A Biodiesel Blend Handling Guide

MINNESOTA DEPARTMENT OF AGRICULTURE

A PUBLICATION OF THE:

Minnesota Biodiesel Technical Cold Weather Issues Team Handling Subcommittee

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Introduction

Biodiesel is a clean-burning alternative fuel made from domestic, renewable resources. In Minnesota it is made primarily from soybean oil, but it can also be made from other vegetable oils, recycled frying oils and animal fats. The term 'biodiesel' refers to the pure, unblended fuel and is referred to as B100; in this document, 'diesel' refers to all petroleum-based diesel fuel. Like petroleum diesel, before biodiesel is accepted into the fuel distribution system, it must meet strict quality standards to ensure trouble-free performance (as required by the American Society for Testing and Materials (ASTM) Biodiesel Specification, D6751). Unprocessed, raw vegetable oils and animal fats are NOT biodiesel — they can cause deposits and engine damage, cannot be used to meet Minnesota's biodiesel requirements and are not registered fuels approved by the U.S. Environmental Protection Agency (EPA).

Biodiesel contains no petroleum, but it can be blended with petroleum diesel in any percentage. Biodiesel blends from 2 percent to 20 percent can be used in most diesel equipment with no or minor modifications. Biodiesel blends are indicated by a "B" with a number following the "B" that represents the percentage of biodiesel in a gallon of fuel. The remainder of the gallon can be No. 1 diesel, No. 2 diesel, kerosene or heating oil.

Biodiesel blends higher than B20 require special handling and may require equipment modifications. These issues can be managed but because of the special handling required, higher level blends are not recommended except in cases where human exposure to diesel particulate matter (PM) is high and health concerns merit the additional attention to equipment and handling (e.g., underground mining).

Diesel engines are a large and growing segment of our transportation fleet. The EPA's recent mandate to drastically reduce sulfur content in diesel is expected to result in quieter, smoother running engines that are actually cleaner than gasoline engines. The greater efficiency of diesel engines and higher energy content of diesel fuel promises a more economical source of transportation power for all vehicles. This could all result in a greater number of diesel engines used in light trucks and passenger vehicles.

As diesel fuel is poised for greater usage in the U.S. transportation fleet, it is appropriate that federal policy includes the commercialization of renewable alternatives. One alternative that is ready for the market is biodiesel. The Energy Independence and Security Act of 2007 requires that the United States use 500 million gallons of biodiesel in 2009 with incremental increases to 1 billion gallons in 2012.

In September 2005, Minnesota became the first state to implement a biodiesel mandate of B2, meaning that virtually all diesel sold in Minnesota contains 2 percent biodiesel and 98 percent petroleum diesel. On May 1, 2009 this mandate will increase to B5 (5 percent biodiesel and 95 percent biodiesel). After tracking many consumer and industry events, a pattern of problems surfaced and various solutions were identified. It is the goal of this publication to outline some of these common and uncommon problems, provide possible solutions and recommend handling and use guidelines that have been found to help, reduce or eliminate problems.

Minnesota Laws for 2008 chapter 297, Article 1, Section 68 required the Commissioners of Agriculture and Commerce to consult with a broad range of stakeholders who are technical experts in cold weather biodiesel and petroleum diesel issues. The goal of this consultation was to make recommendations regarding improvements in the production, blending, handling and distribution of biodiesel blends to further ensure the performance of these fuels in cold weather. The Departments of Agriculture and Commerce convened a "Technical Cold Weather Issues Team" of private and public stakeholders which determined that the best approach would be to form subcommittees of experts that would address their specific areas and report back to the Team and to the Biodiesel Task Force. (The entire report can be found at: http://www.mda.state.mn.us/news/publications/renewable/biodiesel/biodieselcoldissues.pdf) One of the subcommittees of this team, the Handling Subcommittee, decided that a Handling Guide for biodiesel blend users would help answer questions and provide some basic guidelines and recommendations to diesel fuel users. This document is the result of the work of that subcommittee. The State of Minnesota would like to thank the subcommittee members for their hard work and valuable contributions to this report.

This Handling Guide is available at the following web site: (www.mda.state.mn.us/biodiesel)

Identifying your set of circumstances

A specific user may have one or multiple causes to their fuel system problems, including: (1) biodiesel, (2) petroleum diesel fuel, (3) various types of contamination and deposits, and (4) problems with storage vessels and fuel delivery system components including improper filters or the lack of filters in the system or any number of similar problems with vehicles. As you consider your present situation with diesel fuel, consider the following circumstances and turn to the appropriate section of this guidebook.

I am using diesel fuel now with no problems, but I want to keep it that way

I am having some problems with diesel fuel filter plugging

It seems like I've tried everything and I'm still having problems

If this guide has not helped you identify and solve your fuel related problem, contact your fuel supplier. They should help you resolve fuel related issues. However, this does not absolve you, the fuel user, from taking the appropriate steps to safeguard the product you purchase. Proper tank maintenance and housekeeping are the responsibility of the fuel purchaser. In an effort to promote the successful use of biodiesel, there is a Minnesota Diesel/Biodiesel Hotline in place to provide technical assistance to answer questions, help diagnose problems and offer recommendations.

Minnesota Diesel/Biodiesel Hotline: 1-800-929-3437

Working with Fuel Suppliers

The vendor and fleet manager should establish a contractual agreement to ensure product quality on a consistent basis. The following guidelines are designed to ensure receipt of a quality product and minimize potential problems with diesel or biodiesel blends.

General Guidelines

- Ensure that fuel you purchase from your supplier meets ASTM specifications D6751 for B100, D7647 for B6 through B20 and D975 for petroleum diesel including biodiesel blends up to B5. (See Appendix 1 for fuel specifications and a glossary of terms)
- Be sure proper mixing and agitation of biodiesel blends are employed to assure a thorough blend is deployed to your storage vessel. (page 5)
- Always retain a one-quart sample of fuel at delivery. Look at a sample of the fuel in a clear mason jar. The fuel should be clear and bright. Save this sample until the next load of fuel is received. Discard the sample by adding it to the fuel tank.
- As with any ULSD, biodiesel has a shelf life of 6 months to avoid microbial growth and product degradation. With the proper housekeeping, and additives, the shelf life can be extended. Consult your fuel supplier for proper recommendations and testing. Page
- Ensure diesel fuel or biodiesel blends meet cold flow operability and any operational needs by discussing your needs with your supplier prior to purchase. Determine how long your fuel will be in storage. Fuel purchased in July does not contain cold flow additives. If you will be using this fuel in winter months, you may need to add cold flow additives.
- As an additional level of confidence, choose biodiesel marketers and producers that have attained National Biodiesel Board BQ-9000 quality program accreditation. (See Fuel Quality below)
- Be sure your fuel storage tank is clean and free of water at all times, especially with biodiesel blends.
- If you use a biodiesel blend over 5% check with your Original Equipment Manufacturer (OEM) for compatibility with your chosen blend.

Fuel Quality

It is important that when you are purchasing fuel you make sure it is high quality by meeting all ASTM specifications. Fuel that is off specification on just one of the ASTM standards can not only cause serious engine problems, but it can void engine warranties if it is determined that the fuel caused damage. This can cause unnecessary costly repairs for vehicles/equipment. To review specifications for diesel fuel, biodiesel and biodiesel blends, see the specifications in the Appendix.

In an effort ensure that producers and marketers operate in a manner consistent with proper specifications, the National Biodiesel Accreditation Commission created the BQ-9000 program in 2005. This voluntary program establishes quality systems for producers and marketers of biodiesel in the areas of storage, sampling, testing, blending, shipping, distribution and fuel management practices. If purchasing B100 or a biodiesel blend, ask if the biodiesel is from a BQ-9000 biodiesel producer/marketer. If you are unable to get fuel from a BQ-9000 producer/marketer, the next best thing is to verify with your supplier that the fuel meets all ASTM specifications. More information and a list of biodiesel producers and marketers is available at: www.biodiesel.org.

Blending and Storage

Minnesota has a biodiesel mandate – there is no blending required by the end user. In most cases the blending process takes place right at the terminal rack by a process called in-line blending. This is the preferred method because it ensures complete blending. In-line blending occurs when warm biodiesel is added to a stream of diesel fuel as it travels through a pipe or hose in such a way that the biodiesel and diesel fuel become thoroughly mixed by the turbulent movement. This product is sold directly to customers, petroleum jobbers or a distribution company for sale to customers. Minnesota is confident there will be few issues with the use of B5 as the D975 specification for diesel fuel now clearly states that biodiesel blends of up to 5 percent fall within standard specifications.

It is always possible if you want a higher biodiesel blend to ask you supplier. They should be able to deliver/supply any blend of biodiesel that you request. While it is not recommended, if you are going to blend biodiesel into diesel yourself, make sure to follow the blending guidelines below. In doing so you can help ensure that your fuel is properly blended.

Blending Your Own Fuel

First be sure the (D975) diesel and (D6751) biodiesel blending components all meet ASTM specifications as shown in the Appendix and that biodiesel is BQ9000 certified. Biodiesel Stock (B100) and biodiesel blends must be clean in appearance and free of water and sediment. Fuel that is not clear and bright indicates either poor fuel handling and/or storage practices, or poor fuel quality. Biodiesel blending procedures depend on a variety of factors, including the volume of B100 required to make the blend, the finished blend level, the volume of blended products being sold, tank and space availability, and equipment and operational costs. The temperature of the biodiesel should be a minimum of 60°F or 10°F above the cloud point when being blended.

In-line blending, properly designed and executed (as done at refineries and pipeline terminals in Minnesota), is the best way to ensure complete blending of biodiesel and diesel fuel. Splash blending, however, (blending of diesel and biodiesel in separate streams into a transport or truck tank) may be used in locations where in-line blending is not available.

For top loading trucks in warm weather, if possible load both products at the same time through separate lines at high enough fill rates to sufficiently mix the products in the tank. If diesel and biodiesel must be added separately or at separate locations, it is recommended that the diesel fuel be loaded first, then biodiesel be introduced with as high volume and velocity as possible to enhance thorough blending. It is important that the B100 is kept at least 10°F above the cloud point while blending takes place.

An empty truck tank can be so cold that in a short time, biodiesel can cool and gel on the tank bottom before blending takes place. If in-line blending for top loading trucks is not available in cold weather, first add half the diesel (warm if possible). Then, as quickly as possible, add warm (60º F or more) biodiesel at high pressure and volume to enhance thorough mixing followed by the other half of the diesel fuel.

Splash blending may also be done in bottom loading transports. For bottom loading in warmer weather, the biodiesel is loaded in the tank through the manifold system first, followed by the diesel fuel. A homogeneous mixture should be obtained if the flow rate of the diesel fuel is adequate (several hundred gallons per minute).

If in-line blending is not available for bottom loading trucks in cold weather, it is important that the B100 is kept at least 10° F above the cloud point (preferably 60º F or more) while blending takes place. An empty truck tank can be

so cold that in a short time, biodiesel can cool and gel in the manifold before blending takes place. Therefore, in cold conditions, introduce half the diesel fuel (warm if possible) through the manifold first, then add warm biodiesel (60º F) at a high volume and pressure through a port in the top of the tank to get maximum turbulence. Finally, introduce the other half of the diesel through the bottom manifold with as high pressure and volume as possible.

Further agitation may be necessary to achieve a homogeneous blend. The start and stop action of the truck during delivery can be helpful and, if the entire load is pumped into the customer storage tank, this action will usually be enough to cause complete mixing.

For more detailed recommendations on splash blending talk to your supplier.

B100 should be stored at temperatures of at least 50°F or 10°F higher than its cloud point (which can vary depending on the source) prior to blending with petroleum diesel to ensure adequate blending. Depending on the climate and storage method, insulation, agitation, heating systems or other methods to maintain the targeted temperature may be required.

Storage Tanks and Materials Compatibility

Underground storage tanks are preferred to avoid temperature extremes. Above ground storage tanks should be sheltered or painted with reflective paint to resist excessive heat in the summer. High temperatures during storage accelerate fuel degradation. Brass, bronze, copper, lead, tin and zinc may accelerate the oxidation of diesel and biodiesel fuel and potentially create sediments, gels or salts when reacted with some fuel components. Acceptable storage materials include stainless steel, aluminum, Teflon® and most fiberglass. Lead solders, zinc linings, copper pipes, brass regulators and copper fittings should be avoided. According to a National Renewable Energy Laboratory study, elastomers exposed to blends of B20 or less did not exhibit significant changes in dimensions or volume from those exposed to the baseline diesel fuel. The results indicate that all of the elastomers appear to be compatible with biodiesel blends of B20 or less. There are concerns that as temperatures increase, compatibility can be negatively impacted. This is currently being studied by the elastomers manufacturing industry. Watch for leaks and swelling in gaskets.

Fuel Tank Maintenance

Routine maintenance of your fuel system is the key to avoiding fuel related problems. The monitoring and elimination of water in your fuel system is the best preventative measure to take. Overtime, operational problems such as corrosion and sediment buildup can also occur in diesel fuel systems. The presence of free water can promote fuel system corrosion and microbial growth. Microbes live in the interface that forms between the fuel and the free water. Since the introduction of ULSD, microbial contamination in diesel fuel has become a more common problem. Blends of biodiesel and diesel fuel and the presence of free water may increase the propensity for microbial growth in the fuel system. It is recommended that storage tanks have a dispenser filter installed to keep any contamination from being passed along to vehicles.

Checking Tanks for Water and Sediment

To ensure contaminants do not create fuel quality issues it is important to remove them before they buildup. Every fuel system has the potential to experience problems so it is necessary to check frequently for contamination. Every fuel system should be inspected per federal, state and local regulations. In addition to those inspections it is necessary to look for contamination. It is recommended that a storage tank be checked for water and sediment prior to each fuel delivery. If the frequency of the deliveries is such that months go by between them, then check the fuel tank at least once a month. If contamination is found, it should be removed as soon as possible. Water should be removed either by draining water off the tank if it is equipped with a water draw or with a vacuum truck. Whichever

method is used, the removal should be done slowly so that free water can travel to the low point in the tank. A visual inspection of the water and fuel should be done at the same time and continued until the fuel is clear and bright.

Checking Tanks for Microbial Contamination

It is recommended that fuel tanks be tested for microbial contamination twice a year, preferably in the fall and spring. To test for microbial contamination, obtain a quart sample from the tank bottom (see page 11 for information about tank sampling). Contact your fuel distributor about performing a microbial test. Many fuel distributors perform this test for a fee or can give a referral to a reputable lab that can perform testing. The costs associated with routine testing is a small price to pay in relation to the cost of fuel in the fuel tank, the cost to have vehicles go down due to filter plugging and the cost of biocide used to treat microbial contamination. (See page 13-15 for more information on microbial contamination)

Tank Cleaning

If sediment is found then a vacuum truck should be used with a scavenger device to effectively navigate around the tank and remove the contamination. Depending on the severity of the contamination, an internal tank cleaning may be necessary to effectively remove contaminates. Tank cleaning should take place one of two ways; (1) with the use of a high pressure hose with fuel, or (2) by physically scrubbing the inside of the tank. Both cleaning methods will use impingement cleaning, meaning all surfaces are cleaned with either high pressure or physical scrubbing.

Housekeeping Tips

The importance of keeping your tank and fuel system free of contaminants has never been more important than with the introduction of ULSD and biodiesel. Water and sediment can cause fuel filters to plug prematurely and/or fuel quality issues. Inspections and basic housekeeping practices will help promote a problem free experience. Tank venting is a source for water and contaminants to enter into the tank. Vents should be inspected for proper operation and to make sure that water cannot enter into the tank. A desiccant drier in the vent is highly recommended so that water does not enter the tank through the vent system.

Another critical source of contamination is the filling pipe to the tank. Underground storage tanks typically have the filling pipe at or below grade. It is very important that the ground around the filling containment pot is sloped in such a manner that water and debris are drained away from the opening. The lids and caps should be secured and have gaskets to maintain tight seals to prevent any leakage into the tank. The containment area (secondary containment for the fill pipe) should always be checked with a stick (approximately 2 to 3 feet long) and water detecting paste. If any contamination is found it should be removed and not allowed to be drained into the storage tank. Any contamination can be removed by a vacuum truck or a hand held pump. This contaminated product should be disposed of per EPA regulations.

The fuel tank should be checked monthly by obtaining a tank bottom sample. This sample should be visually inspected for water and sediment. Use a clear mason jar for visibility. The sample should look clear and bright. If any free water and/or sediment are found or the sample appears hazy, the water should be removed. To effectively remove contamination from the low end of a storage tank, a vacuum truck should be used with a scavenger. This will allow the device to travel around and slowly remove the contamination.

Summary

- Fuel tanks should be kept as full as possible to reduce the amount of air and water entering the tank.
- Desiccant driers are recommended in tank vent openings.
- Monitor hoses, fill/vapor caps, gaskets for leaks.
- Visually check tanks monthly for free water by obtaining a tank bottom sample.
- Check fuel containment area for water regularly. Remove water when needed.
- Always install a dispenser filter on a storage tank. If there are any issues with contaminants, the dispenser filter will plug but keep it from progressing to the vehicle tanks.
- In the fall before colder weather sets in, check tanks for water concentration and microbial contamination. Check again in the spring.

Fuel Tank Sampling

Before attempting to sample a fuel tank it is important to prepare the necessary equipment (sampling device, a drop-line that is as long as the tank is high and sample containers). Determine what device is going to achieve the best results for the sample being sought. The Bacon Bomb sampler is a very reliable device and is going to retrieve the best bottom sample from a fuel storage tank. It is available in many different sizes to fit almost all tank openings.

Try to make sure that you are sampling the lowest point of the tank. Underground storage tanks can shift and settle overtime. Free water and sediment will settle to the lowest point of the tank. It is best if you can sample from both ends of the tank so you can determine which end is the lowest point.

Refer to the sampling device operating instructions. Prepare the sampling equipment by double checking that all equipment is securely fastened and will not be accidentally lost after dropping it down into the tank. Lower the sampling device slowly into the tank to the desired fuel level to obtain the sample. This may have to be repeated several times to achieve the required quantity. Immediately label the sample so it can be identified (tank number, bottom, top, etc.). After retrieving the desired sample, be sure to securely close all lids and double check them; they should be snug to prevent contaminants from entering into the fuel tank. It is preferred to have the sample retrieved directly off of the bottom of the tank, as this is where water/sediment and many fuel contaminants will most likely be located. If the sample is good from the bottom of the tank, the fuel is good throughout. If trying to obtain a sample for further fuel quality testing, make sure that the sample is not full of water and sediment. If the bottom sample is full of water and/or sediment and it is needed for further testing, it may be better to retrieve a fuel sample from a different level in the fuel tank. Samples to be tested should be put in a clean, sealable, high density plastic bottle (PETE – polyethylene terephthalate or similar) or aluminum container filled to 90 percent capacity. The sooner the sample is sent to the lab the more accurate the results. Refrigeration will preserve the sample until it can be sent to the lab.

In order to sample different levels of the fuel, use a chain or small rope attached to the plunger on the Bacon Bomb. Drop the bomb to the desired level and then pull on the plunger until the sampler is filled and then release. If testing a tank that is suspected to have some form of contamination, it is advisable to retrieve a bottom, middle and top sample to determine the extent of contamination and to determine if the fuel was properly blended.

Fuel Filtration

When switching to biodiesel, some users have experienced problems with premature fuel filter plugging. This is not an issue at low level biodiesel blends but more commonly seen with blends of B20 or higher. This section is designed to help troubleshoot fuel filter plugging.

General Information

Fuel filters are designed to remove water and particulate from fuel in order to protect the fuel system. They are designed to eventually plug. You may want to investigate if you have a change in the frequency of filter changing.

The Original Equipment Manufacturer (OEM) has specified filters for each fuel system to provide optimum performance. When replacing the filters, it is strongly recommended to continue to use the OEM filters or the equivalent aftermarket filters. OEM is not the local mechanic. Check with the OEM headquarters.

Common Challenges

Stability – It is recommended that biodiesel be used within six months of the manufacturing date. Exposure to air, heat, light, water and some metals are contributing factors that will cause it to degrade. A common symptom encountered with degraded fuel is plugged filters. With the proper housekeeping and additives, the shelf life can

be extended. Consult your fuel supplier for proper recommendations and testing.

Cold Flow – Biodiesel has a much higher cloud point/pour point than petroleum diesel fuel. Pure biodiesel can start to cloud at 55°F and gel by 32°F. Cold temperatures may lead to other problems. Wax and water present in the fuel can precipitate in cold temperatures. Additionally, cold temperatures accelerate the process of glycerin and sterol glycosides in biodiesel forming particulates and dropping out of solution.

Water Separation – Water is present in fuel and therefore many fuel systems require a method of water removal before it reaches the fuel injectors.

- Biodiesel has a higher capacity to hold dissolved water.
- Removing water from biodiesel is more difficult than petroleum fuel.
- Water in fuel can lead to increased growth of microbes.
- Water can lead to corrosion in the fuel system.

Cleaning/Solvent Effects – Biodiesel (B100) is an excellent solvent for cleaning any hydrocarbon deposits that may have formed in the fuel system. After switching to biodiesel it is expected that fuel filters may plug quickly to begin with and then return to a normal change interval after the fuel system is cleaned. The same solvency effect can also lead to some other material compatibility problems in the fuel system. It is important to check with your OEM to make sure fuel system components are compatible with the desired concentration of biodiesel.
Microbes – Microbes is a broad description for any biological growth that can occur in the fuel with the presence of water. They are becoming a more common problem in diesel fuel because the ultra low sulfur levels do not inhibit their growth as in the days of high sulfur diesel. The microbes can form a film of sediment that can plug fuel filters. This film is usually found on the interface between the fuel and the water. It is very difficult to get rid of the microbes once they are present. First remove all the free water and treat with a reputable biocide. (See page 15-16 for more information on microbial contamination)

Filter Recommendations

When choosing a filter it is important to consider the OEM specifications. It is best to continue to use the same style and efficiency filter. If it is not obvious what the performance level of the current filter is, try searching the internet or calling the manufacturer. Filters are typically rated in either a percentage or a beta ratio. For example a β10 = 100 means that for particles that are equal or greater than 10µm there are 100 times more particles captured by the filter then passing through the filter. The percentage would be listed the same way—for example, 99% of the 10 micron particles are being removed.

The efficiency of the filter is very important because it is the level of filtration that must be maintained to ensure no damage is done by hard or abrasive particles. If a lower efficiency filter is installed it can cause premature engine wear and damage. If a higher efficiency filter is installed, it can cause performance issues such as power loss, fuel flow problems and frequent filter plugging.

It is highly recommended to add a filter to bulk storage tanks. This will help remove water and particulate contamination before they reach the vehicle. There are two ways to add filters to storage tanks, the first is a side filtration loop and the second is in-line with the fuel pump, between the tank and the vehicle fill. A side filtration loop could be a separate recirculation pump that pushes the fuel through a series of filters to keep it clean and then put the fuel back into the tank. A dispenser fuel filter would filter all of the fuel that goes into the vehicle so less contaminant reaches the fuel tank on the vehicle. Both types of filtration can be utilized to provide more efficient filtration then the vehicle requires by capturing more contaminant.

For water separation, you can choose either a water stripping filter or a water coalescence filter. Both types of filters should remove the water and allow the separated water to be collected at the bottom of the filter. It is important to drain water from the filter daily to prevent water from going back into fuel, forcing its way through the filter or degrading the fuel. Keep in mind that a water separating filter is generally run in the suction side of the fuel pump, so it cannot handle a high pressure drop. To extend the life of the suction side /primary filter, a larger filter, with the same efficiency, can be installed. The larger filter will be able to spread the contaminant around more effectively and provide less flow resistance due to the larger media surface area.

It is very important to monitor the water separating filter on the truck and drain it daily. On an annual basis it is advised to take fuel samples from the bottom of the tank to look for free water and sediment.
Many OEMs use secondary filters; these filters are on the pressure side of the fuel pump. They come in a variety of particle efficiencies that are determined by the OEMs. By using a secondary filter, the primary filter can be made less efficient to prevent frequent power losses and provide a longer field life. The pressure side filter is more efficient and can handle a much higher pressure drop across the filter before any power loss problems are noticed.

Cold Weather Operability

Like regular diesel fuels, biodiesel blends will gel in very cold temperatures. Typically No.2 diesel fuel has a cloud point in the range of -10 to 20°F and No.1 diesel fuel has a cloud point -40°F or less. That means without the use of cold flow improving additives, No.2 diesel will begin to gel and plug filters at their cloud point. Blends of No.1 and No.2 diesel fuel, the use of cold flow additives and/or fuel heating systems are frequently used to meet cold flow operability requirements for the temperatures expected.

The cold flow properties of biodiesel blends up to 5% will be virtually the same as those of the diesel fuel used in the blend. Biodiesel blends over 5% will begin to have higher cloud points and require the use of cold flow additives or No.1 diesel in order to operate in Minnesota winters. All diesel fuel is different. Neither ASTM D975 nor D7467 have a cloud point specification but do require that it be reported to the customer. Work with your fuel distributor to achieve the desired cold weather protection. Get your fuel tested for cloud point and CFPP to determine the level operability. Adjust the ratio of No.1 and additives as needed. Proper tank maintenance and housekeeping practices will further ensure cold weather operability.

Definitions:

Filter Media – *paper/synthetic material inside a filter that extracts contaminants from a fluid.*

Filtration Efficiency *– percentage of contaminants removed by a filter. Filters are rated based on their ability to remove standard dusts of specific particle sizes. To avoid problems make sure the filters chosen follow the OEM specifications for the engine.*

Dissolved Water *– water which is dissolved in fuel; not visible.*

Free Water *– water separate from the fuel; will be visibly separated on the bottom of the tank or vessel.*

Emulsified Water *– small droplets of water that are suspended in the fuel; gives fuel a cloudy appearance.*

Diagnosing Filter Plugging Sources

The following are descriptions of filters that experience filter plugging and their probable cause. This list will help determine what may be the cause of your filter plugging.

Description of Plugged Filter	Likely Cause
Swollen, frayed filter media	Water Contamination (page 10)
Swollen filter, may be covered with glycerin	Water Contamination (page 10)
Slimy filter with odor	Microbial Contamination (page 10)
Black slimy filter with or without odor	Microbial Contamination (page 10)
Filter with brown Vaseline-like substance in the folds	Mono/Diglyceride Build Up (Biodiesel fallout) (page 11)
Fine, black sediment on the filter	Oxidation (page 11)
Black, smooth filter looks like colored with a black a magic marker	Oxidation (page 11)
Clean filter, hazy fuel	Paraffin Wax or Water Contamination
Granules, sediment in the folds	Sediment (page 11)
Filter with wax substance in the folds at temperature at or below the cloud point	Paraffin Wax (page 11)

Water Contamination

High water concentration in the fuel can lead to a build up of water in the filters. Accumulating water can cause many different problems. When excess water is present, fuel filters will swell causing a distortion of the filter. This distortion is visible as the media will be swollen and separating from the end caps. Water that builds up in the filter can also cause icing problems. When the temperature of the filter gets below the 32°F, the excess water freezes and blocks the flow of fuel through the filter. Icing in the filter can be hard to diagnose. When the filter is removed and examined the ice has usually melted. The presence of water can also pull solid elements of biodiesel out of solution. When filters swell with water, glycerin can become attracted to the water on the filter. The glycerin builds up until the filter plugs. Water is the number one cause of filter plugging issues in diesel engines. Routinely checking and removing water in tanks and filters can help minimize problems with plugging filters. (See page 10 for tips on fuel tank maintenance)

Microbial Contamination

Another common filter plugging issue is microbial contamination. Since the introduction of ULSD in 2006, microbial contamination has become a more common problem associated with diesel fuel. Higher sulfur levels used to act as a natural antimicrobial. Bacteria and fungus grow in the water/fuel interface. They can be present in both supply tanks, and vehicle tanks; supply lines and fuel system components. Microbial contamination in filters is often recognized by its smell. Microbial contamination may or may not be accompanied by a brown/black/beige jelly-like byproduct created by the growth. Without water,

microbes cannot grow. This issue can be avoided by routine water maintenance. (See page 10 for tips on fuel tank maintenance) If microbial contamination is apparent, it is recommended that you treat the contamination with a reputable biocide at twice the kill/shock rate. It may also be advisable to contact your fuel distributor to perform a microbial test or recommend a lab that can.

Oxidation

In modern, heavy duty diesel engines, only a portion of the fuel that is circulated to the fuel injectors is actually delivered to the combustion chamber. The remainder of the fuel is circulated back to the fuel tank carrying heat with it. Oxidation is caused by hot fuel returning to the tank and could cause something similar to coking the fuel (burning of the fuel causing it to breakdown and create sediment). In many newer fuel systems, the time it takes to return unused fuel back into the tank has decreased. This fuel, as it comes from the engine, is extremely hot. When this hot fuel enters the cold fuel tank, it will cause the breakdown and oxidation of the fuel. The fuel that is broken down forms sediment that can cause filter plugging. This sediment can be found on the filter element in the form of black granules, which turn the filter black. The first remedy of this situation is to have the fuel system checked to determine if it is functioning properly. If the system is performing as it should, it may also be necessary to use a stability additive for the fuel.

Paraffin Wax

When the temperature of the fuel is at or below its cloud point, paraffin material can precipitate out and collect on the bottom of the tank. In this situation, filters will often times show no signs of filter plugging which is the tell tale sign. When the filter is brought into a warm location to be examined, the paraffin melts and leaves no evidence. The fuel that is experiencing filter plugging problems will appear hazy. When warmed to room temperature, the paraffin wax will go back into liquid. High levels of paraffin material could be the result of the way ULSD is processed. There is no paraffin in biodiesel. WASA or Wax Anti-Settling Agent additives are used to keep paraffin's suspended in solution rather than collecting at the bottom of the tank where they can cause filter plugging. Contact your fuel distributor if this you think your filters were plugged by paraffin wax.

Mono/Diglyceride Build Up (Biodiesel fallout)

An off specification of the total glycerin limits in the biodiesel specification ASTM D6751 will cause a mono/diglyceride build up on the filter. In this case, the filters are plugged with a brown substance similar to brown Vaseline. If this is the case it is recommended that you check with your fuel distributor to ensure that the fuel meets all specifications; specifically it should be checked for free glycerin. Water absorbing filters hold water on the media and then attract glycerin. Glycerin continues to accumulate and doesn't go back into liquid. Unlike the wax drop out caused by paraffin, it takes temperatures of 150°F or more to melt glycerin back into liquid. Sediment on the filter also attracts glycerin. In both of these instances, glycerin may not be the root cause of the filter plugging.

Sediment

In many cases tanks and fuel systems can go un-maintained and neglected. Sediment caused by rust, tank scale and other contaminants will plug fuel filters. Filters plugged by sediment are characterized by sediment in the folds of the filter and solid particles in the filter casing. Sediment on the filter also attracts glycerin which further plugs the filter. It is recommended that tanks be monitored and cleaned when necessary in order to reduce tank contaminants. (See page 10 for fuel tank maintenance)

**It is recommended to change fuel filters going into the winter season. Most causes of fuel filter plugging are more pronounced in the cold weather.

Appendix 1: ASTM Fuel Property Standards

Standards are available from ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA, 19428-2959 USA. www.astm.org.

D975 No. 2 Diesel Fuel

Biodiesel blends up to 5 percent are considered no different than conventional No. 2 petroleum diesel. These blends will meet the ASTM D975 fuel specification and can be used in any application as if they were pure petroleum diesel. No special labeling is required at retail pumps to inform consumers that biodiesel is contained in the fuel.

Property	**ASTM Method**	Limits	Units
Flash Point	D 93	125 min.	Degrees F
Water & Sediment	D 2709	0.05 max.	% vol.
Distillation (One of the following must be met)			
(1) Physical Distillation,T90	D 86	640 max.	Degrees F
(2) Simulated Distillation,T90	D 2887	673 max.	Degrees F
Kinematic Viscosity, 104°F	D 445	1.9 - 4.1	mm2/sec.
Ash	D 482	0.01 max.	% 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 max.	
Cetane Number	D 613	40 min.	
One of the following must be met			
(1) Cetane Index		40 min.	
(2) Aromaticity		35 max.	% volume
Ramsbottom Carbon Residue	D 524	0.35 max.	% mass
10% residue			
Cloud Point	D 2500	Report	Degrees F
Lubricity, HFRR @ 140°F	D 6079	520 max.	micron

D6751 (B100) 100% Biodiesel

Any biodiesel used in the United States must meet all of these specifications before it can be used for blending and meet the following definition:

Biodiesel, noun: a fuel comprised of mono-alkyl esters of long chain fatty acids derived from vegetable oils, animal fats designated B100.

Property	**ASTM Method**	Limits	Units
Calcium & Magnesium, combined	EN 14538	5 max.	ppm (ug/g)
Flash Point (closed cup)	D 93	199.4 min.	Degrees F
Alcohol Control (One of the following must be met)			
(1) Methanol Content	EN14110	0.2 max.	% volume
(2) Flash Point	D93	266 min.	Degrees F
Water & Sediment	D 2709	0.05 max.	% vol.
Kinematic Viscosity, 104°F	D 445	1.9 - 6.0	mm2/sec.
Sulfated Ash	D 874	0.02 max.	% mass
Sulfur			
S 15 Grade	D 5453	0.0015 max. (15)	% mass
S 500 Grade	D 5453	0.05 max. (500)	% mass
Copper Strip Corrosion	D 130	No. 3 max.	
Cetane	D 613	47 min.	
Cloud Point	D 2500	Report	Degrees F
Ramsbottom Carbon Residue	D 4530	0.05 max.	% mass
100% sample			
Acid Number	D 664	0.50 max.	mg KOH/g
Free Glycerin	D 6584	0.020 max.	% mass
Total Glycerin	D 6584	0.240 max.	% mass
Phosphorus Content	D 4951	0.001 max.	% mass
Distillation, T90 AET	D 1160	680 max.	Degrees F
Sodium/Potassium, combined	EN 14538	5 max.	ppm
Oxidation Stability	EN 14112	3 minimum	Hours
Cold Soak Filtration	Annex to 6751	360 max.	Seconds
For use in temps below 10.4°F	Annex to 6751	200 max.	Seconds

D7467 Biodiesel Blends from B6 to B20

Biodiesel blends that contain 6 to 20 percent biodiesel have a separate specification. These blends can be used in many applications that use diesel fuel with minor or no modifications to equipment. Retail fuel pumps are required to indicate that the fuel contains 6 to 20 percent biodiesel in the fuel.

Property	**ASTM Method**	Limits	Units
Acid Number	D 664	0.30 max.	mg KOH/g
Viscosity, 104°F	D 445	1.9 - 4.1	mm2/sec.
Flash Point	D 93	125 min.	Degrees F
Cloud Point	D 2500	Report	Degrees F
Sulfur			
S 15 Grade	D 5453	0.0015 max. (15)	% mass (ppm)
S 500 Grade	D 5453	0.05 max. (500)	% mass (ppm)
Physical Distillation, T90	D 86	650 max	Degrees F
Ramsbottom Carbon Residue	D 524	0.35 max.	% mass
10% residue			
Cetane Number	D 613	40 min.	
One of the following must be met			
(1) Cetane Index	D 976-80	40 min.	
(2) Aromaticity	D 1319-03	35 max.	% volume
Ash	D 482	0.01 max.	% mass
Water & Sediment	D 2709	0.05 max.	% vol.
Copper Strip Corrosion	D 130	No. 1 max.	
Phosphorus Content	D 4951	0.001 max.	% mass
Oxidation Stability	EN 14112	6 min	hours
Biodiesel Content	D 7371	6-20%	% volume
Lubricity, HFRR @ 140°F	D 6079	520 max.	micron

Appendix 2: Fuel Property Descriptions

(from ASTM D975, D6751 and D7467)

Aromaticity – This test indicates the aromatic content of diesel fuel. Increased aromatic content of fuels over specified levels may have a negative impact on emissions.

Ash – This test measures the amount of residual alkali catalyst (chemical used in the production of biodiesel) in the biodiesel as well as any other ash-forming compounds that could contribute to injector deposits or fuel system fouling. Abrasive solids and biodiesel catalyst materials result in wear of fuel system and internal engine components exposed to fuel after injection. Metallic soaps can contribute to deposits in the fuel system. All ash-forming compounds can contribute to the accumulation of materials on diesel particulate filters, requiring increased filter maintenance.

Biodiesel Content – The percentage of biodiesel in volume of B100 in diesel fuel. It is important that the amount of biodiesel utilized in a given fuel blend be identified on the invoice and that the product is uniformly blended.

Cetane – An adequate cetane number is required for good engine performance. Conventional diesel must have a cetane number of at least 40 in the United States. Higher cetane numbers help ensure good cold start properties and minimize the formation of white smoke.

Cloud Point – The temperature at which the first solids form and are visible to the naked eye. This is the most commonly used measure of low-temperature operability; fuels are generally expected to operate at temperatures as low or lower than their cloud point. Biodiesel typically has a higher cloud point than petroleum diesel.

Cold Filter Plugging Point (CFPP) – This is the temperature under a standard set of test conditions (ASTM D6371) at which the filter plugs. The sample is cooled and tested at intervals of 1°C until the wax crystals precipitate out of solution and are sufficient to slow or stop the flow of fuel through the filter.

Cold Soak Filterability – This is the newest requirement. It was added in 2008 in response to data indicating that some B100 could, in blends up to B20, form precipitates above the cloud point. Blends that meet this specification will not form precipitates. This, along with cloud point, is needed to predict low-temperature operability.

Copper Strip Corrosion – The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper alloys such as brass and bronze.

Flash Point – The flash point as specified is not directly related to engine performance. It is, however, of importance in connection with legal requirements and safety precautions involved in fuel handling and storage, and it is normally specified to meet insurance and fire regulations.

Kinematic Viscosity – A minimum viscosity level is required for some engines because of the potential for power loss caused by injection pump and injector leakage. The maximum viscosity is limited by the design of the engine fuel injections systems. Higher viscosity fuels can cause poor fuel combustion that leads to deposit formation as well as higher in-cylinder penetration of the fuel spray, which can result in elevated engine oil dilution with fuel.

Lubricity – This test measures the wear caused by friction between metal parts. Fuel system components are lubricated by the fuel itself. Wear or scarring is a sign of inadequate lubricity. Poor lubricity can result in shorter life of components.

Magnesium and Calcium – Magnesium and calcium are “alkali metals” utilized as absorbents in the production of biodiesel and should be removed through a biodiesel production process that meets the requirements of ASTM D6751. Residual alkaline metals can form deposits in the fuel injection system components and poison emission control after treatment systems.

Oxidation Stability – Biodiesel can oxidize during storage and handling, leading to the formation of peroxides, acids, gums and deposits. The minimum oxidation stability requirement is intended to ensure the storage stability of B100 and biodiesel blends.

Phosphorous – Phosphorous has been shown to hinder the capability of after treatment systems to reduce exhaust emission. The phosphorous accumulates on the after treatment system. Therefore, very low levels of contamination may lead to deterioration of the after treatment system. The phosphorous limit in the B100 Specification is intended to minimize any potential issues associated with phosphorous' impact on the after treatment devices in blended fuels.

Physical distillation – Distillation provides a measure of the temperature range over which a fuel volatizes or turns to a vapor. Lighter fuels typically have a greater volatility than heavier fuels.

Ramsbottom Carbon Residue – This test is intended to provide some indication of the extent of the carbon residue that results from the combustion of the fuel. Biodiesel blends are required to meet the same ASTM D975 limit.

Sodium and Potassium – Sodium and potassium are "alkali metals" utilized as catalysts in the production of biodiesel and should be removed through a biodiesel production process that meets the requirements of ASTM D6751. Residual alkaline metals can form deposits in the fuel injection system components and poison emission control after treatment systems.

Sulfur – Sulfur levels in fuel are regulated by various governmental agencies to assure compatibility with emission standard requirements. In the United States there are currently three sulfur grades: S5000, S500 and S15 for both No. 1 and No. 2 petroleum diesel fuel. Biodiesel blends are required to meet the same maximum sulfur content for the intended application.

Water and sediment – This refers to free water droplets and sediment particles. The allowable level for B100 and B6 to B20 blends is set at the same level allowed for conventional diesel fuel. Excess water can lead to corrosion and provides an environment for microorganisms. Fuel oxidation can also raise sediment levels, so this test can be used in conjunction with acid number and viscosity to determine if fuels have oxidized too much during storage.