The Wärtsilä low-speed, low-pressure dual-fuel engine

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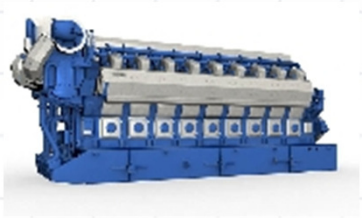
Content

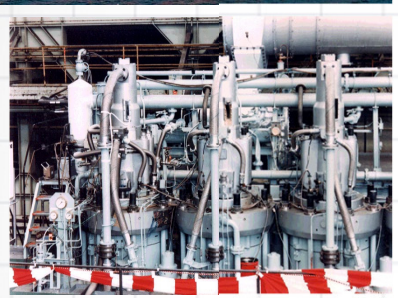
- Introduction
- Concept & Design details
- Emission levels
- Safety aspects
- Fuel gas handling system
- References
- Summary

The development path for gas powered Marine Engines

1972 – launching **7RNMD90**
Low-Pressure DF Engine
for 29,000 m3 LNGC, 'MV Venator'
Moss Yard, Norway



1992 – **Low-Pressure**
Spark-Ignited Engine



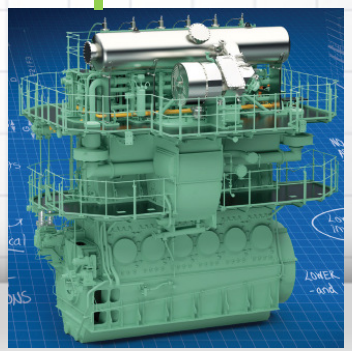
1986 – testing **High-Pressure**
DF Engine **6RTA84** at IHI,
Japan

1995 – **Low-Pressure**
Dual-Fuel Engine
Break through in marine segment

2013 – **Low-Pressure**
Dual-Fuel Engine

1970 1980 1990 2000 2010

1987 – **High-Pressure**
Gas Diesel Engine



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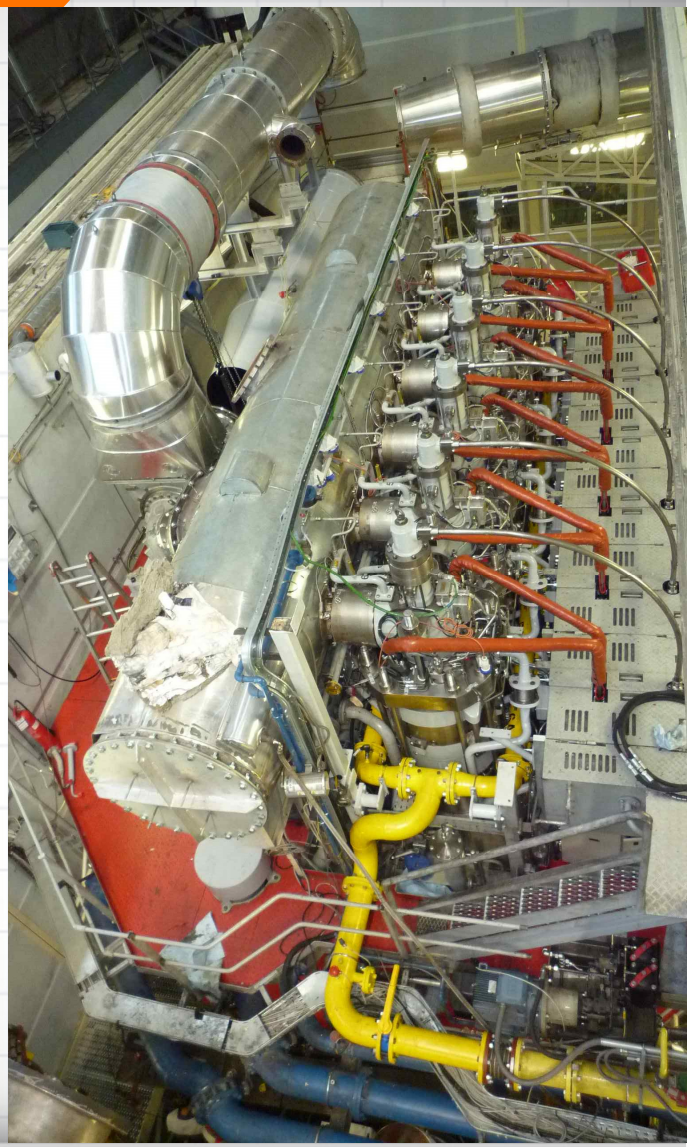
RTX-5 test engine activities

- **6RT-flex50DF** test engine in Trieste, Italy
- Gas trials on **one cylinder in 2011 - 2013** for concept development, ~1000 rhs accumulated
- **Full-scale testing** started in August 2013, ~ 1050 rhs accumulated
- **Engine performance confirmed**
- Key advantages of the 2s DF technology **successfully confirmed**
- Exploration of further **performance improvements** ongoing



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X72DF test engine in Diesel United

- **Strong support / interest from Japanese customers in 2sDF engines**

  → Cooperation with Japanese licensee Diesel United Ltd.

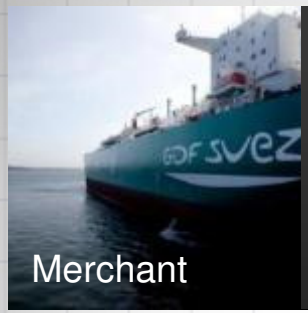
- **6X72DF test engine** will be installed at **Diesel United's facilities**

- Engine start scheduled for **beginning of 2015** (engine production already started)

- **Main objectives:**
  - Additional test engine/facility
  - Further combustion and performance optimization, but on larger bore engine sizes, including fuel sharing mode

6X72, Doosan

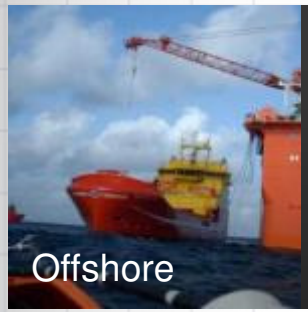
Dual-fuel application references – medium -speed



LNG Carrier	160 vessels
Multigas Carrier	7 vessels
Ro-Ro	2 vessels
Bulk Carrier	1 vessels
Conversion	1 vessels

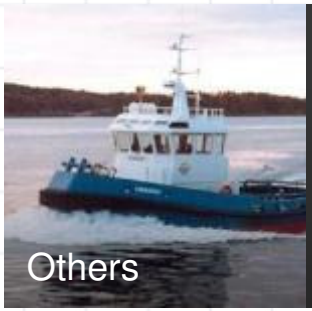
~ 650 engines

Coastal Patrol
- DF-propulsion
- DF main and auxiliary engines



OSV's
- 31 vessels
- 96 engines

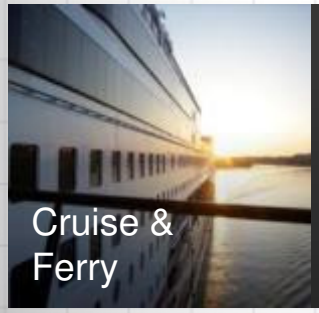
Production
- 2 platform
- 9 FPSO's etc.
- 1 FSO
- 40 engines



TUG
- 2 vessel
- 2 engines each
- Mechanical drive

Guide Ship
- 1 vessel /engine

IWW
- 2 vessel
- 3 engines



LNG Cruise ferry
- 1 vessels
- 4 engines
- Complete gas train

LNG ferries
- 4 ferries
- 18 engines

Conversion
- 1 ferry
- 2 engines

DF Power Plant
- 67 installations
- 354 engines
- Output 4600 MW
- Online since1997

→ 6 segments → >1,170 engines → >10,000,000 running hours

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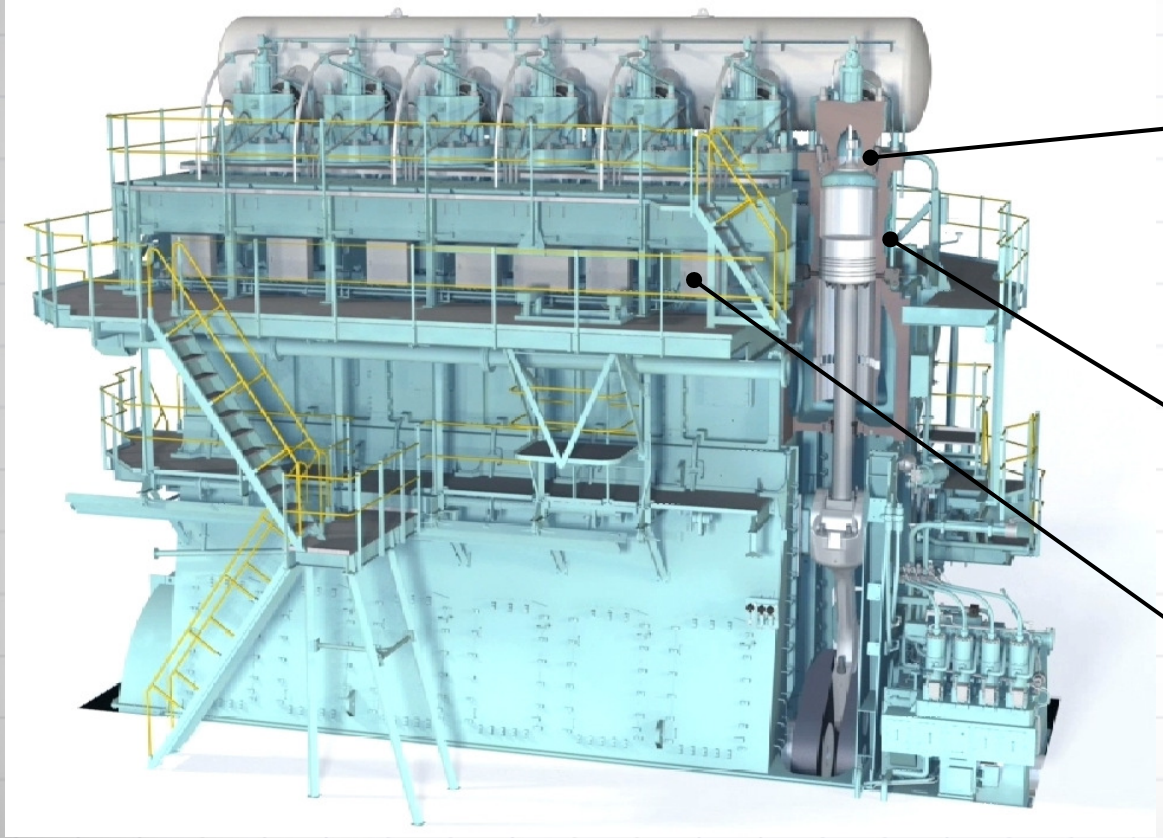
Concept

A few key technologies make the difference...



Pilot common-rail system with pre-chamber injector

Gas admission system

Engine Control & Automation system

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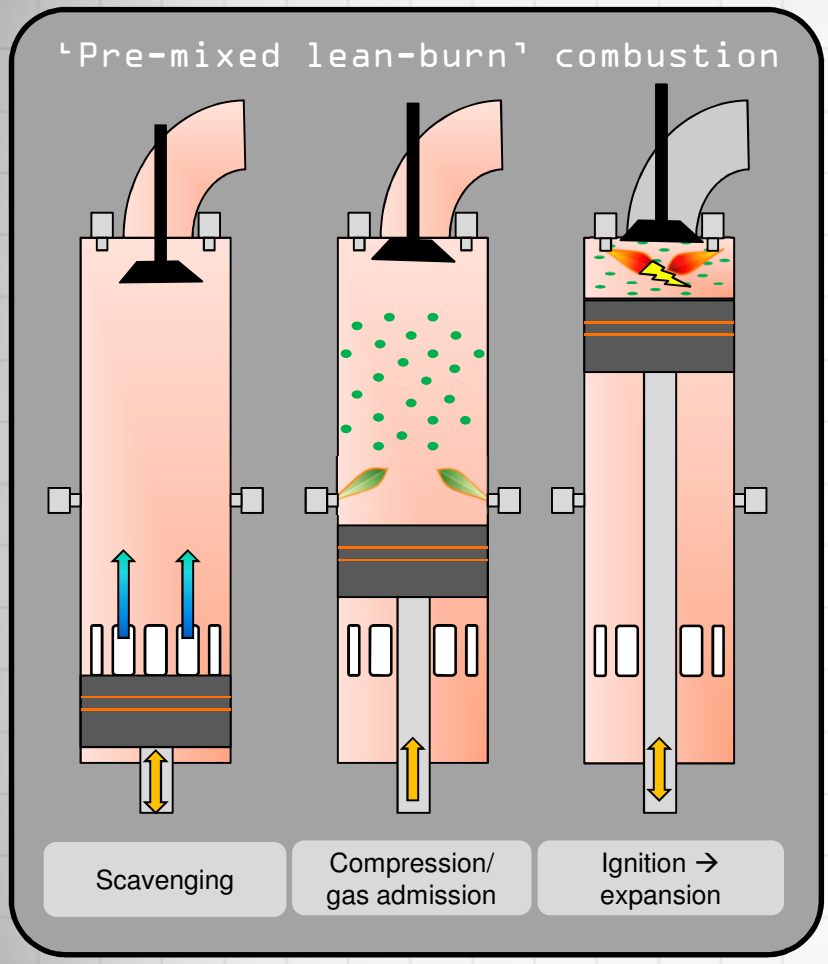
Concept



Principles

- Engine operating according to the **Otto process**
- Pre-mixed **'Lean burn'** technology
- **Low pressure gas** admission at 'mid stroke'
- Ignition by pilot fuel in **pre-chamber**

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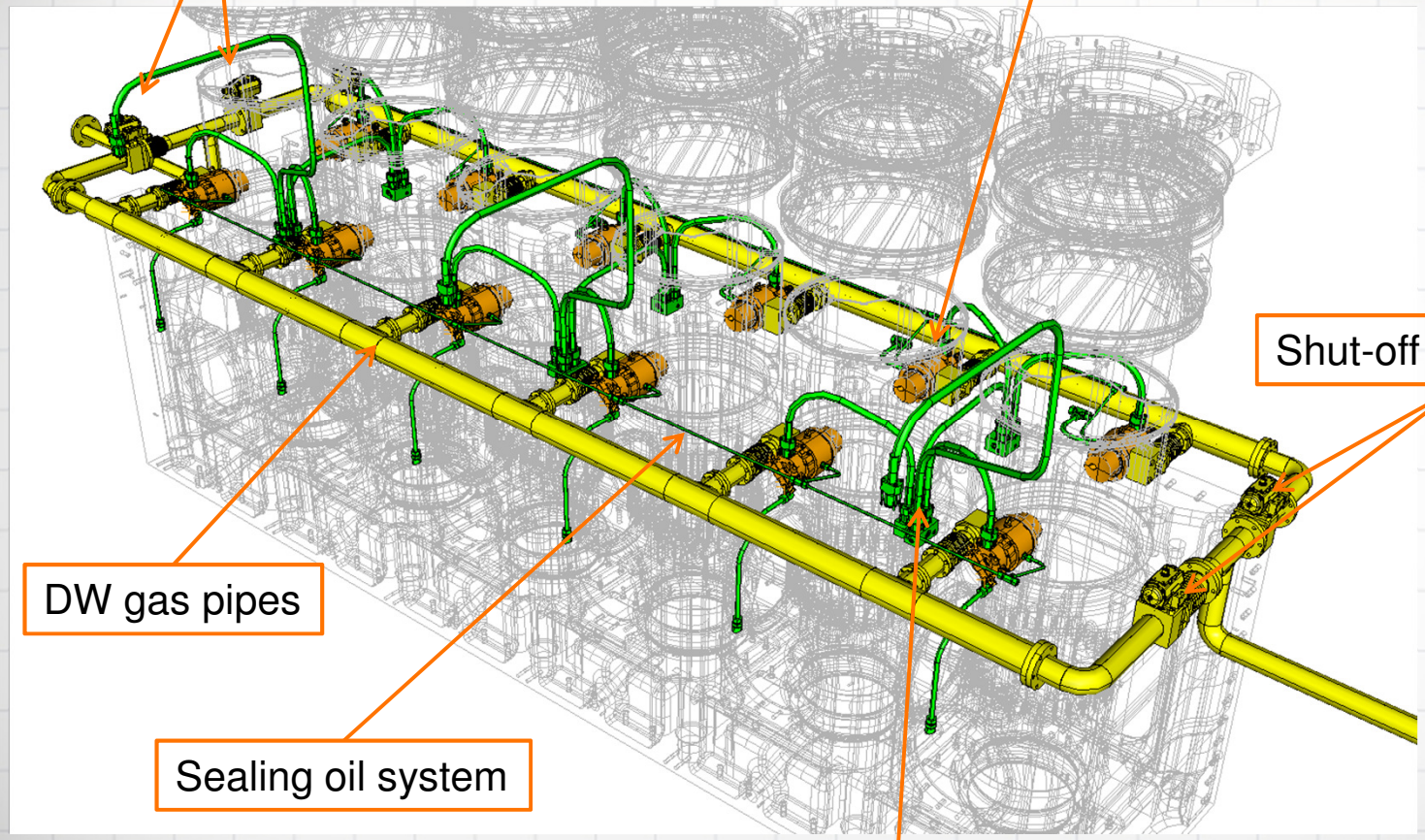
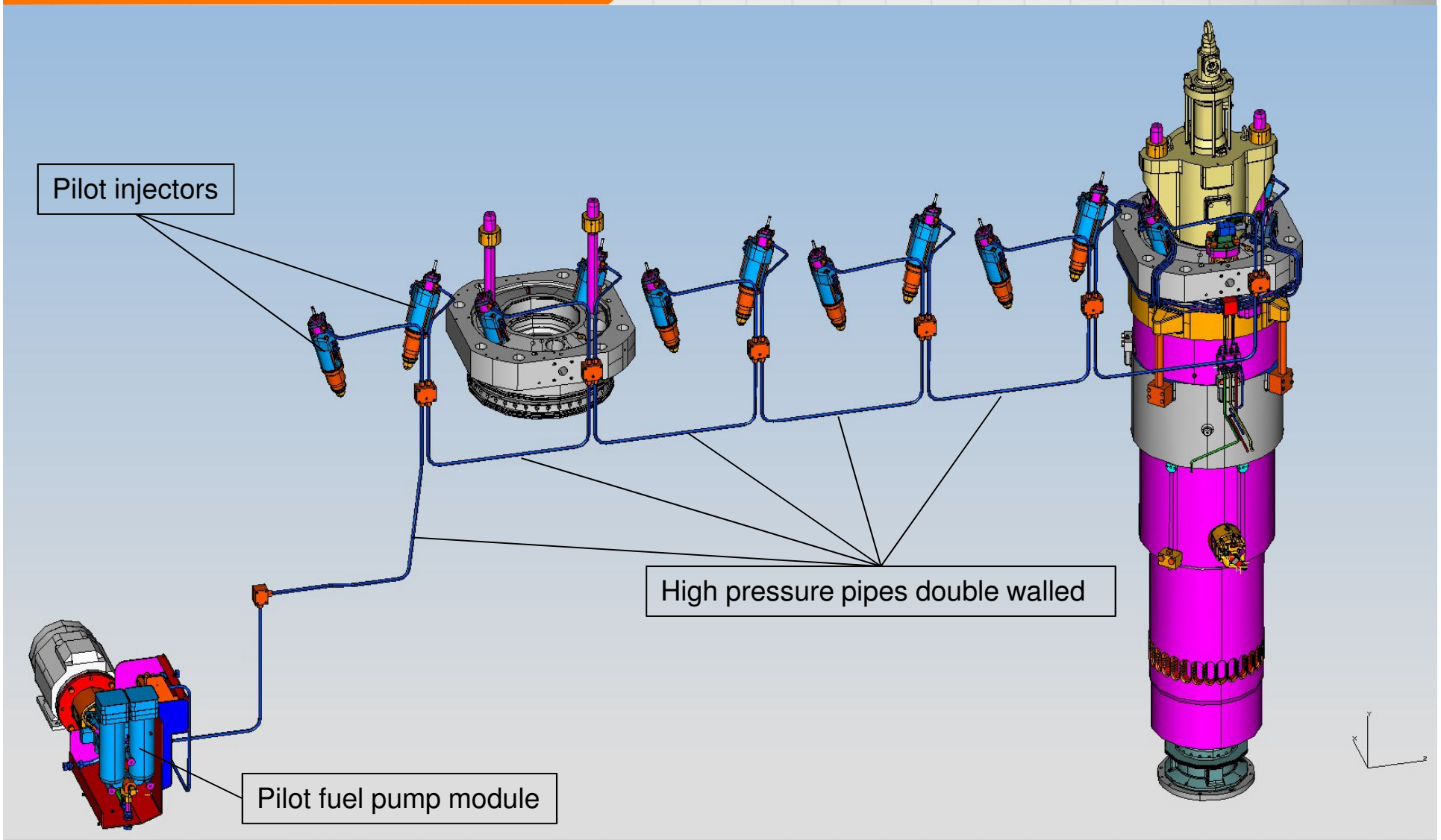
Gas admission system



Pilot fuel system



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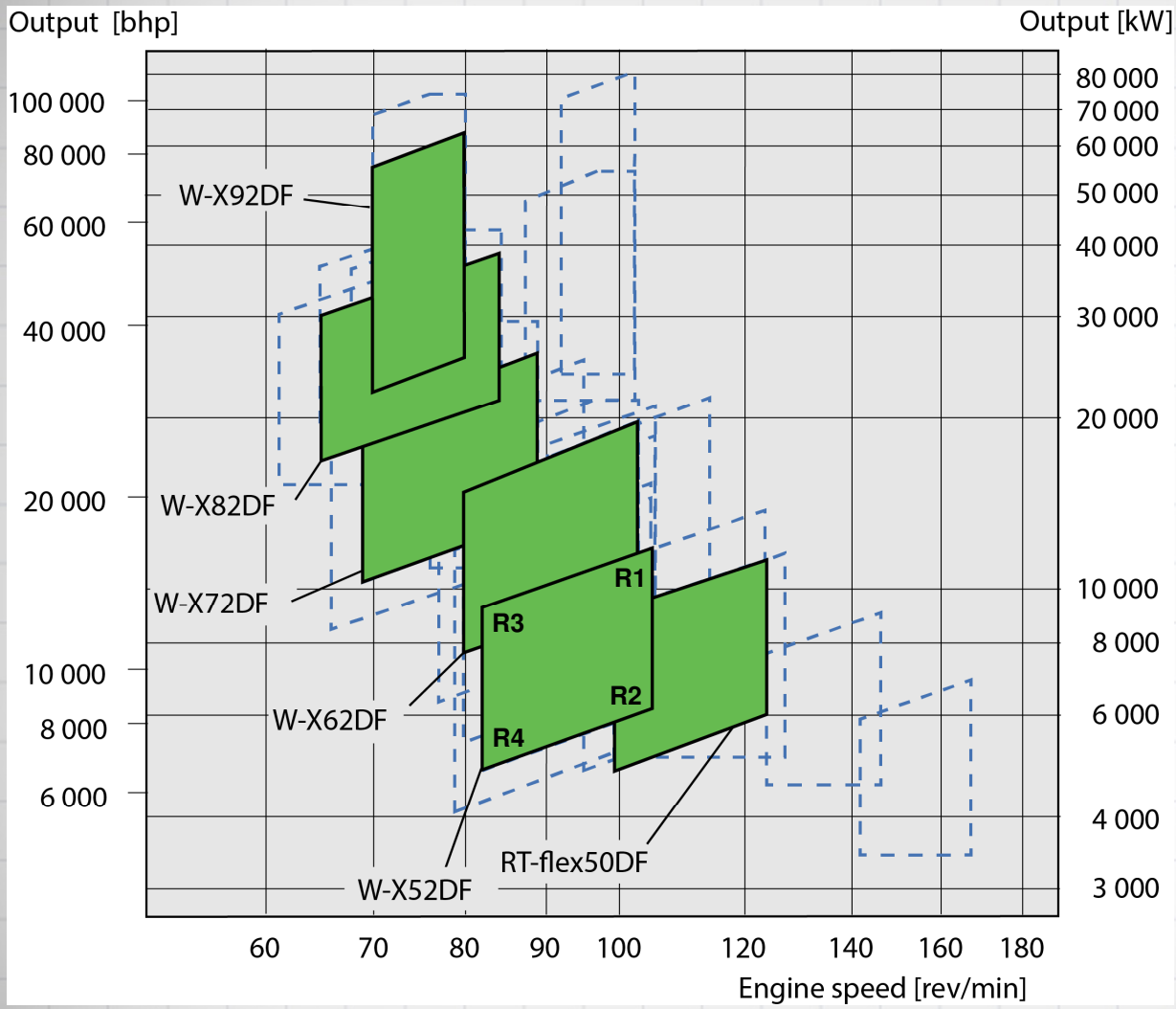
Engine rating fields



Covered vessel segments:

- **LNG Carriers**
- **Container Vessels**
  1000 – 18000 TEU
- **Tankers**
  - Product
  - Aframax
  - Suezmax
  - VLCC
- **Bulkers**
  - Handysize
  - Handymax
  - Panamax
  - Kamsarmax
  - Capesize
  - VLOC
- **PCTC, CONRO**

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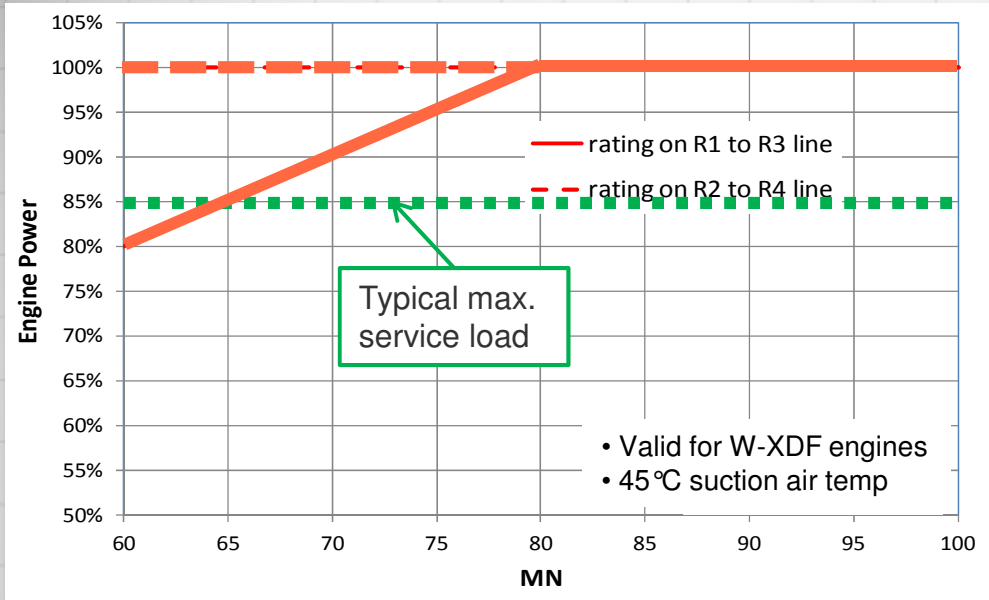
Engine output in gas operation – X52DF, X62DF, X72DF



Methane number

- For the DF engine, actual output may be limited by Methane Number of the gas
- The graph is valid for any installation condition, i.e. from winter up to tropical condition

However:

- Typically, the MN of LNG is 70..100
- Typically, operating area for low speed engines is < 85% CMCR
- In case MN is too low, engine control system will automatically make the necessary adjustments or trip to diesel for 100% output

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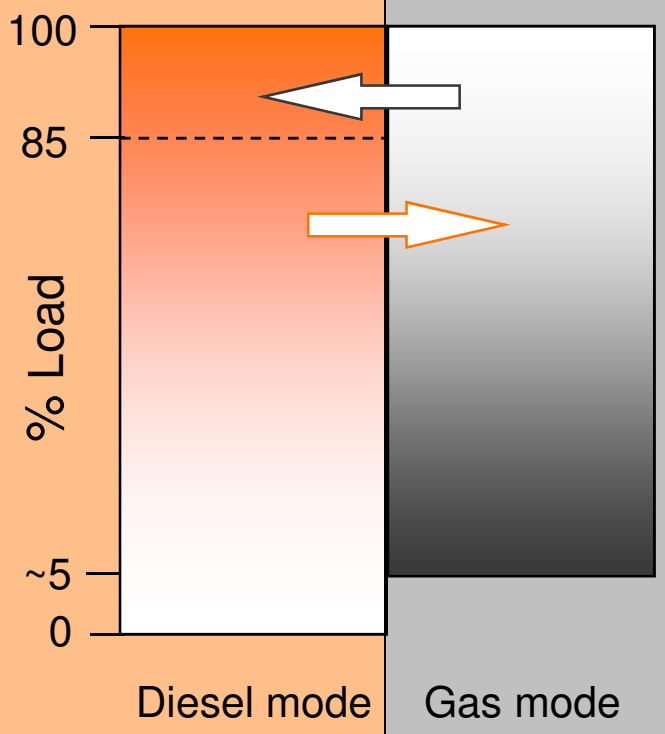
Fuel mode change

Diesel mode

- Running on MDO
- Transfer to gas operation at loads between 5 and 85%
- Pilot fuel injection in operation



Gas mode

- Automatic and instant trip to diesel operation in alarm situations
- Trip to diesel operation on request at any load

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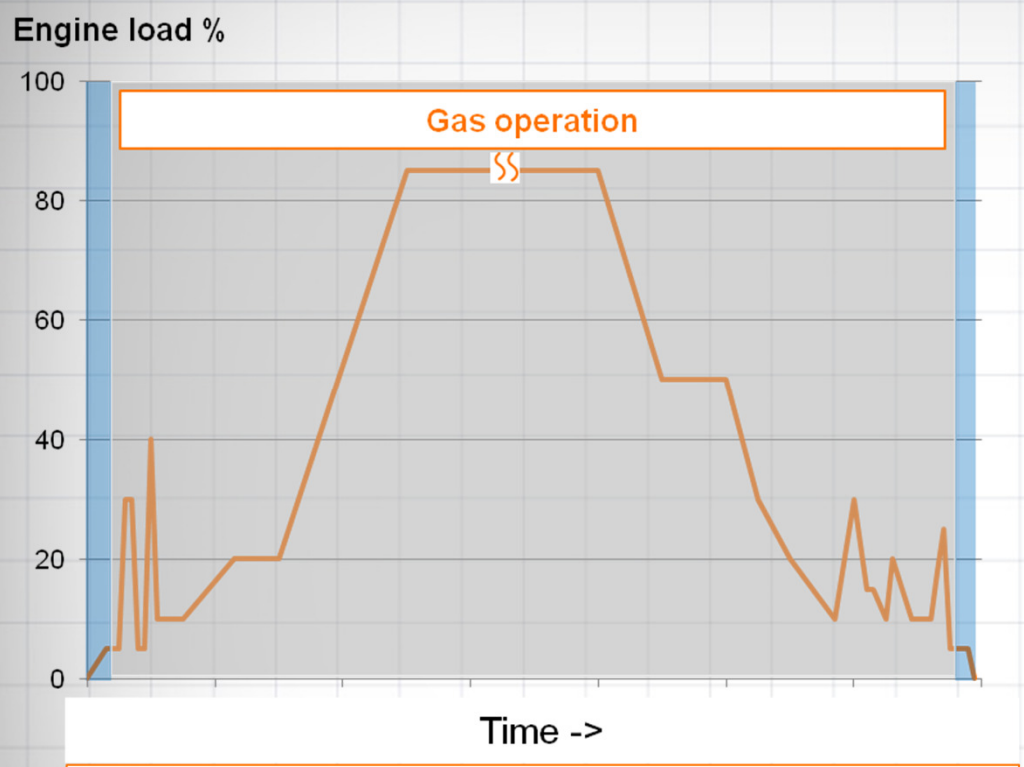
Low pressure DF - operation



Illustrative operating profile

'Port-to-port' operation on gas

- Entire voyage in gas mode
  - Engine start on diesel for safety check
  - Transfer to gas at low load/idling
  - Transfer to diesel before stop
- In case of FPP, reversing/restart will be done on diesel, then transfer back to gas
- Engine Start/Stop in diesel according to the IGF-code (draft) and IACS rules.

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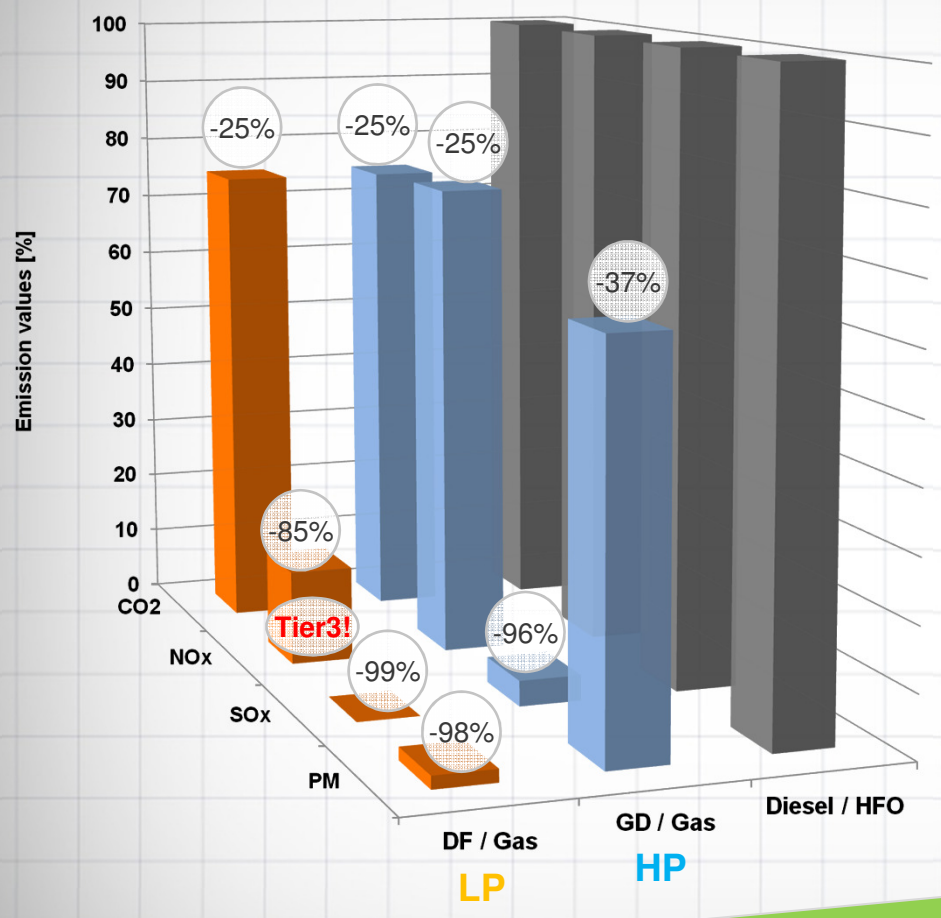
Emission picture



Comparison LP vs HP engine emissions

- CO_2 and SO_x reduced in gas operation due to fuel composition
- NO_x very low with LP technology due to lower peak temperature
- PM further reduced by the DF technology with lean-burn Otto combustion with pre-chamber ignition

NO_x Tier III (2016) and SO_x level in ECA (2015) are fully met !

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Safety aspects - Principles

Goal

Ensure **safe handling of gas fuel under all operating conditions**, to minimize the risk to the ship, persons on board and to the environment

Operational risk

- **Gas safe machinery space**
  → Single failure will not lead to gas release into machinery space
- **Dilute** possible **ignitable gas concentrations** to levels below the lower explosion limit (LEL)
- **Limit consequences** of explosions (worst case)

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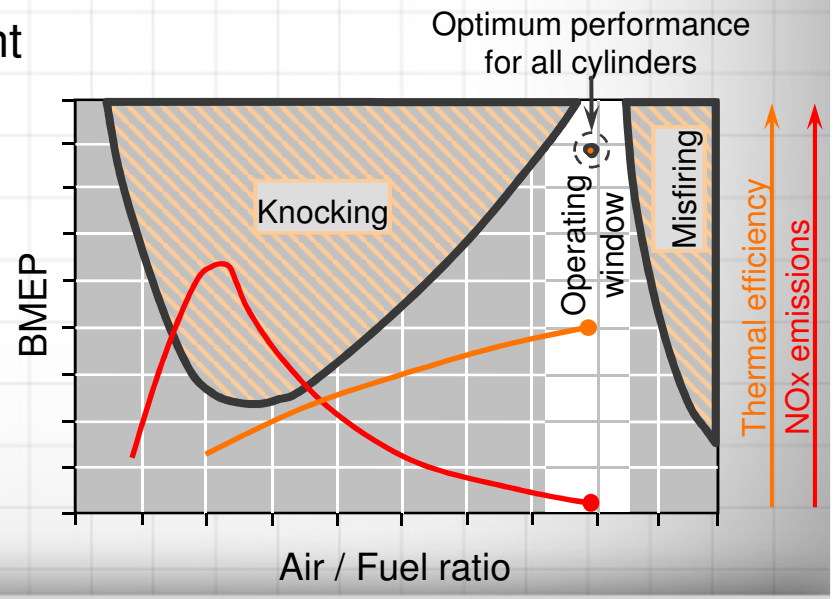
Safety aspects - Principles

Main systems to detect abnormal conditions

- Gas detectors (in double wall pipes, machinery space, on engine)
- Cylinder pressure sensor on each cylinder
- Gas admission valve monitoring
- Knocking sensor on each cylinder

Possible system reactions upon detection of abnormal conditions

- Balancing fuel/air ratio, balancing gas amount
- Trip back to diesel (back-up mode)
  → all gas pipes vented
  → no pressurized gas on engine



Safety principles as stipulated in the IGF-code (draft) and IACS rules

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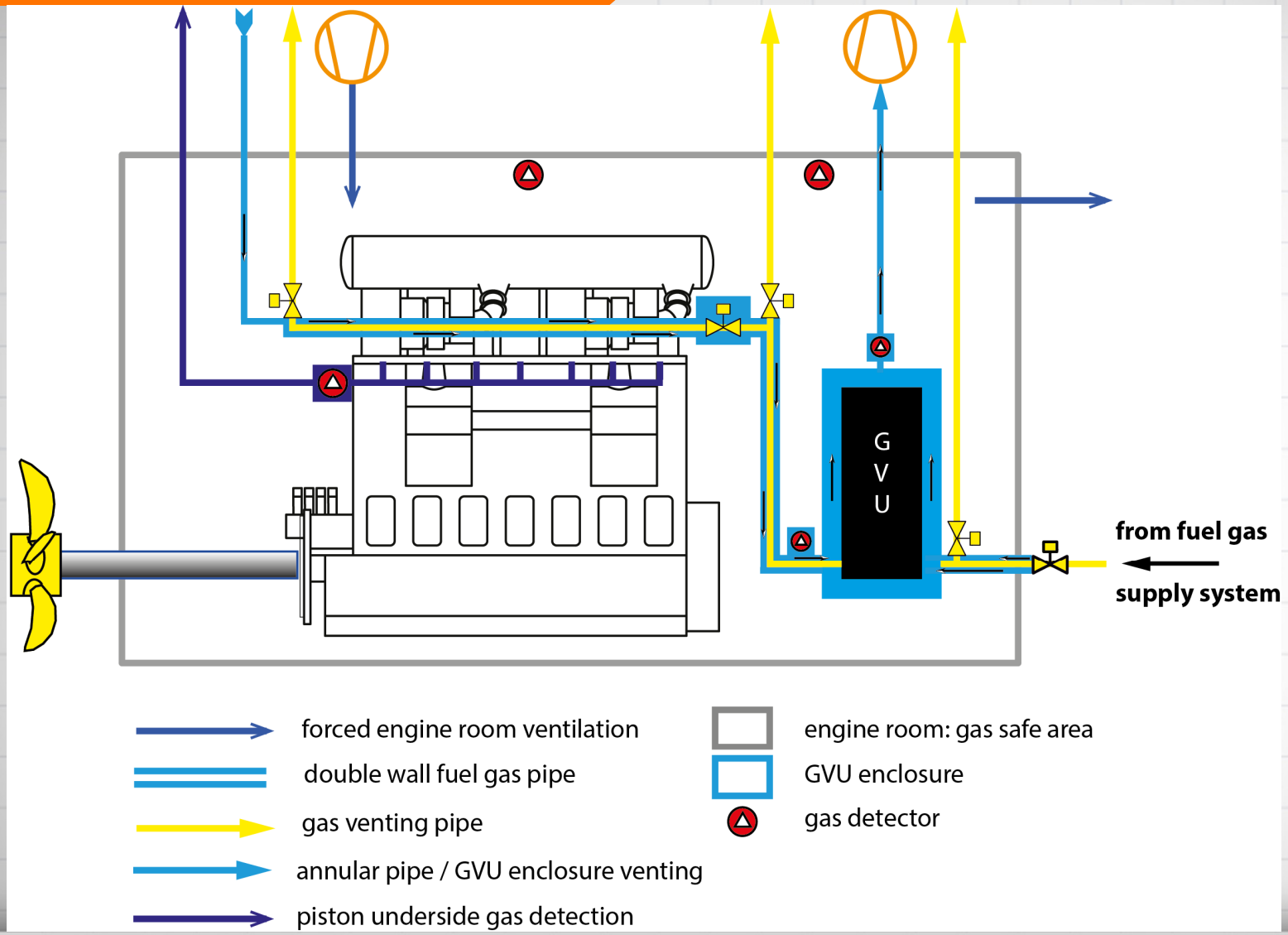
Machinery space concept – Gas safe engine room



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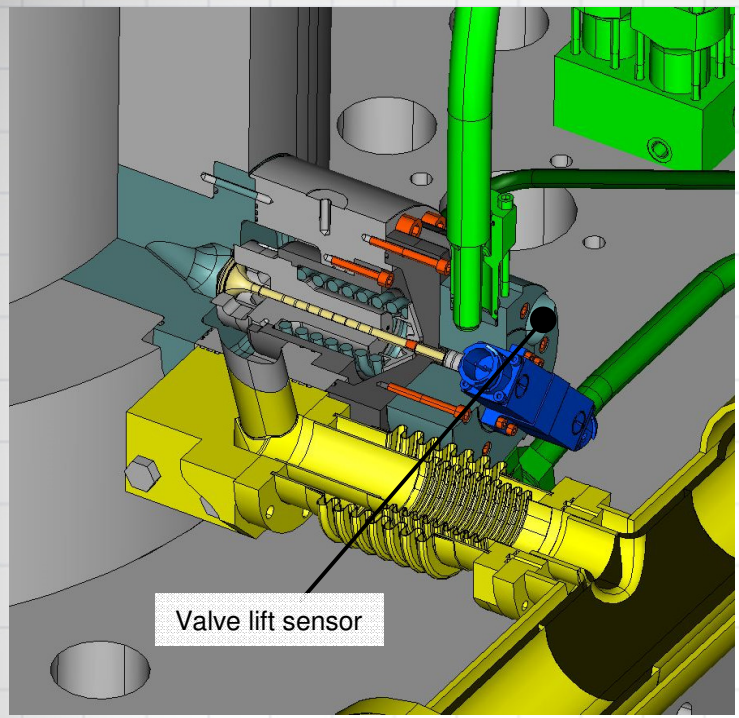
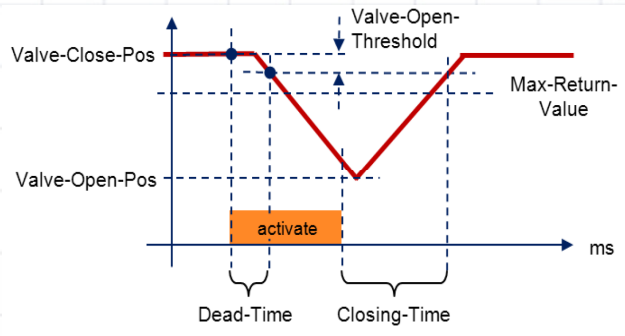
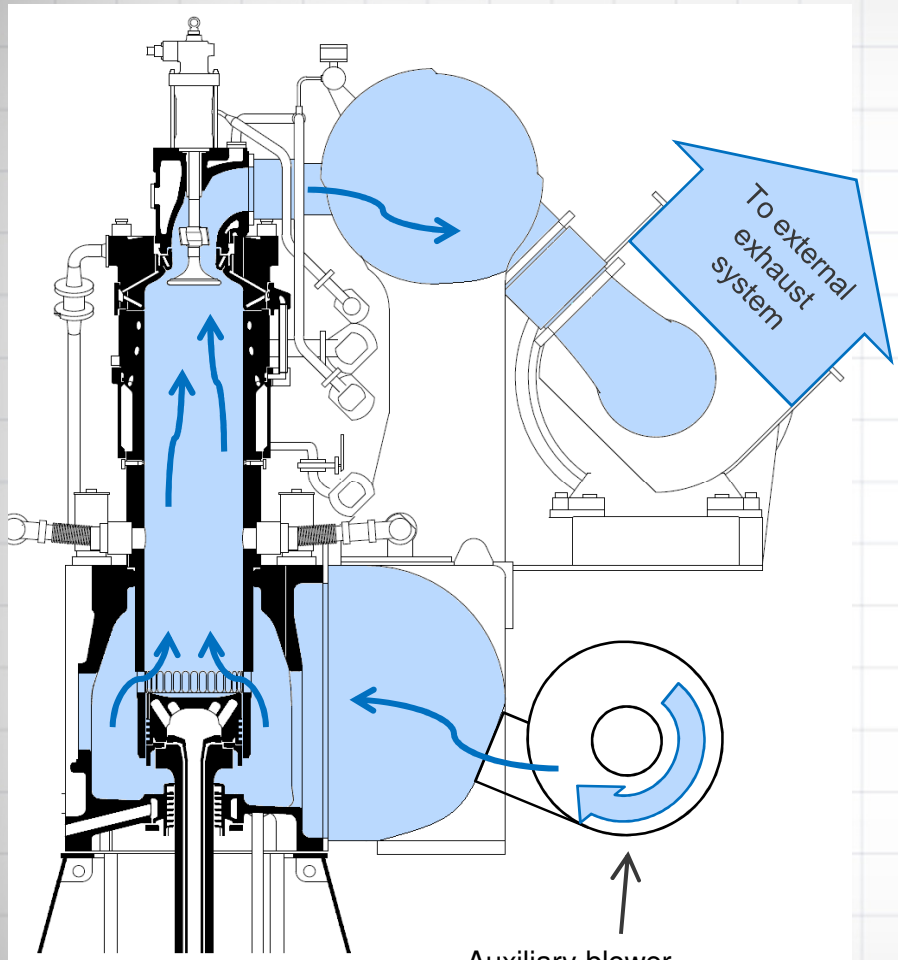
Gas admission system



- Precise gas admission control – from full load to ’idling’
- Valve operation monitored
- Inspection interval: 6,000 RH
- Overhaul/replacement: min. 18,000 RH
  Final value not yet defined, prolonged intervals are expected



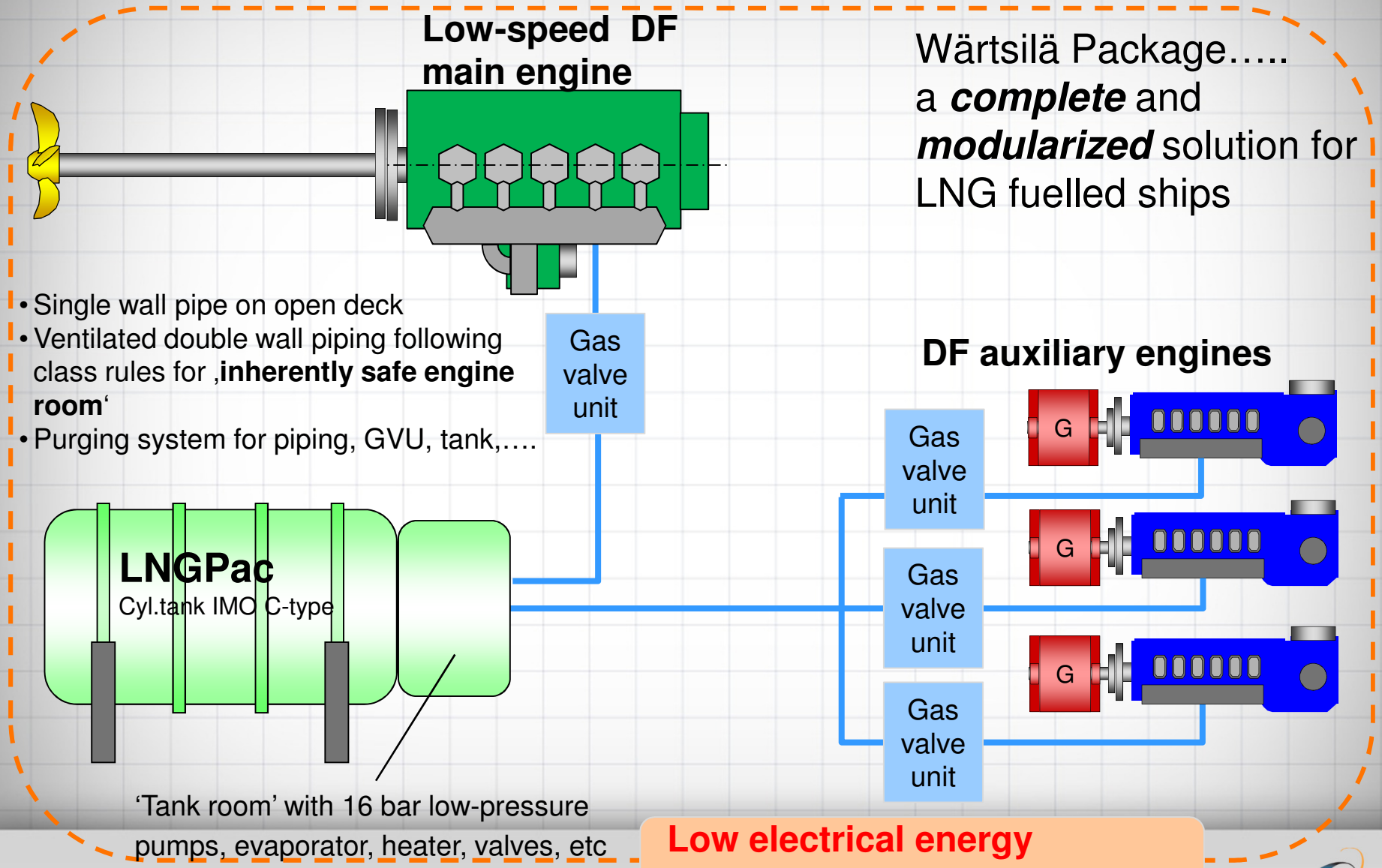
Engine / exhaust system ventilation



Prevent accumulation of gas in the engine and exhaust system

- After emergency stop / shut down in gas mode
- Purging with engine auxiliary blowers
- Exhaust valves automatically opened

Dual-fuel engine machinery for Merchant Vessels



Low electrical energy consumption for gas feed

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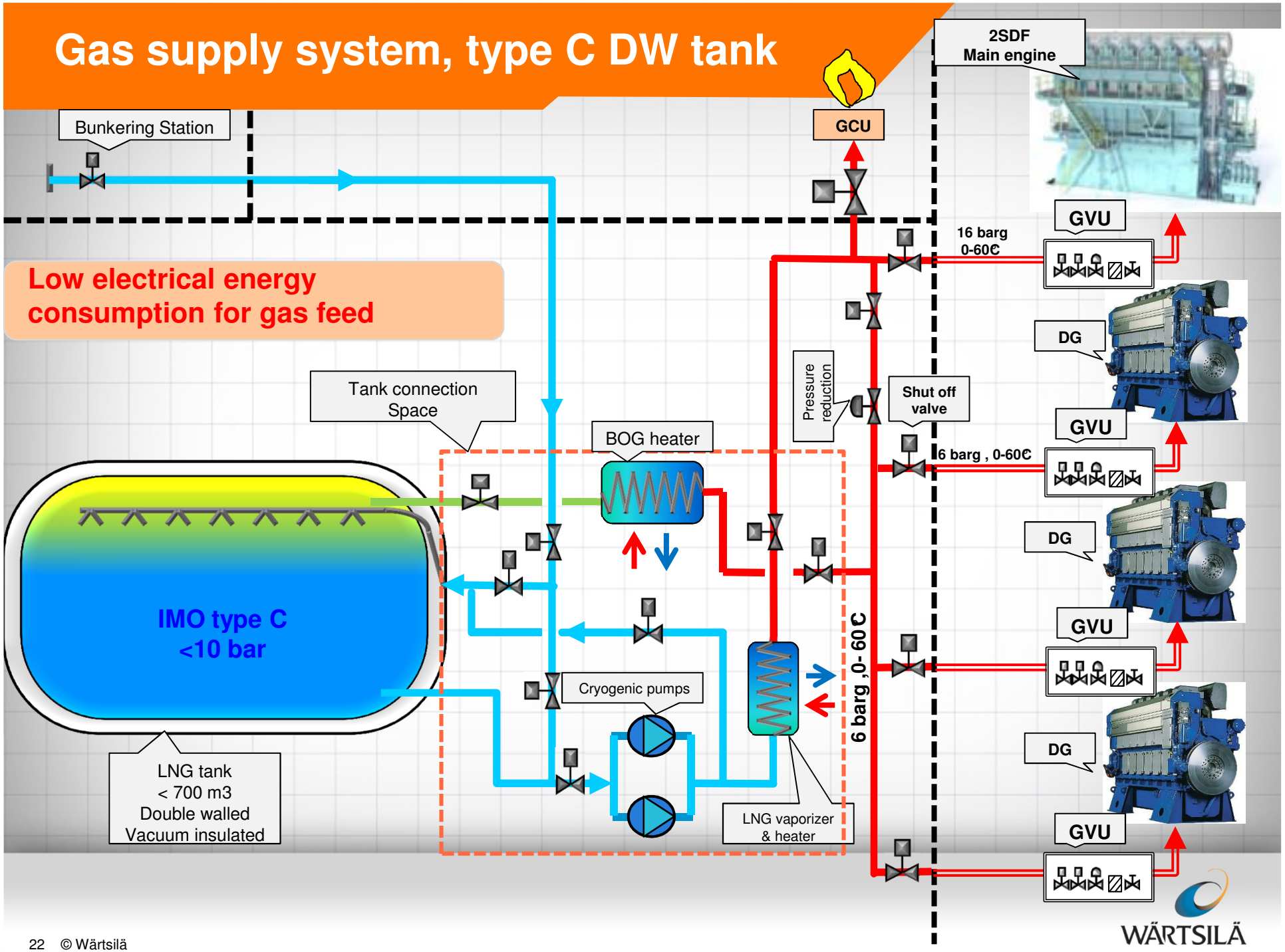
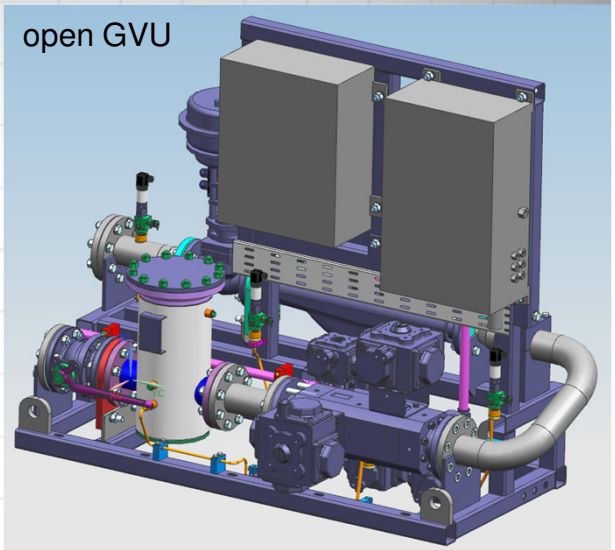
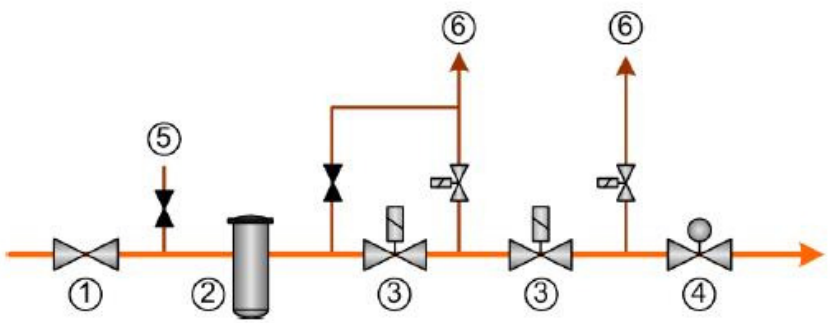
Gas supply system, type C DW tank



Gas Valve Unit

- Wärtsilä standardized and proven design applied
- Pressure regulation, gas filtering and safety valves included
- Emergency venting procedure and leakage test features introduced





(1) Gas inlet valve
(2) Gas filter
(3) Automatic shut-off valve
(4) Gas regulating valve
(5) Inert gas connection
(6) Venting line

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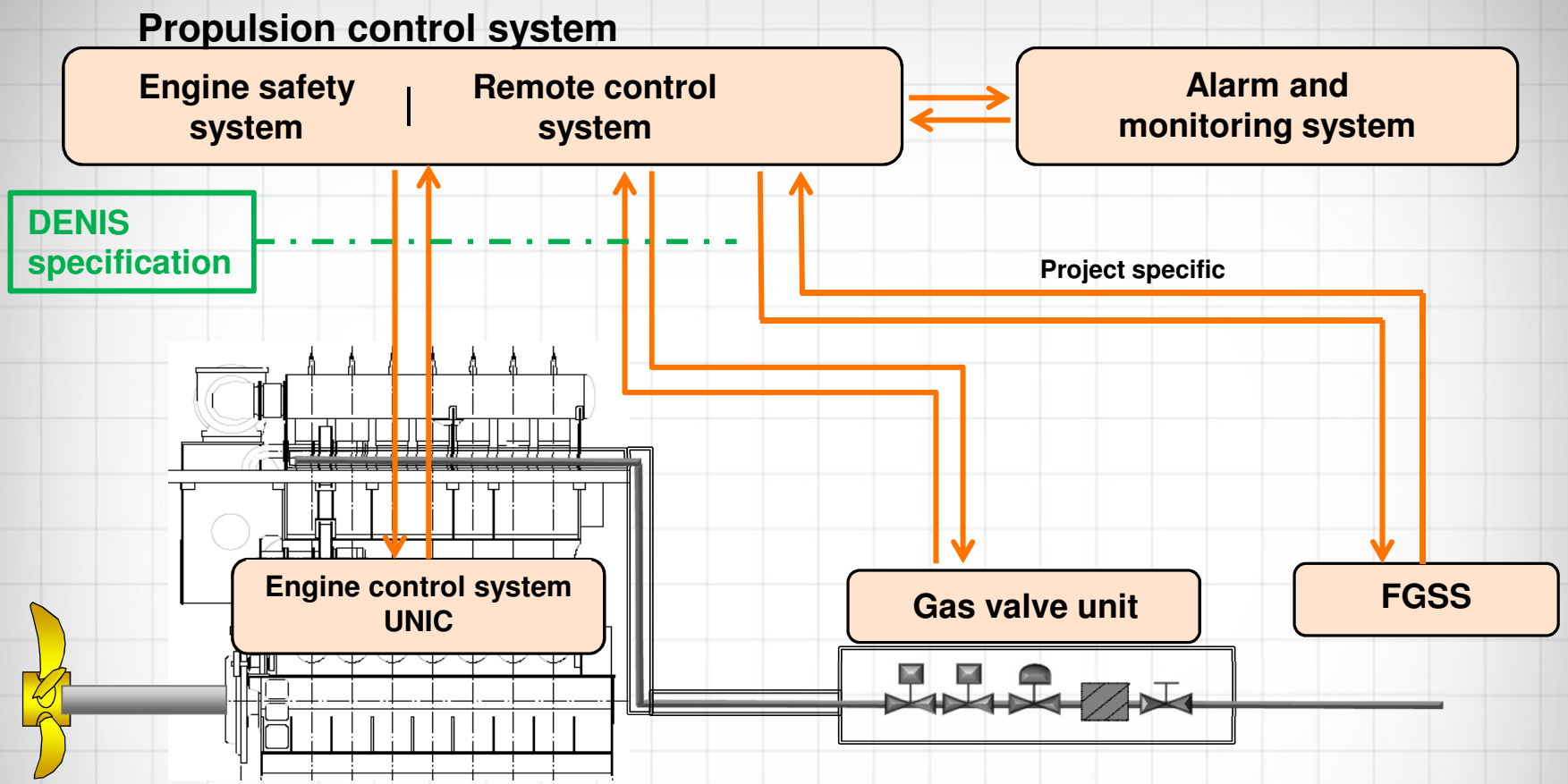
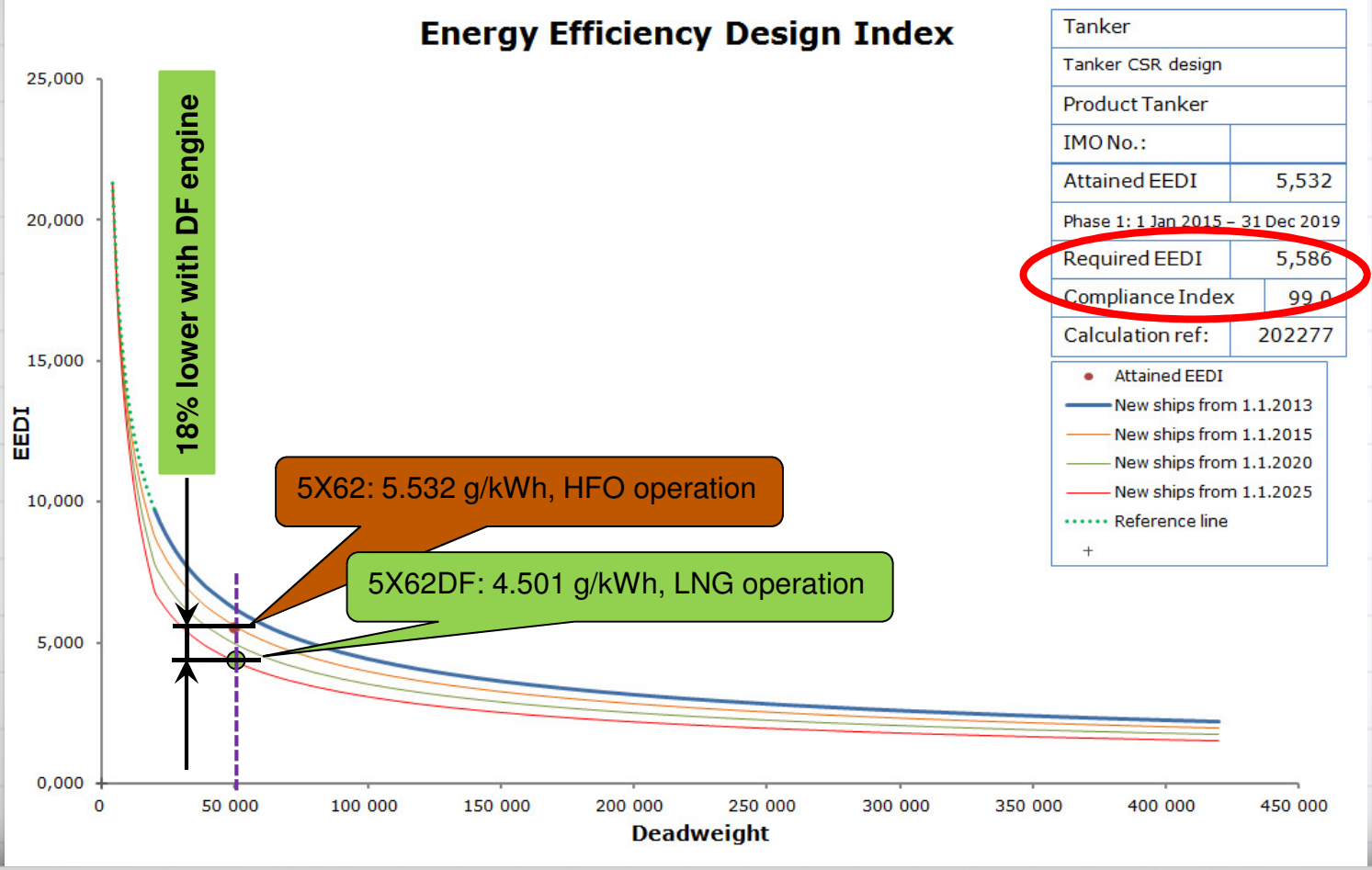
Control layout



Example: EEDI calculation for 50 ktdw Product Tanker

- Engine type — **5X62** (conventional engine) vs **5X62DF** (LNG- fuelled)
- CMCR- power — 9000 kW
- Vessel design speed — 14.5 kn (90% CMCR)



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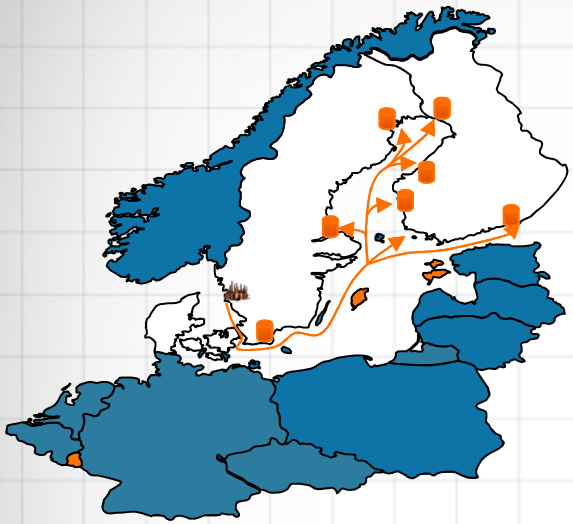
Leading into the Gas Age – Reference 1

INTO the FUTURE - Baltic SO_2lution



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NEOT
North European Oil Trade

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- **Ship type** 4 x 15,000 dwt Chemical Tankers, 14.5 kn (v_{DES})
- **Owner** Terntank Rederi AS, Sweden
- **Shipyard / Class** AVIC Dingheng Shipbuilding Co, China / BV
- **Vessel delivery** Q2, 2016
- **Engine type** **Wärtsilä 5RT-flex50DF,** CMCR of 5850 kW
  Wärtsilä CPP and PTO (PTI for 3 ships)

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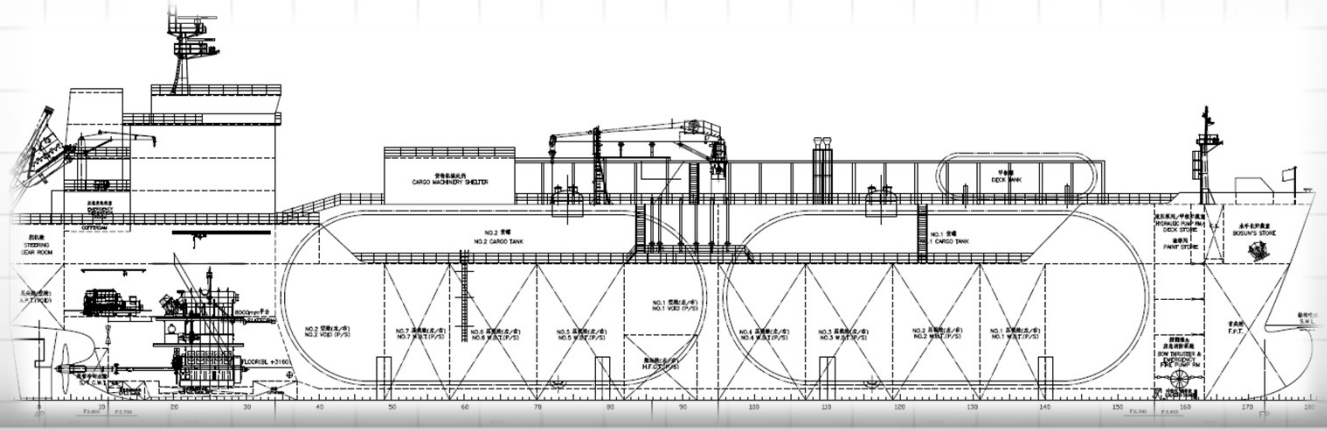
Leading into the Gas Age – Reference 2

First costal LNG Carrier with 2sDF engine

- **Ship type** 14,000 m3 LNG Carrier, 15 kn (v_{DES})
- **Owner** Zhejiang Huaxiang Shipping Co., Ltd
  - Private shipping company
  - Major player in LPG transportation market
  - One of the operators of LNG transportation in China domestic water
- **Shipyard / Class** Qidong Fengshun Ship Heavy Co., Ltd, / CCS
- **Vessel delivery** 2015
- **Engine type** **Wärtsilä 5RT-flex50DF,** CMCR of 6000 kW



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Leading into the Gas Age – Reference 3

First LNG- fuelled Container Feeder Vessel for Baltic Sea operation

- **Ship type** 3 (+1+2) x 1400 TEU C/V, 18.5 kn (v_{DES}), iceclass 1A
- **Owners** GNS Shipping / Nordic Hamburg, Germany
- **Charter** Containerships, Finland
- **Shipyard / Class** Yangzhou Guoyu Shipbuilding, China / ABS
- **Vessel delivery** Q3, 2016

- **Engine type** **Wärtsilä 7RT-flex50DF**
  CMCR of 10070 kW

  6L20DF generating set
  MCR of 1055 kW

  CPP, PTO

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Leading into the Gas Age – Reference 4

First LNG Carrier with low-speed LOW-PRESSURE DF engines

- **Ship type** 2 x 180,000 m3 LNG Carrier, 19.5 kn (v_{DES})
  Twin-skeg, twin-screw
- **Owners** SK Shipping, Korea
  Marubeni Corporation, Japan
- **Charter** Total SA, France
- **Shipyard / Class** Samsung Heavy Industries, Korea / BV
- **Vessel delivery** Q1, 2017
- **Engine type** **Wärtsilä 2 x 6X62DF main engines**
  CMCR of 13450 kW each
  Wärtsilä 4 x L34DF gensets

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Why to choose a Wärtsilä LP DF engine ?

1) **Meets IMO Tier III** requirements **without** exhaust gas after-treatment due to lean burn Otto combustion process

2) **Low CAPEX** due to **low pressure** gas supply system
   - Low pressure equipment (pumps, compressor, evaporator, piping, sensors, ….)
   - No exhaust gas after treatment required

3) **Low OPEX** due to **high overall efficiency**
   - Lower electrical power demand
   - Lower maintenance cost
   - Lower gas leakage risk

4) **Full Wärtsilä Package** - Complete and modularized **solutions** for LNG fuelled ships

5) **Low pressure** - **The industry standard** with 4s gas engines: MAN, Cat/MAK, Rolls Royce, MTU, Mitsubishi, ...

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THANK YOU!

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Leading gas applications in the marine market