台灣國際造船股份公司
CSBC CORPORATION,TAIWAN

主機與發電機選用

陳克仁

110-10-22

主機選用

- 動力推進系統類型
- 船舶阻力與推進
- 推進馬力選定
- EEDI規定
- 低速柴油主機特性
- 機艙相關系統確認
- 主機範例
- 廢氣排放標準

主機選用

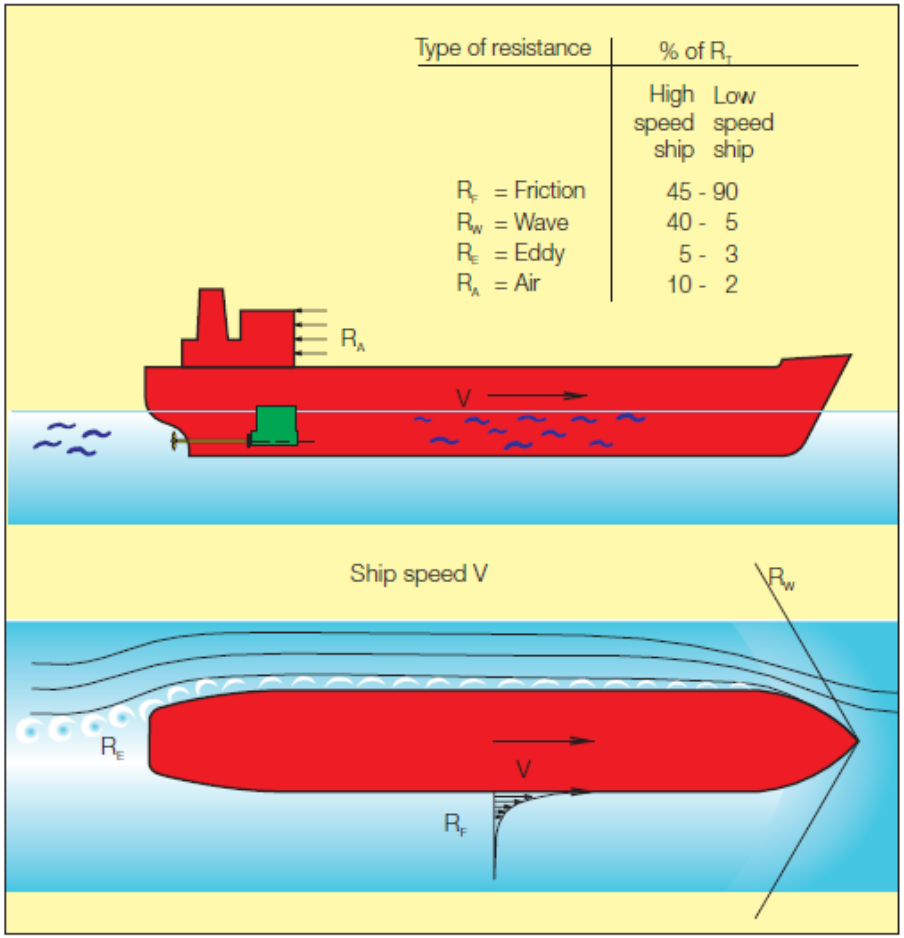
- 發電機選用
- 燃油消耗量計算

參考書籍

- 船舶柴油機：呂傳增等編撰，教育部出版
- 輪機實務與安全：楊仲笵編著，幼獅文化印行

主機選用－船舶阻力與推進

- 船舶阻力R_T
  - ➢ 黏性阻力R_F
    1. 摩擦阻力
    2. 形狀阻力(黏性壓差)
  - ➢ 興波阻力R_W(Wave)
  - ➢ 興渦阻力R_E(Eddy)(附屬物)
  - ➢ 空氣阻力R_A(Air)
- $R_T=R_F+R_W+R_E+R_A$



主機選用－船舶阻力與推進

- 船舶阻力驗證

➢ CFD計算

➢ 船模試驗 (HSVA水槽、SPA水槽)

1. 阻力試驗 (Vs-R)
2. 自航試驗 R=(1-t)T，(t,w)
3. 螺槳單獨試驗 Open Water Test (K-J,η)

主機選用－船舶阻力與推進

- 馬力與效率

  指示馬力 IHP

  制動馬力 BHP

  軸馬力 SHP

  傳達馬力DHP

  有效馬力EHP

  機械效率 $\eta_m = P_{BHP}/P_{IHP}$

  傳達效率 $\eta_t = P_{DHP}/P_{BHP}$

Velocities

Ship's speed : V

Arriving water velocity to propeller (Speed of advance of propeller) : V_A

Effective wake velocity : $V_W = V - V_A$

Wake fraction coefficient : $w = \frac{V - V_A}{V}$

Forces

Towing resistance : R_T

Thrust force : T

Thrust deduction fraction : $F = T - R_T$

Thrust deduction coefficient : $t = \frac{T - R_T}{T}$

Power

Effective (Towing) power : $P_E = R_T \times V$

Thrust power delivered by the propeller to water : $P_T = P_E / \eta_H$

Power delivered to propeller : $P_D = P_T / \eta_B$

Brake power of main engine : $P_B = P_D / \eta_S$

Efficiencies

Hull efficiency : $\eta_H = \frac{1 - t}{1 - w}$

Relative rotative efficiency : η_R

Propeller efficiency - open water : η_O

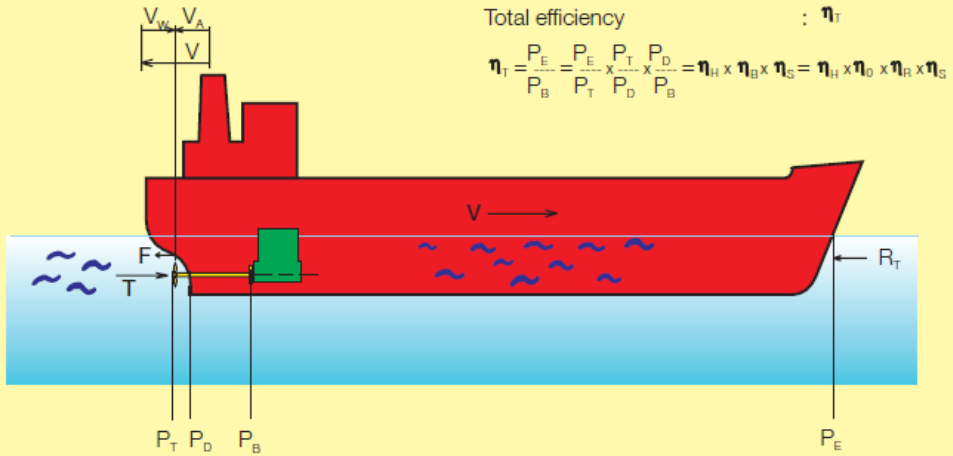
Propeller efficiency - behind hull : $\eta_B = \eta_O \times \eta_R$

Propulsive efficiency : $\eta_D = \eta_H \times \eta_B$

Shaft efficiency : η_S

Total efficiency : η_T

$$\eta_T = \frac{P_E}{P_B} = \frac{P_E}{P_T} \times \frac{P_T}{P_D} \times \frac{P_D}{P_B} = \eta_H \times \eta_B \times \eta_S = \eta_H \times \eta_O \times \eta_R \times \eta_S$$



主機選用-推進馬力選定

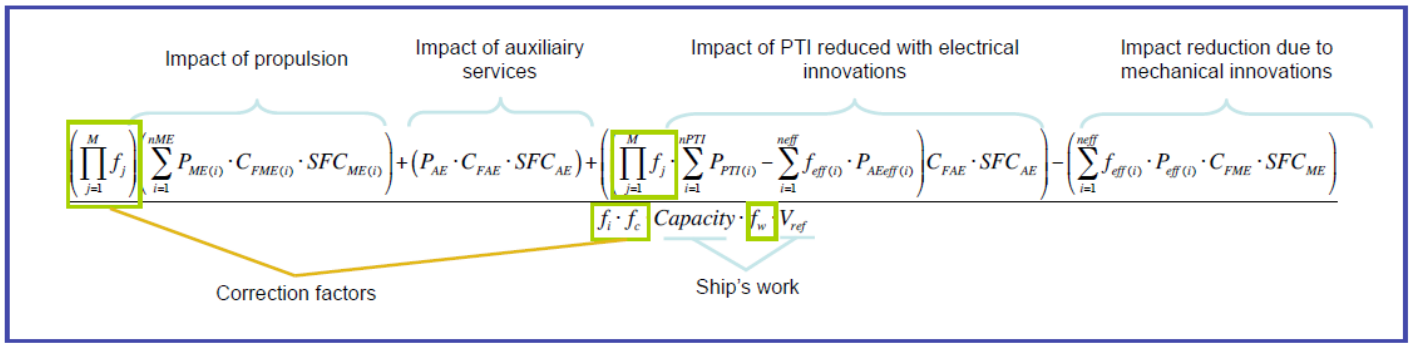
- 主機馬力選定：
  - 船東基本需求：港口限制、載貨量、船速、耗油量、營運維修考量
  - 基本設計規劃：一般佈置圖(GA)、主要尺寸確認、船速與馬力、船艏與船艉線形設計優化
  - IMO規定：EEDI

$$EEDI = \frac{\text{Impact to environment}}{\underset{\textit{(transportation work)}}{\text{Benefit to society}}} = \frac{\text{Power} \times \text{fuel consumption} \times CO_2 \text{ emission factor}}{\text{Capacity} \times \text{ship speed}}$$

主機選用-EEDI 規定

EEDI – Calculation

Resolution MEPC.212(63):



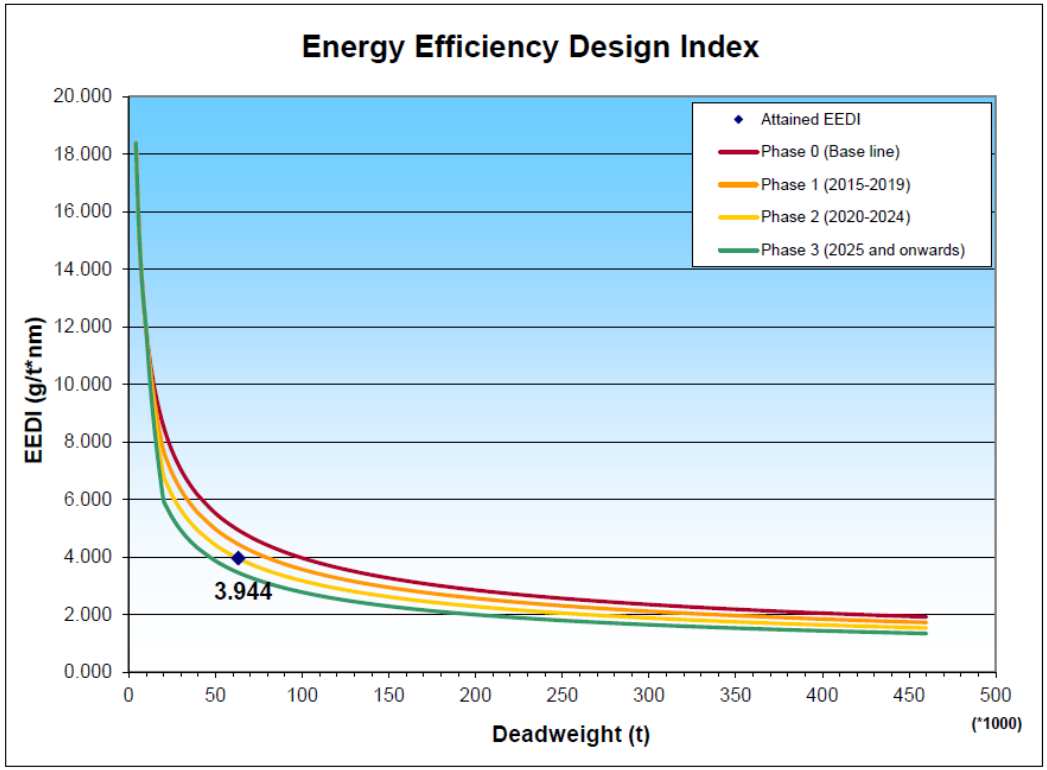
f	Correction factors
C_F	CO_2 emission factor (fuel type)
SFC	Specific Fuel Consumption (g/kWh)
P	Power (kW)
Capacity	tonnage
V	Speed (knots)
"ME"	Subscript for parameters related to Main Engine(s)
"AE"	Subscript for parameters related to Aux. Engine(s)

EEDI units

Grams CO_2 emitted per (tonnes*nautical mile)

主機選用-EEDI規定

- IMO規定：EEDI

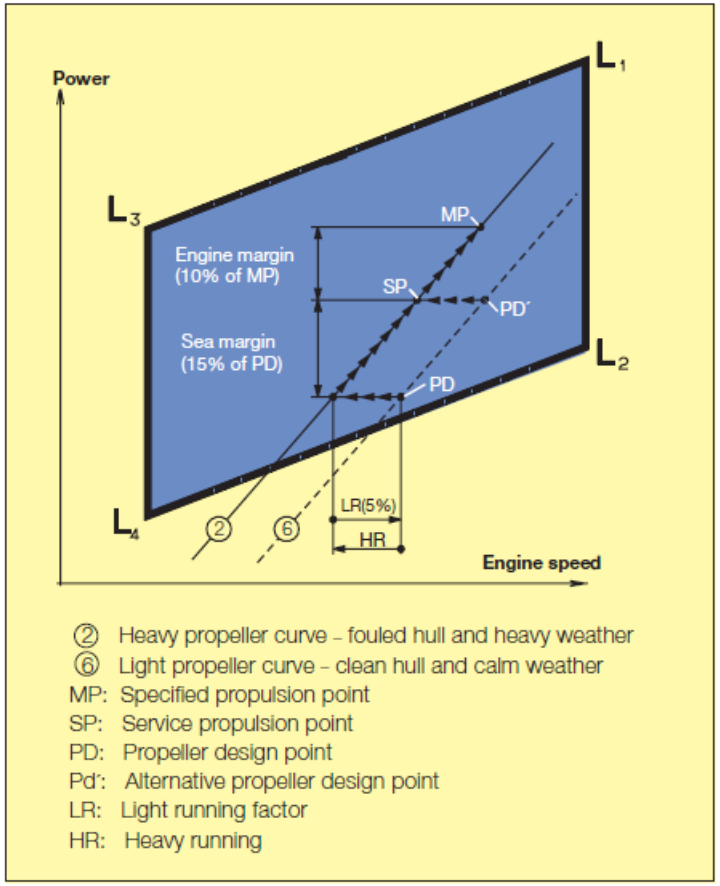


主機選用－低速柴油主機特性

- 馬力單位
  - 1英制馬力= 550 ft·lb/s (約745.7 W)
  - 1公制馬力 PS=75 kgf-m/s (約735.5 W)
  - EHP = Rt (kg) x V (kt)/75
- 連續最大出力MCR: Max. Continuous Rating
- 指定連續最大出力SMCR: Specified Max. Continuous Rating
- 常用出力NOR: Normal Continuous Rating
- 引擎餘裕Engine Margin: 10% ~15% (NOR=90% ~ 85% SMCR)
- 海況餘裕Sea Margin: 15% ~20% (SM= 1-PD/NOR)

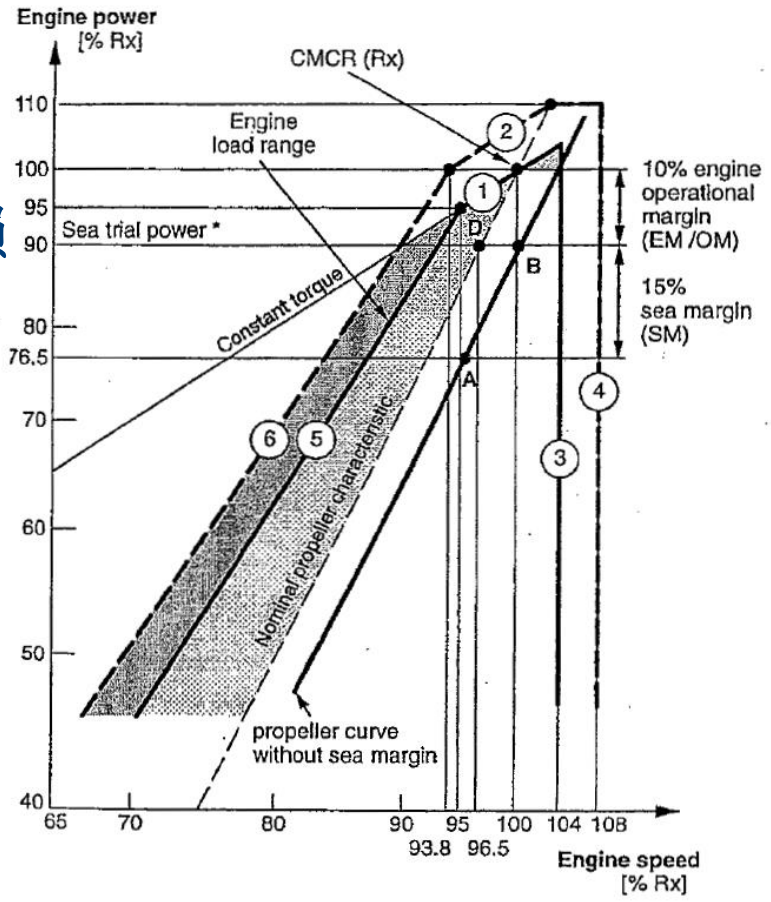
主機選用－低速柴油主機特性

- 規劃區塊Layout
- $L_1(R_1)$：Max. BHP & RPM
- $L_4(R_4)$：Min. BHP & RPM
- L_1-L_3 ：Max. MEP (平均有效壓力)
- L_2-L_4 ：Min. MEP
- L_1-L_2 ：Max. RPM
- L_1-L_3 ：Min. RPM
- 轉速餘裕RPM Margin：5~7%
- 螺槳曲線：過SMCR馬力～速度的三次方 (BHP ～V^3)



主機選用-低速柴油主機特性

- CMCR點：SMCR
- 達到設計船速的馬力與轉速
  - D點NOR ：海況不佳+船殼汙損
  - B點：海況不佳+船殼乾淨
  - A點：海況佳+船殼乾淨
- 線1：通過SMCR點(100%rpm, 100%BHP)的等MEP
- 線2：過負載限制線(過110%SMCR點(103.2%rpm, 110%BHP)的等MEP)

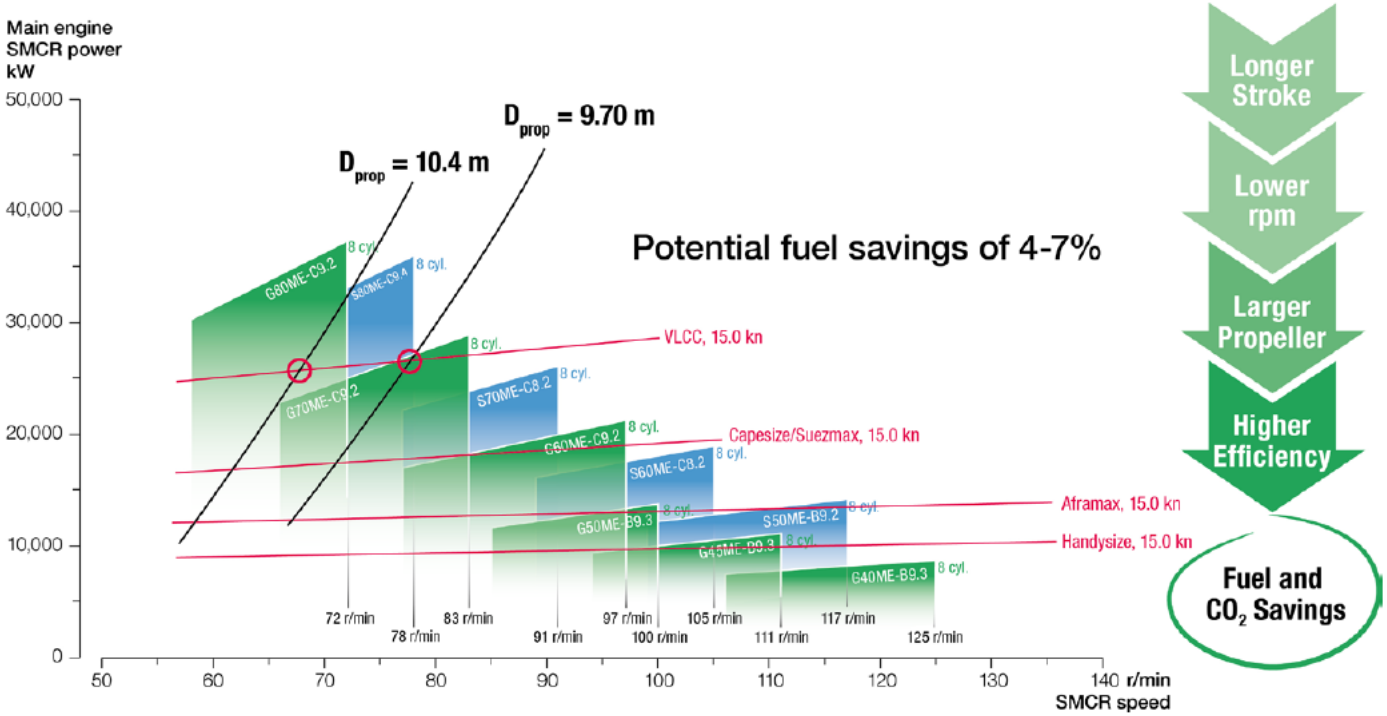


主機選用－低速柴油主機特性

- 線3：轉速限制線(104% RPM，連續運轉)
- 線4：過轉速限制線(108% RPM，試航)
- 線5：扭力速度線
- 線6：最大扭力限制線
- 建議連續操作區域:線1、線3與螺槳曲線所圍範圍
- 螺槳曲線與線5所圍範圍保留為加速與航行於淺水域等彈性使用
- 線5、線6與等扭力線所圍範圍保留為短暫快速加俥操作使用(限制操作時間)

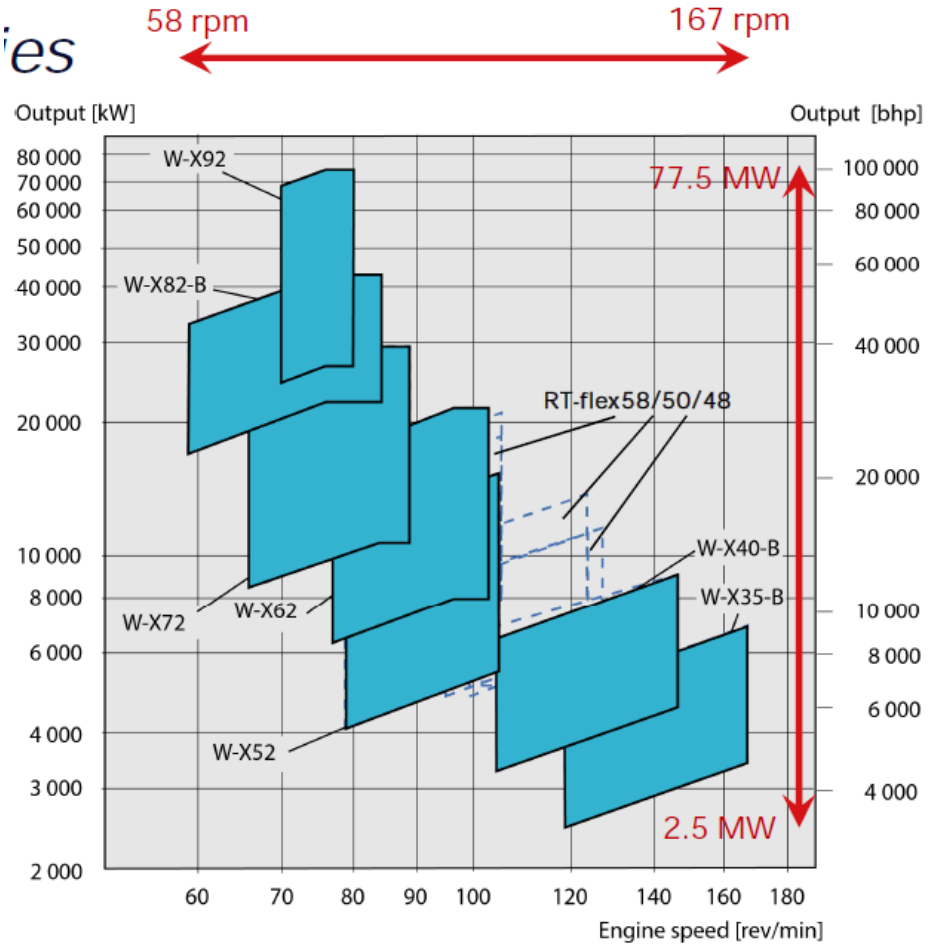
主機選用-低速柴油主機特性

- MAN低速引擎 layout



主機選用－低速柴油主機特性

- WIN-GD 低速引擎 layout (Wartsila-Suzzler)



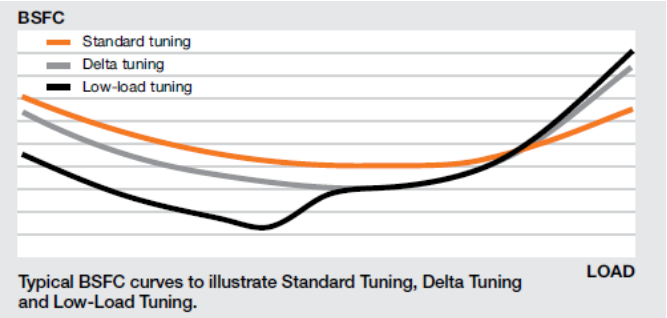
主機選用-低速柴油主機特性

- 比燃油消耗率SFOC (g/kW-hr)以ISO標準狀況下&燃油低熱值LCV 42.7 MJ/kg為基準

ISO standard reference conditions

Total barometric pressure at R1	1.0 bar
Suction air temperature	25°C
Relative humidity	30%
Cooling water temperature before engine	25°C

- SFOC保證值公差裕量
  - 5% at 100%~85%引擎負荷
  - 6% at 84%~65%引擎負荷
  - 7% at 64%~50%引擎負荷
- HFO(Max. 700 cSt @50℃)



Typical BSFC curves to illustrate Standard Tuning, Delta Tuning and Low-Load Tuning.

主機選用-低速柴油主機特性

- WIN-GD (Wartsila) & MAN引擎調校法

Engine tunings

Wärtsilä	MAN
Standard	High Load
Delta	Part Load, ECT, EGB, VT
Low Load, EGB	Low Load, EGB or VT

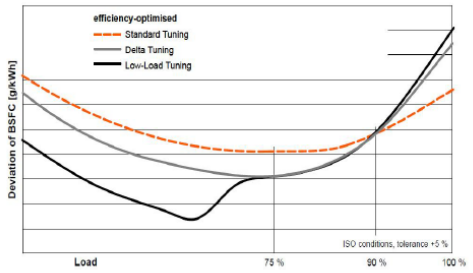


Fig. A4 Typical BSFC curves to illustrate Standard Tuning, Delta Tuning and Low-Load Tuning

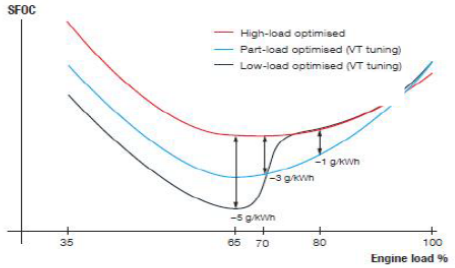
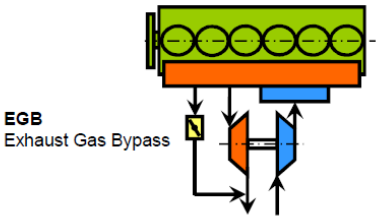


Fig. 1: ME/ME-C engines

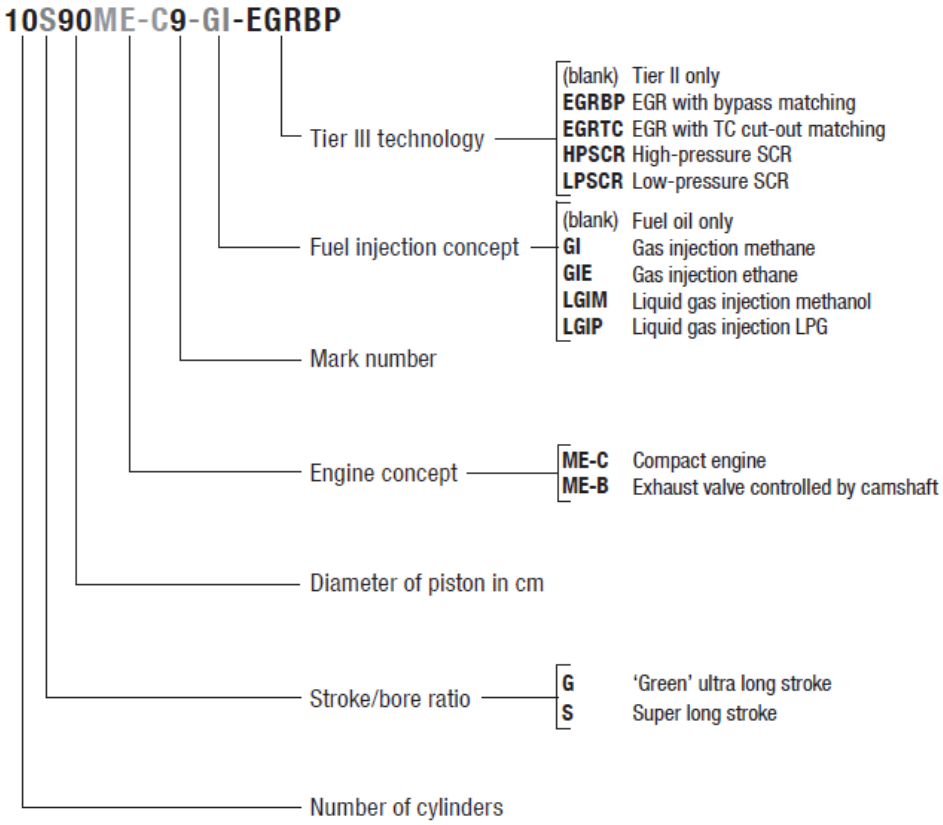


32 © Wärtsilä Ship Power Merchant

WÄRTSILÄ

主機選用-低速柴油主機特性

- MAN低速柴油主機
- SCR(Selected Catalyst Reduction)
- EGR(Exhaust Gas Recirculation)



GI and LGI Dual Fuel Engines

This engine programme includes a number of engines designed for gas fuels (GI engines) and liquid gas fuels (LGI engines) operation.

Fuel	Fuel designation	LCV [kJ/kg]
Methane	GI	50,000
Ethane	GIE	47,500
Methanol	LGIM	20,100
LPG*	LGIP	46,000

*LPG is a mixture of liquid propane and butane.

主機選用－機艙相關系統確認

機艙相關系統確認

- 機艙佈置：空間尺寸
- 推進系統(主機+軸系+螺槳)
- 振動特性(軸向振動，扭轉振動，側向振動，2^{nd} 階不平衡力矩補償器，抗橫搖支撐)
- 機艙自動控制
- 排煙管尺寸(背壓，消音器)
- 風管系統(主機進氣量/輻射熱)
- 蒸汽系統(廢氣節熱器產汽量)

主機選用－機艙相關系統確認

機艙相關系統確認

- 冷卻水系統(LT中央冷卻水、HT缸套冷卻水、海水冷卻)
- 燃油系統(日用系統、淨油)
- 滑油冷卻系統 (T/C、main bearing、液壓控制油、汽缸油)
- 空氣系統(啟動空氣、控制空氣)

主機選用－範例

- 低速柴油主機規格要目

➢主機機型：MAN 8S70ME-C8.5 or WIN-GD 8X72 Low Load Tuning with EGB

➢數量：1部

➢MCR： 24,590 kW x 89 rpm

➢NOR： 22,131 kW x abt. 85.9 rpm

➢汽缸數：8

➢汽缸直徑(bore)：700 mm

➢衝程(stoke)：2,800 mm

主機選用－範例

- 低速柴油主機規格要目

➢燃油消耗率：165.6 g/kWh plus 5%允許誤差
(85%MCR及標準狀況下燃油低熱值為2,700 kJ/kg)

➢旋轉方向：從船艉向船艏看去，順時針為正轉進車

➢電子式調速器(governor) x 1部

➢空氣增壓器(turbo-charger) x 2部

➢淡水冷卻的空氣冷卻器(air cooler) x 2部

➢轉俥機(turning gear、馬達帶動) x 1部

➢輔風機(auxiliary blower、馬達帶動) x 2部

主機選用－範例

- MAN 8S70ME-C8.5

Fuel consumption and gas figures

	Tier II	
SFOC	**SMCR** g/kWh	**NCR** g/kWh
ISO	169.3	167.2
Tropical	171.1	168.9
Specified	170.2	168.0

SFOC: Specific Fuel Oil Consumption (LCV: 42,700 kJ/kg)

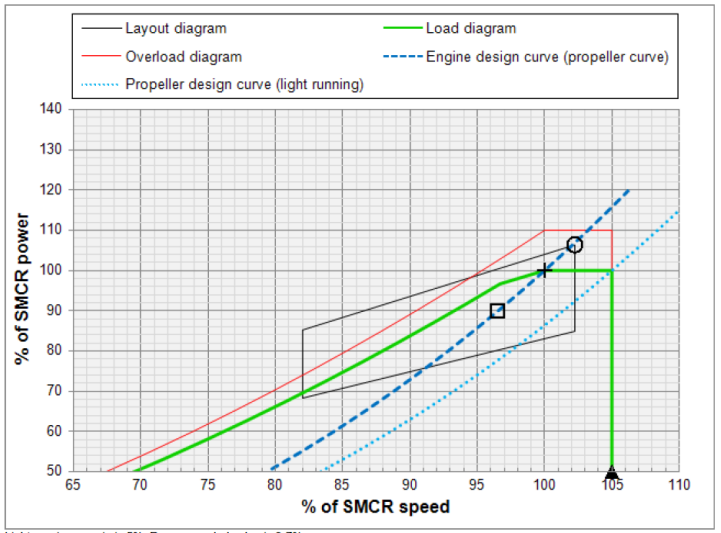
	Tier II	
Exhaust gas amount	**SMCR** kg/s	**NCR** kg/s
ISO	51.9	48.3
Tropical	47.9	44.5
Specified	49.9	46.4

	Tier II	
Exhaust gas temperature	**SMCR** °C	**NCR** °C
ISO	273	260
Tropical	308	295
Specified	290	278

	Tier II	
Turbocharger air consumption	**SMCR** kg/s	**NCR** kg/s
ISO	50.7	47.3
Tropical	46.7	43.5
Specified	48.7	45.4

ISO, tropical and specified conditions are listed in the References and tolerances section

Engine room and performance data for 8S70ME-C8.5-TII with low load exhaust gas bypass tuning.
Project name: CV2500AM
Report made by: K. R. Chen



Light running margin is 5%. Recommended value is 3-7%.

Point		Power kW	Speed r/min	MEP Bar
+	SMCR: Specified Maximum Continuous Rating (94.0% of NMCR)	24,590	89.0	19.2
□	NCR: Normal Continuous Rating (90.0% of SMCR)	22,131	85.9	17.9
	Maximum over load (110% of SMCR)	27,049	-	-
▲	Maximum speed limit (105% of SMCR)	-	93.5	-
O	L1, NMCR: Nominal Maximum Continuous Rating	26,160	91.0	20.0

Further reading: http://www.mandieselturbo.com/Papers/Basic_Principles_Of_Ship_Propulsion p.20-29

主機選用－範例

- MAN 8S70ME-C8.5

Expected lubrication oil consumption

Load	Cylinder oil consumption g/kWh	Lube oil consumption kg/24h
SMCR	0.60	52

Pump	Flow capacity m³/h	Pump head Bar
Fuel oil circulation	11.1	6.0
Fuel oil supply	6.6	4.0
Jacket water	190	3.0
Central water	527	2.5
Sea water for central cooling	670	2.0
Lubrication oil	500	4.4
T/C lubrication oil	18.0	4.0

	Tier II		
Cooler	Flow m³/h	Central water flow m³/h	Heat dissipation kW
Scavenge air	-	300	8,430
Lubrication oil	500	220	1,790
Jacket water	190	220	3,340
Central water*)	670	527	13,750
Fuel oil circulation (MGO/MDO)	-	-	71
T/C lubrication oil	18.0	7	190

Capacities of auxiliary systems

Air cooler cleaning unit	
Air cooler cleaning tank	0.90 m³
Capacity of pump	3.0 m³/h

Cylinder oil system	
Storage tanks	2 x 43 m³
Service tanks	3.3 m³

Fuel oil system	
MGO/MDO service tank, 12 h	58.3 m³
HFO settling tanks, 2 x 12 h	2 x 54.7 m³
HFO service tank, 12 h/95 °C	55 m³
HFO centrifuge, 98 °C	6,020 l/h
Fuel oil pre-heater	192 kW

Lubrication oil system	
Storage tanks (2 x 3 months)	2 x 6.2 m³
Centrifuge, 95 °C	3,560 l/h
Recommended lube oil bottom tank	30 m³

Miscellaneous	
Jacket water expansion tank*)	10 %
Motor rating, auxiliary blowers	2 x 90 kW

*) Jacket water expansion tank volume given in percent of the total jacket water volume.

Starting air system, 30 bar	
Receiver volume (12 starts)	2 x 8.5 m³(n)
Compressors (total)	510 m³(n)/h

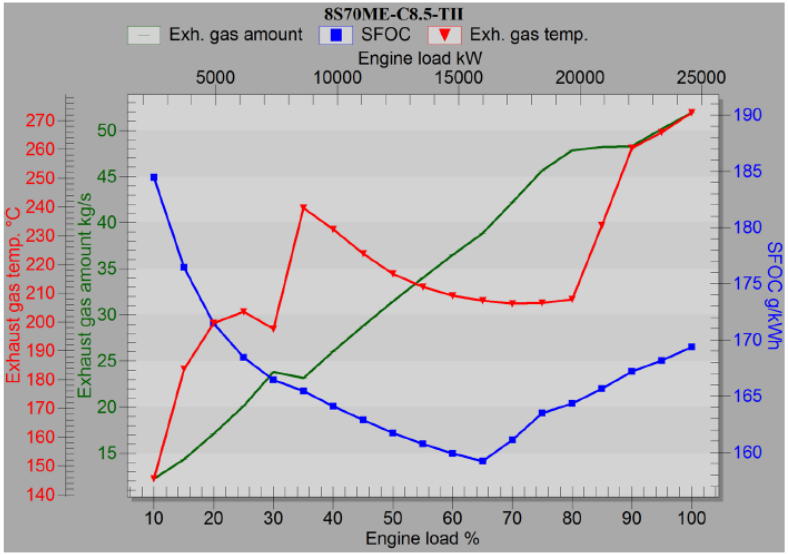
主機選用－範例

- MAN 8S70ME-C8.5

ISO ambient conditions (ambient air: 25 °C, scavenge air coolant: 25 °C)

Load % SMCR	Power kW	Speed r/min	SFOC g/kWh	Exh. gas kg/s	Exh. gas*) °C	Steam**) kg/h
100	24,590	89.0	169.3	51.90	273	6,990
95	23,361	87.5	168.2	50.13	266	6,210
90	22,131	85.9	167.2	48.30	260	5,580
85	20,902	84.3	165.6	48.19	233	3,520
80	19,672	82.6	164.3	47.84	208	1,570
75	18,443	80.9	163.5	45.63	207	1,410
70	17,213	79.0	161.1	42.21	206	1,280
65	15,984	77.1	159.2	38.80	207	1,250
60	14,754	75.1	159.9	36.49	209	1,270
55	13,525	72.9	160.7	34.04	212	1,350
50	12,295	70.6	161.7	31.45	217	1,470
45	11,066	68.2	162.9	28.83	224	1,660
40	9,836	65.6	164.1	26.05	232	1,850
35	8,607	62.7	165.4	23.14	240	1,910
30	7,377	59.6	166.4	23.83	198	400
25	6,148	56.1	168.4	20.13	204	530
20	4,918	52.0	171.4	17.12	200	340
15	3,689	47.3	176.4	14.34	184	0
10	2,459	41.3	184.4	12.26	146	0

Fuel consumption and exhaust gas data (fuel oil, Tier II)



主機選用－範例

- WIN-GD 8X72

Engine Data

Power Rx :	24590.0	= 97.3% R1+	Power R1 :	25270.0 kW	
Speed Rx :	89.0	= 100.0% R1+	Speed R1 :	84.0 rpm	
Turbocharger (MHI type) :	2 x MET66MB		Bore :	720 mm	
Scavenge air cooler :	2 x SACA7-SF		Stroke :	3086 mm	

Brake Specific Fuel Consumption (ISO 3046-1:2002)

		Tolerances	
Air temperature before blower	25.0 °C		
Coolant temperature before SAC	25.0 °C		
Barometric pressure	1000.0 mbar	+ 5 %	100-85 % Power
Relative humidity	30.0 %	+ 6 %	84-65 % Power
		+ 7 %	64-50 % Power

Power [%]	110.0	100.0	90.0	85.0	80.0	75.0	70.0	65.0	60.0	50.0	40.0	30.0	25.0
BSFC [g/kWh]	170.0	169.0	162.7	160.7	159.9	159.5	158.2	156.5	157.2	159.3	162.3	164.9	166.0

BSFC: Brake specific fuel consumption with lower heating value 42707 kJ/kg

Ancillary Systems

Cooling system : Fresh water cooled / single-stage SAC
Cylinder cooling water inlet temperature : 75.0 °C
Cylinder cooling water outlet temperature : 90.0 °C

Lub. oil system : Lubricating oil system incl. TC
Oil temperature before engine : 45.0 °C
Oil pressure before engine: 4.3 bar
Viscosity: 84.3 mm²/s

Exhaust gas back pressure at rated power (Rx) : 300.0 mm WG

WÄRTSILÄ RT-flex — General Technical Data

W7X72 — Low-Load Tuning, FAST Nozzle

24590.0 kW 97.3% R1+
89.0 rpm 100.0% R1+

IMO Tier II compliant

Project:
Yard / Plant:
Owner:
Created: 2015-02-04
Printed: 2015-02-04

Summary (FW cooled / single-stage SAC / separate HT)

Bore	720	mm
Stroke	3086	mm
MEP	18.8	bar
Piston speed	9.2	m/s
Length	10665	mm
Weight dry	642	t
Weight water/oil		t
Lift vertical (standard)	13560	mm
E/R crane capacity	7.5	t
System oil consumption	8.0	kg/cyl per day
Cylinder oil consumption (Pulse lubricating system) *1)	0.6	g/kWh guide feed rate
Turbocharger	MHI	2 x MET66MB
Scavenge air cooler		2 x SACA7-SF
Governor type (electronic)		Integrated in UNIC
Aux. blower: min. installed electric motor power (shaft)	2 x 91	kW (400/440 V / 50/60 Hz)
Turning gear capacity	7.5	kW (400/440 V / 50/60 Hz)
Fuel oil booster P/P	11.1	m³/h
Fuel oil feed P/P	6.1	m³/h
High temperature water circuit P/P	216	m³/h
Low temperature water circuit P/P	580	m³/h
Main lubricating oil P/P	243	m³/h
Sea water P/P	803	m³/h
SAC (LT), heat dissipation	10511	kW
SAC (LT), fresh water flow	383	m³/h
Lub. oil cooler, heat dissipation	2272	kW
Lub. oil cooler, oil flow	243	m³/h
Lub. oil cooler, fresh water flow	197	m³/h
Cylinder cooler, heat dissipation	3677	kW
Cylinder cooler, fresh water flow	216	m³/h
Central cooler, heat dissipation	16460	kW
Exhaust gas, mass flow	168.9	t/h
Exhaust gas, temperature	309.5	°C
Air consumption	170.6	t/h
Engine radiation	217	kW
Main lub. oil drain tank	34	m³
Fresh water expansion tank	0.75	m³
Air compressor (30 bar)	2 x 270	m³/h
Air receiver (30 bar)	2 x 9.0	m³
HFO separator	5090	l/h
LO separator	3440	l/h
FO endheater	207	kW

主機選用－範例

- WIN-GD 8X72

IMO Tier II compliant Printed: 2015-02-04

Engine Performance Data

Conditions	Reference	Design	Specified
Air temperature before blower	25.0 °C	45.0 °C	10.0 °C
Engine room ambient air temp.	25.0 °C	45.0 °C	10.0 °C
Coolant temperature before SAC	29.0 °C	36.0 °C	25.0 °C
Barometric pressure	1000.0 mbar	1000.0 mbar	1000.0 mbar
Cylinder water outlet temperature	90.0 °C	90.0 °C	90.0 °C
Oil temperature before engine	45.0 °C	45.0 °C	45.0 °C
Exhaust gas back pressure	300.0 mm WG	300.0 mm WG	300.0 mm WG
Relative humidity	30.0 %	60.0 %	30.0 %

Fresh water cooled / single-stage SAC - 2 x MET66MB / 2 x SACA7-SF

Performance				Reference			Design			Specified		
Power %	Power kW	Speed rpm	mep bar	BSFC g/kWh	BSEF kg/kWh	tEaTm °C	BSFC g/kWh	BSEF kg/kWh	tEaTm °C	BSFC g/kWh	BSEF kg/kWh	tEaTm °C
110.0	27049.0	91.9	20.1	170.2	6.83	276.5	173.2	6.38	317.6	168.0	7.13	255.3
100.0	24590.0	89.0	18.8	169.2	7.37	268.3	172.2	6.87	309.5	167.0	7.70	246.9
90.0	22131.0	85.9	17.6	162.9	7.63	251.5	165.9	7.08	293.7	160.7	8.01	229.2
85.0	20901.5	84.3	16.9	160.9	7.66	239.9	163.9	7.08	282.6	158.7	8.07	216.9
80.0	19672.0	82.6	16.2	160.1	8.04	215.5	163.1	7.45	254.6	157.9	8.45	194.6
75.0	18442.5	80.9	15.6	159.7	8.18	209.6	162.7	7.56	249.2	157.5	8.63	187.9
70.0	17213.0	79.0	14.9	158.4	8.29	206.1	161.4	7.64	246.4	156.2	8.77	183.7
65.0	15983.5	77.1	14.1	156.7	8.42	204.6	159.7	7.74	245.6	154.5	8.93	181.4
60.0	14754.0	75.1	13.4	157.3	8.60	204.3	160.3	7.88	246.0	155.1	9.15	180.3
50.0	12295.0	70.6	11.9	159.5	8.99	208.6	162.5	8.19	252.1	157.3	9.62	182.7
40.0	9836.0	65.6	10.2	162.5	9.21	220.6	165.5	8.34	266.8	160.3	9.94	191.7
30.0	7377.0	59.6	8.4	165.1	10.69	211.0	168.1	9.77	248.8	162.9	11.51	186.3
25.0	6147.5	56.1	7.5	166.2	10.60	221.0	169.2	9.72	257.8	164.0	11.39	195.9

Abbreviations

BSFC : Brake specific fuel consumption with lower heating value 42707 kJ/kg
BSEF : Brake specific exhaust gas flow
tEaTm : Exhaust gas temperature after turbine (mixed)
mep : Mean effective pressure

The above performance values correspond to the lower heating value of 42707 kJ/kg (MDO). Based on experience during seatrials with HFO, exhaust gas temperature increases by 15°C compared to MDO figures according winGTD.

Tolerances

BSFC + 5 % 100-85 % Power
+ 6 % 84-65 % Power
+ 7 % 64-50 % Power

BSEF ± 5 %
tEaT ± 15 °C

Tolerances apply from and above 50% power

In general, an increase of BSEF by 5 % corresponds to a decrease of tEaT by 15°C.

主機選用-範例

- WIN-GD 8X72

Turbocharging Data

Reference Conditions

Air temperature before blower	25.0 °C	Turbocharger (MHI type) :	2 x MET66MB
Engine room ambient air temp.	25.0 °C	Scavenge air cooler :	2 x SACA7-SF
Coolant temperature before SAC	29.0 °C		
Barometric pressure	1000.0 mbar	Fresh water cooled / single-stage SAC	
Relative humidity	30.0 %		
Back pressure after turbine :	300.0 mm WG		
SAC differential pressure (max.) :	300.0 mm WG		

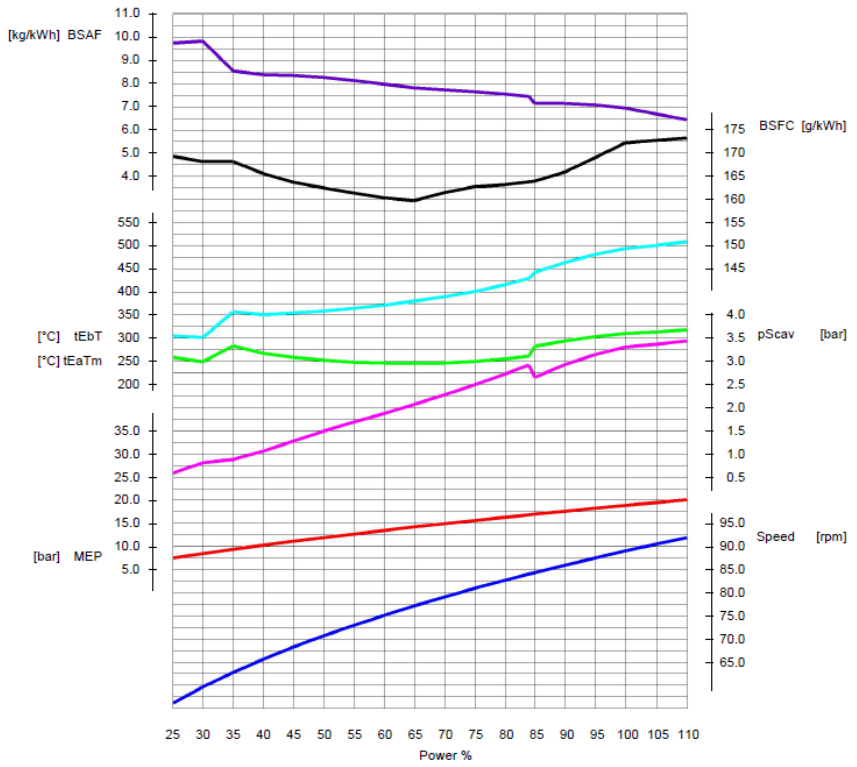
Performance			Scavenge air				Exhaust gas				
Power %	Power kW	Speed rpm	pScav bar	tAac °C	tScav °C	Comp flow kg/s	pExh bar	tEbT °C	tEaT °C	Turb flow kg/s	eta %
110.0	27049.0	91.9	4.59	212.6	35.3	50.77	4.40	456.7	269.0	49.28	69.1
100.0	24590.0	89.0	4.46	207.1	35.0	49.85	4.28	443.2	261.0	48.31	69.8
90.0	22131.0	85.9	4.09	193.2	34.0	46.52	3.91	413.0	244.8	45.03	71.4
85.0	20901.5	84.3	3.82	183.9	33.3	44.13	3.64	391.7	233.6	42.69	72.2
80.0	19672.0	82.6	3.88	185.1	33.2	43.65	3.71	369.2	215.5	43.93	72.1
75.0	18442.5	80.9	3.64	176.5	32.7	41.66	3.48	354.7	209.6	41.90	72.6
70.0	17213.0	79.0	3.43	168.6	32.2	39.45	3.26	343.5	206.1	39.66	72.8
65.0	15983.5	77.1	3.22	160.8	31.7	37.18	3.05	334.3	204.6	37.37	72.9
60.0	14754.0	75.1	3.02	152.6	31.3	35.07	2.86	326.1	204.3	35.24	72.8
50.0	12295.0	70.6	2.63	134.8	30.5	30.56	2.49	313.3	208.6	30.69	72.2
40.0	9836.0	65.6	2.19	113.9	29.8	25.07	2.07	305.3	220.6	25.17	70.8

Abbreviations

pScav	Scavenge air pressure	pExh	Exhaust receiver pressure
tAaC	Air temperature after compressor	tEbT	Exhaust gas temperature before turbine
tScav	Scavenge air temperature	tEaT	Exhaust gas temperature after turbine
		etaTC	Turbocharger overall efficiency acc. to CIMAC 2007

Performance Summary - Diagrams

Design Conditions



主機選用-範例

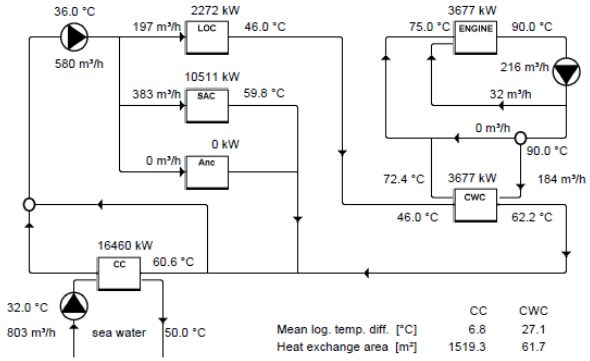
- WIN-GD 8X72

Cooling System

Design Conditions

Air temperature before blower	45.0	°C	Turbocharger (MHI type) :	2 x MET66MB
Engine room ambient air temp.	45.0	°C	Scavenge air cooler :	2 x SACA7-SF
Coolant temperature before SAC	36.0	°C		
Barometric pressure	1000.0	mbar	Fresh water cooled / single-stage SAC	
Relative humidity	60.0	%		

FW Cooled / Single-Stage SAC / Sep. HT



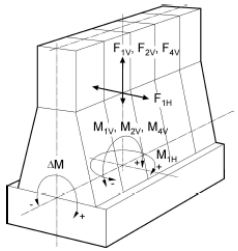
	CC	CWC
Mean log. temp. diff. [°C]	6.8	27.1
Heat exchange area [m²]	1519.3	61.7

Dynamic Characteristics

Massmoments and Forces

External moments	[±kNm]	Free forces	[±kN]
M_{1V} standard counterweights	207	F_{1V}	0
M_{1H} standard counterweights	223	F_{1H}	0
M_{2V}	865	F_{2V}	0
M_{4V}	588	F_{4V}	0

External couples and forces



Countermeasures for Dynamic Effects

External couples (2nd order balancer) :	Balancing countermeasure is not relevant
Torsional vibration :	Detailed calculations have to be carried out for every installation
Axial vibration :	An integrated axial damper is fitted as standard
Lateral rocking (side-stays) :	The countermeasure indicated may be needed
Lateral rocking (longitudinal-stays) :	The countermeasure indicated is not needed

Rating R1+ : 3610 kW/Cyl. / 89 rpm

Lateral H-Moments

Orders	[±kNm]	Orders	[±kNm]
Ord. 1	0	Ord. 7	1437
Ord. 2	0	Ord. 8	0
Ord. 3	0	Ord. 9	0
Ord. 4	0	Ord. 10	0
Ord. 5	0	Ord. 11	0
Ord. 6	0	Ord. 12	0

Lateral X-Moments

Orders	[±kNm]	Orders	[±kNm]
Ord. 1	160	Ord. 7	0
Ord. 2	102	Ord. 8	9
Ord. 3	529	Ord. 9	19
Ord. 4	1931	Ord. 10	122
Ord. 5	149	Ord. 11	42
Ord. 6	21	Ord. 12	2

Torque variation ΔM 1445 [±kNm]

The value of lateral forces and moments of other engine ratings and orders are available on request.

主機選用-範例

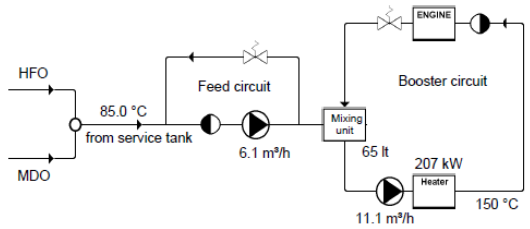
- WIN-GD 8X72

Fuel Oil System

Tank System Data and HFO Treatment

Feed circuit	HFO setting tank	39	m³	8	h operation at MCR
	HFO service tank	39	m³	8	h operation at MCR
	MDO service tank	39	m³	8	h operation at MCR
	Feed pump	6.1	m³/h		
Booster circuit	Booster pump	11.1	m³/h		
	HFO endheater	207	kW		
	Mixing unit	65	lt		
Treatment	Separator throughput	5.1	m³/h		
	HFO preheater	62	kW		

Pressurized Fuel Oil System

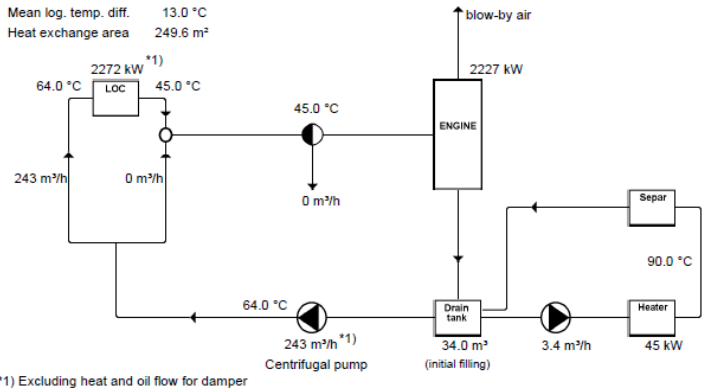


Lubricating Oil System

Design Conditions

Air temperature before blower	45.0 °C	Turbocharger (MHI type) :	2 x MET66MB
Engine room ambient air temp.	45.0 °C	Scavenge air cooler :	2 x SACA7-SF
Coolant temperature before SAC	36.0 °C		
Barometric pressure	1000.0 mbar	Fresh water cooled / single-stage SAC	
Relative humidity	60.0 %		

Main Lub. Oil System incl. TC



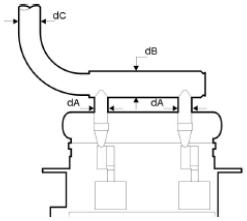
主機選用-範例

- WIN-GD 8X72

Exhaust Gas System

Design Conditions

2 x MET66MB



Exhaust gas

Mass flow	168909	kg/h
Temperature after TC	309.5	°C
Density	0.615	kg/m³
Backpressure	300	mmWG

Pipes	Gas velocity m/s	Volume flow m³/h	Diameter mm
Pipe A	40	137289	dA = 1200
Pipe B	25	274579	dB = 2000
Pipe C	35	274579	dC = 1700

Starting Air System

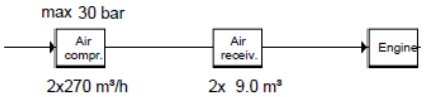
Air temperature before blower	45.0	°C	Turbocharger (MHI type) : 2 x MET66MB
Engine room ambient air temp.	45.0	°C	Scavenge air cooler : 2 x SACA7-SF
Coolant temperature before SAC	36.0	°C	
Barometric pressure	1000.0	mbar	Fresh water cooled / single-stage SAC
Relative humidity	60.0	%	

Number of starts : 12 *2)

Propeller pitch control : FPP

Relative shaft inertia J_{Tot} / J_{Eng} : 2.00000

Engine inertia J_{Eng} : 266600 kgm² *3)



For 30 bar design

Air receiver : 2 x 9.0 m³

Air compressor : 2 x 270 m³/h

主機選用－範例

WÄRTSILÄ

TORSIONAL VIBRATION CALCULATION No. 8X72-TV-3a

INSTALLATION 2500 TEU CV Project
CSBC

ENGINE TYPE **8X72**

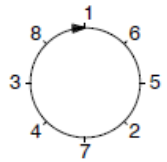
Including variable crank inertia
Excitation: Orders 1. TO 24.

Normal Firing Conditions
Compensated by cyl. output adaption

Barred speed range

Geislinger damper D220/XYZ
light flywheel J=17040 kgm2
LLT-WG Tier2-E0 Tuning

Crank Sequence

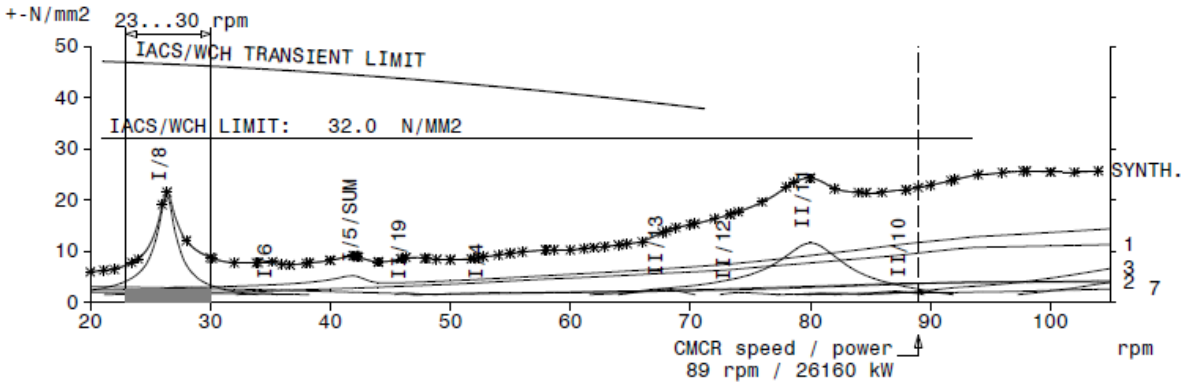


View from flywheel

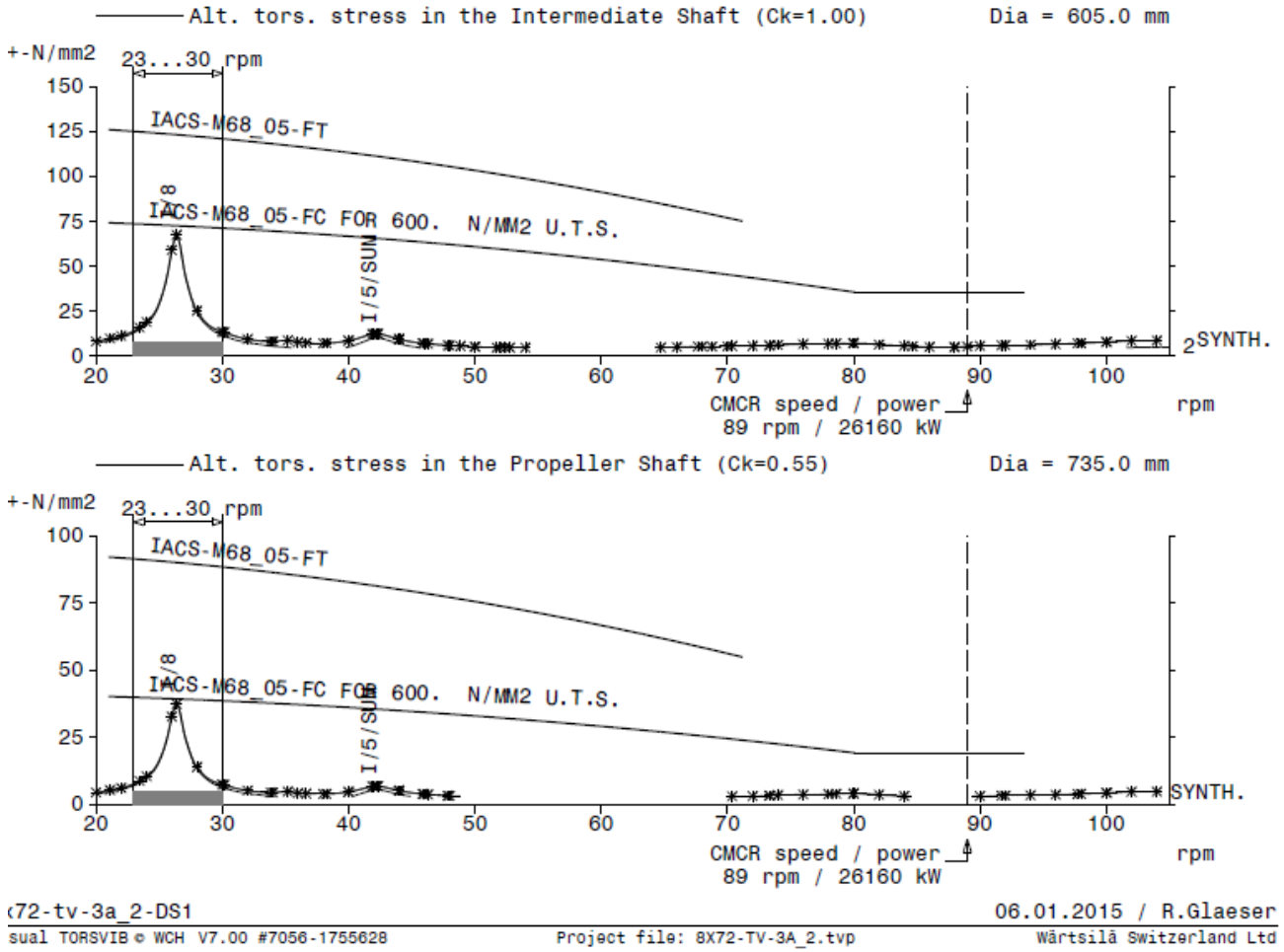
8X72 FCV1 Crankshaft (DB: [19.09.13]
Wärtsilä X72)
Flywheel J=17040 kgm2

FP Propeller 5-bl. Jtot=171883 kgm2
GEISLINGER D 220/22
Js=4390 kgm2 ; Jc=511 kgm2

Alt. tors. stress in the Crankshaft Dia= 880/250 mm



主機選用－範例

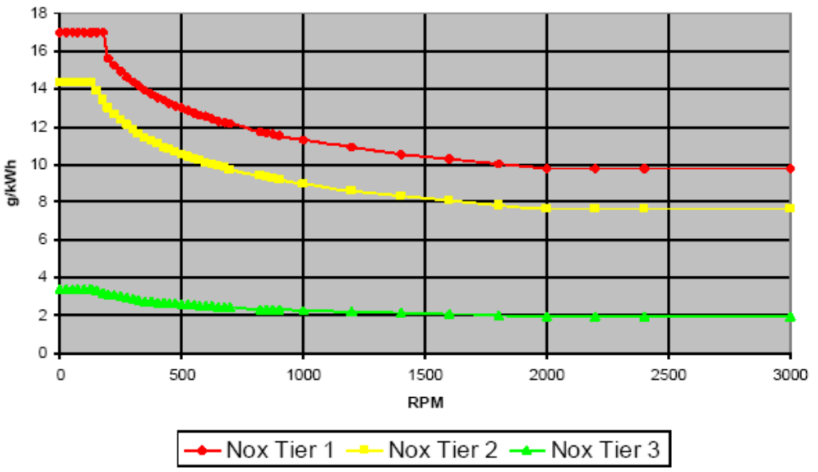

Alt. tors. stress in the Intermediate Shaft (Ck=1.00)
Dia = 605.0 mm
+-N/mm2
23...30 rpm
IACS-M68_05-FT
IACS-M68_05-FC FOR 600. N/MM2 U.T.S.
I/5/SUN
SYNTH.
CMCR speed / power
89 rpm / 26160 kW
rpm
Alt. tors. stress in the Propeller Shaft (Ck=0.55)
Dia = 735.0 mm
+-N/mm2
23...30 rpm
IACS-M68_05-FT
IACS-M68_05-FC FOR 600. N/MM2 U.T.S.
I/5/SUN
SYNTH.
CMCR speed / power
89 rpm / 26160 kW
rpm
(72-tv-3a_2-DS1
06.01.2015 / R.Glaeser
sual TORSVIB © WCH V7.00 #7056-1755628
Project file: 8X72-TV-3A_2.tvp
Wärtsilä Switzerland Ltd

主機選用－廢氣排放標準

NOx Tier III compliance options

1. SELECTIVE CATALYTIC REDUCTION (SCR)
   - MEPC.217(63) – Certification of Marine Diesel Engines fitted with Selective Catalytic Reduction Systems under the NOx Technical Code 2008
   - MEPC.198(62) - 2011 Guidelines addressing additional aspects to the NO_x Technical Code 2008 with regard to particular requirements related to marine diesel engines fitted with SCR
2. EXHAUST GAS RECIRCULATION (EGR) (2-STROKE)
3. DUAL-FUEL (4 STROKE) ENGINES (6-18MW)
4. DUAL-FUEL (2 STROKE) ENGINES (GAS MODE + WHR + EGR)
5. PURE GAS ENGINES (1.5MW to 9MW)*

NOx emission standards - Tier 1, 2 and 3



主機選用－廢氣排放標準

ECA compliance - SOx control

A. Use compliant fuel oil

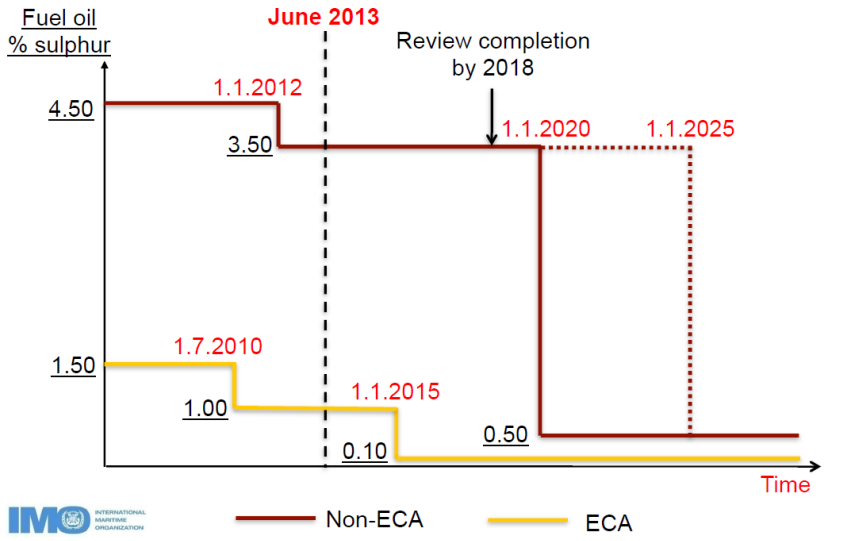
B. Use equivalent e.g., EGCS

C. Use alternative fuels

- **Gas – dual fuel or gas only**
- **biodiesel/methanol**

D. Onshore power supply (MEPC.1/Circ.794)

Regulation 14
Sulphur oxides and particulate matter (SOx & PM)



發電機選用－電力負荷計算

APPARATUS	MOTOR PARTICULAR				LOAD ANALYSIS AT EACH CONDTION																				
					NORMAL AT SEA			NORMAL AT SEA			DEPARTURE			DEPARTURE			DEPARTURE			CARGO HANDLING			INPORT			EMERGENCY		
	NO.	OUTPUT	EFF.	INPUT	WITHOUT REEF.			WITH REEF.			W/O REEF. & B/T			WITH REEF. ONLY			WITH REEF. & B/T.			WITH REEF.			WITHOUT REEF.			AT S/G FULL		
	SET	KW	%	KW	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.	DF%	CONT.	INT.
ELEVATOR	1	5.5	87	6.3	60	--	3.8	60	--	3.8	60	--	3.8	60	--	3.8	60	--	3.8	60	--	3.8	60	--	3.8	60	--	3.8
ACCOM. VENT. FAN	7	0.4	78	0.5	80	2.9	--	80	2.9	--	80	2.9	--	80	2.9	--	80	2.9	--	80	2.9	--	80	2.9	--	--	--	--
ACCOM. VENT. FAN	2	0.2	73	0.3	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	--	--	--
ACCOM. VENT. FAN	2	0.05	73	0.1	80	0.1	--	80	0.1	--	80	0.1	--	80	0.1	--	80	0.1	--	80	0.1	--	80	0.1	--	--	--	--
GARBAGE HANDLING ROOM EXH FA	1	0.02	73	0.03	80	0.02	--	80	0.02	--	80	0.02	--	80	0.02	--	80	0.02	--	80	0.02	--	80	0.02	--	--	--	--
CO2 ROOM FAN (EXH)	1	0.4	77	0.5	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	80	0.4	--	--	--	--
PAINTS STORE EXH. FAN	1	0.2	77	0.3	80	0.2	--	80	0.2	--	80	0.2	--	80	0.2	--	80	0.2	--	80	0.2	--	80	0.2	--	--	--	--
DRY ROOM REDIATOR	2	1	100	1.0	100	2.0	--	100	2.0	--	100	2.0	--	100	2.0	--	100	2.0	--	100	2.0	--	100	2.0	--	--	--	--
GALLEY & LAUND. EQUIP.	1	100	100	100.0	60	--	60.0	60	--	60.0	60	--	60.0	60	--	60.0	60	--	60.0	60	--	60.0	60	--	60.0	--	--	--
STEAM GENERATOR FOR HUMIDIFIE	1	34	100	34.0	100	34.0		100	34.0		100	34.0		100	34.0		100	34.0		100	34.0		100	34.0				
MISCELLANEOUS	1	10	100	10.0	100	10.0	--	100	10.0	--	100	10.0	--	100	10.0	--	100	10.0	--	100	10.0	--	100	10.0	--	100	10.0	--
GENERAL LIGHT	1	100	100	100.0	50	50.0	--	50	50.0	--	50	50.0	--	50	50.0	--	50	50.0	--	70	70.0	--	40	40.0	--	25	25.0	--
COMMUN. & NAV. EQUIP.	1	10	100	10.0	60	6.0	--	60	6.0	--	60	6.0	--	60	6.0	--	60	6.0	--	20	2.0	--	20	2.0	--	20	2.0	--
REQUIRED POWER						1558	294		4548	294		2047	332		5040	332		6837	327		4280	301		903	314		167	17
DIVERSITY FACTOR						1	0.33		1	0.33		1	0.33		1	0.33		1	0.33		1	0.33		1	0.33		1	0.33
NECESSARY POWER						1558	97		4548	97		2047	110		5040	110		6837	108		4280	99		903	104		167	6
GRAND TOTAL						1655			4645			2156			5150			6945			4379			1006			173	
*** GENERATOR CAPACITY ***																												
NO.1 DIESEL GENERATOR		1980 KW				1980			1980			1980			1980			1980			1980			1980			--	
NO.2 DIESEL GENERATOR		1980 KW				--			1980			1980			1980			1980			1980			--			--	
NO.3 DIESEL GENERATOR		1980 KW				--			1980			--			1980			1980			1980			--			--	
NO.4 DIESEL GENERATOR		1980 KW				--			--			--			--			1980			--			--			--	
EMERGENCY GENERATOR		200 KW				--			--			--			--			--			--			--			200	
																											--	
TOTAL POWER SUPPLY						1980			5940			3960			5940			7920			5940			1980			200	
LOAD FACTOR (%)						83.6			78.2			54.5			86.7			87.7			73.7			50.8			86.3	

發電機選用－電力負荷計算

- 根據電力負荷計算，計算航行與離港的電力負荷
- 平均冷凍貨櫃消耗功率：6.6kW/FEU (11kW x 0.6)
- 負荷因素:　0.85 or 0.9
- 發電機常見 轉速 720 rpm, 900 rpm
- 緊急發電機 機型1800 rpm
- 發電機大小配優點 (採用相同缸徑，不同缸數)
- MAN、Wartsila、Daihatsu、Yanmar、Carterpillar

發電機選用－電力負荷計算

主電機規格

- 發電機：防滴型、自行通風冷卻、無碳刷
- 數量：4部
- 容量：1980 kw x 450V A.C. x 60Hz
- 原動機：4衝程、有增壓機、淡水冷卻之柴油機，720rpm

發電機選用－電力負荷計算

- 各種狀況電力需求如下:
  - 航行(無冷凍貨櫃): 1655 kW, 83.6% (1980kW x 1)
  - 航行(裝滿冷凍貨櫃): 4645 kW, 78.2% (1980kW x 3)
  - 離港(無冷凍貨櫃): 2156 kW, 54.5% (1980kW x 2)
  - 離港(裝滿冷凍貨櫃): 5150 kW, 86.7% (1980kW x 3)
  - 靠港: 1006 kW): 1655 kW, 50.8% (1980kW x 1)

Alternative: 1800 kW x 2 + 2200 kW x 2

主電機選用－燃油消耗量計算範例

- 根據電力負荷分析
  - 正常航行(NOR)無冷凍貨櫃下，所需電力為1658 kw
  - 正常航行(NOR)裝滿冷凍貨櫃下，所需電力為4648 kw
  - 靠港後，所需電力為1007 kw
  - 根據蒸氣消耗量計算，靠港下所需蒸汽量為3334kg/hr
- 主機廠家資料，在NOR馬力(67230 ps)，標準狀況及使用燃油低熱值為10200 kcal/kg下，主機耗油率為122.9 g/ps*h + 5%。
- 電機廠家資料，在標準狀況下及使用燃油低熱值為10200 kcal/kg，電機耗油率為135.2 g/ps*h + 5%
- 根據鍋爐廠家資料，使用燃油低熱值為 9650 kcal/kg(在50℃下黏度為600 cSt)，鍋爐產汽量為4000kg/hr下，鍋爐耗油率為299.5 kg/h

主電機選用－燃油消耗量計算範例

- 根據上述設計條件及廠家資料，假設使用低熱值為9800 kcal/kg 的燃油，電機的效率為95%下，計算下列3種情況下每日所需之燃油消耗量
  - 正常航行，無冷凍貨櫃
  - 正常航行，裝滿冷凍貨櫃
  - 船隻靠港時