

Ultra-Low Sulfur Diesel (ULSD) Fuel Technology

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New U.S. Environmental Protection Agency (EPA) standards require a major reduction in the sulfur content of diesel fuels and emission levels from diesel engines and vehicles.



Ultra-Low Sulfur Diesel (ULSD) Fuel Technology

To meet the EPA standards, the petroleum industry is producing ultra-low sulfur diesel (ULSD) fuel, a cleaner-burning diesel fuel containing a maximum of 15 parts-per-million (ppm) sulfur.



Ultra-Low Sulfur Diesel (ULSD) Fuel Technology

After December 1, 2010, fleets will only be able to get ULSD. Therefore, they are considering its use in their current equipment and are concerned about the implications of its use.



Ultra-Low Sulfur Diesel (ULSD) Fuel Technology

The use of ULSD has two key benefits:

1. Engines using ULSD fuel burn cleaner, emitting lower emissions.
2. ULSD fuel enables the use of advanced emission control devices (aftertreatment systems) further lowering harmful exhaust emissions.



Ultra-Low Sulfur Diesel (ULSD) Fuel Technology

While ULSD fuel has many benefits, there are some challenges associated with its use. In order to fully understand these challenges, we will review the key attributes of a quality diesel fuel and its role in lubricating, cooling, and providing power and performance to the diesel engine.

We cannot fully appreciate our opportunities until we fully understand the challenges.

Content/Objectives

1. Understanding diesel fuel and the fuel system.
2. Understanding Ultra Low Sulfur Diesel (ULSD) Technology.
3. Understanding Biodiesel fuel and ULSD.
4. Summary.

Objective 1: Understanding diesel fuel and the fuel system.

Diesel fuel is the key energy source for the diesel engine. While the correct amount and timing of diesel fuel injection provides efficient power, the fuel itself has several other key roles.



Objective 1: Understanding diesel fuel and the fuel system.

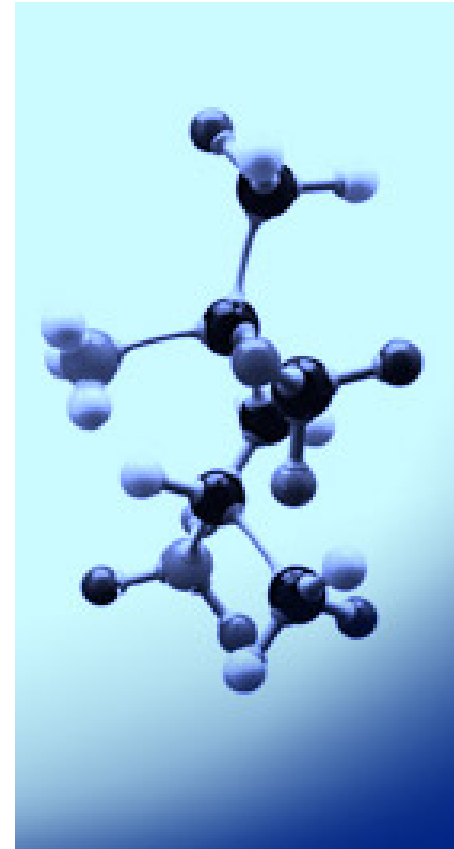
Diesel fuel, made up primarily of hydrogen and carbon, and impurities such as sulfur, has several different roles which include:

- Cooling
- Lubricating
- Cleaning
- Power source



Objective 1: Understanding diesel fuel and the fuel system.

- **Cooling:** Fuel that flows *to* the injection pump and circulates *through* the pump absorbs unwanted heat generated by the engine and transferred to the pump.
- While the heated fuel continues to circulate in the system, the heat dissipates: in this way, the fuel acts like a coolant.



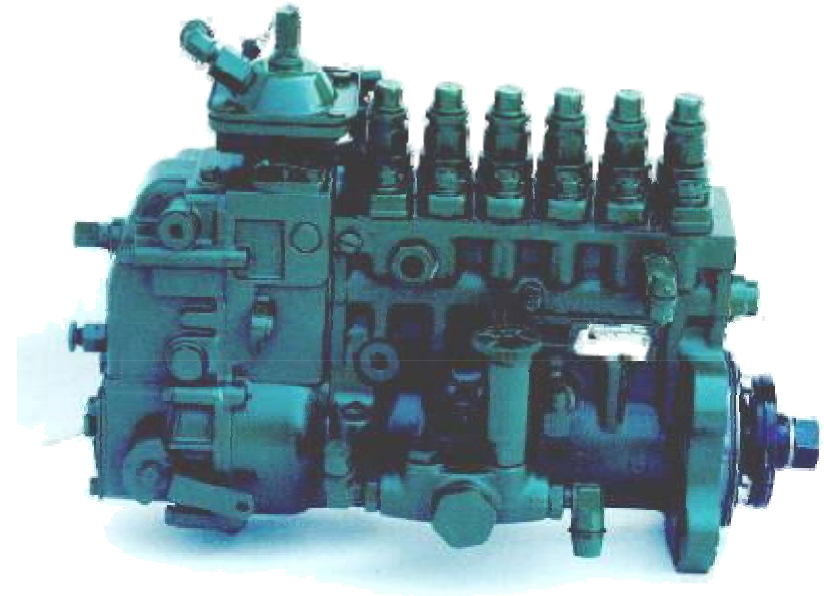
Objective 1: Understanding diesel fuel and the fuel system.

- **Lubricate:** Diesel fuel has lubricating properties and lubricates the moving components of both the fuel transfer pump and the fuel injection pump assembly.
- Fuel lubrication is critical to reduce unwanted wear in the fuel system components, ensuring long trouble-free life.



Objective 1: Understanding diesel fuel and the fuel system.

- For adequate lubrication, fuel has a specific **viscosity**, or resistance to flow.
- If the viscosity gets too low (due to high heat), it may not provide adequate lubrication.
- If the viscosity gets too high, it will not flow as well.



Oxidation of fuel, a result of high heat, can increase viscosity.

Objective 1: Understanding diesel fuel and the fuel system.

- **Cleaning:** Diesel fuel picks up unwanted contamination in the fuel system, transferring the contaminant to the fuel filtration components, where contaminants are removed.
- By cleaning fuel system components, the fuel contributes to long trouble-free life.



Objective 1: Understanding diesel fuel and the fuel system.

- **Energy Source:** Diesel fuel is the primary energy source (when combined with the correct amounts of air) for the diesel engine.
- Diesel fuel specifications ensure it meets the requirements for providing the correct amount of power, regardless of temperature and operating conditions.



Objective 1: Understanding diesel fuel and the fuel system.

There are various grades and blends of diesel fuels that have specific uses related to temperature and markets.



Objective 1: Understanding diesel fuel and the fuel system.

- Diesel fuel has a **cetane** number which is a measure of its ignition quality. It relates to the starting and warm-up characteristics of the fuel.
- In cold weather or in service with prolonged low engine load, a higher cetane number is desirable.



Objective 1: Understanding diesel fuel and the fuel system.

Flash point is the lowest temperature at which the fuel can ignite from vapor.

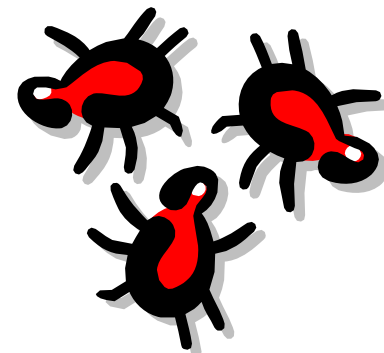
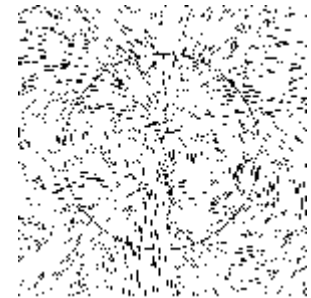


Objective 1: Understanding diesel fuel and the fuel system.

Contamination:

Fuel system contamination is a fact of life. The most common contaminants found in the diesel fuel are:

- Organic elements
- Micro-organisms
- Water
- Inorganic elements

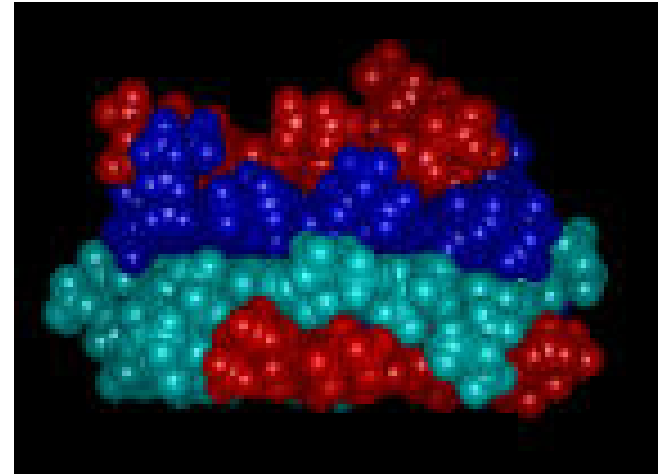


Objective 1: Understanding diesel fuel and the fuel system.

Organic components of the fuel can become contaminants, such as asphaltenes.

They form as a result of:

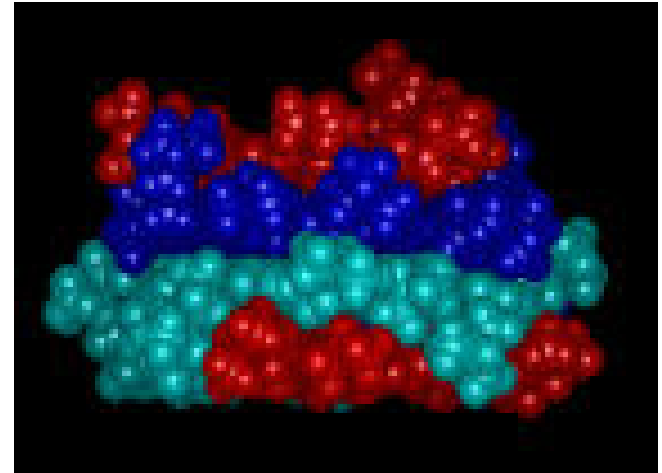
- Oxidation or degradation of the fuel
- Poor thermal stability (ability to handle heat)
- Cold temperature reactions (waxing)
- Unstable reaction to additive mixing (lube additive mixed with fuel additive)



Molecular Model
of Asphaltenes

Objective 1: Understanding diesel fuel and the fuel system.

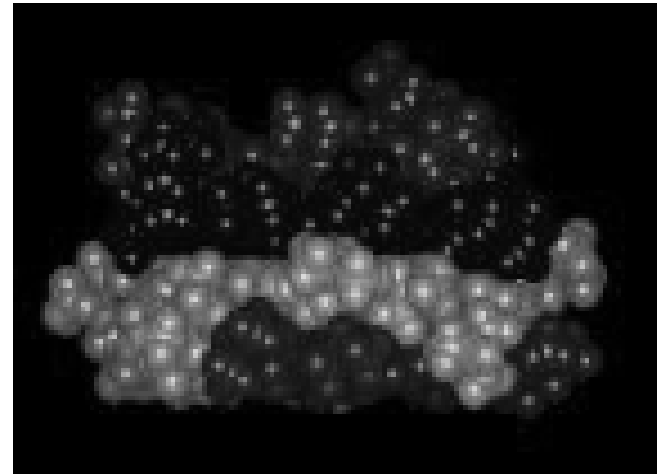
- Asphaltenes are naturally occurring hydrocarbons found in fuel. In their natural state, they are too small to be seen and pass through the filter. They also contribute positively to the BTU content of the fuel.
- Heat causes them to come out of suspension, agglomerate, and become trapped in filters.



Molecular Model
of Asphaltenes

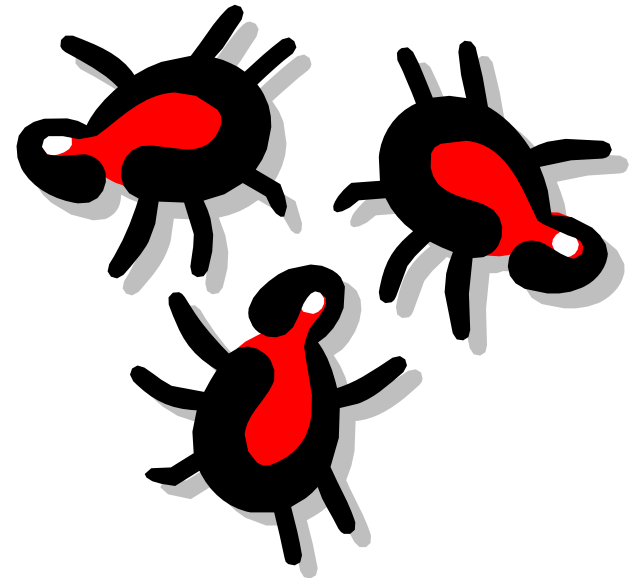
Objective 1: Understanding diesel fuel and the fuel system.

- Inspection of used fuel filters with a shiny black material coating the media or a gel build-up is evidence of organic contamination.
- The effect of organic contamination is shorter fuel filter life.



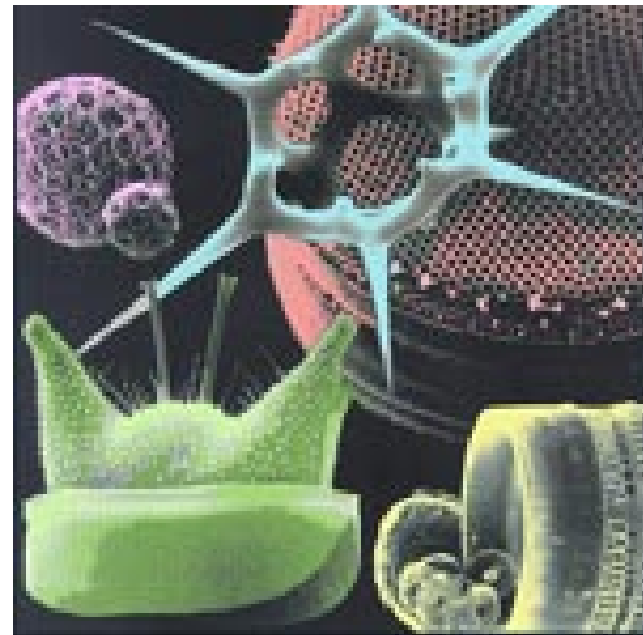
Objective 1: Understanding diesel fuel and the fuel system.

Micro-organism growth can occur when a mixture of water and diesel fuel sits idle for any extended period of time. These micro-organisms live in the water, feed off the diesel fuel, and can thrive at any fuel/water interface.



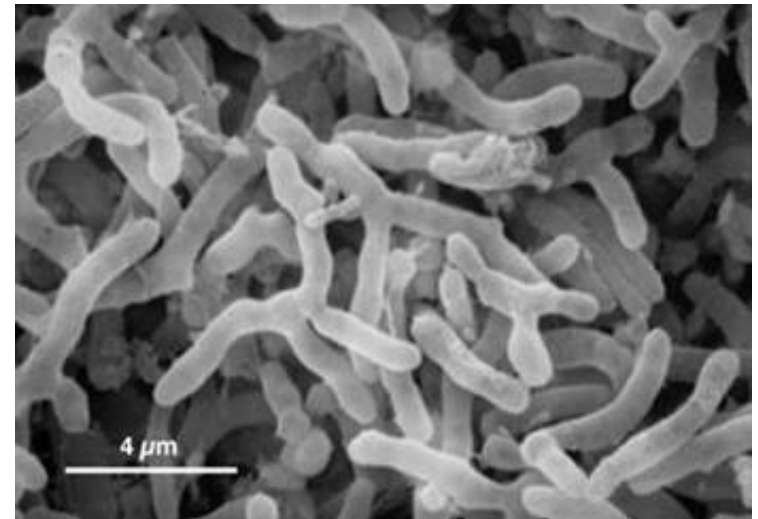
Objective 1: Understanding diesel fuel and the fuel system.

- Micro-organisms contaminate tanks, both primary storage and on the vehicle. This can cause system corrosion, fouling of injectors, premature filter plugging and general degradation of the fuel, affecting engine performance.
- They can also degrade plastic and fiberglass components found in some fuel systems.



Objective 1: Understanding diesel fuel and the fuel system.

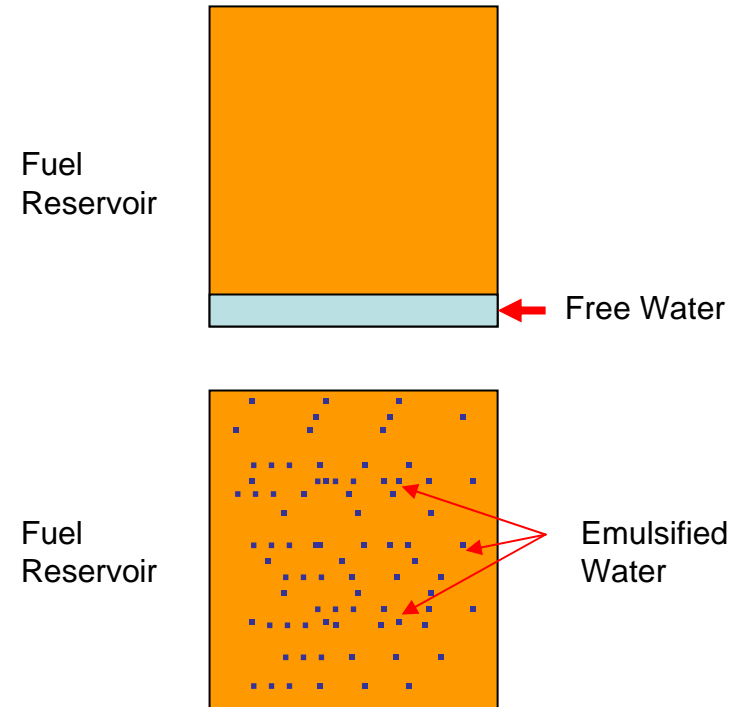
- Diesel fuel with micro-organisms can have a sour or foul odor and can be visible on an inspected filter as a slimy greenish brown or black material coating the media.
- Other forms are found, but not as easily identified visually as micro-organisms.



Objective 1: Understanding diesel fuel and the fuel system.

Water in fuel can be found in two forms: *free* and *emulsified*:

- Free water is *not* entrained in the fuel and settles out over a short period of time.
- Emulsified water is entrained in the fuel and much harder to remove. This bonding with the fuel occurs as the fuel/water mixture passes through a fuel pump.



Objective 1: Understanding diesel fuel and the fuel system.

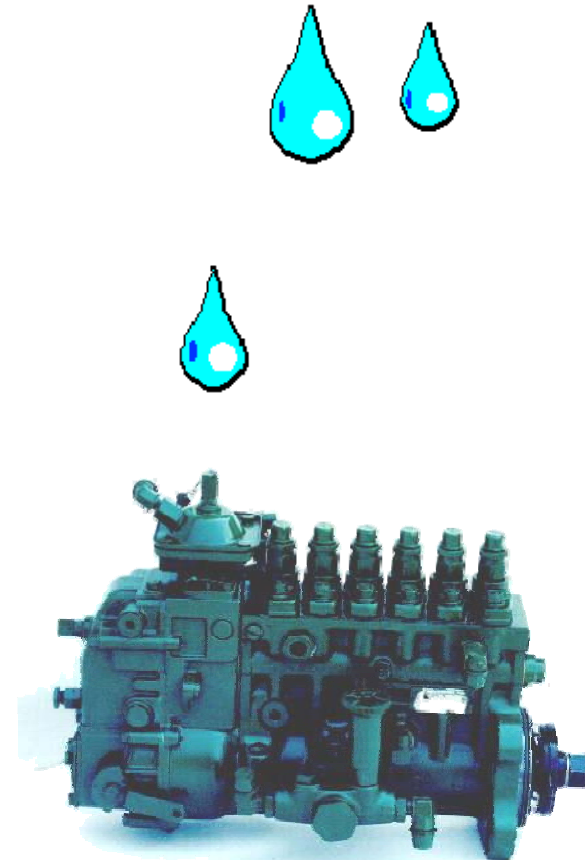
Water can be introduced into the fuel in various ways:

- The natural fuel burning process allows cooler air to enter the tank as fuel levels drop. Cooler air meets the hotter fuel and condensation occurs.
- Water can exist in the fuel from the fuel source, either from storage tanks or the fuel supplier.



Objective 1: Understanding diesel fuel and the fuel system.

- **Water** in fuel can cause premature component failure or short component life, increasing operating costs and downtime.
- **Water** can also contain micro-organisms and/or provide a place for micro-organisms to develop. Trapped by the filter, the micro-organisms further result in shorter filter life.



Objective 1: Understanding diesel fuel and the fuel system.

Inorganic Contamination includes:

- Component wear metals
- Rust
- Scale
- Dirt

***This contamination can
cause the most damage
to fuel system
components due to its
hard and abrasive nature.***

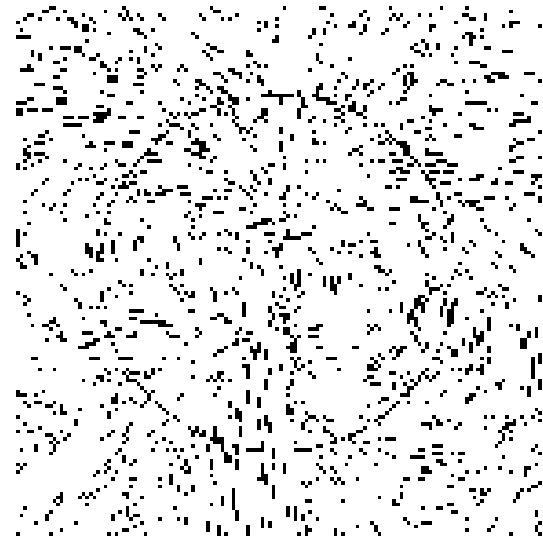
Objective 1: Understanding diesel fuel and the fuel system.

- Small holes in injector tips and tight precision fitting components in injection pumps are described in terms of “*strict tolerances.*”
- In today’s engines, components are built to *very* strict tolerances to meet emission requirements and ensure efficient and cost effective operation.
- Inorganic contamination can have serious adverse effects on these components.



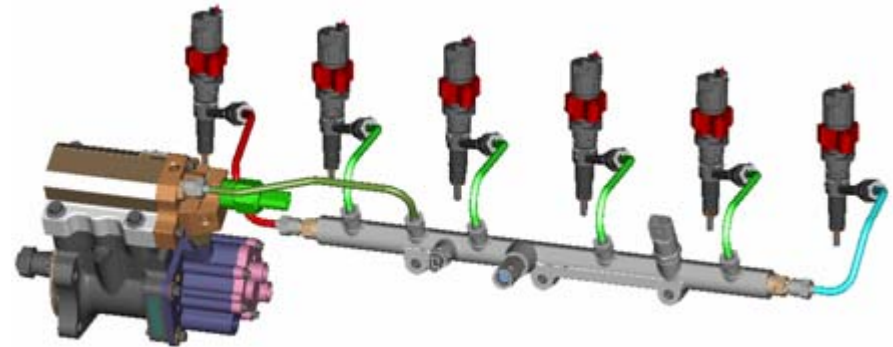
Objective 1: Understanding diesel fuel and the fuel system.

- Wear metals are the toughest to deal with because they occur through normal system operation. They can get into tight tolerance areas, affecting fuel delivery, timing and overall operation.
- They also lead to further wear particles. This type of contaminant is known as “self generated”, and it occurs continually inside the system if not controlled by proper filtration.



Objective 1: Understanding diesel fuel and the fuel system.

Many engine manufacturers use a High Pressure Common Rail (HPCR) system, which means high pressure fuel will be maintained, regardless of engine speed, in a common rail or tube that connects to every fuel injector. Pressures can be as high as 29,000 psi.



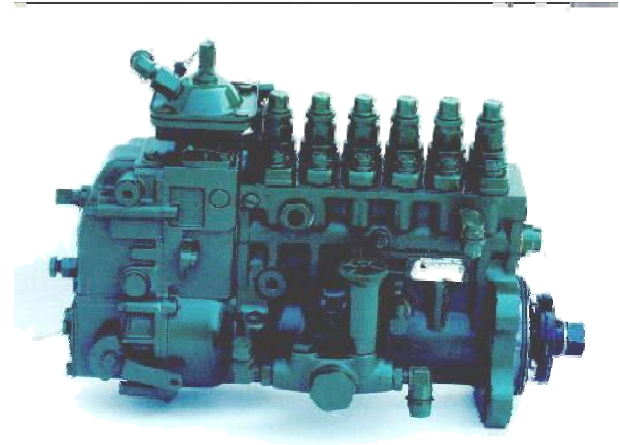
Cummins uses HPCR systems in its Mid Range engines and High Horse Power engines.

It is critical to have high efficiency filtration with high system pressures and tighter tolerances.

Objective 1: Understanding diesel fuel and the fuel system.

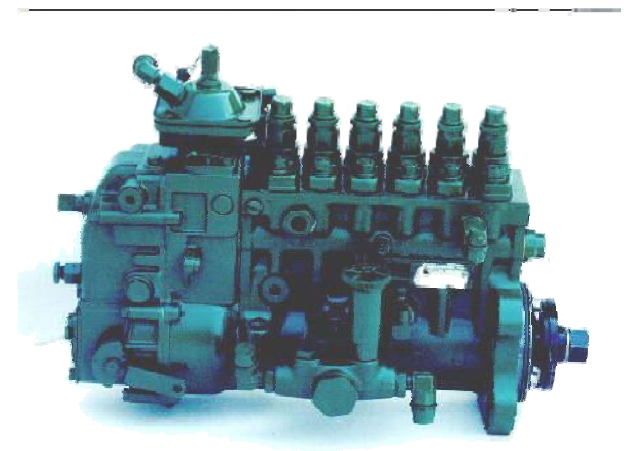
Cold operating conditions present additional challenges to engine operation and the fuel system:

- Water, which is almost always present in fuel, is affected by cold conditions, i.e. turning to ice crystals.
- Paraffin wax, a natural component of fuel (helps give fuel its power), also forms crystals under cold conditions.



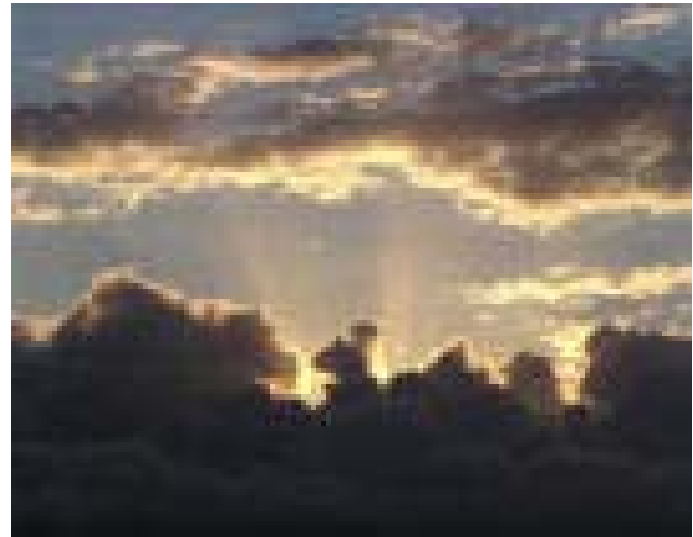
Objective 1: Understanding diesel fuel and the fuel system.

- Under test conditions, wax crystallization is measured when the first crystals form.
- As temperatures decrease, wax crystals form.
- Crystals inhibit fuel flow through the fuel lines and the filter itself.



Objective 1: Understanding diesel fuel and the fuel system.

- Cloud point of fuel is the temperature at which the first wax crystals appear.
- It is *not* a good indicator of what temperature a filter will gel-up or plug.



Objective 1: Understanding diesel fuel and the fuel system.

CFPP

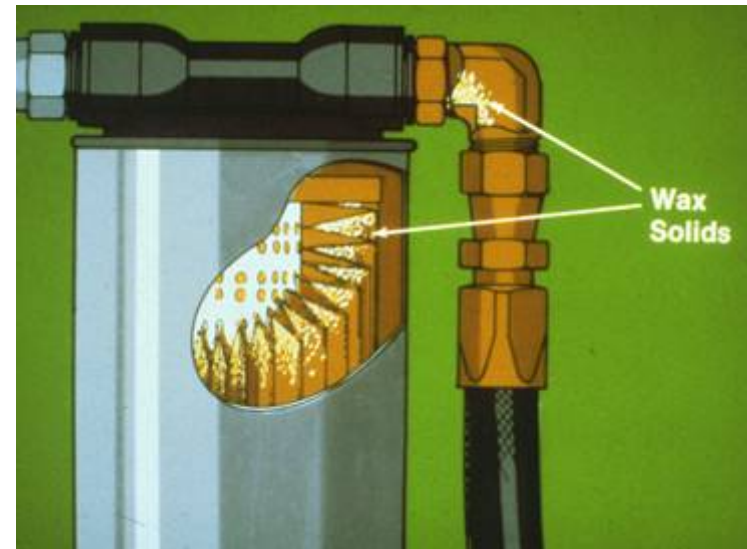
Cold Filter Plugging Point (CFPP) is a measure of the lowest temperature at which a specific fuel will cause filter plugging.



Objective 1: Understanding diesel fuel and the fuel system.

Pour Point

- Pour point is the lowest point at which fuel can still flow.



Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Now that we understand diesel fuel and the fuel system, let's examine what is different about ULSD Technology.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

The Engine Manufacturers Association (EMA) is a trade association representing worldwide manufacturers of internal combustion engines used in applications such as trucks and buses; farm and construction equipment; marine vessels, lawn, garden and utility equipment and generators.

EMA works with government and industry stakeholders to help the nation achieve its goals of cleaner fuels, more efficient engines and cleaner air.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

EMA and **ASTM International** (formerly the American Society for Testing and Materials), among others, have contributed to the specifications, testing and research that allow the ability to use ULSD in 2007 and prior engines.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

- Ultra-low sulfur diesel (ULSD) is a number 2 diesel fuel with a maximum allowable limit of 15 parts-per-million (ppm) of sulfur.
- Ultra-low sulfur kerosene (ULSK) is a number 1 fuel with a maximum allowable limit of 15 ppm of sulfur.



Kerosene is often referred to as No. 1 Diesel.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

In comparison, low sulfur diesel (LSD) is fuel with a maximum allowable limit of 500 ppm.

Current #2 LSD fuel has 350 – 500 ppm sulfur.

LSD has been the standard for on-highway applications in North America for several years and is becoming the standard for the current off-highway emissions standard throughout 2006.

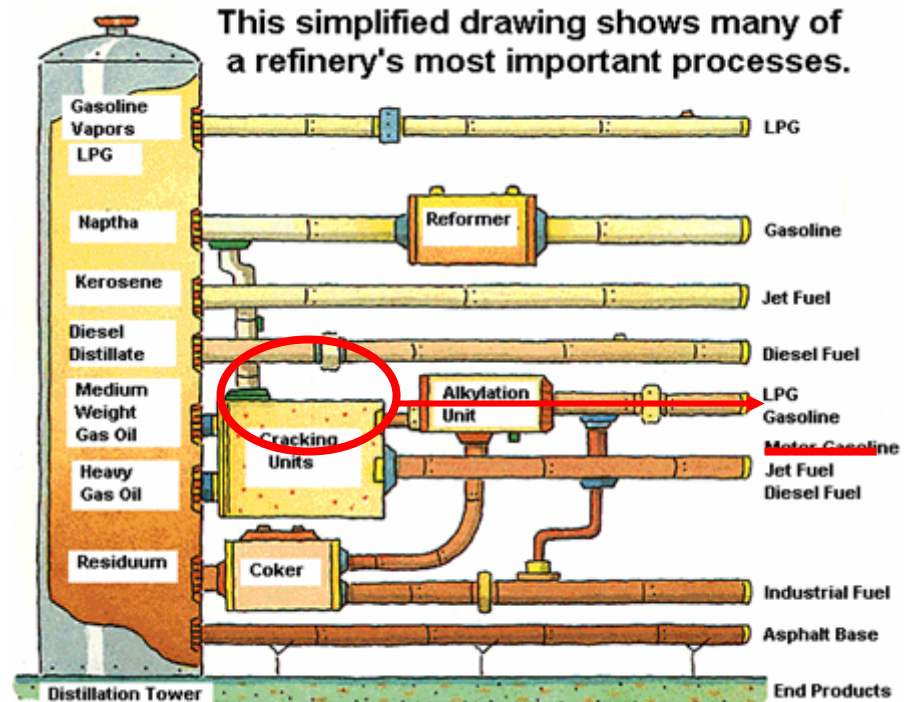
Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

How is sulfur removed from ULSD, and how does it affect the fuel?

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Hydro-treating and hydro-cracking are part of the fuel refining process and contribute to the lower sulfur content. These processes could raise the cetane number by 3 to 5 from today's average.

Cetane: increased from 43 to 46 – aids starting and produces less smoke.



Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

While removing sulfur contributes to lower emissions and better exhaust aftertreatment life, there are some negative aspects as well.

The positive aspects of sulfur include:

- Effective lubricant for fuel system components
- Natural poison to micro-organisms

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Aromatics are organic compounds containing carbon atoms which are a natural part of diesel fuel.

- Aromatics relate to the heat (energy) content of the fuel.
- Hydro-cracking and hydro-treating both remove aromatics, which lowers the density of the fuel.
- This relates to the BTU (British Thermal Unit) of the fuel which will be lower.

The process used to remove sulfur will lower the BTUs by 1 to 2%.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Even though there is a slight decrease in BTU (1-2%), under typical operating conditions, there should be no noticeable impact on overall *power* using ULSD fuel.

Cummins has done extensive research and testing to ensure its engines maintain their superior fuel economy.

Many engine manufacturers are claiming increases in fuel economy with their 2007 engines.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

- ULSD, due to the refining process, has lower lubricity.
- As necessary, additives to increase lubricity and inhibit corrosion are added to ULSD fuel, prior to its retail sale.
- This process takes place at the fuel pipeline rack.

With these additives, ULSD fuel is expected to perform as well as LSD fuel.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

This is the first time that ASTM has a lubricity requirement in the diesel fuel specification, which represents a key change and an important improvement to the fuel specification.

Fleets may consider the addition of supplemental fuel additives as a further protective measure due to the minimum level of lubricity being added.

The lubricity specification value is known as HFRR or High Frequency Reciprocating Rig:

- The value will be maintained between 460 and 520 HFRR.
- **EMA** recommends 400 – 460 HFRR.

Note: A lower value is better, so the specification is actually at the minimum.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

What about cold weather operation: will there be additional challenges with ULSD (No. 2) and ULSK (No. 1)?

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

ULSD has a higher wax content. This will relate to a higher cloud point (where wax crystals first form) and increased winter wax gelling.

There is a high probability for increased filter plugging in cold weather operation.

There is an increased need for winter fuel additives.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

For cold weather operation, only ULSK (No. 1) may be blended with ULSD (No. 2) fuel to improve cold weather performance.

Note: The EPA has **not** mandated that kerosene be ULSK, which could mean a low supply available for blending, again, increasing the need for winter fuel additives.

Care must be taken to select ULSK with a maximum of 15 ppm sulfur.

Blend rates will remain the same as with LSD fuel.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

What other factors should fleets be aware of regarding ULSD Technology?

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

ULSD also has a lower solvency. This relates to the fuel's decreased ability to dissolve injector and other deposits.

There may be an increased need for supplemental injector cleaner products. Fleetguard Asphaltene Conditioners provide injector cleaning.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

- ULSD fuel is more susceptible to micro-organism growth (due to the lower sulfur content).
- As diesel storage tanks are converted to ULSD, there could be increased filter plugging due to the longevity of the fuel in the tank.

Fleets may experience shorter filter life due to micro-organism contamination.

Fleetguard Microbicide™ is highly effective in eliminating eliminate micro-organism growth.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Engine manufacturers expect ULSD fuel to be fully compatible with the existing fleets, including 2006 and earlier model year vehicles.

In some instances, the introduction of ULSD fuel to older vehicles may affect fuel system components or loosen deposits in fuel tanks.

Owners and operators are encouraged to monitor their vehicles closely for potential fuel system leaks or premature fuel filter plugging during the change-over to ULSD fuel.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Many fleets are concerned about periodically using low sulfur diesel in their 2007 certified engines (due to miss-fueling or lack of availability of ULSD).

Most engine manufacturers have answered this concern by stating that one tank filling of low sulfur diesel should *not* adversely affect the engine or aftertreatment devices.

Continued use of low sulfur diesel will harm aftertreatment devices.

It is illegal to use low sulfur diesel in 2007 certified engines.

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

We have mentioned the possible need for fuel additives. Are Fleetguard additive packages suitable for fleets for 2007?

Objective 2: Understanding Ultra Low Sulfur Diesel (ULSD) Technology.

Fleetguard fuel additives, including Asphaltene Conditioner and Winter Conditioner, will be ULSD compliant by January 2007.



Objective 3: Understanding Biodiesel fuel and ULSD.

Now let's discuss the relationship between biodiesel fuel and ULSD.

Objective 3: Understanding Biodiesel fuel and ULSD.

Biodiesel is a blend of petroleum diesel fuel and any fuel processed from a grain, or vegetables, i.e.:

- Soy
- Canola (Rape)
- Palm
- Cotton
- Olive
- Coconut
- Peanut
- etc.

The percentage of the processed fuel in the petroleum is represented by the term B5: B representing biodiesel and 5 representing a 5% concentration.

Blend rates will remain the same as with ULSD fuel.

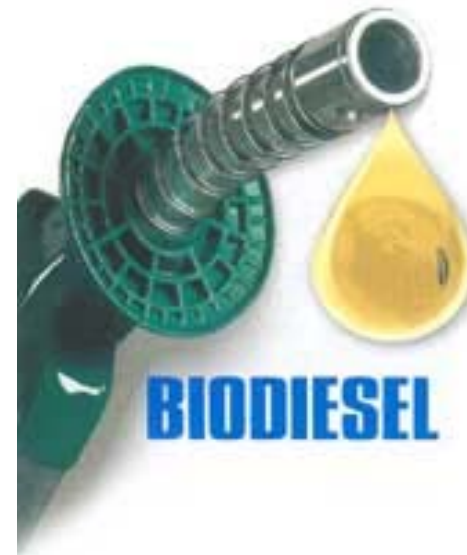
Objective 3: Understanding Biodiesel fuel and ULSD.

Currently, all members of EMA approve the use of a B5 biodiesel (5%) blend, providing the blends meet accepted ASTM fuel quality standards, and the ULSD sulfur limits.

Cummins recently approved the use of B20 blends for use in all 2002 and newer model engines.

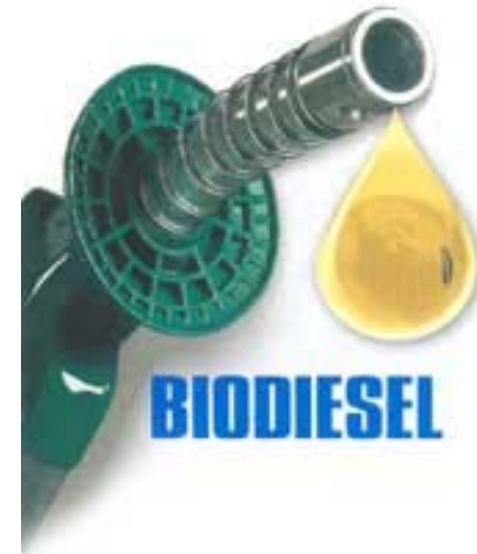
Objective 3: Understanding Biodiesel fuel and ULSD.

- B2 blends actually add lubricity to ULSD and help protect fuel systems.
- B5 – B20 ULSD blends exhibit poor thermal and oxidative stability, resulting in premature filter plugging.
- B5 – B20 ULSD blends have a higher wax content, which increases wax gelling, resulting in filter plugging.



Objective 3: Understanding Biodiesel fuel and ULSD.

- B5 – B20 ULSD blends have a lower density and lower BTU value, which relates to poorer fuel economy by 1 – 2%.
- B5 – B20 ULSD blends act as a solvent when initially used in fuel systems, resulting in premature filter plugging (which should only be a short term concern).



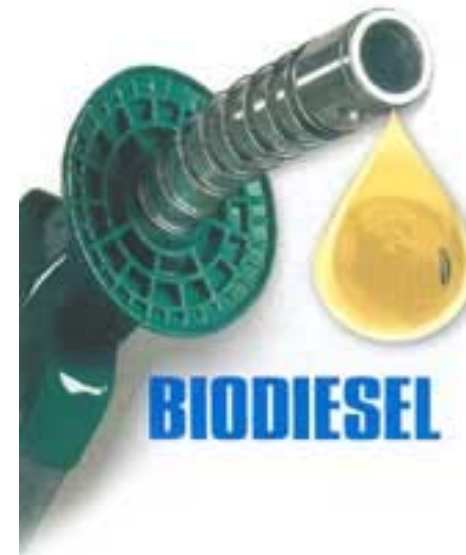
Note: While a poor solvent (ULSD) cannot dissolve deposits and cause filter plugging, a *better* solvent (biodiesel) can dislodge more deposits, and at the extreme, also cause filter plugging.

ULSD has 1 – 2 % lower BTU, in addition to the lower BTU of biodiesel – contributing to poor fuel economy.

Objective 3: Understanding Biodiesel fuel and ULSD.

- B5 – B20 ULSD blends are *very* challenging in removing emulsified water.
- B10 – B20 ULSD blends require special gaskets and seals.

When using B10 and higher blends, it is recommended to use either 2 spin-on filters, or the *plus size* processor filter to ensure adequate fuel/water separation.



Objective 3: Understanding Biodiesel fuel and ULSD.

How do Fleetguard fuel processors work with biodiesel fuel?

Objective 3: Understanding Biodiesel fuel and ULSD.

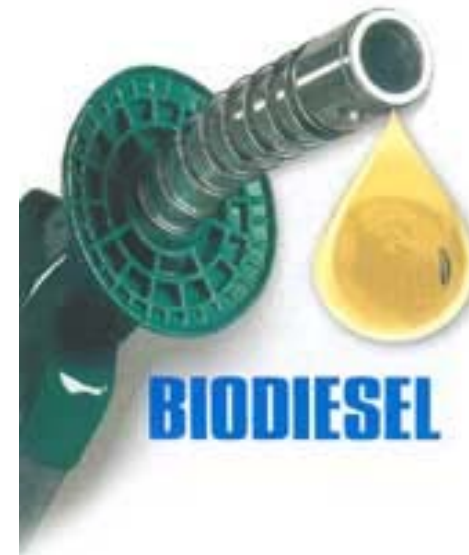
- For B10 blends and higher, *plus size* fuel processor elements must be used to ensure proper emulsified water removal.
- Fleetguard biodiesel compatible upgrade elements (which include the special gaskets and seals) are available.



When using B10 and higher blends, it is recommended to use either 2 spin-on filters, or the *plus size* processor filter to ensure adequate fuel/water separation.

Objective 3: Understanding Biodiesel fuel and ULSD.

- All Fleetguard Fuel Processors include biodiesel compatible permanent seals.
- This includes the following Fleetguard fuel systems:
 1. Fuel Pro®
 2. Diesel Pro®
 3. Industrial Pro™
 4. Sea Pro™



All Davco Processors supplied to fleets through OEMs after January 1st, 2007 are biodiesel compatible.

Objective 3: Understanding Biodiesel fuel and ULSD.

To ensure proper quality, consumers should use only biodiesel ULSD fuel blends that are properly mixed by a qualified biodiesel blender.

Consumers should not create their own biodiesel blends by adding biodiesel to ULSD fuel in a vehicle's fuel tank.

There should be no operational problem if consumers switch from a biodiesel-ULSD blend to ULSD fuel without biodiesel.

Summary.

Let's review the key points our customers should know about
ULSD Technology.

Summary.

- ULSD Technology was developed and introduced to lower exhaust emissions and enable 2007 engines and aftertreatment devices to function properly.
- Power and fuel economy should remain unchanged, and in some cases, improve.
- There is less energy (BTU) in ULSD, but engine manufacturers' design improvements have led to claims of similar, if not increased, fuel economy and performance.

Summary.

- The process used to reach lower sulfur content *could* affect some of the thermal and oxidative stabilities of the fuel - leading to premature filter plugging by organic contaminants (asphaltenes).
- Lower aromatic content of fuel *may* make it a poorer solvent - *possibly* shortening fuel filter life due to filter plugging (poorer solvent cannot dissolve deposits, which in turn plugs filters).

Summary.

- High pressure fuel systems have tighter tolerances, increasing wear potential with smaller inorganic contamination.
- Higher fuel temperatures with increased engine operating temperatures impact oxidation rates, leading to asphaltene plugging.

Summary.

Water removal and premature filter plugging due to poor fuel stability are key challenges, and efficient filtration to reduce system wear is critical.

Fleetguard fuel/water separation filtration systems offer higher efficiency and capacity than competitive filters.

Summary.

- Fleetguard fuel filter systems offer a balance:
 - Remove wear-causing, microscopic contamination - *Efficiency*
 - Provide Extended Service Intervals with higher capacity to hold contaminant – *Capacity*
 - Have more effective water-removal capability – *Especially for emulsified water*

Summary.

- Fuel system maintenance is critical – proper filtration is a must.
- Fleetguard fuel filter products offer a balance of efficiency, capacity and water removal ability, designed to meet the demands of the high pressure fuel systems, including:
 - OEM products designed for engine specifications
 - Remote mount fuel processors designed for customer needs

Summary.

- Fleetguard fuel chemical products (Ashphaltene Conditioner and Winter Conditioner) provide:
 - increased fuel lubricity
 - improved fuel stability
 - new products for winter conditioners for both ULSD and ULSD/biodiesel blends.
- Fleetguard Microbicide™ eliminates corrosive micro-organisms that can shorten filter life.