

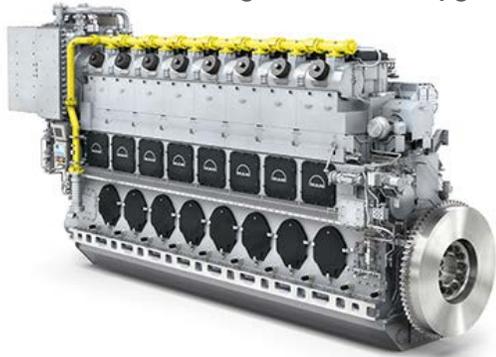
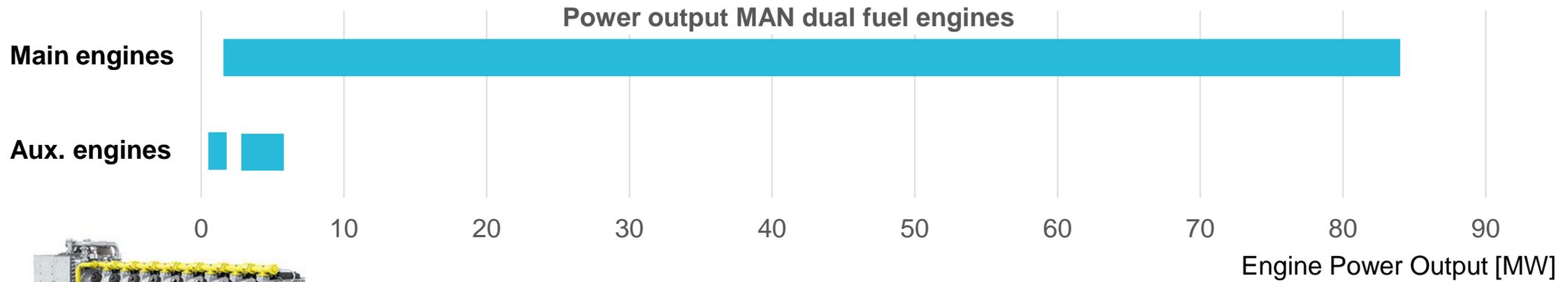
# MAN Small-bore Dual Fuel Genset

# Agenda

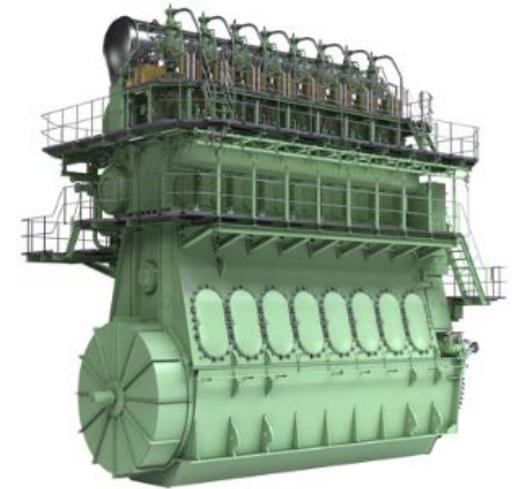
- 1 The Holeby DF engines**
- 2 DF design and safety**
- 3 Service experience**
- 4 Training courses**

# Overview and market relevance

## MAN dual fuel portfolio



Emissions	Influence of NG / LNG fuel	IMO Legislation
NO <sub>x</sub>	↓	✓
SO <sub>x</sub>	↓	✓



**MAN ES covers the whole range from 0.5 to 82.4 MW by dual fuel engines running on NG/LNG**

# MAN Small bore Dual Fuel GenSets

## 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



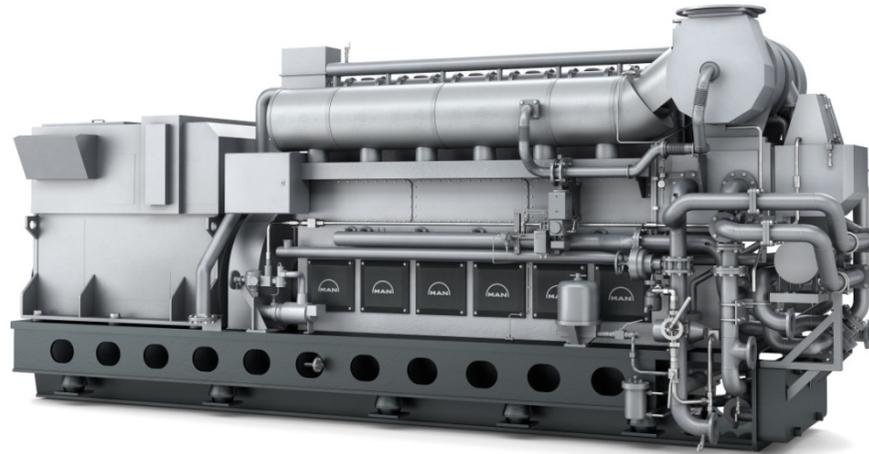
# Operation Modes

Compliance with IMO Tier III in gas mode

**Diesel mode**  
Main fuel nozzle

100%  
**Diesel** →  
MGO (DMA)

**No HFO!!!**



**Gas mode**  
Gas admission valve

Natural gas  
(vaporized LNG)

← **Gas** 98,2%

← 1,8%

Pilot fuel via main fuel nozzle  
Fuel type: MGO (DMA)

# Engine data

MAN small bore DF engines are based at well proven engine types

## Main engine data: 28/32DF

<b>Bore</b>	<b>: 280 mm</b>
<b>Stroke</b>	<b>: 320 mm</b>
<b>Cylinder numbers</b>	<b>: 5-6-7-8-9</b>
<b>Speed</b>	<b>: 720 / 750 rpm</b>
<b>Output / cylinder</b>	<b>: 200 kW/cyl.</b>
<b>Mean Effective Pressure</b>	<b>: 17 / 16.3 bar</b>
<b>Mean Piston Speed</b>	<b>: 7.7 / 8.0 m/sec</b>
<b>Combustion Pressure</b>	<b>: &lt;145 bar</b>
<b>Fuel</b>	<b>: MGO / GAS</b>
<b>MN</b>	<b>: &gt; 80</b>
<b>Temperature before engine:</b>	<b>&lt; 45 °C</b>

## Main engine data: L23/30DF

<b>Bore</b>	<b>: 225 mm</b>
<b>Stroke</b>	<b>: 300 mm</b>
<b>Cylinder numbers</b>	<b>: 5-6-7-8</b>
<b>Speed</b>	<b>: 720 / 750 / 900rpm</b>
<b>Output / cylinder</b>	<b>: 125 /125 /150 kW/cyl.</b>
<b>Mean Effective Pressure</b>	<b>: 17.5 / 16.8 / 16.8 bar</b>
<b>Mean Piston Speed</b>	<b>: 7.2 / 7.5 / 9.0 m/sec</b>
<b>Combustion Pressure</b>	<b>: &lt;145 bar</b>
<b>Fuel</b>	<b>: MGO / GAS</b>
<b>MN</b>	<b>: &gt; 80</b>
<b>Temperature before engine:</b>	<b>&lt; 45 °C</b>

# L28/32DF and L23/30DF

What's next to come?

## Current power range

- L23/30DF 625 – 1,000 kW → 900 rpm version with increased power output → 625 – 1,200 kW
- L28/32DF 1,000 – 1,800 kW

## Safe & reliable operation

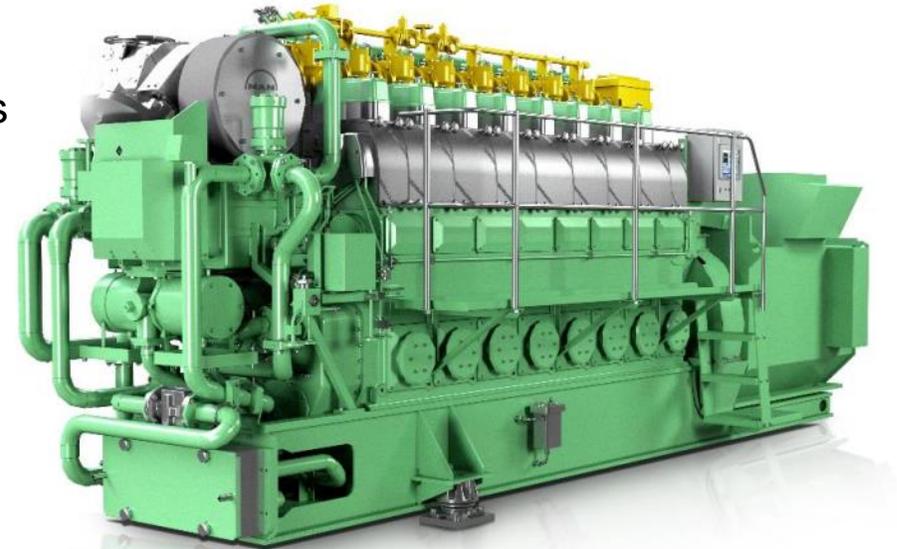
- Service experience on the DF engine will be used to improve robustness
- More robustness, lower energy consumption, lower emissions.

## Full fuel flexibility

- Full IMO Tier III compliance with SCR in both gas and diesel operation
- Wider range of liquid fuels will be tested
- Test of Mn influence and propulsion variant

## Competitive CAPEX – simplified fuel injection system

- Cost down activities



**MAN ES design activities focus on competitiveness**

# L28/32DF IMO Tier III Compliant

MAN Holeby Dual Fuel GenSets

Test of L28/32DF for:

- Gas Mode: IMO Tier III
- Diesel Mode: IMO Tier II
- 110% power output in Diesel Mod
- 110% power output in Gas Mode
- Safe and reliable/stable operation

Verified test results shows  
NOx-level well below limit



**SIEM Car Carrier**

2+2 x 7500 PCTC

1 x  
7L28/32DF  
2 x  
9L28/32DF

# Approvals & certificates

## L23/30DF IMO Tier III Certificate

**NOx Technical File**  
Issued under the provisions of the Protocol of 1997 as amended by resolution MEPC. 176(58) in 2008 to the amendment of the International Convention for the Prevention of Pollution from Ships, 1973 as modified by the Protocol of 1978 relating thereto MARPOL 73/78, Annex VI. EEEEF4

**Engine Group Certification**  
**Engine Group: 23/30DFa**  
**Tier II/III**  
**Parent Engine: 5L23/30DF**  
**Engine no: 17090**

Engines of the engine group have to be equipped and adjusted according to the specifications given in engines technical file. The main parameters are listed below:

Engine speed	750 rpm
Engine power	125 kW / cylinder
Test cycles	E2 / D2
Mean effective pressure	16,8 bar
Electronic injection control	No
Variable injection timing	Yes
Exhaust gas re-circulation	No
Water injection/emulsion	No
Air injection	No
Exhaust after-treatment	No
Dual fuel	Yes, liquid and gaseous
Ignition in dual fuel mode	Pilot injection of liquid fuel
Variable turbocharger geometry	No
Max. inlet water temperature	
charge air cooler	36°C
Maximum charge air temperature	48°C (corresponding to 25°C sea water temp.) 70°C (with preheating at load below 30%)
Maximum exhaust back pressure	30 mbar
Liquid Fuel oil to be used on-board	DMA acc. to ISO 8217
Gaseous Fuel to be used on-board	LNG
Lubrication oil specification	SAE 30
Fuel cam plunger lift at TDC	Max. 5.81 mm (average value)
IMO identification numbers	according chapter 8

  
EXAMINED  
EIAPP-G-173288-0001  
SEE LETTER Date: 2018-01-11  
*i. A. / R. S. 4-11*



## 28/32DF Type Approval



**DNV·GL**  
Certificate No: **TAM000011T**

**TYPE APPROVAL CERTIFICATE**

**This is to certify:**  
**That the Dual Fuel Engine**  
with type designation  
**L28/32DF**  
Issued to  
**MAN Energy Solutions**  
**Copenhagen SV, Denmark**

is found to comply with  
**DNV GL Rules for classification, Ships - DNVGL-RU-SHIP-Pt4 Ch3 Sec1,**  
**Reciprocating Internal Combustion Engines**

**Application :**  
Multi engine plant: electrical propulsion and auxiliary

Product approved by this certificate is accepted for installation on all vessels classed by DNV GL.

This Certificate is valid until **7th March, 2024**.  
Issued at **Høvik** on **8th March, 2019**

for DNV GL  
DNV GL local station: **Copenhagen**  
Approval Engineer: **Tage Olav Alexander Strøm**

  
Location: DNV GL Havn, Norway  
Signing Date: 08.03.2019, see stamp if

**Oddvar Deinboll**  
Head of Section

This Certificate is subject to terms and conditions overleaf. Any significant change in design or construction may render this Certificate invalid. The validity date relates to the Type Approval Certificate and not to the approval of equipment/systems installed.

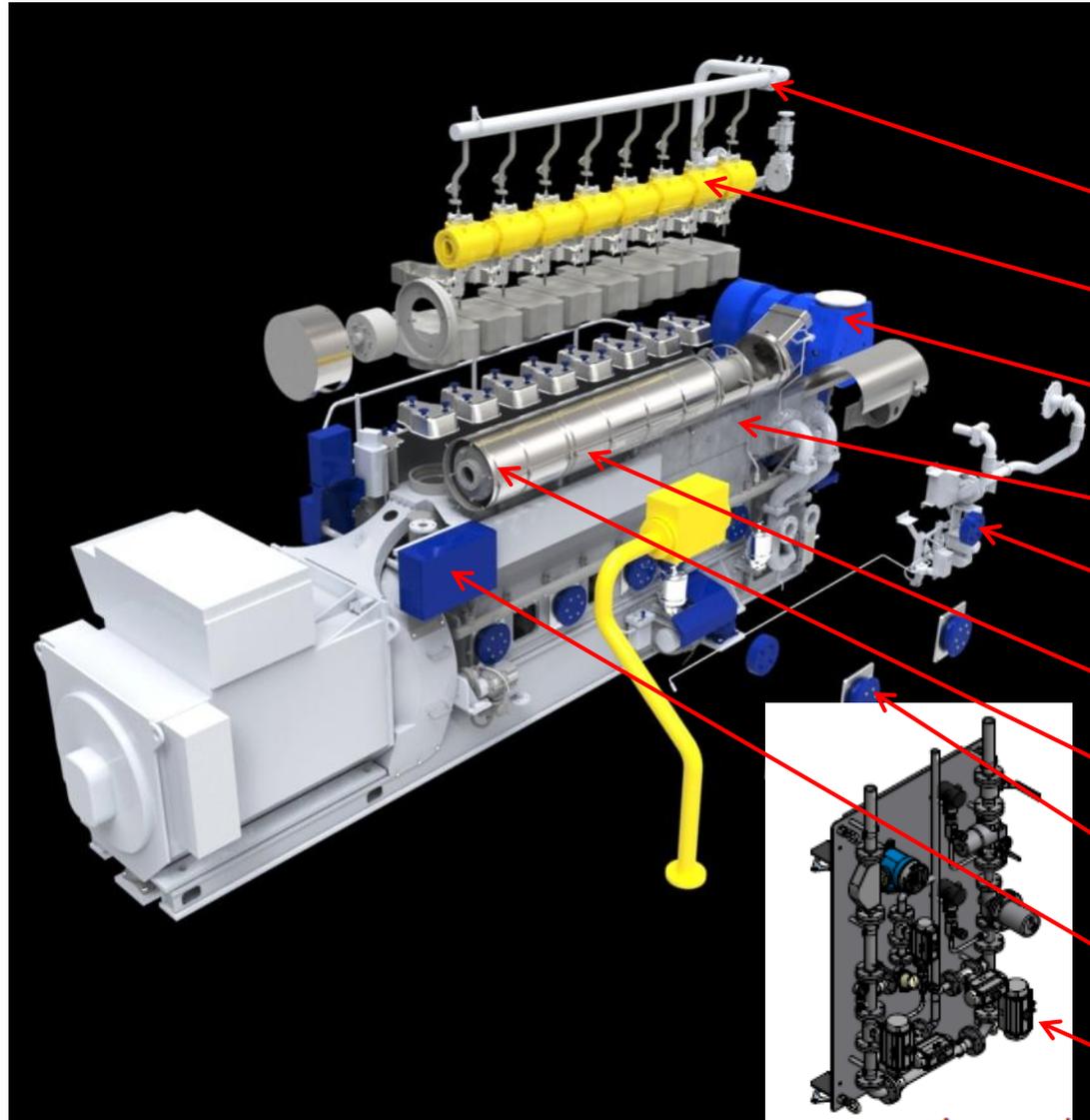
Form code: TA 1413a Revision: 2015-05 www.dnvgl.com Page 1 of 3

**Type approval and IMO Tier III certificate is achieved – now aiming for optimisations**

# Design and safety

# Components for Dual Fuel Operation

New Building and Retrofit Package

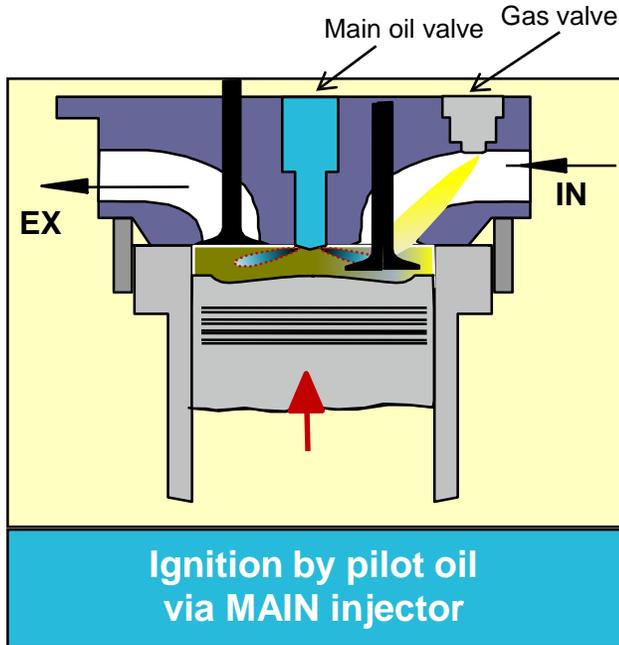


Modified/New parts that to be installed:

- Cooling water pipe
- Gas injection valve and pipe
- Turbocharger + Shut-off Valve
- Pistons
- Waste Gate (air/gas ratio)
- Valve/valve seats
- Fuel pumps
- Pressure relieve valves
- Dual fuel/knocking control
- External Gas Valve Unit

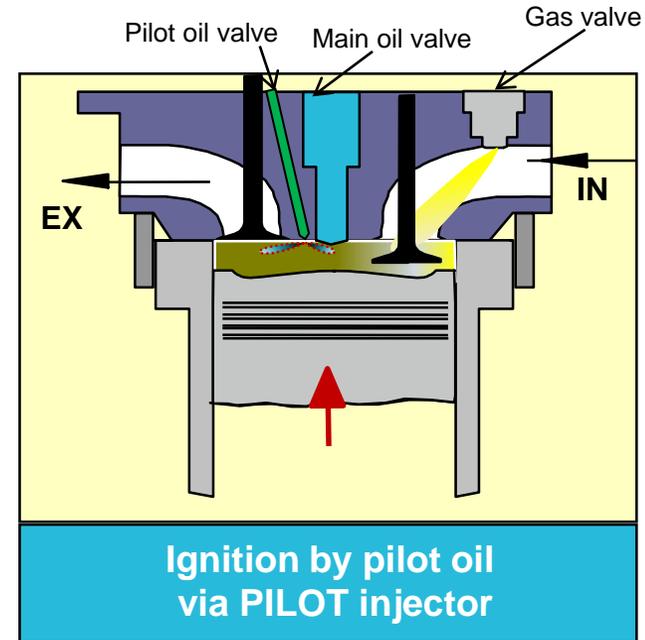
# Injections Concept

## Small bore Concept



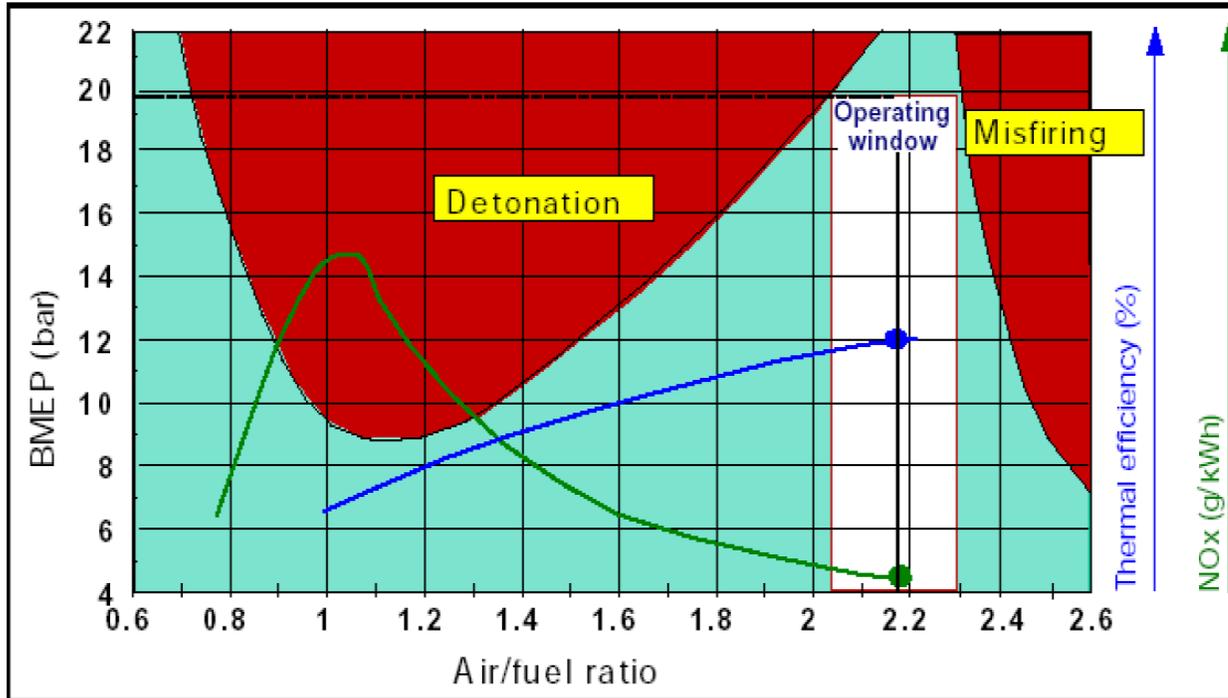
- Operation on MGO (DMA) in liquid and gas mode

## Conventional



- Operation on HFO/MDO in liquid mode
- Lower SGC/Pilot Oil
- Special parts & common rail

# Engine Design suitable for Dual-Fuel?



MEP < 20 bar. Air/fuel ratio limited. Reduce risk “knocking”/misfire

Liquid Engine	MEP (bar)	Dual Fuel Engine	MEP (bar)
L23/30H	~18 - 20	L23/30DF	~16 - 18
L28/32H	~18 - 19	L28/32DF	~16 - 17
L16/24	~21 - 24		
L21/31	~22 - 27		
L27/38	~23 - 27		

### Classic design

Already close to required MEP,  
-> only minor power reduction.

### Compact design

Far from required MEP,  
-> larger power reduction necessary.

# Power reduction at conversion to DF

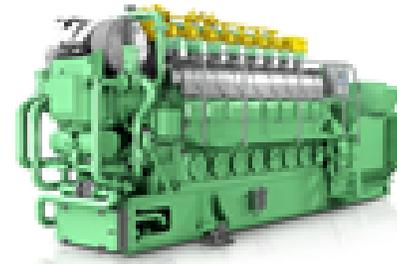
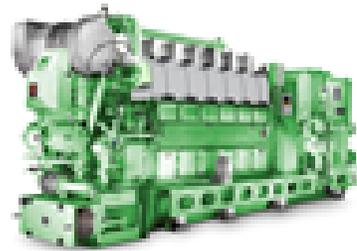
## Main engine data: L23/30H

Bore : 225 mm  
Stroke : 300 mm  
Cylinder numbers : 5-6-7-8-9  
Speed : 720/750/900 rpm  
Output / cylinder : 142/148/175 kW/cyl.

## Main engine data: L23/30DF

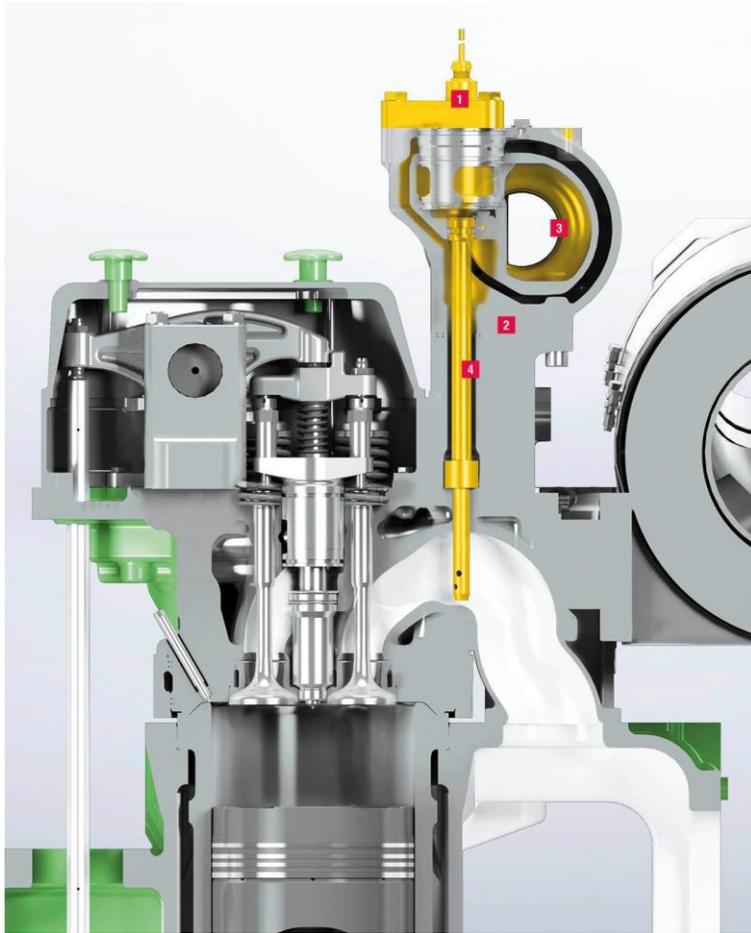
Bore : 225 mm  
Stroke : 300 mm  
Cylinder numbers : 5-6-7-8-9  
Speed : 720/750/900 rpm  
Output / cylinder : 125/125/150 kW/cyl.

Conventional → Dual Fuel  
**Power Reduction: 12–15%**



# Gas pipes on engine

Main parts overview



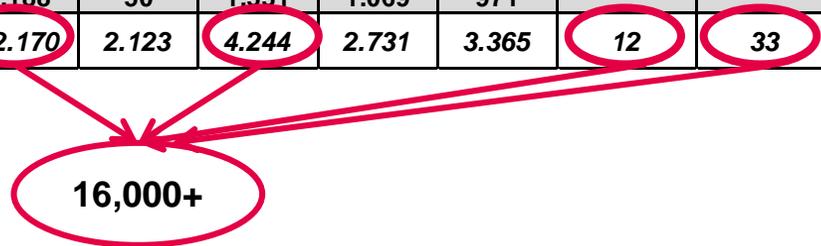
1. Gas Injector Valve (SOGAV)
2. Gas Block
3. Double-Wall Pipe with gas leak detection
4. Gas pipe/gas connection



# Service experience

# MAN Small bore Marine Engines in service

Engine Builder	L16/24	L23/30	L21/31	L28/32	L27/38	L32/40	L23/30DF	L28/32DF	Total
CMP	1.015	3.674	604	400	215	43	12	12	5.975
CXZ/SQE	139		29						168
SXD	227		158			93			478
HND	170		32						202
Weichai	18		71		115	49			253
STX Korea	621	3.896	871	1.141	570	1.566		6	8.671
Doosan	5	910	113	34	112	633		15	1.822
Adria & Split		490	5		5				500
HCP/FSA	41	95	18	442	24	9			629
MDT FRH	12	391	59	264	447				1.173
MDT Holeby	217	526	66	632	84				1.525
MDT India			47		90	1			138
Others	265	2.188	50	1.331	1.069	971			5.874
<b>Total</b>	<b>2.730</b>	<b>12.170</b>	<b>2.123</b>	<b>4.244</b>	<b>2.731</b>	<b>3.365</b>	<b>12</b>	<b>33</b>	<b>27.408</b>



# Vessels in service with DF engines

Owner	Sea trial date	Vessel name	IMO	Engines
Tote	01.10.2015	Isla Bella	9680841	3X9L28/32DF
	01.10.2016	Perla Del Caribe	9680853	3X9L28/32DF
Crowley	01.06.2017	El Corqui	9721968	3X9L28/32DF
	01.11.2018	Taino	9721970	3X9L28/32DF
ESL Shipping	01.02.2017	Haaga	9797632	1X5L+2X8L23/30DF
	30.08.2017	Viiki	9797620	1X5L+2X8L23/30DF

# L28/32DF and L23/30DF

## Service experience

### 100,000 hours in gas mode

- Smooth switch between diesel mode and gas mode
- Trouble-free load step behaviour

### Issues in service

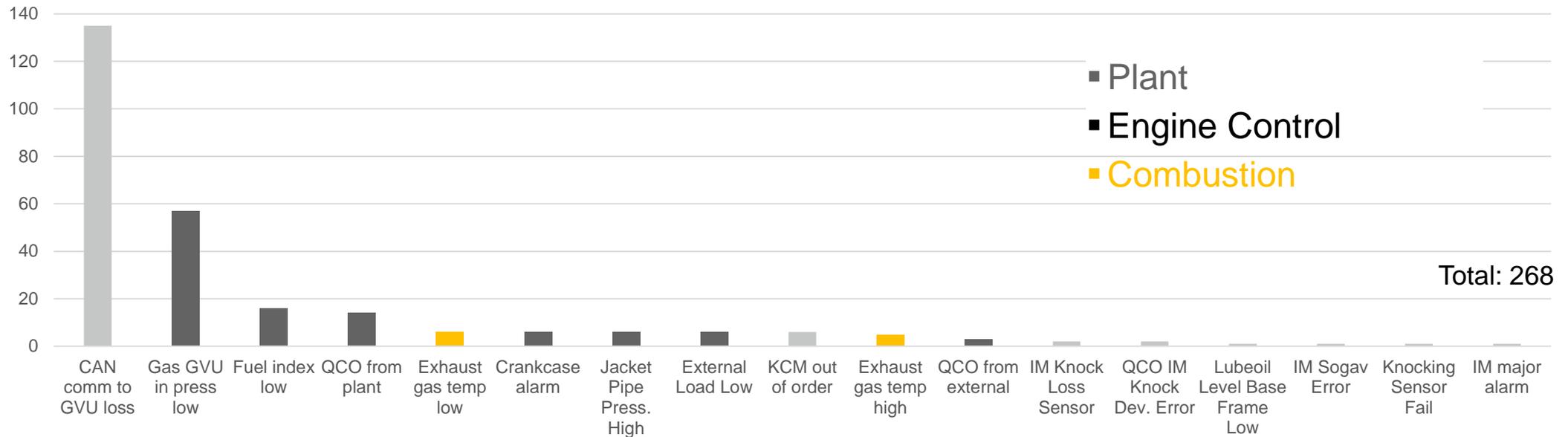
1. QCO - Electrical interference
2. Weak non-return Valve
3. Leaking gaskets in exhaust gas system
4. Burned exhaust gas valves
5. Malfunction of waste gate
6. Deviation at exhaust gas temperature in gas mode
7. Operational conditions due to external systems



**Field tests/observations with reference customers ongoing – continuously improving reliability**

# QCO Accumulated on TOTE vessels

Start Jan to End Apr 2018

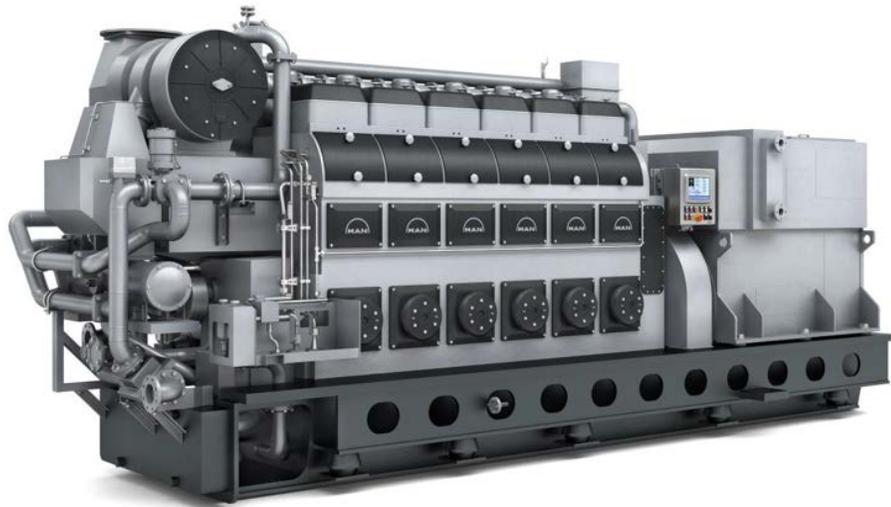


Not every QCO is resulting from a problem

e.g. low Gas pressure at GVU inlet is a common situation for given operation ???

- 102 are related to the vessels gas plant operation, and not related to engine system
- 166 related to the engine operation and control system.
  - 11 are related to in-cylinder combustion (exhaust gas temperature low or high)

# 1. QCO - Electrical Interference



Lost communication between engine and GUV

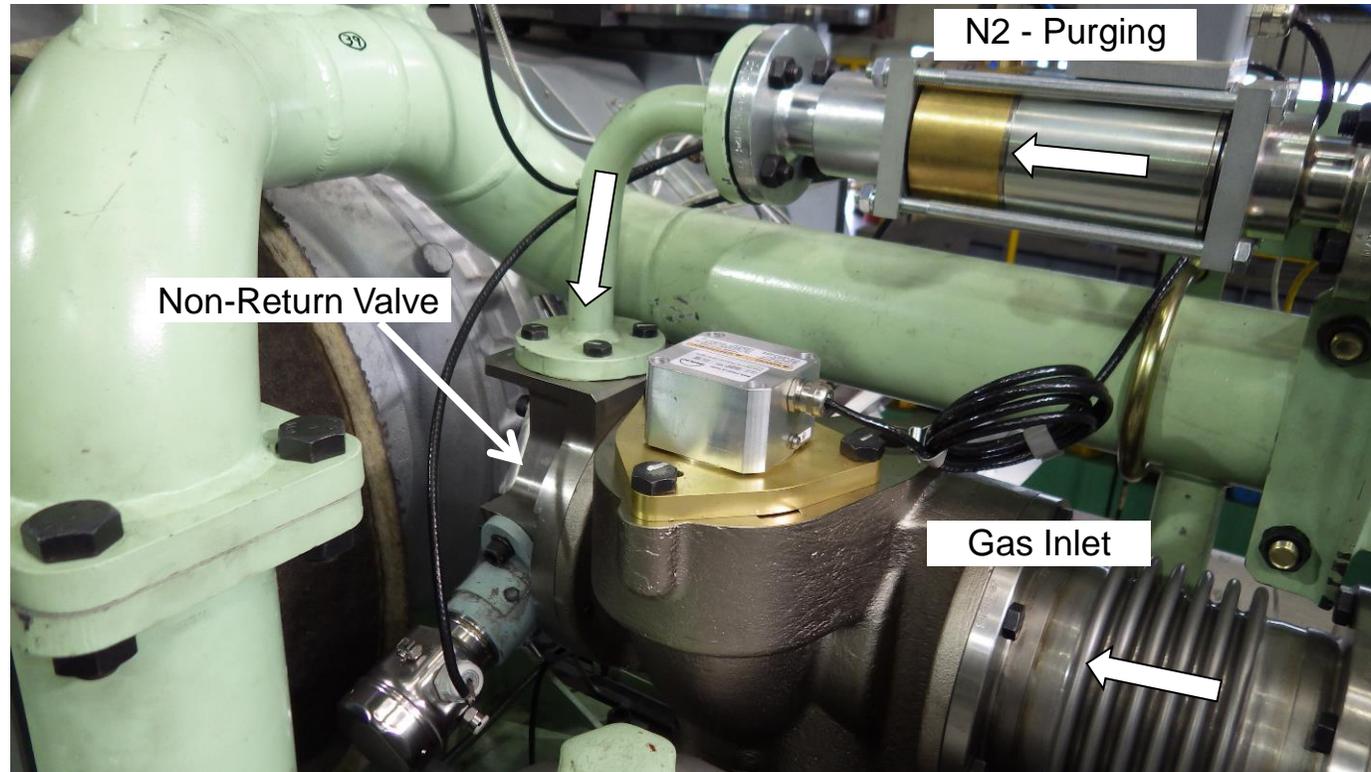
Communication cables changed

Cables relocated in order to avoid EMC interference

Updated Sacos software is presently in field test



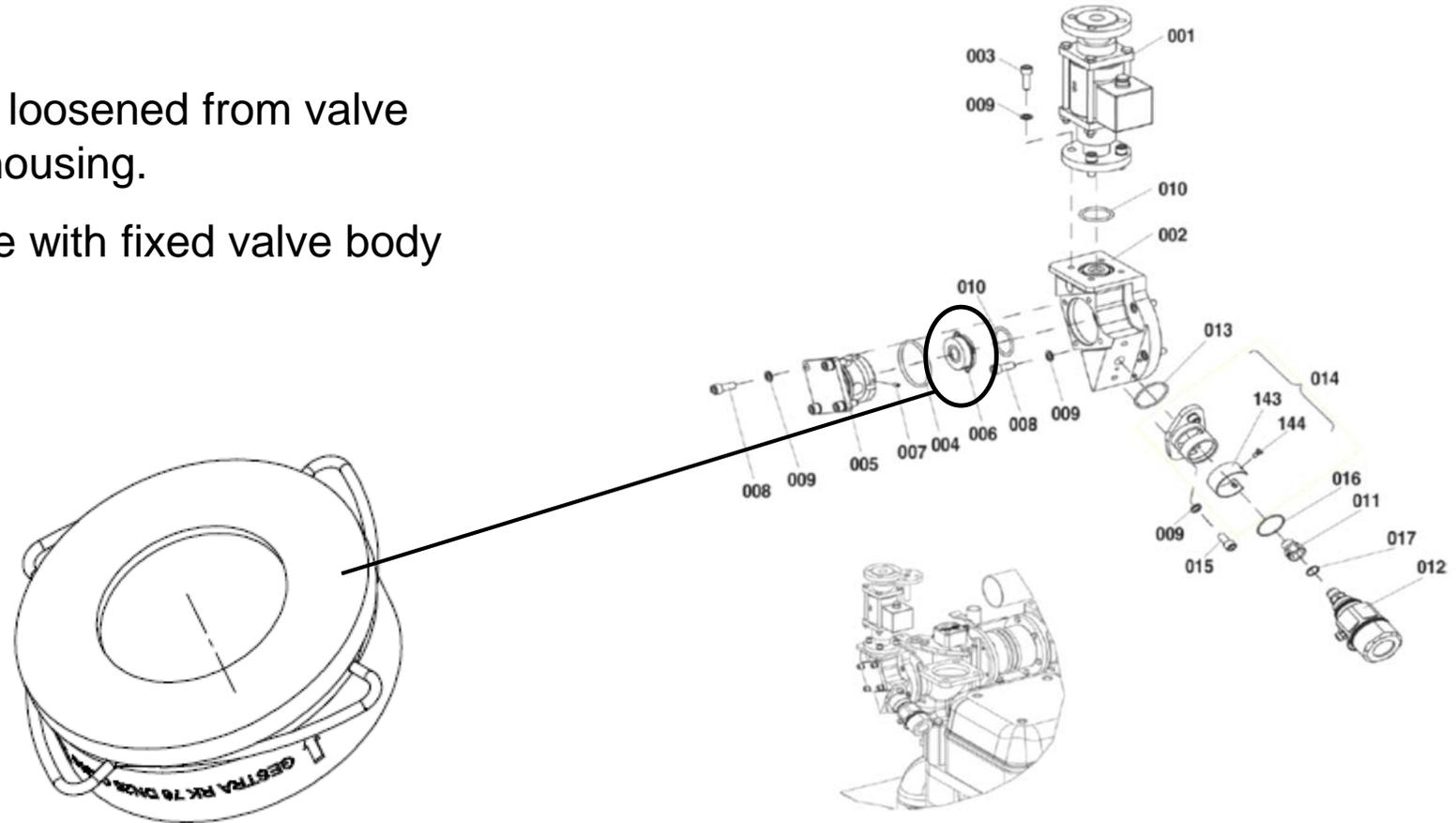
## 2. Weak Non-Return Valve – Purging



# Weak Non-Return Valve – Purging

Valve body in non return valve loosened from valve housing and fall in to the gas housing.

New improved non return valve with fixed valve body introduced.



### 3. Leaking gaskets in exhaust gas system

Gaskets in the exhaust gas was found leaking.  
Wrong gasket type installed by engine builder.  
Installed gaskets was without steel reinforcement.  
All was gaskets replaced with reinforced type.



# Burned Exhaust Gas Valves

- A/E #2:  
Burned outlet valves after 18 months in service
- Action:  
Overhauling of cylinder cover, correct valve adjustment and new lub. Oil with lower TBN level.
- A/E #2:  
Follow up inspection 12 months later  
Good condition



# Knocking sensor fail

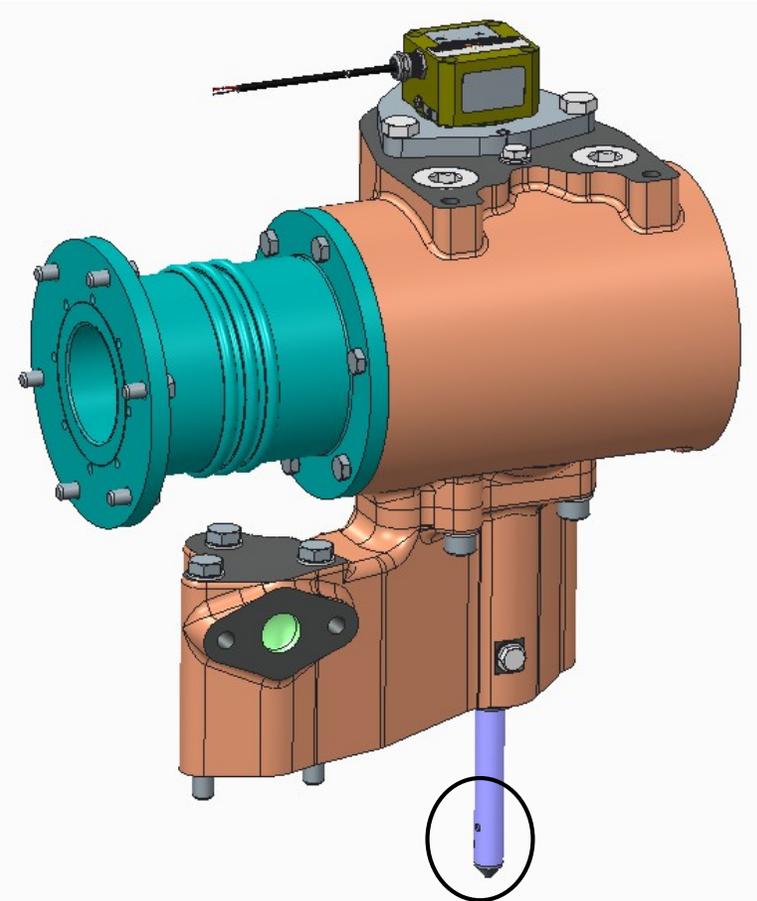
Knocking sensor fault caused by insufficient spot facing at cylinder cover, causing the knocking sensor body to rest at the edge of the casting.

Spot facing modified to avoid similar problem in the future.

Correct torque of mounting bolt are essential in order to ensure correct function of the knocking sensor.



# Deviation at exhaust gas temperature in Gas mode



High exhaust temperature at cylinder 8 in gas mode only.

Investigation revealed that the problem was caused by deformation at one of the holes in the gas supply pipe to cylinder no 8.



# Training courses

# MAN PrimeServ Academy

Hands On Training at Holeby Site

## DF Training Course

- 6 – 8 Superintendents per class
- Duration of Five Working Days

## For Hands On Practice

- DF components
- SaCoSone (DF version)
- GVV

## Qualified Superintendents

- MDT will issue certificate upon completion of test

MAN | PrimeServ Academy



COURSE: C00000724 - 28/32DF-GENSET Commissioning - one week course					
Location:	COURSE/TITLE: 28/32DF-GENSET Commissioning - internal course				IMPLEMENTATION DATES: 06/2016
	1 <sup>st</sup> day	2 <sup>nd</sup> day	3 <sup>rd</sup> day	4 <sup>th</sup> day	5 <sup>th</sup> day
08:30 - 09:15	Safety presentation	Gas Valve Unit	Safety concept Exercise	Firmware Updates on various modules	Commissioning Procedure: Software Setup
09:15 - 10:00	Welcome and introduction	GVU	Safety concept Exercise	Practical Exercise	Commissioning Procedure: Software Setup
10:00 - 10:15	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
10:15 - 11:00	Dual fuel engine vs Diesel engine	GVU practical session	SaCoSone	SaCoSone: Speed Governor & Limiters	Commissioning Procedure
11:00 - 11:45	Dual fuel engine in general	GVU practical session	SaCoSone	SaCoSone: Speed Governor & Limiters	Commissioning Procedure
11:45 - 12:45	Lunch	Lunch	Lunch	Lunch	Lunch
12:45 - 13:30	Mechanical parts for Dual Fuel	Safety concept for Dual Fuel	SaCoSone	SaCoSone: Speed Governor & Limiters	Documentation Workflows
13:30 - 14:15	Mechanical parts for Dual Fuel	Safety concept for Dual Fuel	SaCoSone	SaCoSone: Speed Governor & Limiters	Course Evaluation
14:15 - 14:30	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
14:30 - 15:15	PM (P <sub>max</sub> )	Safety concept for Dual Fuel	SaCoSone / WAGO PLC	SaCoSone: Practical Exercise	
15:15 - 15:30	PM (P <sub>max</sub> )	Safety concept for Dual Fuel	SaCoSone / WAGO PLC	SaCoSone: Practical Exercise	

Subject to change without prior notice



# Disclaimer

Strictly  
confidential

All data provided in this document is non-binding.

This data serves informational purposes only and is especially not guaranteed in any way.

Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

# Thank you very much!

Author  
Department  
Phone  
E-Mail  
Day, Month, Year