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Biodiesel Fuels Seminar – September 2014

Executive Summary

Biodiesel (fats converted into fuel) has become a significant player in the fuels marketplace, with production and use increasing exponentially since the mid-to-late 2000s. Biodiesel blends offer excellent environmental and operational benefits for consumers, including increased cetane and lubricity, and lower emissions. Biodiesel's largest drawbacks of storage instability and gelling in cold weather (which can vary substantially depending on the oil from which the biodiesel was made) may be cost-effectively treated with bio-specific fuel treatments such as **Bio Dee-Zol Life** and **Bio Cold Flow Improver** from Bell Performance.

"What is Biodiesel" – Definition and Terminology

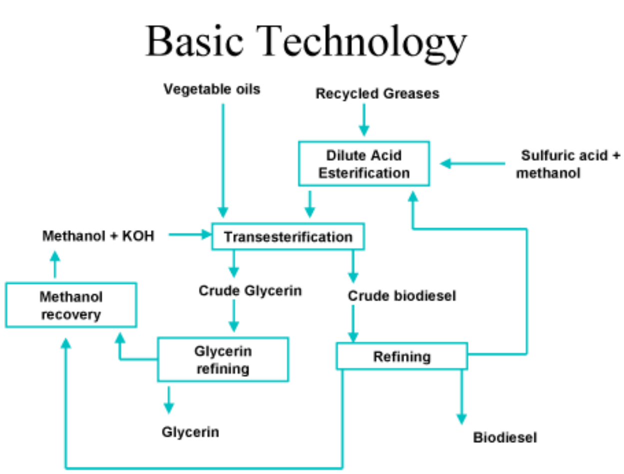
"Biodiesel" is a fat that has been transformed through a series of chemical reactions, producing a fuel that can be burned in a diesel engine in place of conventional #2 petrodiesel fuel.

Contrary to the terms that are thrown around in the marketplace and on Internet message boards, "biodiesel" refers to the actual "FAME" chemical that results from the chemical conversion of fat into fuel. The legal definition of biodiesel is "a long chain fatty acid ester containing only one alcohol molecule on one ester linkage". Thus, "FAME" stands for "fully alkylated methyl ester".

Some consumers talk about putting raw vegetable oil or animal fat in their vehicle and burning it as fuel, referring to this practice as burning biodiesel fuel. However, raw vegetable oil chemically contains three ester linkages and therefore is not legally defined as biodiesel.

Whenever the sole term "biodiesel" is used, legally it always refers to the 100% FAME product. Pure biodiesel is also preferred to as B100 (100% biodiesel). When biodiesel FAME is mixed with diesel fuel, you get a "biodiesel blend" that is designated as Bxx, relating to the percentage of biodiesel within the overall blend. B2, B5, B11 and B20 are the most popular and commonly found blends. Blends above 20% are more difficult to find because engine manufacturers do not warrant their engines to run on blends above 20% biodiesel. B2 and B5 are very commonly found in states that have a biodiesel mandate, such as Minnesota and Louisiana. Minnesota was the first state in the Union to mandate state-wide blending of biodiesel into all of their diesel fuel, starting in 2005. It should also be noted that in many states, it is legal to blend up to 5% biodiesel into petrodiesel fuel and not disclose the biodiesel content on the labelling. This means that many diesel users are already using low-level biodiesel blends on an everyday basis, without realizing it.

Making Biodiesel



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Let's talk a little bit about how to make biodiesel The basic recipe for producing biodiesel is:

> *100 units plant/animal oil + 20 units alcohol + catalyst → 100 units of FAME feedstock + 10 units of recovered alcohol + 10 units crude glycerin.*

Another way to produce biodiesel is to take 100 lbs fat + 10 lbs short-chain alcohol + catalyst (NaOH or KOH), all of which yields 100 lbs of biodiesel (about 13.5 gallons) and 10 lbs of glycerin.

The major steps in the process to make biodiesel can be described as such:

> **Pretreatment** – Some feed stocks, like vegetables oil, that have an excess of "free fatty acids" need to be pre-treated in order to increase the ultimate yield of biodiesel after the trans-esterification process. These stocks are reacted with an acid/alcohol mixture and heated. This prepares these feed stocks for maximum biodiesel production.
>
> **Step 1** - Heat the oil feed stock to a designated temperature and them mix it with the alcohol and the catalyst. Chemical reactions (trans-esterification) will take place to create a liquid with two primary layers. The top layer will be the biodiesel FAME (methyl ester). The bottom layer will be glycerin. The FAME must be separated from the glycerin – commercial producers will use centrifuges to do this.
>
> **Step 2**- The biodiesel is now mixed with water (washed), which draws out remaining impurities and any glycerin left over. The FAME can then be distilled to remove any remaining excess methanol. The final step is to heat and filter the biodiesel (drying), which removes any remaining water. The biodiesel is now ready for use.

These formulas and processes speak to why biodiesel production is relatively popular – all of the ingredients are cheap and easy to find, and the reaction processes are fairly simple. You don't need a PhD to produce biodiesel fuel. The catalyst for the reaction is sodium hydroxide, and the short-chain alcohol most commonly used is methanol, both cheap and easy to find. However, the downside to all of this is it is also easy for the small-time "backyard" biodiesel producer to produce biodiesel that of "out-of-spec" if they are not rigorous in their processes.

As stated above, glycerin is the main waste product produced in biodiesel manufacturing, and the nationwide expansion of biodiesel production after 2005 has resulted in an excess of glycerin in the marketplace, causing glycerin prices to drop. This waste glycerin is most commonly disposed of by use in other chemical applications, like soap and makeup production

The washing process (Step 2) is vitally important to producing good biodiesel that meets legal standards. This step removes all of the alcohol and the waste glycerin from the fuel. Biodiesel with excessive amounts of either will be "out-of-spec" and cause engine performance problems that will be touched on later.

Biodiesel Production in the United States

As early as 2001, total biodiesel production in the US was less than 10 million gallons per year.

Year	Production (Million Gallons)
2000	2
2001	5
2002	15
2003	20
2004	37
2005	118
2006	246
2007	512
2008	711
2009	450
……………..	
2012	999
2013	1330

The exponential increase in production after 2004 was due in large part to a federal tax credit of $1.00 per gallon for users of ASTM-spec biodiesel (meaning the biodiesel had to meet all of the ASTM specifications in order to qualify for the tax credit).

Production peaked in 2008 and dropped in 2009 because of market uncertainty due to an upcoming expiration of the tax credit in 2010. The tax credit was later reinstated and production levels for the past couple of years have exceeded even the brightest industry projections from years past.

The Benefits of Biodiesel Use

Now that we know about biodiesel production and how to make it, let's talk about why people like to use it. Biodiesel blends offer some great benefits for consumers:

1. Higher cetane

B100 has a higher cetane number than most conventional diesel fuels; high cetane rating means easier starting and is comparable to the octane rating of gasoline.

Cetane increase varies by the type of feed stock used to manufacture the biodiesel. Highly saturated fuels made from animal fats (like leftover frying animal grease) can have cetane rating as high as 70; polyunsaturated feed stocks (including soy and rape seed) are closer to a 47 cetane rating.

2. Low Sulfur Content

The nature of biodiesel leads to a naturally low sulfur content, which makes it easy to incorporate into a fuel system without running afoul of stringent ultra low sulfur diesel regulations, where sulfur content is capped at a mere 15 ppm (parts per million).

3. Superior lubricity (B2 → 66% more lubricity than #2 diesel)

Making biodiesel blends with ultra-low sulfur diesel solves one of ULSD's biggest problems – lack of lubricity. As little as 2% of biodiesel in a fuel blend adds 66% more lubricity to #2 diesel than before.

However this lubricity increase is not a linear one, as a curve of added lubricity benefit levels off as the composition approaches just 2.5%. So there is no additional benefit of added lubricity when comparing a B5 or a B20 to just a B2 blend.

For test purposes, adding just 1% FAME to ULSD fuel can produce a 50% improvement on lubricity-measuring tests like the BOCLE Scuff test or the HFRR test over pure ULSD.

4. Cleaner Emissions

This is the biggest reason why cities and government entities have been implementing biodiesel and using it for their fleets. Most large urban areas already fail the EPA air standard qualities, which puts them in the hands of the government, which can force them to adopt measures to improve air qualities or else lose federal monies.

Depending on the blend percentage, biodiesel combustion results in lower emissions for most measured emissions:

HC: 2.2 – 67% drop over #2
PM: 1.3 – 47% drop

Biodiesel emissions have lower levels of polycyclic aromatic hydrocarbons and other harmful carbon ring compounds than conventional diesel fuel. A B20 blend will lower those by 20-40%.

Biodiesel has a neutral to slightly negative effect on NOx emissions, which contribute to ozone production and poor air quality. However, these figures are in dispute by the National Biodiesel Board and research is still ongoing.

- NOx: 0.2 – 10% INCREASE

Compared with internal combustion engines, NOx does decrease when biodiesel is burned in **boilers/home heating oil**, due to burner differences (which influence how the fuel is burned and can change burn temperatures, which in turn impact the NOx formation reaction). When blended into heating oil, NOx is reduced by 1% for each 1% biodiesel blend added. This NOx reduction seen with biodiesel blends used in boilers is independent of the type of biodiesel feed stock used (i.e. it happens with all of them).

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The Drawbacks of Biodiesel Use

The negatives of biodiesel should also be considered.

1. Less BTU energy value than Diesel = Less Mileage

Relative to weight, the biodiesel FAME molecule contains less energy than a diesel hydrocarbon chain molecule. Less energy and lower heat of combustion results in lower mileage.

B100 contains 8.5% less energy per gallon than diesel. The biggest part of the energy difference is due to the FAME containing 12% greater oxygen – more oxygen instead of carbon. When you factor in differences in density, this energy difference is reduced to 8.5%.

Typical energy values for the two fuels are 118170 BTU for B100 vs 129,050 BTU for #2 diesel. However, at lower blending ratios like B20, the drop is not noticeable by most drivers, since 80% of the blend is now diesel fuel.

2. Cold Flow problems

Biodiesel cold flow properties are highly dependent on the feed stock from which the biodiesel was made. Highly saturated feed stocks (palm oil, coconut oil, animal fats) have the worst cold flow properties but are the most stable.

A B20 blend has a gel point 3-10 degrees F higher than regular diesel.

The cloud point for most B100 starts at 30-32 deg F for mono- and poly-unsaturated feedstocks (most vegetable oils) but can be up to 80 deg F for animal fats and highly saturated frying oils.

The biodiesel pour point is only a few degrees lower than the cloud point. For example, soy FAME (pure B100) has a cloud point of 38 degrees F, CFPP of 28 and a pour point of 25 F. Other differences between cloud point and pour point are usually 8-10 degrees F total – not very much.

If feasible, gelled biodiesel can be restored by heating the fuel to dissolve the precipitated crystals. To get crystals back into solution, the fuel needs to be warmed back up to 100-110 deg F to melt the most highly saturated crystals back into solution.

3. Materials Compatibility (Not As Much Of A Problem, Today)

Nitrile rubber, polypropylene, polyvinyl, Tygon are all susceptible to attack from B100

- Biodiesel blends higher than B20 can damage hoses and pump seals.
- Blends lower than B5 have no effect

Materials compatibility is more of a problem in old engines made before 1993. Engines made after 1993 are less likely to have these susceptible materials in them. In reality, the industry has done a satisfactory job in overcoming materials issues like these. Most contemporary engines and fuel systems won’t be bothered by biodiesel.

4. Increased NOx Emissions

NOx production in internal combustion engines can vary by feedstock. The difference in NOx emissions between high and low NOx feedstocks is about 15%.

The composition of biodiesel determines how much NOx is produced. More highly unsaturated feedstocks produced higher NOx levels. Vegetable oil feedstocks are most unsaturated and animals fats are least, so you would expect vegetable FAMEs like soy and canola to product the worst results on NOx emissions.

Why is this?

Some past research has indicated that the increased NOx is related to differences in injection rates into the combustion chamber caused by biodiesel’s higher bulk modulus and higher viscosity, which makes it less compressible than regular diesel. The higher bulk modulus and higher speed of sounds of biodiesel means the pressure rises in the fuel lines and develops an advance of nearly two degrees in injection timing. This in turn generates a faster pressure and temperature rise in the combustion chamber, leading to an increase in NOx.

It is apparent the best way to reduce NOx is by modification of engine technology. Retarding the engine timing by 1-5 degrees can bring B100 NOx emissions down to diesel baselines or below.

5. Effects on engine lubrication

Biodiesel use seems to have a negative effect on the engine lubrication. For example, European OEMs prescribe a 50-70% reduction in oil drain intervals with the use of blends above B5. A practical reason for this might be that biodiesel's higher density and surface tension leads to fuel dilution of the lubrication in the crankcase.

6. Cleaning Effects

Methyl esters have been used as low VOC cleaners for many years. When first added to a fuel system, B100 dissolves sediments present in the fuel filter and fuel storage tank and can cause fuel filter clogging and bursting, leading to injector deposits.
It is recommended to clean tanks and fuel systems before first introduction of B100 to a system. B20 is too dilute to have a similar cleaning effect.

7. Stability Issues

The typical shelf life for soy/canola B100 is about 4-6 months. Ultimately, the working storage life of a fuel is dependent upon storage conditions.

The corollary to biodiesel cold flow issues seems to be its stability concerns (biodiesel with good cold flow response have poor stability and vice-versa). Biodiesel is susceptible to oxidation from exposure to air, water, light and certain metals. Biodiesel can first become hazy, and then form a thick precipitate gel. Analysis of this gel shows that it is mostly made up of organic compounds that are directly produced by the "oxidative cleavage" of double-bonds in the FAME molecule. In other words, oxygen-containing compounds (including water) will chemically attack the biodiesel molecule and break it apart, producing a mixture of components (aldehydes, carboxylic acids, ketone) that combine to produce biodiesel gel and sediment.

It is interesting to note that B100 will not produce sediments at the same rate that biodiesel blends like B5 and B20 will. This is because B100's higher viscosity and greater concentration of chemical bonds act to disperse and suspend these oxidative compounds, preventing them from working together to accelerate the chain reactions that lead to sediment formation. So, as a general rule, B100 is more stable than B20 and other biodiesel blends.

When discussing fuel stability characteristics, one may refer to Thermal Stability and Oxidative Stability. Thermal stability is the fuel ability to resist breakdown when exposed to heat for periods of time. B100 FAMEs tend to have good thermal stability features, due to the feedstock use in common cooking applications. If thermal breakdown did occur, injector coking would be the most likely engine problem associated with the poor-quality fuel.

Oxidative stability is the fuel's ability to resist oxidation when exposed to factors like air, water, and certain metals. This is the biggest weakness of biodiesel. One reason for susceptibility to oxidation is that the processing of some of the feed stocks can remove natural antioxidants from the compound. More highly saturated feed stock seems to be more resistant to this and have better oxidative stability.

Contact with air provides the oxygen necessary to fuel oxidation reactions that break the fuel down. Contact with water causes the biodiesel to hydrolyze and form organic acids, which are partly responsible for the compatibility problems with various rubbers. Contact with metals like tin and copper will degrade biodiesel and create sediments.

In addition to oxidative compounds like aldehydes and ketones, formic acid, acetic acid, other organic acids, water and methanol are common products produced by fuel degradation. These end products of the oxidation process may be harmful to fuel injector equipment and can cause problems such as injector clogging, corrosion of FIE components, gelling at low temperatures, and fuel seal failure.

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Occurrences of biodiesel oxidation are even higher in erratically-used engines, such as generators and seasonal vehicles. Biodiesel blends that are stored for long periods of time accumulate water and are exposed to air and heat for long periods of time, and have the greatest chance of developing microbial contamination, which can produce further acids that accelerate fuel breakdown.

Common tests for fuel stability are the EN 14112 (Rancimat), ASTM D-2274 (Standard Test Method for Oxidation Stability of Distillate Fuel Oil), ASTM D-6468, and the ASTM D-4625 (Standard Test Method for Middle Distillate Fuel Storage Stability at 43 Degrees Celsius/110 Degrees F). The first two tests (Rancimat and D-2274) are common within the industry and are accelerated test methods. The third (ASTM D-6468) is the primary test of thermal stability, which involves measuring black residue formed as the fuel is heated to high temperature for 90 or 180 minutes.

It is, however, useful to adopt the fourth method (ASTM D-4625) for a clearer picture of a fuel's behavior in long-term storage and its potential for formation and separation of oxidized precipitates and sediments. This test was developed from research conducted by the U.S. Navy in the 60s and 70s to help them judge the potential for sediment formation in diesel fuels transported to remote base locations for storage and use. One interesting conclusion they found in their work was that the amount of insoluble material (oxidation sediment) formed in just one week of storage at 110 degrees F was equal to the amount of sediment formed in four weeks of storage at ambient temperature. While this research was conducted at the time on conventional diesel, its findings have implications for the storage life of biodiesel blends.

In monitoring the condition of biodiesel and its blends in storage, the properties most closely relating to changes in stability are Viscosity, Acid Number and Sediment.

The Effect of Feed Stock Differences on Stability

A feed stock is the type of fat or oil that the biodiesel FAME is manufactured from. The cost of biodiesel feed stock accounts for the majority (up to 80%) of production costs. A typical production cost scenario would be that it takes 7.3 lbs of feedstock, at 30-35 cents per gallon of material cost, to produce a gallon of B100 at $2.45 a gallon.

It is important to remember that the feed stock used affects the physical properties of the biodiesel FAME produced. The different feedstock fats/oils contain mixtures of 10 different fatty acids between 12 and 22 carbons in molecule length. These acids are either saturated, un-saturated, mono-unsaturated or poly-unsaturated. Differing proportions of each type cause variations in properties like oxidative stability and resistance to gelling at low temperatures.

Higher levels of un-saturation lead to faster oxidation of fuel. "Un-saturation" means each fat molecule is not filled with the maximum number of hydrogen on each molecule, which means there are "empty spaces" for other less-desirable atoms to come and attach themselves to the molecule, like iron or sulfur. These empty spaces also can participate more easily in chemical reactions that cause the long-chain molecules to break apart into smaller molecules. This is what happens during oxidation and breakdown of the fuel. Most vegetable oils except for the tropical ones tend to be unsaturated and therefore more prone to this.

As a rule, for each increase in double-bond un-saturation, the stability of fuel decreases by a factor of 10.

On the flip side, animal fats are highly saturated and so make the most stable FAME. Soybean oil has low saturation levels; tallows, animal fats and palm oil have higher saturation levels.

Increasing the level of saturated fats in the feedstock improves stability and cetane, but lowers cold flow properties (resistance to gelling in cold temperatures). Highly saturated fatty acids help reduce NOx emissions

Comparisons of Feed Stocks

Saturated feedstocks have high stability and cetane but also high cloud point (poor cold flow).

- COCONUT, ANIMAL FATS, YELLOW GREASE
- High levels of saturated fats, which produces a FAME which performs poorly in cold weather, with pour points as high as 59 degrees F.

Monounsaturated feedstocks are in the middle with medium stability, cetane and cloud point.

- PEANUT OIL, YELLOW GREASE (high in both saturated and mono-unsaturated components), CANOLA

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Polyunsaturated feedstocks have low cetane and stability but low cloud point (good cold flow).

- SOYBEAN, MOST VEGETABLE OIL LIKE CORN AND SAFFLOWER

Most Common Bio Feedstock Sources Across The Globe

Because biodiesel tends to be in competition with diesel, it is extremely sensitive to price issues. Many producers will switch between feedstocks depending on what is most available at any given time. Different countries tend to produce biodiesel based on what's most readily and cheaply available in their region.

USA – Soy, tallow
Canada – fish oil and tallow
Brazil – soy, mamouna
Ecuador – Palm
Europe – rapeseed
Asia and India – jatropha
Australia – tallow
Indonesia – palm

Biodiesel Specifications and What They Mean (Important Properties)

Only biodiesel FAME that meets all of the specification set down in ASTM D-6751 can legally be sold as "biodiesel". It is legally assumed that if the FAME meets specification and the diesel fuel meets ASTM D-975 specifications, then any biodiesel blend made from those fuels will be in spec.

One thing to remember is that you can test for biodiesel fuel quality before it is blended into diesel fuel to make a biodiesel blend, but not after. This is because you cannot test for free glycerin in a blend and thus you cannot complete the PS121 test.

<u>Following are the most common specifications and properties for biodiesel, along with possible causes and effects on equipment when they are not met:</u>

FLASH POINT – higher than diesel fuel specification, to ensure the FAME manufacturer has removed all excess methanol (MeOH). Even small amounts of MeOH contamination will lower the flash point. Recall that methanol is one of the short-chain alcohols used in biodiesel production.

- Residual MeOH affects fuel pumps, seals and elastomers and can result in poor combustion properties.

WATER AND SEDIMENT – set to same level as conventional diesel fuel; protects against poor drying techniques.

- Excess water leads to microbial growth and corrosion
- Excess sediment can be caused by fuel oxidation – the test can be combined with acid number and viscosity tests to determine if fuel has oxidized in storage

VISCOSITY – affects injection of fuel; too high viscosity causes poor fuel combustion leading to deposit formation and high in-cylinder penetration of the fuel spray which results in engine oil dilution.

SULFATED ASH – relates to the amount of residual alkali catalyst (KOH or NaOH) left over

- Contributes to possible injector deposits and fuel system fouling

SULFUR – D5453 test is preferable over D2622, which can provide false high test results with oxygen interference in the fuel

COPPER STRIP CORROSION – identifies potential difficulties with copper and bronze fuel system components.

- Prolonged contact with such metals causes fuel degradation and sediment formation.

CETANE NUMBER – the minimum cetane rating for B100 is 47, which is higher than normal #2 diesel. However cetane index as calculated by D-976 is not accurate for biodiesel since it is based on calculations involving specific gravity and distillation curve measures which differ for biodiesel over petrodiesel.

CLOUD POINT – Ensures good performance in cold weather.

CARBON RESIDUE – measures the carbon-depositing tendency of a fuel and is approximation of the tendency for carbon deposits to form in an engine. For conventional diesel fuel, carbon residue is measured based on a 10% distillation range, whereas B100 boils in the high end of the diesel fuel range; thus it is difficult to obtain a 10% residual for biodiesel in the same temperature range as diesel fuel. Therefore the specification for biodiesel dictates use of the entire sample rather than just the 10% distilled residue.

ACID NUMBER – an indicator of free fatty acid content; this can be elevated if the fuel is not properly manufactured or has undergone oxidative degradation.

- Acid numbers higher than 0.80 are associated with fuel system deposits and reduced life of fuel pumps.

FREE AND TOTAL GLYCERIN – measures the amount of unconverted/partially converted fat and by-product glycerin present in the finished fuel. Incomplete conversion of fat into biodiesel leads to high total glycerin readings. Incomplete removal of glycerin leads to high free glycerin and total glycerin readings.

- Excess numbers result in fuel system and storage tank fouling, and filter plugging.

PHOSPHORUS – can damage catalytic converters, so strict limits of 10ppm.

T90 DISTILLATION – ensures the fuel has not been contaminated with high boiling-point materials like used motor oil. B100 exhibits a boiling range instead of a distillation curve.

IODINE VALUE - a measurement of the level of un-saturation in the finished fuel; unsaturated feed stock oils oxidize faster and polymerize more rapidly.

Use of Vegetable Oil in Diesel Engines

With the increase in biodiesel popularity, the practice has increased of consumers using straight, unconverted vegetable oil in their diesel engines. Or trying to, at least. Straight vegetable oil is not a legal motor fuel and doesn't meet typical fuel specifications. Using raw oils in diesel engines, even in concentrations as low as 10-20%, causes long-term engine deposits, ring sticking, and lube oil gelling. This is due to the raw oil's greater viscosity than diesel fuel (40 mm2/s vs. 4.1 mm2/s max for diesel fuel).

Conversion of the raw oil to a FAME form reduces the viscosity of the oil to a suitable level (4-5 mm2/s). The viscosity is now close enough to petrodiesel so as to avoid problems.

United States OEM Position(s) on Biodiesel Use

OEMs have monitored biodiesel use since its increase in popularity, due to the potential for engine and warranty issues. As you may expect, OEMs have been cautious from the start, but have slowly warmed up to the fuel as its popularity and use have increased.

OEM Concerns with Biodiesel

- Corrosion and deposits in injection systems
- Compatibility with rubber seals in fuel systems

Use of up to B5 will not void engine warranties – this is universal among all manufacturers. Cummins, Case Holland and Caterpillar also warrant B20 use.

Federal law prohibits the voiding of a warranty simply because biodiesel happened to be used – the biodiesel must be proven to have been the cause of the engine failure. This means if the biodiesel can be shown to have met all the specifications, it is very unlikely that it can be judged to have been the cause of warranty-voiding engine damage.

Blending and Storage Issues

The National Biodiesel Board (NBB) recommends a 6-month storage life for B100. B20 has a longer storage life than B100, but is still recommended to use within 6 months.

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Optimal storage is recommended at 45-50F. Underground storage is preferred; above ground storage should be insulated.

If biodiesel is blended with cold diesel fuel, crystallization of saturated compounds can occur. For remediation, you can heat the fuel above 100 degrees to dissolve crystals or filter them out.

To prevent crystal formation, one can blend biodiesel with kerosene (#1 fuel) at a 50:50 rate, then blend mix into cold diesel fuel (similar to tempering in cooking)

Government Mandates for Alternative Fuels

The Energy Policy Act amendment of 1996 requires 75% of new fleet purchases by certain government agencies to be alternative fuel vehicles. In the following years, Congress used tax policy to drive consumer behavior towards greater use of renewable fuels like biodiesel. The $1 per gallon subsidy had been allowed to expire, and then reinstated, several times in that time period. Each time the tax credit lapses, biodiesel use and production drops precipitously. For example, in 2010, Congress allowed the subsidy to expire in April. The following month, 90% of the biodiesel production facilities went idle, while the rest of them produced fuel at just 10% capacity. When the subsidy was reinstated in June 2010, the facilities went back to normal production.

So it seems clear that without this government subsidy, it may be difficult for consumers to bear the added cost of biodiesel, which does not bode well for its long-term viability.

Bell Performance Bio Dee-Zol Life Product Overview

Bio Dee-Zol Life is a treatment product for biodiesel blends, introduced by Bell Performance in 2007. The product is intended to both protect stability of biodiesel blends and reverse degradation of biodiesel fuel quality which has already started dropping. The recommended treat ratio is 1:1000 for biodiesel blends up to 20% concentration (20%), with increasing treat rates for blends higher than 20%.

The Rancimat Rating for Fuel Stability

The standardized way for determining stability of biodiesel blends is the Rancimat specification, measured in hours of life in the test. The United States standard requires biodiesel to maintain three hours of stability under the Rancimat method. The European biodiesel standard requires six hours.

In surveys conducted on soy biodiesel evaluated for oxidative stability, it has been determined that most biodiesel samples will initially exceed the three hour minimum specification. However, the stability of in-spec biodiesel diminishes upon storage due to factors described earlier.

Fuel	Composition	Rancimat Hrs
A	Soy	1.85
B	Soy	2.86
C	Soy	1.49
D	Soy	3.19
E	Soy	4.46
F	Soy	2.98
G	Soy	5.44
H	Soy	3.60

All of these fuel samples initially met ASTM specifications for stability, meaning their Rancimat ratings were a minimum of 3.00 hours. Four of the samples not longer met the specification, meaning they had already undergone oxidation and had become partially “rancid.”

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Bio Dee-Zol Life and Oxidized Fuel Stabilization

Traditional stabilizers are added to biodiesel to prevent the destabilization of biodiesel. In certain instances, these stabilizers can correct oxidative degradation which has already occurred. This benefit is in contrast to cold flow improvers, which can be used to prevent fuel gelling but cannot reverse gelling once it has occurred.

Additive	Fuel A		Fuel B		Fuel C		Fuel D		Fuel E		Fuel F	
Bio Dee-Zol Life (treat rate)	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000
Rancimat Hrs	1.85	4.98	2.86	5.29	1.49	3.16	3.19	7.11	4.46	9.00	2.98	6.8

Testing performed with the active ingredients in **Bio Dee-Zol Life** showed that the Rancimat ratings of biodiesel fuels treated with the ingredients increased by 100-170% (a 100% increase means the Rancimat rating doubled) compared to untreated fuel. This shows that the active ingredient in **Bio Dee-Zol Life** was effective in correcting instability issues associated with aged and already-oxidized biodiesel blend fuel.

Bio Dee-Zol Life and Mingled Fuel Instability

Fresh biodiesel and aged biodiesel are often mixed together within storage tanks. Mixing old and new biodiesel together adversely impacts the stability of the entire blend. Research has shown that the Rancimat rating for such a blend decreases as the percentage of aged biodiesel increases. Adding just 10% aged biodiesel to fresh biodiesel reduces the Rancimat rating of the blend by almost 50%. Increasing the percentage to 25% cuts the Rancimat rating by over 70%. Adding as little as 15% of an unstable biodiesel can drag the stability of a high quality biodiesel fuel out of specification.

Fuel Mix								
% Stable Biodiesel		100	95	90	85	75	50	25
% Unstable Biodiesel	100		5	10	15	25	50	75
Rancimat Hrs	<1	6+	4.01	3.31	2.47	1.72	0.64	0.42

Bio Dee-Zol Life helps minimize the Rancimat depression that occurs when adding old and new biodiesel together. When a blend of old and new fuel in a ratio nof 15% old to 85% new, with an out-of-spec Rancimat rating of just 2.03 hours was treated with Bio Dee-Zol Life, the stability rating improved by 160%, up to 5.32 hours, well above the standard specification. So **Bio Dee-Zol Life** helps minimize potential problems when old and new biodiesel fuels are mixed together.

Additive	**85% Fresh, 15% Aged**	
Bio Dee-Zol Life	0	1000
Rancimat Hrs	2.03	5.32

The increase in Rancimat hours showed that **Bio Dee-Zol Life** worked to correct the reduction in stability of the fuel blend.

Bio Dee-Zol Life and Instability Caused by Metallic Exposure

The presence of a transition metal like copper will cause up to an over 80% loss in oxidative stability for the blend. When treated with the active stabilizer in **Bio Dee-Zol Life**, the reduction in Rancimat rating was reduced by 90%, such that the biodiesel samples remained above specification for stability.

Additive						
Copper (Cu) 0.16ppm	0	YES	YES	0	YES	YES
Bio Dee-Zol Life	0	0	1000	0	0	1000
Rancimat Hrs	5.44	1.15	4.76	3.6	0.60	3.28

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Bell Performance Bio Cold Flow Improver Product Overview

Bio Cold Flow Improver provides effective protection for biodiesel blends against gelling in cold weather conditions. It contains a proprietary mixture of cold flow improver and viscosity modifiers to target both the FAME and Diesel Fuel fractions of the blend. This differs from conventional cold flow improvers for diesel fuel, which are ineffective in B100 and B20 because they cannot effectively modify the viscosity of the FAME when its temperature drops.

The product has a base treat rate of 1:1500, but as with most cold flow situations, the treat rate can be modified up or down depending on the situation.

Projection Cold Flow Benefits

- B5 blends
  - Reduction in cold filter plug point (CFPP) of up to **31 degrees F**
  - Median reduction of **20 degrees F**

- B20 blends: 7 samples tested
  - Reduction in CFPP of about **12 degrees F**
  - Reduction in CFPP of **up to 23 degrees F**

Related Issue – The Use of Dee-Zol in Biodiesel Blends – What Effect Will It Have?

Dee-Zol is Bell Performance's multi-function diesel fuel treatment, first formulated in 1957. Many consumers who have used **Dee-Zol** for years to treat their diesel fuel have asked about its use in biodiesel blends, especially in areas where blends like B5 are more the norm than the exception.

As a general rule, **Dee-Zol** will provide the same benefits in biodiesel blends like B5 or B20 as it will in straight conventional #2 diesel. These blends are still composed to 80-95% diesel fuel, where the **Dee-Zol** will continue to have the same effects.

- Combustion improver should have a similar effect, as it will act upon the diesel fuel phase.
- Detergents will still work and should be beneficial for cleaning of hydrolysis deposition products, which is still carbonaceous in nature.
- Water control agents will be especially beneficial for protecting the biodiesel phase.

For consumers desiring multi-function benefits for their biodiesel blends, Bell Performance would recommend use of **Dee-Zol** in their fuels. For consumers needing specialized protection for stability improvement or cold flow protection of biodiesel blends, Bell Performance recommends its specialty biodiesel products **Bio Dee-Zol Life** and **Bio Cold Flow Improver**.

For information on biodiesel fuel issues, as well as these fuel treatments, visit us on the web at www.BellPerformance.com and www.WeFixFuel.com.

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