



**RL-2**

**&**

**RL-3**

## Diesel Ignition Improvers

**Additives Designed for Heavy-Duty Fleet Use**

## TECHNICAL MANUAL

Diesel fuel quality continues to decline, but modern diesel equipment manufacturers continue to reduce engine tolerances in order to improve emissions and efficiency. However, to take full advantage of these designs, diesel fuel must provide near-perfect cleanliness in the injectors and ring areas. These needs are not adequately addressed by fuel manufacturers but Red Line's proven diesel fuel technology provides the following performance improvements:

- Restores power
- Restores fuel economy
- Reduces emissions
- Cleans diesel injectors
- Satisfies Cummins L10 "Superior" Cleanliness
- Maintains injector, ring, and engine cleanliness
- Boosts cetane - improves start-up, warm-up, and reduces noise (RL-3)
- Controls rust and corrosion
- Stabilizes diesel fuel
- Provides low-temperature benefits over 30% kerosene at much lower cost (Winterized)
- Helps prevent low-temperature filter-plugging due to wax and ice (Winterized)
- EPA registered for use in diesel fuel
- Removes water from the fuel system (Winterized)

### Cleans Injectors

Cummins had experienced field problems where engines operated under certain driving conditions developed injector deposits which caused a significant decrease in power. Cummins developed an engine test where the engine is operated for 125 hours and the injectors are removed and rated. Red Line RL-2 and RL-3 provides typically 65% less deposits when added to even "dirty" test fuels and allows them to pass with "Superior" performance. Injectors which were "dirtied" in this test can be cleaned up 20% by subjecting them to another 125 hours of Red Line treated fuel in this dirty up test. These additives work equally as well in indirect injectors. Testing RL-2 in the European dirty reference fuel in the Peugeot XUD-9 Nozzle Coking Test provided a 77% improvement in flow - an excellent result. Fleet testing using several varieties of Japanese Indirect Injection engines showed an improvement in injector flow of 42% after 6,000 miles on Red Line treated fuel.

### Improves Fuel Economy

Red Line additives are designed to provide measurable and statistically significant fuel efficiency improvements. Red Line RL-2 and RL-3 (contains cetane booster) both improve efficiency by 4 - 8% relative to untreated fuel. These efficiency improvements are due to injector and ring belt cleanliness and the reduction of friction. A significant amount of friction is generated in the high-pressure fuel injectors

and fuel pumps which are fitted to direct injection engines. Tremendous pressures are required to provide proper atomization of diesel fuel. To produce these high pressures, tolerances must be very tight, which increases damage from friction and wear. Also, where the top ring reverses its direction in the cylinder is another high-friction location due to poor oil film formation. The synthetic upper-cylinder lubricants used can provide a significant improvement at these high temperatures. The use of RL-2 and RL-3 also increases the power output of a diesel engine by approximately 2.5%. Fuel economy is also improved by similar percentages unless all of the additional power is used to provide faster speeds and acceleration. Fleet tests have shown increases in fuel economy of 4 - 8% after a few thousand miles of use with Red Line additives.

Red Line additives were tested in a 22 truck fleet test for 12 months accumulating 50,000 hours of cement hauling. The engines were Cummins 10 and the service was severe for injector deposits. New fuel injectors were placed in each engine so that cleanup of the injectors by the additives were not the source of improvements in efficiency. This fleet utilized routes and loading which was very similar for most trips. These tests were conducted with half using 15 oz RL-2 per 300 gallons and half were using the commercial fuel only. This field test showed injector deposits reduced by 44% and fuel economy based on fleet records increased by 6.8%.

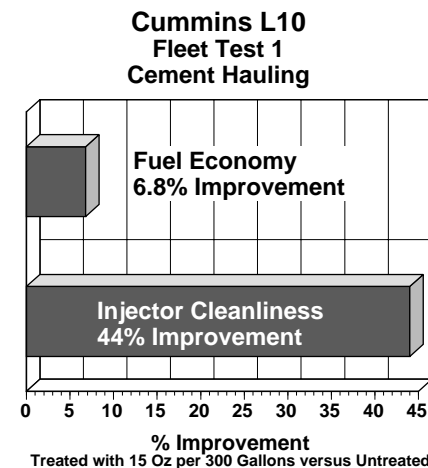


Figure 1: Fuel economy improvements and injector keep clean using 15 oz RL-2 per 300 gallons.

In a second field test, Red Line additives were tested for 18 months in 4,000,000 miles of Class 8 Line Haul. 31 trucks used the commercial fuel only, while

28 used the fuel treated with 15 oz RL-2 per 300 gallons. Part of the fleet was Cummins L10 and part was Detroit Diesel Series 60. The Cummins engines were fitted with injectors which had been tested in the Cummins L10 Injector test and the deposits measured. After 18 months all the injectors were removed and again the deposits were measured. Those which used only the commercial fuel reduced the deposits by only 1%. Those which used the Red Line treated fuel cleaned the injector deposits by 32%. The Red Line treated trucks with Cummins engines obtained 4.6% better fuel economy than the untreated fleet. The Red Line treated trucks with Detroit Diesel engines obtained 4.1% better fuel economy than the untreated fleet.

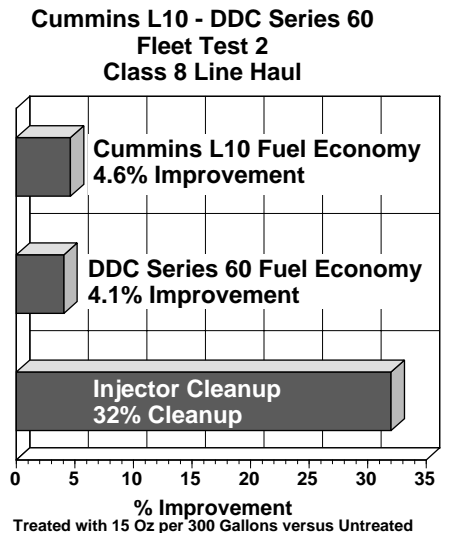


Figure 2: Fuel economy improvements and injector clean up using 15 oz RL-2 per 300 gallons.

A third field test used four Japanese normally aspirated indirect injection engines. They were one Daihatsu 2.8l, one Mitsubishi 2.5l, and 2 Isuzu 2.2l. Each vehicle was driven 4500 miles with the base fuel then 4500 miles on fuel treated with 15 Oz RL-2 per 300 gallons of fuel. The clean-up response was remarkable. Over-the-road fuel economy improved 13.6%, brake specific fuel consumption (Fuel Consumption per Horsepower) measured with a chassis dynamometer improved 11.6%. Exhaust gas opacity, or black smoke, was reduced 42%, injector flow improved 42% when measured on a flow apparatus, and engine noise was reduced 2.5 dB.

A fourth field test again used Japanese normally aspirated indirect injection engines, but this time they

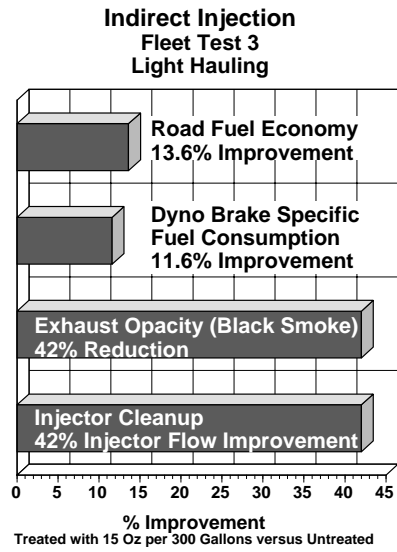


Figure 3

were new vehicles. There were two of each vehicle listed above. In order to cancel out the fuel efficiency improvement resulting from break in, one of each vehicle was initially operated on the base fuel, while the other was operated on the base fuel treated with 15 Oz RL-2 per 300 gallons of fuel. Each was operated for 6800 miles and then the fuel was switched. The initially treated vehicles now used untreated, and initially untreated vehicles now used treated fuel for another 6800 miles. Again, the response was remarkable, but since the vehicles were new, little of the

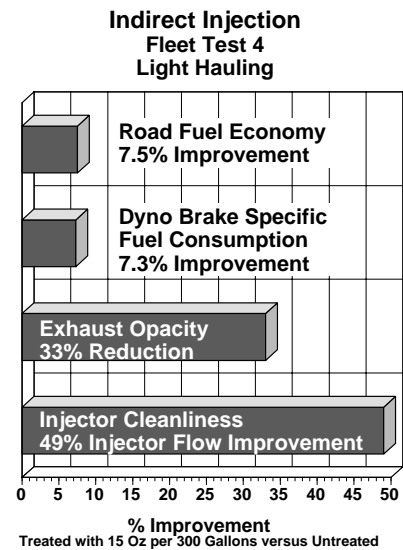


Figure 4

response was from cleanup. Over-the-road fuel economy improved 7.5%, brake specific fuel consumption measured with a chassis dynamometer improved 7.3%. Exhaust gas opacity, or black smoke, was reduced 33%, injector flow improved 49% when measured on a flow apparatus, engine noise was reduced 2.7 dB.

#### Reduces Friction

Figure 5 shows the significant reduction in friction obtainable with these synthetic lubricants when added to diesel fuel at the recommended concentrations. RL-2 can reduce the friction of diesel fuel by 48%. Some additives such as a commercial water antifreeze and fuel conditioner can actually increase the coefficient of friction as shown in Figure 5.

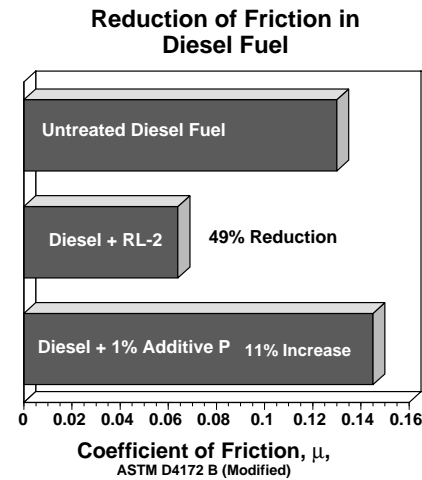


Figure 5: Reduction of friction in diesel fuel with treatments of Red Line fuel additives.

#### Reduces Wear

Figure 6 shows the wear volumes which result in this bench wear test. Red Line additives can significantly reduce wear as demonstrated in this test and as proven in the field by significantly increasing the life of the injector and reducing scoring on the injector plungers by a factor of two-to-three, which corresponds very well with bench test results.

#### Keeps Injectors Clean and Reduces Emissions

Red Line RL-2 is a very effective detergent for keeping injectors in near perfect condition and keeping exhaust emissions low. An EPA On-Highway Certification emissions test was conducted using a Cummins L10 Injector Test to "dirty" two sets of injectors. One set was "dirtied" using the base fuel, and the other was "dirtied" with the base fuel treated with 15 Oz RL-2 per 300 gallons. Each set of injectors were then placed in a Cummins L10 engine and the

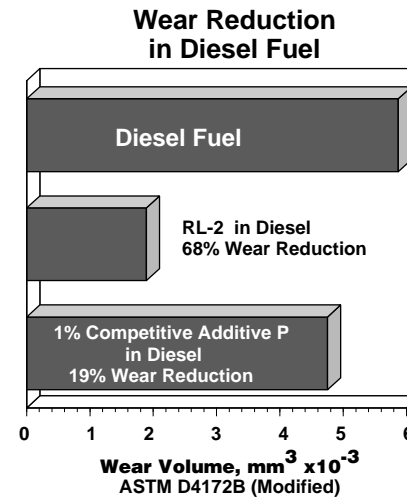


Figure 6: Reduction of steel on steel wear in diesel fuel with treatments of Red Line fuel additives.

emissions were evaluated using the EPA Emissions Certification Test. Both sets of injectors used the same engine. The injectors which were "dirtied" using the fuel treated with RL-2 provided significantly reduced emissions in this Certification Test compared to the base fuel. Figure 7 shows significant reduction in all emissions except NOx and a moderate reduction in NOx. Brake Specific Fuel Consumption was also reduced by 1.85% with the RL-2 treated fuel. Comparing the two sets of injectors at Full Rated Load and Speed, we see that the RL-2 provided 2.5% more torque and horsepower, while consuming 3.5% less fuel. This amounts to a 6% improvement in Brake Specific Fuel Consumption. RL-2 and RL-3 are a powerful tool for the fleet owner to reduce emissions and improve fuel efficiency at a cost which is a fraction of the value which will be returned to the fleet.

#### Cetane Improvement

Cetane is a measure of the ease of the diesel fuel to ignite in the combustion stroke. A higher cetane fuel means that the fuel will ignite earlier in the compression process which reduces the rate of pressure increase or "explosiveness" of the diesel fuel. This reduces the knocking noise which is heard from a diesel engine. If the cetane value of the fuel is too low, starting and warm-up will be difficult and the knocking may cause premature engine wear. Red Line RL-3 contains a cetane booster which will increase the cetane level of a fuel from 4 to 7 cetane numbers. This improvement in cetane will reduce knocking, assist cold starting and warm-up significantly, and will provide and additional fuel efficiency benefit of 1-2.5%. Red Line RL-3 contains the same

lubricants and detergents as RL-2 and contains cetane improver in addition. The efficiency improvements obtainable with the cetane booster in RL-3 can be added to the lubrication benefits of RL-2 to obtain expected efficiency improvements in the range of 6-7% for RL-3.

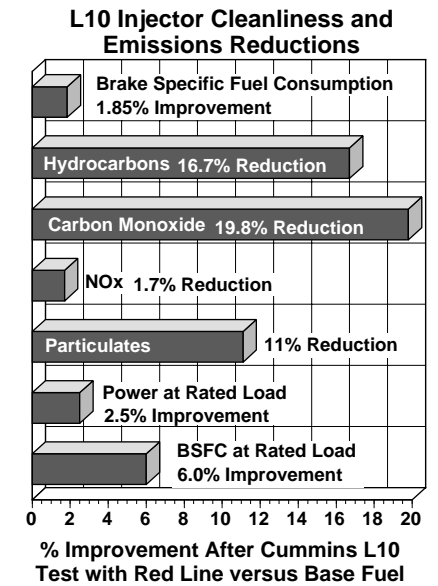


Figure 7: Emission reductions as measured in a Federal Test Procedure required by the EPA for highway certification.

#### Reduces Rust and Corrosion

Red Line diesel fuel additives contain corrosion inhibitors which will help control fuel system rust and corrosion even in the presence of water.

#### Stabilizes Fuel

Red Line diesel fuel additives contain stabilizers which slow the degradation of diesel fuel and dispersants which will prevent insoluble decomposition products from forming sludge. Red Line diesel fuel additives can also disperse sludge from old storage tanks. Good filtration should be in place on the fill hose from the storage tank.

#### Cold Weather Treatment

RL-2 and RL-3 are available in winterized versions which contain cold-flow improver to reduce the pour-point of diesel fuel by approximately 25°F and contains the Red Line Water Remover & Antifreeze to handle water from condensation down to 0°F. For severe cold snaps, RL AntiGel contains a wax dispersant which keeps the wax suspended, significantly reducing filter plugging compared to even Winterized diesel fuels.