

## Background

Diesel fuel is typically produced through refining and distillation of crude oil. Crude oil components range from methane and propane to gasoline to diesel fuel, to asphalt and other heavier components. The refining process separates the crude oil into mixtures of its constituents, based primarily on their volatility. Diesel fuels are on the heavy end of a barrel of crude oil. This gives diesel fuel its high BTU content and power, but also causes problems with diesel vehicle operation in cold weather when this conventional diesel fuel can gel. As the introduction of ultra low sulfur diesel fuel (15ppm) approaches it is anticipated that it will have possess more challenging cold flow characteristics than its predecessor LSD (500 ppm) by way of the additional processing required to remove the sulfur to these very low levels.

A tremendous effort has been made over the years to understand how to deal with the cold flow properties of diesel fuel—or the low temperature operability—of existing diesel fuel. The cloud point and the cold filter plugging point (CFPP) or the low temperature filterability test (LTFT) commonly characterize the low temperature operability of diesel fuel. They are defined below, and the test methods used are generally accurate to plus or minus 3 to 5 °F. It is important to take into consideration these test variables and factor them into your cold flow development efforts in the field.

**Cloud Point:** The temperature at which small solid crystals are first visually observed as the fuel cools. This is the most conservative measurement of cold flow properties.

**Cold Filter Plugging Point (CFPP) (or LTFT):** The temperature at which a fuel will cause a fuel filter to plug due to fuel components, which have begun to crystallize or gel. The CFPP is less conservative than the cloud point, and is considered by some to be the true indication of low temperature operability.

In general, Number 2 diesel fuel will develop low temperature problems sooner than will Number 1 diesel fuel. Number 1 diesel fuel also is referenced as kerosene and Y grade kero. The gelling of diesel fuel in cold climates is a commonly known phenomenon and diesel fuel suppliers, as well as customers and diesel engine designers, have learned over time to manage the cold flow problems associated with Number 2 diesel fuel in the winter. Helpful suggestions to address cold weather performance with diesel fuel and biodiesel-blended fuels are as follows,

- First, know what your base diesel fuel cold weather specifications are, cloud, pour point and cold filter plugging point. You will never know what your biodiesel blended fuel is to be rated for without determining what you originally blended it with.
- Ask your fuel suppliers for cold weather specifications at all times.
- Do not treat your biodiesel or diesel fuel or a combination of both with an additive once the fuel reaches its noted cloud point. Additives need to be introduced before this temperature and needs to be properly blended through agitation to be deemed effective.
- Recognize that commercially available fuel additives touted for biodiesel and biodiesel blends are working specifically on the generic portion of your biodiesel blends. In addition, the National Biodiesel Board does not endorse any fuel additives performance.
- Blending with kerosene

- Selecting and utilizing a proven cold flow improver additive, which enhances cold flow properties of generic diesel fuel that the biodiesel is being blended with is a challenge. Ask the company selling the additive to provide actual field or laboratory data to verify the performance, which they are representing as well what you may experience in the field. Encourage your supplier to accept and verify field samples to determine the additives effectiveness.
- Utilization of fuel tank, fuel filter or fuel line heaters.
- Storage of the vehicles in or near a building when not in use.
- Prepare to meet your target cold weather performance targets before winter sets in. November is not the right time to start the evaluation process on how you will develop or market a winter ready fuel.
- Make sure that the additive, which you select, meets the 15-ppm sulfur rule as well.

In most diesel engine systems today, diesel fuel is re-circulated through the engine transferring warm fuel back into the fuel tank. This assists in keeping the fuel from gelling in cold weather. This is, in part, why diesel engines are kept running overnight at truck stops in cold climates. In addition, many of the trucks used in cold climates today are outfitted with fuel tank and fuel filter heaters.

The cold flow properties of diesel fuel vary considerably throughout the year and geographical region—depending on what is needed for satisfactory vehicle operation. In general, petroleum companies and distributors manage their fuel inventory and additive treatment rates based on a history of cold weather experience so that the right blends of kerosene and Number 2 or the right amount of additives are present to eliminate cold flow problems. A recent study conducted by U.S. Army TARDEC Fuels and Lubricants Research Facility (SwRI)<sup>1</sup> of diesel fuels used in military facilities in the U.S. showed cloud points of conventional diesel fuel and kerosene in actual field use varied from 34 °F to -100 °F.

## **Establishing a Benchmark for Cold Flow Protection**

In Minnesota, the cold flow temperatures of diesel fuel needed to operate without freezing can vary from 25 °F in October to -34 °F in January, while temperatures in Missouri range from 34 °F to 4 °F and those in Louisiana range from 41 °F to 25 °F (October to January). These values are based on the Tenth Percentile Minimum Ambient Air Temperatures for the United States (Except Hawaii). The tenth percentile minimum ambient air temperatures were derived from an analysis of historical hourly temperature readings recorded over a period of 15-21 years from 345 weather stations in the United States. For more information on the ASTM 10<sup>th</sup> percentile visit [www.astm.org](http://www.astm.org).

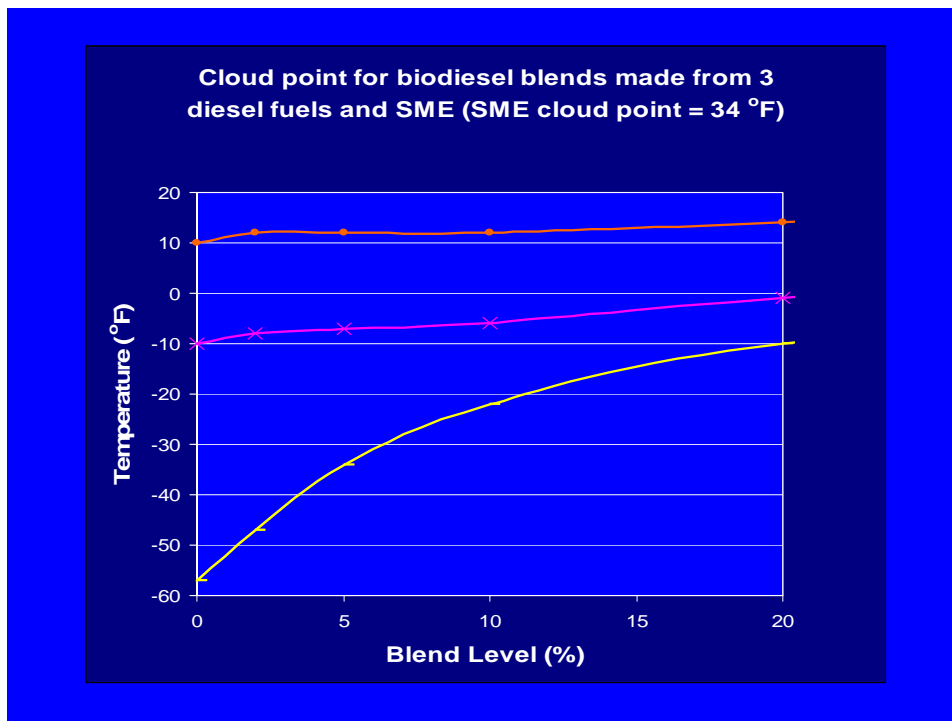
## **Biodiesel and Cold Flow Properties**

During the last seven years, the cold flow properties of biodiesel and biodiesel blends have been thoroughly tested with a variety of diesel fuels, both with and without cold flow enhancing additives. Biodiesel blends (primarily B20) have also been used in a variety of climates—including some of the coldest weather on record—without cold flow problems.

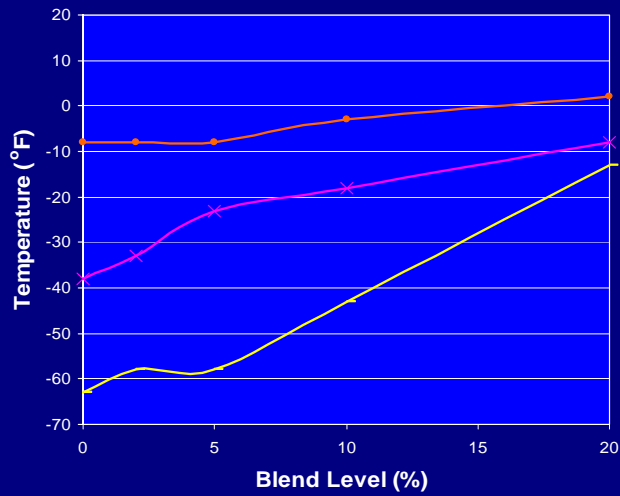
The chart below shows CFPP results for biodiesel and Number 2 diesel fuel at various concentrations. The University of Missouri prepared the fuel blends and they were analyzed at Cleveland Technical Center in Kansas City. The data suggests that the fuel mixture starts to gel sooner as the concentration of biodiesel increases. High concentrations of biodiesel (i.e. blends over 20%) may not be appropriate for

use in cold climates without blending extreme percentages of kerosene combined with proven cold flow improvers specific to conventional diesel fuel.

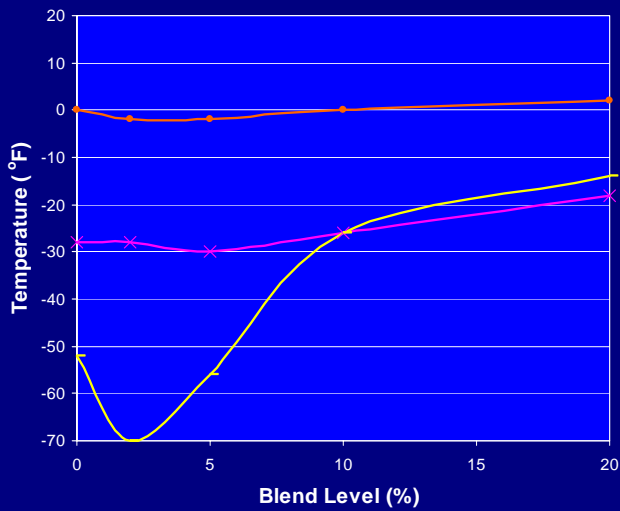
However, these results are specific to only this particular group of fuels and **should not be relied on to develop your future blending plan**. To minimize fuel related problems with diesel fuel and diesel fuel blended with biodiesel It is highly recommended to know what temperatures your fuel may be subjected, what the cold flow parameters of your conventional fuel is prior to blending biodiesel then following your final blend of conventional fuel, additive and biodiesel be prepared to sample the fuel for cloud point and cold filter plugging point. **In the final analysis it is important to start with the best base stock available coupled with an appropriate blend of kerosene and fuel additive to secure the lowest operating temperature of biodiesel blended fuels.**



**Pour point for biodiesel blends made from 3 diesel fuels and one SME (SME cloud point = 34 °F)**



**CFPP for biodiesel blends made from 3 diesel fuels and one SME (SME cloud point = 34 °F)**



This example demonstrates that nothing eliminates testing of fuels to benchmark cold flow operability. The other noteworthy point is that for fuels that are highly additized with cold flow improvers, the pour point and CFPP may give a compromised operability value.

- In cases where the climate is more temperate, or where there is cloud point giveaway relative to the seasonal diesel specification for that region, the small increase in the temperature at which B20 starts to freeze compared to petrodiesel goes unnoticed and users take no additional precautions.
- If it is desired to reduce the cold flow properties of B20 blends (or lower blends of biodiesel with petrodiesel), users should implement the same solutions as they would with Number 2 diesel fuel—blend with kerosene, use cold flow enhancing additives specific to conventional fuels, turn on fuel filter or fuel line heaters, or store vehicles in or near a building.

An example provided by Lubrizol provided the results below with biodiesel mixtures and a cold flow additive. With the incorporation of additives, the cold filter plugging point of the B20 and the B10 mixtures were both *better* than that of the base diesel fuel alone.

<u>Fuel</u>	<u>Additive</u>	<u>Treat Rate (ppm)</u>	<u>CFPP ( °F)</u>
Base Diesel		-----	+ 4
B20	LZ7670	1000	-12
B10	LZ7670	1000	-22

### Conclusions:

- Number 2 diesel fuel can experience significant cold flow problems in cold weather.
- The diesel industry have met the challenge associated with Number 2 diesel through a variety of means that are in common practice today, i.e., kerosene and cold flow additives
- These same solutions should be used with biodiesel blends to assure satisfactory cold weather performance, focus on the conventional fuel depressing the cold flow values as deep as possible with kerosene and additives while starting with a base fuel that possesses low cloud and cold filter plugging point values.
- Incorporation of blends less than 20% biodiesel (i.e. B5 or B2) into existing diesel fuel has demonstrated little or no negative effect on the cold flow properties of the finished blend however it is very important to ensure observation of cold flow properties of base fuels and ensure proper blending principals of diesel and biodiesel
- Select fuel additives on performance data only.
- Plan now for winter operations. Discuss with your fuel supplier and additive supplier how best set the strategy for uninterrupted winter performance.

### References:

- 1 "Survey of Diesel Fuels and Aviation Kerosene's From U.S. Military Installations", Paper by Steven R. Westbrook (SwRI) and Maurice E. LePera (US Army TARDEC), Presented at the 6<sup>th</sup> International Conference on Stability and Handling of Liquid Fuels, October 13-17, 1997, Vancouver, B.C., Canada.

2 “Low-Temperature Properties of Triglyceride-Based Diesel Fuels: Transesterified Methyl Esters and Petroleum Middle Distillate/Ester Blends”, Journal of the American Oil Chemists Society, JAOCS, Vol. 72, No. 8 (1995).

3 “Cold Flow Properties of Biodiesel and Biodiesel Blends – A Review of Data”, Ken Bickell, University of Minnesota Center for Diesel Research