Evaluation of the Use of Ultra Low Sulfur Diesel Oil for an Emergency Diesel Generator

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1. Introduction

One of the major fuel oils used in medium-large diesel engines for the normal driving of vessels and the generation of emergency power at power plants is heavy fuel oil. There are no vessels and power generation engines known to use high-quality diesel oil which is widely used in cars.

However, in nuclear power plants (NPPs) in South Korea, the diesel generator for emergency power supply uses high-quality diesel oil for a rapid response to operations and for high reliability.

In 2008, Korea was faced with strong environmental regulations. Thus, the production of Low-sulfur diesel (LSD: Sulfur content max. 500 ppm) ended. Since September 2009, Korean NPPs have used ultra-low-sulfur diesel (ULSD: sulfur content max. 15 ppm).

The aim of this study is to assess the compatibility and effect on driving an emergency diesel generator using ULSD examining the specific gravity and lubricity of the oil. Because generators at NPPs use ULSD which is not mostly used for medium-large diesel generator engines, this study seeks to provide effective precautions for the driving stability of emergency diesel generators.

2. Effect of Sulfur in Fuel Oil

The sulfur content of diesel fuel is oxidized into SO_2 after combustion, and some of those contents convert into SO_3 through the expansion stroke. As the dew point of the combustion gas increases, the H_2SO_4 condensates on the surfaces of the cylinder wall [1]. This H_2SO_4 must be minimized because it causes corrosion of the cylinder liner, piston crown and other metals. On the other hand, it decreases the wear trouble of the fuel supply system extending the life of the engine.

3. Review of the Characteristic of ULSD

3.1 Fuel Energy Content

The specific gravity of hydrocarbons decreases, that is, the number of carbon molecules decreases. That results in higher heating values per specific weight and lower heating values per specific volume [1, 2]. The emergency diesel generators at NPPS control the amount of fuel according to its volume. Therefore, the actual heating value goes down and more fuel must be supplied to maintain the same power shown in Figure 1.

The Q_p of Table I calculated Low heat value (LHV: the net heat of combustion at constant pressure) using ASTM D4868 indicates a 3.4% [MJ/kg] increase in the LHV (0.2% [MJ/ m^3] decrease).

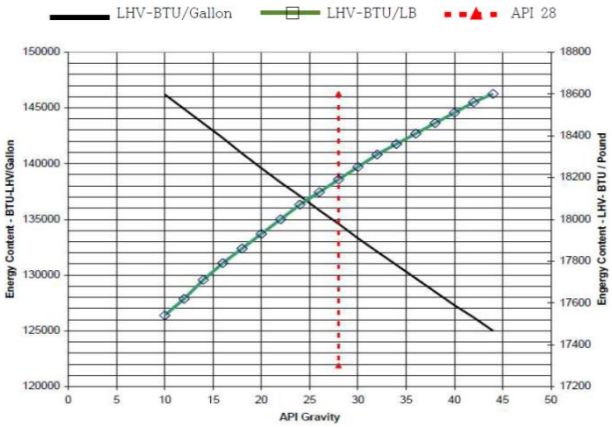

Figure 1 Typical Diesel Fuel Oil Heat Content: LHV/Gallon and LHV/Pound [3]

Table I : LSD and ULSD Low Heat Values

	d	x	y	s	Qp (LHV)
LSD	851.2	0.005	0.001	0.033	41.382
ULSD	821.7	0.002	0.001	0.005	42.788

$$Q_p = (46.423 - 8.792d^2 \times 10^{-6} + 3.170d \times 10^{-3})[1 - (x + y + s)] + 9.420s - 2.449x$$

$Q_p(LHV) = net\ heat\ of\ combustion\ at\ constant\ pressure, MJ/kg$
$d =$ density at 15℃, kg/m^3
$x =$ mass fraction of water (%, divided by 100)
$y =$ mass fraction of ash (%, divided by 100)
$s =$ mass fraction of sulfur (%, divided by 100)

In the case of the ENGINE-A, the mainly used engine at NPPs in South Korea, fuel consumption (Table II) for driving a 6,500 kW power generator increased 3.6% [m^3/hr.]

Table II : LSD and ULSD Fuel Consumption at the rated load

	Eng. power [kW]	Rated load SFOC [g/kWhr.]	Qp (LHV) [MJ/kg]	Fuel Consumption. [m^3/hr.]
LSD	6,371	203.7	41.382	1.610
ULSD			42.788	1.668

*Generator overall efficiency: 96.57%

3.2 Lubricity

There is a very strict limit on the clearance among the fuel injection pump plunger, barrel, and injection nozzle. Therefore, sufficient lubrication and cooling process with the diesel fuel are required; otherwise, wear and sticking problems arise. ULSD causes a lower viscosity resulting in insufficient lubrication in the refining process and eliminating the molecules which have a key part as a lubricant.

ASTM D975 recommends a diesel fuel oil with a wear scale diameter (WSD) lower than 520 ㎛. The ENGINE-A suggests that a diesel fuel oil with less than 500 ppm of sulfur contents keeps the WSD below 520 ㎛ as well [4].

The ULSD of NPPs has a standard retaining WSD of 337 ㎛ for lubricity using engine additives which are below the recommend criteria 520 ㎛. A look at the data suggests that there is only a low possibility of problems caused by insufficient of lubricity, especially from parts in a fuel system sticking while operating new power plants. The leading cause of problems shall be from foreign materials which were in the engines initially operated.

Table III : ULSD Test Result

Engine Type & Fuel	Cetane Index	Sulfur (%)	Density (kg/㎥)	Lubricity (㎛)
ULSD	**54.6**	**0.005**	**821.7**	**337**
ENGINE-A	40≤	≤0.1	≤870	≤520
ENGINE-B	45≤	≤5.0	≤887	-
ENGINE-C	40≤	≤0.5	834≤ ≤898	-
ENGINE-D	40≤	≤0.5	-	-
ENGINE-E	-	-	≤991	-
ENGINE-F	45≤	≤0.5	801≤ ≤876	≤520

3.3 Cetane Index

In a diesel engine, higher cetane fuels will have shorter ignition lag periods than that of lower cetane fuels. There will be faster self-ignition of the fuel around the combustion chamber as well. This aspect positively complies with the capability of emergency diesel generators which must reach the rated voltage and frequency in a short time.

Diesel engine manufacturers for NPPs highly recommend a minimum cetane index of 40 for the engines being used while ENGINE-A endorses a cetane index of 45. Still, the USA Engine-A user group has succeeded in operating an experimental drive with a cetane index of 40 without any significant obstacles [5]. Table shows that the ULSD used in South Korea has a cetane index of over 50; therefore, these findings suggest that there will be no problems related with ignition lag.

3.4 Fuel Particulate Build-up Increase

The increased engine additives for improving the lubricity of the fuel and preventing corrosion are precipitated after long term storage. Educed additives converted into foreign particulates cause contamination in the fuel system and fuel filter clogging. However, this integrated research suggests that since ULSD has been used, there have been no increases in foreign materials inside the storage tank and no reported problems including filter clogging.

4. Conclusions

The findings of this study suggest that when driving a diesel generator, there will be increased fuel consumption by 3.6% [m^3/hr.]. Furthermore, the mechanical fuel limiter on the engine needs an upward adjustment because the system is set for 110% load operations for the former LSD fuel.

Both LSD and ULSD retain lubricity with a WSD around 330~350㎛. These results clearly show that bad lubricity problems are not expected to occur.

We had presumed an increased amount of foreign particulates because of the increased additives for high lubricity and oxidative stability. However, the research data show equivalent quantitative results, and we expect no increase in filter clogging and fuel system wear. Nevertheless, the particulates are still a major and potential risk factor. Therefore, analysis should be done on the foreign particulates in the fuel storage tank periodically.

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