Why do we need fuel additives?

- To meet fuel specifications
- To meet regulatory requirements
- To improve fuel performance
Enhanced Performance Diesel Additives can include:

- Detergents
- Low temperature operability components
  - Cold Flow Improvers
  - De-icers
- Lubricity improvers
- Conductivity improvers
- Cetane improvers
- Corrosion inhibitors
- Stabilizers
- Metal deactivators
- Demulsifiers
## NCWM “Premium” Diesel Criteria

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Method</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cetane Number</td>
<td>ASTM D613</td>
<td>Minimum number of 47</td>
</tr>
<tr>
<td>Low Temperature Operability</td>
<td>ASTM D2500, ASTM D4539</td>
<td>Cloud Point or LTFT must meet ASTM D975 10th percentile minimum ambient temperature charts/maps</td>
</tr>
<tr>
<td>Thermal Stability</td>
<td>ASTM D6468</td>
<td>Minimum 80% Reflectance</td>
</tr>
<tr>
<td>Lubricity</td>
<td>ASTM D6079</td>
<td>Maximum wear scar diameter (WSD) of 520 microns</td>
</tr>
</tbody>
</table>
Diesel Fuel Overview

2006 – Ultra Low Sulfur Diesel Introduced -- ASTM D975 reduces sulfur content to ≤15 ppm for on road diesel
  • Reduced Lubricity
2008 -- ASTM D975 allows 5% Biodiesel
2008 – Engine Manufacturers Association (EMA) acknowledge injector deposit problems
  • ULSD
  • Not refiner specific
  • Not CARB diesel related
  • Not linked to biodiesel

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Your consistent answer to inconsistent fuel!
Diesel Fuel Overview

2008 – Petroleum Equipment Institute (PEI) and Steel Tank Institute (STI) report excessive corrosion identified in petroleum handling equipment

- Underground tanks
- Dispensers/Pumps
- Submerged pumps
- Etc.

Is ULSD the cause?
Diesel Fuel Overview

2012 -- Biodiesel usage continues at high level
Diesel Fuel Overview

Fuel System Issues & Concerns w/Biodiesel blends

- Injector deposits
- Fuel filter plugging
- Injection pump durability (viscosity of Bio vs.#2 D)
- Materials incompatibility
- Fuel instability
- Metals contamination
- Low temperature handling
- Water
- Bacterial growth
Diesel Engine Technology Changes Coinciding with Changes in Emissions Standards

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Changes in Diesel Engine Fuel System Technologies

- Fuel System Changes
  - Higher injection pressures
  - Emergence of common rail injection systems
  - Nozzle design
  - Multiple injections per combustion cycle
  - Tighter tolerances

- Convergence of light duty and heavy-duty designs
XLP® Diesel Additive

- Multi-functional additive
  - Detergent
  - Stabilizer
  - Corrosion Inhibition
  - Lubricity Improver
  - Low Temperature Operability
Injector Deposit Areas

Traditional Nozzle coking

Needle Deposits

Source: Lubrizol

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Fuel System Testing

• Cummins L-10 outdated and obsolete
• Many engine specific tests surfaced over the last 20 years, but no industry standard to replace L-10
• Peugeot DW-10
  – Industry standard by default
  – Details about the test -- next slide
DW10 Nozzle Fouling
Test Summary

Hardware
- High speed, direct injection common rail engine.
- Euro V-type injectors (to promote fouling)
- Measures **Loss of Power** relative to start of test
- High speed/load conditions

Test procedure comprised of:
- 16 hr new injector bedding-in
- 8 hr cyclic running
- 4 hr soak (engine off)
- 8 hr cyclic running
- 4 hr soak (engine off)
- 8 hr cyclic running
- Total time = 16 + 32 + 12 = 60 hrs

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DW-10 Nozzle Fouling Test for Common Rail Direct Injected Diesel Engines

- Test data demonstrates loss of engine power
- Some data suggests the power loss problem to be worse with biodiesel blends
- Following slides demonstrate this in B5 and B20 blends
- Test data demonstrates additives ability to return engine to full power
Deposits in Newer Technology Fuel Systems

• Seen as distinct from “classic” nozzle coking and needle deposits
  ▪ Internal vs. external to fuel pressure-side
  ▪ Sticking vs. physical blockage
  ▪ Similar in physical/chemical nature

• Have become known as Internal Diesel Injector Deposits (IDID)
Internal Diesel Injector Deposits

- **Internal Diesel Injector Deposits**
  - Control valve plunger
  - Needle guide
  - Above the needle seat

- **Deposits inside spray channel** reduce the hydraulic flow leading to a loss of power

- **Injector tip deposits** adversely effect the fuel spray leading to increased emissions and fuel consumption
Internal Diesel Injector Deposits

• Performance problems manifested as:
  ▪ Poor/no start
  ▪ Rough idle/driveability
  ▪ Excess power/particulate production (sticking open)
  ▪ Loss of power (sticking shut)
DW-10 Test Data Examples

Note: The next three slides are for informational purposes only. They do not represent performance of XLP® Diesel Additive at its normal treat rates. They do, however, demonstrate power loss as measured by the DW-10 test and the ability of detergents to restore lost power.
Biodiesel & trace metal can cause problems in modern low emission DI Engines

8-27% power loss due to injector fouling

Source: Chevron Oronite

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Engine Test Results in B5 with 1ppm Zn

Power loss of nearly 7% without additive

Source: BASF

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Your consistent answer to inconsistent fuel!
A customized clean up test utilized dirty injectors from an extended base fuel test. The engine was then run on MCC 9910 to complete power recovery in 16 cycles. The above data is presented to demonstrate that at higher detergency treat rates, clean up can occur more rapidly. This is not intended to represent specific performance of XLP® Diesel Additive.

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Fuel Detergency

• Detergents are used in diesel fuel to
  ▪ Clean up pre-existing deposits.
  ▪ To help prevent fouling and deposit formation on and in fuel injector nozzles (Keep Clean)
  ▪ To help maintain cleanliness of the fuel pump and component parts
  ▪ To help reduce emissions
  ▪ To help restore lost power and fuel economy

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Fuel Detergency

• Detergents designed for legacy engine technologies such as Cummins L-10 are not cost effective to meet the needs of today’s high pressure common rail direct injected engine technology.
Cummins L10 Injectors

Fouled Direct Injector

Clean Direct Injector

Source: Chevron Oronite

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Your consistent answer to inconsistent fuel!
High Pressure Common Rail Direct Injectors

Fouled Direct Injector

Clean Direct Injector

Source: Lubrizol

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Your consistent answer to inconsistent fuel!
Why are Lubricity Improvers needed?

• Ultra Low Sulfur Diesel (ULSD) has less lubricity due to the refining process used to remove sulfur
• Lubricity is required to protect fuel injection systems
• Lubricity is measured as a function of wear
  ▪ Measured by ASTM D 6079 – High Frequency Reciprocating Rig (HFRR)
ASTM D6079 – Standard Test Method for Evaluating Lubricity of Diesel Fuels by the High-Frequency Reciprocating Rig (HFRR)
Lubricity Benefits of XLP® Diesel Additive

- Enhance performance of fuels with poor lubricity characteristics such as ultra low sulfur diesel
- Increase service life of fuel handling and metering systems
- Demonstrates minimal interaction with basic system contaminates (lube oils and caustic)
- Excellent tolerance to water contamination
- Does not contribute to combustion deposits
Why are operability additives needed for diesel fuel?

• At low temperatures, wax crystals form in diesel fuel causing problems with pumping and filtration.

• Wax can accumulate on fuel filter media leading to plugging of small orifices and lines

(see pictures on following page)
Why are operability additives needed for diesel fuel?

Wax Crystal Formations in Untreated Diesel

Wax Crystal Formations in Treated Diesel

Source: BASF

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Low Temperature Operability Tests for Diesel Fuel

- Cold Filter Plugging Point test is the industry standard test for determining low temperature filterability of diesel fuel.

- Pour Point test is the industry standard test for identifying the temperature at which a fuel can be effectively pumped.
ASTM D 6371 - Standard Test Method for Cold Filter Plugging Point of Diesel and Heating Fuels

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Your consistent answer to inconsistent fuel!
Low Temperature Performance of XLP® Diesel Additive

<table>
<thead>
<tr>
<th>Blend</th>
<th>Pour Point, °F</th>
<th>CFPP, °F*</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULSD Baseline</td>
<td>-1</td>
<td>10</td>
</tr>
<tr>
<td>ULSD w/XLP Diesel Additive</td>
<td>-36</td>
<td>-22</td>
</tr>
</tbody>
</table>

XLP Diesel Additive improves low temperature characteristics of diesel fuel

* CFPP = Cold Filter Plugging Point
Benefits of Operability Additives

Operability additives

• Lower the pour point and cold filter plugging point.

• Reduce problems with gelling and filter plugging of diesel fuel.
Why is Deicer needed?

- Water contamination in diesel fuel is common.
- Ice crystals form in cool fuel and settle to the bottom of tanks.
- Ice crystals may cause additional problems with fuel pumpability and fuel filter plugging.
Diesel Fuel Deicer Performance

**XLP® Diesel Additive is effective in reducing ice formation**

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Your consistent answer to inconsistent fuel!
Benefit of Deicer in XLP® Diesel Additive

- Reduces temperature at which water in diesel fuel forms ice crystals
- Improves operability of diesel fuel at cold temperatures
Why is Corrosion Protection needed?

Corrosion Inhibitors are attracted to the exposed surfaces of metal to form a protective film which acts as a barrier to prevent water from contacting the surface of metal components.
Corrosion Protection

National Association of Corrosion Engineers Test (NACE)

B+ or Better Grade is a pass
C or D Grade is a fail

Fail     Pass

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## Corrosion Protection

<table>
<thead>
<tr>
<th>Fuel mixture</th>
<th>NACE Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>LSD blank</td>
<td>C</td>
</tr>
<tr>
<td>ULSD blank</td>
<td>C</td>
</tr>
<tr>
<td>LSD with XLP Diesel Additive</td>
<td>A</td>
</tr>
<tr>
<td>ULSD with XLP Diesel Additive</td>
<td>A</td>
</tr>
</tbody>
</table>

XLP® Diesel Additive improves the corrosion protection of diesel fuel

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Benefits of Corrosion Inhibitors in XLP® Diesel Additive

- Corrosion Inhibitors protect fuel handling systems and components from corrosive effects of water
Why are Fuel Stabilizers needed?

- Stability is an indication of the sediment and gum forming tendency of fuel.
- Gums and sediment can cause filter plugging, combustion chamber deposits, and can result in sticking of pumping and injection system components.
- Combinations of ULSD fuel combined with biodiesel fuel (B20) are unstable and some are difficult to stabilize. (SwRI – CRC report 2005)
Oxidation Stability (ASTM D2274)

XLP® Diesel Additive improves the storage stability of diesel fuel

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Your consistent answer to inconsistent fuel!
Benefits of Fuel Stabilizers in XLP® Diesel Additive

- Reduces filter deposits and plugging caused by gums and sediment formed in unstable fuel
- Reduces potential for injection and pumping system component sticking
Summary

• XLP® Diesel Additive....
  – Can provide engine clean up and keep clean performance in legacy engines
  – Can help control deposit formation on fuel injector nozzles and act to prevent corrosion of nozzle ports.
  – Can aid in preventing deposit and gum formation on high pressure fuel injector parts.
  – Can remove pre-existing deposits.
  – Can help restore lost fuel economy
  – Can help reduce emissions
Summary

• XLP® Diesel Additive….
  – Can provide excellent corrosion protection
  – Can improve fuel stability
  – Can help meet the lubricity recommendations of the Engine Manufacturer’s Association*
  – Can reduce pour point, by up to 35 degrees*
  – Can reduce cold filter plugging point, by up to 32 degrees*
  – Can provide deicing protection down to <-50 °F

*Results are fuel specific
Diesel Additive

• Reformulate current product
  – Improved detergency levels
  – w/Cetane improver – drums only

• Introduce small bottle for pickup truck
  – 1 tank product
Premium Deposit Control for the Gasoline Aftermarket

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XLP Gas Additive is a premium injector and intake valve deposit control additive combined with the powerful benefits of a friction modifier to provide your customers with a performance boosting aftermarket additive – beginning with the first time it is used.
Why is Deposit Control needed?

The Clean Air Act mandates that all gasoline be treated with detergent which is intended to prevent formation of fuel system deposits, based on the premise that clean engines operate more efficiently and ultimately reduce emissions.

These “minimum” levels of detergent may not prevent the formation of deposits on fuel injectors, carburetors, and intake valves, in fact, they may contribute to deposits.
The Hump Effect

prop = pounds per thousand barrels

Source: BASF

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Your consistent answer to inconsistent fuel!
What are the harmful effects of deposits?

• Carburetor/Fuel Injector Deposits Cause:
  – Hesitation/Stumbling
  – Higher Emissions of Hydrocarbons and Carbon Monoxide
  – Lower Fuel Economy
  – Lower Power Output

• Intake Valve Deposits Cause:
  – Hesitation/Stumbling
  – Higher Emissions of Hydrocarbons, Carbon Monoxide and Nitrogen Oxides
  – Lower Power Output
Intake Valve Deposits
- Power Loss
- Reduce Driveability
- Increased Exhaust Emissions

Injector Pintle Deposits
- Reduced Driveability
- Power Loss
- Reduced Fuel Economy
- Increased Exhaust Emissions
Intake Valve Deposits

Dirty Valves

Clean Valves

Source: Chevron Oronite

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Your consistent answer to inconsistent fuel!
Port Fuel Injector Performance

Fuel Injector:
The clearances in a port fuel injector are as fine as a human hair. Deposits disrupt fuel flow and spray pattern.

Symptoms:
Hesitation or stumble during acceleration, loss of power and increased emissions.

\[1\] XLP® Gas Additive does not contribute to Combustion Chamber Deposits

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Your consistent answer to inconsistent fuel!
Port Fuel Injector Performance

Deposits on Injector Pintel

Clean Injector Pintel

Source: Chevron Oronite

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Your consistent answer to inconsistent fuel!
Fuel Injector Deposits

Dirty Injector

- Flow Restriction
- Poor Spray Pattern

Clean Injector

- No Flow Restriction
- Even Spray Pattern

Source: Chevron Oronite

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Your consistent answer to inconsistent fuel!
Direct Fuel Injector Deposits

Source: Chevron Oronite

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Your consistent answer to inconsistent fuel!
Performance Benefits of the Deposit Control Additive

XLP® Gasoline Fuel System

Cleaner can:

• Provide excellent port fuel injector deposit cleanup and keep-clean performance
• Provide excellent intake valve deposit cleanup and keep-clean performance
• Have no detrimental side effects
Performance Benefits of the Friction Modifier
Can be both Immediate and Long-Term

• Immediate Benefits include:
  – Can Improve Fuel Economy
    ✓ Up to 4%
  – Can Reduce Internal Friction in the Engine

• Long Term Benefit with continued use can improve/restore fuel efficiency of engine oil
Performance of the Friction Reducer

Additized gasoline is transferred from the fuel tank to the injector

Additized gasoline injected into the cylinder/combustion chamber

Immediate gain from wetting the walls of the cylinders, providing additional upper cylinder lubrication

Long term gain from accumulation in crankcase engine oil

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Your consistent answer to inconsistent fuel!
Long Term Benefit from Accumulation in the oil can depend upon:

- Additive treatment rate
- Quantity of fuel used between oil changes
- Additive accumulation rate
Advantages to your Customers Can Include:

• Restoring Lost Power
• Improving Acceleration
• Smoothing Out Rough Idling
• Increasing Fuel Economy
• Eliminating Intake Valve Sticking
• Providing Excellent Protection against Corrosion
• Use in New and Old Engines
• No Detrimental Side Effects

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Your consistent answer to inconsistent fuel!