台灣國際造船股份公司
CSBC CORPORATION,TAIWAN

節能環保新設計

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110-10-29

節能環保新設計

- 廢氣排放標準
  - Tier III (NOx排放標準)方案
  - SOx排放標準與方案
  - 雙燃料DF引擎介紹
- EEDI規定
- 節能設計
  - 廢熱回收
  - 軸發電機
  - 變頻運用

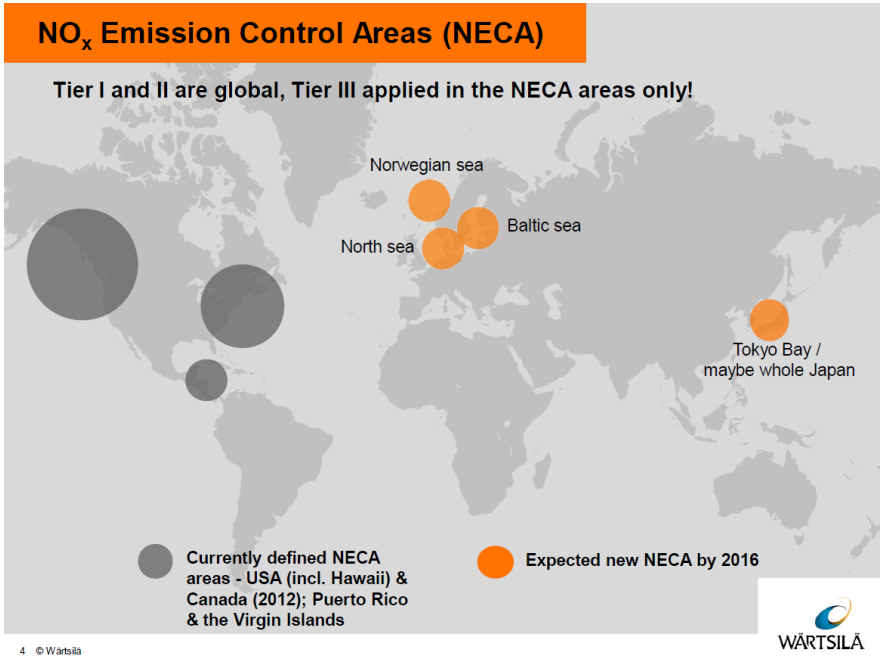
廢氣排放標準－滿足NOx & SOx排放方案

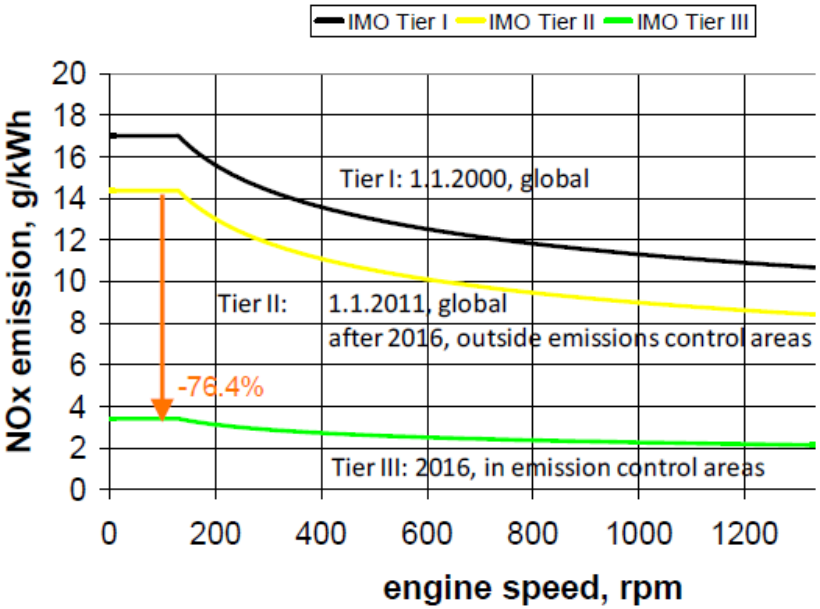
- 因應Tier III對NOx、PM及SOx的嚴格排放標準，下列的解決方案組合。
- 低硫燃料 (MGO) +觸媒降低法(SCR)
- 低硫燃料 MGO + 排氣循環法EGR
- 洗滌器(Scrubber) + SCR
- 洗滌器Scrubber + EGR

廢氣排放標準－滿足NOx & SOx排放方案

- 雙燃料引擎(Dual Fuel engine)-WINGD雙燃料引擎(10bar以下的低壓LNG注氣系統)，當燃料由重油切換到LNG燃料，不需加排煙後處理設備即可滿足Tier III的排放標準
- MAN的二衝程雙燃料引擎為高壓(300bar)LNG注氣系統，需要300bar加壓泵，但僅能滿足Tier II的排放標準，需再加SCR才能滿足Tier III的排放標準。
- Wartsila四衝程雙燃料引擎早已經符合Tier III要求，廣泛的應用在LNG船、海洋工程船上

廢氣排放標準– NOx排放標準





降低NOx排放技術– SCR or EGR

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)*

Fig. 1.02: Two-way approach for Tier III engine – EGR and SCR solutions

降低NOx排放技術– EGR

Bypass matching - 45 ≤ Bore ≤ 70

	Tier II mode			Tier III mode		
MCR	EGR	CBV	EGB	EGR	CBV	EGB
100	Closed	Closed	Open	Open	Open	Closed
75						
65						
50						
25					Closed	

Bypass Matching - Bore ≤ 40

	Tier II mode			Tier III mode		
MCR	EGR	CBV	EGB	EGR	CBV	EGB
100	Open	Closed	Closed	Open	Open	Closed
90						
75	Closed		Open			
65						
50						
25					Closed	

Table 1.05: Control valve operation

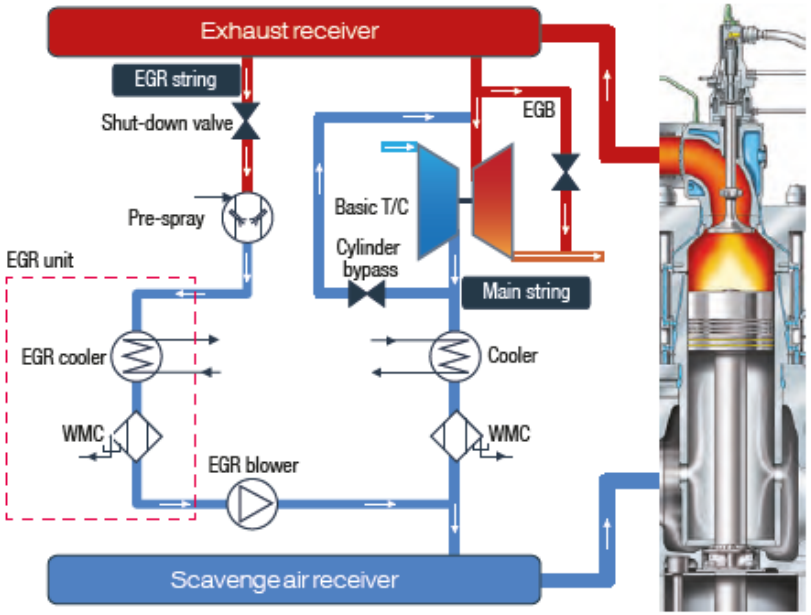


Fig. 1.04: EGR process diagram. Bypass matching

降低NOx排放技術– EGR

TC cut-out matching - Bore ≥ 80

	Tier II mode			Tier II mode – TC cut-out			Tier III mode		
MCR	EGR	CBV	T/C	EGR	CBV	T/C	EGR	CBV	T/C
100	Closed	Closed	Cut in	Not applicable			Open	Closed	Cut out
75								Partly Open	
65				Closed	Closed	Cut out			
50									
25								Closed	

Table 1.07: Control valve operation

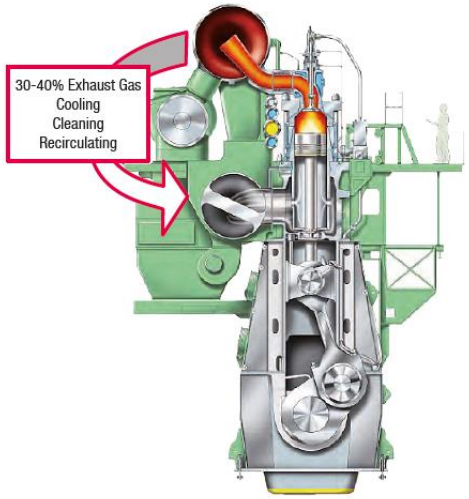
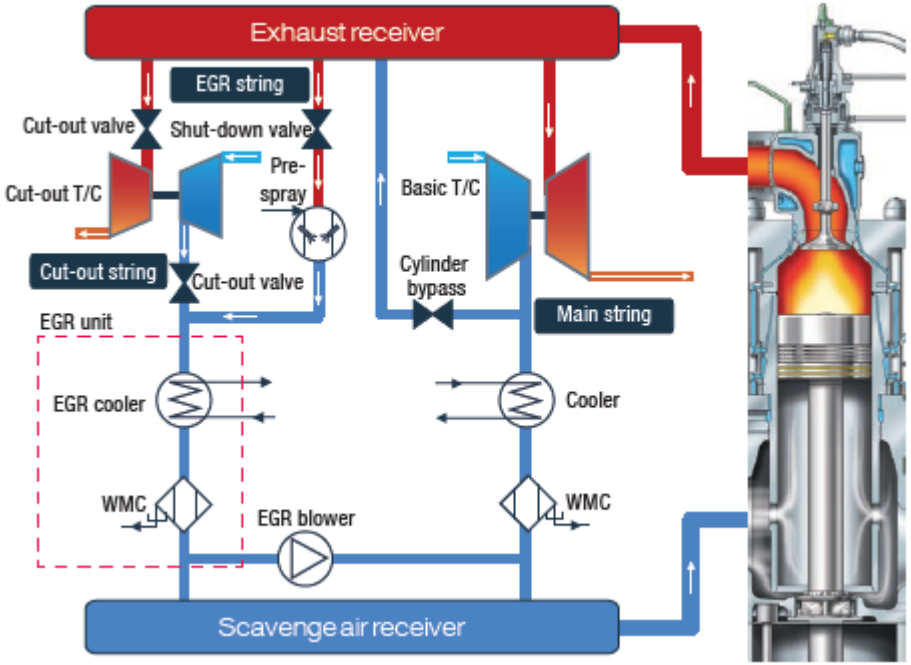
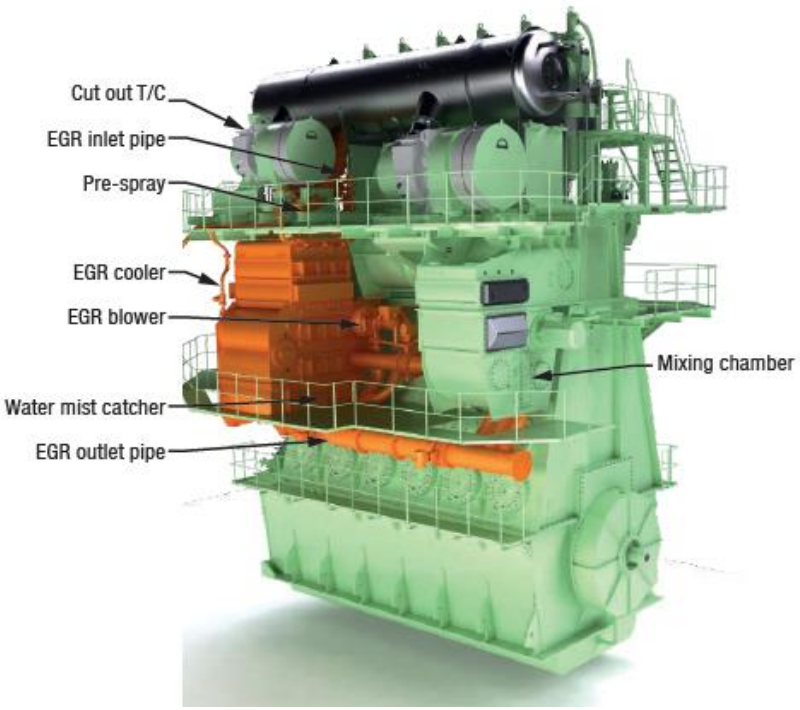


Fig. 1.03: Principle of EGR



降低NOx排放技術– EGR



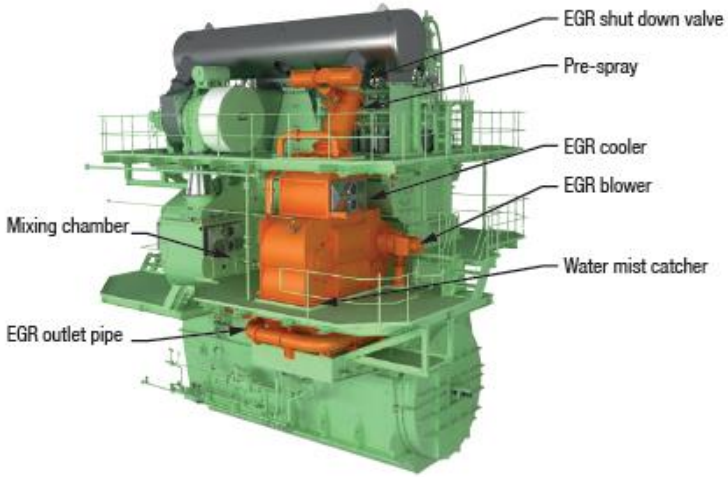


Fig. 1.10: Integrated EGR layout for bypass matching – 6S60ME-C8.2

降低NOx排放技術－ EGR

- MAN建議針對35~70缸徑引擎，採用By-Pass EGR；針對80~95缸徑引擎，採用T/C cut out EGR。
- EcoEGR是新引擎的調校法，在Tier III操作模式，約有35%~45%排煙經過冷卻清潔循環，進入掃氣系統，可以滿足Tier III排放需求，但在Tier II操作模式，僅有10%~15%排煙經過冷卻清潔循環，進入掃氣系統，SFOC可以最佳化，得到較佳的比燃油消耗率，EcoEGR投資約2年半可以回收，MAN估算EcoEGR安裝成本與HP SCR接近。
- 截至107年10月，MAN已經有121部EGR引擎訂單，其中8部引擎已經正式營運中。

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降低NOx排放技術－ SCR

- 觸媒降低法SCR/(Selected Catalyst Reduction)
- SCR系統透過泵浦，將40%的尿素溶解液注入排煙管上的SCR主反應器內，當尿素蒸發分解成HNCO、NH_3及CO_2，將排煙中的NO及NO_2透過觸媒(二氧化鈦titanium dioxide)與NH_3反應後，分解成氮氣(N_2)及水(HO_2)，為達到足夠的反應速率及避免積垢，最佳操作溫度約300~ 450℃，視燃油含硫量而定。

降低NOx排放技術－ SCR

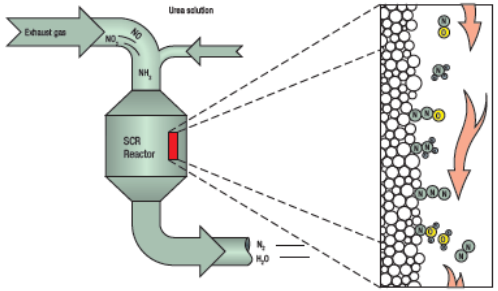


Fig. 1.34: The SCR system

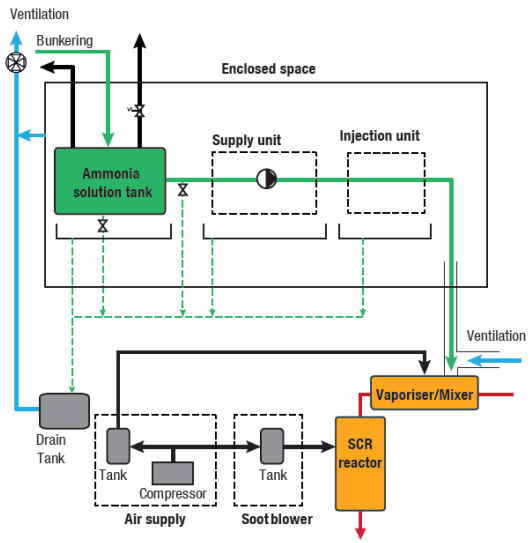


Fig. 1.47: Example of supply system for aqueous ammonia

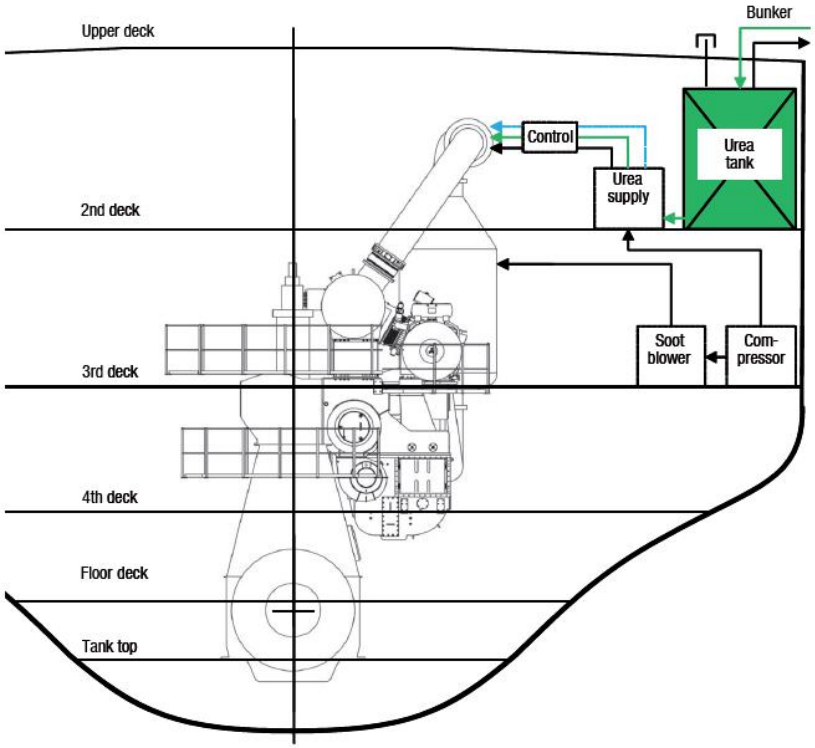


Fig. 1.48: Example of an SCR arrangement in the engine room

降低NOx排放技術－ SCR

- SCR觸媒反應器安裝在排煙管上的位置大不相同，SCR觸媒反應器安裝在排煙管上(LPSCR，詳如右圖)，SCR觸媒反應器與機器本體安裝在一起(HPSCR，詳如左圖)，

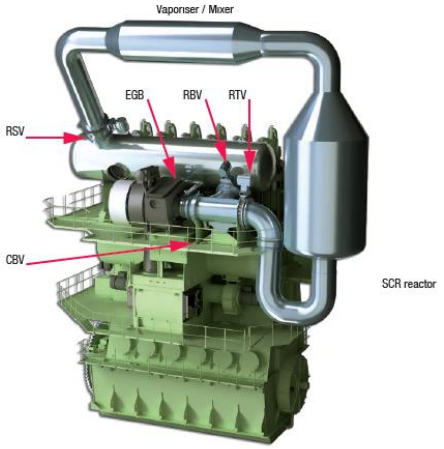


Fig. 1.41: Layout of a high-pressure SCR system, as supplied by Hitachi Zosen

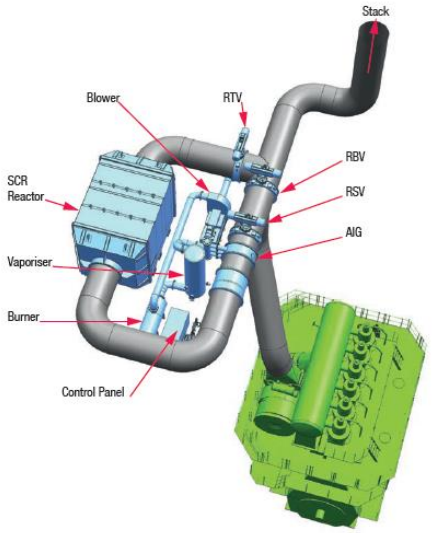


Fig. 1.42: Layout of a low-pressure SCR system, as supplied by Doosan

降低NOx排放技術－ SCR

- 目前，廠家也全力發展大缸徑主機的SCR技術，降低SCR觸媒反應器的尺寸，以降低成本及對機艙佈置的衝擊。
- HP SCR (High Pressure Selected Catalytic Reduction)：此技術適用含硫量0.1%S~3.5%S的燃油。
- LP SCR (High Pressure Selected Catalytic Reduction): 此技術適用最大含硫量0.1%S的燃油
- 截至107年10月，MAN已經有253部2行程主機引擎HP SCR & LP SCR引擎訂單，其中20部引擎已經正式營運中。

廢氣排放標準—SOx排放標準

ECA compliance - SOx control

A. Use compliant fuel oil

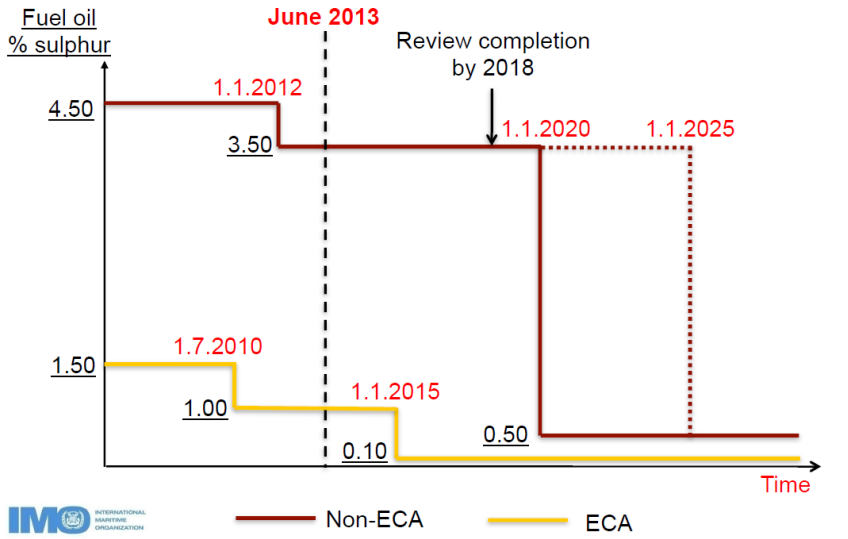
B. Use equivalent e.g., EGCS

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)



降低SOx排放技術-Scrubber

- 因應SOx排放標準要求，目前大部份海運公司採用含硫量0.1%以下的MGO/MDO燃料，當船隻航行到排放管制區，將燃料由重燃油切換到MGO，此種方法較為簡單，但MGO較重燃油昂貴，隨著船隻航行排煙管制區的時間愈久，油價上漲，成本愈高，此時，採用重燃油為燃料搭配排煙洗滌器脫硫裝置的作法，和MGO燃料比較，營運成本相對便宜。
- 排煙洗滌器脫硫有open loop (Sea water mode)、Close loop (Fresh water mode)以及hybrid 系統

降低SOx排放技術-Scrubber

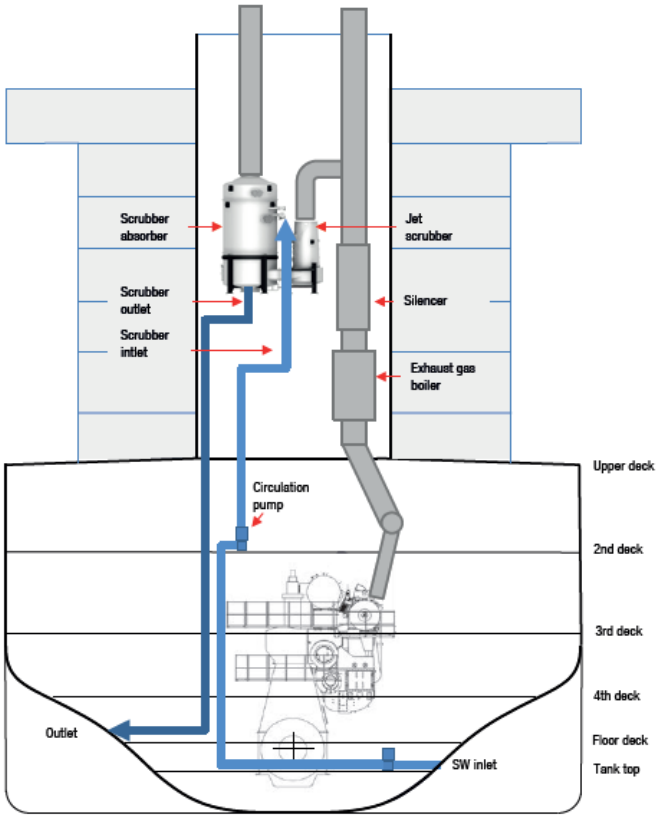


Fig. 2.12: Schematic arrangement of an open loop SO_x scrubber system (SW)

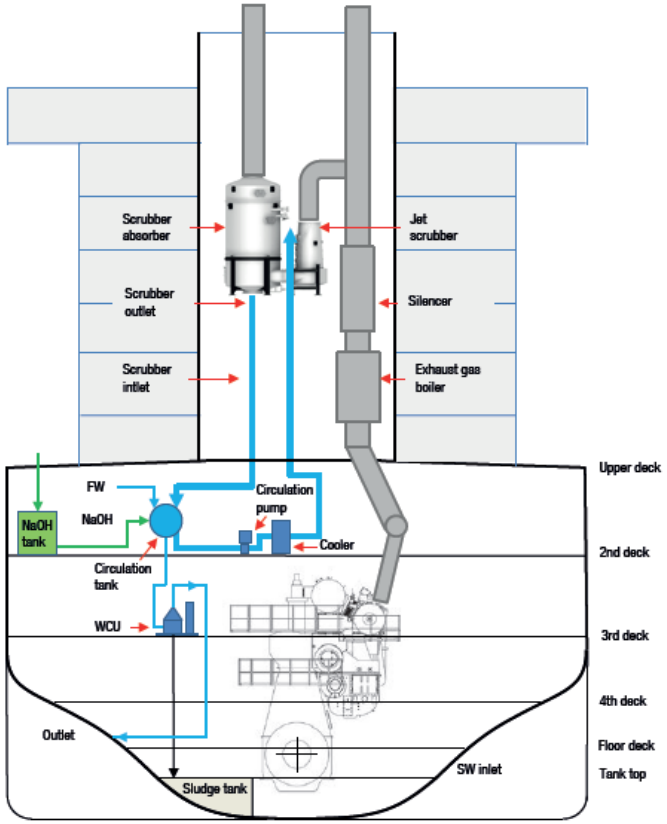


Fig. 2.13: Schematic arrangement of a closed loop SO_x scrubber system (FW)

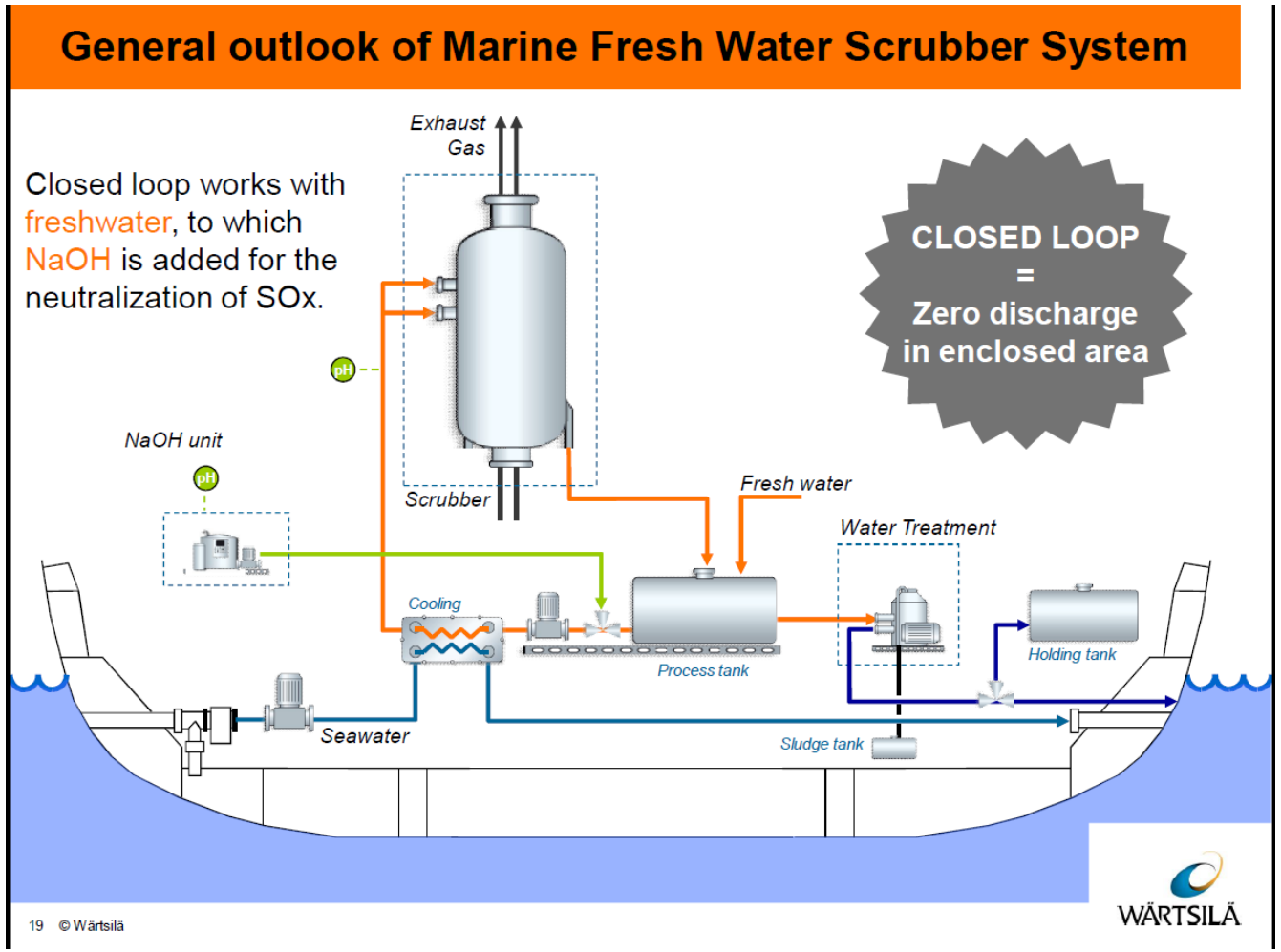
降低SOx排放技術-Scrubber

Close loop (淡水模式)

洗滌器原理係將50%氫氧化鈉溶液自動加入洗滌水循環系統，以維持循環過程的PH值濃度，經由循環泵浦將處理櫃(process tank)內的洗滌水打到海水熱交換器降溫後，再打回洗滌器上方及中間，經噴嘴注入排煙中，排煙由洗滌器底部進入，由頂部排出，洗滌水會吸收排煙中的硫化物、熱量以及其他物質排放物，落入洗滌器底部的洗滌水再回處理櫃(process tank)。

在此密閉迴路中，因水分的蒸發或累積雜質濃度過高而排放掉，需要隨時補充淡水，此為淡水洗滌器系統。

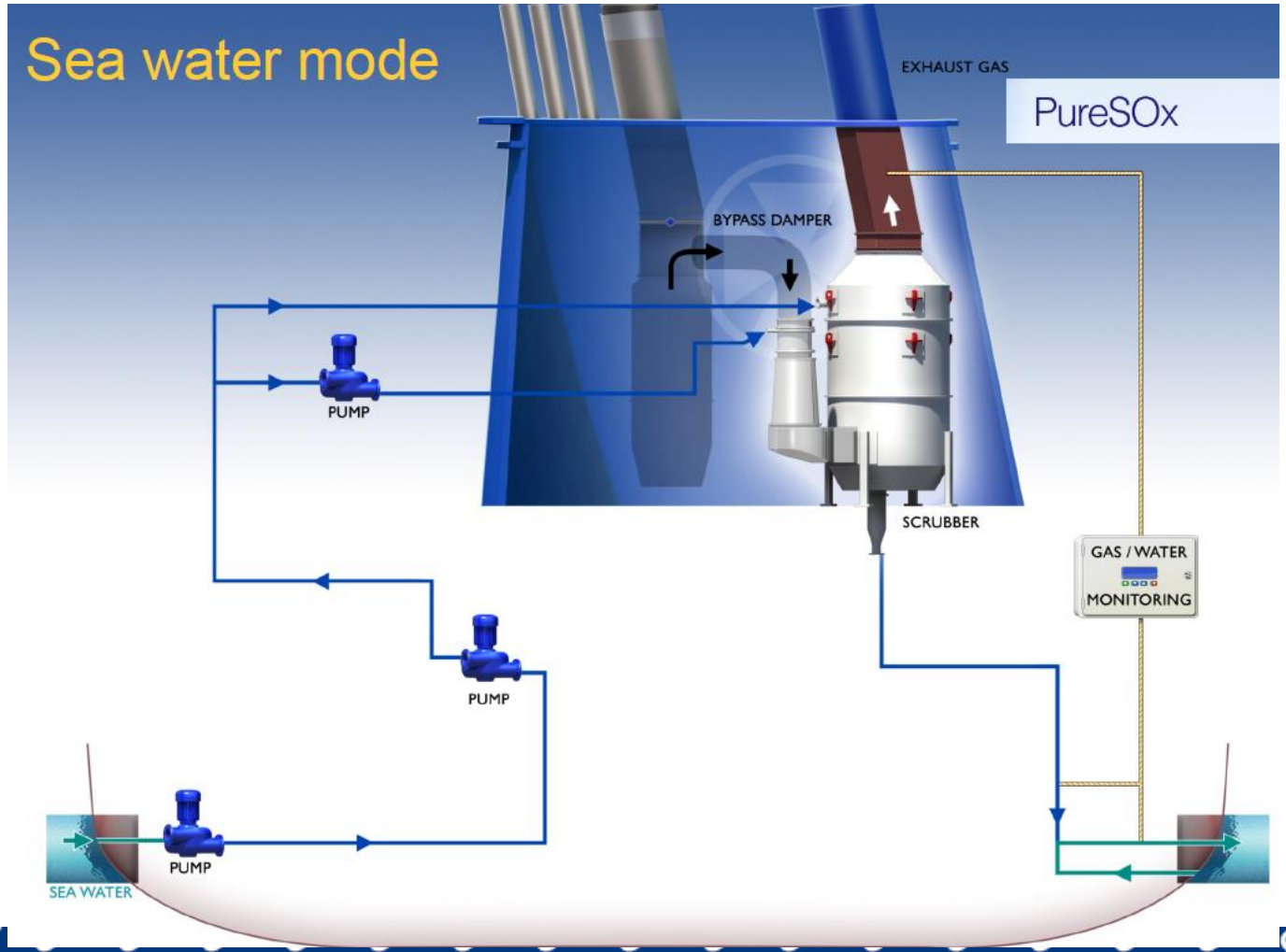
降低SOx排放技術-Scrubber



降低SOx排放技術-Scrubber

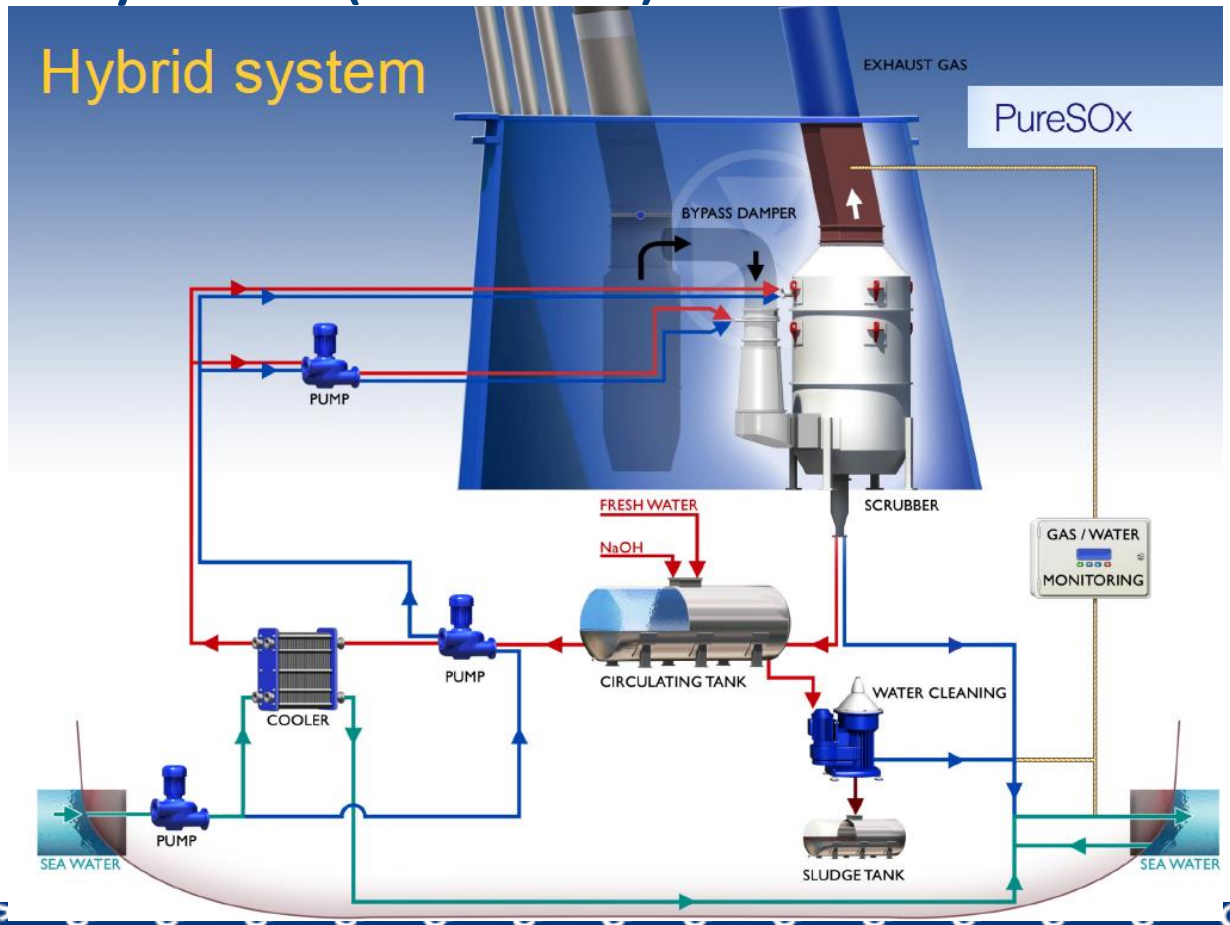
- Open loop (海水模式)
- 為減少淡水消耗量及簡化系統以節省成本，推出新式的海水洗滌器系統，將海水經由洗滌器供應泵浦直接打入洗滌器內頂部、中間及排煙導管入口，經噴嘴注入排煙內，而排煙由導管上部進入往下走，從洗滌器側面進入，再經洗滌器頂部排出，洗滌水會吸收排煙中的硫化物、熱量以及其他物質排放物，落入洗滌器底部的洗滌水再回到除氣櫃(de-aeration tank)，處理後的水質符合排放標準後，直接排出船外。

降低SOx排放技術-Scrubber



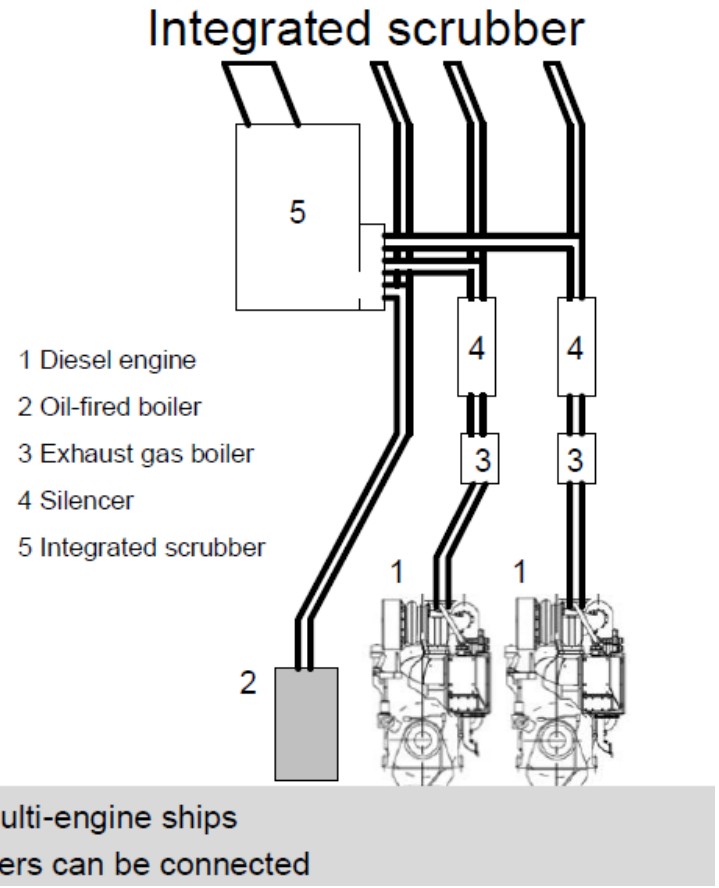
降低SOx排放技術-Scrubber

Hybrid System (FW+SW)



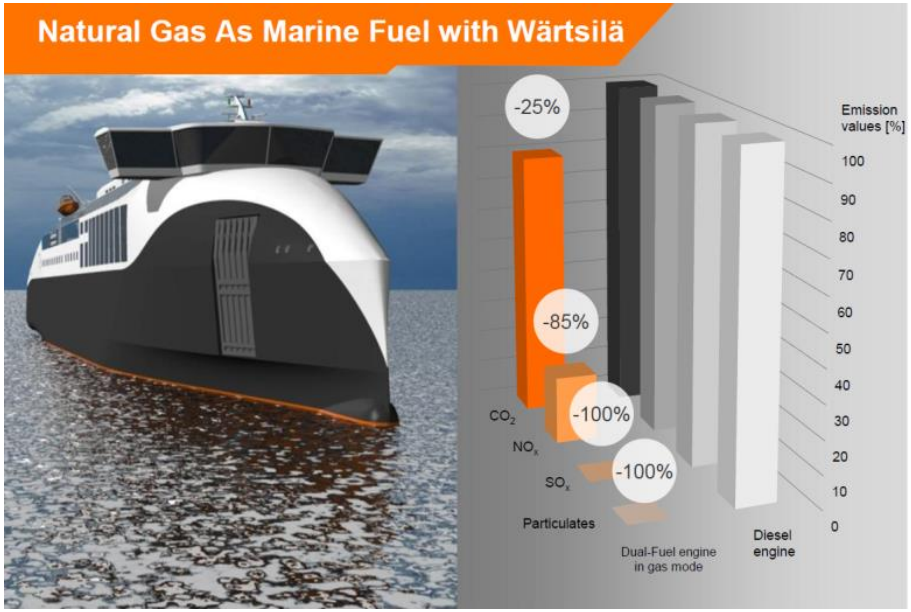
降低SOx排放技術-Scrubber

整合式洗滌器(integrated scrubber)是針對多部引擎(含主機及多部電機)及輔鍋爐排煙佈置，每一根排煙管上加裝旁通管及擋板，將所有旁通管插到旁通主管，連接到洗滌器。當船隻航行到排放管制區時，旁通道擋板開啟，每部引擎或輔鍋爐的主煙道擋板關閉。

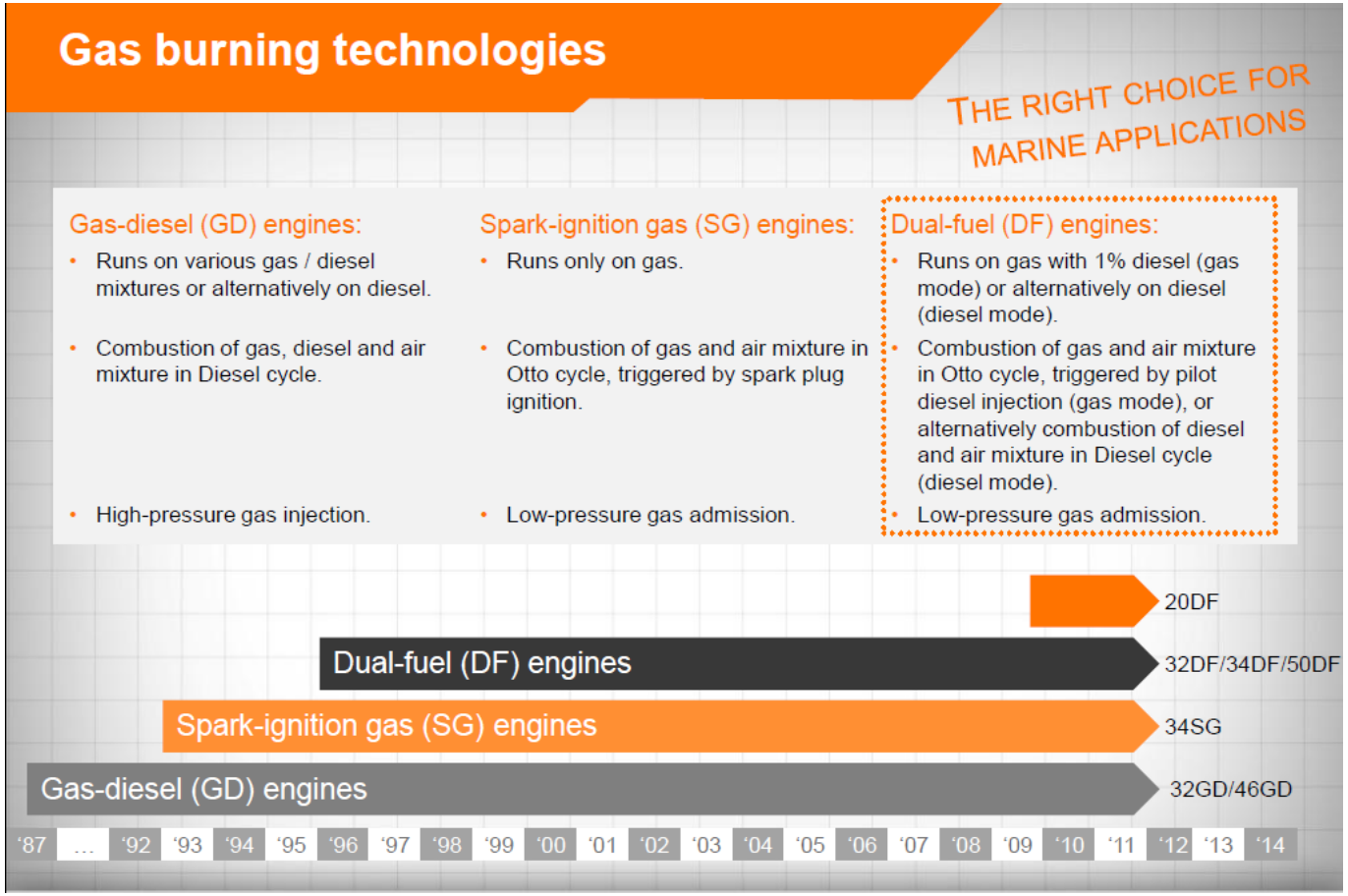


雙燃料DF引擎介紹-

- Wartsila DF引擎使用天然氣，相對於重燃油，其排煙不含硫化物與懸浮物、氮化物大幅減少85%，二氧化碳降低25%。



雙燃料DF引擎介紹-

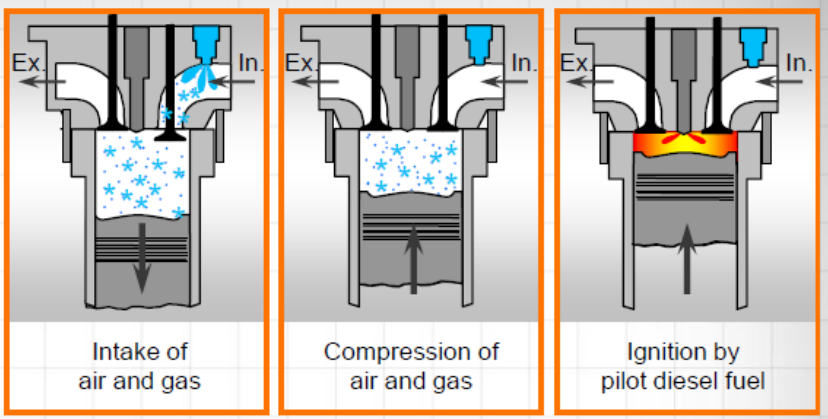

Gas burning technologies
THE RIGHT CHOICE FOR MARINE APPLICATIONS
Gas-diesel (GD) engines:
• Runs on various gas / diesel mixtures or alternatively on diesel.
• Combustion of gas, diesel and air mixture in Diesel cycle.
• High-pressure gas injection.
Spark-ignition gas (SG) engines:
• Runs only on gas.
• Combustion of gas and air mixture in Otto cycle, triggered by spark plug ignition.
• Low-pressure gas admission.
Dual-fuel (DF) engines:
• Runs on gas with 1% diesel (gas mode) or alternatively on diesel (diesel mode).
• Combustion of gas and air mixture in Otto cycle, triggered by pilot diesel injection (gas mode), or alternatively combustion of diesel and air mixture in Diesel cycle (diesel mode).
• Low-pressure gas admission.
20DF
Dual-fuel (DF) engines
32DF/34DF/50DF
Spark-ignition gas (SG) engines
34SG
Gas-diesel (GD) engines
32GD/46GD
'87 ... '92 '93 '94 '95 '96 '97 '98 '99 '00 '01 '02 '03 '04 '05 '06 '07 '08 '09 '10 '11 '12 '13 '14

雙燃料DF引擎介紹-

DF-engine

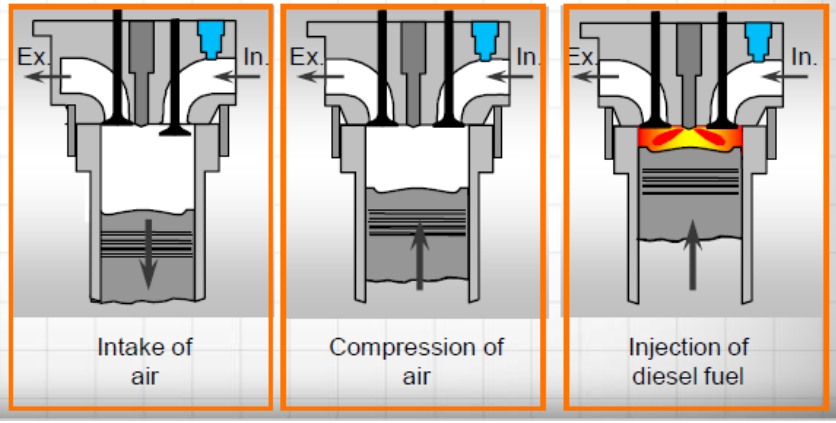
Gas mode:

- Otto principle
- Low-pressure gas admission
- Pilot diesel injection



Diesel mode:

- Diesel principle
- Diesel injection



雙燃料DF引擎介紹-

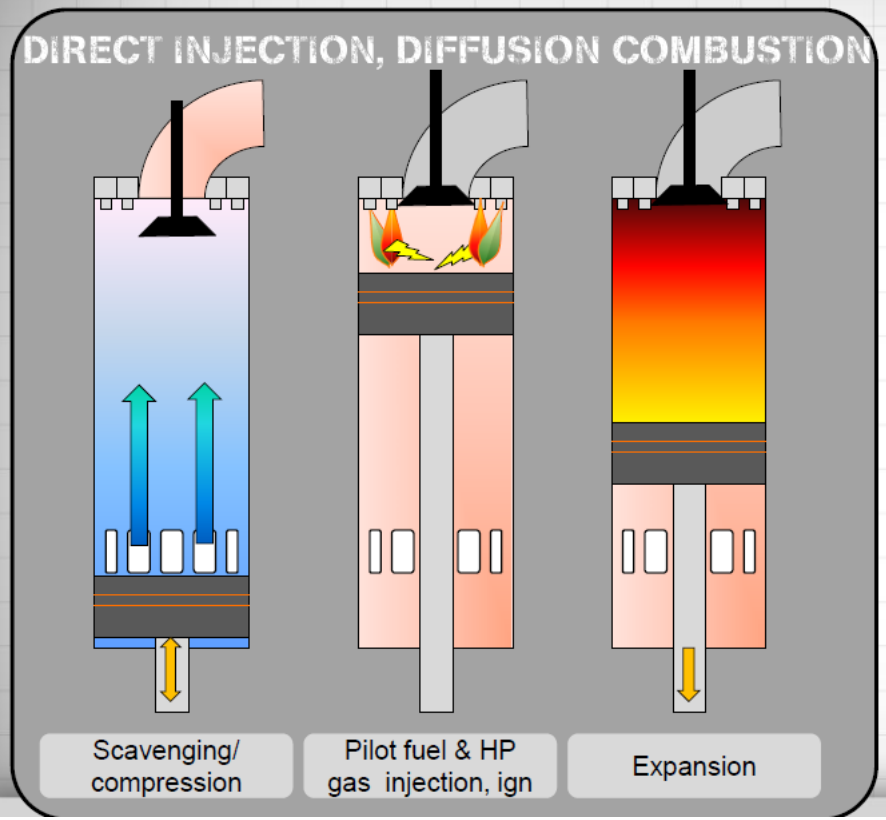
Technology comparison

Technology in gas mode	Competitor	Wärtsilä Product
Spark ignited engine (Otto)	Rolls-Royce Bergen C25:33 and C35:40	W34SG and W50SG, not for propulsion applications.
Lean burn, low pressure, DF engine (Otto/Diesel)	MAN 51/60DF	W20DF, W34DF, W50DF Wärtislä 2-S RT-flex50
High pressure gas injection (Diesel)	MAN ME G-I	W32GD (and W46GD) 4-stroke engine, not for marine applications.

Wärtsilä promotes the DF technology for marine use.

雙燃料DF引擎介紹-

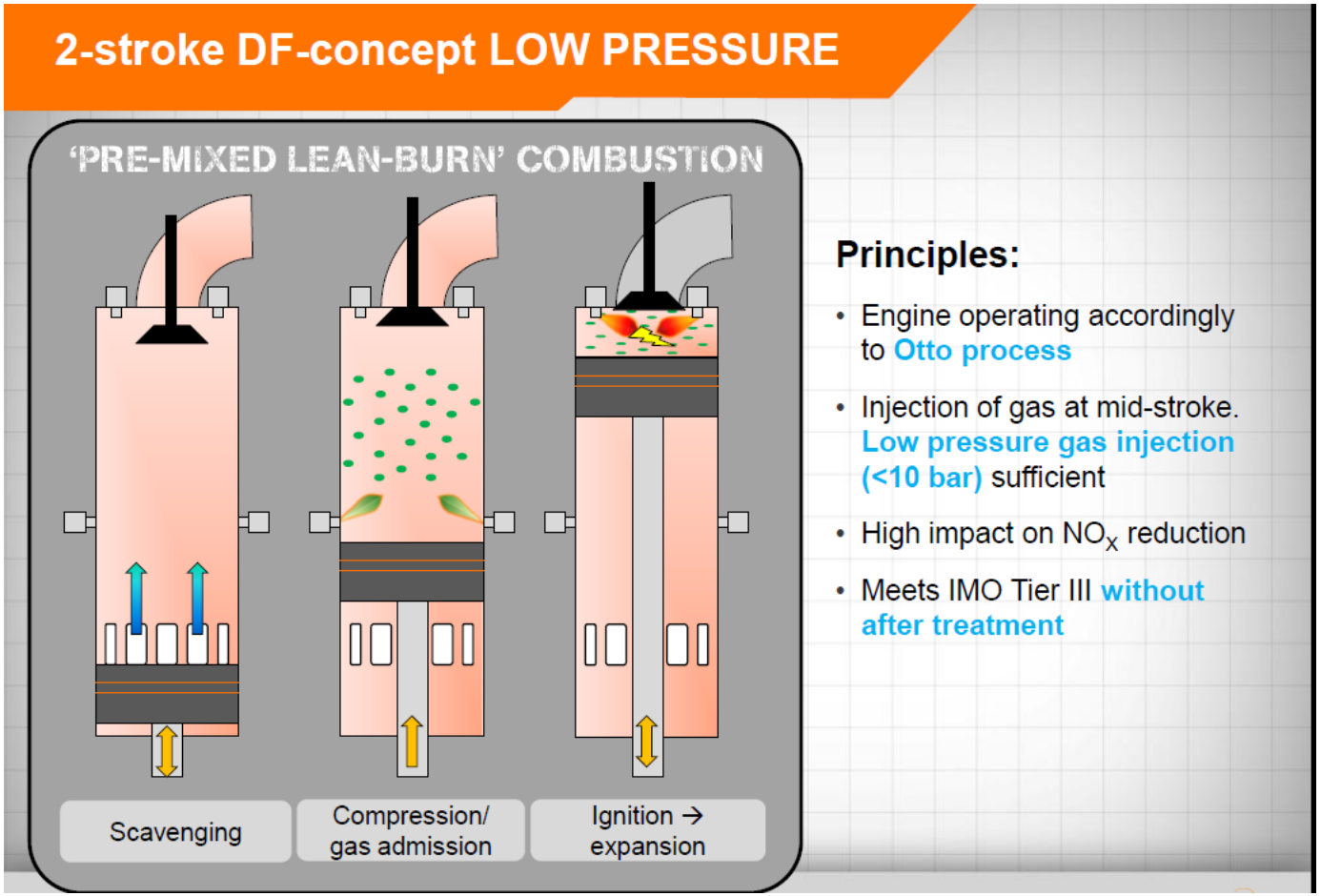
2-stroke GD-concept HIGH PRESSURE



Principles:

- Engine operating accordingly to **Diesel process**
- Injection of gas close to TDC. Air is completely compressed and, therefore, **high pressure gas injection (300 bar)** is required.
- No significant NO_X reduction
- Requires **SCR or EGR** (not proven) in order to meet IMO Tier III levels

雙燃料DF引擎介紹-


2-stroke DF-concept LOW PRESSURE
'PRE-MIXED LEAN-BURN' COMBUSTION
Scavenging
Compression/ gas admission
Ignition → expansion
Principles:
• Engine operating accordingly to Otto process
• Injection of gas at mid-stroke. Low pressure gas injection (<10 bar) sufficient
• High impact on NO_X reduction
• Meets IMO Tier III without after treatment

雙燃料DF引擎介紹-

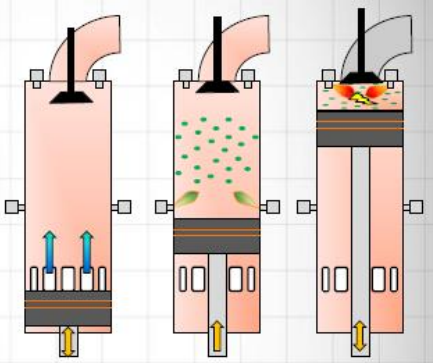
Design requirements

1. To meet the Tier III NOx requirements
   - without after treatment of the exhaust gas

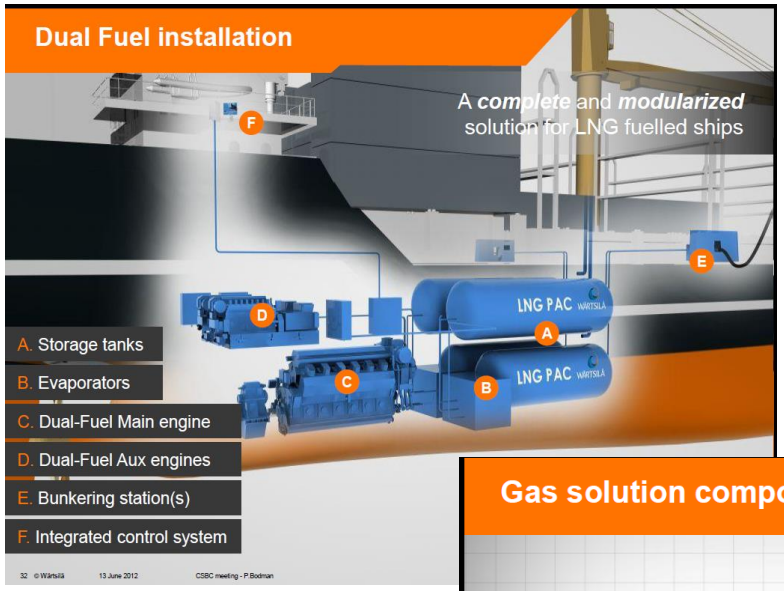
   yes!
2. Low pressure gas system (< 10 bar) and avoid compressor or cryogenic pump
   - lower Capex and Opex
   - lower parasitic load/better efficiency

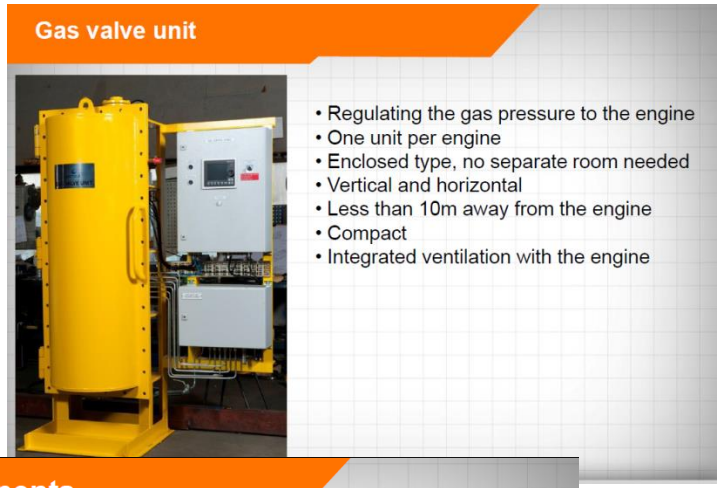
   yes!
3. Dual Fuel capability
   - operation on either gas or HFO

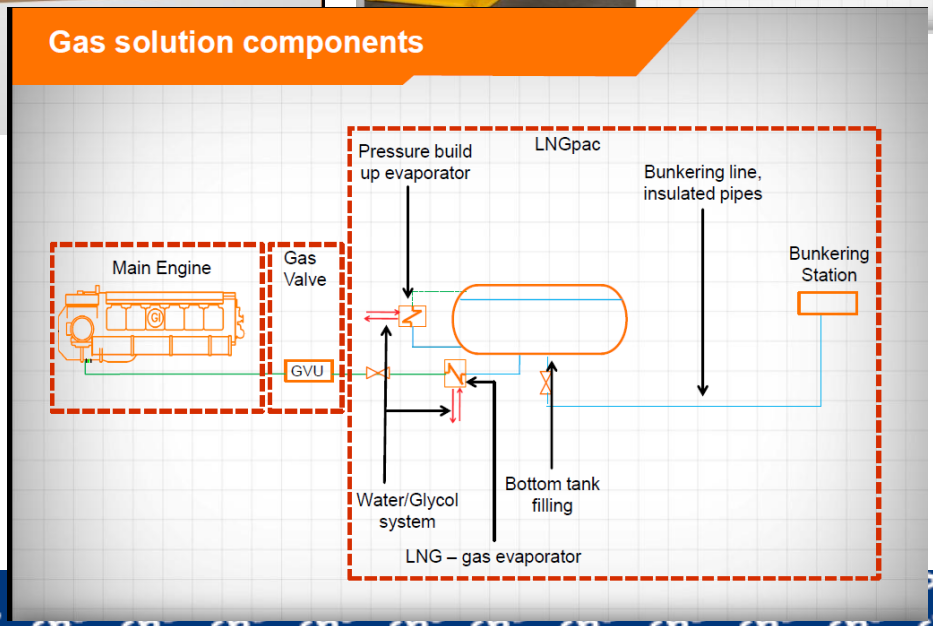
   yes!



雙燃料DF引擎介紹-


Dual Fuel installation
A complete and modularized solution for LNG fuelled ships
F
E
D
A
C
B
LNG PAC
LNG PAC
A. Storage tanks
B. Evaporators
C. Dual-Fuel Main engine
D. Dual-Fuel Aux engines
E. Bunkering station(s)
F. Integrated control system

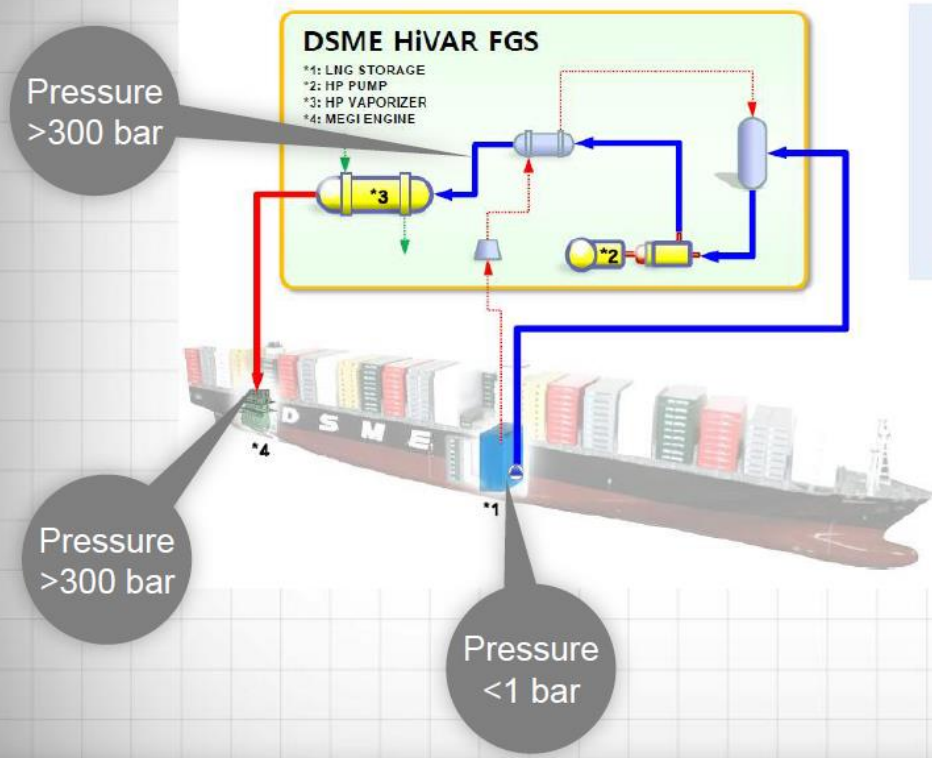

Gas valve unit
• Regulating the gas pressure to the engine
• One unit per engine
• Enclosed type, no separate room needed
• Vertical and horizontal
• Less than 10m away from the engine
• Compact
• Integrated ventilation with the engine


Gas solution components
Pressure build up evaporator
LNGpac
Bunkering line, insulated pipes
Bunkering Station
Main Engine
Gas Valve
GVU
Water/Glycol system
Bottom tank filling
LNG – gas evaporator

雙燃料DF引擎介紹-

2-stoke High pressure

❑ Conceptual Process Flow Diagram



❑ Features

- HP Pump + HP Vaporizer
- 300 bar Design Pressure
- BOG Recondensing
- Compact Size
- Low Power Consumption
- Low Noise & Vibration
- Easy Maintenance

Power Consumption Comparison (for reference)	
HP Compressor System	HiVAR
1400 kW	70 kW

雙燃料DF引擎介紹-

MAN 5G70ME-C9.5-GI與WinGD 5X72DF的比較

	MAN-GI	WinGD DF
循環	Diesel循環	Otto 循環
LNG進氣壓力	300 bar	10 bar
SFOC/SGC	較佳	較差
Pilot oil (DO)消耗	較高	較低
Methane slip / GHC	較佳	較差
FGSS -高壓LNG pump	需要	不需要
EGR	需要	不需要
水質處理設備	需要	不需要
考慮EGR等額外電力消耗	需要	不需要
符合Tier III排氣標準	MAN GI + HP LNG + EGR +水質處理設備	WinGD DF
初期成本	較高	較低

雙燃料DF引擎介紹-

MAN 5G70ME-C9.5-GI與WinGD 5X72DF的比較

根據上述比較，MAN-GI引擎技術改善的重點放在整合相關輔助設備，朝降低初期成本方向，而WinGD DF引擎技術改善的重點朝提高MEP，提高輸出馬力與降低SFOC/SGC方向，經過這幾年技術改善，MAN-GI引擎系統得初期成本有顯著地降低。

節能設計－廢熱回收

- 廢熱回收
  - 淡水製造機 (FW Generator)
  - 廢氣節熱器 (EGE)
  - WHR (Waste Heat Recovery)

節能設計－廢熱回收-MAN範例

Power Turbine Stand Alone

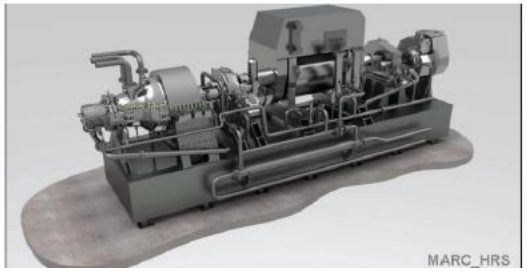
PTG – Power Turbine Generator

Steam Turbine Stand Alone

STG – Steam turbine generator

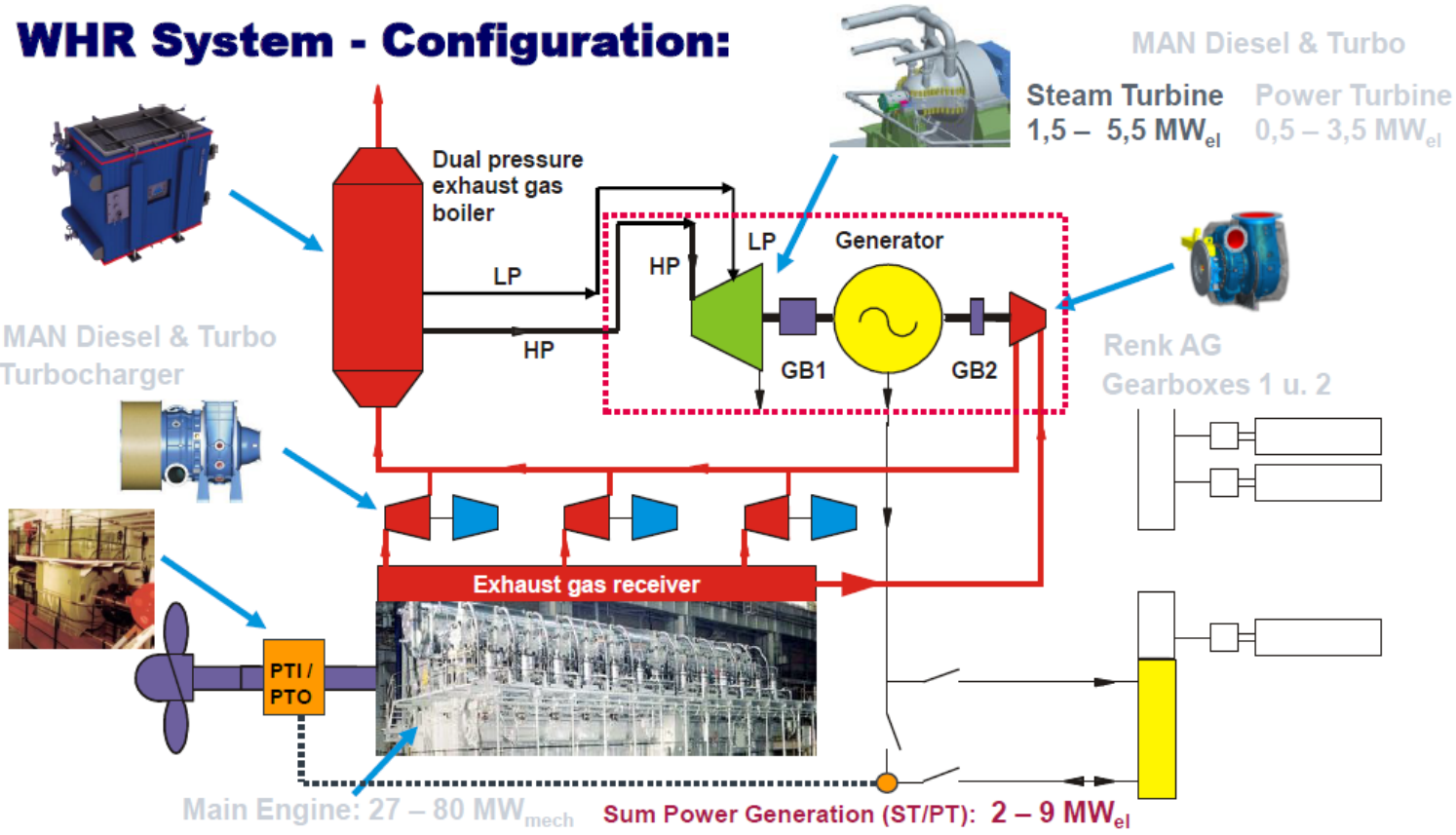
Combined Turbines

Steam turbine – Power turbine



節能設計－廢熱回收-MAN範例

Combined Turbine

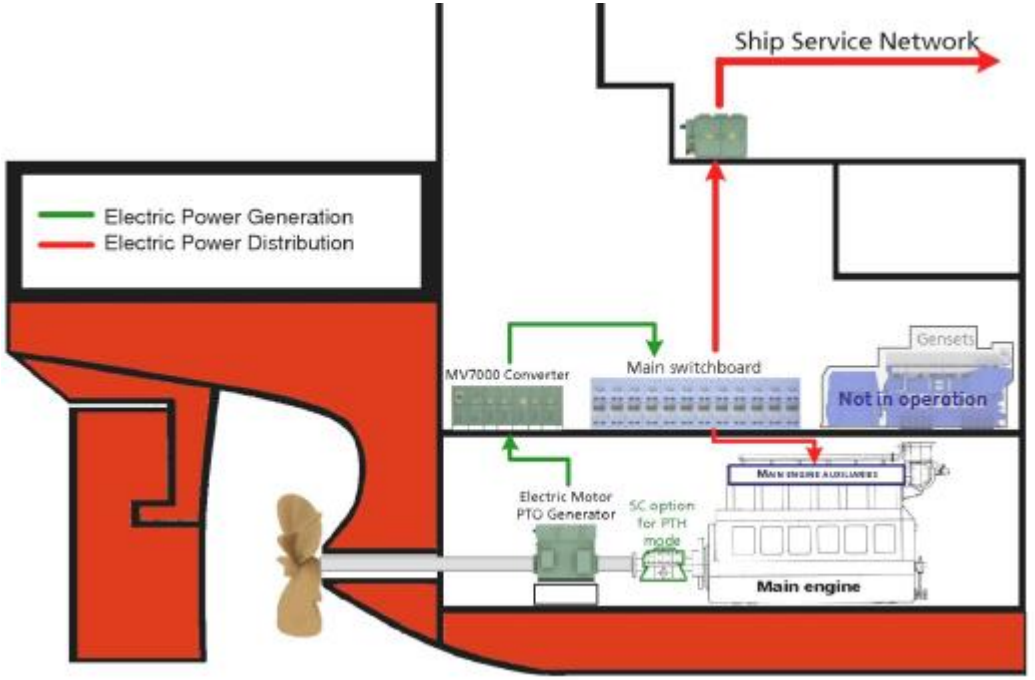


節能設計－軸發電機

- 軸發電機
  - PTO
  - PTI
  - PTH
  -

節能設計一軸發電機(GE Energy範例)

PTO: POWER TAKE OUT (ELECTRIC POWER GENERATION MODE)

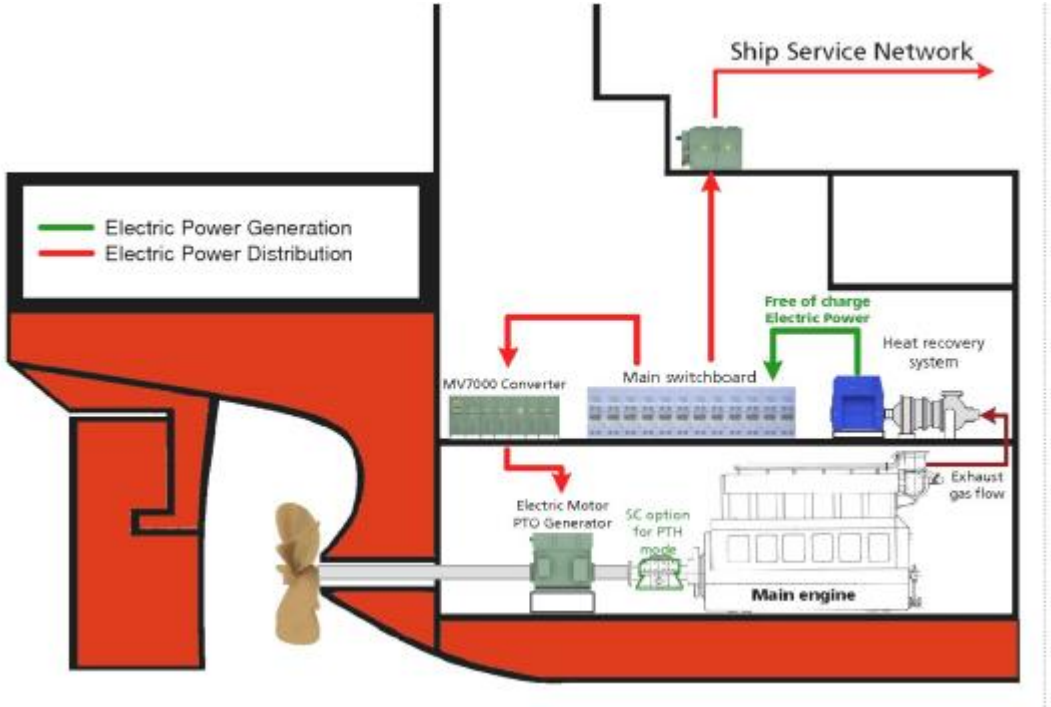


Main advantages:

- **Economic electric power generation:**
  - Redundancy of electric power sources (Electric power is supplied by PTO generators and generators of the Main gensets)
  - Independence of main engine with regard to gensets (no need of gensets to supply main engine auxiliaries)
- **Improved Genset integration:**
  - Less gensets needed onboard (a part of electric power generation comes from PTO generators)
  - Less maintenance on gensets (Gensets are not used during free sailing)
  - Less noise, vibrations and losses in engine control room (gensets are not used during free sailing)

節能設計一軸發電機(GE Energy範例)

PTI: POWER TAKE IN (BOOSTER MODE)

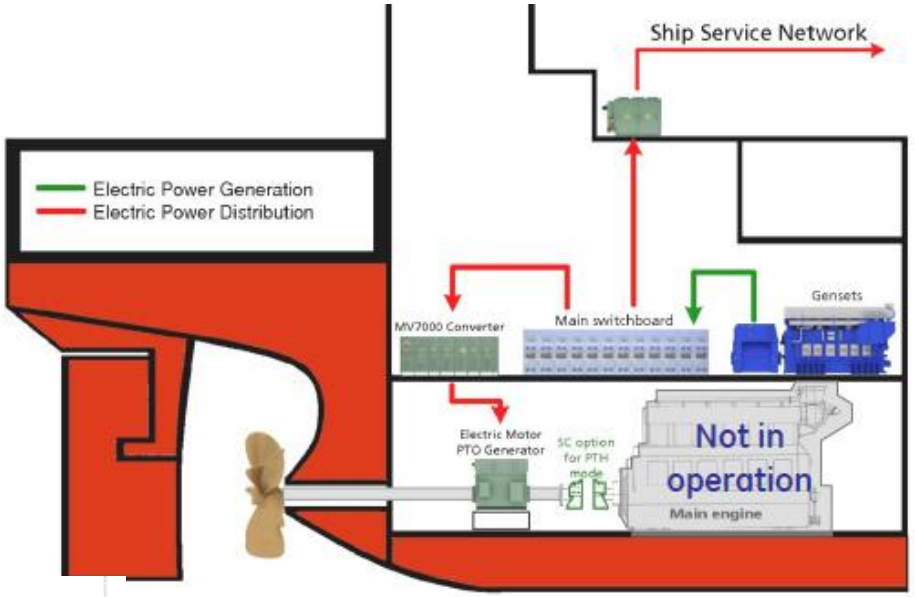


Main advantages:

- **Free of charge electric power:**
  - **Increased propulsion power**: for shipbuilding of new heavy tankers, power is not sufficient, in order to keep only one shaft line. Electric Booster is the simplest solution to maintain competitive operational vessel speed.
  - **For the same vessel speed, main engine can be smaller**: the global thrust power is supplied by main engine and PTI electric motor.
  - For the same main engine, **vessel has a better overall efficiency**, represented by an increase of free sailing speed.
  - **Allows fuel cost savings**

節能設計一軸發電機(GE Energy範例)

PTH: POWER TAKE HOME (EMERGENCY MODE)

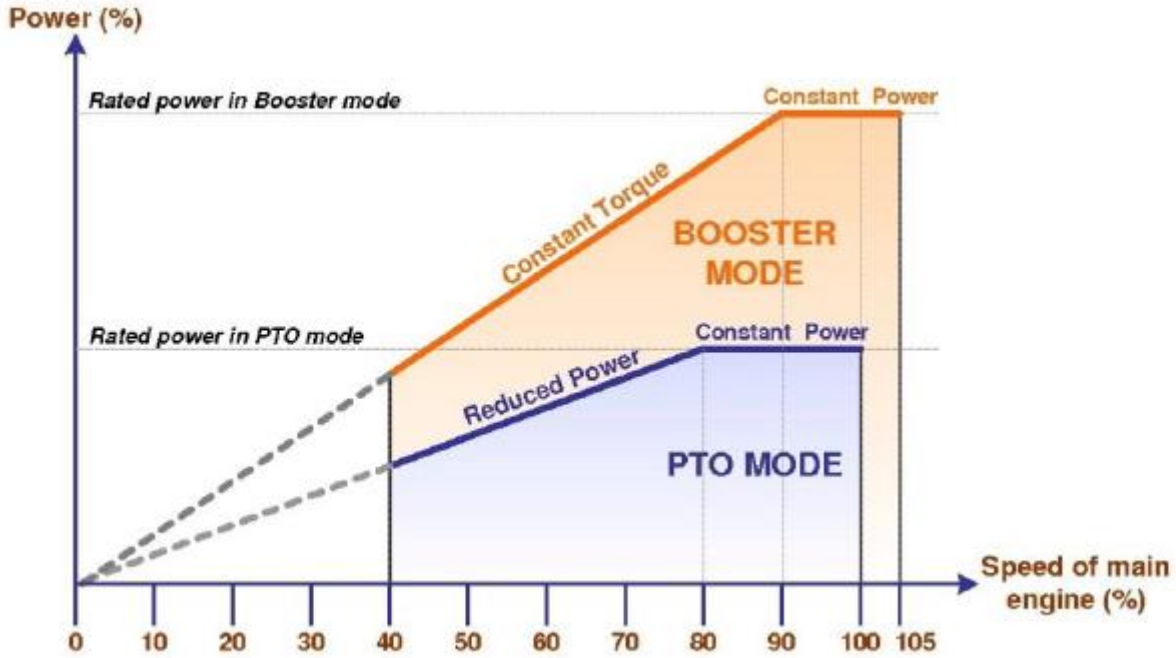


Main advantages:

- **Fully redundant propulsion system:**
  - Fully independent propulsion system in case of main engine failures: in case of emergency, vessels fitted with PTH drive are able to maintain maneuverability and reach terminal harbor.
  - Fully compliant with redundancy class specified by classification societies for the minimization of cargo loss which can lead to ecological disasters.
  - Electric propulsion is available in short order: vessels can start quickly in case of emergency.

- **Economical benefits:**
  - Main propulsion system only used during free sailing: With PTH drive, main engine are only used during optimum load conditions so less engine maintenance is needed.
  - Ship-owner can benefit of electrical propulsion advantages during slow speed maneuvers: During harbor maneuvers and slow speed transit, electric propulsion can be used. Electric propulsion main advantages are:
    - Fuel savings (better overall efficiency)
    - Environmental friendliness (fully compliant with harbor regulations)

節能設計一軸發電機(GE Energy範例)



EXAMPLE:

For BOOSTER mode:

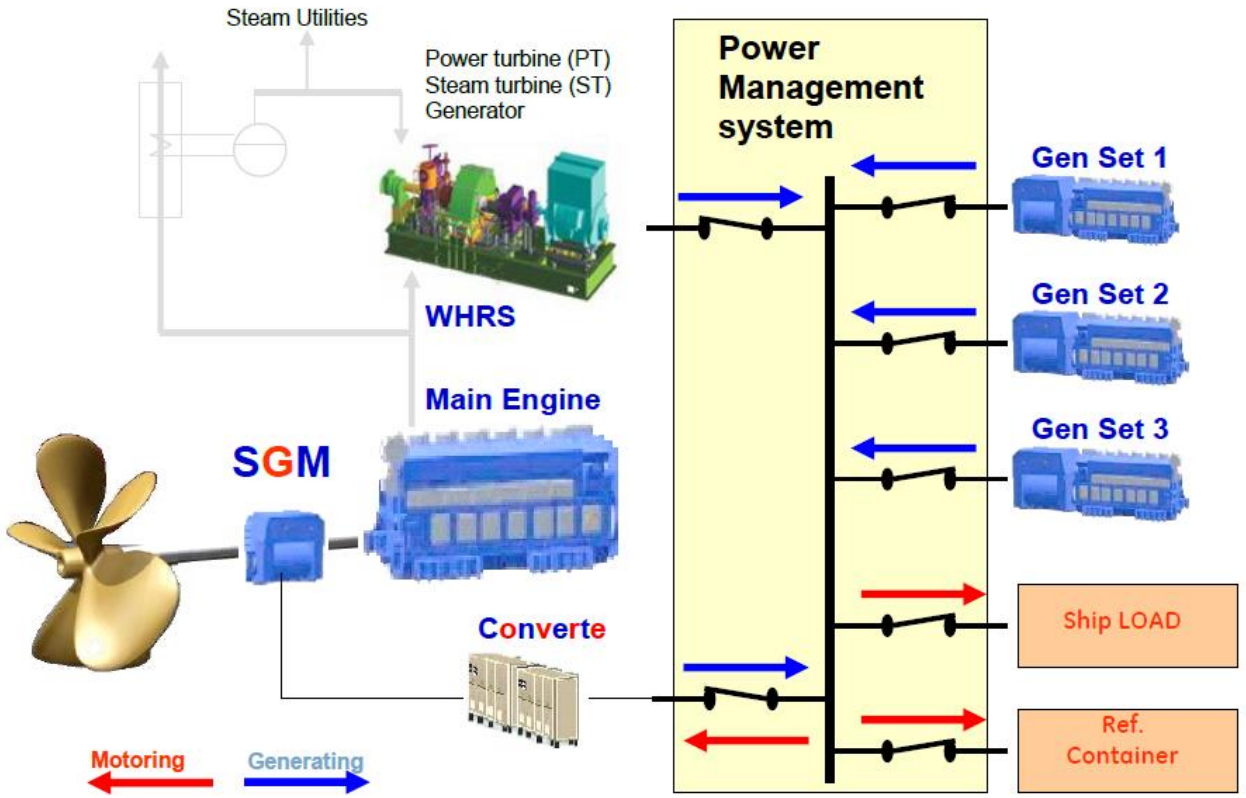
- Constant torque between 40 & 90% of the nominal main engine speed
- Constant power between 90 & 105% of the nominal main engine speed

For PTO mode:

- Constant power between 80 & 100% of the nominal main engine speed
- Reduced power between 40 & 80% of the nominal main engine speed

節能設計－軸發電機(GE Energy範例)

- **WASTE HEAT RECOVERY / PTI & PTO SYSTEM MONITORING FUNCTION**



節能設計－變頻運用

- 變頻技術使用
- 中央冷卻水系統(海水泵+中央冷卻水泵)
- 機艙與貨艙通風

Q & A