YANMAR SERVICE NEWS

Subject	Arrangements for Yanmar Diesel Engines to Correspond to 2020 Low Sulfur Fuel Oil Regulation	Issue No. : 18-2-G-02-013-L Dated: 2019.02

Engine Model	All Diesel Engines	Use	Marine Main & Aux. Engines
		Engine Nos.	

1. Background

IMO (International Maritime Organization) regulates SOx emissions from marine vessels and mandates to use fuel oils of which sulfur content is below 0.1% in ECA (Emission Control Area) and below 3.5% in the global seas, (general waters).

Effective from Jan. 1, 2020, IMO will mandate the use of fuel oils of which sulfur content is below 0.5% for all marine vessels, irrespective of their date of building, operating in the global seas.

It is envisaged that each oil company will review their oil refining method to cope with the scheduled tightening of SOx regulation. At the current moment, they are examining the refining method for producing the applicable fuel oils to comply with that regulation. The information on the applicable fuel oils, including concrete fuel oil properties, etc., are not published yet.

However, according to the information we obtained domestically and abroad, we assume the applicable properties of low sulfur HFO are the kinematic viscosity of 2~180mm^2/s(cSt)@50°C and the pour point of max. 30°C.

2. Selection of Fuel Oil and Onboard Equipment

With the scheduled tightening of fuel oil regulation, marine fuel oils supplied hereafter can be classified as follows:

① For use in ECA , 0.1% low sulfur MDO and MGO
② 0.5% low sulfur MDO and MGO
③ 0.5% low sulfur HFO
④ Conventional high sulfur HFO (+Scrubber)

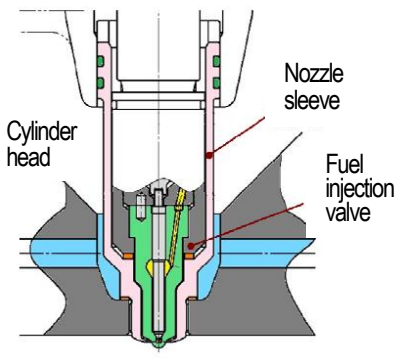
The specifications of diesel engines and other onboard equipment, that are suitable for operation on the fuel oils selected in consideration of the operations of your vessel, are classified into the patterns of (1) ~ (3) below. We recommend you examine which pattern be selected.

(1) Vessels Operated on 0.5% and 0.1% Low Sulfur MDO & MGO

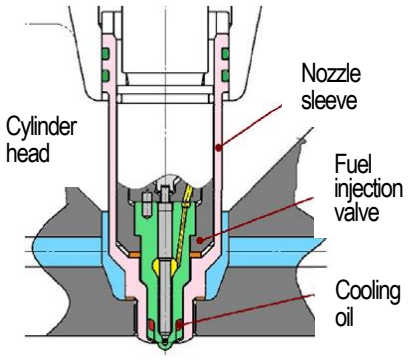
Newly built ships already introduce MDO specialized engines. The engines operated on HFO in operating ships, however, need to be modified to the MDO specialized engines. If or not the modification is required, and the modification engineering vary depending on the engine model and engine number. To know the details, please contact your Yanmar service contact.

1) Modification of FO injection valve from Cooling Type to Non-cooling Type

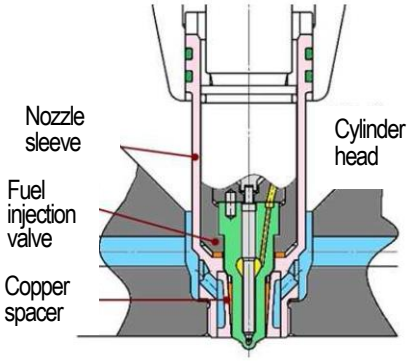
The structure of Yanmar FO injection valve is largely classified into Non-cooling Type, Direct Cooling Type and Indirect Cooling Type.



[Non-cooling Type]



[Direct Cooling Type]



[Indirect Cooling Type]

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Yanmar FO injection valves, in order to extend their service lives and control carbon deposits, come in 3 types for selective use on the MGO, MDO and HFO. If the cooling type FO injection valve for use on high temperature HFO was used for low load operation on normal temperature on MDO for long hours, sulfuric acid will condensate on the FO injection valve surface for causing low temperature corrosion. This in the worst case, can cause FO injection valve to be cracked and fuel oil to leak inside the cylinder for entailing in a serious trouble. When operating the HFO spec. engines on MDO constantly, the FO injection valves need to be changed to the non-cooling type structure excepting for the partial engine models.

[In the Case of Direct Cooling Type]
Change the FO valve nozzle to the non-cooling type or remove the cooling oil piping.
[In the Case of Indirect Cooling Type]
Change the FO valve nozzle and nozzle sleeve to the non-cooling type.
Extract and replace the nozzle sleeve according to the instructions of the operation manual.

Concerning N18, N21, N26 and N28 engine models, the nozzle sleeve screw diameter for installing the cylinder head, differs between MDO and HFO specifications. Although our Parts List requires the replacement as a cylinder head assembly, we have newly established a special nozzle sleeve for replacement. Leave the cylinder head as it is and replace only the nozzle sleeve, (Fig.1).

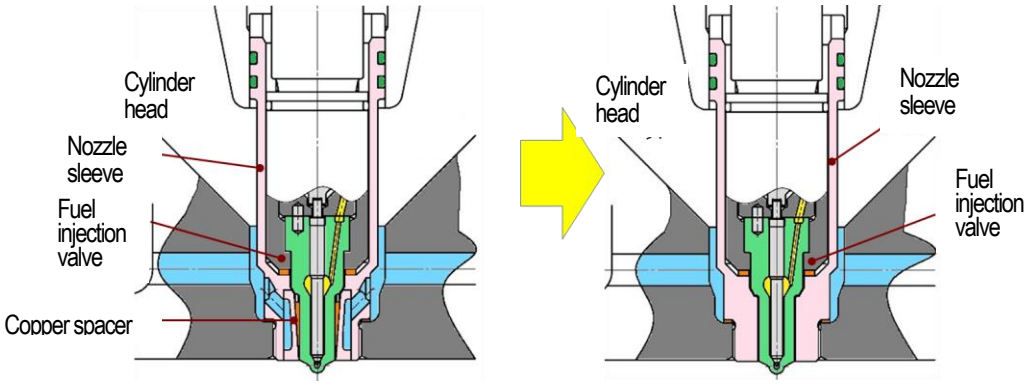

Fig.1 Replacement Nozzle Sleeve for Models N18, N21, N26 and N28

2) Change the FO injection pump plunger & barrel clearance to that of the MDO spec.
In several engine models, the plunger and barrel clearance differs between MDO and HFO specifications. In the HFO specifications, the clearance is wider than the standard in order to prevent seizure due to contaminants in fuel oil. When MDO with low kinematic viscosity is used under this condition, fuel oil leaks, (lower part leaks), will increase a little. There is no problem with the operation on MDO as it is, but fuel oil leaks can be reduced when modified to MDO specifications with narrower clearance. Accordingly, we recommend that you would change the existing plunger & barrel to those of the MDO specifications upon your next maintenance opportunity when you would operate the engine on MDO constantly. In addition, concerning the engines using the inline FO injection pump, depending on the engine model and the applicable fuel oil viscosity, plunger & barrel replacement is recommended.
3) Remove FO injection pump pinion lubrication pipe and plug the end.
With this modification, it is possible to curtail the pinion lubrication quantity, (approx.. 5~10 L/24 hrs.)
4) The other parts, (turbocharger, exhaust valve, FO pressure regulating valve, FO pump chamber heat insulation, FO pressure gauge seal pot, etc.) can be used as they are continuously. (Modifications required in 1) ~ 4) are listed in Table 1.)
5) Use lube oil of CD/CE Class, SAE30&40, total base number (BN) 9~15. Lube oil of SAE30 or 40 varies depending on engine model. Please check the use in the operation manual of the relevant engine model.
6) Basically, there is no need to heat the engine before starting. For better starting of the HFO direct start/stop engines, if possible, the jacket heating unit had better not be used, but use the mutual heating among engines only.
7) Concerning the ships already in operation, start and operate the engine as follows by the ship's fuel oil system:
A. For MDO Start/Stop Changeover System with Engine driven FO Feed Pump:
Operate the Engine driven FO Feed Pump for raising pressure of low sulfur MDO , (0.1% and 0.5% both), and switch the fuel on the pipe line before engine for operation.
B. For MDO Start/Stop Changeover System with MDO Electric Transfer Pump or Direct HFO Start/Stop System:
Operate the MDO electric transfer pump for raising pressure of low sulfur MDO, (0.1% and 0.5% both), and switch the FO supply at the electric pump inlet or supply 0.5% low sulfur MDO to the HFO line for operation with stopping the heater and viscosity controller. (Please contact the manufacturer to know if or not the electric transfer pump can be used when the FO viscosity dropped.)

8) Cautions for Using Existing Cooling Type FO Injection Valve of HFO Spec. Engines in Operating Ships:
There is no problem with the engine performance when the existing cooling type FO injection valve, not replacing with the non-cooling type FO injection valve, is used continuously. However, since the FO injection valve tip is cooled, low temperature corrosion can arise when the engine was operated at low/medium load range continuously. Accordingly, we recommend operating the engine at high load as far as possible, or curtail the servicing interval by about half for checking if or not corrosion appeared.

9) The use of lube oil of improper alkalinity value can cause lacquering. In this case, refer to Yanmar Service News, (No.97-2-E-12-047-L), for settling the problem.

10) When operating on low sulfur fuel oils, MDO,MGO , take care of the low kinematic viscosity:
Since MGO, being equivalent to DMA, the lowest kinematic viscosity may be as low as 1.5 mm^2/s (40°C). The kinematic viscosity, depending on the bunker area is considerably low. Extremely low kinematic viscosity can cause FO injection pump plunger & barrel seizure. Check the kinematic viscosity of fuel oil bunkered by the FO Property Table. Calculate the viscosity by the FO temperature of fuel oil for supply to the engine. Ensure that the viscosity is over 1.8 mm^2/s at engine inlet. If this is not possible, we recommend that you would install the FO cooling equipment, (FO cooler, chill cooler, etc.), in the MGO/MDO system. For the details of FO cooler selection, please refer to the section of [FO Cooler], described below.

(2) Vessels Operated on 0.5% low sulfur HFO, 0.1% or 0.5% low sulfur MDO and MGO

1) Concerning the onboard fuel oil system, the existing HFO system needs not be changed. Circulate low sulfur HFO, while controlling the FO temperature, in the HFO line. Supply 0.1% or 0.5% low sulfur MDO or MGO to the MDO line.

2) Concerning the low sulfur HFO assumed at the present moment, the kinematic viscosity is 2~180mm^2/s (50°C) and the pour point is max. 30°C.
In the case of using HFO, we recommend adjusting the kinematic viscosity by the automatic viscosity controller and the heater to be 11~14mm^2/s at the engine inlet. Keeping the kinematic viscosity at this level is instrumental in preventing the injection system parts from being damaged due to extreme injection pressure and keeping the fuel oil at high temperature is effective for ensuring satisfactory combustion and controlling accumulation of carbon deposits inside the cylinders. Since the kinematic viscosity of the scheduled regulation compliant fuel oils assumed is very low at min. 2 mm^2/s, it is very important that fuel oil temperature will not lower the pour point and that the FO valve will not be over-cooled. In view of these conditions, we have decided to review our recommendations on the fuel oils at our engine inlet as follows:

[A] For Using Fuel Oils with Kinematic Viscosity Over 30mm^2/s @50°C:
Adjust kinematic viscosity at engine inlet to 11~14 mm^2/s as has been done before.
[B] For Using Fuel Oils with Kinematic Viscosity Over 3~30 mm^2/s @50°C:
Adjust FO temperature within the range of 60~90°C. (We recommend 80°C.)

The relations between FO kinematic viscosity and temperature above are shown in Fig.2 below.
By adjusting fuel oil kinematic viscosity and temperature to fall within the range, shown in Fig.2 below, it is possible to comply with the operation on low sulfur HFO of which kinematic viscosity is over 3 mm^2/s (50°C) with no further modification of the engine. However, when using fuel oils of 3~15 mm^2/s (50°C), FO injection pump plunger needs to be coated since it can be seized depending on some engine models. (Applicable Engine Models: EY18, N18, N21, M200, M220 and other old engine models)
To know if or not your present FO supply system, including the FO heater, etc., can make the FO viscosity and temperature adjustment above, contact the relevant manufacturer.
If the adjustment is not possible and the fuel oil temperature lowers 60°C constantly, the engine needs to be modified to be the equivalent specifications to that of the MDO specialized engine.
Concerning the FO purifying equipment, we require to heat fuel oil to 98°C in general for pre-treatment of fuel oil. In the case of pre-treating low viscosity fuel oil, FO heating temperature needs be changed to comply with the kinematic viscosity recommended by the manufacturer. For details, please contact the relevant manufacturer.

3) Selection of Lube Oil for Use with Engines Operated on 0.5% Low Sulfur HFO:
As has been done before, select the lube oil of which alkalinity value is 9~15mgKOH/mg (BN) to comply with the sulfur content in fuel oil. However, since the properties of low sulfur HFO are not clear to us yet, we, in collaboration with lube oil makers, are now reviewing the alkalinity value and the brands we recommend. These are subject to change hereafter.

4) Switching between Low Sulfur HFO and MDO / MGO:

Concerning the HFO / MDO changeover operation, the operation on MDO has hitherto been limited up to 300 hours to prevent scuffing caused by carbon deposit accumulation inside the cylinder because of the excessive alkalinity components contained in lube oil.

However, in future engine operation, since the alkalinity value of lube oils for use with sub-0.5% Low Sulfur HFO and MDO will be identical at 9~15mgKOH/mg, there is no risk of scuffing and accordingly, no operation limit up to 300 hours is required. However, when operating on MDO and MGO at low load for long hours, maintain the FO injection valve in advanced timing, that is, about one half of the regular maintenance interval. If any abnormality, including corrosion, etc., was found, replace the FO injection valve. In addition, if the fuel oil is switched to MDO and the viscosity of that fuel oil at the engine inlet found to be lower than 1.8mm²/s, install the FO cooler or chill cooler as described in (1) above.

5) Discrimination between Low Sulfur HFO and MDO / MGO:

Distillate residue oil corresponding to the recent downward tendency of Low Sulfur HFO viscosity, the properties of HFO is envisaged to approach those of MDO or MGO. When it is hard to determine if the fuel oil purchased is distillate or residue oil, use the following standard for discrimination. When any of the items of the standard is applicable, determine that it is the residue oil and implement fuel oil pre-treatment by the FO heater and purifier. When purchased as being the residue oil, implement the same pre-treatment as above.

- Carbon residue, over 0.3%
- Ash content, over 0.01%
- Al + Si, over 5mg/kg
- Vanadium, over 5mg/kg

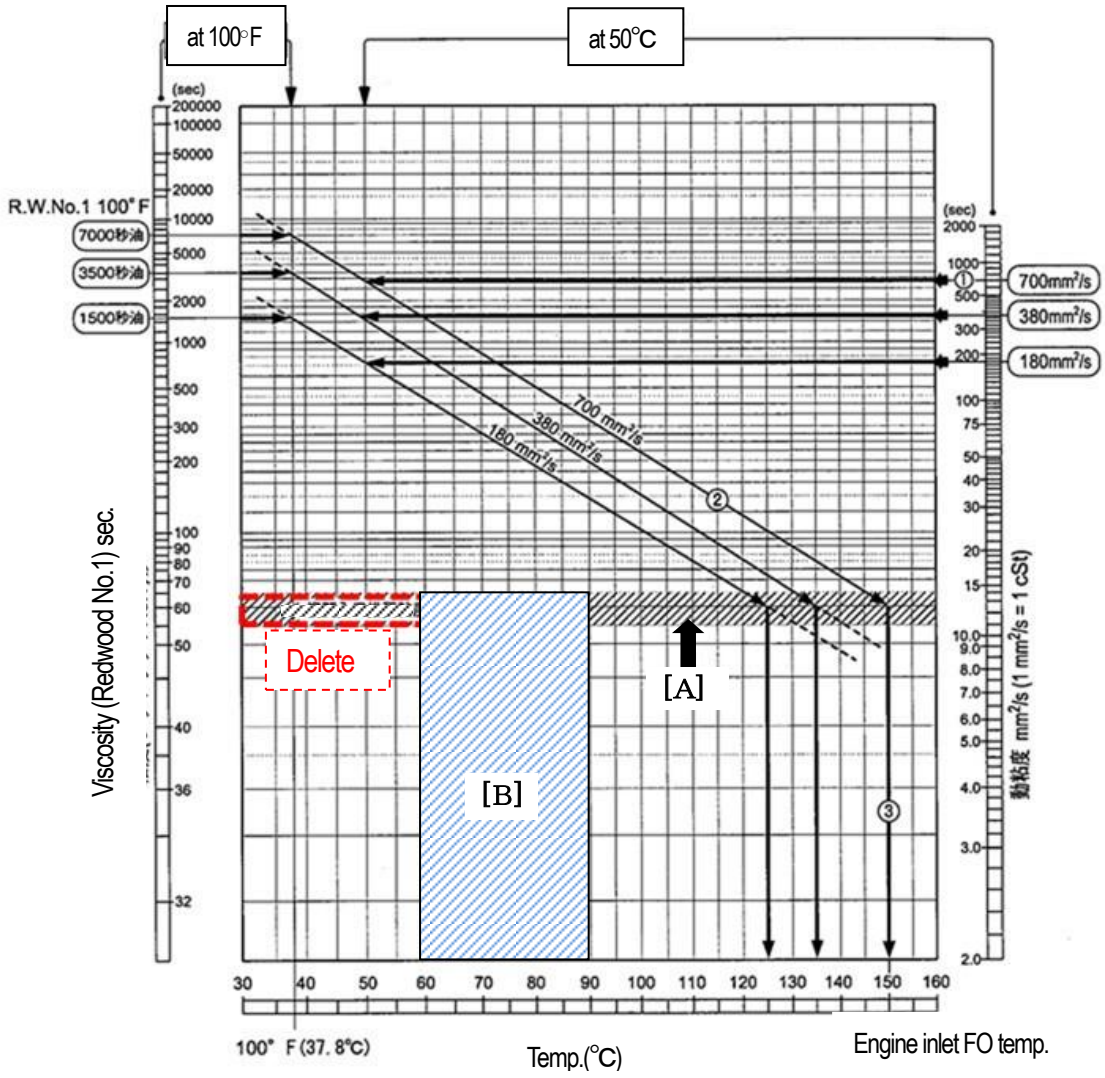

Fig.2 Engine Inlet FO Viscosity & Temp. Adjustment Range

(3) Vessels Operated on 0.1% or 0.5% Low Sulfur MDO, MGO and Conventional High Sulfur HFO:

Install SOx scrubber and treat exhaust gas and use High Sulfur HFO as has been done before.

1) Concerning both the fuel oil and onboard fuel oil system, operate and maintain the engine, as have been done before. The scrubber, since being installed at the engine exhaust outlet, gives resistance to the exhaust gas emitted. Select the scrubber and the exhaust gas pipe so that the total of their exhaust resistance, (exhaust back pressure), lowers 550 mmAq.
2) For the details of design condition to install the scrubber, please consult the relevant manufacturer.

(Note)

- The applicable engine models and their engine specifications vary in a wide range. For more details of above or if you whish to modify the engine concretely, please consult your contact at Yanmar Engineering Co., Ltd. or Marine Products Sales and Marketing Division of Yanmar Co., Ltd.
- This Service News is based on the information currently available to us at the present moment. The contents and descriptions thereof are subject to change according to the fuel oil trend in the market, development trend of compliant lube oils, etc.

Table 1. Engine Parts to Be Modified upon Spec. Change from HFO to MDO

Use		Engine	Fuel Oil	FO valve cooling type	Parts to be modified upon engine specification change (HFO →MDO)					
					Cyl. head	Nozzle sleeve	FO valve	FO injection pump	Exhaust valve	Turbo-Charger
Aux	Main									
○	—	EY33	MDO	Non-cooling	—	—	○	—	—	△
			HFO	Direct cooling						
○	○	EY26	MDO	Non-cooling	—	—	—	△	—	△
			HFO							
○	○	EY22	MDO	Non-cooling	—	○	—	△	△	△
			HFO	Indirect cooling						
○	—	EY18	MDO	Indirect cooling	—	—	—	△	△	△
			HFO							
○	○	N33	MDO	Non-cooling	—	—	○	—	△	△
			HFO	Direct cooling						
○	—	N28	MDO	Non-cooling	(○) *	○	○	△	△	△
			HFO	Indirect cooling						
○	—	N26	MDO	Non-cooling	(○) *	○	○	△	△	△
			HFO	Indirect cooling						
○	—	N21	MDO	Non-cooling	(○) *	○	○	△	△	△
			HFO	Indirect cooling						
○	—	N18	MDO	Non-cooling	(○) *	○	○	△	△	△
			HFO	Indirect cooling						
○	—	M220	MDO	Non-cooling	—	○	○	△	△	△
			HFO	Indirect cooling						
○	—	M200	MDO	Non-cooling	—	○	○	△	△	△
			HFO	Indirect cooling						

○ : Replace.
(○) * : No replacement required when the special nozzle sleeve was installed.
△ : Continued use is possible. (We recommend replacement upon maintenance and other servicing opportunities for modification.)

Note 1) List above shows the typical examples. Modification specifications vary depending on the engine model and the time of manufacture. For further details, including the engine models not listed above, consult service contact at Yanmar.

Note 2) When modifying engine specifications from MDO to HFO again, all ○, △ marked parts need to be replaced.

[FO Cooler]

1) For selecting FO cooler to be installed, refer to the installation example, line diagram, FO cooler capacity calculation method, etc. shown below.

2) Example of FO Cooler Installation

It sometimes occurs that extremely low viscosity fuel oil, (min. 1.5 mm²/s, (40℃)), is used as the low sulfur fuel oil, MGO , DMA (ISO8217:2005)). However, the extreme low viscosity fuel oil can cause plunger barrel seizure of the FO injection pump. In this case, it is necessary to maintain the fuel oil viscosity over 1.8 mm²/s at the engine inlet. The example of FO cooler installation in the MGO/MDO circulation line is shown in Fig.3 Circulation Line Diagram and in Fig.4 Detailed Drawing.

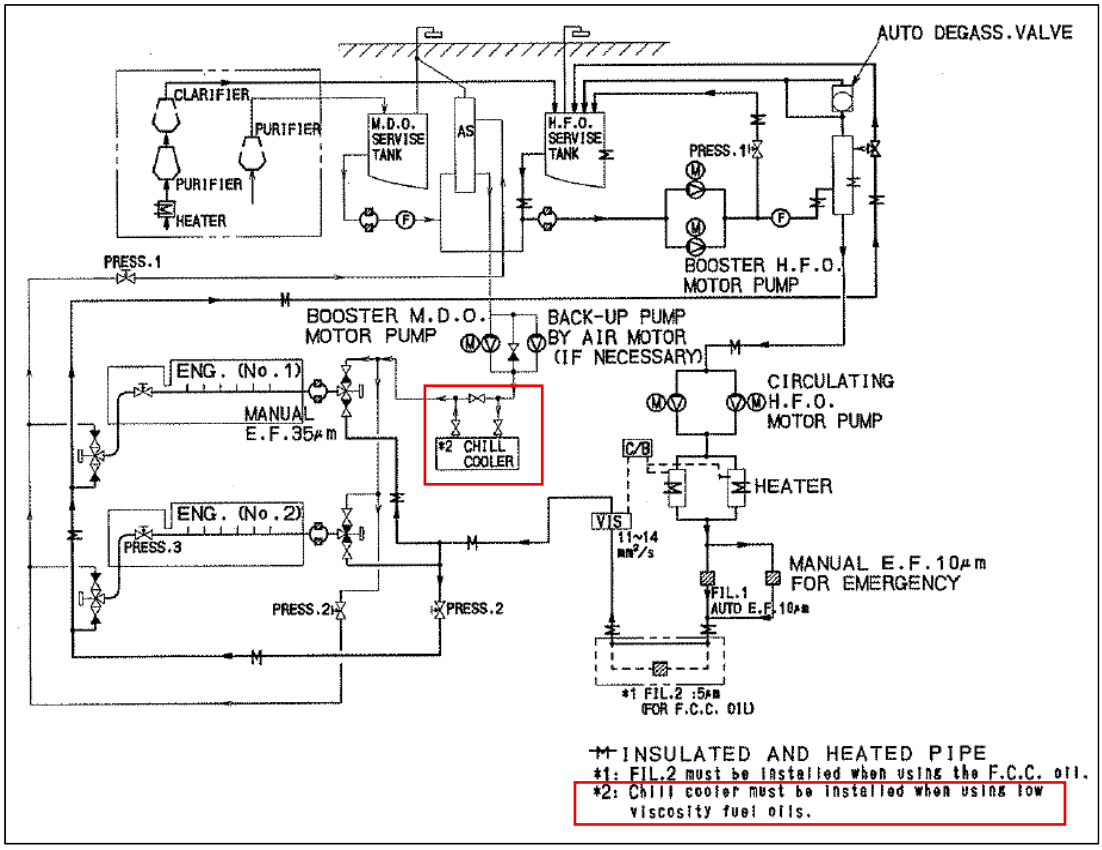

Fig.3 Circulation Line Diagram

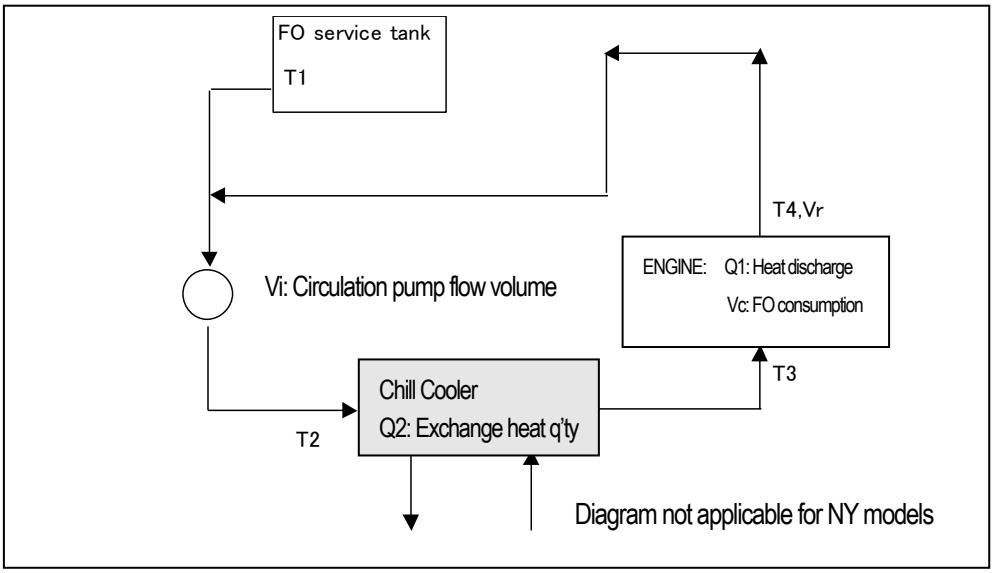

Fig.4 Detailed Drawing

3) Selection of FO Cooler Capacity

The design data of FO cooler for Yanmar 8N21L-SW engine as an example are as follows. (Refer to Table 2 below.)

〔Design Condition〕

- MGO viscosity : min. 1.5mm²/s @40℃ / ISO8217: 2005 DMA
- FO service tank temp. : 45℃
- Electric circulation pump : 0.70 m³/h
- Heating to ensure 1.8mm²/s : 20℃ or below (min. 10℃ or over)
- Calculation is for one engine unit. (Multiply by the numbers of unit to obtain the approximate value for multiple engine units.)

Table 2

Item	Unit	Value	Remarks
R : FO density	kg/m³	890	: From FO Property Table
C : FO specific heat	kJ/Kg℃	2	: Constant
kW : Engine output	kW	880	: Completion Specification Table
FOC : FO specific consumption	g/k Wh	199	
Q 1 : Heat discharge to FO from engine	MJ/h	9.2	: Refer to heat discharge to FO in Table 3
	kW	2.56	=MJ/h /3.6
T1 : FO service tank temperature	℃	45	(Max. engine room temp. assumed)
T3 : FO engine inlet temp.	℃	20	: DMA (1.5mm²/s(40 ℃)⇒1.8 mm²/s
Vi : FO circulation pump flow volume	m³/h	0.700	: Completion Specification Table
Vc : FO consumption	m³/h	0.197	=kW x FOC / R
Vr : FO return volume from engine	m³/h	0.503	= Vi-Vc
ΔT : FO engine inlet/outlet temp. difference	℃	10.3	= Q/(Vr*R*C)
T4 : FO engine outlet temperature	℃	30.3	= T3 + ΔT
T2 : FO cooler inlet temperature	℃	34.4	=(((Vr x ΔT)+(Vc x (T1-T3))) /Vi)+ T3
Q2 : Heat discharge to FO cooler from FO	MJ/h	18.0	= Vi x R x C x (T2-T3)
	kW	4.99	=MJ/h /3.6

4) Standard for Selecting FO Cooler

-1 : Decide the engine inlet FO temperature, (FO cooler outlet FO temp.) based on the properties of FO actually used.

-2 : FO Cooler Capacity

Calculate the capacity as follows.

Heat Discharge: (Heat quantity supplied to FO from engine) + (FO own heat quantity supplied from service tank).

FO circulation volume return volume: Circulation volume = FO circulation pump capacity.

FO return volume = (Circulation pump capacity) — (FO consumption)

-3 : Obtain the heat discharge to FO from engine from Table 3 below:

Table 3. Heat Discharge to FO from Engine

Engine Model	Engine Output kW	Revs. min-1	Heat Discharge to FO from Engine (Q1) MJ/h
6NY16L(W)	265～441	1200	5.6
6N165L(W)	441～530	1200	6.7
6EY18L(W)	400～615	720	5.1
	445～800	900	9.8
6N21L(W)	615～800	720	6.9
	745～1020	900	12.9
8N21L(W)	880～1065	720	9.2
	1100～1360	900	17.1
6EY22L(W)	660～1080	720	9.3
	880～1370	900	17.3
6EY26L(W)	1400～1840	720	13.9
8EY26L(W)	1900～2450	720	30.2
6N330L(W) 6EY33LW	2059～2648	720	22.9
8N330L(W) 8EY33LW	2795～3530	720	40.7

5) The FO cooler installation outline is based on Yanmar Service News already issued, No.06-2-G-07-009-S-Rev.5, " Use of Low Sulfur (1.5%～0%) Fuel Oils. "