-15.0	6.8	5.0
B10/SDX-4	Cold Flow Improver B20 Winterizer	C	2.27 4.54	10.4	-14.0	-15.0	6.8	5.0
B10/ULSD Base Fuel	No additives			9.5	-14.0	-15.0	6.8	5.0
B10/ULSD	Cold Flow Improver PDR B20 Winterizer	A, Formula 1	2.53 18.5 3.16		-16.0	-17.0	3.2	1.4
B10/ULSD	Cold Flow Improver PDR B20 Winterizer	A, Formula 2	1.90 4.73 3.16		-17.0	-18.0	1.4	-0.4
B10/ULSD	Cold Flow Improver PDR B20 Winterizer	B	1.90 6.15 6.15		-16.0	-17.0	3.2	1.4
B10/ULSD	Cold Flow Improver PDR B20 Winterizer	C	1.33 4.17 4.54		-16.0	-17.0	3.2	1.4

The charts listed as *Figure 1* and *Figure 2*, compare the results of the B10 blends with their parent base fuels. *Figure 1* compares the results of the B10 derived from the 'Supreme' grade of base diesel with the unblended diesel base. *Figure 2* compares the results of the B10 derived from the regular ULSD grade of base diesel with the unblended base diesel.

As expected, the unblended diesel had superior cold flow performance characteristics as compared to the B10 blends, when considering both the Cloud Point and LTFT Pass results. However, the results also indicate that, particularly when additives are used, B10 blends certainly can be consumed in Tennessee during the state's coldest weather months. Although the Cloud Point results from the 'Supreme' grade of diesel, both with the unadditized fuel and with additive treatment from supplier A's – Formula-1



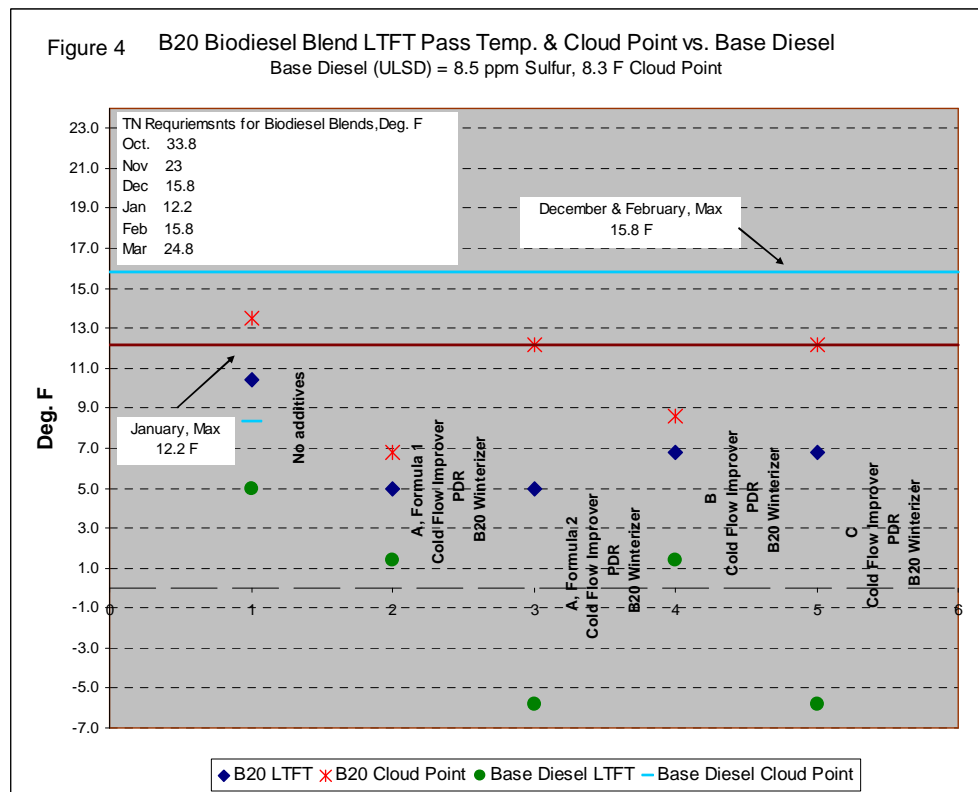
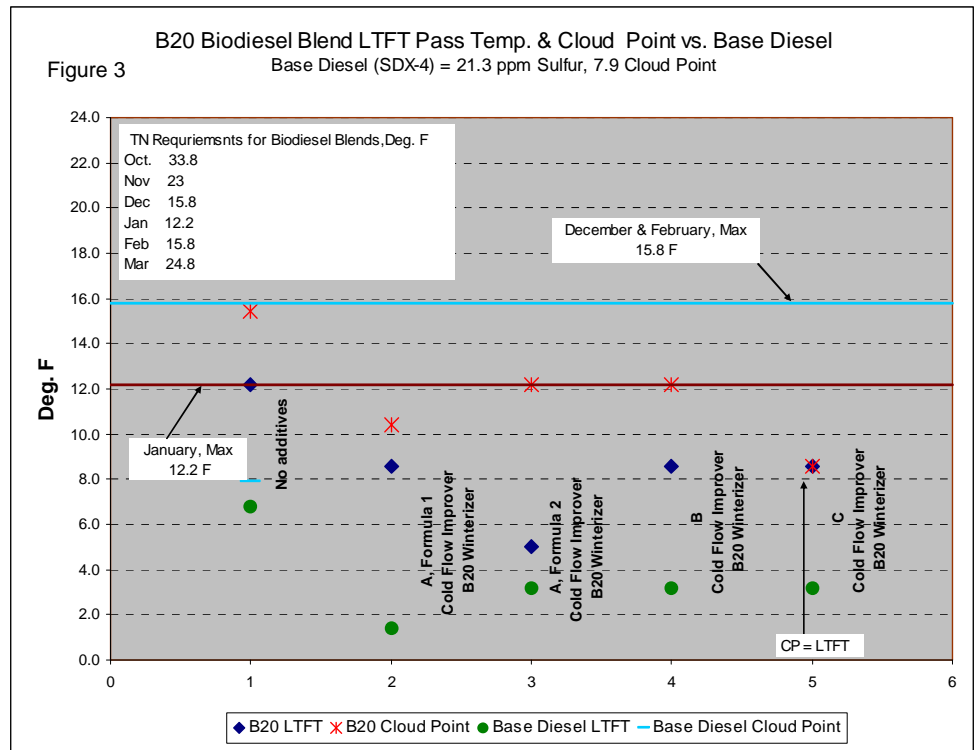
package, were borderline for Tennessee's January requirements, the LTFT Pass results were well within a safety zone for typical December – February expected low temperatures in all observed cases for both grades of base diesel used in the study.

## B20 Blends

The B20 samples derived from the base diesel fuels had cloud points of 15.4 °F and 13.5 °F. B20 Cloud Points on the ‘Supreme’ grade of base diesel were generally responsive to the additives, averaging 10.9 °F, while the Cloud Points measured on the base ULSD grade were more erratic with only two of the four treated samples exhibiting any appreciable response to the treatments. As with the B10 samples, the B20 fuels treated with cold flow additives displayed measurable improvements in predicted performance versus the untreated B20 blends when subjected to the LTFT test. The LTFT results in *Table 3* below indicate that the Pass values on the two untreated B20 samples were 12.2 °F and 10.4 °F, while the average LTFT Pass results of the treated fuels was found to be 6.8 °F, with results from 5.0 °F to 8.6 °F (range 3.6 °F).

<i>Table 3 – Cold Flow Results of B20 Blends</i>								
Sample	Additive	Additive Supplier	Treat Rate mL/gal	Cloud Point, F	Pass LTFT, Deg C	Fail LTFT, Deg C	Pass LTFT, Deg F	Fail LTFT, Deg F
B20/SDX-4 Base Fuel	No additives			15.4	-11	-12	12.2	10.4
B20/SDX-4	Cold Flow Improver B20 Winterizer	A, Formula 1	15.14 6.31	10.4	-13	-14	8.6	6.8
B20/SDX-4	Cold Flow Improver B20 Winterizer	A, Formula 2	15.14 6.31	12.2	-15	-16	5.0	3.2
B20/SDX-4	Cold Flow Improver B20 Winterizer	B	10.41 7.57	12.2	-13	-14	8.6	6.8
B20/SDX-4	Cold Flow Improver B20 Winterizer	C	4.54 9.08	8.6	-13	-14	8.6	6.8
B20/ULSD Base Fuel	No additives			13.5	-12	-13	10.4	8.6
B20/ULSD	Cold Flow Improver PDR B20 Winterizer	A, Formula 1	5.05 11.37 6.31	6.8	-15	-16	5.0	3.2
B20/ULSD	Cold Flow Improver PDR B20 Winterizer	A, Formula 2	3.79 3.46 6.31	12.2	-15	-16	5.0	3.2
B20/ULSD	Cold Flow Improver PDR B20 Winterizer	B	3.79 3.46 6.31	8.6	-14	-15	6.8	5.0
B20/ULSD	Cold Flow Improver PDR B20 Winterizer	C	2.65 8.33 9.08	12.2	-14	-15	6.8	5.0

The charts listed as *Figure 3* and *Figure 4* compare the results of the B20 blends with their parent base fuels. *Figure 3* compares the results of the B20 derived from the 'Supreme' grade of base diesel with the unblended diesel base. *Figure 4* compares the results of the B20 derived from the regular ULSD grade of base diesel with the unblended base diesel. The charts suggest that B20 blends can be used during Tennessee's coldest weather months and meet regulatory requirements. However, in order to be successful, the tests indicate from December - February, the use of additives with B20 blends is recommended.



## Conclusions

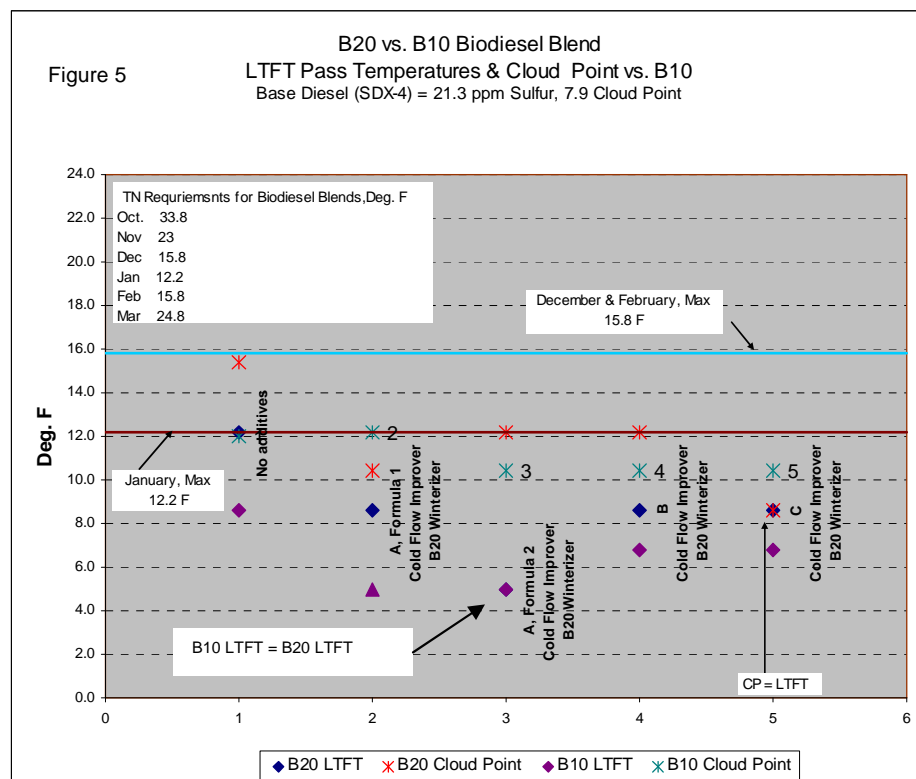
The results of this study indicate that the base diesel fuels tested would likely provide satisfactory performance in Tennessee in each month of concern, with or without the use of additives. As one would expect, petroleum diesel fuel demonstrated overall better cold flow properties than B10 and B20 Biodiesel Blends. However, this study also demonstrated that with the use of additives, biodiesel blends up to 20 percent can be used successfully in Tennessee throughout the winter.

Tennessee rules pursuant to cold flow properties of biodiesel blends require that all blends must demonstrate the ability to provide cold weather performance during the months of October through March. The fuel must qualify by being subjected to either ASTM International standard test methods D2500 (Cloud Point) or D4539 (LTFT). *Table 4* lists the tenth percentile minimum ambient air temperatures for Tennessee in each of the regulated months, according to ASTM D975 Standard Specification for Diesel Fuel Oils.

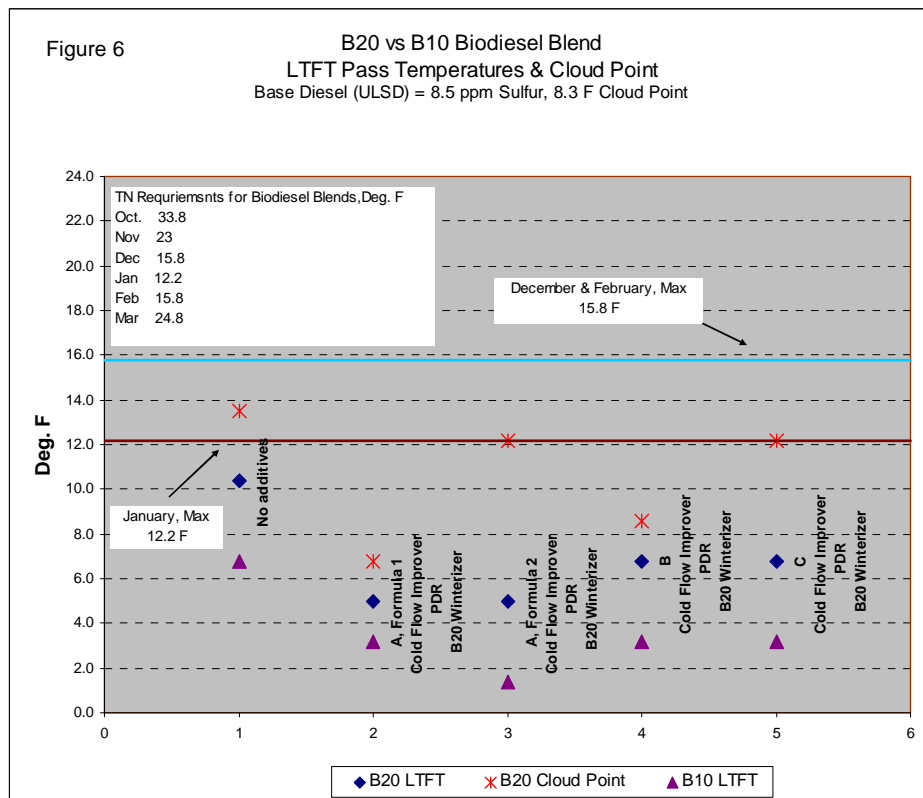
This means that biodiesel blends conveyed in Tennessee must receive a pass result on the LTFT or a Cloud Point value that is *less than* the values indicated in this table for each applicable month. As these are tenth percentile temperatures for Tennessee, fuels meeting these limits will protect the users at least 90 percent of the time.

Month	Deg C	Deg. F
Oct	1	33.8
Nov	-5	23
Dec	-9	15.8
Jan	-11	12.2
Feb	-9	15.8
Mar	-4	24.8

The results also conclude that blenders of biodiesel may wish to blend biodiesel in the ten percent range rather than twenty percent when temperatures are expected below the values listed in Table 4. Figures 5 and 6 compare the cold flow performance of the B10



and B20 blends. In all cases except for one, where the LTFT Pass values were the same for B10 and B20, the B10 blends consistently provided superior cold flow values when compared with B20 blends. As noted in the results discussion,



B10 samples treated with cold flow improvers has an average LTFT Pass result of 4.3 °F while the B20 blends had an average Pass value of 6.8 °F.

These results confirm what would be predicted in terms of the cold flow performance stability of diesel fuels. It also confirmed that the use of additives can greatly enhance the ability of the biodiesel blends to perform well throughout Tennessee’s typical winters.

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Appendix A

Supreme Diesel Certified Test Values

A.P.I. Gravity (ASTM D-287)	37.8
Sulfur, ppm (ASTM D-4294)	21.3
Flash, Penski-Martin, F (ASTM D-93)	167
Cetane Index (ASTM D-4737)	50.5
Cloud Point, F (ASTM D-2500)	7.9
Pour Point, F (ASTM D-97)	-10.0
Distillation (ASTM D-86)	<u>F</u>
IBP	379
10%	402
50%	499
90%	611
EBP	653

ULSD Certified Test Values

A.P.I. Gravity (ASTM D-287)	37.7
Sulfur, ppm (ASTM D-4294)	8.5
Flash, Penski-Martin, F (ASTM D-93)	159
Cetane Index (ASTM D-4737)	49.0
Cloud Point, F (ASTM D-2500)	8.3
Pour Point, F (ASTM D-97)	-20.0
Distillation (ASTM D-86)	<u>F</u>
IBP	358
10%	396
50%	490
90%	608
EBP	657

### Supreme B10 Certificated Test Values

A.P.I. Gravity (ASTM D-287)	37.7
Sulfur, ppm (ASTM D-4294)	18.6
Flash, Penski-Martin, F (ASTM D-93)	167
Cetane Index (ASTM D-4737)	52.0
Cloud Point, F (ASTM D-2500)	12.0
Pour Point, F (ASTM D-97)	-15.0
Distillation (ASTM D-86)	<u>F</u>
IBP	372
10%	408
50%	514
90%	627
EBP	650

### Supreme B20 Certificated Test Values

A.P.I. Gravity (ASTM D-287)	36.6
Sulfur, ppm (ASTM D-4294)	16.4
Flash, Penski-Martin, F (ASTM D-93)	169
Cetane Index (ASTM D-4737)	52.1
Cloud Point, F (ASTM D-2500)	15.4
Pour Point, F (ASTM D-97)	-5.0
Distillation (ASTM D-86)	<u>F</u>
IBP	378
10%	412
50%	537
90%	633
EBP	641

### ULSD B20 Certified Test Results

A.P.I. Gravity (ASTM D-287)	35.7
Sulfur, ppm (ASTM D-4294)	6.6
Flash, Penski-Martin, F (ASTM D-93)	165
Cetane Index (ASTM D-4737)	49.3
Cloud Point, F (ASTM D-2500)	13.5
Pour Point, F (ASTM D-97)	-10.0
Distillation (ASTM D-86)	<u>F</u>
IBP	368
10%	408
50%	527
90%	636
EBP	654

### ULSD B10 Certified Test Results

A.P.I. Gravity (ASTM D-287)	36.7
Sulfur, ppm (ASTM D-4294)	7.3
Flash, Penski-Martin, F (ASTM D-93)	161
Cetane Index (ASTM D-4737)	49.0
Cloud Point, F (ASTM D-2500)	9.5
Pour Point, F (ASTM D-97)	-15.0
Distillation (ASTM D-86)	<u>F</u>
IBP	361
10%	397
50%	508
90%	624
EBP	642

## Biodiesel Blending Stock Certified Test Results

<u>Property</u>	<u>ASTM Method</u>	<u>Limits</u>	<u>Results</u>
Flash Point	D93	130° C min	158°C
Water & Sediment	D2709	0.050 % vol. max	0.040
Kinematic Viscosity, 40° C	D445	1.9-6.0 mm <sup>2</sup> /sec.	4.1
Sulfated Ash	D874	0.020 % mass max	0.002
Sulfur	D5453	15 ppm max	1
Copper Strip Corrosion	D130	No. 3 max	1a
Cetane	D613	47 min.	48
Cloud Point	D2500	Report to customer	1°C
Carbon Residue, 100% sample	D4530	0.050 % mass max	0.010
Acid Number	D664	0.50 mg KOH/gm max	0.33
Free Glycerine	D6584	0.020 % mass max	0.014
Total Glycerine	D6584	0.240 % mass max	0.180
Phosphorus Content	D4951	0.001 % mass max	<0.001
Distillation temp., atmospheric equiv. temp., 90% recovered	D1160	360 °C max	349° C
Sodium & Potassium Metals	EN 14538	5ppm max combined	<1.0
Calcium & Magnesium Metals	EN 14538	5 ppm max combined	< 1.0
Oxidation Stability	EN 14112	3 hours minimum	> 8.0