Cold Flow Impacts

Background

Diesel fuel is typically produced through a refining and distillation process from crude petroleum oils. Crude petroleum oils contain the entire range of fuel components—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. This is not an issue for gasoline vehicles.

A tremendous amount of effort has been spent over the years to understand how to deal with the cold flow properties—or the low temperature operability--of existing petroleum based diesel fuel. The low temperature operability of diesel fuel is commonly characterized by the cloud point, and the cold filter plugging point (CFPP) or the low temperature filterability test (LTFT). They are defined below, and the test methods used are generally accurate to plus or minus 3 to 5 °F.

Cloud Point: The temperature at which small solid crystals are first visually observed as the fuel is cooled. 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 is sometimes referred to as kerosene. 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 time. The leading options to handle cold weather with diesel fuel are:

- Blending with kerosene
- Utilization of an additive that enhances cold flow properties
- Utilization of fuel tank, fuel filter or fuel line heaters
- Storage of the vehicles in or near a building when not in use

In most diesel engine systems today, excess diesel fuel is brought to the engine and warm fuel that has come close to the engine is recycled back to 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 already outfitted with fuel tank and fuel filter heaters.

The cold flow properties of diesel fuel vary considerably through out the year and geographical region—depending on what is needed for satisfactory 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)[1] of diesel fuels used in military facilities in the U.S. showed cloud points of convention diesel fuel and kerosene in actual field use varied from 34 °F to –100 °F.

In Minnesota, the cold flow temperatures of diesel fuel needed to operate without freezing can vary from 25 °F in October to - 25 °F in January and February, while temperatures in Missouri range from 35 °F to 5 °F and those in Louisiana range from 40 °F to 25 °F (October to February).

Biodiesel and Cold Flow Properties

Over the last seven years, the cold flow properties of biodiesel and biodiesel blends have been thoroughly tested with a variety of diesel fuel, 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 attached chart shows CFPP results for biodiesel and Number 2 diesel fuel at various concentrations. The fuel blends were prepared by the University of Missouri and analyzed at Cleveland Technical Center in Kansas City. It can be seen from this data that the fuel mixture starts to gel sooner as the concentration of biodiesel is increased. As can be seen from the chart, high concentrations of biodiesel (i.e. blends over 20% biodiesel) may not be appropriate for use in cold climates. In this particular case, the data showed a small improvement in the CFPP of the B20 blend compared to pure petrodiesel. However, most of the data shows there is a 3 to 5 °F increase in the cold flow properties of B20 blends. More than likely, the small improvement seen in this particular set of data is just a manifestation of the inherent test variability in cold flow analysis and is not real.

The study performed by Dunn and Bagby, Oil Chemical Researchers at the USDA laboratory in Peoria, Illinois below[2] are representative of the majority of the cold flow results with biodiesel

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Biodiesel (soy methyl esters) Concentration (vol. %)*	Cloud Point Degrees F
0	3
10	5
20	7
30	14
50	18
100	32

* Blended with Number 2 diesel fuel

One can see from the attached chart and the table above that as the concentration of the biodiesel is decreased below 20% biodiesel the impact on the cold flow properties of the blend become indistinguishable from that of the diesel fuel with which it has been blended. This was verified recently by testing performed at System Lab Services, a division of Williams Pipeline, of fuel provided to by the Agricultural Utilization and Research institute in Mankato, Minnesota:

Fuel Blend	CFPP (°F)
50 %#1, 50% #2	-22
2% biodiesel with above	-20
5% biodiesel with above	-28

This data shows that there is no real difference in the CFPP of any of these blends (even though the 5% biodiesel blend had the lowest CFPP, i.e. the best, all these results are within the repeatability of the test method and can therefore be considered the same).

In most cases, the small increase in the temperature at which B20 starts to freeze compared to petrodiesel goes un-noticed and users take no additional pre-cautions. This was the case in Cedar Rapids, Iowa where Five Seasons Transportation used B20 for over 1.4 million miles of operation in their bus fleet during one of the coldest winters on record (temperatures were below -20 °F for almost a week). They made no changes to their operation, other than to incorporate 20% biodiesel into their existing diesel fuel. Mr. Bill Hoekstra of Five Seasons wrote:

> "As you well know, this demonstration started out during the coldest winter we have had in years. Even with this obstacle, the program continued without any particular problem showing up that could be attributed to Biodiesel."

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This was also the case in Ft. McCoy, Wisconsin where B20 was used in two buses and conventional diesel fuel was used in eight of their buses. Department of Logistics Energy Officer Terry Nolan wrote the following:

> "All buses had been parked outside. The weekend temperatures averaged below zero with above average winds. The temperature the morning of the 27th [of December] was approximately –3 degrees. The winds were approx. 15 miles per hour making for a wind chill factor of approx. –25 degrees [Fahrenheit]. The two (2) Soy/Diesel buses started up without any problems. Two (2) of the eight (8) regular, Diesel powered buses would not start and had to be serviced."

If it is desired to reduce the cold flow properties of B20 blends (or lower blends of biodiesel with petrodiesel), users implement the same solutions as they would with Number 2 diesel fuel--blend with kerosene, use cold flow enhancing additives, turn on fuel filter or fuel line heaters, or store vehicles in or near a building. For example, 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.

Fuel	Additive	Treat Rate (ppm)	CFPP (°F)
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 has solved the problems with Number 2 diesel through a variety of means that are in common practice today.
- These same solutions should be used with biodiesel blends to assure satisfactory cold weather performance.
- B20 has been used successfully in fleets experiencing extremely cold weather without any additional precautions.
- When using blends of B20 or lower, the cold weather performance of the blend is mostly determined by the diesel fuel portion.
- Incorporation of blends less than 20% biodiesel (i.e. B5 or B2) into existing diesel fuel has little or no affect on the cold flow properties of the finished blend.

References:

1 "Survey of Diesel Fuels and Aviation Kerosenes From U.S. Military Installations", Paper by Steven R. Westbrook (SwRI) and Maurice E. LePera (US Army TARDEC), Presented at the 6th 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).