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PATENTED TECHNOLOGY » PROVEN RESULTS » PAYBACK

HIGHLIGHTS

Ultra-Low Sulfur Diesel: Operational Challenges Facing Engine Operators

Why ultra-low sulfur diesel (ULSD) fuel?

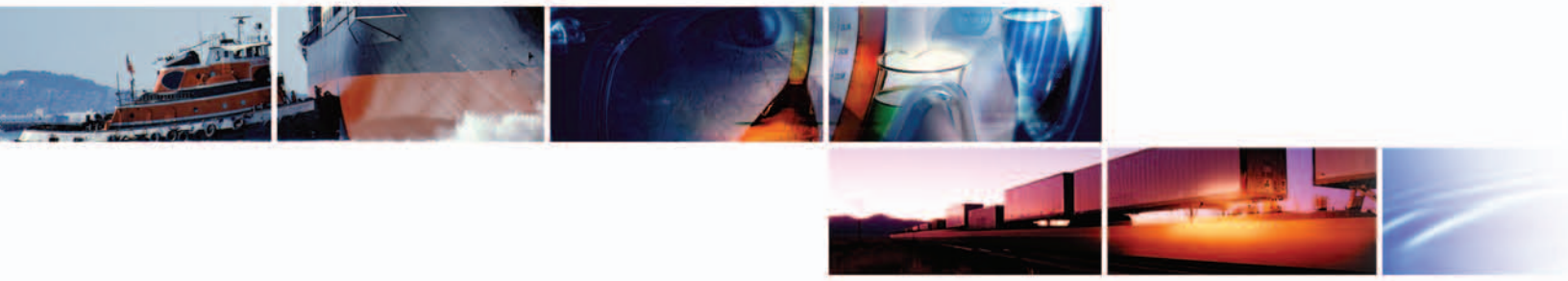
Over the past several years, the U.S. Environmental Protection Agency (EPA) has established diesel engine emissions limits significantly below that of current engines. Reduced sulfur content in diesel fuel is a key component of the tightening emissions limits.

What are the U.S. EPA standards regarding diesel fuel sulfur content?

The U.S. EPA has outlined different sulfur requirements for diesel fuel for various end users. Per 40 CFR Part 69, the EPA mandates that refiners begin producing highway diesel fuel with a maximum sulfur content of 15 parts per million (ppm) on June 1, 2006. The non-road sulfur requirements are different and are displayed below:

Maximum Sulfur Content	Land-based Non-road Diesel Engines	Locomotive and Marine Diesel Engines
500 ppm	June 2007	June 2007
15 ppm	June 2010	June 2012

Source: 40 CFR Part 69

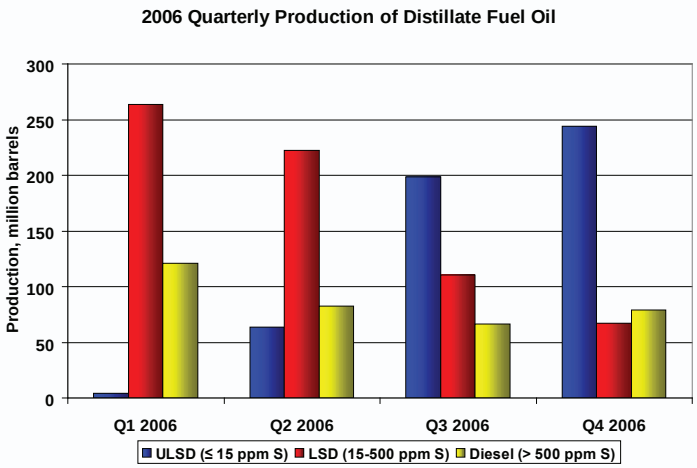


Will ULSD enter the non-road diesel fuel supply before 2010?

Although the EPA does not require ULSD fuel for non-road diesel applications for several years, ultra-low sulfur diesel fuel is already a reality for non-road diesel-engine owners and operators throughout the U.S.

It makes sense that ULSD fuel would quickly dominate the market. Highway diesel represents a significant portion of domestic diesel fuel consumption. In 2003, highway diesel consumption totaled 37.8 billion gallons, while non-road diesel consumption totaled 17.0 billion gallons (Oak Ridge National Laboratory, *Transportation Energy Data Book*, 2006). Naturally, fuel will be produced to serve the majority of the end users.

In order to produce ULSD fuel, refining facilities have to be upgraded with new desulfurization units. Billions of dollars and years of work have been invested on refinery upgrades already. To optimize capital expenditures, refiners will complete this process only once. The chart below displays the recent shift in diesel production, highlighting the increase in ULSD from just over four million barrels in the first quarter of 2006 to almost 244 million barrels during the fourth quarter.



Source: Energy Information Administration

What are the implications of ULSD?

The introduction of ULSD fuel into diesel engines presents several operational and safety challenges. The table below addresses the ability of EnviroFuels DFC (Diesel Fuel Catalyzer) to address those challenges.

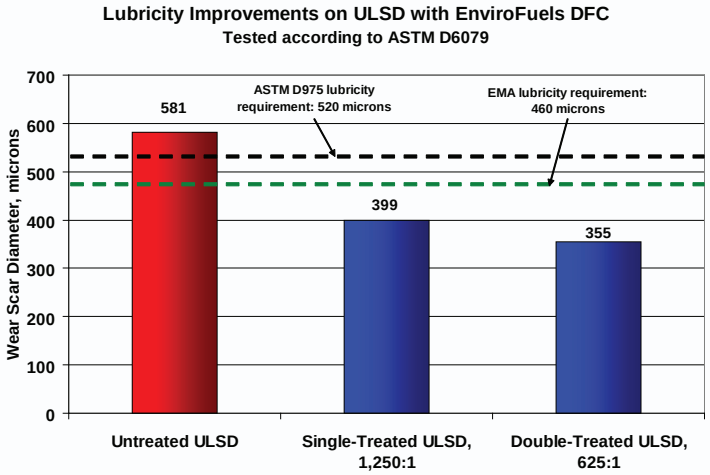
Challenge	Operational Implication	EnviroFuels DFC Benefit
Insufficient lubricity	Increased component wear and possible failure	Sufficient lubricity verified by ASTM D6079
Reduced energy content	Reduced power or increased fuel consumption	Improved engine efficiency verified by EPA and SwRI
Degraded thermal stability	Faster fuel degradation	Enhanced stability verified by ASTM D tests 6468 and 2274
Lower electrical conductivity	Higher risk of static electricity buildup and safety hazards	Restored conductivity verified by ASTM D2624-06

EnviroFuels DFC Satisfies the Most Stringent Lubricity Requirements

Diesel fuel is the primary lubricant for diesel engine fuel injection systems and related components. As sulfur is removed from diesel fuel, lubricity of the fuel decreases. This can increase the wear of fuel system equipment and reduce component life.

The new standard specification for diesel fuel, ASTM D975-06, has established a lubricity requirement specifying a maximum wear scar diameter of 520 micrometers using ASTM D6079 at 60°C. The Engine Manufacturers Association (EMA) supports an even more stringent lubricity requirement that specifies a maximum wear scar diameter of 460 micrometers (Engine Manufacturers Association, August 18, 2005).

Testing was performed according to ASTM D6079 - High Frequency Reciprocating Rig Test - on standard ULSD fuel and on ULSD fuel treated with EnviroFuels DFC. The results demonstrated that EnviroFuels DFC significantly improves the lubricity of ULSD fuel as shown by the lower wear scar diameter in the following graph.



EnviroFuels DFC Increases Engine Efficiency

The reduced energy content of ULSD fuel will cause engines to produce less power per unit of fuel consumed. EnviroFuels DFC positively impacts the combustion reaction by increasing the heat release rate. In multiple field tests, including one conducted through the U.S. EPA, and in laboratory tests conducted at Southwest Research Institute, EnviroFuels DFC has consistently increased the combustion efficiency of diesel engines. EnviroFuels DFC can mitigate ULSD power loss through its engine efficiency improvements. The following table displays the ability of EnviroFuels DFC to compensate for the lower energy content of ULSD and ULSD-biodiesel blend (B20-ULSD) by increasing the rate of heat release, which is directly proportional to increases in power potential.

Fuel	Peak Heat Release Rate (J/ms)		Percent Change
	Untreated Sample	Treated Sample	
ULSD	2,122	2,301	8.4%
B20-ULSD Blend	2,255	2,350	4.2%

EnviroFuels DFC Enhances Thermal Stability

The natural thermal stability of diesel fuel decreases as sulfur is removed during the refining process. When less stable fuel is stored for extended periods of time, its quality can significantly degrade, possibly causing filter plugging. EnviroFuels improves the thermal stability of ULSD. Samples of standard ULSD fuel and ULSD fuel treated with EnviroFuels DFC were tested according to ASTM D6468, the Standard Test Method for High-Temperature Stability of Distillate Fuels. High reflectance indicates greater stability.

Fuel	Reflectance
Untreated ULSD	57%
Treated ULSD	85%

ASTM D975 specifies that for severe use, fuel should have a minimum of 80% reflectance. EnviroFuels DFC clearly restores ULSD fuel to an acceptable level of stability.

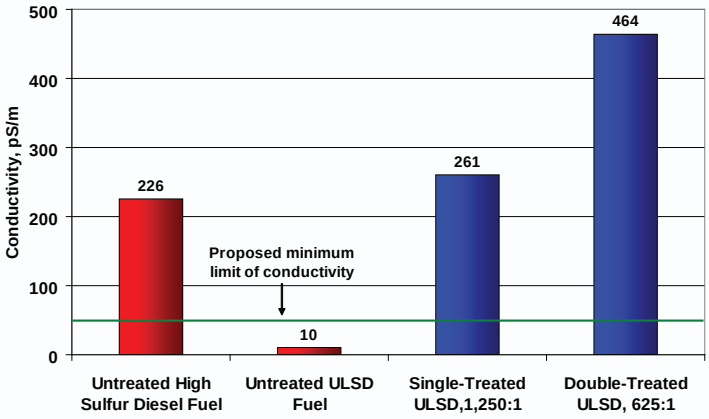
EnviroFuels DFC increases oxidation stability, ensuring that the fuel meets the stability requirements within the National Council of Weight and Measures (NCWM) Premium Diesel Specification. Samples of standard ULSD fuel and ULSD fuel treated with EnviroFuels DFC were tested according to ASTM D2274, which indicates improved stability with lower total insolubles. EnviroFuels DFC provides excellent storage stability as indicated by reduced total insolubles.

Fuel	Total Insolubles (mg/100 mL)
Untreated ULSD	0.16
Treated ULSD	0.03

EnviroFuels DFC Improves Electrical Conductivity

The electrical conductivity of diesel fuel decreases as sulfur is removed during the refining process. A decrease in conductivity increases the risk of static electricity accumulation and related safety concerns. Most diesel fuel produced prior to 2006 contained significantly higher sulfur content and commonly exhibited electrical conductivity between 150 to 250 picosiemens per meter (ps/m), depending on the sulfur content of the fuel. The following graph compares the conductivity values for pre-2006 high sulfur diesel fuel with that of regular ULSD and ULSD treated with EnviroFuels DFC, all of which were measured according to ASTM D2624-06.

Improved Electrical Conductivity with EnviroFuels DFC



EnviroFuels DFC is the Proven Solution to ULSD Operational Challenges

EnviroFuels DFC provides proven technical answers to the operational and safety implications inherent in ULSD fuel. The combination of improved lubricity, increased engine efficiency, enhanced thermal stability, and restored electrical conductivity make EnviroFuels DFC an ideal fuel treatment product for diesel engines operating in today's and tomorrow's ever-changing fuel climate.

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