FUEL ECONOMY TESTS
OF HIGH PERFORMANCE FUEL FILTERS

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This test program was designed to determine the benefits if any of using high performance Diesel Engine Fuel Filters. The Filters selected were manufactured by WaterGuard Filters, Inc., Houston, Texas, and contain a new patented Water Removing Chemistry that allows these New Environmental Filters to be used as Diesel Engine Fuel Filters, Return Line Filters on Hydraulic Oil Systems, and Industry Turbine, and Transformer Oil Filters which require a high degree of cleanliness to operate at design capabilities. The conclusions resulting from an analysis of the test results are:

1. **That Environmental Filters clean diesel fuel better than standard fuel filters by removing Liquid Water, Emulsified Water, Acids, and Solid Particulate to a greater degree that other filters especially in the smaller micron particle sizes.**
2. **That clean fuel contributes to more efficient engine performance. The following Filter Fuel Mileage tests showed a 4.90% average improvement of miles per gallon fuel consumption resulting from the engine's use of cleaner and dryer fuel.**
3. **That Environmental Fuel Filters produced an average of Ten Dollars of fuel saving for each one Dollar spent in filter costs.**

TEST PROGRAM FOR DIESEL FUEL FILTER CONTENT

The first part of the test program was to take samples of the diesel fuel at various fleet terminal sites. "Karl Fisher" a standard test method for measuring water content of a fuel was used to measure the water content of the fuel samples that were taken. It has been determined that Water in diesel fuel can be hi three different forms.

1. Free Water: which is not bonded to the fuel and that can gravity separate from the fuel with relative ease;
2. Emulsified Water which is finely dispersed within the fuel, which gives the fuel a cloudy appearance and which is difficult to remove from fuel.
3. Dissolved water which is not seen and which is similar to humidity in atmosphere and which requires special "Hi" vacuum equipment to remove. You will find dissolved water in fuel at a ratio of about one part per million for each degree of temperature in farenheights. As an example, if a fuel is at 70° F temperature and a Karl Fisher Test shows total water at 100 parts per million of water, 70 P.P.M. will be dissolved water and 30 P.P.M. will be free water, which a percentage of which may be emulsified into the fuel so as to not settle out by gravity attraction and which is very difficult to remove. Diesel fuel is Hydroscopic by nature so there is always some water present. Controlling water is very important for Fuel Quality, because water provides the mechanism for oxidation and bacteria growth, which causes fuel Deterioration to take place in storage tanks. Water must be removed to produce maximum fuel efficiency for as a non-combustible material Water lowers the energy of the fuel to produce combustion temperatures hot enough to fully burn all the hydrocarbons of the fuel.

Solids are also demonstrated by the test data to reduce engine performance and that particulate levels can vary dramatically in fuel delivered by different distributors. The following table No. 1 shows the particle count of the 5 to 100 micron size range particles found in six different fuel samples selected at random. The samples were taken from the terminal fuel systems of operating fleets participating in these test.

TABLE NO. 1

	PARTICLE COUNT		PARTICLE COUNT
TERMINAL 1	1,744,460	TERMINAL 2	744,060
TERMINAL 3	100,340	TERMINAL 4	444,820
TERMINAL 5	887,500	TERMINAL 6	334,670

It was reported that in the opinion of the terminal manager, all of the fuel tested met with No. 2 diesel fuel specifications, yet there was a wide range in particle count and the appearance of the fuel varied dramatically.

Table No. 2 below shows the total particle count of table no. 1 as particle distribution in the fuel samples by particle size that roughly 90% of the particles found were in the 5 - 15 micron size range.

TABLE NO. 2

	5-15 SIZE	15-25 SIZE	25-50 SIZE
TERMINAL 1	1,613,600	123,060	7,650
TERMINAL 2	627,080	89,680	18,700
TERMINAL 3	67,870	31,600	870
TERMINAL 4	398,730	37,700	7,870
TERMINAL 5	743,880	110,030	30,480
TERMINAL 6	286,940	42,570	5,150

Fuel dispenser pumps and on board engine fuel filters for the most part are designed to remove large size particulate and are designed to remove particulates that are in the 10 to 25 microns or larger size particles. However, it is the small size particulates that are known to cause equipment damage. The terminal using the high particle count fuel reported its fleet frequently experienced injector and pump problems. Even though they were using engine manufacturers recommended engine fuel filters on the engine fuel systems rated to remove as low as 10 microns size particles. How well a particular filter does this depends on the efficiency of the filter and how contaminated the fuel is.

Environmental Filters Co. report its filters are Hi tech and are designed to remove water as well as particulate from hydrocarbon fluids. We wanted to see how well their filters cleaned the worst quality diesel fuel we could find. Sample of Terminal 1 diesel fuel were filtered through an Environmental 4”x5” spin-on type filter.

The next table No. 3 shows the results of that test. These are one pass readings, meaning that the fuel passed through the filter just once. The results were consistent with other tests conducted.

TABLE NO. 3

	5-15 SIZE	15-25 SIZE	25-50 SIZE	WATER PPM
TERMINAL 1	1,613,600	123,060	7,650	98
ONE PASS THROUGH ENVIRONMENTAL FILTER	8,250	910	320	80

The above data demonstrates that both fuel quality and filter efficiency must be evaluated when examining engine performance.

ENGINE PERFORMANCE AND FUEL ECONOMY

Environmental filter customers indicated that the filters produced increases in fuel efficiency. To confirm this, standard fuel mileage tests as published by the Society of Automotive Engineers (SAE) were selected to measure engine fuel performance in the field.

The test methods used were based on SAE vehicle fuel tests using the concept of keeping everything the same except the fuel filtering system. The critical parameters were, to run the same route, at the same speed, over the same distance, with the same load, and fill the tanks to the same fullness after each run. The test results show a strong correlation between fuel quality and vehicle fuel efficiency. The next table No. 4 shows the percentage of improvement in fuel efficiency caused by changing from the standard filter being used by the fleet to a Environmental filter and relating to the particle count of the fuel.

TABLE NO. 4

ORIGINAL PARTICLE COUNT OF FUEL		MPG IMPROVEMENT
TERMINAL I	1,744,460	+53.99%
TERMINAL 5	887,500	+ 38.04%
TERMINAL 6	334,670	+ 16.41%

The above fuel improvement results are indications that fuel consumption on a per mile basis is greatly influenced by burning cleaner fuel. The results are consistent with customer reports. We believe it is the first report that looks at fuel quality at the micron level of particle count of contamination by particle size and moisture on a PPM level and correlates that fuel quality with fuel efficiency.

FIELD TEST PROGRAM

The majority of the vehicles tested used computer generated reports to tract each vehicles fuel performance. This provided a historical record of each vehicle's performance. Examination of the data showed that miles per gallon (MPG) varies from month to month on particular vehicles, but nevertheless on average represents the general performance of that vehicle. Additionally, because there are other variables that can affect a vehicle's performance during a given month, we worked with the customer to find a base line average for the test vehicles used in the test, and a suitable number of vehicles to produce a mean average of fuel consumption on a loaded per mile basis. After consideration of the above, we selected historical fuel consumption data in September as the base line month and selected 30 trucks for the actual test size. The test results are shown in the following Table No. 5.

FIELD TEST RESULTS NO. 5

TRUCK #	MPG HISTORICAL BASE	MPG DURING TEST	MPG Change	% MPG Change	Fuel Used in Test Period
009	3.52	4.60	+ 1.08	+ 30.68%	826
1330	4.94	5.79	+ 0.85	+17.21%	190
1331	6.73	7.07	+ 0.34	+5.05%	959
1333	6.19	6.34	+ 0.15	+2 .42%	2007
1334	6.43	6.69	+ 0.26	+4.04%	1580
1335	6.95	7.01	+ 0.06	+0.86%	515
1336	5.70	7.24	+ 1.54	+27.02%	1213
1339	6.50	6.07	-0.43	-6.62%	2351
1340	6.72	6.20	-0.52	-7.74%	1352
1341	7.01	7.20	+ 0.19	+2.71%	2477
1343	6.64	6.51	-0.13	-1.96%	1960
1344	5.53	7.10	+ 1.57	+28.39%	283
1345	7.08	6.06	-1.02	+14 .41%	2213
1321	6.54	6.13	-0.41	-6.27%	1370
1330	4.94	6.77	+ 1.83	+37.04%	1888
1331	6.73	6.52	-0.21	-3.12%	2400
1333	6.19	6.92	+ 0.73	+11.79%	1989
1334	6.43	6.87	+ 0.44	+6.84%	2145
1335	6.95	5.81	-1.14	+16.40%	1461
1336	5.70	6.83	+ 1.13	+19.82%	1726
1339	6.50	5.48	-1.02	+15.69%	1688
1340	6.72	6.36	-0.36	-5.36	2157
1341	7.01	7.22	+ 0.21	+ 3 .00%	2122
1343	6.64	6.15	-0.49	-7.38%	2220
1344	5.53	6.60	+1.07	+19.35%	1514
1345	7.08	6.81	-0.27	-3 .81%	2402
631	5.85	6.19	+0.34	+5.81%	137
418	5.43	5.99	+0.56	+10 .31%	111
459	6.40	5.88	-0.52	-8.13%	184
2108	5.94	6.63	+ 0.69	+11.62%	96

The data from the field tests show an average improvement of 4.90% in mpg of fuel used. The total fuel used in the test period was 43535 gallons. As a result, 4.9% would be the expected improvement in an average fleet fuel consumption on a loaded miles traveled basis due to changing to this type of high performance filters. It is the improvement in fuel consumption that would be expected if a comparison was made between a test period of Environmental type filters use and a previously recorded period of standard filter use.

ECONOMICS

Using the weighted average of fuel savings from the above Table No. 5 the value of the fuel saved is $2,134 based on $1.00 per gallon fuel cost, the allocated filter cost based on normal filter maintenance change out for the test period is $209.50 based on list price cost of the Environmental filters. The ratio of filter costs to fuel savings is approximately 1 to 10. The filters produce a $10.00 savings for each one dollar of filter cost.

CONTROL DATA AND SEASONAL EFFECTS

In calculating mpg improvements of the above tests, seasonal effects on MPG were considered. Mileage data for the October and November test months was compared with data from the September base period. Control data on other vehicles not using Environmental filters during the test period, indicated that the average fleet mpg for the October and November test periods were decreasing. The following Table No. 6 shows average mpg ratings for the control and test vehicles during the test period.

TABLE NO. 6

	SEPTEMBER	OCTOBER	NOVEMBER
CONTROL VEHICLES MPG	6.59	6.29	6.11
TEST VEHICLE MPG	6.60	6.61	6.50

The data shows that, in October the control trucks averaged 6.29 mpg, a 4.5% decrease from September. In November, the control trucks averaged 6.11 mpg a 2.9% decrease. The total decrease is 7.4% from September mpg.

FILTER CAPACITY

One of the objectives of the test program was to confirm life cycle tune of the filters. It was observed that the limiting factor was the water content and quality of diesel fuel in the field. Tests showed that the average moisture or water content was about 100 parts per million in the fuel samples taken. Using 100 PPM as the average fuel water content, and the capacity of the WGF40510SP Environmental filter which is designed to hold 12 oz. of water, the filter would be full after filtering 3600 gallons of fuel. The larger

WGF40910SP filter which holds 16 oz. of water would be full after filtering 4800 gallons.

Most of the test vehicles used the larger filter and data indicates the filters were still efficient after filtering 5000 gallons of fuel.

FILTER CHANGE OUT

Based on an analysis of all the test results our recommendation is to follow the engine manufacturer's recommended filter change intervals. Tests show that the filters hold about twice as much contamination as standard filters but they also remove particulate and water to much lower levels. The net effect is they should last as long as other commonly used filters. However, if the vehicle is using very duty fuel, the filters will be changed more frequently. For average quality fuel, however, the above data appears to be accurate.

INDIVIDUAL TRUCK ANALYSIS

To determine there were no factors overlooked that should be examined which may have contributed to the test data, a truck by truck analysis of some of the data was performed. The conclusion is that random testing of similar vehicles during the same time period will provide similar results of the filters performance, however changes in the load, route, and idling time will on average affect the test data and similar experience must be maintained in the control vehicle for accurate comparison data. A sampling of truck data and related comments is as follows:

Truck #1343
Historical mpg - 6.90
Base mpg - 6.64
Test mpg - 6.51
Historical load miles / total miles - .77
Base load miles / total miles - .83
Test load miles / total miles - .84
Filter installation date - 10/11
Routes - (before change) VA, MD, NJ, MO, OK, NC, SC, GA - (after change) MD, CA,WA, GA, SC, MS, LA, CO, AL
Mpg % improvement test vs base (1.96%)
Comments - The base is the September mpg. The mpg for the first 11 days in October was 5.95 mpg.

Filter installation date - 10/21
Routes - (before change) NV, UT, MO, ID, IL, NY, PA, FL, GA, NV, CA, OK - (after change) TX, OK, CA
Mpg % improvement test vs base (14.41%)
Comments - Can not find a reason for the decrease in mpg during the test period. Load vs total mile ratio is high but not enough to explain the 10% decrease in mpg. However, there were a number of short hauls and about 4000 miles of travel over the week which probably affects the reading.

Truck #1331
Historical mpg - 6.83
Base mpg - 6.73
Test mpg - 7.07
Historical load miles / total miles - .69
Base load miles / total miles - .53
Test load miles / total miles - .50
Filter installation date - 10/16
Routes - (before change) IL, IA, NC, SC, NC, RI, PA, NC, ID, IL - (after change) NY, PA, MD, ID, IL, OK, TX, KS, IL, CO
Mpg % improvement test vs base 5.05%

Truck #1335
Historical mpg - 6.70
Base mpg - 6.95
Test mpg - 7.01
Historical load miles / total miles - .70
Base load miles / total miles - .74
Test load miles / total miles - .84
Filter installation date - 10/21
Routes - (before filter change) TX, ARK, MO, NJ, MD, OH - (after filter change) CA, TX
Mpg % improvement test vs base 0.86%
Comments - Better mileage despite more loaded miles.

Truck #1336
Historical mpg - 6.85
Base mpg - 5.70 Test mpg - 7.24
Historical load miles / total miles - .66 Base load miles / total miles - .80
Test load miles / total miles - .79
Filter installation date - 10/06
Routes - (before change) MO, TX, AR, TX, AL, AL - (after change) GA, AL, TX, MO, AL, LA, TX, IL, NY, NJ, VA, TX Mpg % improvement test vs base 22.02%
Comments - The base mpg is low but even if the test is compared with the historical average, there is improvement.

Truck #1333
Historical mpg - 5.99
Base mpg - 6.19
Test mpg - 6.34
Historical load miles / total miles - .77
Base load miles / total miles - .66
Test load miles / total miles - .74

Filter installation date - 10/11
Routes - (before change) MD, NC, GA, NJ, NY, VA, MD, NJ, TN, GA - (after change) NC, NJ, OH, CA, KS, OK, IL, ID, IL, ID
Mpg % improvement test vs base 2.42%

Truck #1344
Historical mpg - 6.10
Base mpg - 5.53
Test mpg - 7.10
Historical load miles / total miles - .73
Base load miles / total miles - .81
Test load miles / total miles - .78
Filter installation date - 10/28
Routes - (before change) SC, GA, CA, AR, CA, FL, SC, NC, AK, OK AL, MD, NJ - (after change) CN, PA, TX
Mpg % improvement test vs base 28.39%
Comments - The filter was installed near the end of the month, the truck traveled over 2000 miles in the following 2 days a fair measure of performance for a new filter.

Truck #1341
Historical mpg - 6.90
Base mpg - 7.01
Test mpg - 7.20
Historical load miles / total miles - .77
Base load miles / total miles - .84
Test load miles / total miles - .79
Filter installation date - 09/28
Routes - (after change) FL, GA, TN, NC, GA, PA, DL, TN, AL, TN, GA, CA, OK, AK, AR, CA, NY, MD, NJ, IL, ID, IL, KS, IL, NV
Mpg % improvement test vs base 2.71%
Comments - This is a complete month of testing over 18,000 miles.

Truck #1345
Historical mpg - 6.54
Base mpg - 7.08
Test mpg - 6.06
Historical load miles / total miles - .74
Base load miles / total miles - .80
Test load miles / total miles - .84