EFS Combustion Catalyst Technology[1]

EFS' patented high performance FuelSpec® liquid combustion catalysts improve combustion efficiency, provide fuel savings, and reduce emissions resulting from heavy fuel oil and Diesel fuel combustion (including ash, Carbon Dioxide, Carbon Monoxide, NOx, Sulfur Dioxide, and unburned hydrocarbons or "UHCs" where UHCs include particulate matter or "PM" as well as soot and unreacted fuel; as a species, UHCs are also referred to as products of incomplete combustion or "PICs"). The catalysts work effectively on a range of fuels used in 2-stroke and 4-stroke Diesel engines. Better combustion provides secondary benefits such as overall improved equipment performance, extended equipment life, and a reduction in operating and maintenance costs.

Overall, use of FuelSpec®, a green technology, provides a high return-on-investment solution to the owners and operators of Diesel engines, enables energy conservation and sustainability, and has a significant positive effect on human health and the environment.

Based on extensive field testing, empirical observations, stoichiometric analyses and thermodynamic postulates, EFS confirms fuel savings of approximately 10% on fuel containing 1% or more sulfur (containing 10,000+ ppm sulfur), 8% on lighter Diesel fuels, and 7% on ultra-low sulfur Diesel (containing a maximum of 15 ppm sulfur). The relationship between sulfur content and fuel savings is demonstrated below, in Diagram 3.

FuelSpec® catalysts are benign to the environment, have no negative effects of any kind on personnel, and have no adverse impact from long-term use on the combustion equipment, fuel storage, piping & pumping equipment. All products of combustion exit through the exhaust and are also benign to the environment. There is no deposition or scaling of any kind on the equipment, or inside the combustion and exhaust spaces.

FuelSpec® catalysts are safe to transport, have a long shelf life, are chemically stable and easy to apply. There is no performance fade (prior use has demonstrated that 2-year old catalyst performs equivalent to freshly formulated batches). The catalysts mix easily with ultra-low sulfur (low asphaltene), medium sulfur, Diesel oil and high sulfur (high asphaltene) fuels, and work effectively across a broad range of equipment operating conditions (including under less than maximum continuous rating conditions). The catalysts do not react with or degrade fuel, or undergo phase separation while in storage, are easy to apply to bulk fuel tanks and central fueling facilities, and do not interfere with the effectiveness of other fuel additives (such as icing and corrosion inhibitors, lubricants, antistatic agents, and other additives) and/or emissions reduction systems such as SCR, DEF and Diesel particulate filters. Implementation of the catalyst systems requires only a minor retrofit to existing engines and fuel systems.

FuelSpec® catalysts have undergone continuous enhancements. EFS has made significant advancements and innovations in reducing the effective dosing ratios and improving the injection

[1] This summary accompanies the *FuelSpec® Combustion Catalyst FAQs* and the information contained here may overlap with other EFS technical publications

equipment required for optimal fuel savings (the recommended dosing ratio is 1 part of FuelSpec® mixed with 3,840 parts of fuel-oil, by volume). We have engineered the combustion catalyst to operate at such small doses that there will not be any adverse effect on any engine that utilizes the product. An extremely low dosage ratio of 1 part FuelSpec® added to 3,840 parts of fuel ensures the actual total amount of catalyst going into the engine is only about 1.4 mg/Kg, or, 1.4 ppm (more information provided below in the section, **Catalyst and Combustion Characteristics**).

Catalyst Development

A summary of the components found in fuels would be instructive. All liquid hydrocarbon fuels contain two main types of combustible compounds, aliphatic compounds that combust easily, and asphaltenic compounds that burn with difficulty. For example, Methane (molecular structure shown in **Diagram 1**), a gas, is the simplest aliphatic compound that combusts easily (to further elucidate this point, aliphatic compounds such as Methane, Ethane, Propane and Butane are gases under ambient conditions, combust completely and release all energy during combustion; whereas more complex hydrocarbons increase in complexity and take the form of liquids and then solids, as they become more complex). More complex asphaltenes (representative molecular structure shown in **Diagram 2**) are harder to burn. When used in a 4-stroke or a 2-stroke Diesel engine, a portion of the fuel remains unburned due to the presence of the "harder-to-burn" asphaltenes as well as complex aliphatic compounds; this unburned fuel is emitted through the exhaust gases as UHCs (and/or PICs) and PM, and causes a loss of efficiency.

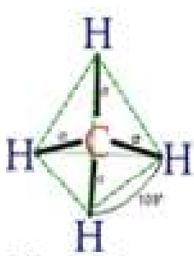

Diagram 1

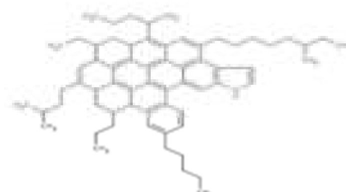

Diagram 2

We first assessed the effect of FuelSpec® catalysts while using the technology in combustion turbines (at the HHI Daeson Refinery Power Plant in S. Korea), where we witnessed a significant reduction in PM; a summary of "before" and "after" results are noted below in **Table 1**, showing the use of the catalyst on four Westinghouse 501D5 104 MW Turbines operating on LSWR fuel.

Average PM measurements with no catalyst ("before") were > 160 mg/M^3 (whereas the Korean Government requirement for PM was < 40 mg/M^3).

Table 1

PM measurements with the catalyst ("after") for the four turbines are provided below				
Turbine #	*1*	*2*	*3*	*4*
Measured PM – High (mg/M^3)	*18.1*	*18.2*	*22.7*	*22.0*
Measured PM – Low (mg/M^3)	*10.3*	*8.1*	*5.4*	*9.2*
Ave. PM (mg/M^3)	*13.8*	*12.4*	*13.4*	*14.4*

As demonstrated in **Table 1**, use of the catalyst brought down the PM well below the required 40 mg/M^3 threshold. Since PM emitted through the exhaust consists of UHCs (or, unreacted fuel and/or PICs), a reduction in PM indicates a reduction in wasted fuel. This suggested an improvement in combustion efficiency, with resulting fuel savings. Realizing the significance of the results, we conducted further tests that showed consistent combustion improvement in reciprocating engines (both compression and spark ignited engines) from the use of the catalyst.

Consequently, we established a causal relationship between the asphaltene content of a fuel, as represented by the presence of sulfur, and the effect of the catalyst on combustion efficiency improvement. This relationship is depicted in **Diagram 3** (X-axis represents the concentration of asphaltenes in a given fuel-type, via the Log Sulfur PPM). To elucidate, FuelSpec® utilizes an organometallic principle to perform heterogeneous catalysis (treating the combustion of liquid fuels as a second order chemical reaction) to improve combustion (e.g., during combustion without catalysis, aliphatics combust at 50,000 mol/s, and asphaltenes at 1,500 mol/s; as such, asphaltenes remain largely unreacted with only up to 25% being combusted; whereas, with catalysis using FuelSpec®, up to 96% of the aspahltenes are combusted):

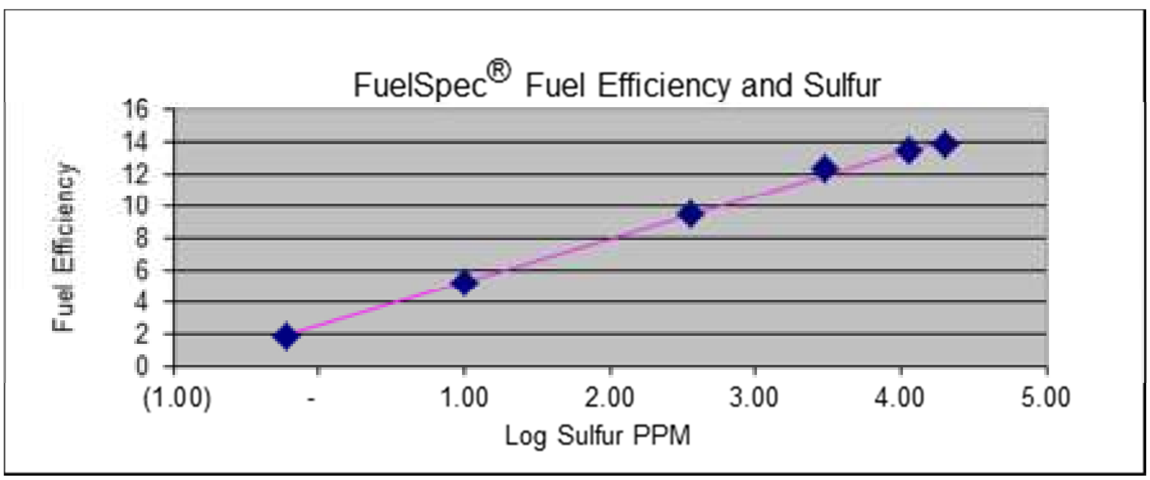

Diagram 3

Catalyst and Combustion Characteristics

The catalyst is injected in very small doses (mixing ratio = 1 part catalyst : 3,840 parts fuel, by volume), and constitutes of widely used solvents and chemicals (MSDS information available).

Catalyst physical characteristics (representative properties) are – clear orange colored liquid with an approximate density of 0.85 gm/cc @ 20°C, viscosity 5 cSt @ 40°C, pour point < 0° C and flash point > 62° C.

All components of combustion are emitted via the exhaust. The minimum melting point of the products of combustion is about 1,585 °C, considerably higher than the maximum combustion temperatures found in Diesel engines, so there is no deposition or scaling of any kind inside the combustion chamber and the exhaust spaces.

From the engine maker's perspective, EFS wishes to highlight an important aspect of FuelSpec® combustion catalysts, which is the total amount of "ash-bearing" or "ash-forming" components in the product. Engine makers do not want to add anything to their engines that may have the potential to harm the engine by adding ash-bearing components (for example, based on the fuel additive policy of one of the world's largest manufacturers of 2-stroke and 4-stroke engines, any product with ash-bearing components in excess of 50 ppm is not favored).

FuelSpec® adds an approximate total of 1.4 ppm of ash-bearing components.

Furthermore, due to the fuel savings from the use of FuelSpec®, there is a net reduction in the amount of ash-bearing components that go through the engine.

This is a significant benefit that further underscores that use of FuelSpec® actually improves the performance of the engines and their useful operating life (this also explains why customers see a significant reduction in operating and maintenance costs due to lower carbonization and soot deposition). We also highlight that due to the catalysts' effect in improving combustion efficiency…thereby reducing ash, PM and other exhaust gas emissions, it renders operation of the engines safer for personnel and is improves human health and well-being.

Finally, component particle sizes in the FuelSpec® catalyst are less than 0.01 micrometers, which are significantly less than any filtration equipment (including centrifugal purification systems) and smaller than any orifice and/or nozzle specification in use, on existing 2-stroke and 4-stroke engines.

No Negative Effect on Fuel and Equipment

FuelSpec® does not alter the fuel in any way. A recent test conducted by EFS at the Southwest Research Institute ("SwRI"), in San Antonio, Texas, USA, clearly shows that addition of FuelSpec® does not degrade or modify Diesel fuel (SwRI is one of the oldest and most respected testing and research facilities of its kind in the US; the US Govt. uses SwRI heavily for fuel-related testing for the Dept. of Defense and for other government institutions; SwRI is an independent and non-profit organization; more information at http://www.swri.org/ (and at http://en.wikipedia.org/wiki/Southwest_Research_Institute).

The test was conducted on a sample of ultra-low Sulfur Diesel ("ULSD"), containing about 11 ppm of Sulfur (compared with significantly higher ppm Sulfur in heavy fuel-oil and other fuel types). Since ULSD is a distillate fuel, no negative effect on ULSD clearly demonstrates that FuelSpec® is safe for use on heavier fuel types as well as on engines that are capable of running on these fuels (heavy fuel-oil contains significantly larger concentrations of solids and other contaminants).

A summary of the test results is shown in **Table 2** (the complete SwRI test report is available).

"SwRI Sample ID CL-14 6618 Results" are for the ULSD before the FuelSpec® is added to the fuel. "SwRI Sample ID CL-14 6622 Results" are for the ULSD after the FuelSpec® is added to the fuel.

As shown in the report, the results after the addition of FuelSpec® fall well within the requirements of the ASTM D975 Standard Specification for Diesel Fuel Oils.

To reiterate, EFS affirms that FuelSpec® will not degrade fuel in any way, including if the fuel-oil in use is mixed with the catalyst and stored for a long time. It will not damage Diesel engines and any fuel-oil storage and piping & pumping equipment. It will not harm any or the environment, and any other life-forms in any way.

Conversely, use of the catalyst will reduce ash and PM emissions (PM and ash in Diesel exhaust are widely acknowledged as carcinogenic, and harmful to human health and to other life-forms). It will diminish the emissions of CO2, NOx, CO (widely acknowledged as greenhouse gases) and SOx (widely acknowledged as harmful to human respiration, and an agent of acid-rain), and other harmful matter present in Diesel exhaust.

We reemphasize, since FuelSpec® does not interact with the fuel and does not interfere with other additives that may be used, there is no risk of clogging or fouling the fuel purification (e.g., centrifugal separators) and filtration (e.g., line filters and catalytic fines separators) equipment in use.

Table 2

Test	Method	Units	SwRI Sample ID CL14-6618 Results	SwRI Sample ID CL14-6622 Results	Specification D975 Table 1 Limits	
					min	max
Flash Point (Pensky Martin)	D93	°C	57.5	59.5	52	
Water and Sediment	D2709	vol %	<0.005	<0.005		
Distillation	D86					
IBP		°C	176.8	177.7		
5%		°C	196.3	197.3		
10%		°C	203.6	203.7		
15%		°C	211.3	210.4		
20%		°C	217.5	216.9		
30%		°C	230.0	230.3		
40%		°C	242.5	242.8		
50%		°C	254.7	255.1		
60%		°C	267.4	267.7		
70%		°C	280.3	280.5		
80%		°C	295.9	295.9		
90%		°C	317.0	317.0	282	336
95%		°C	334.7	334.9		
FBP		°C	341.9	342.2		
Residue		%	1.5	1.4		
Loss		%	1.1	1.0		
T50-T10		°C	51.1	51.4		
T90-T10		°C	113.4	113.3		
Kinematic Viscosity	D445					
40°C		cSt	2.28	2.29	1.9	4.1
Ash Content	D482	mass %	<0.001	<0.001		0.01
Total Sulfur Content	D5453	ppm	9.8	9.6		15
Sulfur Content	D2622	ppm	11.0	10.3		0.05
Copper Strip Corrosion	D130					
Test Duration		hrs	3.0	3.0	3	
Test Temperature		°C	50	50	50	50
Rating		-	1A	1A		3
Cetane Number	D613	-	54.5	53.7	40/40/30	
Calculated Cetane Index	D976	-	55.4	55.5	40	
Aromatic Content	D1319					
Aromatics		vol %	19.7	18.3		35
Olefins		vol %	1.5	2		
Saturates		vol %	78.8	79.7		
Cloud Point	D2500	°C	-11	-12		
Cold Filter Plugging Point	D6371	°C	-15	-14		
Ramsbottom Carbon Residue (10% btms)	D524	wt %	0.05	0.06		0.35
Lubricity (HFRR)	D6079	mm	0.51	0.51		520
Electrical Conductivity	D2624					
Electrical Conductivity		pS/m	51	118	25	
Temperature		°C	21	20		
Density (15°C)	D4052	g/mL	0.8183	0.8183		

<u>EFS Team</u>

The EFS team comprises of professionals experienced in all aspects of the development, formulation, manufacturing and application (including ship-board application) of the FuelSpec® combustion catalysts. The EFS team conducted a thorough review of the FuelSpec® combustion catalysts, and after a successful review of the technology, EFS bought the patents and other assets pertaining to FuelSpec® catalysts, in July 2014. EFS is supported by investors with significant experience in providing energy conservation solutions to Fortune 100 companies. All FuelSpec® catalysts and injection equipment is manufactured at EFS' partner companies in Texas and Louisiana in the United States.