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Service Letter

Date : Sep 11, 2019
Ref. No.: HGS-HSM-SL-19-012
〈Replaces HGS-HSM-SL-18-006〉

Subject: HiMSEN Engine Operation with Low Sulphur Fuel

Type: H17/28 , H21/32 , H25/33 , H32/40(V)

Rule & Regulation: IMO MARPOL ANNEX Ⅵ,REG.14.-SOx , SECA

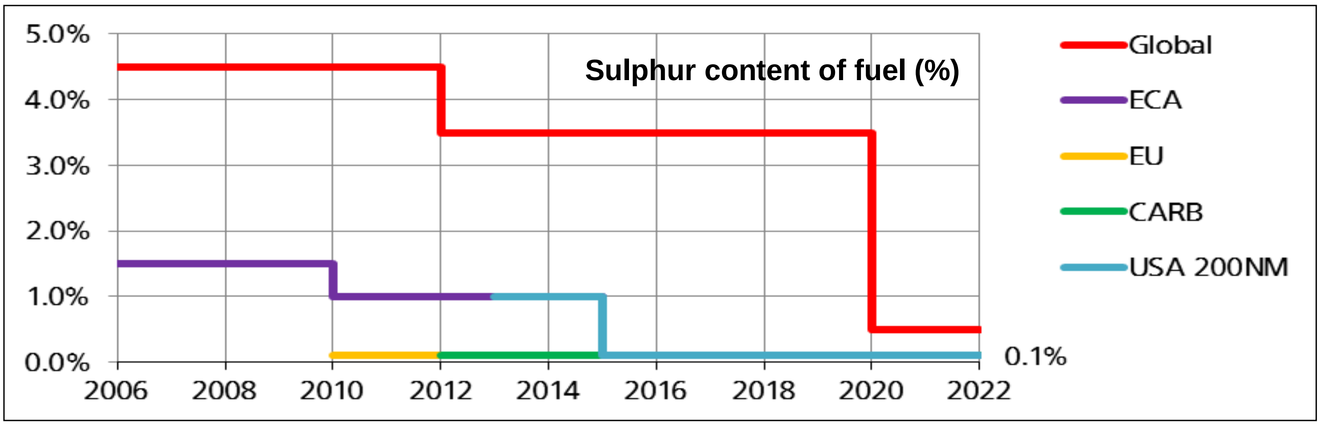
To whom it may concern

Introduction

This letter was written to inform our customers of operation guidance for HiMSEN Engine to comply with IMO MARPOL ANNEX Ⅵ Reg.14.8 which is to come into force as of 1 January,2020 and the regulation of the SECAs.

Background

IMO (International Maritime Organization) has decided that all ships have to comply with 0.5% Sulphur contents in Fuel by 2020. Furthermore SECA expects to be expanded worldwide.



(Fig.1 Road map of Limitation of Sulphur in Fuel)

<table>
<tr><th>Implementation date</th><th>Global</th><th>SECA</th></tr>
<tr><td>2005.05.19</td><td rowspan="2">〈 4.5% S</td><td>〈 1.5% S</td></tr>
<tr><td>2010.07.01</td><td rowspan="2">〈 1.0% S</td></tr>
<tr><td>2012.01.01</td><td rowspan="2">〈 3.5% S</td></tr>
<tr><td>2015.01.01</td><td rowspan="2">〈 0.1% S</td></tr>
<tr><td>2020.01.01</td><td>〈 0.5% S</td></tr>
</table>

(Tab.1 Comparison of Sulphur limitation)

*SECA : SOx Emission Control Area (Baltic Sea, English Channel and North Sea, Eastern China Sea)

**CARB : California Air Resources Board (24 Nautical Miles from California)

Definitions

The following terms are used in this document as below table.

TERM	Description	Sulphur content (% m/m)
MGO	Light Fuel Oil	〈 0.1
MDO	Light Fuel Oil	0.1〈S〈2.0
LSHFO	Low Sulphur Heavy Fuel Oil	〈 1.5
HFO	Heavy Fuel Oil	〉 1.5
LSFO	Low Sulphur Fuel Oil	〈 0.5

(Tab.2)

Check Points for operation with Low Sulphur Fuel

Except some Offshore vessels, HiMSEN engines for Marine(Gen-set, Propulsion) are optimized to operate with HFO in consideration of the economic engine operation.

Therefore, following points should be taken into consideration in order to operate HiMSEN engine properly with Low Sulphur Fuel which shows different characteristics as Fuel oil.

1. Viscosity of Fuel

- Minimum viscosity at 40℃ to be 2 cSt for ISO8217(2017) Category ISO-F-DMA & DMB but recommend stable viscosity Engine inlet to be 3cSt at 40℃,or above.
- Low viscosity of Fuel may result in Fuel Pump leakage, if 'Sealing oil' is not applied.

2. Lubricity of Fuel

- The poor lubricity of Low Sulphur fuel is not been considered as a problem for fuel injection components as long as the Sulphur content is above 100 ppm.
  However, poor lubricity of Low Sulphur fuel may result in rapid wear down of Cylinder head Intake valve spindle & seat ring and seizing of plunger&barrel of F.O injection pump if optimized solution is not applied.

3. Selection of Lubricating oil based on Sulphur contents

- Lubricating oil should be selected properly based on Sulphur contents and SLOC.
- Recommend BN value, when using Low Sulphur Fuel less than 0.5% to be between 10 and 20 according to instruction manual.

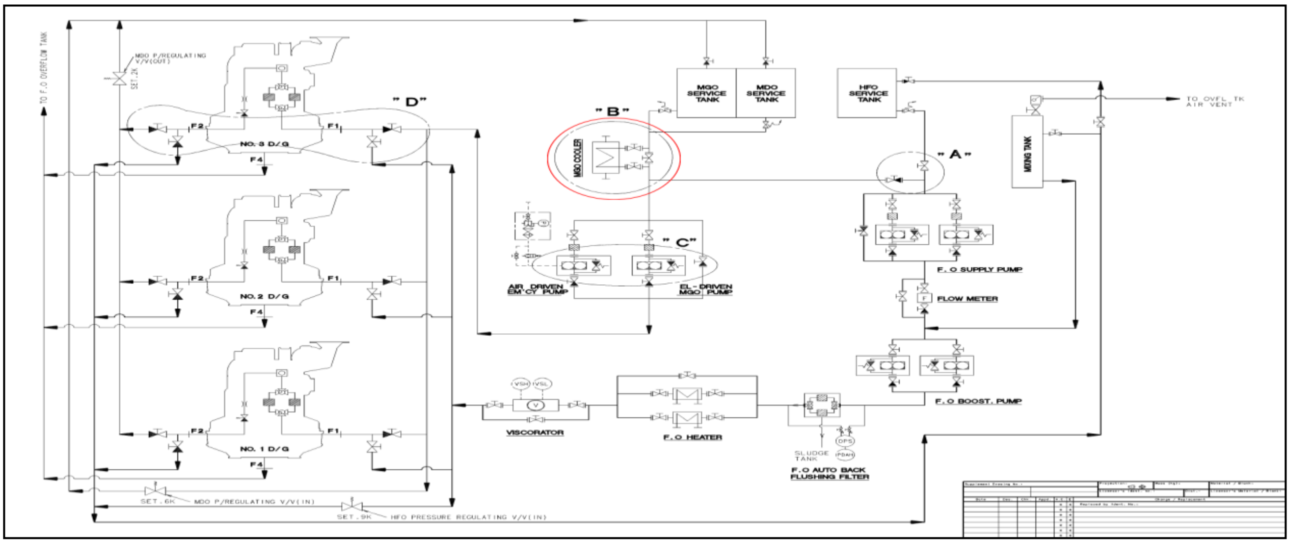
4. Catalyst fines in fuel oil

- In order to meet the increasing demands resulted from IMO sulfur cap 2020, the oil companies are willing to produce Low Sulphur fuel oil from residual fuel oil through additional desulfurization process, which makes aluminum and/or silicon as a by-product of fuel catalytic cracking process. For that reason, proper fuel oil treatment system such as fuel oil purifier, FO auto back flushing filter and etc. should be operated in order to reduce content of Cat Fines to maximum 15mg/kg before engine inlet.

Recommended solution for safe operation of HiMSEN with Low Sulphur fuel

1. Cooler or Chiller unit for MGO/MDO operation.

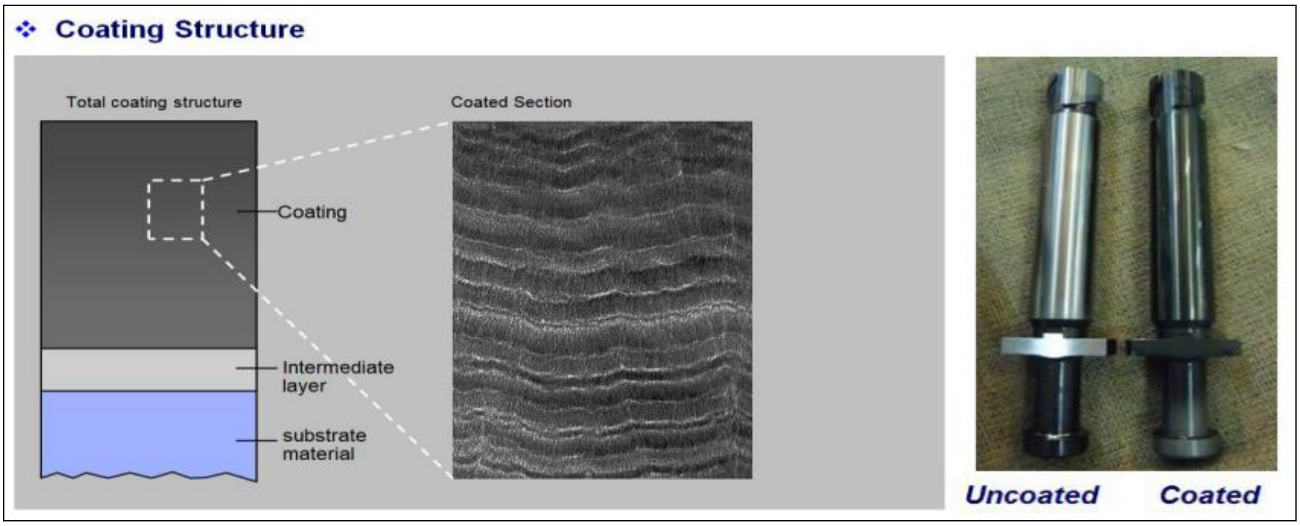
- It is important to keep viscosity of fuel at engine inlet within recommended range.
- In case of using MGO/MDO, Cooler or Chiller unit may be needed to keep viscosity of fuel at engine inlet (Minimum 2cSt).



(Fig.2 Example piping for installation of MGO Cooler)

2. Coated Plunger & Barrel for F.O injection pump

- Coated plunger & Barrel for F.O injection pump has been developed to achieve improved lubrication performance for Low Sulphur fuel.



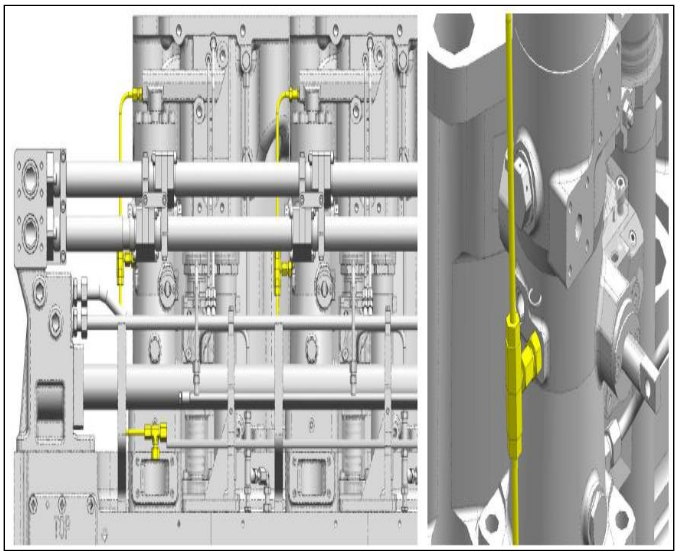
(Fig.3 Coated Plunger)

3. Sealing Oil to F.O injection pump

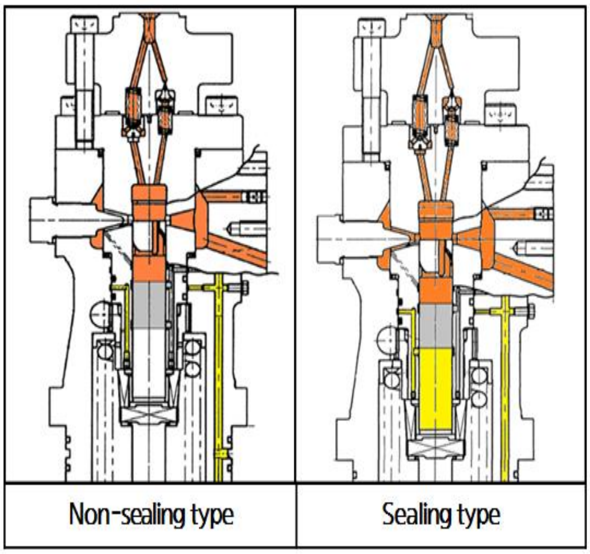
- Sealing Oil system is recommended when using low viscosity fuel such as MGO/MDO

※ Sealing oil for H17/28 and H32/40 is supplied via external pipes as shown Fig.4, therefore it is required to install external sealing oil feed pipe to F.O injection pump.

※ Sealing oil for H21/32 and H25/33 is supplied via the channel in F.O injection pump body as shown Fig.5, therefore it is required to replace F.O injection pump complete with Sealing type to apply Sealing Oil system.



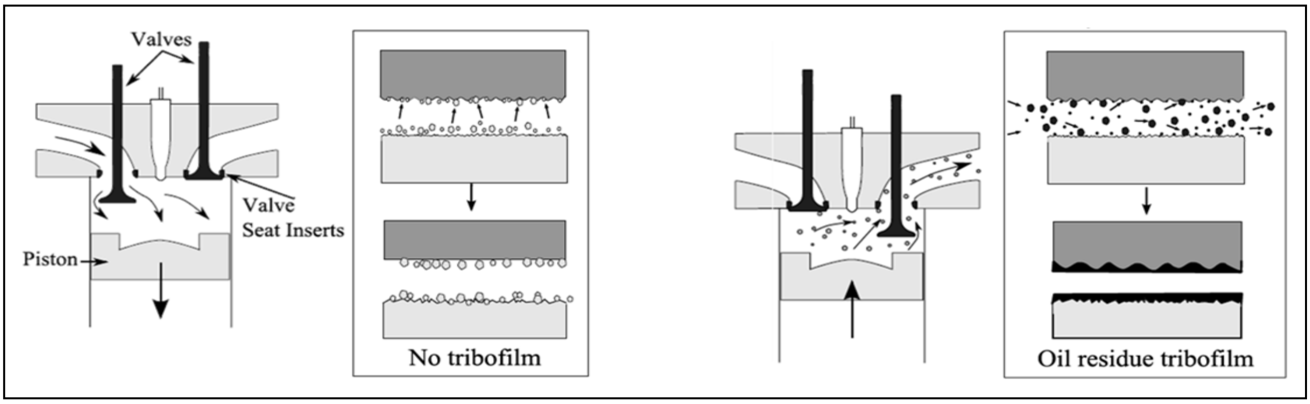
(Fig.4)



(Fig.5)

4. Tribaloy Intake valve seat ring

- Tribaloy welded Intake seat ring is effective to prevent excessive wear down of Intake Valve of Cylinder head when using the fuel having sulphur contents less than 0.1% m/m



(Fig.6 Effect of Tribaloy weld)

5. Switch over Nozzle cooling system

- When using Light fuel oil, it is recommended to block the flow of cooling media to Fuel injection valve since cooling media will affect the viscosity of fuel. Therefore Nozzle cooling system should be switched over properly based on fuel specification.

6. Solution for each case

- The solutions for each case of engine operation with the fuel are listed in below table.

ITEM	Case	H17/28	H21/32	H25/33	H32/40(V)
Nozzle cooling system	MGO	□	□	□	□
	MDO	□	□	□	□
	LSHFO	▣	▣	▣	▣
	HFO	■	■	■	■
Coated Plunger & Barrel	MGO	■	■	■	■
	MDO	■	■	■	■
	LSHFO	■	■	■	■
	HFO	▣	▣	▣	▣
F.O Pump Sealing Oil	MGO	■	■	■	■
	MDO	■	■	■	■
	LSHFO	▣	▣	▣	▣
	HFO	□	□	□	□
Tribaloy Intake Seat ring	MGO	■	■	■	■
	MDO	□	□	□	□
	LSHFO	□	□	□	□
	HFO	□	□	□	□

[Tab.3]

■ : Standard , □ : Non-Standard , ▣ : To be considered based on the specification of Fuel

※Note : Due to the variety of LSHFO specifications in the market, application of some solutions should be considered after reviewing actual specification of LSHFO.

Conclusion

The contents in this document are general recommendation for HiMSEN Engine operating with Low Sulphur fuel in order to comply with IMO SOx regulation.
Therefore the optimized solution for your good vessel may be different and we can provide the optimized solution after reviewing specific information of your vessel.

Should you have any further question, please feel free to contact the nearest HGS service station.

We hope this information will be helpful to you.

Enclosure

- Technical Information Doc No. : K24110/KCM/0102
- TEC2015_K2D0_003 : Suitability of Hybrid Fuel Oils on HiMSEN engine

G. Y. Oh, General Manager

Machinery Service Dep't

Technical Division

http://www.hyundai-gs.com/

[EOD]

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

1. General

The regulations such as EU Directive 2005-33-EC and California Code of Regulations that came into force on 01/Jan/2010 restrict sulfur content in fuel oil below 0.1% mass by using MGO (Marine Gas Oil, DMA as defined in ISO 8217) to reduce SOx emissions.

According to these latest rules and regulations, the concerned systems and cares are needed properly by customers in order to meet the environmental demand during the operation of genset with MGO (below 0.1% sulfur) in specific areas.

	EU Directive 2005-33-EC	California Code of Regulations	
Effective date	1 January 2010	1 July 2009	1 January 2012
Sulphur contents	Max 0.1% m/m	MGO: Max 1.5% m/m MDO: Max 0.5% m/m	Max 0.1% m/m
Target area	Berths in EU ports	Regulated California Waters	
Target ship	Ships at berth in EU ports for two hours or more (*)	LOA: more than 400 feet; or GT: more than 10000; or Volume of one cylinder: more than 30 liter	
Target fuel oil	FO which is used during at berth	FO which is used for Main diesel engine, aux. diesel engine and aux. boiler	
Target equipment (Example)	G/E Boiler for COPT etc.	M/E, G/E Aux.boiler	

(*): The requirement shall not apply to ships which switch off all engines and use shore-side electricity at berth in ports.

2. Effect of low sulfur MGO using on HiMSEN engine

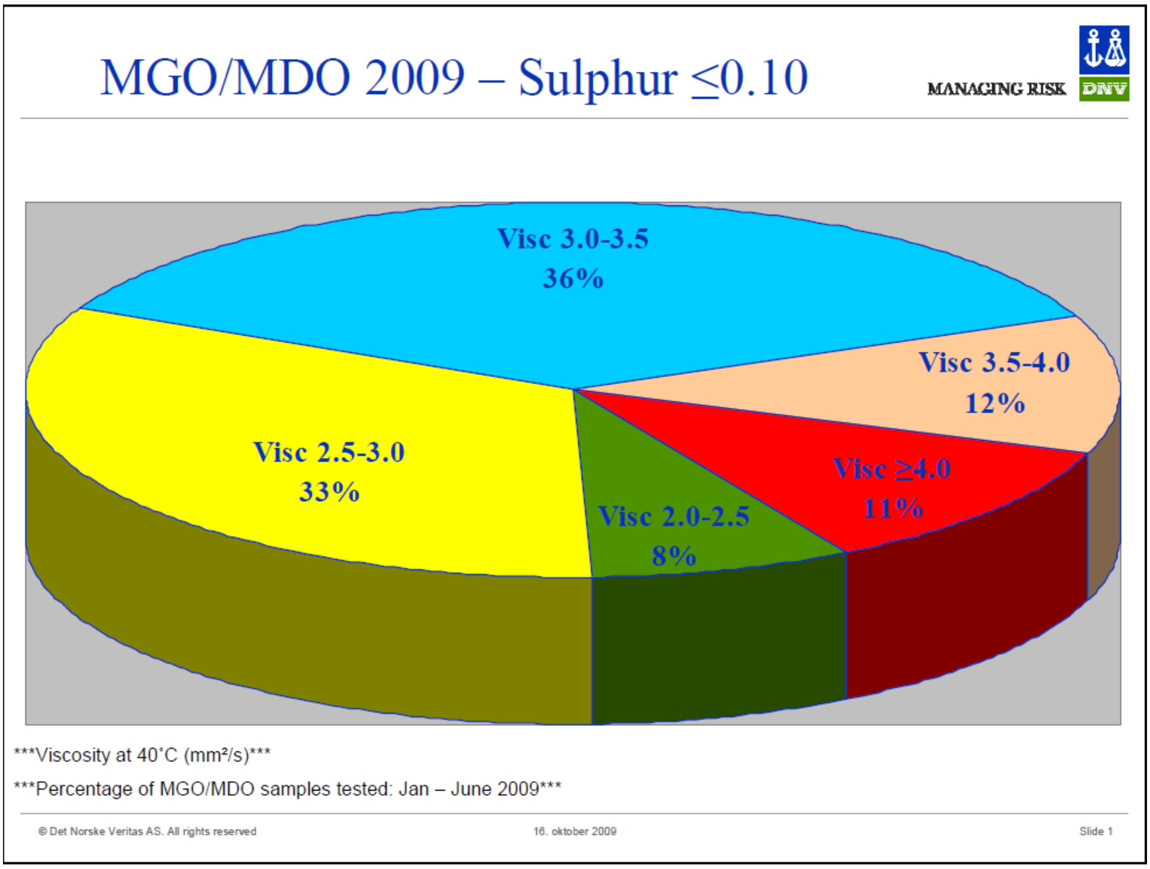
1) The minimum viscosity at 40℃ as per ISO 8217 is 1.5 cSt for MGO. In case of too low viscosity (below 2 cSt), it may occur the damage to the fuel injection pump such as sticking. Please find the specification for Marine Distillate Fuels (Figure 1) and viscosity ranges of 1.5 - 6cSt @40 ºC based on DNV document (Figure 2) as defined in ISO 8217 as below.

- To be continued -

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

Charateristic	Unit	Limit	DMX	DMA (MGO)	DMB	DMC
Density at 15°C	kg/m³	max.	-	890.0	900.0	920.0
Viscosity at 40°C	mm²/s	min.	1.40	1.50	-	-
Viscosity at 40°C	mm²/s	max.	5.50	6.00	11.0	14.0
Flash point	°C	min.	-	60	60	60
Sulphur	%(m/m)	max.	1.00	1.50	2.00	2.00

< Figure 1 >



< Figure 2 >

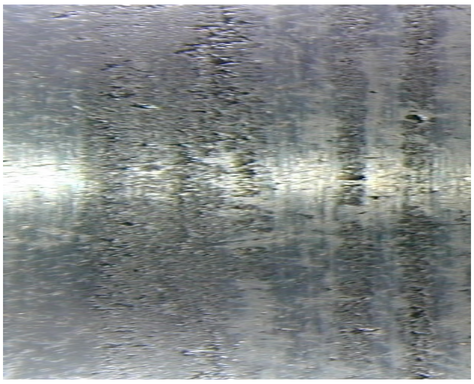
- To be continued -

☎ 052-202-7274, FAX.: 052-202-7696

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

2) The more drain fuel oil amount from fuel oil injection pump and fuel oil injection valve can be expected compared to operation on HFO.
3) Although the sulfur content of fuel oil has a lubricating effect, poor lubricity of low sulfur MGO has not been considered as a problem for fuel injection components as long as the sulfur content is above 100 ppm (=0.01 % m/m) For your reference, we are scheduled to introduce lubricity limit in HiMSEN engine fuel oil, especially MGO, specification (Max. between 460 and 520 µm, Preliminary value) after introducing in the international specifications.
4) It is important that proper balance is maintained between the BN coming from the lube oil and the fuel sulfur level by choosing proper lube oil in order to avoid following problems.

- High sulfur fuel + Low BN lube oil
  → Excessive corrosive wear



- Low sulfur fuel + High BN lube oil
  → Excessive top land deposit formation

- To be continued -

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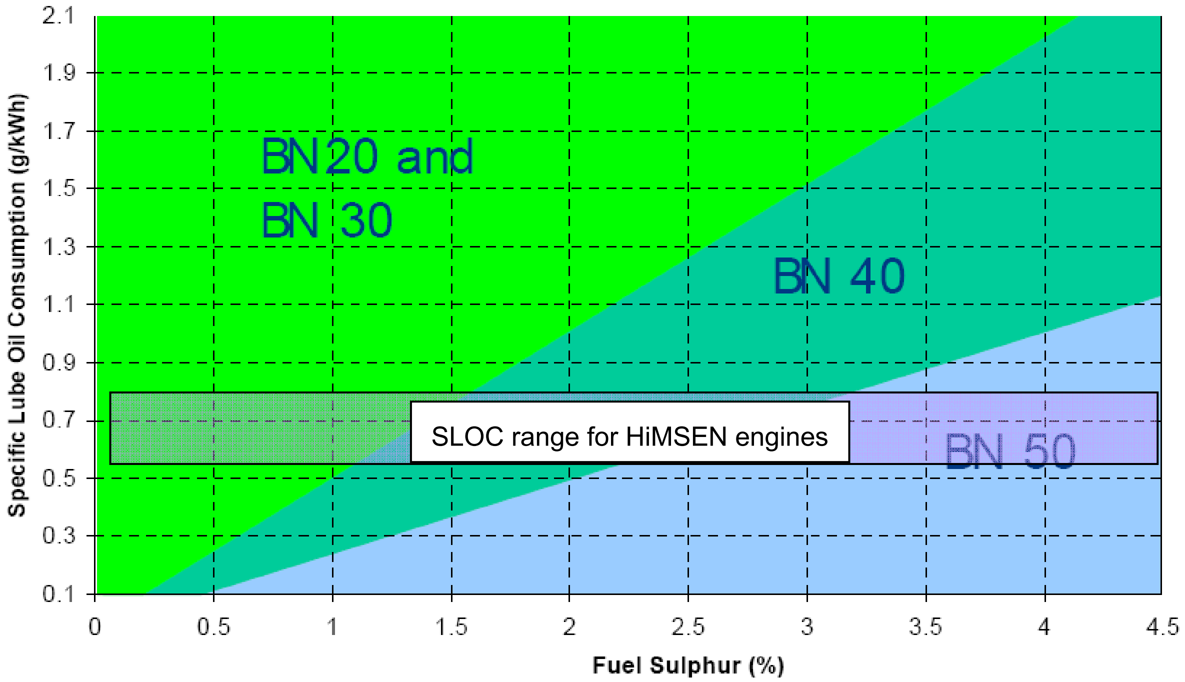
SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

3. HiMSEN guideline for lube oil using low sulfur MGO

1) Typical recommended BN depending on the fuel sulfur contents and SLOC (g/kWh)



Reference: CIMAC recommendation number 29/2008 'Guide lines for the lubrication of medium speed diesel engine'

2) When the MGO is to be used only for temporary engine operation (e.g. in port), higher BN lube oil used for residual fuel (HFO) should not present any problems. The acceptable period of temporary operation is less than 200 hours. When engine is not operated continuously with low sulfur fuel, lube oil should be chosen according to the highest sulfur contents of the fuel with normal operation. However, in case of continuous operation on low sulfur fuel such as MGO, it is necessary to use proper L.O based on sulfur content of low sulfur fuel as per the L.O list for HiMSEN engine described on the instruction manual in order to avoid excessive deposits in the combustion chamber, exhaust gas ways and turbocharger.

- To be continued -

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

4. HiMSEN guideline for fuel oil using low sulfur MGO

1) All HiMSEN engines are suitable and developed for continuous operation on HFO as well as MDO/MGO as per the F.O specification for HiMSEN engine described on the instruction manual in detail.

There is no lower limit for the sulfur content of fuel oil. In connection to the low viscosity of MGO, (Marine Gas Oil, DMA as defined in ISO 8217) the viscosity at engine inlet should be kept within the value of 2 ~ 14 cSt in order to avoid possible wear or sticking of fuel injection pump due to low lubricity and in order to maintain the suitable hydrodynamic film between fuel injection pump plunger and barrel.

- Recommended stable viscosity at engine inlet: Min. 3 cSt
- Recommended minimum viscosity at engine inlet: Min. 2 cSt

So, we recommend installing a MGO cooling device (MGO cooler or chiller etc.) to keep the above mentioned viscosity (2 ~ 14 cSt) at engine inlet under shipyard's scope of supply, if needed. For shipyard's designing of MGO cooling device, it is about the maximum 10℃ for the temperature deviation (△T) between engine inlet and outlet when using MGO (Marine Gas Oil, DMA as defined in ISO 8217). For your reference, it should be maintained about 22℃ of MGO temperature to obtain viscosity of 2 cSt at engine inlet in case of MGO with 1.5 cSt at 40℃.

2) Considering the more drain fuel oil amount from fuel oil injection pump and fuel oil injection valve compared to operation on HFO, separate drain lines, ie, clean oil drain to FO overflow tank and waste oil drain to FO sludge tank, will be prepared and introduced for new contracted vessels.

- To be continued -

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SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

5. Recommendations for low sulfur MGO operation

1) MGO operation through HFO system

a) A proper cooling device to be provided to meet the minimum viscosity of 2 cSt at engine inlet, if necessary.

[Notice]

In case of MGO operation through HFO system, it is recommended to install the cooling device after FO booster pump to keep a suitable viscosity range.

b) The type of the external pumps to supply low viscosity fuel without loss to be considered. Generally, screw pumps instead of gear ones would be preferable.

c) A smooth and careful change-over from HFO to MGO and vice versa is to be done as follows to protect the fuel injection equipments against rapid temperature changes during the change-over from residual fuel to distillate fuel and vice versa (refer to “A” on the attached).

[Change-over from MGO to HFO]

- Maintain HFO level with 50~90% and HFO temp. with 60~90 ℃ in HFO service tank.
- Maintain the engine load with 30~70 %.
- Open the steam tracing and auto filter steam inlet valve in F.O system.
- Open the steam in/out valve in F.O heater.
- Rise F.O temperature gradually until 60 ℃ at a rate of about 2 ℃ per minute through opening steam control valve in viscosity controller.

  ⚠ WARNING ***Maintain the F.O viscosity over 4 cSt because F.O viscosity is the first priority than temperature. And maintain the cylinder outlet cooling water temperature with 75~85 ℃.***

- To be continued -

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

- When the MGO temperature at engine inlet reaches 50~60 ℃, change-over from MGO to HFO using HFO/MGO change-over valve.
- When the HFO temperature at engine inlet reaches 70 ℃, viscosity controller is set with auto-mode.
- When the change between viscosity and temperature to be observed, viscosity is set 12~18 cSt on viscosity controller.

[Change-over from HFO to MGO]

- Reduce the engine load below 50 %.
- Close the steam in/out valve slowly in F.O heater until 25 cSt viscosity in viscosity controller to protect the F.O injection equipment against rapid temperature changes.
- Close the steam tracing and auto filter steam inlet valve in F.O system.
- Change-over from HFO to MGO using HFO/MGO change-over valve.
- Confirm that MGO viscosity is about 2~3 cSt when the MGO temperature is about 40 ℃.

  ⚠ WARNING ***Although MGO viscosity range at engine F.O inlet is limited 2 ~ 14 cSt in the instruction manual, MGO viscosity should not drop 3 cSt for safety as this might cause fuel injection pump and fuel injection valve sticking/scuffing.***

2) MGO operation through MDO/MGO system

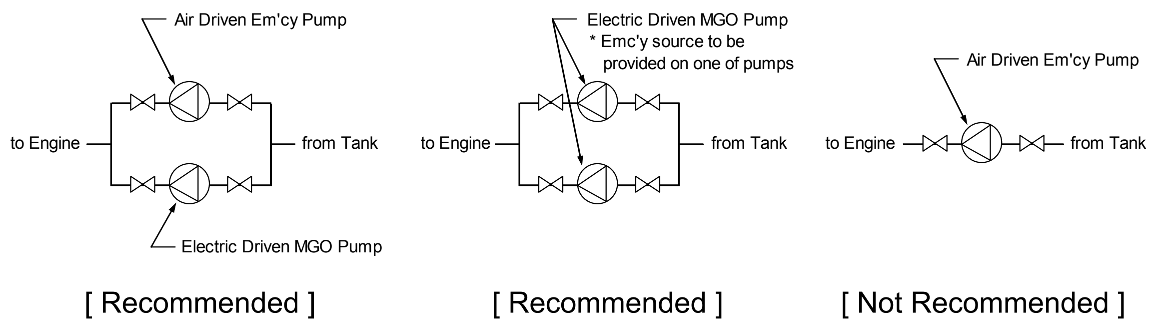
If it is difficult to follow the above recommendation a) caused by uncertain condition such as incompatibility between HFO and MGO or unsuitable control during change-over, MGO operation through MDO/MGO system can be done under the below recommendations.

a) A proper cooling device to be provided to meet the minimum viscosity of 2 cSt at engine inlet, if necessary (refer to “B” on the attached).

- To be continued -

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

b) Electric motor driven MGO pump(s) having all engine's capacities is needed (refer to the below and "C" on the attached).



[Notice]
An air motor driven pump, if provided by HHI-EMD, is only for emergency purpose such as black-out starting and not recommended to use for MGO operation to avoid any risks of low pressure and shut-down of the engine caused by lack of air source from the tank to air motor pump.

c) A smooth and careful change-over from HFO to MGO and vice versa is to be done as follows, but the actual procedure could be little different for individual project depending on ship's system (refer to "D" on the attached).

[Change-over from MGO to HFO]

- Open HFO outlet valve, close MGO outlet valve and open HFO inlet valve of stand-by G/E.
- After changing MGO to HFO of stand-by G/E, Circulate HFO until viscosity maintains about 12～18 cSt or a suitable temperature level according to the used fuel oil on-board.
- Start stand-by G/E and stop running G/E.
- Fuel change of stopped G/E to be carried out same as 1st and 2nd step above.
- Stop G/E MDO flushing pump when fuel change is completed.

- To be continued -

SUBJECT: HiMSEN guideline - Fuel oil control by EU Directive 2005-33-EC and California Code of Regulations

[Change-over from HFO to MGO]

- Open G/E & Boiler MGO cooler inlet/outlet valves and close MGO cooler by-pass valve.
- Start G/E MDO flushing pump.
- Close HFO inlet valve of stand-by G/E and wait for a while (about 3~5 minutes) to flush HFO by MGO.
- Open MGO outlet valve and close HFO outlet valve of stand-by G/E, then circulate MGO until fuel temperature reaches around 35℃.
- Start stand-by G/E and stop running G/E.
- Open the HFO Service tank inlet valve or L.S HFO Service tank inlet valve from G/E F.O return line for flushing stopped G/E by properly throttling valve handle.
- Fuel change of stopped G/E to be carried out same as 3rd and 4th step above.
- Close the HFO Service tank inlet valve or L.S HFO Service tank inlet from G/E F.O. return line.

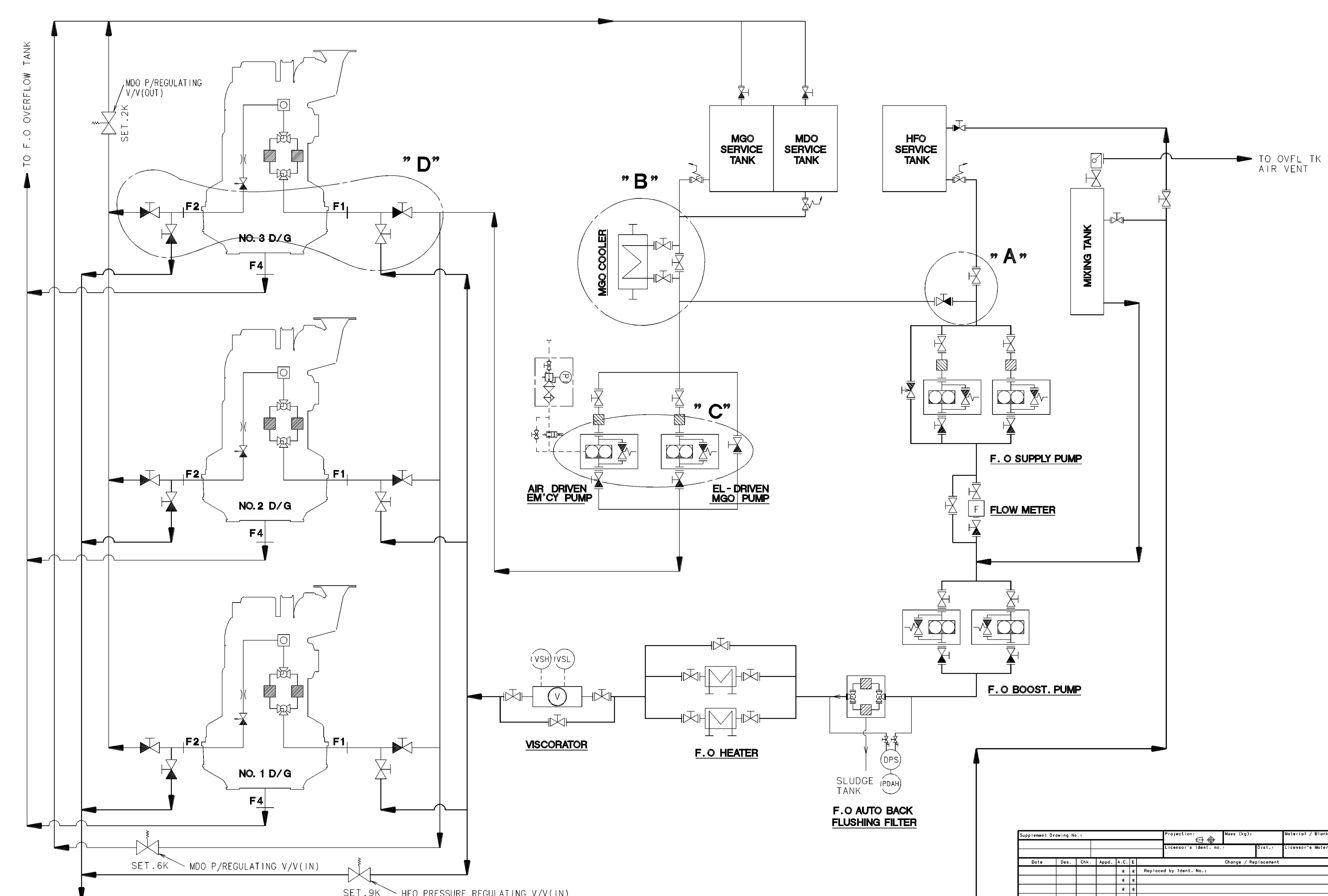
  [Notice]

  The change-over, whether it is handled at locally or remotely, is to be done to stand-by engine, not to running engine, with a certain time delay aforementioned.

6. Guidance for external fuel oil system

   The external fuel oil system attached is typical for guidance, and the actual arrangement for individual project is designed by shipyard's practice and engine manufacturer's recommendation.

Attached #1 : Fuel oil system for guidance only (B91-052974-8) [The end]



Standard for surface roughness

The basic symbols and class numbers are in accordance with ISO 1302-1978.

Class No.	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11	N12
R_a max. value µm	0,025	0,05	0,1	0,2	0,4	0,8	1,6	3,2	6,3	12,5	25	50

Tolerances for dimensions without tolerance indication(ISO 2768-1989)

This standard states the permissible devations for dimensions without direct tolerance indications on metallic components manufactured by machining

Nom.measurement mm / Permissible deviations	0,5 up to 6	over 6 up to 30	over 30 up to 120	over 120 up to 315	over 315 up to 1000	over 1000 up to 2000
Medium series	±0,1	±0,2	±0,3	±0,5	±0,8	±1,2

Date	Des.	Chk.	Appd.	A.C.	E	Change / Replacement	C.No
				*	*	Replaced by Ident. No.:	9
				*	*		8
				*	*		7
				*	*		6
				*	*		5
				*	*		4
				*	*		3
				*	*		2
				*	*		1
100209	JJO	JJO	KSR	*	*		0

Supplement Drawing No.:
Projection:
Mass (kg):
Material / Blank:
Licensor's Ident. no.:
Dist.:
Licensor's Material / Blank:
Similar Drawing No.:
Replacement of Ident. No.:
Scale: 1:1
Size: A1
Type: -
Page No.: 01 (01)
HYUNDAI HEAVY INDUSTRIES CO., LTD.
Info. No.: -
Description: FUEL OIL SYSTEM
Ident. No.: B91-052974-8

CAD Drawing - do not correct by hand

HSEF-k210-010(R1)
현대중공업(주) 엔진사업본부
A1(841mmx594mm)트레싱지

TECHNICAL CIRCULAR

Suitability of Hybrid Fuel Oils (ULSFO) on HiMSEN engines

ENGINE TYPE: H17/28, H21/32, H25/33(V) and H32/40(V)

Ref. No.: TEC2015/K2D0 - 003
Date: 8th June, 2015

[BACKGROUND]

In accordance with revised MARPOL Annex VI regulations, the sulfur content limit for bunker fuels used in emission control areas for SOx (ECA-SOx) is max. 0.10% m/m from 1 January 2015.
In response, several fuel suppliers have released new hybrid fuel products containing a maximum of 0.10% m/m sulfur as an alternative to using distillates in order to meet the MARPOL Annex VI requirements as below tables.

Characteristics	Unit	Limit	HDME 50 (EXXONMOBIL)	Fuel Oil (Chemoil)	DMB (Chemoil)	Fuel Oil (Chemoil)2	ULSFO (Shell)	SK ULSFO (SK Energy)	BP 0.1 RMD (BP)	Eco Marine Fuel (Lukoil)
Kinematic viscosity at 50 °C	mm2/s	min/max	25 to 45	16.84	10.5	26.3	10-60	30~40	6-13	65
Density at 15 °C	kg/m3	max	895 to 915	0.8589	0.885	0.896	790-910	0.928	850-890	0.91
Cetane index	—	min			40				—	
CCAI	—		795 to 810			795	800	790~800	760-820	860
Sulphur	mass %	max	0.1	0.084	0.085	<0.1	<0.1	<0.1	0.10	0.095
Flash point	°C	min	70	>60	70	>60	>60	70	60	60
Hydrogen sulfide	mg/kg	max	1		0.1		<2		2	2
Acid number	mg KOH/g	max	0.1		0.1	2.35	<0.5		2.5	2.5
Total sediment existent	mass %	max	0.01	0.01	0.05	0	0.01-0.05	0.02	—	
Total sediment aged	mass %	max	0.01	0.01		0.01	0.01-0.05	0.02	0.07	0.1
Oxidation stability	g/m3	max	0.01						—	
Carbon residue: micro method	mass %	max	0.3	<0.10	0.1	3.8	2	6	4	14
Cloud point	°C	max	—							
Pour point (upper) W	°C	max	9 to 15	-20	-4	-6	18	20~25	+27	20
S	°C	max	9 to 15							
Appearance	—	—	brown/ green - opaque	Not Clear and bright	ɔt Clear and brig	Not Clear and bright		Black	—	
Water	volume %	max	0.05		0.05		0.05	0.2	0.3	0.1
Ash	mass %	max	0.01	0.003	0.005	0.06	0.01	0.05	0.04	0.07
Lubricity, (wsd 1,4) at 60 °C	µm	max	320		310				—	
Vanadium	mg/kg	max	1			<1	2	0.7	50	2
Sodium	mg/kg	max	1	4		1	10	2	50	2
Al & Si	mg/kg	max	3	<3		<10	12-20	10~20	25	17
Calcium	mg/kg	max	1	13		175	free of ULO	5		free of ULO
Phosphorus				7		<1	free of ULO			free of ULO
Zinc	mg/kg	max	1	2		<1	free of ULO	1		free of ULO
Calc. Gross Specific Energy	mg/kg								45.2	

[Suitability of Hybrid Fuel Oils (ULSFO) on HiMSEN engines]

1. HDME50 (EXXONMOBIL)
   A. HDME50 fuel is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

2. Fuel Oil (Chemoil)
   A. Fuel Oil (Chemoil) is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

C. Vanadium content should be checked to confirm the possibility of high temperature corrosion. It is essential to ensure the vanadium content should be maintained below the limit as mentioned page 5/5 of attachment as residual fuel oil. If vanadium content exceeds the limit, it will cause high temperature corrosion on the inner surface of exhaust valve or turbocharger.

3. DMB (Chemoil)
   A. DMB (Chemoil) fuel is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.
   C. Vanadium content should be checked to confirm the possibility of high temperature corrosion. It is essential to ensure the vanadium content should be maintained below the limit as mentioned page 5/5 of attachment as residual fuel oil. If vanadium content exceeds the limit, it will cause high temperature corrosion on the inner surface of exhaust valve or turbocharger.
   D. Sodium contents should be checked to confirm the possibility of high temperature corrosion or deposition. Sodium contributes to high temperature corrosion on the exhaust valves when combined with high sulfur and vanadium. If the sodium is lower than 1/3 of the vanadium content the risk of high-temperature corrosion will be small. If the sodium content is higher than 100 mg/kg, an increase of salt deposits is to be expected in the combustion space and in the exhaust system. This condition will have an adverse effect on engine operation.
   E. Al + Si (Catalyst fines) will damage fuel injection system. The fines are particles of spent aluminum and silicon catalyst that arise from the catalytic cracking process in the refinery. If not reduced by suitable treatment, the abrasive nature of these fines will damage the engine, particularly fuel pumps, injectors, piston ring and liners.

4. Fuel Oil (Chemoil) 2
   A. Fuel Oil (Chemoil) 2 is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

5. ULSFO (Shell)
   A. ULSFO (Shell) is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

6. SK ULSFO (SK Energy)
   A. SK ULSFO (SK Energy) is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

7. BP 0.1 RMD (BP)
   A. BP 0.1 RMD (BP) is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

8. Eco Marine Fuel (Lukoil)
   A. Eco Marine Fuel (Lukoil) is suitable as residual fuel oil on all HiMSEN engines.
   B. Low BN lube oil for low sulfur fuel oil should be chosen to avoid any sediment in the lubricant which could cause scuffing or deposition on exhaust valve, piston or liner.

Attachment: HiMSEN engine fuel oil specification (G05100-1G) -------------------------------- 5 sheets

Yours sincerely,

Y. S. Ryoo

Y.S. Ryoo / General Manager
HiMSEN Engineering Department 2

1. 일반사항

엔진은 최고 700cSt at 50℃의 점도를 가진 잔사유(HFO/MDO)로 운전 가능하다. 이 값은 ISO8217(2012)에 따라 RMK700의 등급에 해당된다. 이 엔진은 저 점도의 혼합 연료뿐만 아니라 정제유(MDO/MGO)로도 운전 가능하다.

요구되는 정제유 (MDO/MGO)의 품질은 ISO8217 (2012) 내에 ISO-F-DMA, DMZ 그리고 DMB 등급에 따르고 있다.

연료는 아래와 같이 엔진에 공급되기 전 정제되고 예열되어야 한다.

2. 연료 처리 과정

1) 정제

잔사유(HFO/MDO)는 항상 고체 입자, 소금 및 물 등으로 오염되어 있기 때문에 원심분리기로 정제되어야 한다.

연료의 고체 오염물질은 피스톤 링과 실린더 라이너의 과도한 마모를 유발하거나, 연료 분사 펌프와 연료 분사 밸브의 고착을 일으킬 수 있다.

연료 내에서의 액체 오염 물질은 배기 시스템과 터보과급기 뿐만 아니라 연료 분사 펌프와 연료 분사 밸브의 부식 및 공동현상을 일으킬 수 있다.

그러므로 적합한 분리 장치가 외부 연료 시스템에 설치되어야 한다. 잔사유(MDO/HFO) 및 정제유(MGO/MDO)는 선상에서 쉽게 오염되기 때문이다.

연료의 원심분리는 원심분리기 메이커 메뉴얼에 따른다.

1. General

The engine can be operated on Residual fuel oil (HFO/MDO) of viscosity up to 700cSt at 50℃, which corresponds to the grades of ISO8217(2012). It can be also operated on blended fuels of lower viscosity as well as distillate fuel oil (MDO/MGO).

The quality requirements for MDO/MGO shall be in accordance with ISO-F-DMA, DMZ and DMB grade in ISO8217(2012).

The fuel should be cleaned and preheated before entering the engine as follows.

2. Fuel Treatment

1) Purification

Residual fuel oil should be purified by centrifuging because the fuel oils are always contaminated with solid particles, salt and water etc.

Solid contaminants in the fuel oils can cause excessive wear to the piston rings and cylinder liners or seizure of fuel injection pump and fuel valve.

Liquid contaminants in the fuel oils can cause fouling of exhaust systems and turbochargers as well as corrosion and cavitations of fuel injection pumps and fuel valves.

Therefore qualified separation equipment should be included in the external fuel oil system not only for HFO but also for MDO/MGO which is easily contaminated on board.

Fuel oil separation should be carried out accordance with separator maker's manual.

2) 가열

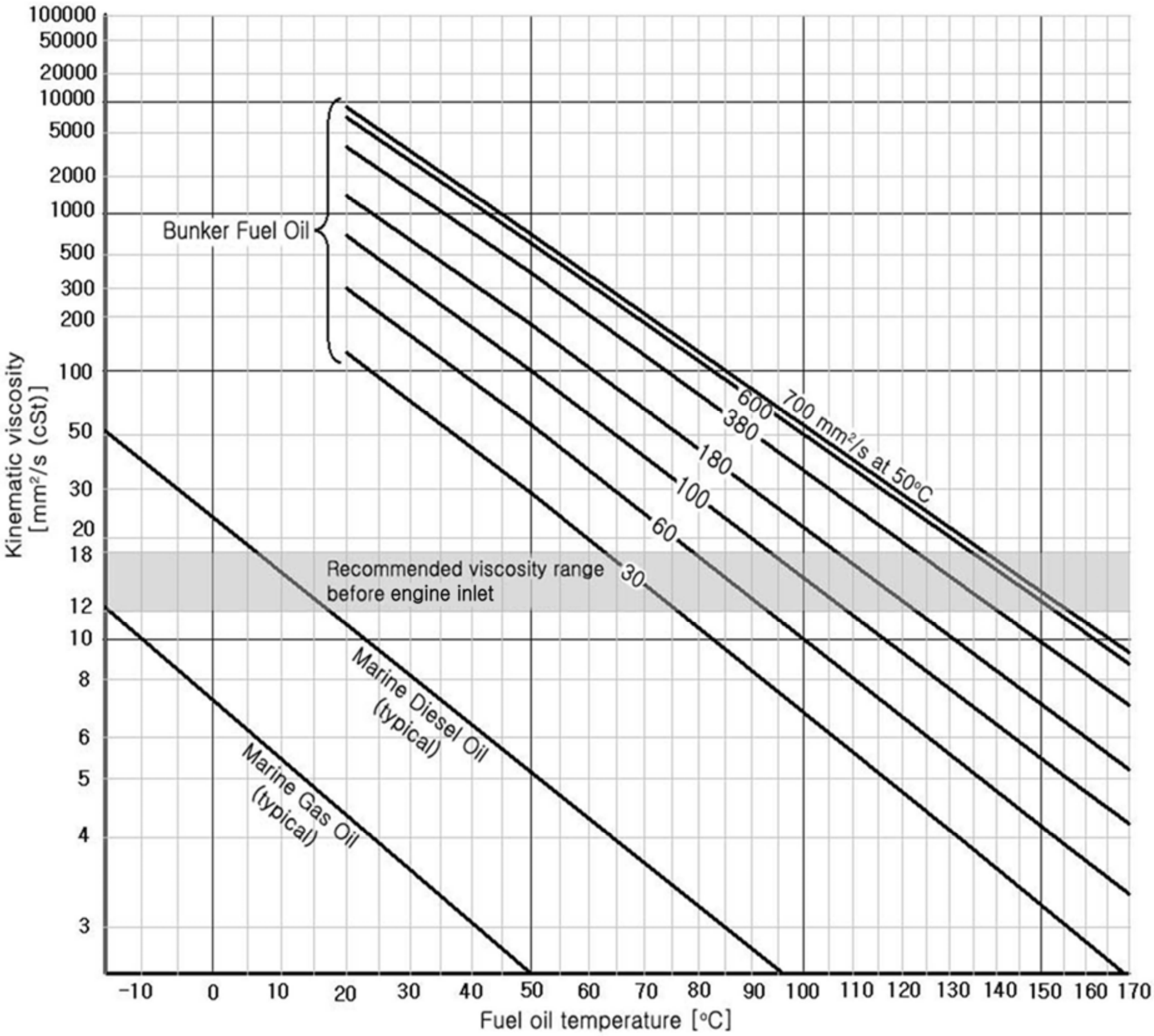
엔진으로 들어가는 RMB30 이상의 잔사유(HFO)는 12 ~ 18 cSt의 점도를 유지하고 있어야 한다. (단, 정제유 및 RMA10 잔사유(MDO/MGO)의 엔진 입구에서의 요구 점도:2~14 cSt) 그러나, 점도는 연료의 물성치 및 온도에 따라 변한다. 중유(HFO)의 최대 예열 온도는 155℃로 제한되어 있으며, 이는 연료 시스템에서 연료의 기포발생을 막기 위해서 이다. 따라서, 연료는 공급자의 권고대로 가열되어야 한다.

온도에 대한 연료의 대표적인 점도 선도가 아래에 나타나 있다.

2) Heating

The viscosity of residual fuel oil(HFO) between RMB30 and RMK700 to the engine should be kept within the value of 12 ~ 18 cSt. (Viscosity range at engine inlet for distillate fuel oil and RMA10 fuel oil(MDO/MGO) :2~ 14 cSt) However, the viscosity varies depending on the properties and the temperature of the fuel oil. Maximum preheating temperature of HFO is limited up to 155℃ to avoid vaporing in fuel system. Therefore, the fuel should be heated according to the suppliers' recommendation.

A typical fuel oil viscosity diagram regarding temperature is as follows.



3) 점도의 제어

12 ~ 18 cSt의 분사 점도를 유지하기 위해, 가열기는 연료가 엔진 연료 시스템에 들어가기 전에 자동 점도 조절기에 의해 제어되어야 한다.

경 고 *고 점도 또는 저 점도로 인해 연료분사 시스템에 심각한 손상을 초래할 수 있습니다.*

3) Viscosity Control

In order to ensure correct injection viscosity of 12 ~ 18 cSt, the heater are to be controlled by an automatic viscosity controller before the fuel enters into the engine fuel system.

WARNING ***Higher or lower viscosity may cause serious damages on fuel injection system.***

3. 표준 연료 특성치

엔진은 정격 출력의 감소 없이 다음과 같은 사양을 가진 연료로 연속 운전되도록 설계되었다.

3. Standard Fuel Oil Characteristics

The engine is designed to operate continuously on the fuels with the following specifications without reduction of the rated output,

Distillate Fuel Oil

Characteristics		Unit	Limit	Category ISO-F-		
				DMA	DMZ	DMB
Kinematic viscosity at 40 ℃[a]		mm^2/s	max.	6,000	6,000	11,00
			min.	2,000	3,000	2,000
Density at 15 ℃		kg/m^3	max.	890,0	890,0	900,0
Cetane index		-	min.	40	40	35
Sulfur[b]		mass %	max.	1,50	1,50	2,00
Flash point		℃	min.	60,0	60,0	60,0
Hydrogen sulfide		mg/kg	max.	2,00	2,00	2,00
Acid number		mg KOH/g	max.	0,5	0,5	0,5
Total sediment by hot filtration		mass %	max.	-	-	0,10[d]
Oxidation stability		g/m^3	max.	25	25	25[e]
Carbon residue: micro method on the 10% volume distillation residue		mass %	max.	0,30	0,30	-
Carbon residue: micro method		mass %	max.	-	-	0,30
Cloud point		℃	max.	-	-	-
Pour point (upper)[c]	winter quality	℃	max.	-6	-6	0
	summer quality	℃	max.	0	0	6
Appearance		-	-	Clear and bright[h]		[d,e,f]
Water		volume %	max.	-	-	0,30[d]
Ash		mass %	max.	0,010	0,010	0,010
Lubricity, corrected wear scar diameter (wsd 1,4) at 60 ℃[h]		㎛	max.	520	520	520[g]

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 of ISO8217(2012).

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

d 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 of ISO8217(2012).

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

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

g This requirement is applicable to fuels with a sulfur content below 500 mg/kg (0,050 mass %).

h If the sample is dyed and not transparent, then the water limit and test method as given in 7.6 of ISO8217(2012) shall apply.

Residual Fuel Oil

Characteristics		Unit	Limit	Category ISO-F-										
				RMA	RMB	RMD	RME	RMG				RMK		
				10[a]	30	80	180	180	380	500	700	380	500	700
Kinematic viscosity at 50 ℃[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
Density at 15 ℃		kg/m^3	max.	920,0	960,0	975,0	991,0	991,0				1010,0		
CCAI		—	max.	850	860	860	860	870				870		
Sulfur[c]		mass %	max.	Statutory requirements										
Flash point		℃	min.	60,0	60,0	60,0	60,0	60,0				60,0		
Hydrogen sulfide		mg/kg	max.	2,00	2,00	2,00	2,00	2,00				2,00		
Acid number[d]		mg KOH/g	max.	2,5	2,5	2,5	2,5	2,5				2,5		
Total sediment aged		mass %	max.	0,10	0,10	0,10	0,10	0,10				0,10		
Carbon residue: micro method		mass %	max.	2,50	10,00	14,00	15,00	18,00				20,00		
Pour point (upper)[e]	winter quality	℃	max.	0	0	30	30	30				30		
	summer quality	℃	max.	6	6	30	30	30				30		
Water		volume %	max.	0,30	0,50	0,50	0,50	0,50				0,50		
Ash		mass %	max.	0,040	0,070	0,070	0,070	0,100				0,150		
Vanadium		mg/kg	max.	50	150	150	150	350				450		
Sodium		mg/kg	max.	50	100	100	50	100				100		
Aluminium plus silicon		mg/kg	max.	25	40	40	50	60				60		
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										

[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 of ISO8217(2012).

[d] See Annex H of ISO8217(2012).

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

Note 1: The following kinds of fuel are not to be used:

1) Bunker fuel including cat-fines 2) Bunker fuel including land-used lubricating oil waste

3) Bunker fuel including acidic compounds (Acid Number ≥ 3 mg KOH/g)