Revision A

Marine Fuel Oil (MGO & HFO) and FCC Additive Technical Analysis

ADDF-REP-TA-0006

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MARINE FUEL OIL (MGO & HFO) AND FCC ADDITIVE TECHNICAL ANALYSIS

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1 EXECUTIVE SUMMARY

Fuel Conditioner Concentrate (FCC) is added directly to fuel storage tanks to eliminate the problems associated with water contamination. FCC ensures that vehicle fuel systems remain clean and free from corrosion, gums, and varnishes. The main benefit of the FCC is derived from its regular use to maintain fuel systems free from liquid water. This prevents biological activity, reduces corrosion and inhibits reaction of the fuel with water. Regular use of FCC ensures that carburetors and fuel injectors work at peak performance eliminating poor running problems and expensive maintenance. The benefits of FCC extend throughout the fuel system.

Key summary based on the technical analysis of the MGO and HFO spiked with FCC improves and enhances the fuel properties in categories below:

Safety

- FCC does not impact the hazard level classification of the fuel which determines and affects the storage and handling fuel. With a low moderate hazard level fuel, the classification and hazard level remains unchanged with addition of FCC (minimal change in Flash Point).

Environmental

- FCC reduces white smoke on startup, and reduce NOx (Nitrogen Oxide) and Particulate Matter (PM) emissions (Increase in Cetane Index).
- FCC reduces Sulfur content in MGO DMB by 2.7% which is an important aspect with stricter sulfur in fuel requirement particularly in SECAs (Sulfur Emission Controlled Areas).

Combustion, Fuel Efficiency

- FCC helps to improve fuel combustion (Increase in Cetane Index) for MGO DMB with a minimal 0.4% increase.
- FCC does not modify composition (Gross Heat of Combustion / Calorific Value, Density, Distillation and Aromatics content) of the fuel which may cause incombustible components.

Performance, Maintenance

- FCC improves lubricity by a significant 16.8% in MGO and 3.2% in MGO DMB, which improves durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
- FCC maintains this important characteristic of the fuel for Filter Blocking Tendency (FBT) for MGO which affects performance and lifetime of the engine.
- FCC maintains the non-corrosive nature of the fluid (copper corrosion test) where corrositivity of the fuel remain constant.

2 INTRODUCTION

FCC is an innovative and scientifically proven blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's engines. It's a non-hydrocarbon fuel conditioner that cleans fuel and improves performance whilst lowering emissions and increasing fuel efficiency. It is suitable for use for a large variety of fuel types.

With FCC, improvements in fuel efficiency and savings in maintenance costs are achieved through cleanliness and a better burn; as opposed to tampering with the combustion characteristics of the fuel.

2.1 BACKGROUND

FCC is a blend of blend of surfactants (detergents), oxygenates and corrosion inhibitors developed to meet the challenge of today's high performance engines. The Primary benefits of FCC are:

- Solubilises liquid water into the fuel.
- Reduces or eliminates the conditions favourable to the growth of microorganisms.
- Stabilises fuel by inhibiting the formation of gums and varnish.
- Inhibits corrosion of fuel system components.
- Promotes a uniform fuel spray pattern in combustion chambers, thus reducing carbonisation and improving combustion efficiency.
- Inhibits formation of corrosive acids in combustion chambers.

2.2 DOCUMENT SCOPE

The intent of this document scope is to provide technical analysis on 2 main types of Marine fuel oil with variation from both main categories;

- Marine Gas Oil (MGO),
- Marine Gas Oil type DMB,
- Heavy Fuel Oil (HFO) @ 180 cSt and
- Heavy Fuel Oil (HFO) @ 380 cSt.

The properties of the marine fuel are assessed after addition of fuel additive, herein referred to as FCC (spiked with ratio of 1:4000) and analysis is made in comparison to control sample. The primary properties assessed (based on Report of Analysis – Attachment 1) are:

Properties	**MGO**	**MGO (DMB)**	**HFO** (180 cSt)	**HFO** (380 cSt)
• Flash Point,	✓	✓	✓	✓
• Filter Blocking Tendency,	✓	×	×	×
• Mean Wear Scar Diameter / lubricity	✓	✓	×	×
• Gross Heat of Combustion / Calorific Value	✓	✓	✓	✓
• Cetane Index,	✓	✓	×	×
• Density,	✓	✓	✓	✓
• Distillation,	✓	✓	×	×
• Sulfur Content,	✓	✓	✓	✓
• Copper Corrosion	✓	✓	×	✓
• Aromatics.	✓	✓	×	×

2.3 REQUIREMENTS / SPECIFICATIONS

2.3.1 SPECIFICATIONS FOR MGO

Marine gas oil (MGO) is a marine version of normal diesel and is used on the vessels to power the main engines and generator sets, to provide propulsion and general services to the vessels, such as power and heating. An international ISO standard ISO 8217 is setup to define the requirements for petroleum fuels for use in marine diesel engines and boilers prior to appropriate treatment before use (Ref [7]).

The requirements for MGO (Distillate Marine Fuel (with density < 900 kg/m³) are as summarised in Table 2.1 below:

Table 2.1: Requirements for MGO (Distillate Marine Fuel) (Ref [7])

Specification of properties	Category ISO-F-DMX/DMA/DMZ/DMB
Kinematic viscosity (cSt) (min / max)	1,400 / 6,000
Density (kg/m³) (max)	890 – 900
Cetane Index (min)	35 – 45
Sulfur (mass %) (max)	1.0* – 2.0
Flash Point (°C) (min)	43 – 60
Wear Scar Diameter (µm) (max)	520

*The Sulfur in fuel requirement is reduced from 1.0% to 0.1% as from 1 January 2015 in SECAs (Sulfur Emission Controlled Areas).

2.3.2 SPECIFICATIONS FOR HFO

HFO, also known as “residual fuel oil”, is based on the high viscosity, tar-like mass, which remains after the distillation and subsequent cracking of crude oil in order to produce lighter hydrocarbon products, such as petrol, distillate diesel fuels and heating oil or feedstocks for lubricants. RMA, RMB, RMD, RME, RMG or RMK are the international trade names.

The requirements for HFO as per ISO standard ISO 8217 (Ref. [6]) are as summarised in Table 2.2 below:

Table 2.2: Requirements for HFO (Heavy Fuel Oil) (Ref [6])

Specification of properties	Values
Kinematic viscosity (cSt) (min / max)	55 at 100ºC / 700 at 50ºC
Density (kg/m³) (max)	1,010 at 15ºC
Flash Point (°C) (min)	60
Hydrogen Sulfide (mg/kg) (max)	2.0
Pour Point (°C) (max)	30
Acid number (mg KOH/g) (max)	2.5
Total sediment aged (mass %) (max)	0.10

3 ABBREVIATIONS & DEFINITIONS

3.1 ABBREVIATIONS

Abbreviations	Definition
AddFuel	AddFuel Pty. Ltd.
ASTM	American Standard Test Method
CO	Carbon Monoxide
CN	Cetane Number
DMB	Distillate Marine fuel oil type B (No. 4 or No. 5 fuel oil)
FBT	Filter Blocking Tendency
FCC	Fuel Conditioner Concentrate
HFO	Heavy Fuel Oil
IEC	International Electrotechnical Commission
IP	International Protection
ISO	International Organization for Standardization
MGO	Marine Gas Oil
NATA	National Association of Testing Authorities, Australia
NOx	Nitrogen Oxide
PAH	Polycyclic Aromatic Hydrocarbons
PM	Particulate Matter
SECA	Sulfur Emissions Controlled Areas

The classification for ISO 8217 standards provides detailed specifications / categories of marine fuels based on the main applications and characteristics of the products. The classification is broadly broken down into distillate fuels and residual fuels (Ref [11]).

The products are designated by a code that consists of:

Initials	Category	Type	Application	Properties
ISO	F	D / R	M	X, A, B, C, …, K
	Petroleum Fuels	Distillate / Residue	Marine	-
ISO-F-**DMX / DMA / DMZ / DMB**				

Distillate Fuel	Kinematic viscosity (mm^2/s at 50ºC)	Density (kg/m^3 at 15ºC)
DMX	1.4 to 5.5	-
DMA	1.5 to 6.0	< 890
DMB	< 11	< 900
DMC	< 14	< 920

3.2 DEFINITIONS

The property's definitions are summarised as below:

Property	Definition
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.
Wear Scar Diameter	Measure of lubricity of fluid which is the ability of fluid or compound (in this case MGO) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load.
Gross Heat of Combustion / Gross Calorific Value	Total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. The chemical reaction is a hydrocarbon (MGO) reacting with oxygen to form carbon dioxide and water and releases heat. Directly impacts the economics of engine performance.
Cetane Index	Measures the performance / quality of a fuel in an engine by its ability for auto-ignition.
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids but much greater for gases.
Distillation	Distillation (batch) provides boiling range of MGO. The distillation characteristics affects starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both. The presence of high boiling point components in fuels can significantly affect the degree of formation of solid combustion deposits.
Sulfur Content	Sulfur in MGO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO2) and sulfate (SO4) particulate matter (PM)), leads to engine cylinder wear and forms deposits in the engines.
Copper Strip Corrosion	Indicates potential for corrosive attack on metal parts / relative degree of corrosivity of MGO.
Aromatics	Group of hydrocarbons of which benzene is the parent. They are called "aromatics" because many of their derivatives have sweet or aromatic odors. Aromatics in hydrocarbons (MGO) increase particulate emissions and cause related problems in combustion.

3.3 REFERENCES

The references used in this document are:

1. Intertek; Report of Analysis, Laboratory Report ID: 2635282 (Job No. 2017-PTAD-000105), 13-Feb-2017 (Att.1).
2. Dictionary of Chemical Engineering, Schaschke, Carl (ISBN 978-0-19-965145-0)
3. http://www.engineeringtoolbox.com/flash-point-fuels-d_937.html
4. http://www.environment.gov.au/topics/environment-protection/fuel-quality/standards/diesel
5. http://www.viscopedia.com/viscosity-tables/substances/bunker-oil-marine-fuel-oil/
6. http://powerplants.man.eu/fuels/hfo
7. http://www.environment.gov.au/science/soe/2011-report/7-antarctic/2-state-and-trends/2-4-station-environment
8. http://www.shippipedia.com/marine-fuels/
9. Everything You Need to Know About Marine Fuels, Chevron, Monique B. Vermeire
10. https://www.astm.org/Standards/D130.htm
11. https://www.dieselnet.com/standards/inter/fuel_marine.php
12. https://en.wikipedia.org/wiki/Heat_of_combustion
13. http://ec.europa.eu/environment/air/transport/pdf/Report_Sulfur_Requirement.pdf
14. https://www.astm.org/Standards/D86.htm
15. Notes on Heavy Fuel Oil Publication, American Bureau of Shipping (ABS)

3.4 ATTACHMENTS

1. Intertek Report of Analysis
2. Everything You Need to Know About Marine Fuels, Chevron, Monique B. Vermeire – Section III Fuel Oil – Table 1 (Requirements for distillate marine fuels).
3. Heavy Fuel Oil Specifications

4 MARINE FUEL OIL PROPERTIES

4.1 FLASH POINT

4.1.1 DEFINITION

The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.

The rapid combustion occurs in the form of momentary flash point. Flash point data is important for the safe storage and transportation of volatile liquids. Flash Point for typical MGO and HFO are tabulated in Table 4.1 below:

Table 4.1: Flash Point for MGO / HFO Oils

Fuel	**Flash Point (°C)**
Standard MGO / Standard MGO DMB	70.00 / 68.00 (Att. 1)
Standard MGO + FCC / Standard MGO DMB + FCC	69.00 / 68.00 (Att. 1)
Standard HFO (180 cSt)	73.00 (Att. 1)
Standard HFO (180 cSt) + FCC	74.00 (Att. 1)
Standard HFO (380 cSt)	118.00 (Att. 1)
Standard HFO (380 cSt) + FCC	118.00 (Att. 1)
Biodiesel	130.00
Diesel Fuel (1-D)	37.78
Diesel Fuel (2-D)	52.22
Diesel Fuel (4-D)	54.44
Fuels Oil No.1	37.78 – 72.22
Fuels Oil No.2	52.22 – 95.56
Fuels Oil No.4	61.11 – 115.56
Fuels Oil No.5 Lite	68.89 – 168.89
Fuels Oil No.5 Heavy	71.11 – 121.11

4.1.2 ANALYSIS

A low flash point is a high fire hazard. The accepted, safe, minimum flash point for fuel oils established by most regulatory bodies is 60°C for Marine Gas Oils (Ref. 15) and 61.5°C based on ASTM D93 (Ref. 4) for safe storage and handling of fuel.

Standard MGO Flash Point is 70°C (Fuel Oil No. 4 – 5) and with addition of FCC, the Flash Point remain almost the same at 69°C and within the moderate low hazard level classification. MGO DMB flash point remained unchanged after addition of FCC at 68ºC.

Standard HFO (180 cSt) Flash Point is 73°C (Fuel Oil No. 4 – 5) and with addition of FCC, the Flash Point remain almost the same at 74°C. HFO (380 cSt) flash point remained unchanged after addition of FCC at 118ºC.

Hence, addition of FCC does not impact on Flash Point of the marine fuel and the storage and handling of the fluid.

Flash Point Hazard Level classification is summarised in Table 4.2 below:

Table 4.2: Hazard Level Classification based on Flash Point

Hazard Level	Flash Point (°C)
Very low hazard	> 93
Moderate low hazard	66 to 93
High to Moderate Hazard	38 to 66
Extremely High to High Hazard	-18 to 38
Extreme Hazard	< -18

4.2 FILTER BLOCKING TENDENCY

4.2.1 DEFINITION

FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter. Unstable fuels can form soluble gums or insoluble organic particulates. Both gums and particulates may contribute to injector deposits, and particulates can clog fuel filters. The formation of gums and particulates may occur gradually during long-term storage or quickly during fuel system recirculation caused by fuel heating. Sometimes a combination of fuel behaviour and fuel system design can cause filter plugging.

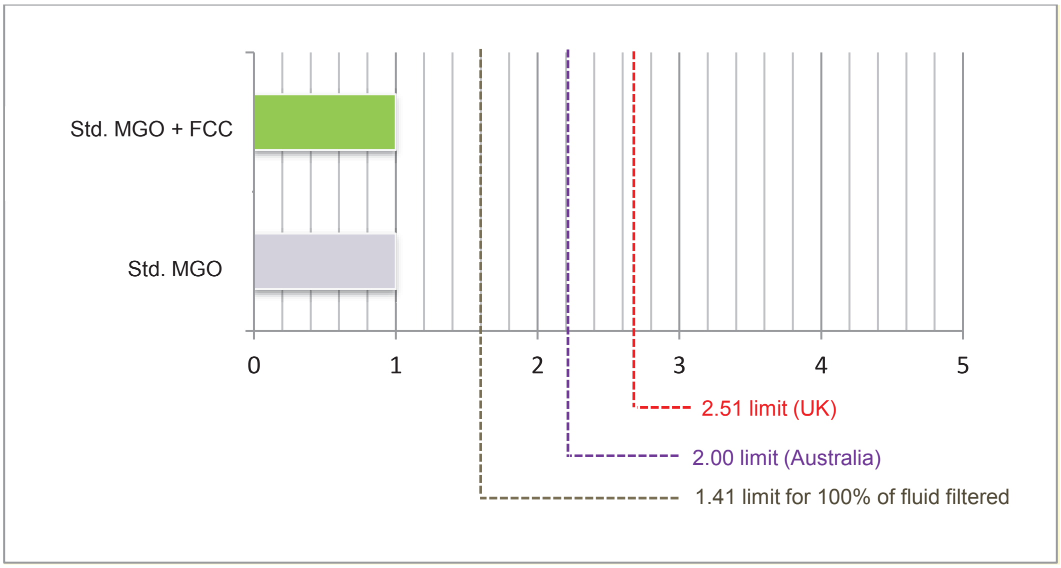
4.2.2 ANALYSIS

Based on the test results, there is no change in FBT after addition of FCC as the Standard MGO used as control sample has a low FBT. This low FBT of Standard MGO (control sample) and Standard MGO + FCC is 1.00, which is below 1.41, which means all of the volume 100% of flow could be filtered. This indicates that FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.

The FBT limits are detailed below and illustrated in Figure 4.1:

- FBT values exceeded 1.41 indicates that not all of the volume could be filtered.
- Australia FBT limit value of 2.0 for Diesel fuels (Ref. 4).
- United Kingdom FBT limit < 2.51 (UK EN590 Specifications).

Figure 4.1: FBT (Fuel Specifications)



4.3 WEAR SCAR DIAMETER (LUBRICITY)

4.3.1 DEFINITION

Wear Scar Diameter is a measure of lubricity of fluid which is the ability of fluid or compound (in this case MGO) to act as a lubricant to minimize friction and damage to surfaces in contact under relative motion load.

Some moving parts of petrol fuel pumps and injectors are protected from wear by the fuel. Lubricity is ability of a lubricant (MGO) to minimize friction between and damage to surfaces in relative motion under load. The lubrication mechanism is a combination of hydrodynamic lubrication and boundary lubrication. In hydrodynamic lubrication, a layer of liquid prevents contact between the opposing surfaces. Fuels with higher viscosities will provide better hydrodynamic lubrication. Boundary lubrication becomes important when high load and/or low speed have squeezed out much of the liquid that provides hydrodynamic lubrication, leaving small areas of the opposing surfaces in contact. Boundary lubricants are compounds that form a protective anti-wear layer by adhering to the solid surfaces.

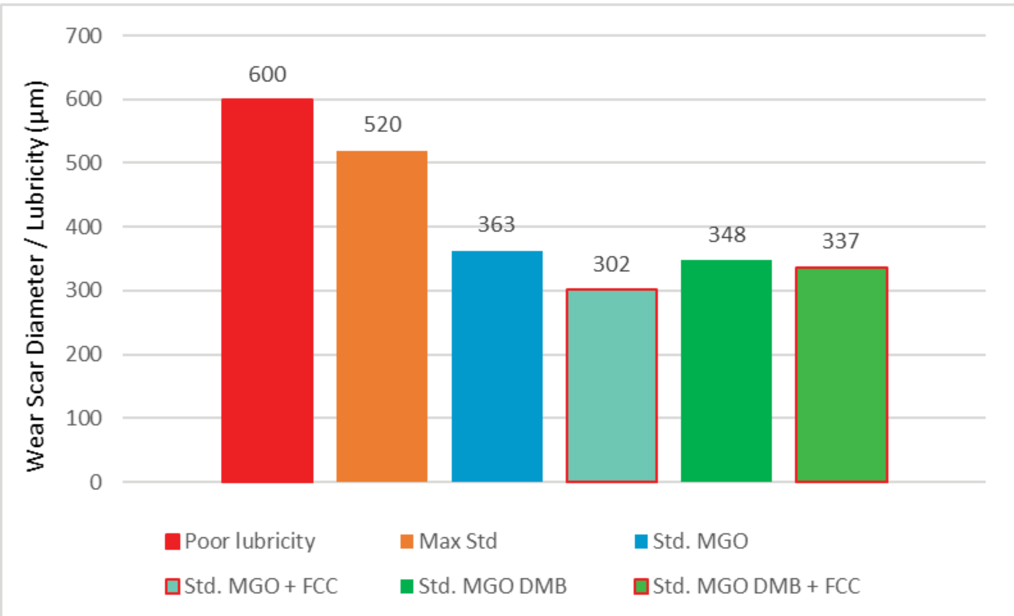
4.3.2 ANALYSIS

The maximum standard lubricity / wear scar diameter is 520 µm (Ref. 9) to ensure sufficient lubricity for the engine's operation. Poor lubricity / great scar diameter (>600 µm) could potentially causes excessive wear and at the extreme, causes catastrophic failure.

The lubricity of MGO improves by a significant 16.8% with addition of FCC from 363 µm to 302 µm and the lubricity of MGO DMB improves by 3.2% with addition of FCC from 348 µm to 337 µm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.

The specification of lubricity as illustrated in Figure 4.2 below.

Figure 4.2: Lubricity (MGO Specifications)



4.4 GROSS HEAT OF COMBUSTION / GROSS CALORIFIC VALUE

4.4.1 DEFINITION

The gross heat of combustion / gross calorific value is a measure of the total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions. The chemical reaction is a hydrocarbon (MGO/HFO) reacting with oxygen to form carbon dioxide and water and releases heat. This directly impacts the economics of engine performance.

4.4.2 ANALYSIS

Based on the laboratory analysis by Intertek (Attachment 1), MGO and HFO with addition of FCC has no/minimal impact on the gross heat of combustion / gross calorific value of the fuel. This indicates that FCC does not modify composition of the fuel which may cause incombustible components.

The aromatics content from the test results are as summarised below.

Properties	**MGO**	**MGO (DMB)**	**HFO** (180 cSt)	**HFO** (380 cSt)
Gross Heat of Combustion (Btu/lb)	19,661			18,252
Gross Heat of Combustion (Btu/lb) with FCC	19,661			18,247
Gross Calorific Value (MJ/kg)		45.61	42.29	
Gross Calorific Value (MJ/kg) with FCC		45.61	42.30	

4.5 CETANE INDEX

4.5.1 DEFINITION

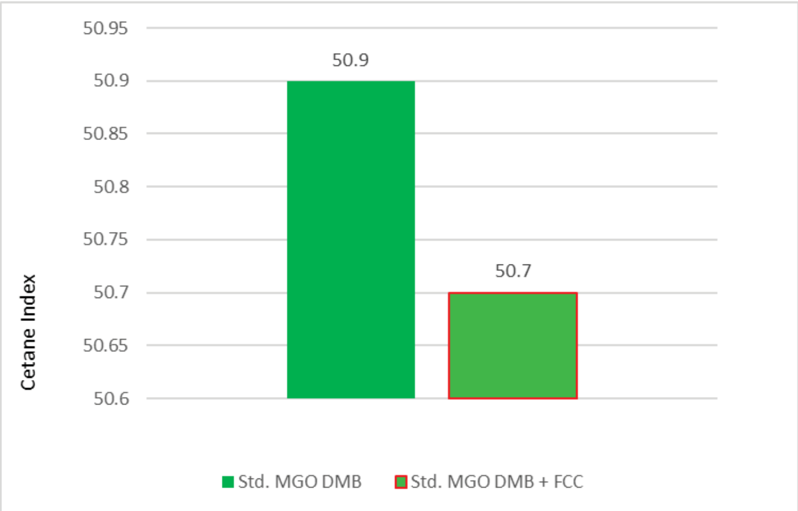
The quality of diesel fuels can be expressed as cetane number or cetane index. The cetane number (CN) is expressed in terms of the volume % of cetane (($C_{16}H_{34}$) which has high ignition (CN = 100)) in a mixture with alpha-methyl-naphthalene (($C_{11}H_{10}$) which has low ignition quality (CN = 0)) that has the same ignition characteristics as a fuel being tested in a standard engine. It is therefore, an indication of ease of self or auto-ignition characteristic of a fuel. The cetane index (CI) is a number calculated from the average boiling point and density of a petroleum fraction in the diesel fuel boiling range, which then estimates the CN of the fraction.

4.5.2 ANALYSIS

Based on the laboratory analysis by Intertek (Attachment 1), MGO with addition of FCC remained unchanged at 52.4. Based on the results for MGO DMB addition of FCC has improved the CI by a marginal 0.4% from 50.9 to 50.7. The slight increase of CI on the fuel increase the ease of self-ignition of the fuel and therefore enables engine to operate more effectively and improves engine performance. The specification of CI range is typically from 35 to 45.

The CI from the test results are as illustrated in Figure 4.3 below.

Figure 4.3: Cetane Index (MGO)



Increasing the cetane number improves fuel combustion, reduces white smoke on start-up, and tends to reduce NOx and PM emissions. NOx seems to be reduced in all engines, while PM reductions are engine-dependent. For high speed engine, high CI fuels are desirable as engine performance improvement on the high-speed engine is evident in comparison using low CI fuels.

4.6 DENSITY

4.6.1 DEFINITION

Characteristics of a substance indicated as mass per unit volume varies with temperature and pressure. This variation is typically small for solids and liquids (non-compressible) but much greater for gases (compressible). Non-compressible liquids / solids have relatively higher density than gas.

4.6.2 ANALYSIS

Changes in fuel density affect the energy content of the fuel brought into the engine at a given injector setting. Reducing fuel density tends to decrease NOx emissions in older technology engines that cannot compensate for this change. Emissions from modern engines, with electronic injection and computer control, are not influenced by the density of the fuel.

The density of MGO specification is typically 890 to 900 kg/m³ (Ref. 7). Standard Density of MGO (control sample) is 838.7 kg/m³, MGO DMB is 844.8 kg/m³, HFO (180 cSt) is 989.4 kg/m³ and HFO (380 cSt) is 988.4 kg/m³. Addition of FCC, have no impact on density for all marine fuel oil tested.

4.7 DISTILLATION

4.7.1 DEFINITION

The basic test method of determining the boiling range of a petroleum product by performing a simple batch distillation. The distillation (volatility) characteristics of hydrocarbons have an important effect on their safety and performance, especially in the case of fuels and solvents. The boiling range gives information on the composition, the properties, and the behaviour of the fuel during storage and use. Volatility is the major determinant of the tendency of a hydrocarbon mixture to produce potentially explosive vapours.

The distillation characteristics are critically important for both automotive and aviation gasolines, affecting starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both. The presence of high boiling point components in these and other fuels can significantly affect the degree of formation of solid combustion deposits.

HFO is residual fuel oil which remains after the distillation. The main components in HFO are alkanes, cycloalkanes and different carbon hydrides. The boiling range is between 300°C and ~700°C and are fuels which has less than 65% by volume (including losses) distils at 250°C by the ASTM D86 method. If the distillation cannot be determined by the ASTM D86 method, the petroleum product is likewise categorised as a heavy fuel oil.

4.7.2 ANALYSIS

The initial boiling point temperature and final boiling point temperature of MGO and MGO DMB is assessed and addition of FCC have minimal impact of the boiling point of the MGO. Addition of FCC into MGO changes the initial boiling point to 171.4ºC from 173.5ºC and the final boiling point to 360.5ºC from 360.6ºC. Similarly, for MGO DMB, addition of FCC changes the initial boiling point from 180.1ºC to 180.7ºC and the final boiling point from 360.3ºC to 361.5ºC.

Changes of boiling points have no impact on MGO performance as boiling points are used for categorisation of types of fuels.

4.8 SULFUR CONTENT

4.8.1 DEFINITION

Crude petroleum contains sulfur compounds, most of which are removed during refining. However, of the sulfur compounds remaining in the petroleum product, some can have a corroding action on various metals and this corrosivity is not necessarily related directly to the total sulfur content. The effect can vary according to the chemical types of sulfur compounds present. However, presence of sulfur in the MGO/HFO will results in emission of SOx (Sulfur oxides): Sulfur oxide refers to many types of Sulfur and oxygen containing compounds that can be found in ship exhaust gas. The most frequent Sulfur content in ships emissions in Sulfur dioxide (SO_2).

Sulfur in MGO/HFO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO_2) and sulfate (SO_4) particulate matter (PM)), leads to engine cylinder wear and forms deposits in the engines. The Sulfur in fuel requirement is reduced from 1.0% to 0.1% as from 1 January 2015 in SECAs (Sulfur Emission Controlled Area).

4.8.2 ANALYSIS

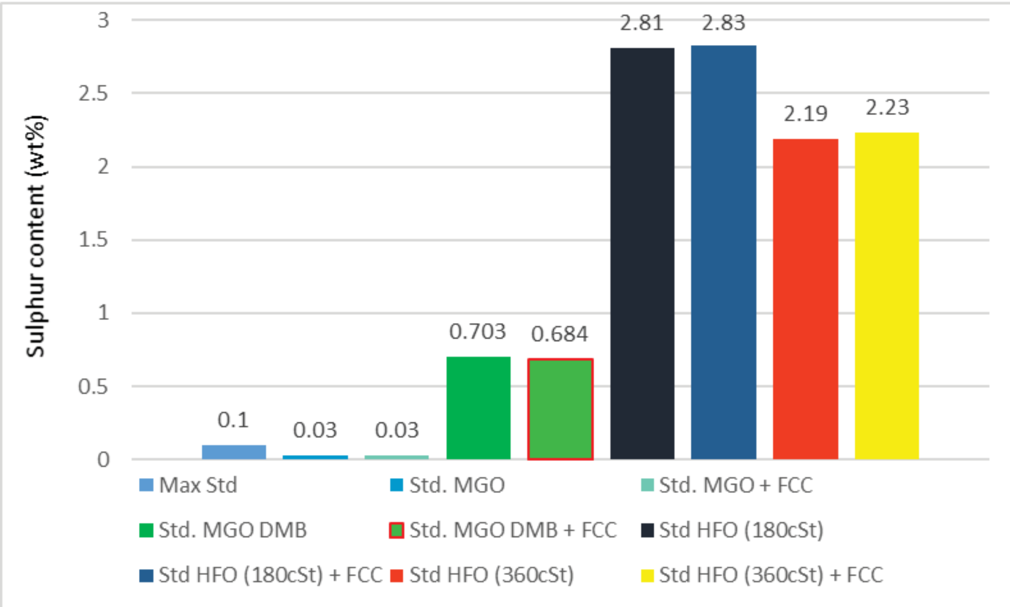
From the Intertek analysis (Attachment 1), MGO DMB Sulfur content has improved 2.70% with addition of FCC from 0.703 wt% down to 0.684 wt%. The improvement i.e. reduction in Sulfur content upon addition of FCC in MGO DMB will reduce the emission of Sulfur dioxide (SO_2).

No change is observed for MGO where the initial content of Sulfur in control sample is very low i.e. 0.030 wt%, much lower than the required Sulfur content of 0.1%.

Addition of FCC on HFO has a minimal increase in the Sulfur content from 2.81% to 2.83% for HFO (180 cSt) and from 2.19% to 2.23% for HFO (380 cSt).

The Sulfur content from the test results are as illustrated in Figure 4.3 below.

Figure 4.4: Sulfur Content (MGO/HFO)



4.9 COPPER CORROSION

4.9.1 DEFINITION

Crude petroleum contains sulfur compounds, most of which are removed during refining. However, of the sulfur compounds remaining in the petroleum product, some can have a corroding action on various metals and this corrosivity is not necessarily related directly to the total sulfur content. The effect can vary according to the chemical types of sulfur compounds present. The copper strip corrosion test is designed to assess the relative degree of corrosivity of a petroleum product (Ref. [10]).

4.9.2 ANALYSIS

The Copper Corrosion Test classification is provided in Table 4.3 below:

Table 4.3: Copper Corrosion Test

Class	Designation	Description
1	Slight Tarnish	1a Light orange, almost the same as a freshly polished strip 1b Dark Orange
2	Moderate Tarnish	2a Claret Red 2b Lavander 2c Multi- colored with lavender blue and/or silver overlaid on claret red 2d Silvery 2e Brassy or gold
3	Dark Tarnish	3a Magenta overcast on brassy strip 3b Multicolored with red and green showing (peacock), but no gray
4	Corrosion	4a Transparent black, dark gray or brown with peacock green barely showing 4b Graphite or lusterless black 4c Glassy or jet black

From the test results (as summarised below), addition of FCC will not change the corrositivity of the initial MGO / HFO which is desirable and indicates that FCC preserves the non-corrosive nature of the marine fuel.

Properties	**MGO**	**MGO (DMB)**	**HFO** (380 cSt)
Control sample Copper Corrosion Class	1b	1a	1b
Control sample + FCC Copper Corrosion Class	1b	1a	1b

4.10 AROMATICS

4.10.1 DEFINITION

Marine fuel oil contains approximately 60% aromatics, and is a high-density fraction. Aromatic hydrocarbons ($C_NH_{(2N-6)}$) possess a much higher specific gravity than the other classes. Aromatics are very stable under heat and are chemically active to a moderate degree. The aromatic compounds contain a higher proportion of carbon than the other hydrocarbon types. Due to this characteristic, they have a tendency to smoke, which somewhat limits their use in diesel engines (Ref. 15).

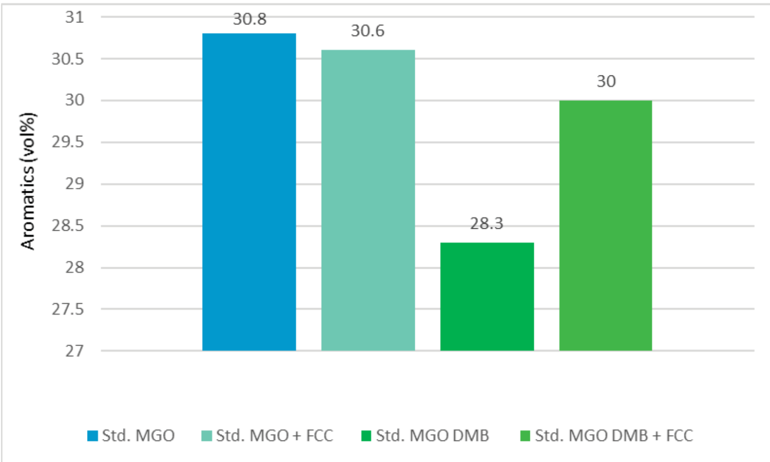
Most studies indicate that reducing total aromatics has no effect on the emissions of hydrocarbon and particulate matter. However, reducing total aromatics from 30% to 10% reduces NOx emissions (Ref. 9).

4.10.2 ANALYSIS

From the test results for MGO, the percentage of aromatics are slightly increased from 30.6 vol% to 30.8 vol% with addition of FCC. As for MGO DMB the percentage of aromatics are increased from 28.3 vol% to 30.0 vol% with addition of FCC. The change in aromatic content is illustrated in Figure 4.5 below.

As the percentage of change is below 10%, no significant impact is anticipated with addition of FCC on NOx emissions and fuel continues to remain stable under heat without significant change to fuel's composition that consequently affects combustion.

Figure 4.5: Aromatics (MGO)



5 SUMMARY

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Flash Point	The lowest temperature at which a volatile liquid will produce sufficient amount of vapour above the liquid such that spontaneous ignition will occur if a spark is present in air, at a given pressure.	ASTM D93	Indication of fire and explosion hazard which is important for the safe storage and transportation of volatile liquids. A low flash point is a high fire hazard.	• Very low hazard > 93°C • Moderate low hazard, 66 to 93°C • High to Moderate Hazard, 38 to 66°C • Extremely High to High Hazard, -18 to 38°C • Extreme Hazard < -18°C	70°C to 69°C (no impact)	68°C (no change).	73°C to 74°C (no impact).	118°C to 118°C (no change).
Filter Blocking Tendency	FBT is a calculated dimensionless value that defines the tendency of particulates in a fuel to plug or block a filter.	IP 387 (Procedure A)	At low temperatures below the cloud point of diesel fuel, wax precipitates from fuel and can cause filter blocking and affecting quality of fuel.	If values exceeded 1.41 not all of the volume could be filtered. Limit < 2.51 (UK EN590 Specifications).	1.00 – No change / impact.	-	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Wear Scar Diameter / Lubricity	Ability of a lubricant (in this case diesel fuel) to minimize friction between and damage to surfaces in relative motion under load.	IP 450	Poor lubricity causes excessive wear and at the extreme, causes catastrophic failure.	>600 µm might not prevent excessive wear Specification of 520 µm max	302 µm (16.8% reduction / improvement from 363 µm)	337 µm (3.2% reduction / improvement from 348 µm)	-	-
Gross Heat of Combustion / Gross Calorific Value	Total energy released as heat when a substance undergoes complete combustion with oxygen under standard conditions.	ASTM D4838-00(10)	Directly impacts the economics of engine performance.	-	19,661 Btu/lb (no change)	45.61 MJ/kg (no change)	42.3 MJ/kg from 42.29 MJ/kg (no impact)	18,247 Btu/lb from 18,252 Btu/lb (minimal 0.03% decrease, no impact)
Cetane Index	Measures the performance / quality of a fuel in a diesel engine by its ability for auto-ignition.	ASTM D4737	Increase in Cetane will reduce emission of NO_x [(a)]. High speed engine operates more effectively with high CI fuels.	• CI of 45 (Diesel No. 1) is used in high speed engines, trucks and buses. • CI of 40 (No. 2). • CN = 30 is used as Railroad diesel fuels (similar to the heavier automotive diesel fuels, but have higher boiling ranges up to 400°C.	52.4 (no change)	50.7 (0.4% increase from 50.9).	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Density	Characteristics of a substance indicated as Mass per unit volume varies with temperature and pressure.	ASTM 4052	Affects heating value and hence fuel economy. Density to be used in equation along with Heating Value to determine Heat of Combustion which consequently affects engine performance. Reduction in density will reduce NOx emissions [a].	MGO: Range from 890 – 900 kg/m³ depending on country / location. HFO: 1010 kg/m³	838.7 kg/m³ (no change)	844.9 kg/m³ from 844.8 kg/m³ (0.01% increase, no impact)	989.4 kg/m³ (no change)	988.3 kg/m³ from 988.4 kg/m³ (0.01% decrease, no impact)
Distillation	Distillation (batch) provides boiling range of MGO. The distillation characteristics affects starting, warm-up, and tendency to vapor lock at high operating temperature or at high altitude, or both.	ASTM D86-15	The presence of high boiling point components in fuels can significantly affect the degree of formation of solid combustion deposits.	-	Initial boiling point to 171.4ºC from 173.5ºC, final boiling point to 360.5ºC from 360.6ºC – no impact	Initial boiling point from 180.1ºC to 180.7ºC, final boiling point from 360.3ºC to 361.5ºC – no impact	-	-

Property	Definition	Test Method	Effect of Property on Performance / Significance of Property	Limits / Specifications	MGO	MGO DMB	HFO (180 cSt)	HFO (380 cSt)
Sulfur Content	Sulfur in MGO is converted to sulfur oxides during combustion which affects particulate emissions (forms sulfur dioxide (SO_2) and sulfate (SO_4) particulate matter (PM)),	ASTM D4294-16e1	Sulfur leads to engine cylinder wear and forms deposits in the engines.	0.5 – 2.0 wt%	0.0030 wt% (no change)	0.684 wt% (2.7% improvement from 0.703 wt%)	2.83 wt% (slight increase from 2.81 wt%)	2.23 wt% (slight increase from 2.19 wt%)
Copper Corrosion	Indicates potential for corrosive attack on metal parts / relative degree of corrosivity of marine fuel.	ASTM D130-12	Corrosion of metal parts of equipment / engine	1 – slightly tarnish 2 – moderate tarnish 3 – dark tarnish 4 – corrosion	1b (no change)	1a (no change)	-	1b (no change)
Aromatics	Group of hydrocarbons of which benzene is the parent. They are called “aromatics” because many of their derivatives have sweet or aromatic odors.	ASTM D1319-15	Aromatics in hydrocarbons (MGO/HFO) increase particulate emissions and cause related problems in combustion.	No specification for MGO/HFO. Limit applies to diesel < 11vol%	30.8 vol% from 30.6 vol% (increase 0.65%, no impact)	30 vol% from 28.3 vol% (increase 6%, no impact)	-	-

(a) For heavy duty engine emissions.

Key summary based on the technical analysis of the MGO and HFO spiked with FCC on a comparative basis to a MGO and HFO control sample respectively:

1. **Flash Point**: No change in classification of hazard level (moderate low hazard). Hence, addition of FCC does not impact on Flash Point of the MGO and HFO in storage and handling of the fluid / fuel.
2. No change in **FBT**. FCC maintains this important characteristic of the fuel for FBT which affects performance and lifetime of the engine.
3. **Wear Scar Diameter / Lubricity:** Improves by a significant 16.8% with addition of FCC in MGO from 363 μm to 302 μm and a 3.2% improvement with addition of FCC in MGO DMB from 348 μm to 337 μm. This increase in lubricity will improve durability of equipment and premature wear of equipment by allow equipment to operate to its intended design life.
4. **Gross Heat of Combustion / Calorific Value**: Addition of FCC into MGO and HFO has no/minimal impact on the gross heat of combustion / gross calorific value of the fuel which indicates that FCC does not modify composition of the fuel which may cause incombustible components.
5. **Cetane Index:** Increasing the cetane number improves fuel combustion, reduces white smoke on startup, and tends to reduce NOx and PM emissions. MGO DMB Cetane Index is slightly increased with addition of FCC from 50.7 to 50.9.
6. No change in **Density**. MGO and HFO are high density fuel and addition of FCC have no change this property.
7. No change in **Distillation**: Similarly, as MGO and HFO are residue fuel in distillation process and stable under heat and characteristic of the fuel remain unchanged with addition of FCC.
8. **Sulfur Content**: Addition of FCC in MGO DMB yields an improvement of 2.7% reduction of Sulfur content from 0.703 wt% to 0.684 wt% which is an important aspect with stricter sulfur in fuel requirement particularly in SECAs (Sulfur Emission Controlled Areas).
9. **Copper Corrosion**: No further corrosion is observed with addition of FCC where the copper test readings remained constant before and after addition into MGO and HFO.
10. **Aromatics**: Minimal changes in aromatics content upon addition of FCC with slight 0.65% increase in aromatics for MGO from 30.6 vol% to 30.8 vol%. An increase of 6% is observed with addition of FCC into MGO DMB from 28.3 vol% to 30 vol%. Changes is minimal and fuel continues to remain stable under heat without significant change to fuel's composition that consequently affects combustion.

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Report of Analysis

Justin West
Addfuel
PO Box 318
Nedlands
WA,6909
Australia

Laboratory Report ID : 2678653
Job No. : 2017-PTAD-000105
Client Reference : Not Supplied

Sample ID	: 2017-PTAD-000105-002	**Date Taken**	: Not Supplied
Sample Designated as	: MGO	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: MGO (without Additive)		

Method		**Test**	**Result**	**Units**
ASTM D93		Procedure Used	A	
		Corrected Flash Point	70.0	°C
IP 387	i	Filter Blocking Tendency	1.00	
IP 450	i	Corrected Mean Wear Scar Diameter	363	µm
ASTM D4868		Gross Heat of Combustion	19661	BTU/lb
ASTM D976		Cetane Index	52.4	
ASTM D4052	i	Density @ 15°C	0.8387	kg/L
ASTM D86	i	Barometric Pressure	763	mm Hg
		Initial Boiling Point	173.5	°C
	i	5% Recovery	203.5	°C
	i	10% Recovery	215.4	°C
	i	20% Recovery	234.2	°C
	i	30% Recovery	249.3	°C
	i	40% Recovery	262.1	°C
	i	50% Recovery	273.7	°C
	i	60% Recovery	285.5	°C
	i	70% Recovery	298.1	°C
	i	80% Recovery	313.3	°C
	i	85% Recovery	322.3	°C
	i	90% Recovery	334.4	°C
	i	95% Recovery	352.1	°C
		Final Boiling Point	360.6	°C
	i	Corrected Loss	0.5	Vol %
	i	Corrected Residue	1.8	Vol %
	i	Corrected Total Recovery	99.5	Vol %
IP 336	i	Sulfur Content	< 0.030	% (m/m)
ASTM D130	i	Copper Corrosion @ 50°C (122°F)/3 hr	1b	
ASTM D1319	i	Aromatics	30.6	Vol %

Sample Received Condition	: Good (No Seal)
Seal Number	: None
Sampling Method	: Not Applicable
Remarks	: Not Supplied

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Report of Analysis

Laboratory Report ID	: 2678653
Job No.	: 2017-PTAD-000105
Client Reference	: Not Supplied

Sample ID	: 2017-PTAD-000105-003	**Date Taken**	: Not Supplied
Sample Designated as	: MGO	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: MGO + FCC Fuel Conditioner by AddFuel (1:4000)		

Method		Test	Result	Units
ASTM D93		Procedure Used	A	
		Corrected Flash Point	69.0	°C
IP 387	i	Filter Blocking Tendency	1.00	
IP 450	i	Corrected Mean Wear Scar Diameter	302	µm
ASTM D4868		Gross Heat of Combustion	19661	BTU/lb
ASTM D976		Cetane Index	52.4	
ASTM D4052	i	Density @ 15°C	0.8387	kg/L
ASTM D86	i	Barometric Pressure	767	mm Hg
		Initial Boiling Point	171.4	°C
	i	5% Recovery	203.4	°C
	i	10% Recovery	214.8	°C
	i	20% Recovery	234.2	°C
	i	30% Recovery	249.1	°C
	i	40% Recovery	262.5	°C
	i	50% Recovery	273.5	°C
	i	60% Recovery	285.3	°C
	i	70% Recovery	298.0	°C
	i	80% Recovery	312.8	°C
	i	85% Recovery	321.8	°C
	i	90% Recovery	333.4	°C
	i	95% Recovery	350.5	°C
		Final Boiling Point	360.5	°C
	i	Corrected Loss	0.0	Vol %
	i	Corrected Residue	1.8	Vol %
	i	Corrected Total Recovery	100.0	Vol %
IP 336	i	Sulfur Content	< 0.030	% (m/m)
ASTM D130	i	Copper Corrosion @ 50°C (122°F)/3 hr	1b	
ASTM D1319	i	Aromatics	30.8	Vol %

Sample Received Condition	: Good (No Seal)
Seal Number	: None
Sampling Method	: Not Applicable
Remarks	: Not Supplied

Attachment 1 (B)

Sample ID	: 2017-PTAD-000105-004	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst (without Additive)		

Method	Test	Result	Units
ASTM D93	Procedure Used	B	
	Corrected Flash Point	118.0	°C

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Report of Analysis

Laboratory Report ID : 2678653
Job No. : 2017-PTAD-000105
Client Reference : Not Supplied

Sample ID	: 2017-PTAD-000105-004	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst (without Additive)		

Method		Test	Result	Units
ASTM D4868		Gross Heat of Combustion	18252	BTU/lb
IP 365	j	Density @ 15 °C	0.9884	kg/L
ASTM D4294		Sample Preparation	Centrifuged	
		Sulfur Content	2.19	Wt %
ASTM D130	j	Copper Corrosion @ 50°C (122°F)/3 hr	1b	

Sample Received Condition : Good (No Seal)
Seal Number : None
Sampling Method : Not Applicable
Remarks : Not Supplied

Sample ID	: 2017-PTAD-000105-005	**Date Taken**	: Not Supplied
Sample Designated as	: HFO 380cst	**Date Submitted**	: 13-Feb-2017
Sampling Point	: Not Supplied	**Date Tested**	: 21-Feb-2017
Job Location	: Intertek-Port Adelaide Laboratory	**Drawn By**	: Client
Representing	: HFO 380cst + FCC Fuel Conditioner by AddFuel (1:4000)		

Method		Test	Result	Units
ASTM D93		Procedure Used	B	
		Corrected Flash Point	118.0	°C
ASTM D4868		Gross Heat of Combustion	18247	BTU/lb
IP 365	j	Density @ 15 °C	0.9883	kg/L
ASTM D4294		Sample Preparation	Centrifuged	
		Sulfur Content	2.23	Wt %
ASTM D130	j	Copper Corrosion @ 50°C (122°F)/3 hr	1b	

Sample Received Condition : Good (No Seal)
Seal Number : None
Sampling Method : Not Applicable
Remarks : Not Supplied

The analysis results denoted by (j) are part of the laboratory NATA accreditation. Accredited for compliance with ISO/IEC 17025.

This Report supersedes Laboratory Report ID 2635282 issued on 21-Feb.2017.
Test IP450 result was amended.

Amended Report of Analysis

Signed: ____________________ Date: 06-Apr.2017

Michelle Fernandez, Laboratory Supervisor

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Attachment 1 (C)

CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-001

SAMPLE NO. : 2017-MIS-012165-001
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : DMB
Source : Without Additive

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	68.0
Lubricity	IP 450-00	microns	Report	348
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	45.61
Calculated Cetane Index	ASTM D4737-10(Proc A)		Report	50.9
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.8448
Distillation Range	ASTM D86-15			
Initial Boiling Point	ASTM D86-15	°C	Report	180.1
10% Recovered	ASTM D86-15	°C	Report	218.1
20% Recovered	ASTM D86-15	°C	Report	236.1
30% Recovered	ASTM D86-15	°C	Report	251.7
40% Recovered	ASTM D86-15	°C	Report	265.7
50% Recovered	ASTM D86-15	°C	Report	278.2
60% Recovered	ASTM D86-15	°C	Report	289.6
70% Recovered	ASTM D86-15	°C	Report	301.5
80% Recovered	ASTM D86-15	°C	Report	315.1
90% Recovered	ASTM D86-15	°C	Report	332.8
95% Recovered	ASTM D86-15	°C	Report	347.1
Final Boiling Point	ASTM D86-15	°C	Report	360.3
Residue	ASTM D86-15	Vol %	Report	1.8
Loss	ASTM D86-15	Vol %	Report	0.2
Sulphur	ASTM D4294-16e1	wt %	Report	0.0703
Copper Strip Corrosion @ 50 °C for 3 hrs	ASTM D130-12		Report	1a
Aromatics	ASTM D1319-15	Vol %	Report	28.3

REMARKS :

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Laboratory: Singapore Technical Centre 1 Seraya Avenue Singapore 628208 Tel: +65 6896 7428 Fax: +65 6896 7429
Regional OCM Technical Centre 1 Clementi Loop #02-03 Singapore 129808 Tel: +65 6469 9109 Fax: +65 64691982

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-001

Ten Chaw Hsia
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SINGAPORE TECHNICAL CENTRE
INTERTEK - Cargo and AA

This is an interim report, final and official report (COA/COQ) will be issued upon completion.

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-002

SAMPLE NO. : 2017-MIS-012165-002
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : DMB
Source : With Additive (2017-MIS-012164-001) at Ratio 1:4000

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	68.0
Lubricity	IP 450-00	microns	Report	337
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	45.61
Calculated Cetane Index	ASTM D4737-10(Proc A)		Report	50.7
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.8449
Distillation Range	ASTM D86-15			
Initial Boiling Point	ASTM D86-15	°C	Report	180.7
10% Recovered	ASTM D86-15	°C	Report	217.7
20% Recovered	ASTM D86-15	°C	Report	235.8
30% Recovered	ASTM D86-15	°C	Report	251.2
40% Recovered	ASTM D86-15	°C	Report	265.6
50% Recovered	ASTM D86-15	°C	Report	277.7
60% Recovered	ASTM D86-15	°C	Report	289.0
70% Recovered	ASTM D86-15	°C	Report	301.4
80% Recovered	ASTM D86-15	°C	Report	314.8
90% Recovered	ASTM D86-15	°C	Report	332.1
95% Recovered	ASTM D86-15	°C	Report	346.3
Final Boiling Point	ASTM D86-15	°C	Report	361.5
Residue	ASTM D86-15	Vol %	Report	1.2
Loss	ASTM D86-15	Vol %	Report	0.3
Sulphur	ASTM D4294-16e1	wt %	Report	0.0684
Copper Strip Corrosion @ 50 °C for 3 hrs	ASTM D130-12		Report	1a
Aromatics	ASTM D1319-15	Vol %	Report	30.0

REMARKS :

Intertek Testing Services (Singapore) Pte Ltd UEN: 197401138D
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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012165-002

Ten Chaw Hsia
Lab Coordinator
SINGAPORE TECHNICAL CENTRE
INTERTEK - Cargo and AA

This is an interim report, final and official report (COA/COQ) will be issued upon completion.

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012155-001

SAMPLE NO. : 2017-MIS-012155-001

JOB NO :

DATE RECEIVED : 27-Mar-2017

REPRESENTING : INTERTEK - PORT ADELAIDE

ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : HFO 180cst
Source : Without Additive

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	73.0
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	42.29
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.9894
Sulphur	ASTM D4294-16e1	wt %	Report	2.81

REMARKS :

Ten Chaw Hsia
Lab Coordinator
SINGAPORE TECHNICAL CENTRE
INTERTEK - Cargo and AA

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CERTIFICATE OF QUALITY

S/NO.: 2017-MIS-012155-002

SAMPLE NO. : 2017-MIS-012155-002
JOB NO :
DATE RECEIVED : 27-Mar-2017
REPRESENTING : INTERTEK - PORT ADELAIDE
ADDRESS : 2 ELDER ROAD (PART OF TRANS P & O BUILDING)BIRKENHEADSOUTH AUSTRALIA

SAMPLE DESCRIPTION :

Product : HFO 180cst
Source : With Additive (2017-MIS-012164-001) at Ratio 1:4000

The above sample was tested at Singapore Technical Centre (1 Seraya Avenue Singapore 628208) on 29-Mar-2017 in accordance with the test method(s) stipulated, with the result(s) as follows:-

TEST	METHOD	UNIT	SPECIFICATION	RESULT
Flash Point, PMCC	ASTM D93-16a	°C	Report	74.0
Gross Calorific Value	ASTM D4868-00(10)	MJ / kg	Report	42.30
Density @ 15 °C	ASTM D4052-15	kg / L	Report	0.9894
Sulphur	ASTM D4294-16e1	wt %	Report	2.83

REMARKS :

Ten Chaw Hsia
Lab Coordinator
SINGAPORE TECHNICAL CENTRE
INTERTEK - Cargo and AA

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Laboratory: Singapore Technical Centre 1 Seraya Avenue Singapore 628208 Tel: +65 6896 7428 Fax: +65 6896 7429
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Table 1: Requirements for distillate marine fuels

Characteristics	Unit	Limit	Category ISO-F- DMX	DMA	DMZ	DMB	Test method reference
Kinematic viscosity at 40°C[a]	mm^2/s	max.	5,500	6,000	6,000	11.00	ISO 3104
		min.	1,400	2,000	3,000	2,000	
Density at 15°C	kg/m^3	max.	–	890.0	890.0	900.0	see 7.1 ISO 3675 or ISO 12185
Cetane index	–	min.	45	40	40	35	ISO 4264
Sulfur[b]	mass %	max.	1.00	1.50	1.50	2.00	see 7.2 ISO 8754 ISO 14596
Flash point	°C	min.	43.0	60.0	60.0	60.0	see 7.3 ISO 2719
Hydrogen sulfide[c]	mg/kg	max.	2.00	2.00	2.00	2.00	IP 570
Acid number	mg KOH/g	max.	0.5	0.5	0.5	0.5	ASTM D664
Total sediment by hot filtration	mass %	max.	–	–	–	0.10[e]	see 7.4 ISO 10307-1
Oxidation stability	g/m^3	max.	25	25	25	25[f]	ISO 12205
Carbon residue: micro method on the 10% volume distillation residue	mass %	max.	0.30	0.30	0.30	–	ISO 10370
Carbon residue: micro method	mass %	max.	–	–	–	0.30	ISO 10370
Cloud point	°C	max.	-16	–	–	–	ISO 3015
Pour point (upper)[d] winter quality	°C	max.	–[j]	-6	-6	0	ISO 3016
Pour point (upper)[d] summer quality	°C	max.	–[j]	0	0	6	ISO 3016
Appearance	–	–	Clear and Bright[k]			[e,f,g]	see 7.6
Water	volume %	max.	–	–	–	0.30[e]	ISO 3733
Ash	mass %	max.	0.010	0.010	0.010	0.010	ISO 6245
Lubricity, corrected wear scar diameter (wsd 1.4) at 60°C[h]	µm	max.	520	520	520	520[g]	ISO 12156-1

a 1 mm^2/s = 1 cSt.

b Notwithstanding the limits given, the purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See Annex C.

c Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance. For distillate fuels the precision data are currently being developed.

d Purchasers should ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

e If the sample is not clear and bright, the total sediment by hot filtration and water tests shall be required, see 7.4 and 7.6.

f If the sample is not clear and bright, the test cannot be undertaken and hence the oxidation stability limit shall not apply.

g If the sample is not clear and bright, the test cannot be undertaken and hence the lubricity limit shall not apply.

h This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0.050 mass %).

j Modified per approved correction to ISO 8217:2010.

k If the sample is dyed and not transparent, then the water limit and test method as given in 7.6 shall apply.

Table 2: Requirements for marine residual fuels

Characteristics	Unit	Limit	Category ISO-F-											Test method reference
			RMA	RMB	RMD	RME	RMG				RMK			
			10[a]	30	80	180	180	380	500	700	380	500	700	
Kinematic viscosity at 50°C[b]	mm^2/s	max.	10.00	30.00	80.00	180.0	180.0	380.0	500.0	700.0	380.0	500.0	700.0	ISO 3104
Density at 15°C	kg/m^3	max.	920.0	960.0	975.0	991.0	991.0				1010.0			see 7.1 ISO 3675 or ISO 12185
CCAI	–	max.	850	860	860	860	870				870			see 6.3 a)
Sulfur[c]	mass %	max.	Statutory requirements											see 7.2 ISO 8754 ISO 14596
Flash point	°C	min.	60.0	60.0	60.0	60.0	60.0				60.0			see 7.3 ISO 2719
Hydrogen sulfide[d]	mg/kg	max.	2.00	2.00	2.00	2.00	2.00				2.00			IP 570
Acid number[e]	mg KOH/g	max.	2.5	2.5	2.5	2.5	2.5				2.5			ASTM D664
Total sediment aged	mass %	max.	0.10	0.10	0.10	0.10	0.10				0.10			see 7.5 ISO 10307-2
Carbon residue: micro method	mass %	max.	2.50	10.00	14.00	15.00	18.00				20.00			ISO 10370
Pour point (upper)[f] – winter quality	°C	max.	0	0	30	30	30				30			ISO 3016
Pour point (upper)[f] – summer quality	°C	max.	6	6	30	30	30				30			ISO 3016
Water	volume %	max.	0.30	0.50	0.50	0.50	0.50				0.50			ISO 3733
Ash	mass %	max.	0.040	0.070	0.070	0.070	0.100				0.150			ISO 6245
Vanadium	mg/kg	max.	50	150	150	150	350				450			see 7.7 IP 501, IP 470 or ISO 14597
Sodium	mg/kg	max.	50	100	100	50	100				100			see 7.8 IP 501 IP 470
Aluminium plus silicon	mg/kg	max.	25	40	40	50	60				60			see 7.9 IP 501, IP 470 or ISO 10478
Used lubricating oils (ULO): calcium and zinc; or calcium and phosphorus	mg/kg	–	The fuel shall be free from ULO. A fuel shall be considered to contain ULO when either one of the following conditions is met: calcium > 30 and zinc > 15; or calcium > 30 and phosphorus > 15											see 7.10 IP 501 or IP 470 IP 500

a This category is based on a previously defined distillate DMC category that was described in ISO 8217:2005, Table 1. ISO 8217:2005 has been withdrawn.

b 1 mm^2/s = 1 cSt.

c The purchaser shall define the maximum sulfur content in accordance with relevant statutory limitations. See 0.3 and Annex C.

d Due to reasons stated in Annex D, the implementation date for compliance with the limit shall be 1 July 2012. Until such time, the specified value is given for guidance.

e See Annex H.

f Purchasers shall ensure that this pour point is suitable for the equipment on board, especially if the ship operates in cold climates.

Attachment 3

Power Plants

HFO

HFO, also known as "residual fuel oil", is based on the high viscosity, tar-like mass, which remains after the distillation and subsequent cracking of crude oil in order to produce lighter hydrocarbon products, such as petrol , distillate diesel fuels and heating oil or feedstocks for lubricants.

The main components are alkanes, cycloalkanes and different carbon hydrides. The boiling range is between 300°C and ~700°C.

Due to its semi-fluid consistence, HFO has to be preheated to make it combustible in engines.

RMA, RMB, RMD, RME, RMG or RMK are the international trade names.

Cheap, but challenging

As a residual product, HFO is a relatively inexpensive fuel – it typically costs 30% less than distillate fuels (MDO/MGO) (Verlinkung). It thus became the standard fuel for large marine diesel engines during the oil crisis in the 1970s and 1980s, and it required extensive adaptation of the injection system and other components of low and medium speed engines – which are still the only reciprocating engines capable of running on HFO.

Most of our MAN medium speed liquid fuel engines (http://powerplants-staging.md-man.biz/products/liquid-fuel-engines/at-a-glance) can burn heavy fuel oil (HFO). Of course, our medium speed dual fuel engines (http://powerplants-staging.md-man.biz/products/dual-fuel-engines/at-a-glance) are capable of burning HFO in liquid fuel mode as well.

Fuel oil specification

Heavy fuel oil

ISO 8217, ISO-F-RM			K700
Fuel-system related characteristics values			
Viscosity (at 50 °C)	mm²/s (cSt)	max.	700
Viscosity (at 100 °C)	mm²/s (cSt)	max.	55
Density (at 15 °C)	kg/m³	max.	1,010
Flash point	°C	min.	60
Pour point	°C	max.	30
Hydrogen sulfide	mg/kg	max.	2
Acid number	mg KOH/g	max.	2.5
Total sediment aged	mass %	max.	0.10
Engine-related characteristic values			
Carbon residues (Conradson)	m%	max.	20
Sulphur	m%	max.	5

Attachment 3

Ash	m%	max.	0.15
Vanadium	mg/kg (=ppm)	max.	450
Water	Vol.%	max.	0.5
Additional parameters			
Aluminium and silicon	mg/kg	max.	60
Asphalts	m%	max.	2/3 of carbon residues (Conradson)
Sodium	mg/kg		Sodium < 1/3 vanadium, sodium < 100
Used lubricating oil (ULO)	mg/kg		Ca >30 and Zn >15 or CA >30 and P >15

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