



Fuel Treatment

Revision 2008-07-23



Product information and test results for Green Performance Fuel Treatment.
7/21/2008

What is Green Perform™ Fuel Treatment

Green Perform™ Fuel Treatment is an advanced EPA Certified formula specifically developed to accelerate the combustion rate of hard-to-burn hydrocarbon molecules. It functions by promoting the decompression of the large fuel particles in the flame and thus produces smaller fragments, which in turn are quickly burnt. This facilitates to complete the final stages of combustion reaction by lowering the temperatures at which soot burns, while virtually eliminating opacity (black smoke) problems. Slagging, fouling and corrosion are also less likely, thereby extending equipment life. Green Perform™ Fuel Treatment can be used with both diesel and gasoline engines and is also available for HFO (heavy fuel oil) applications.

Why use Green Perform™ Fuel Treatment

Green Perform™ Fuel Treatment offers large fossil fuel consumers a simple, cost-effective approach to combat today's high petroleum prices and reduce operating costs, especially where incomplete combustion is a problem. The underlying cause can be high levels of asphaltenes in the bunker oil, which leads to loss of ignition or carbon burnout problems, that result in excess soot formation, carbon deposits, black smoke (particulates or DPM), cold end corrosion and fouling with sulfur (sulphur) or vanadium.

Green Perform™ improves fuel efficiency and combustion efficiency, by liberating more of the fuel's chemical energy, in the flame zone of boilers, or during the power stroke of diesel engines. Soot formation is prevented and less fuel is wasted in the form of particulate emissions. Greenhouse gas (CO₂) and acid rain gases (SO₂ and SO₃), soot (black smoke), carbon build-up and fouling, slagging and cold-end corrosion are all reduced, while engine and boiler performance improves. Turbochargers and exhaust gas boilers remain cleaner and require less maintenance and water washing.

Green Perform™ Fuel Treatment reduces fuel consumption by 3 to 5% across a wide range of fossil fuels, from coal and heavy residual fuel oils to intermediate fuel oil blends, refined diesel fuels.

Green Perform™ Fuel Treatment is effective in industrial boilers and diesel engines of all sizes and is used in marine shipping, power generation, mining, construction, ground transportation and wherever high fuel prices or compliance with emissions or opacity regulations is a concern.

The benefits of Green Perform™ Fuel Treatment were scientifically measured at the Battelle Memorial Institute (www.battelle.org), in both the United States and in Europe, and by the Southwest Research Institute (www.swri.com) in the United States. Tests were conducted under controlled furnace, boiler and diesel genset conditions to determine, with laboratory certainty, the effect of Green Perform™ Fuel Treatment on the combustion performance of bituminous coal, crude oil, heavy and light fuel oils and diesel fuel.

The primary benefits of Green Perform™ HFO Treatment (Heavy Fuel Oil) are improved combustion efficiency, reduced ash formation and the virtual elimination of unburned carbon in the exhaust system and bottom ash. The result is fuel savings on bunker C or heating oil and a significant reduction of environmental pollution. Detailed information about the mode of action of the catalyst in the burner has allowed the development of strategies to control NO_x emissions and in the case of coal and heavy fuel oil (HFO) to achieve a net reduction in NO_x emissions.

Green Perform™ Fuel Treatment does not affect normal diesel engine wear and it has no detrimental effects upon fuel characteristics. Green Perform™ Fuel Treatment is safe to use and it produces no harmful incremental emissions as a by-product, unlike many fuel additives. Green Perform™ also reduces the volatile fraction of particulate emissions (PAH's) which can promote skin cancer in humans.

Secondary benefits of Green Perform™ Fuel Treatment include better engine performance, extended equipment life and reduced maintenance costs, all with minimal disruption to normal engine or boiler operations. Soot formation and slagging on exhaust gas boilers is eliminated and time intervals between major overhauls of components, such as turbochargers, can be increased. Internal engine components, including pistons, rings, valves and fuel injector tips remain free of hard carbon deposits.

How Does Green Perform™ Fuel Treatment Work

The Problem of Incomplete Combustion - Fossil fuels are a complex mixture of carbon and hydrogen containing molecules referred to as hydrocarbons (HC). In addition to the pure hydrocarbon molecules, fuels also have a small fraction of molecules containing nitrogen, sulphur and other elements including many metals such as vanadium. Poor quality fuels, such as coals, are comprised of very large, mostly carbon containing molecules. The amount of hydrogen in the fuel increases as the size of the molecules decrease and the quality of the fuel increases. Higher quality fuels which have more hydrogen and smaller molecules burn faster and more completely. When fossil fuels burn, oxygen is reacting with the hydrocarbon molecules to produce carbon dioxide (CO₂), water (H₂O), oxides of the trace elements (Nox, Sox, Vox, etc. where x is 0 or a small number) and heat. How completely the hydrocarbons burn depends upon three basic factors:

- The rate at which the molecules burn.
- (This rate is a function of how large the molecules are.)
- How much oxygen is present around the fuel molecules
- The length of time that the fuel molecules spend in the fireball

How it Works - Green Perform™ Fuel Treatment accelerates the rate of combustion of hard-to-burn hydrocarbon molecules. It functions in at least two ways:

1. Green Perform™ Fuel Treatment promotes the decomposition of the large fuel particles in the flame and thus produces smaller fragments which in turn are quickly burnt.
2. Green Perform™ Fuel Treatment helps to complete the final stages of the combustion reaction by lowering the temperatures at which soot burns.

The Benefits - Green Perform™ Fuel Treatment dramatically reduces the carbon particulate emissions while simultaneously reducing the excess air requirements. The benefits are more efficient combustion which produces more energy and lower emissions per unit of fuel burned.

The secondary benefits of using Green Perform™ Fuel Treatment are difficult to quantify, although they can be significant. There is the obvious saving associated with increasing the energy output of the fuel. The increased combustion efficiency also reduces fouling and corrosion thereby improving heat transfer, extending equipment life, reducing maintenance costs and minimizing interruptions of plant operations. Other efficiency gains include lower excess air requirements, reduced fan power for soot blower operation, the ability to effectively employ a lower-cost fuel and better recovery of marketable ash from coal combustion.

- Opacity (black smoke) problems are virtually eliminated.
- Electrostatic precipitator performance is improved.
- Slagging, fouling, and corrosion are less likely.
- Decreasing the excess air in generic industrial oil-fired boilers from 30 to about 10 percent is equivalent to as much as a two percentage point increase in overall efficiency.
- Green Perform™ Fuel Treatment cleans carbon deposits from engine or boiler surfaces thereby extending equipment lifetime.

The environmental benefits of using Green Perform™ Fuel Treatment in all types of combustion warrant mention. Green Perform™ Fuel Treatment promotes the combustion of the carbon particles (soot) and condensed tar which result from the incomplete combustion of fuels. When present in sufficient particle size and quantity, soot in exhaust gases constitutes a black smoke. Although soot is not the most abundant pollutant, it may be one of the most hazardous since soot particles are the proper size to be ingested deep into the lungs.

In addition, the polycyclic aromatic hydrocarbons (PAH's) which are absorbed on soot can promote skin cancer in humans, as many PAH's are known to be carcinogenic. The fraction of volatile particulates was greatly decreased (33-68 percent) by Green Perform™ Fuel Treatment, even when firing at ultra-low excess combustion air.

Research also indicates that soot adsorbs sulphuric acid formed during combustion and contributes to its formation via reactions on the carbon surface. The adsorbed H₂SO₄ can be as much as 20% by weight of the carbon retained in the boiler. If volatilized, this causes acid smut fallout and boiler cold-temperature corrosion.

Applications for Green Perform™ Fuel Treatment

The quantitative burnout of carbon in flames of solid and liquid fossil fuels remains a continuing combustion-engineering challenge, made more difficult by the use of many NO_x control strategies. Because unburned fuel carbon represents a source of both pollution and inefficiency, there is an increasing need for the development of technologies that enhance carbon burnout. The introduction of Green Perform™ Fuel Treatment provides a new option for industries of all types to use in resolving fuel and site specific combustion problems. Green Perform™ Fuel Treatment comes in the right packaging for your fuel treatment requirements.

Automotive - From passenger cars to light trucks, Green Perform™ Fuel Treatment maximizes power & economy for diesel applications. With fuel prices in a constant flux, Green Perform™ Fuel Treatment helps today's new generation of electronically controlled, low emission, high speed, high horsepower diesel and gasoline engines by ensuring complete combustion while reducing emissions. The reason for this new technology is the need for engine manufacturers to meet the clean air acts of 1998 and 2002. Automotive manufacturers are accomplishing this by using electronic engine management systems that constantly monitor engine performance. Fuel refineries are also changing the fuel we presently burn to meet these tough new standards. Green Perform™ Fuel Treatment helps in the following ways in diesel applications in our ever growing automotive industry:

- EPA Certified
- Lower fuel consumption (ie. Better fuel efficiency)
- Cleaner exhaust emissions

- Lower maintenance requirements
- Fewer carbon particles in lubricating oil
- Carbon deposits in the combustion chamber are reduced
- Easier starts in cold weather
- Can be used in both diesel and gasoline engines

Fleets - Today we have a new generation of electronically controlled, low emission, high speed and high horsepower diesel engines. The reason for this new technology is the need for diesel engines to meet the clean air acts of 1998 and 2002. They are accomplishing this by using electronic injectors and by changing the diesel fuel we are presently burning.

With this new generation of diesel engines you need to take precautions to properly maintain the engine. This includes installing a proper fuel / water separator along with using a proper fuel additive designed to meet the challenges for today's electronic controlled engines. If you take these precautions it will save you costly down time and money.

In order to understand the 1994 version of diesel fuel criteria, we must go back to the 1970's. As a result of a growing demand for middle distillates, which include kerosene, jet fuel, #1 and #2 diesel fuel... refineries no longer simply distilled crude oil to make distillates, they resorted to catalytic cracking.

The difference between light, middle, and heavier fuels is the boiling ranges. The cat-cracking process breaks up heavier fuels so they will meet the specifications for the lighter products, the refineries made the investment to catalytically crack more crude. Today's heating oil and diesel fuel that you buy is the product of severe catalytic cracking.

So what does this mean? Fuel that has been refined this way doesn't want to stay in its new form. It wants to change back into something heavier. The heat of an engine raises the temperature of the fuel in the return lines, thereby accelerating the formation of particulates. In fact any energy that we put into today's diesel and heating oil (regardless of sulfur content) speeds up the production of solids. These solids take many shapes and forms. They are typically sticky gums, varnishes and sludge's that will plug filters, strainers, nozzles, and injectors. In fact 93% of what clogs today's filters is not dirt or algae, but it is the repolymerization of the fuel. The microscopic particulates that form will grow larger and eventually clog your fuel system. Clean Boost will not only help this process from not happening, but at the same time reduce emissions and reduce fuel soots within the engine. Cleaner fuels mean longer running engines. Green Perform™ Fuel Treatment helps the following in diesel engine application in our ever growing trucking Industry.

- Lower fuel consumption (ie. Better fuel efficiency)
- Cleaner exhaust emissions
- Lower maintenance requirements
- Fewer carbon particles in lubricating oil
- Carbon deposits in the combustion chamber are reduced
- Easier starts in cold weather

Industrial - In today's markets of diesel fuels for non-highway application, Green Perform™ Fuel Treatment can help in many ways. Fuel consumption, fuel storage, cleaner running fuels and to always ensure the BTU rating of the fuel stays consistent. Industrial type fuels will include (Construction Equipment, Mining, Agriculture, Oil Drilling, Off Shore Drilling, Generation units and more.) The EPA is proposing new emission standards for non-highway diesel engines used in construction, agricultural and

industrial operations. The Agency is also proposing a more than 99 percent reduction in the sulfur content in fuel used by these engines. The proposed emission standards would achieve a reduction in particulate matter (PM) and nitrogen oxide (NOx) levels of more than 90 percent. Green Perform™ Fuel Treatment can help on all of the items listed above as this will significantly improve the air quality for countries world wide. For further information on our HFO (Heavy Fuel Oils) additive read our product information document entitled "Green Perform™ HFO (Heavy Fuel Oil) Treatment.

Oil & Gas - From drilling in the oceans to the mountains, oil and gas operators are under pressure to assure their operations are friendly to the environment. In today's economy, drilling companies are having to determine safer, cleaner ways to produce oil and gas for our ever growing countries and at the same time, reduce fuel costs. In many cases, drilling operations have had to convert their drilling rigs to all electric platforms just to reduce emissions. This is a very expensive alternative.

Green Perform™ Fuel Treatment can help oil and gas developers reduce emissions while drilling in the mountains and oceans around the world and at the same time keep their diesel engines running cleaner and longer.

Transit Systems - Cleaning up our cities around the world has been of great concern for a longer, healthier life span as well as to ensure a "green" environment. Green Perform™ Fuel Treatment delivers this process by changing the environmental impact on the exhaust emissions in Buses and Transit Systems the world over.

Green Perform™ Fuel Treatment not only saves transit companies thousands of dollars in fuel consumption, but at the same time... lowers fuel consumption through better fuel efficiency, cleaner exhaust emissions and lower maintenance requirements. Incomplete combustion leads to a host of problems in bus engines, including soot formation, carbon deposits, black smoke and corrosion. Transit and owner operators can reduce soot formation, extend maintenance intervals, and reduce the need for major component overhauls by using Green Perform™ Fuel Treatment. Some of the many benefits of a cleaner running transit with Clean Boost:

- Fewer carbon particles in lubricating oil
- Carbon deposits in the combustion chamber are reduced
- Easier starts in cold weather
- Allowing the busses to run cleaner, lube oils to last longer and to reduce emissions in our larger cities to help the Clean Air Act.

Additional Benefits of Green Perform™ Fuel Treatment

Vanadium or High-Temperature Fouling - Although there is not much information available on the combination of combustion catalysts and vanadium fouling, two points can be raised.

Combustion catalysts favor high oxidation-state compounds, such as V₂O₅, and may have an adverse effect on vanadium fouling. The less highly oxidized V₂O₃ and V₂O₄ are high melting and innocuous, while V₂O₅ is low melting and troublesome. Therefore the addition of combustion improvers to high vanadium fuels, without using magnesium, may exacerbate high temperature fouling.

In the case of fuels with high asphaltene levels the use of a combustion catalyst, such as Green Perform™ Fuel Treatment, with the magnesium additives is recommended. Unless conventional

magnesium additives are supplemented by a combustion catalyst, partially burned asphaltene are likely to compound high-temperature corrosion and deposit problems.

High-temperature corrosion is caused by deposits of low-melting point (less than 1250°F) ash containing primarily sodium, vanadium and sulphur. These complex alkali sulphates and vanadates cause fouling problems which interfere with heat transfer to the tubes. Additives are considered one of the better techniques for high-temperature corrosion and fouling problems because they can raise the melting point of the ash deposits and prevent the sticking action.

The five elements which have been used in treating high-temperature fouling are magnesium, aluminum, silicon, manganese and calcium.

While magnesium is the primary element used to combat vanadium fouling some reports have suggested that other elements may be beneficial. It now appears that there is no synergistic effect of the other elements on the activity of magnesium. Therefore the preferred additives are compounds of magnesium.

Magnesium reacts with the sodium vanadates to form high melting sodium magnesium vanadates and thus reduces vanadium fouling. This effect is stoichiometric, not catalytic, and at least as much magnesium must be added as there is vanadium in the fuel. Typical additive rate are three parts magnesium for one part vanadium in the fuel. Thus a high vanadium fuel with 100 ppm vanadium would require 300 ppm magnesium added to the boiler to combat high temperature fouling.

Utility companies may use a water-slurry of MgO which is injected through the soot blowers in the convection pass to control high-temperature corrosion. MgO pastes are the least expensive form of the additive and are approximately 30 percent magnesium by weight. Although this approach involves a significant capital investment and high feed system maintenance costs, it allows use of lower cost grades of MgO.

Smaller utilities and boiler operators that do not want to invest in the equipment use an oil soluble form of magnesium. This material is a carbonate/hydroxide magnesium colloid in oil which contains about 14 percent magnesium by weight. These additives dissolve directly into the oil and thus do not require any retrofitting or maintenance cost. The additives cost about the same amount as the MgO powders however they contain roughly half the magnesium and are therefore twice as expensive (to treat a given vanadium concentration).

SO₃ or Cold Temperature Fouling - Cold-end corrosion is caused by the formation of sulphuric acid, H₂SO₄, which is formed from the reaction of SO₃ and H₂O. The sulphuric acid attacks the iron used in the boiler construction to form scale deposits of ferrous and ferric sulphate.

The fuel bound sulphur is readily oxidized to SO₂. Greater than 99 percent of the sulphur leaves the combustion chamber as SO₂. Further oxidation of SO₂ to SO₃ can occur to a very small extent in the combustor and this small amount of SO₃ results in cold-end corrosion. The SO₂ has no negative impact upon the combustion systems but does react with water and oxygen in the upper atmosphere to produce acid rain.

Two types of chemical additives can be effective in controlling problems related to sulphuric acid. Combustion catalysts, such as Green Perform™ Fuel Treatment, can reduce the formation of sulphuric acid while chemicals like the magnesium based additives neutralize the acid after it is formed. The important points regarding the impact of combustion catalysts on SO₃ formation are:

SO3 concentration in the flue gas can vary by alternate adsorption and desorption on soot. Therefore reducing soot is important in the elimination of bursts of high SO3 concentrations.

Green Perform™ Fuel Treatment allows reduction in excess air which will lower SO3 formation. More efficient combustion and lower excess air levels can reduce the amount of SO3 formed.

Combustion catalysts generally can't control sulphate formation completely and must be supplemented with a neutralizing chemical, usually a magnesium additive

Testing Results for Green Perform™ Fuel Treatment

SAE J1321 Fuel Consumption Test Evaluation - Southwest Research Institute (SwRI®) Fleet and Field Evaluations Section conducted fuel consumption tests utilizing three class-8 diesel trucks. Fuel consumption was measured during a baseline segment with commercially available #2 diesel fuel. The purpose of the program was to determine possible fuel savings benefits of a diesel fuel additive product, Green Perform™ Fuel Treatment, added to the diesel fuel compared to the baseline condition.

The procedure chosen for this evaluation was the SAE J1321 "Joint TMC/SAE Fuel Consumption Test Procedure Type II". This recommended practice provides a standard test procedure for comparing in-service fuel consumption of one or more vehicles operating under two conditions. An unchanging control vehicle is run in tandem with the test vehicle(s) to provide reference fuel consumption of one vehicle in two different test conditions.

The result of the average percent improvement in fuel economy for the test segment with Green Perform™ Fuel Treatment added to the diesel fuel compared to the baseline segment was 3.06% - an unprecedented result for this type of test.

		% Improvement in Fuel Economy		
Diesel Fuel		Test Truck 415568	Test Truck 415572	Avg. of 2 Test Trucks
Baseline Segment	Commercially available #2 diesel			
Test Segment	Commercially available #2 diesel fuel with Clean Boost™*	3.63%	2.49%	3.06%

Reduced Emissions - Green Perform™ Fuel Treatment promotes the combustion of unburnt fuel. Now, there is little effect if the combustion catalyst is used in highly-efficient, well-tuned engines running under laboratory test conditions. On the other hand, Green Perform™ Fuel Treatment is active and very effective when inefficient combustion occurs, as is often the case in the real world. The inefficient combustion may result from either a poorly maintained (or designed) engine or from the use of poor quality fuels.

In laboratory tests of Green Perform™ Fuel Treatment, the engines were run under less than ideal operating conditions to simulate the normal stress placed on an engine under actual field conditions. Dr. Reuther states on page 15 of the Battelle report on the Evaluation of Green Perform™ Fuel Treatment as a Diesel Engine Combustion Additive:

"The advanced diesel engine used had been designed to minimize particulate emissions and carbon burnout problems. To offset this situation, the diesel test engine was operated at an off-peak load (85 percent), which maximized the amount of particulates it emitted."

Standardized tests were conducted by Battelle Columbus Division in a production diesel engine (Superior Model 2406D/Mitsubishi Model S6U-PTA). This 4-stroke, 6-cylinder, 4300 cubic-inch diesel engine is rated at 1,400 brake-horsepower and 1,200 rpm at full load, but was run at 85% load to artificially create a particulate emissions problem.

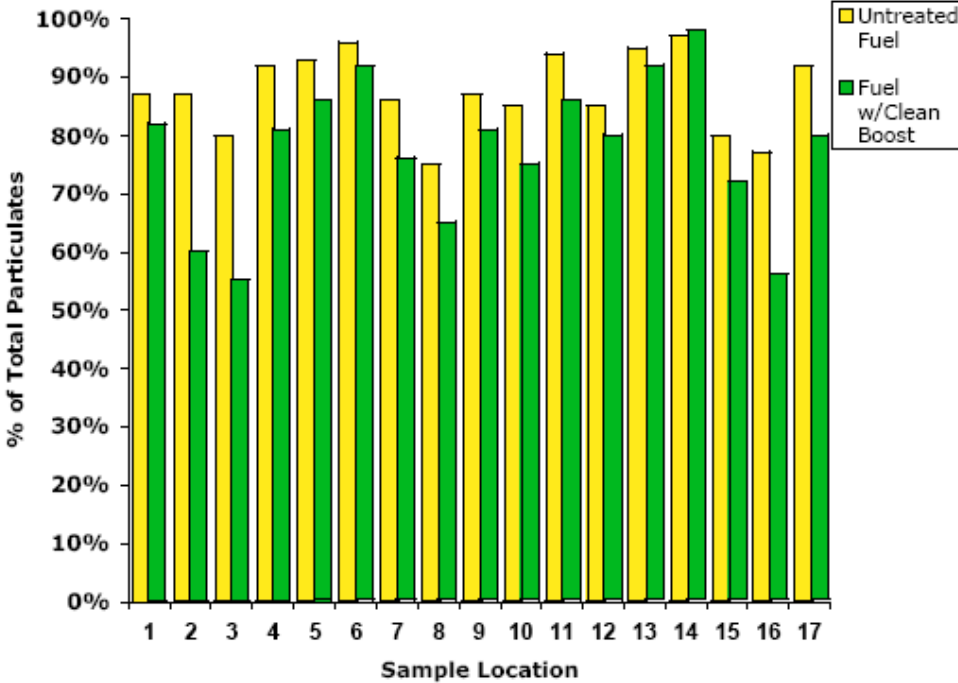
The measurable and reproducible results of adding Green Perform™ Fuel Treatment to conventional No. 2 diesel fuel are as follows:

- CO emissions reduced by 10 percent,
- HC emissions reduced by 9 percent,
- Particulate carbon reduced by 26 percent,
- Particulate emissions reduced by 43 percent,
- Combustion efficiency increased by 0.4 percent,
- No increase in NOx emissions

With most emission control technologies based on fuel or engine modifications, there is an apparent trade-off between NOx and particulates. The U.S. National Research Council (NRC), considered the magnitude of this trade-off and estimated that a 50 percent reduction in NOx emissions will probably be accompanied by a 30 to 100 percent increase in particulates. Moreover, the NRC also estimated that a 50 percent reduction in NOx would be accompanied not only by a 30 percent or more increase in particulates, but also by a 50+ percent increase in HC emissions and a 7 percent or more penalty in fuel consumption. Green Perform™ Fuel Treatment offers a unique, cost-effective means by which to reduce diesel engine particulate emissions without aggravating NOx emissions or diminishing fuel economy.

Unlike most aftermarket products aimed at reducing DPM emissions, but which also impose a stiff fuel penalty (such as particulate filters or traps), Green Perform™ Fuel Treatment actually rewards operators by reducing fuel consumption. Field tests conducted by Ontario Power Generation at the Gull Bay remote generation station confirmed the Battelle results on emissions reductions and also quantified these fuel savings at 3 to 5 percent. The tests involved diesel gensets ranging in size from 130 kW to 250 kW (Detroit Diesel 2-cycle, Caterpillar 3406TA and 3406B) under actual operating conditions over a period of weeks.

Mining Test Shows 21% Reduction in Diesel Particulate Emission – The test was directed by Jim Blair, Mine Service Manager, Carey Salt. The figure below presents effect of product on the carbon emission of caterpillar diesel engines.



Marine Test Demonstrates 3.7% Fuel Savings in Chinese Ship - Green Perform™ HFO (Heavy Fuel Oil) Treatment was tested recently onboard an 8,800 tonne passenger and vehicle ferry sailing between the Chinese ports of Dalian and Yantai, east of Beijing. The Yinhegongzhu ("Milky Way Princess") is powered by a pair of medium-speed diesel engines (type NIGATA 8PC2-5L each rated at 5200 bhp) running on No. 6 bunker oil. The ship is owned and operated by Yantai Sea Emergency and Salvage Bureau under the Chinese Ministry of Transportation.

After one continuous month of Green Perform™ HFO (Heavy Fuel Oil) Treatment, the Milky Way Princess was found to be consuming 3.7% less fuel oil than on previous voyages, with all other operating parameters unchanged. Black smoke from the exhaust was visibly reduced and the engines were reported to be running more smoothly than normal. Green Perform™ HFO (Heavy Fuel Oil) Treatment is one of the few North American manufactured fuel additives that has been tested and approved for sale within China.

Concluding Statements – Please note that early testing including EPA registration for Green Perform™ Fuel Treatment was under the brand name "CleanBoost™".

In summary, Green Perform™ Fuel Treatment has been lab and field tested and proven to be an effective additive for stationary and mobile diesel and gasoline engines for both environmental and economical reasons.



Green Perform™ Fuel Treatment Usage Rates for Fuel Oils

Since Green Perform™ Fuel Treatment is fuel and site specific, blending ratios may vary. The recommended blending rates are:

- Green Perform™ Fuel Treatment for diesel fuel - treatment 1: 3,000
- Green Perform™ Fuel Treatment for gasoline – treatment 1:4,000
- Green Perform™ HFO (Heavy Fuel Oil) Treatment for #6 fuel oil - treatment 1:5,000