

**WORLD CLASS
PERFORMANCE | WITH**

GRÜNTROPFEN®

**MULTI-FUNCTIONAL
DIESEL FUEL TREATMENT**



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GRÜNTROPFEN®
BIO
BASED

MAJOR ISSUES

Worldwide petroleum demand is projected to grow significantly in the next decade. The need to convert a greater portion of the crude barrel to diesel fuel and more severe refinery processing has resulted in “less stable” and “dirtier burning” fuels. Diesel fuels are showing generally downward quality trends with respect to:

- Fuel System Lubrication
- Ignition Quality
- Engine Cleanliness
- Stability
- Low Temperature Filter Plugging
- Moisture Control

In the past few years, the consequences of declining fuel quality began to appear in terms of field performance to a degree that merits attention. High combustion noise levels at low engine speeds, excessive smoke, sluggish performance and anything less than the best fuel economy are all symptoms after extended use of untreated fuel. European, Japanese, and U.S. engine manufacturers have experienced some or all of these problems.

The other major concern in the U.S. is related to exhaust particulate emissions. The more stringent limits on these and other emissions are stressing engine design technology past the limit. Indeed, currently there is a smaller margin for any deterioration of emissions or performance from deposits in any part of the engine.

INTRODUCTION

GRÜNTROPFEN is a premium diesel fuel conditioner that offers a large number of performance benefits. The concentrated additive technology in the multi-functional benefits, bio-based formula contains anti-wear, anti-oxidants, corrosion inhibitors, detergents, and dispersants. This technology has been extensively tested both in the laboratory and in the field with impressive results.

- Provides superior rating level of injector cleanliness as shown by the Cummins L10 test
- Exceeds CSCA requirements for Peugeot XUD-9 injector cleanliness
- Reduces exhaust emissions compared to base fuel
- Improves fuel economy and power
- Provides superior corrosion protection
- Enhances fuel stability in storage
- Offers exceptional lubricity for reduced fuel system wear
- Reduces water entrainment and prevents stable emulsion formation

There are clear and measurable advantages to incorporate this multi-functional diesel fuel additive into diesel fuel. The end user of GRÜNTROPFEN treated fuel will appreciate the differences of improved drivability, reduced combustion noise, longer component life, and reduced operating costs.

1- CUMMINS L 10 DEPOSITING TEST

BACKGROUND

Cummins had a field problem that occurred in some fleets. Certain engines developed injector deposits that led to a noticeable decrease in power. Cummins analyzed the driving patterns on the effected fleets and a laboratory test method was developed to stimulate these deposits. The test can be used to discriminate fuel/fuel additive quality.

TEST SUMMARY:

- Two L-10 Cummins Engines in tandem
 - 2300 RPM, 50-60 HP
 - 15 second cycle – one engine driving, the other being driven. Then roles are reversed for each subsequent 15 second cycle
 - 125 hour duration
 - Rating
 - Percent flow loss
 - CRC Visual rating of plunger deposits
 - Cummins Criteria:
 - Pass Limit - CRC Rating < 10 Flow loss < 5%
- (CRC rating goes from 0 to 100 with 0 being totally clean)

TREAT RATE:

1 gallon of GRÜNTROPFEN per 1.000 gallons of fuel for clean up.

Injector keep clean can be accomplished with 1 gallon of GRÜNTROPFEN per 2.000 gallons of fuel.

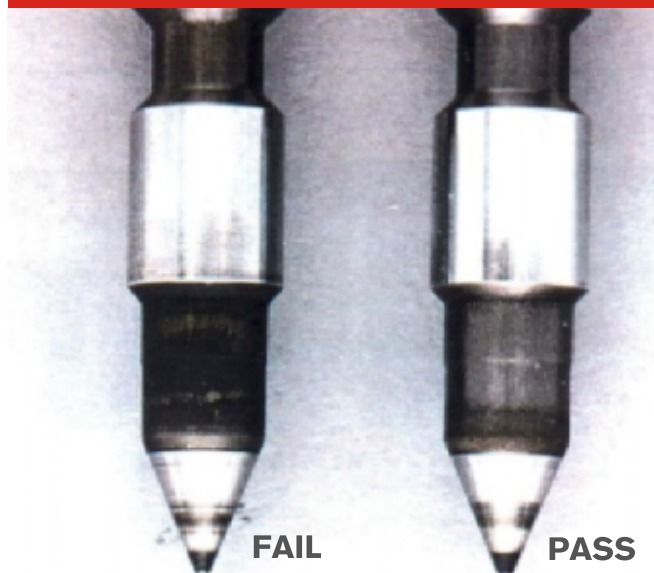
CRC INJECTOR RATING METHOD

- Based on CRC (Co-ordinating Research Council) piston and ring rating system as described in CRC manual 18.
- Scale runs from 0 to 100, 0 is perfectly clean.
- Cummins has determined that the lacquer deposits have little effect on flow performance and carbon is a more significant factor in performance degradation (SAE 912331). In the L10 procedure, carbon is weighted at 10X lacquer (for example, if an injector has 100% heavy carbon, the rating is 100; if it has 100% black lacquer, the rating is 10).
- All six injectors are rated individually and then averaged across the set in the Cummins L10 Depositing Test Procedure.

CUMMINS L10 DEPOSITING TEST



TEST STAND SET-UP AT ETS



CUMMINS L10 INJECTORS RUN IN THE CUMMINS L10 DEPOSITING TEST

CUMMINS L10 DEPOSITING TEST

GRÜNTROPFEN TECHNOLOGY PERFORMANCE SUMMARY

Fuel	Base Fuel	Treated Fuel	% Improvement
A	17.2	5.6	67
B-CAT 1K	21.3	10.6	50
C-CAT 1K	27.6	7.6	72
D-CAT 1K	22.2	7.2	68
E-CAT 1K	24.8	7.8	69
F	30.4	10.6	65

INJECTOR CLEAN-UP DATA

The ability of GRÜNTROPFEN additive technology to clean up existing injector deposits was evaluated through the use of Cummins Injector Depositing Test Cycle. A set of injectors was run in the Cummins L 10 test using untreated Cat 1K fuel. They were rated. The same injectors were rerun in the Cummins L 10 Injector Depositing Cycle with treated Cat 1K fuel. This test showed a reduction in average injector deposits of 20.3 percent.

CRC RATING (AVG)	
Initial dirty-up base line Cummins L10 test (untreated fuel)	25.2
Same injectors after Cummins L10 test (treated fuel)	20.1

INJECTOR CLEAN-UP DATA II

The ability of GRÜNTROPFEN additive technology to clean up existing injector deposits was also evaluated through the use of a steady state cycle that would simulate a heavy duty truck cruising at normal road speed.

A set of injectors were run in Cummins L 10 test using untreated Cat 1K fuel to create the dirty injectors for the start of the test. These injectors were rated and then used to develop baseline FTP (Federal Test Procedure) transient emissions results. The engine was then run at steady state (1,800 RPM, 600 ft-lbs torque).

After 2,300 liters (608 US Gallons) of fuel was consumed, the injectors were re-rated. FTP emissions were run at the mid-point and end of test for comparison to starting emissions.

This test showed a reduction in average injector deposits of 53.9 percent. Specific regulated emissions were reduced up to 24.1% and brake specific fuel consumption decreased by 2.6%. Test results are highlighted in the following tables.

**CUMMINS L10 INJECTOR CLEAN-UP
FTP TRANSIENT EMISSION TESTING**

COMPARISON OF EXHAUST EMISSION AND ENGINE PERFORMANCE

	HC	Nox	CO	PM	BSFC
Start of test	0.45	4.69	3.32	0.381	0.382
Midpoint	0.40	4.55	2.92	0.383	0.379
End of test	0.38	4.71	2.52	0.376	0.372
% Change	-15.6	0.4	-24.1	-1.3	-2.6

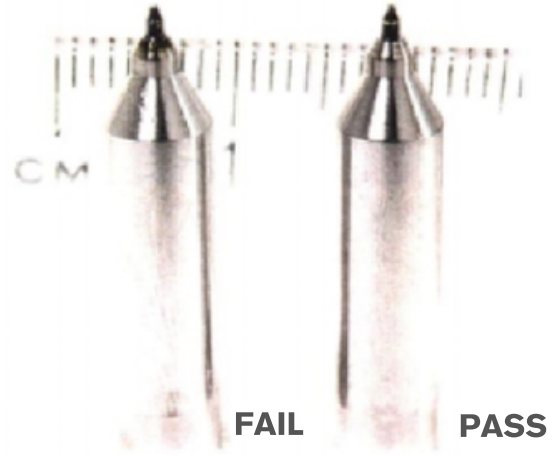
INJECTOR DEPOSIT AND FLOW COMPARISON

	CRC Rating	Flow Rating
Start of test	24.1	132.2
End of test	11.1	131.2
% Change	-53.9	-0.76

PEUGEOT XUD9 NOZZLE COKING TEST



TEST STAND AT LUBRIZOL



PEUGEOT XUD9 INJECTORS RUN IN THE PEUGEOT XUD9 NOZZLE COKING TEST

Test is a recognized industry evaluation of deposits in an indirect injected passenger car diesel engine. It was developed in Europe by Group PF26 of the CEC.

TEST PARAMETERS

Engine:	Peugeot XUD9
Cylinders, swept volume:	4, 1.9L
Speed:	3000 RPM
Load:	58 Nm
Duration:	6 hours

TEST/CRITERIA SUMMARY

New nozzles are flowed with air and measurements are taken at lift points of 0.1, 0.2, 0.3, and 0.4mm. The nozzles are reassembled in the engine. The engine is warmed up to test conditions and then run for 6 hours. Nozzles are then reflowed and compared to the initial flow rate.

The original procedure was developed by Group PF26, but they specified no pass/fail limits. A French OEM group, CFCA, has developed a pass/fail criteria: greater than 15% remaining injector flow as compared to original flow at 0.1mm of pintle lift.

The attached graph detail the excellent results when using GRÜNTROPFEN.

Treated fuel gave an 87% improvement in Average Residual Flow and passed CFCA requirements.

Combined with the excellent Cummins L10 results, this demonstrates GRÜNTROPFEN's performance versatility for DIRECT INJECTION and INDIRECT INJECTION engines.

LABORATORY BENCH TESTS

GRÜNTROPFEN offers excellent wear protection, oxidation stability, corrosion protection, and water separation.

The following laboratory tests can also be used to evaluate diesel fuel quality and additive effectiveness. Below is a short description of each test. The following pages give test conditions and test results.

ASTM D6078, BOCLE TEST:

Measure of a fuel's lubricity characteristic. (The Scuffing test method is a modified SAE BOCLE test that better simulates conditions in a diesel engine, Reference SAE Paper No. 932691).

ASTM D6079 HIGH FREQUENCY RECIPROCATING RIG TEST:

Measure of a fuel's lubricity characteristic.

ASTM D2274 FUEL OIL STABILITY TEST:

Measure of the oxidative stability of a diesel fuel.

Octel America F21-61, FUEL OIL STABILITY TEST:

Measure of the thermal stability of a diesel fuel. This test is being adopted by ASTM and is used by the National Conference on Weights and Measures to help define premium diesel fuel.

NACE RUST TEST (NACE):

National Association of Corrosion Engineers: measure of the anti-corrosion ability of a fuel.

ASTM D1094, WATER TOLERANCE:

Measure of a fuel's ability to separate from water.

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ASTM D6078 BOCLE TEST

TEST PARAMETERS

BASE FUEL: Isopar M (50 ml)
TEMPERATURE: 25° C (77° F)
RELATIVE HUMIDITY: 10%
TEST CONDITIONS: Non-Rotating Ball applies 1000 g force to cylinder rotating @ 240 RPM.
DURATION: 30-Minute Duration
PERFORMANCE CRITERIA: Measure Wear Scar on Ball.

TEST RESULTS

Fuel:	Mean Wear Scar (mm):
ISOPAR M	0,838
ISOPAR M (TREATED)	0,541

CONCLUSION

When added to Isopar referent fuel, GRÜNTROPFEN provides excellent antiwear performance as measured.

ASTM D6079 HIGH FREQUENCY RECIPROCATING RIG (HFRR) TEST

TEST PARAMETERS

BASE FUEL: Swedish MK-1 City Diesel Fuel
TEMPERATURE: 60° C (149° F)
TEST CONDITIONS: A 50 HZ reciprocating ball with a stroke of a length of 1 mm is brought into contact with a stability disk. The load is 200g and the duration is 75 minutes.
PERFORMANCE CRITERIA: Measure wear scar on ball.

TEST RESULTS

Mean Wear Scar (mm):	
BASE FUEL	0,54
BASE FUEL (TREATED)	0,33
PASS/FAIL LIMIT (EMA)	0,45

CONCLUSION

Adding GRÜNTROPFEN to Base Diesel Fuel improves lubricity performance by 39% in this test. This performance enhances the wear protection of fuel pumps and other fuel system components.

ASTM D2274 STABILITY TEST

TEST PARAMETERS

BASE FUEL: Commercial No.2 Diesel Fuel
TEMPERATURE: 95° C (203° F)
TEST TIME: 16 Hours
TEST CONDITIONS: Oxygen Is Bubbled Through
The Sample At A Rate Of 3 Liter/Hour
PERFORMANCE CRITERIA: Amount Of
Insolubles And The Fuel Color Change

TEST RESULTS

Additive	ASTM Color		Filter Insolubles (mg/100 ml)
	Initial	Final	
NONE	L0,5	L1,5	0,69
TREATED	L0,5	L0,5	0,15

CONCLUSION

In the ASTM D2274 Fuel Oil Stability Test, GRÜNTROPFEN provides excellent stability as illustrated by the 78% reduction in fuel insolubles and strong color stability. Oxidation of diesel fuel can cause the formation of gums, which can increase the formation of deposits and increase the chance of filter plugging. GRÜNTROPFEN protects against oxidation.

OCTEL AMERICA F21-61 STABILITY TEST

TEST PARAMETERS

BASE FUEL: Commercial No.2 Diesel Fuel
TEMPERATURE: 150° C (302° F)
TEST TIME: 180 Minutes
PERFORMANCE CRITERIA: Percent Reflectance
Using Proper Light Meter

TEST RESULTS

Insolubles Additive	Reflectance Final	Filter (mg/100 ml)
NONE	4%	19,5
TREATED	72%	8,3

CONCLUSION

In this test, GRÜNTROPFEN's additive technology provides excellent stability as illustrated by the 68% increase in light reflection and the 57% reduction in fuel insolubles. Thermal degradation of diesel fuel can cause the formation of deposits and increase the chance of filter plugging. GRÜNTROPFEN protects against this thermal degradation.



NACE RUST TEST

TEST PARAMETERS

BASE FUEL: Depolarized ISO-Octane
TEMPERATURE: 37.8° C (100° F)
WATER PHASE: Distilled
FUEL WATER CONTACT: Stir Fuel 30 Minutes, Stop, Introduce Water, Stir 3.5 Hours
STEEL SPINDLE: Polished, cold rolled SAE 1020, 1/2"
PERFORMANCE CRITERIA: Visual evidence of rust

TEST RESULTS

Additive	NACE Visual Rating	% Rust
NONE	D	50-75%
TREATED	A	NONE

CONCLUSION

GRÜNTROPFEN provides superior anti-corrosion protection in depolarized ISO-Octane Fuel. This characteristic ensures superior anti-rust protection to storage facilities, fuel handling systems, and end users diesel engines.

ASTM D1094 WATER TOLERANCE

TEST PARAMETERS

BASE FUEL: Commercial NO. 2 Diesel Fuel
TEMPERATURE: 25° C (77° F)
WATER PHASE: Distilled
FUEL/WATER CONTACT: Hand Shaken for 2 minutes (80 ml of fuel, 20ml of water)
SETTLE TIME: 5 Minutes
PERFORMANCE CRITERIA: Degree of fuel/water separation, clarity of phases, interface rating

TEST RESULTS

Additive	Rating after 5 min		Time Required to settle (min)
	Interface	Separation	
NONE	3	3	10+
TREATED	1	1	2

CONCLUSION

GRÜNTROPFEN improves the fuel/water separation performance of base fuels to insure trouble-free handling after any contact with water. GRÜNTROPFEN will ensure that emulsions will not readily form, thus not causing drivability and rusting concerns.

2- FLEET TEST

TREAT RATE

1 gallon of GRÜNTROPFEN per 1.000 gallons of fuel for **clean up**.

1 gallon to 2.000 gallons for **set clean**.

FLEET 1

LOCATION: Charleston, SC

FLEET: Cement Trucks

NO. OF UNITS: 22 Total (11 Base / 11 Treated)

ENGINES: Cummins L10

TOTAL MILES: 400,000

AVERAGE SERVICE: 18,200 Miles and 2,300
Hours

OBJECTIVE

The fleet was chosen in cooperation with Cummins Engine Company and Engineering Test Services to closely match the L10 test cycle in service. (Engineering Test Services is a division of Cummins Engine Company.)

TEST

The fleet was equipped with new injectors and monitored for one year. The injectors were then rated.

CONCLUSION

At the end of test, the treated units had injectors that were 44% cleaner than the base unit injectors were. The treated units also had more horsepower and better fuel economy. Fuel economy data is graphed on the following page.

CRC RATINGS (AVG.)

Base Units: 30.3

Treated Units: 16.9

FLEET 2

LOCATION: Charleston, SC

FLEET: Class 8 Line Haul

NO. OF UNITS: 59 Total (31 Base / 28 Treated)

ENGINES: Cummins L10, Detroit Diesel Series 60,
Mack E6

TOTAL MILES: 4,000,000

AVERAGE SERVICE: 70,000 Miles

OBJECTIVE

The fleet was represented as a well-maintained line haul distribution fleet. This test monitored long-term additive effects including injector cleanliness and fuel economy over a wide variety of engines.

TEST

"Keep clean" and "clean up" tests were evaluated in Cummins L10 engines in normal service. The Cummins L10 procedure was used to determine injector cleanliness. The Detroit Diesel and Mack engines were used to obtain fuel economy data along with the Cummins engines. Test duration was 18 months.

CONCLUSION

Overall, the treated data showed no fuel system related problems and an improvement in fuel economy. In addition, treated fuel was successful in keeping injectors clean and cleaning up dirty injectors in the Cummins fleet.

3- EMISSIONS AND POWER DATA

TREAT RATE

1 gallon of GRÜNTROPFEN per 1.000 gallons of fuel for **clean up**.

1 gallon to 2.000 gallons for **set clean**.

TEST SEQUENCE

Run Cummins L10 Injector Depositing test with base fuel and fuel additized with GRÜNTROPFEN diesel treatment.

At the conclusion of the test, remove injectors and place them in another L10 engine.

Run the engine on the transient emission cycle. This cycle is used for on-highway certification of trucks in the USA and it has 4 phases that simulate driving in:

- New York city urban
- New York city highway
- Los Angeles highway
- New York city urban

The test is considered representative of real world driving conditions.



CONCLUSIONS

GRÜNTROPFEN

- Significantly reduces emissions compared to unadditized fuel.
- Provides excellent cleanliness within the engine, which leads to increase fuel economy.
- It's cleanliness and lubricity properties help to maintain engines in like "new" condition, which maintains power.



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