

# MAN Diesel & Turbo

News and Updates on LNG



2018

## MAN Diesel & Turbo SE

„Engineering the Future – since 1758.“

Rüdiger Schmidt / Olaf Lingstädt

# Agenda



- 1 MAN Diesel & Turbo – Introduction
- 2 2-Stroke ME-GI & other concepts
- 3 4-Stroke Dual Fuel Main Propulsion Engines
- 4 Dual Fuel GenSets
- 5 MAN Cryo – LNG System Provider
- 6 Retrofitting of Wes Amelie – 48/60 to 51/60DF

# Volkswagen Group

12 brands



Audi



BENTLEY



Nutzfahrzeuge



SCANIA



VOLKSWAGEN FINANCIAL SERVICES

AKTIENGESELLSCHAFT

# MAN Diesel & Turbo

A worldclass product portfolio



## Engines & Marine Systems

Two-stroke and four-stroke engines for marine applications

Propellers and complete propulsion systems incl. fuel gas systems

Turbochargers



## Power Plants

Two-stroke and four-stroke engines for stationary applications

Diesel and gas power plants



## Turbomachinery

Compressors, gas and steam turbines, expanders

Complex machinery trains

Chemical reactors



## Service: MAN PrimeServ

Worldwide network of service hubs: 24/7 OEM service around the globe





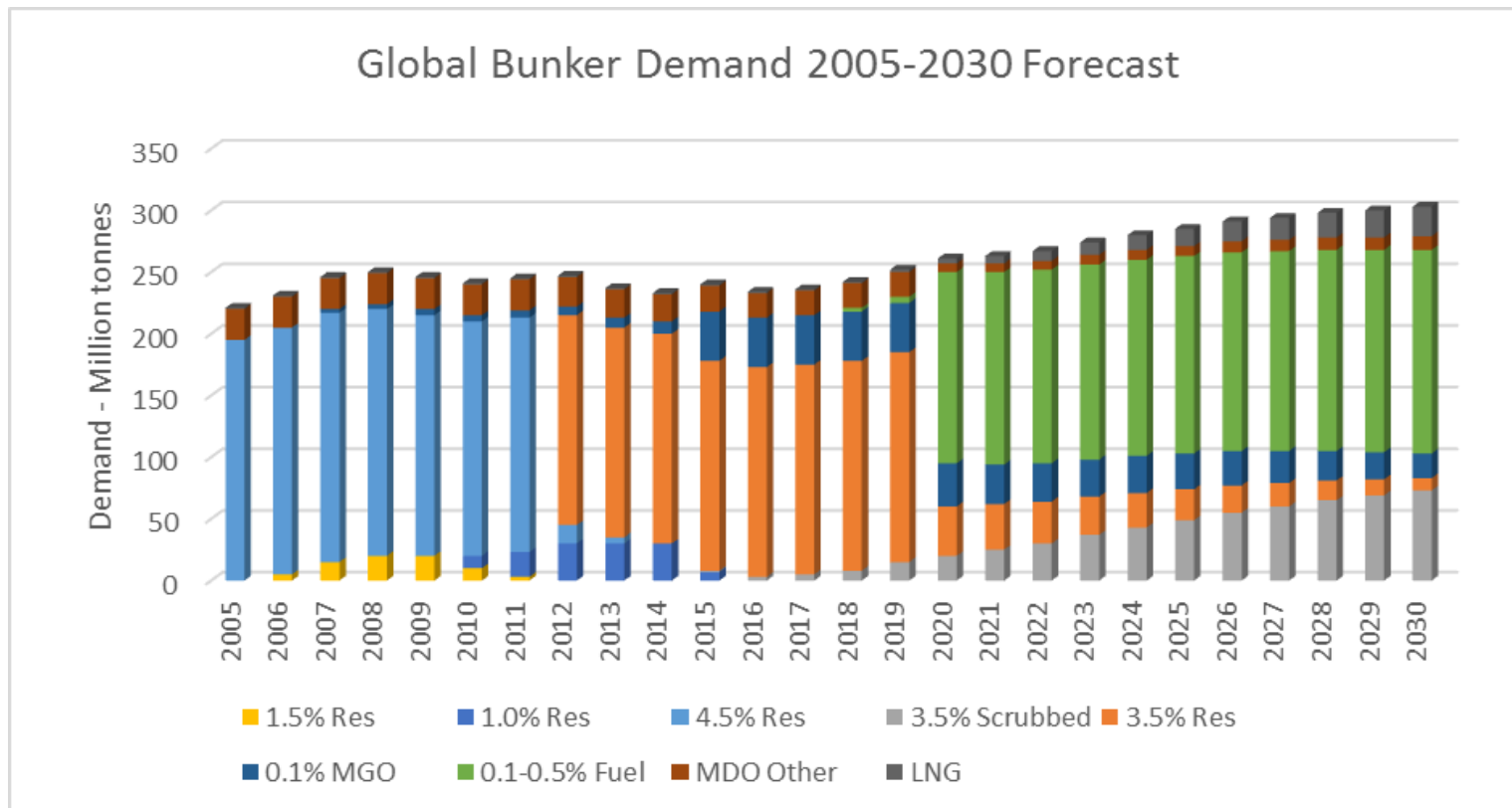
# 50% of World Trade Powered by MAN Engines



Powering one of the world's largest container ships:  
The "CSCL Globe" is propelled by a MAN B&W 12S90ME-C two-stroke engine with 69,720 kW

# Global Fuel Types

## Before and after the 2020 Sulphur Cap of 0.5 %



The demand for different types of fuels. Based on: "Outlook for marine Bunkers and Fuel Oil to 2035"  
Marine and Energy Consulting Ltd, with changes made due to 2020 sulphur cap legislation.

# MAN Diesel & Turbo

Comprehensive applications in diverse industry areas



MARINE

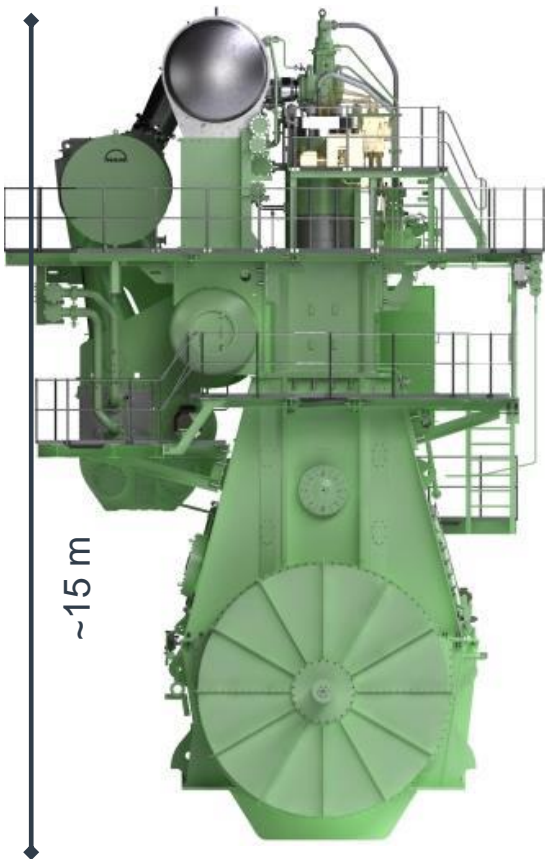
OIL & GAS

PROCESS INDUSTRY

POWER PLANTS



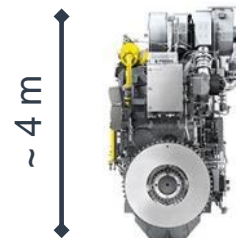
# MAN's Dual Fuel Solutions for Marine Applications



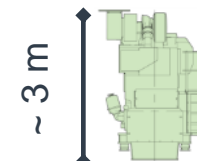
ME-GI (G40-G95)  
5.500-82.440kW



L/V 51/60DF  
6.300-18.900kW



L35/44DF  
3.060-5.300kW



L28/32DF  
1.000-1.800kW



L23/30DF  
625-1.200kW



# Agenda



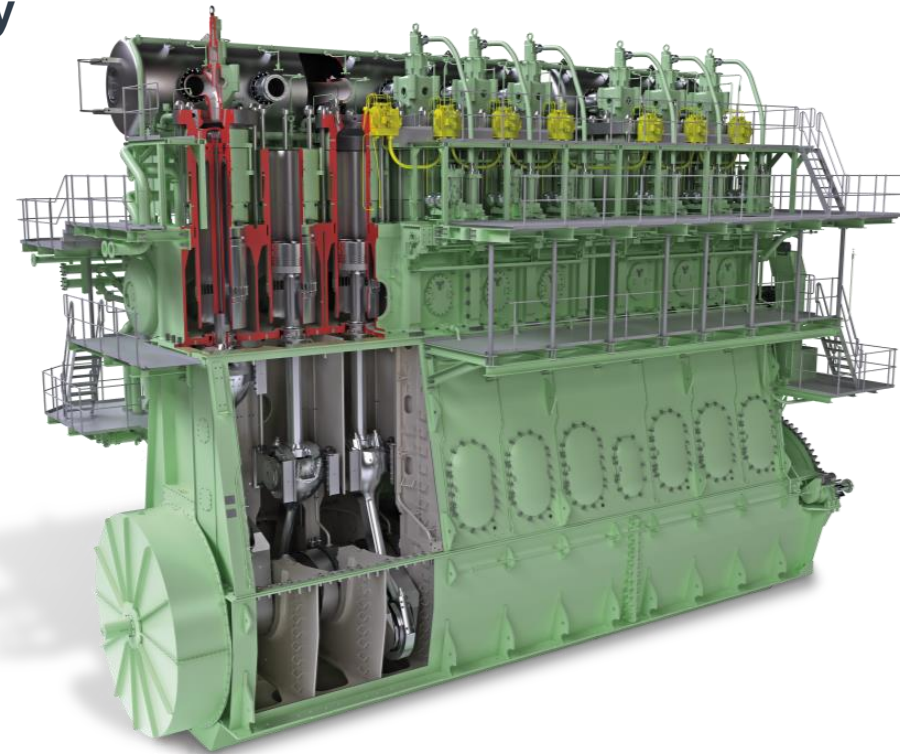
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# What is the ME-GI Engine?



The ME-GI is derived from the industry standard M series of engines

- More than **22,000 M** engines in service
- **Diesel-cycle** high fuel efficiency **~50%** versus much lower for other engine types
- High fuel flexibility – burns all gas grades **without derating**. Burns all fuel types
- **High reliability** – same as fuel engines
- **No derating** because of knocking danger
- **Negligible Methane GHG slip**
- **No Formaldehyde formation in exhaust**
- Gas becomes too expensive and operation is switched to oil - **the ship is still competitive on fuel oil**



# ME-GI development – Mk.2

Mk.2 engine under development



MAN Diesel & Turbo is designing the new ME-GI Mk.2 with main targets:

- Less on-engine components
  - Removal of valves on gas block
  - Eliminate double wall return piping on-engine
- Easier engine installation
  - Reduction of shipyard's cost

CAPEX

- Reduction of pilot oil consumption down to 1% (currently 3%)
- Individual cylinder cut-out
- Easier and controlled gas return after stop
- New purging method

OPEX

# ME-GI / ME-LGI Gas Fuel Mode

Port to port in dual fuel mode



## Fuel oil only mode

- Operation profile as conventional engine

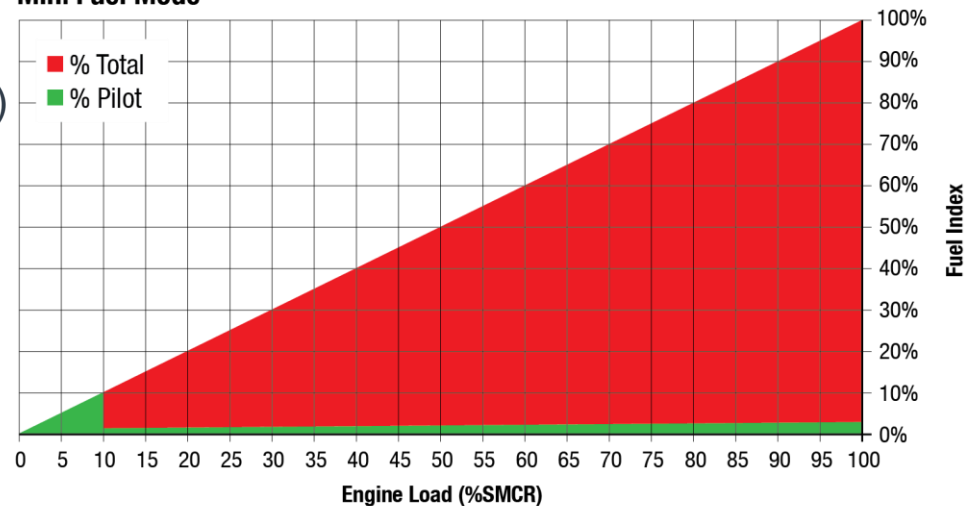
## Dual fuel operation mode

- No fuel slip
- No knocking problems
- Insensitive to gas fuel (methane number)
- Unchanged load response

## News:

- Pilot oil amount 3% → 1% (ME-GI Mk.2)
- Load on gas → 10% load

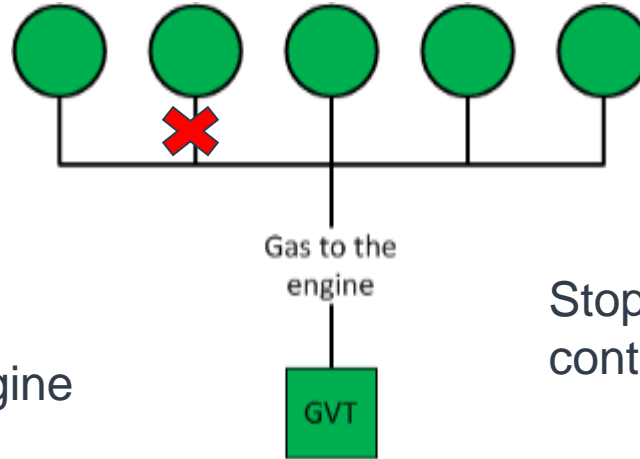
Min. Fuel Mode





# ME-GI Mk.2

Individual cylinder cut-out example

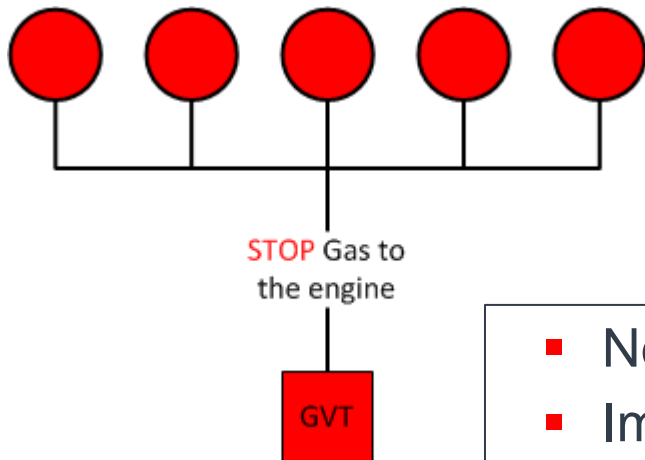


Gas operation

- Cylinder gas failure

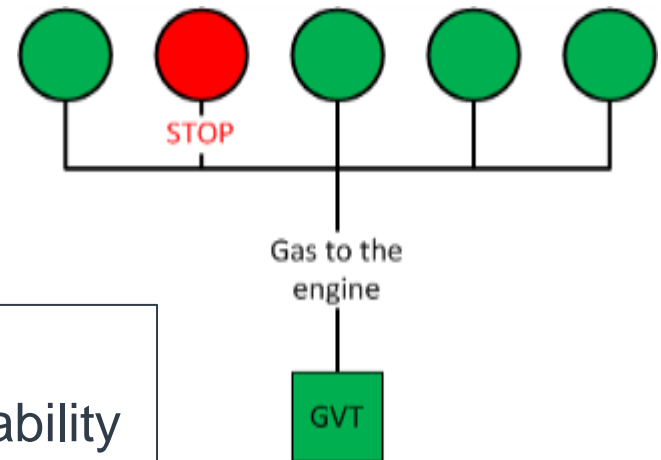
Stop gas operation on engine

ME-GI Mk.1



Stop gas operation in cylinder continues on fuel oil

ME-GI Mk.2



- New feature
- Improved gas availability

# ME-GI Pump Vaporizer Unit (PVU)

## Objective



The goal for development of the PVU as a fuel gas supply system is to make ME-GI engines more competitive by:

- Simplification and optimization
- Standardization - type approval
- Utilization of engine integration



# The ME-C engine is LNG ready as is

From ME-C to ME-GI, relative cost



Conventional ME-C Engine : 100 %

LNG ready ME-C : 100 %

LNG prepared ME-C : 102 - 105 %

New ME-GI : 120 – 125 %

Retrofitted ME-GI : approx 150 %\*

Retrofitted ME-GI : approx 127 – 130 %\*



\*Cost estimated for ME-C Engines bigger than 25 MW.

Supervision and Commissioning cost excl. fitter cost is incl in estimate.

# World's First LNG Powered Container Vessel

In Service between Jacksonville and Puerto Rico



- TOTE495 (Nov. 2017)  
Total hrs.: 27,522  
Gas hrs.: 14,462  
51% operating in Gas Mode

- TOTE496 (Jan. 2018)  
Total hrs.: 26,509  
Gas hrs.: 11,498  
43% operating in Gas Mode

> **25,000hours in GAS MODE**

- Smooth switchover between diesel mode and gas mode



Isla Bella



Perla Del Caribe



# New MAN B&W Dual Fuel Engine Orders



## Evergas & Ineos:

**Ethane-Fuelled Engine to Power A Giant VLEC Very Large Ethane Carrier to transport shale gas between USA and China from 2019.** The MAN B&W 6G60ME-GIE engine will enable the VLEC to operate on ***ethane gas*** or fuel oil.

**Waterfront Shipping Company Ltd.,  
Marinvest/Skagerack Invest (Marinvest), IINO Kaiun  
Kaisha, Ltd. (IINO), Mitsui & Co., Ltd. (Mitsui), and the  
NYK Group (NYK) are proud to announce their  
investment to build four new ocean-going vessels  
powered by clean-burning methanol fuel using the MAN  
B&W 6G50ME-LGIM**



# New MAN B&W Dual Fuel Engine Orders



## World's first LPG powered VLGC for Exmar

Hanjin Heavy Industries has announced that it will construct 2 × VLGCs (Very Large Gas Carriers) in Korea for EXMAR, the Belgian energy-supply-chain provider. The 79,500-m<sup>3</sup> newbuildings will each be powered by individual *MAN B&W 6G60ME-LGIP Mk9.5* engines

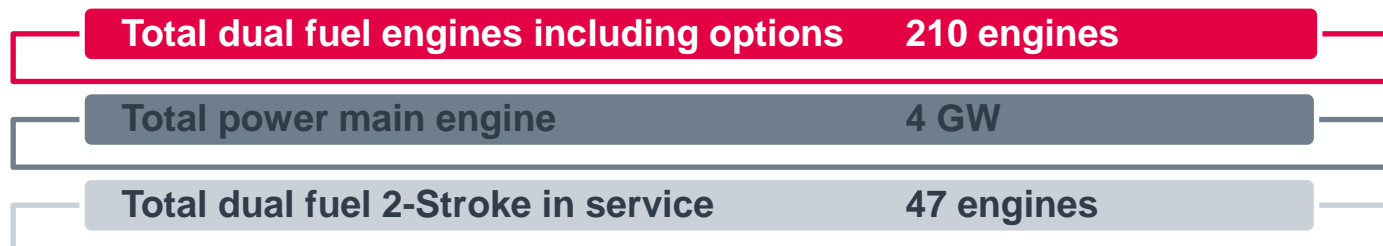


# Dual fuel engine reference list

## Orders including options



No. of engines	Engine type			Mk.	Gensets
5	S	90	ME-C-GI	10.5	
6	G	90	ME-C-GI	9.5, 10.5	
4	S	80	ME-C-GI	9.5	
6	S	70	ME-C-GI	7, 8.2, 10.5	6 x 9L28/32 DF
132	G	70	ME-C-GI	9.2, 9.5	8 x 7L35/44 DF
5	L	70	ME-C-GI	8.2	15 x 9L28/32 DF
2	S	60	ME-C-GI	10.5	
8	S	50	ME-C-GI	8.2, 9.5	
5	G	50	ME-C-GI	9.5	8 x 7L28/32 DF / 4 x 5L28/32 DF
4	G	45	ME-C-GI	9.5	4 X 5L23/30 DF / 8 x 8L23/30 DF
11	G	50	ME-B/ME-C –LGIM	9.3, 9.5	
3	S	50	ME-B-LGIM	9.3	
6	G	60	ME-C-GIE	9.5	
3	G	50	ME-C-GIE	9.5	
10	G	60	ME-C-LGIP	10.5	



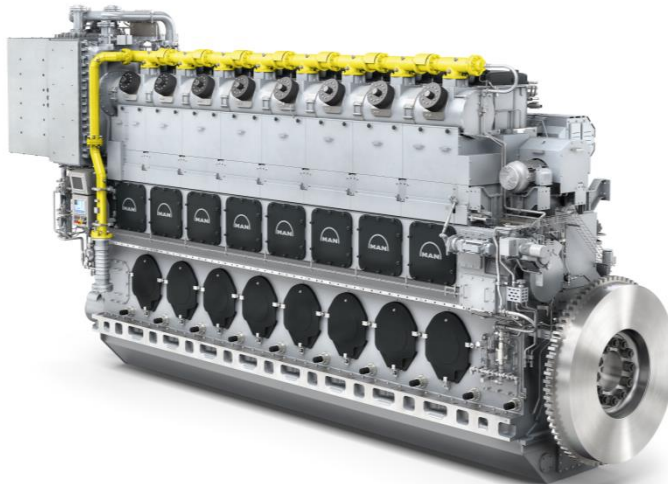
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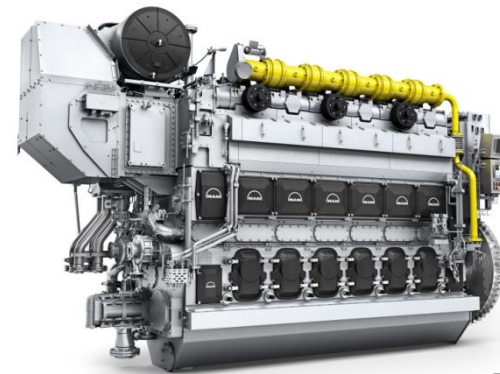
# MAN DF Propulsion Engines



3D Animation  
PORTAL

## 51/60DF

6L – 18V cylinders  
6,300 – 18,900 kW



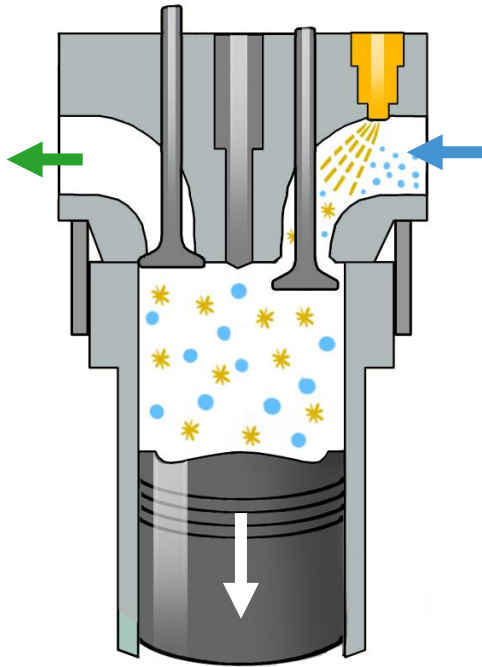
3D Animation  
PORTAL

## 35/44DF

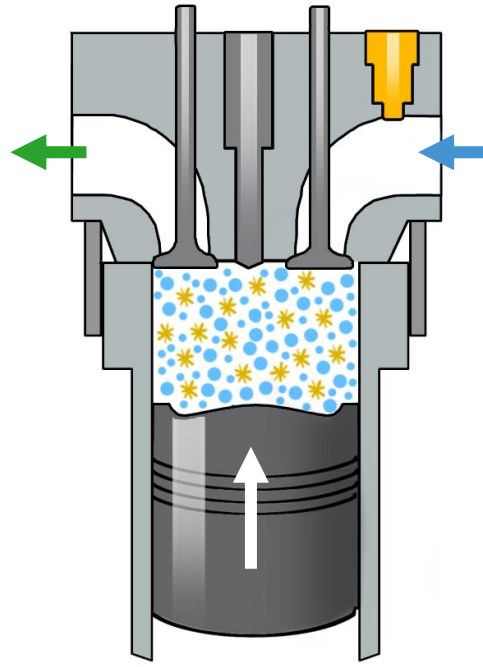
6L – 10L cylinders  
3,180 – 5,300 kW

# Otto Cycle Process

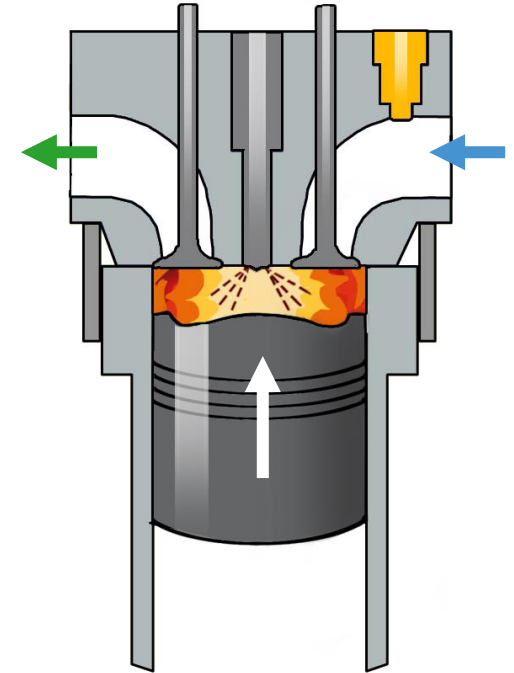
Low Injection Pressure with Individual Valves



**Air and Gas  
Intake**



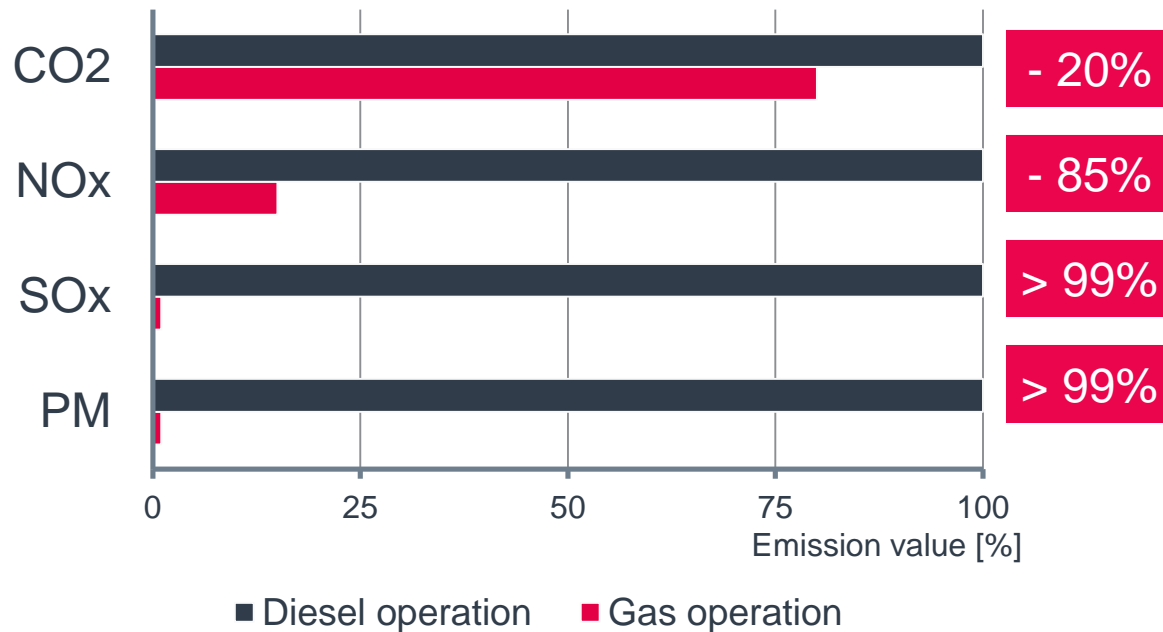
**Compression**



**Ignition by  
Pilot Fuel**

# Exhaust Emissions Diesel vs. Gas

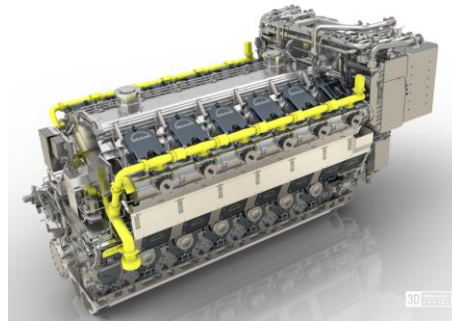
MAN 51/60DF performance, facts & figures



**4-Stroke DF engine offers IMO Tier III and SO<sub>x</sub> compliance in gas mode without any further exhaust after treatment**



### Drive for Efficiency & Environment



(09/2017)

Engine

Key Features

- $\Lambda$ -Control: Waste Gate, VTA
- **1,050 kW/cyl. (Efficiency Version) | 1,150 kW/cyl. (Power Version)**
- **SFGC 7,200 kJ/kWh \* | SFGC 7,400 kJ/kWh\***  
(without attached pumps, valid up to 50 mbar backpressure)
- **SFOC 177,0 g/kWh \* | SFOC 184,0 g/kWh\***  
(without attached pumps, valid up to 50 mbar backpressure)
- **Gas Start Capability** for invisible smoke also during start-up (gas mode).
- **Full Rating plus 10% overload margin for up to 50 mbar backpressure for both, diesel mode & gas mode (i.e. ready for combination with SCR without power loss)**

\* Tol. acc. ISO 3046-1, MN  $\geq$  80, LHV<sub>min</sub> Gas 28,0 MJ/Nm<sup>3</sup>, LHV Liquid Fuel 42,7 MJ/kg, 85 % Load, w/o attached pumps, Gas Mode inc. Pilot fuel, ISO conditions, diesel – mechanic application

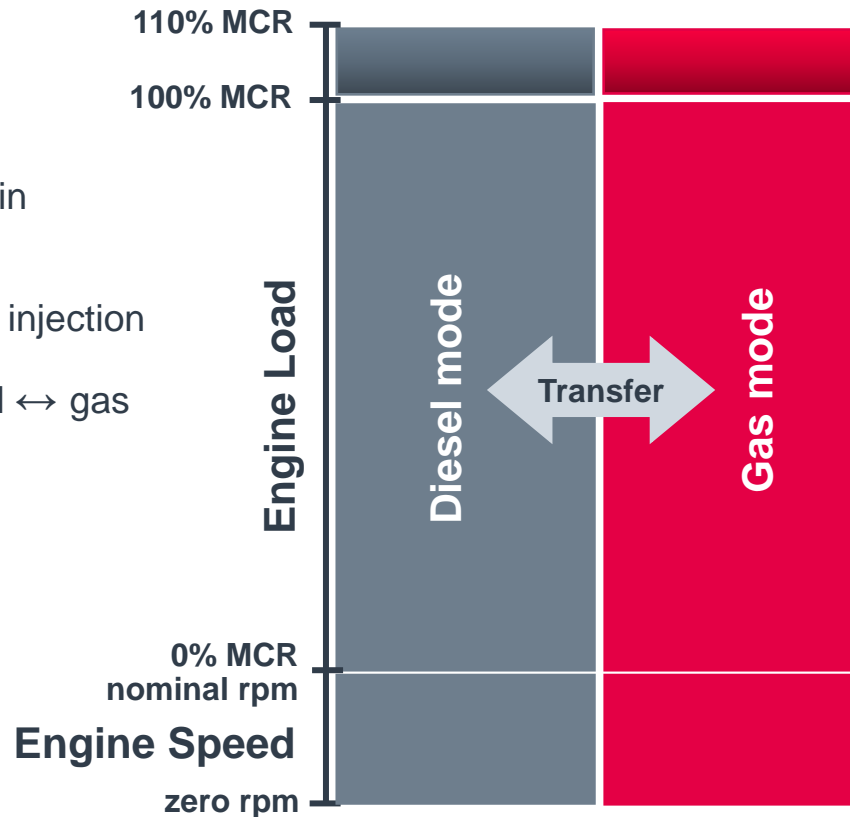
# Engine Characteristics – Fuel Mode Transfer



## MAN 51/60DF (1,050 & 1,150 kW/Cyl)

### Diesel Mode

- Engine start / stop in diesel mode
- Main fuel + pilot oil injection
- Fuel transfer diesel ↔ gas in about 2 min.



### Gas Mode

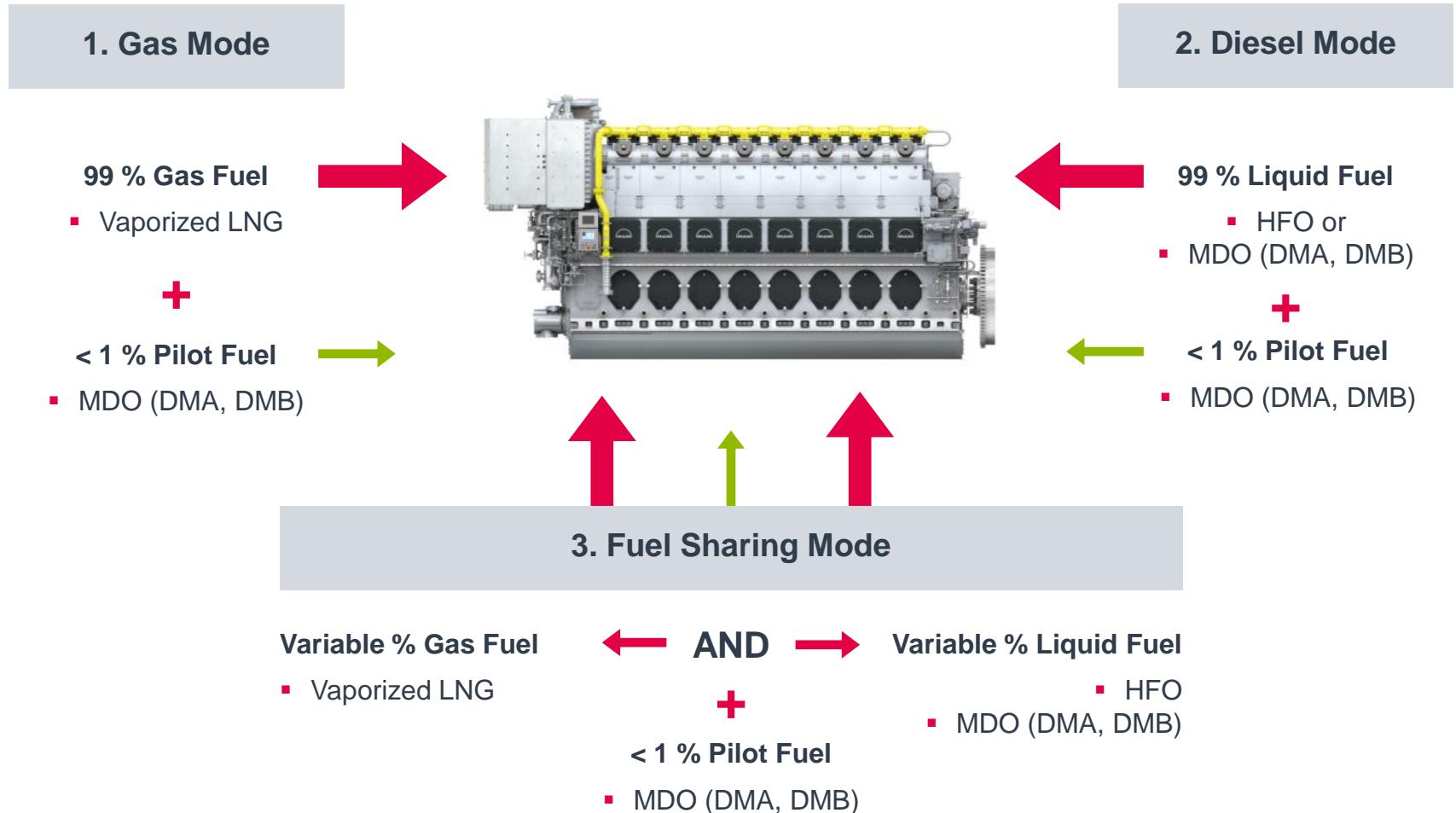
- Engine start / stop in gas mode
- Gas fuel + pilot oil injection
- Operation in gas mode w/o time limit for loads  $\geq 10\%$  - 100% MCR
- Overload capability of 10% for regulating purposes
- Quick change over gas → diesel in emergency case

▶ **Maximum flexibility between Diesel and Gas operation across entire load range**



# Operating Modes

MAN 51/60DF performance, facts & figures



# MAN 51/60DF in Action

## References



### LNG Carrier

17 Vessels  
76 x MAN 51/60DF



### FSRU

3 Vessel  
12 x MAN 9L51/60DF



### Conversion

1 Container Vessel,  
3 Power Plants  
7 x MAN 51/60DF



### Offshore

1 Semi-sub  
12 x MAN 8L51/60DF



### Power Plants

8 Power Plants  
34 x MAN 51/60DF



### Power Ships

8 Power Ships  
46 x MAN 51/60DF

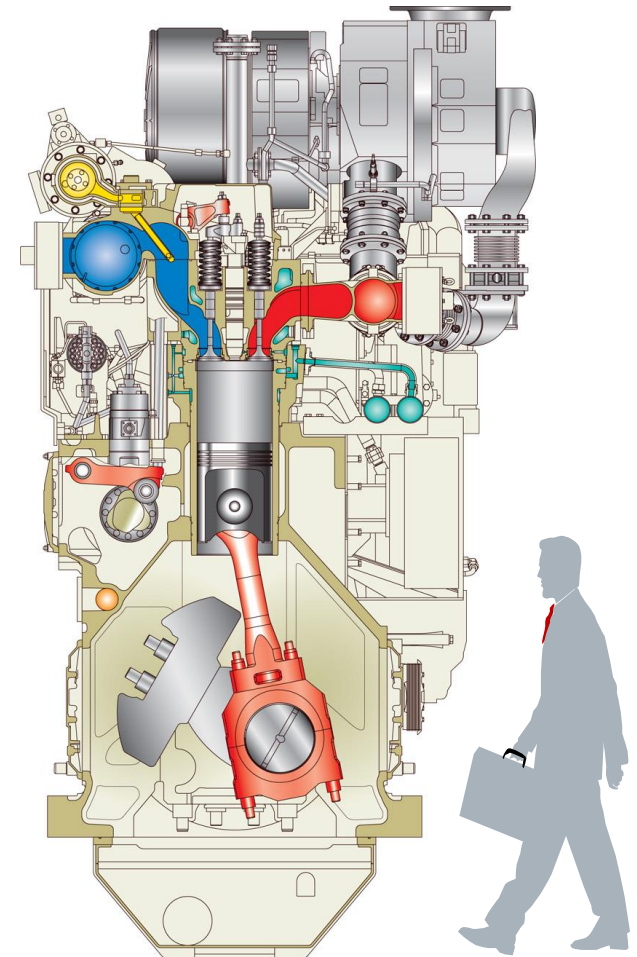
▶ 185 x MAN 51/60DF engines, 2.2 GW installed power, 2.0 Mio operating hours

# Main Technical Data 35/44DF

*Electric propulsion (E2 cycle)*



Specification	Dimension	50 Hz	60 Hz
Bore / Stroke	mm	350 / 440	
Cylinder Configuration	-	6,7,8,9,10	
Engine Speed	min <sup>-1</sup>	<b>750</b>	720
Rated Output per Cylinder	kW <sub>m</sub>	<b>530</b>	510
Mean Effective Pressure (MEP)	bar	<b>20</b>	
Mean piston speed	m/sec	<b>11.0 / 10.5</b>	
Power range	kW <sub>m</sub>	3,060 – 5,300	
Fuels		MGO, MDO, HFO up to 700cSt Natural Gas (LNG)	
SFGC / SFOC* Tol. acc. ISO 3046-1, IMO Tier II in Liquid Mode, IMO Tier III in Gas Mode, <b>MN ≥ 80</b> , <u>85 % Load</u> , w/o attached pumps, Gas Mode inc. Pilot fuel, 30mbar exhaust gas pressure * MGO (DMA ISO 8217 - 2010)	kJ/kWh g/kWh	Gas mode: 7,515 Diesel mode*: 175.0	
Emissions	-	- Tier II in Liquid Mode - Tier III in Gas Mode <b>- Tier III in Liquid Mode with MAN SCR</b>	



**Most powerful engine in its class incl. all cylinder numbers from 6 to 10.**

# Operating Modes



## Gas Mode

LNG > 99%

Gas Mode

Pilot fuel (MGO) < 1%

110% power in gas mode for regulation purposes



## Liquid Fuel Mode

HFO, MDO > 99%

Diesel Mode

Pilot fuel (MGO) < 1%

Engine is Tier III compliant in Gas mode and Tier II in Diesel Mode w/o SCR.



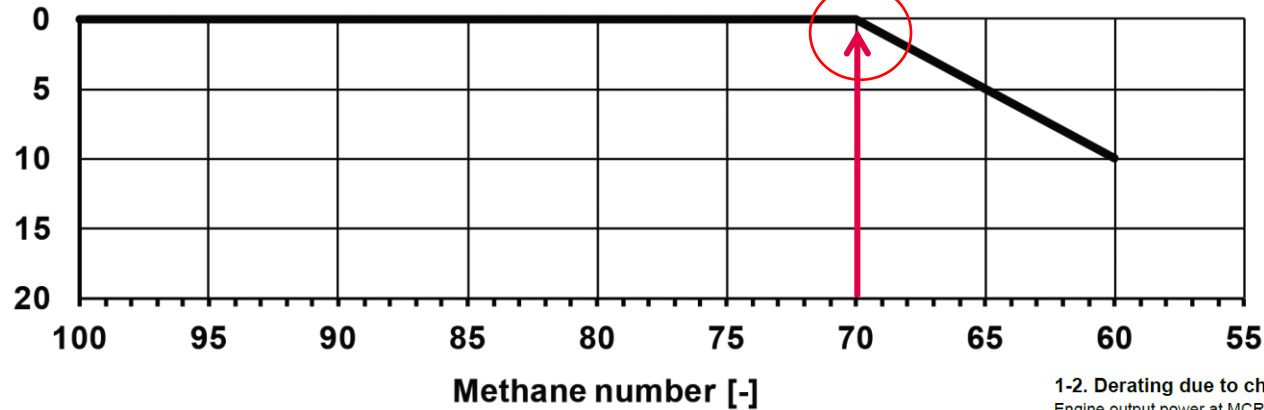


# 35/44DF Dual Fuel Engine

Engine performance - Methane Number

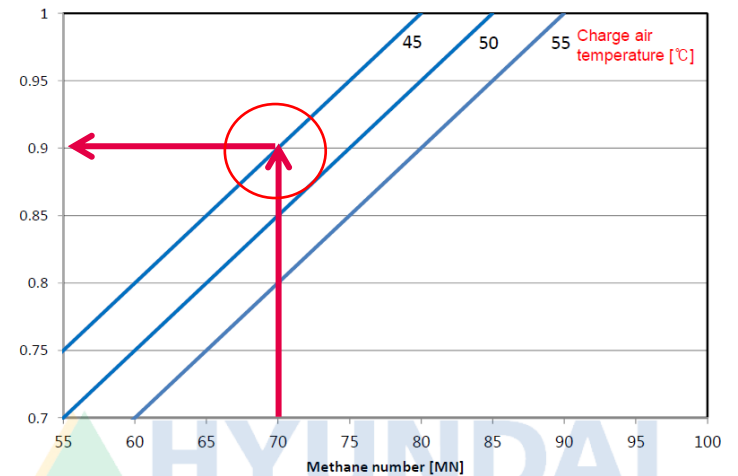


Derating  $d_{MN}$  [%]



**35/44DF:**  
**Full Cylinder output**  
**down to MN 70**

1-2. Derating due to charge air temperature and methane number (MN)  
Engine output power at MCR shall be reduced depending on the charge air temp and methane number.



**MDT 35/44DF full engine output down to Methane Number 70.**

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# MAN Holeby Dual Fuel GenSets

## Advantages



### Power Range:

- L23/30DF 625 – 1,200 kW
- L28/32DF 1,000 – 1,800 kW



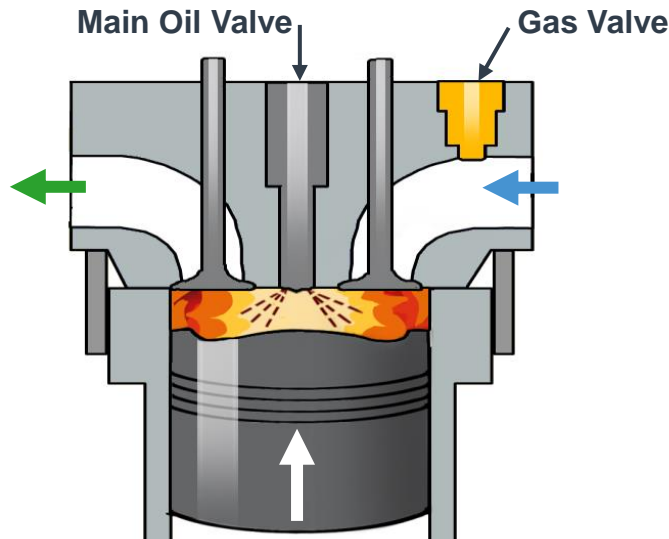
- Safe & Reliable Operation – design is based on engine types with decades of service experience
- Competitive CAPEX – simplified fuel injection system
- Flexible Installation – engine and GVU can be up to 100m apart
- Low Maintenance Cost – extended TBO

# Unique Injection Concept

Power to Trust



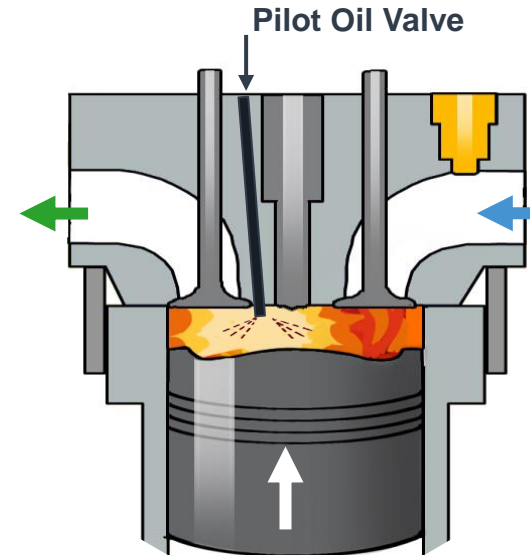
## “Holeby” Concept



Ignition by Pilot Oil  
via MAIN injector

- Low CAPEX
- Operation on MGO (DMA)
- Simple retrofit solution
- Low Maintenance

## Conventional Concept



Ignition by Pilot Oil  
via PILOT injector

- High CAPEX
- Operation on HFO/MDO in diesel mode
- Special parts & common rail
- Complex retrofit solution

# L23/30DF IMO Tier III Compliant

## MAN Holeby Dual Fuel GenSets



- Verified Test results shows NOx-level well below limit
- Gas Mode: IMO Tier III
- Diesel Mode: IMO Tier II
- 110% power output in Diesel Mode
- 110% power output in Gas Mode
- Safe and reliable/stable operation

### Applications / Certificates

- IMO Tier III (Gas Mode)
- Marine GenSets (constant speed)
- Diesel Electric Propulsion (excl. DP)
- Power Stations/Plants
- WB 2007





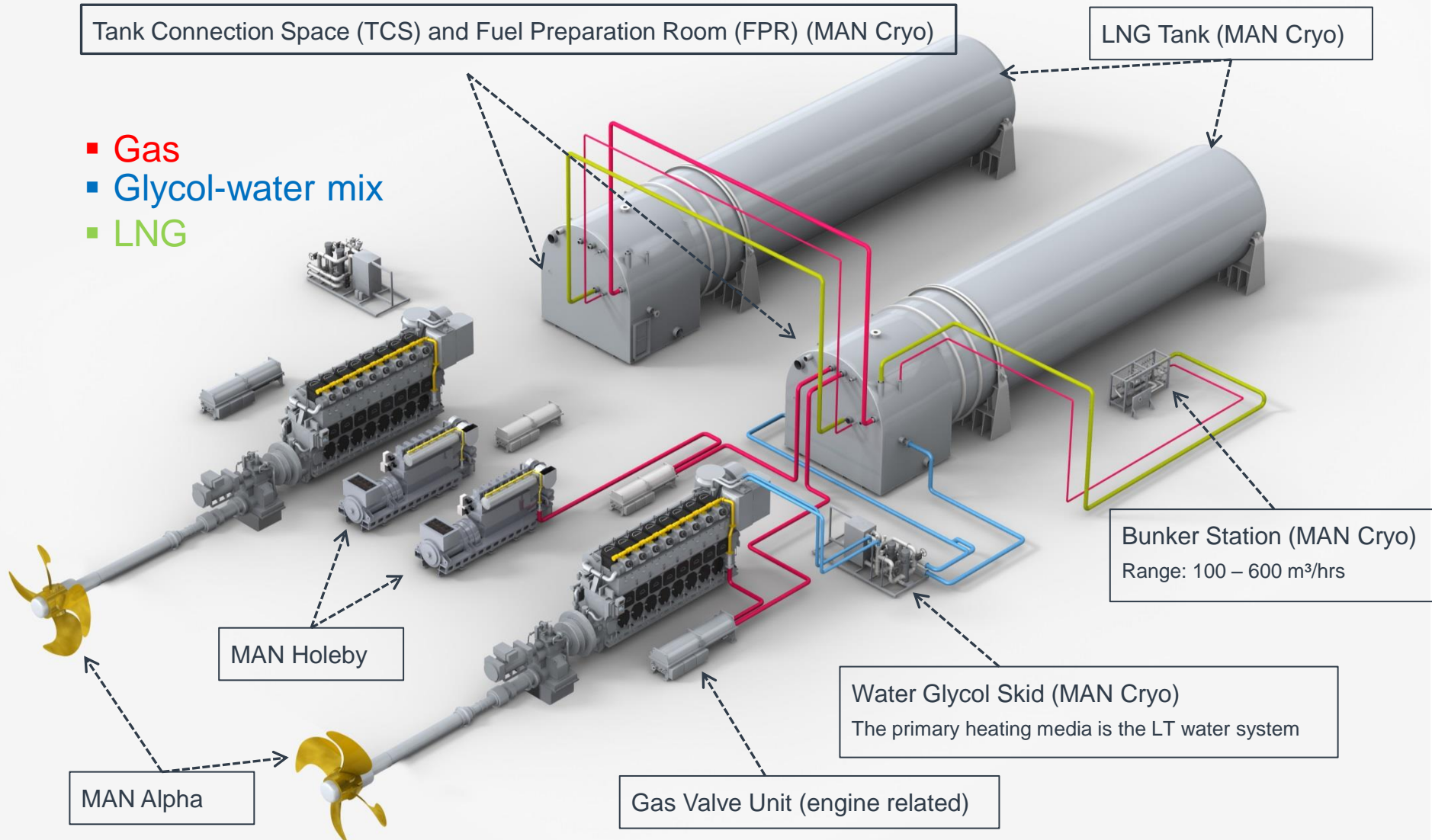
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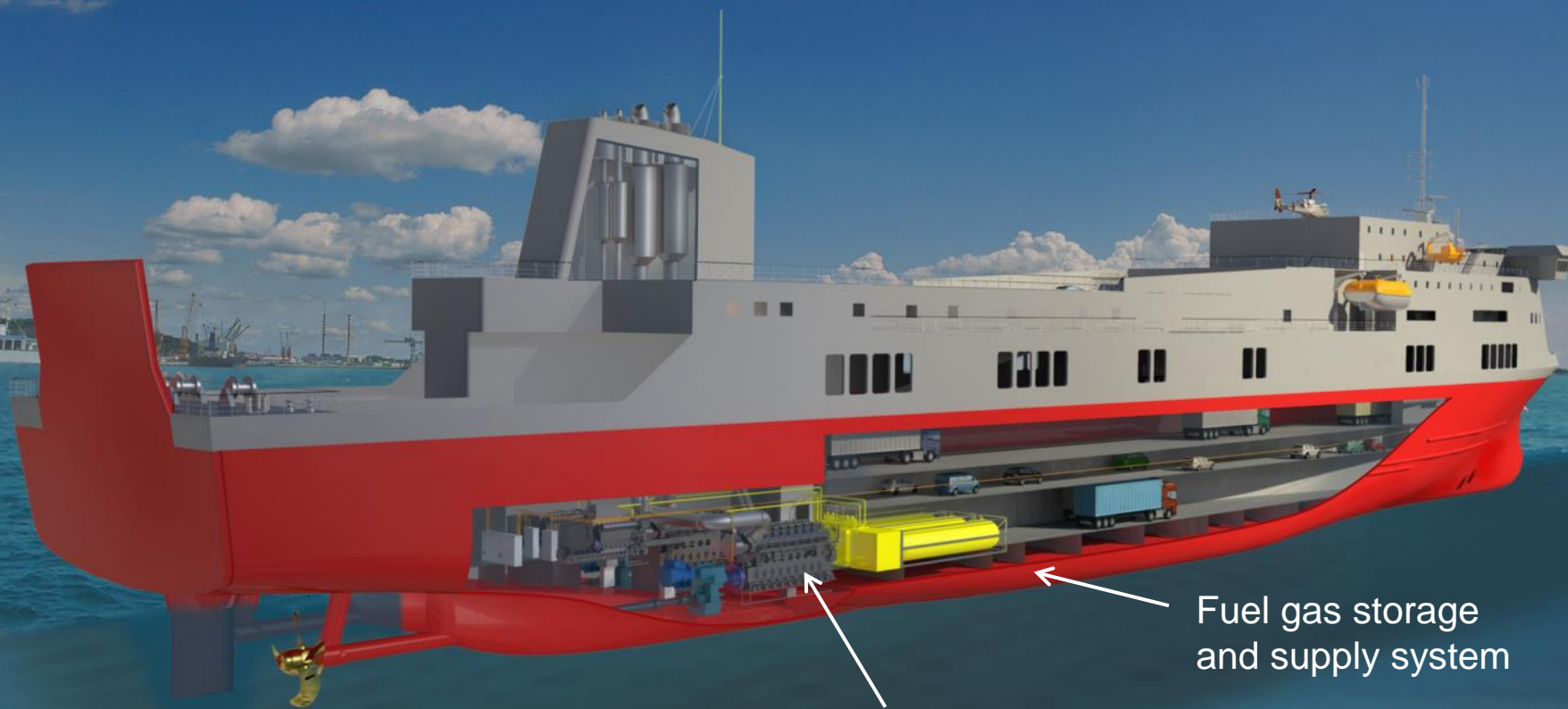
# Products Portfolio MAN Package

Fuel Gas Supply System (FGSS)



# CRYO's Fuel Gas Storage and Supply System

Solutions for IMO TIER III Regulations and Market Requirements



Dual fuel engines  
and gas valve units

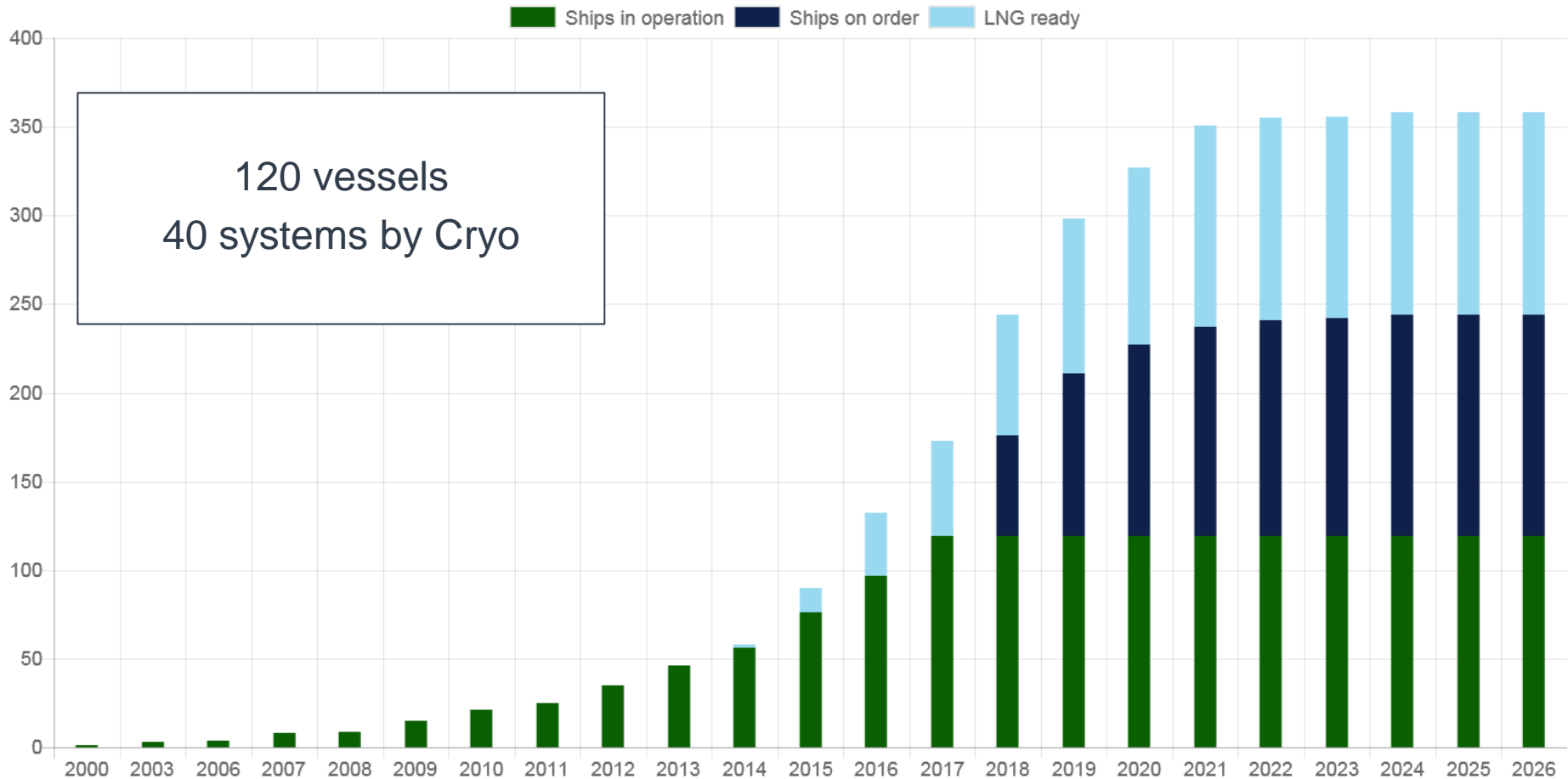
Fuel gas storage  
and supply system



# Mile Stones



Yearly development of fleet



# The Solutions: Integrated gas propulsion systems



GLUTRA FERRY 1<sup>st</sup> Fuel Gas System



SEAGAS 1<sup>st</sup> Bunker Ship



Icebreaker "POLARIS",  
2 x 400 m<sup>3</sup>, vertical tanks



Tallink, High speed RoPax ferry,  
2 x 300 m<sup>3</sup>, horizontal tanks



SeaRoad, RoRo ferry, mobile LNG tanks, exchanged via trailers

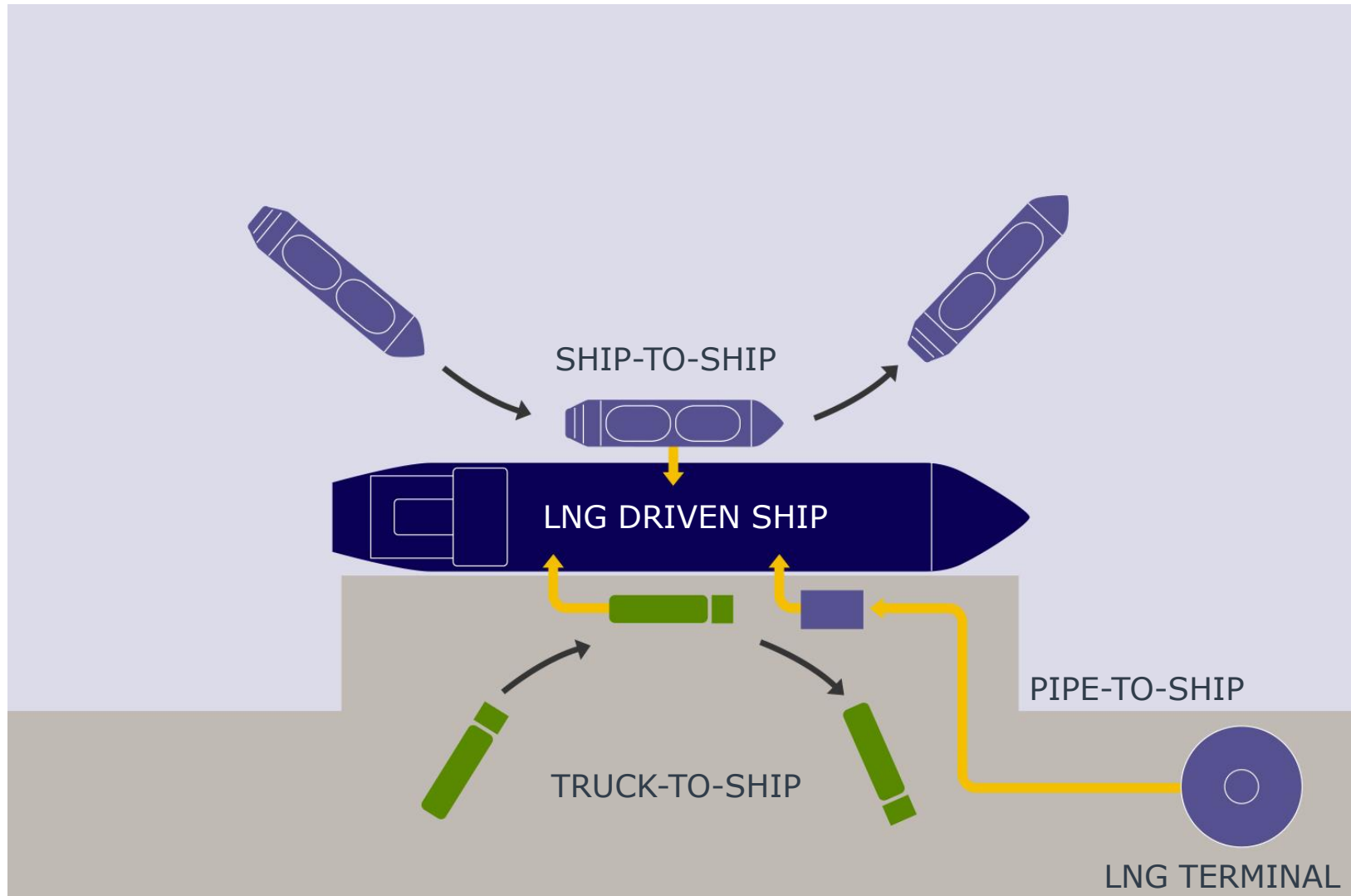


LNG fuel tank trailers

**MAN Cryo has been the pioneer for marine fuel gas systems and has delivered 40 systems.**



# Bunkering methods



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# Thank You For Your Attention



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