WHEN TRUST MATTERS

LNG and Alternative Fuels on Gas Carriers

Presentation in SIGTTO Regional Panel, London 2023-10

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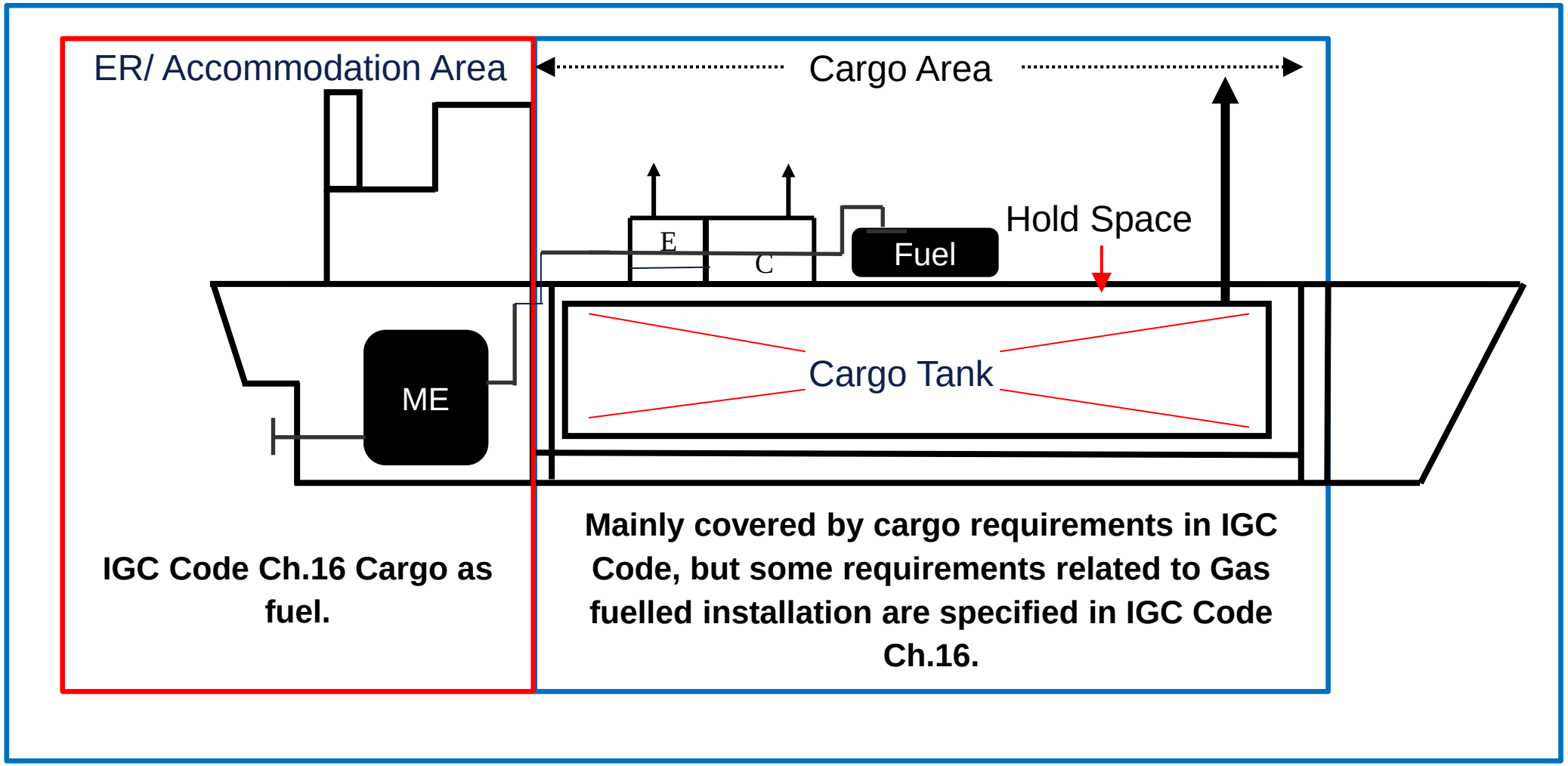
2016 IGC Code Gas fuel requirements

- IGC Code Ch. 16 covers “Use of cargo as fuel” and have all the relevant requirements for such Gas Fuel installations.
  - Covers mainly the added requirements of the equipment outside cargo area.
  - All other chapter of the code remains valid.
  - The basic gas fuel is methane from cargo, however Ch.16.9 gives requirements for Alternative fuel and technologies.
- Note that the IGF Code applies for other ships than gas carriers, but not to Gas carriers.

Which requirements are covered in the IGC code

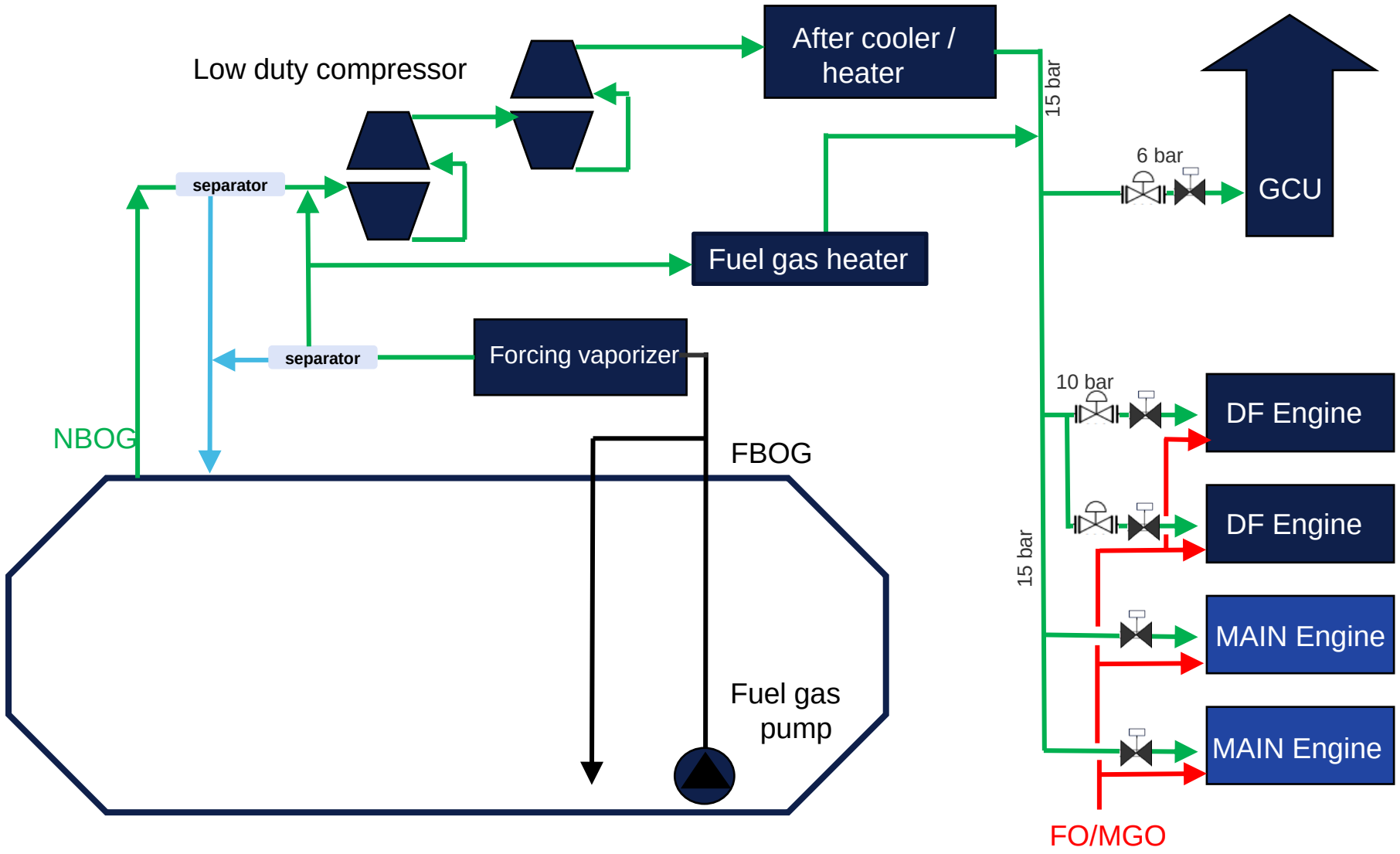


Gas Carriers and Gas as Fuel in IGC Code

IGC code chapter 16 - Sections – Use of cargo as fuel

1. **General** – LNG as fuel
2. **Use of cargo vapour as fuel** - In Boilers, IGG, Engines, GCU and Gas turbines.
3. **Arrangement of spaces containing Gas consumers** – Ventilation, Gas detection and Electrical installations.
4. **Gas fuel supply** – Piping arrangements, remote stop, leak detection and isolation of gas fuels from engine room.
5. **Gas fuel plants and related storage tanks** – Location in cargo area, and remote stops.
6. **Special requirements for main boilers** – Arrangement and safety.
7. **Special requirements for Gas-fired internal combustion engines** – Arrangement and safety.
8. **Special requirements for Gas turbine** – Arrangement and safety.
9. **Alternative fuels and technologies** – Other cargo cases may be uses as fuel, provided the same level of safety as natural gas in the code is demonstrated and accepted by the Flag administration.

LNG carriers fuel gas system – Simplified overview



IGC code and DNV Rules – Fuel gas system main safety principles

Segregation

Protection of gas fuel installation and gas fuelled installation towards safe areas

Double barriers

Protect against leakages for safe areas

Leakage detection

Give warning and enable automatic safety actions

Automatic isolation of leakages

Reduce consequences of a leakage

Gas Carriers and Gas as Fuel in IGC Code

IGC code requirement 16.4 – Subsections - Gas Fuel Supply

1. **General** – Covering installations outside cargo area, but noted some of this installations are positioned in cargo area, with pipeline routing and gas freeing of fuel gas piping.
2. **Leak detection** – Continuous leak detection and shut down fuel supply.
3. **Routeing of fuel supply pipes** – Double wall design with pressurized IG pipes, or mechanical exhaust ventilation, and automatic shut down of fuel gas (Master gas valves) when conditions are not maintained.
4. **Requirements for gas fuel with pressure greater than 1 MPa** – Requirement for double wall piping from the Master gas valves.
5. **Gas consumer isolation** – Arrangement required to isolate each gas consumer by automatic block and bleed with venting of this to a safe location.
6. **Spaces containing gas consumers** – Isolation arrangement for each individual with Master gas valve located in cargo area depending on continuous or non continuous gas supply arrangement.
7. **Piping and ducting construction** – Basic requirements to welded joints.
8. **Gas detection** – Alarm for 30% LFL and shut down master gas valve at no more than 60% LFL.

Gas Carriers and Gas as Fuel in IGC Code

IGC Code requirement 16.4.6 – Spaces containing gas consumers – Isolation arrangement with Master gas valve located in cargo area depending on continuous or not-continuous gas supply piping arrangement.

Not continuous double barrier

The individual master valve for the space shall operate under the following circumstances:

- .1 automatically by:
  - .1 gas detection within the space;
  - .2 leak detection in the annular space of a double-walled pipe;
  - .3 leak detection in other compartments inside the space, containing single-walled gas piping;
  - .4 loss of ventilation in the annular space of a double-walled pipe; and
  - .5 loss of ventilation in other compartments inside the space, containing single-walled gas piping; and
- .2 manually from within the space, and at least one remote location.

Continuous double barrier

The individual master valve *(for each gas consumer)* shall operate under the following circumstances:

- .1 automatically by:
  - .1 leak detection in the annular space of a double-walled pipe served by that individual master valve;
  - .2 leak detection in other compartments containing single-walled gas piping that is part of the supply system served by the individual master valve; and
  - .3 loss of ventilation or loss of pressure in the annular space of a double-walled pipe; and
- .2 manually from within the space, and at least one remote location.

Gas Carriers and Gas as Fuel

IGC code Chapter 16 - Summary

1. LNG as fuel - Will need to comply with IGC Code Chapter 16, except 16.9
   - Depending on Engine types (ME-GI, ME-GA and WINGD the designs will be slightly different, with double wall pipes required from Master gas valve in cargo area for >1.0 MPa supply

     (The fuel supplied to ER will be in Gas form, with ME-GI at approximately 300 bar, ME-GA / WinGD at approximately 15 bar.)
   - For other engines and GCU with lower gas fuel supply pressure, only Engine room area/ Safe spaces will require double wall pipes.
2. LPG as fuel - Will need to comply with IGC Code 16.9.
   - The use of LPG fuel on LPG carriers are now the normal standard used on more than 50 vessels to DNV class, including conversions. (Fuel supplied to ER will be liquid form at 50 bar)
3. Ammonia as fuel – Presently it is a challenge to use IGC Code 16.9.
   - IGC Code 16.9.2 specifies that that use of cargoes identified as toxic is not permitted as fuel, so Flag Administration will need to be involved. Proposal to accept this in IMO is ongoing with Ammonia to be subject to special consideration and new guidelines considering Ammonia to be concluded.

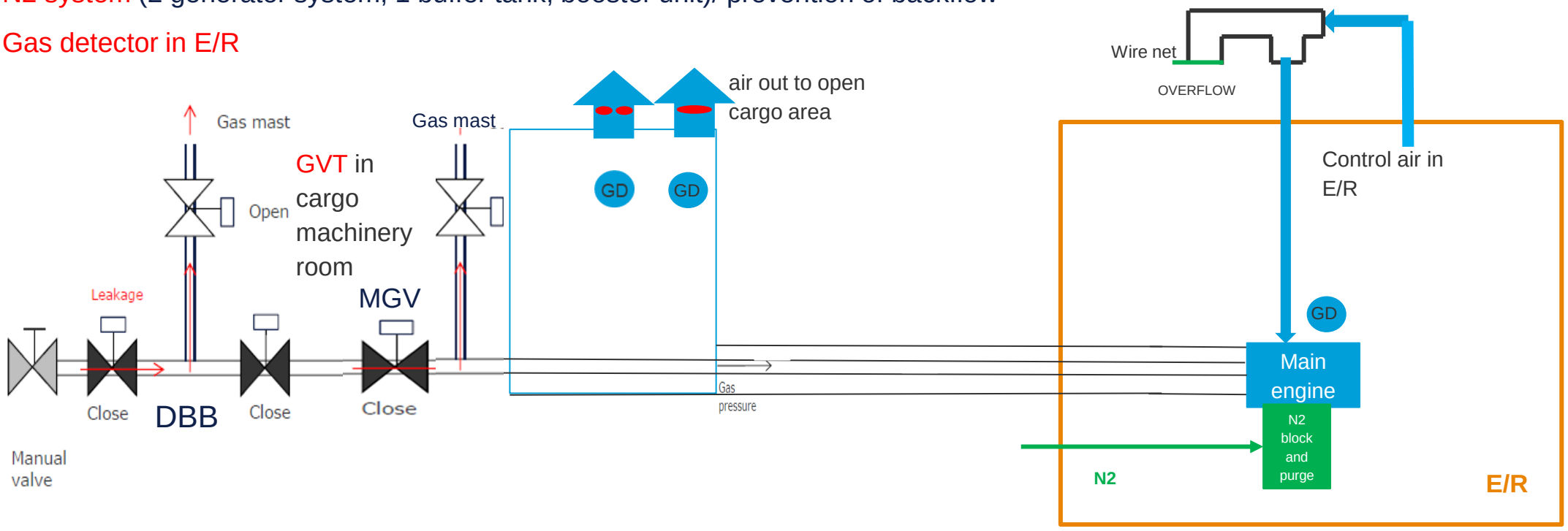
Arrangements - Gas safe machinery space for Gas carriers (IGC) – Main engine type 1

Secondary enclosures for gaseous fuel piping :

- GVT (Gas Valve Train) outside E/R for Main engine (ME-GI / ME-GA) ; GVT can be inside E/R for ME-GA (similar to X-DF)
- Mechanical ventilation : Exhaust 30 air changes/ h. Two fans (2 x 100 %)/In & outlet shall be in cargo area / Loss of ventilation stop fuel supply
- Gas detectors : Gas detection will stop fuel supply by MGV (Master Gas Valve)
- Double block and bleed arr't : (DBB) and for safe shut down of gas supply to the engines

• N2 system (2 generator system, 1 buffer tank, booster unit)/ prevention of backflow

• Gas detector in E/R



Arrangements - Gas safe machinery space for Gas carriers (IGC) – Main engine type 2

Secondary enclosures for gaseous fuel piping :

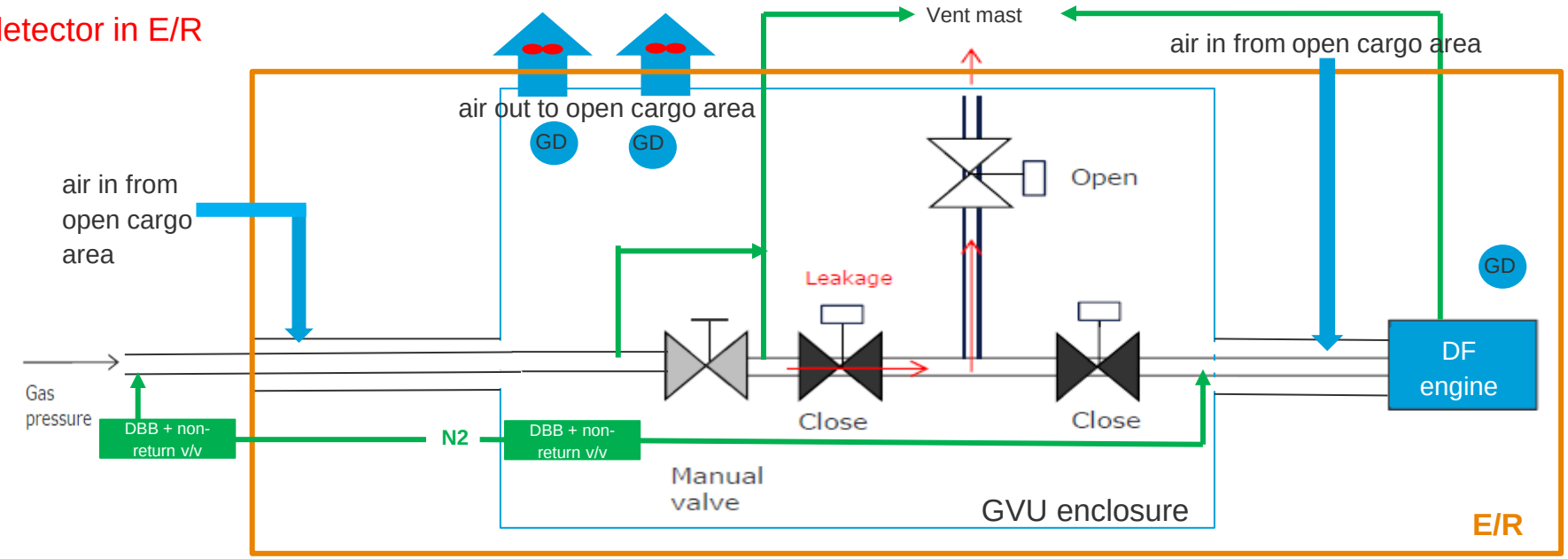
- GVU (Gas Valve Unit) enclosure (HAZARDOUS ZONE 1) for main engine (X-DF): inside E/R

- Mechanical ventilation : Exhaust 30 air changes/h. Two fans (2 x 100 %) / All ventilation in/ outlet shall be in cargo area / Loss of ventilation will stop fuel supply.

- Gas detectors : Gas detection will stop fuel supply.

- Double block and bleed arrangement : For safe shut down of gas supply to the engines.

- N2 system (2 generator system, 1 buffer tank)/ prevention of backflow.
- Gas detector in E/R



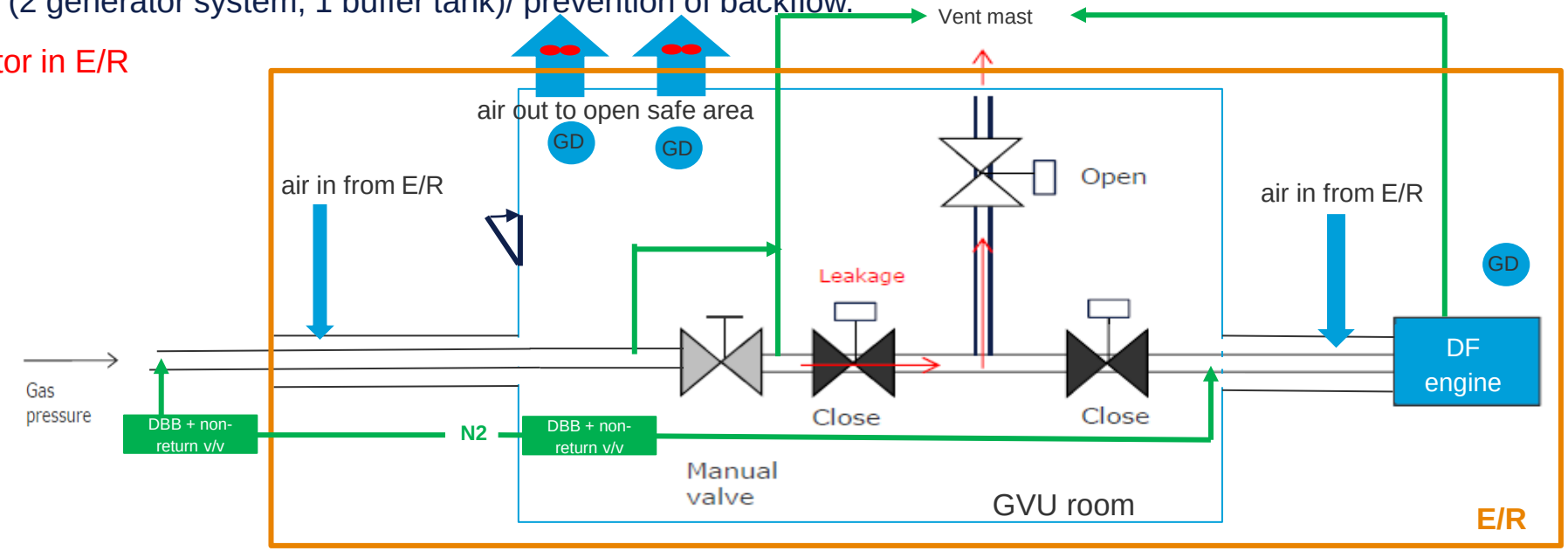
Arrangements - Gas safe machinery space for Gas carriers (IGC) – DF Gen. sets/ boilers 1

Secondary enclosures for gaseous fuel piping :

- GVU rooms (HAZARDOUS ZONE 1) for DF generator engines / DF boiler / GCU : inside E/R
- Access via E/R by gas tight door with self closing device, but without air-lock
- Mechanical ventilation : Exhaust 30 air changes/h. Two fans (2 x 100 %) / ventilation inlet can be from E/R, outlet to open safe area/ loss of ventilation will stop fuel supply
- Gas detectors : Gas detection will stop fuel supply
- Double block and bleed arr't : For safe shut down of gas supply to the engines

• N2 system (2 generator system, 1 buffer tank)/ prevention of backflow.

• Gas detector in E/R



IGC code 16.9 - Alternative fuels and technologies

16.9.1 If acceptable to the Administration, other cargo gases may be used as fuel, providing that the same level of safety as natural gas in this Code is ensured.

16.9.2 The use of cargoes identified as toxic products shall not be permitted.

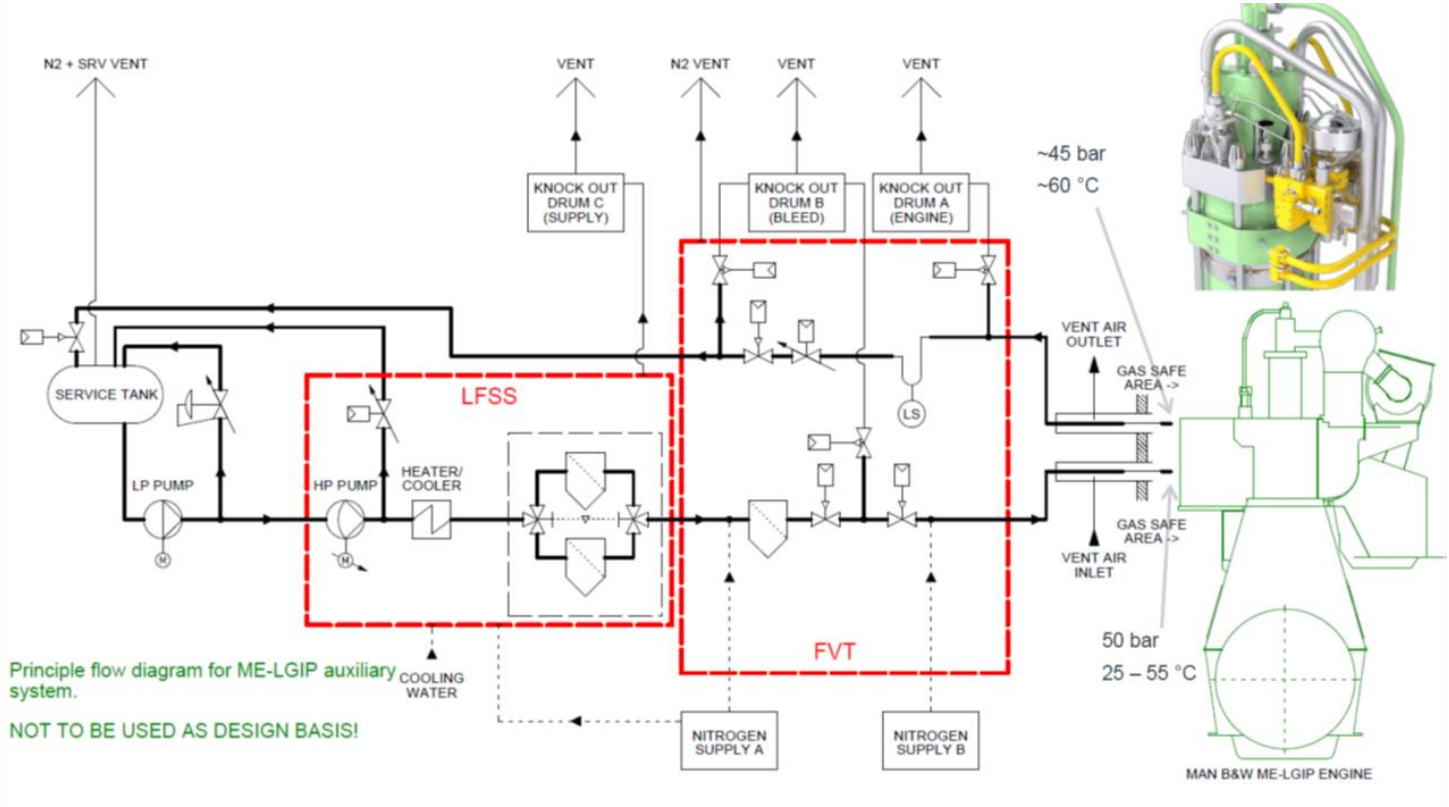
16.9.3 For cargoes other than LNG, the fuel supply system shall comply with the requirements of 16.4.1, 16.4.2, 16.4.3 and 16.5, as applicable, and shall include means for preventing condensation of vapour in the system.

16.9.4 Liquefied gas fuel supply systems shall comply with 16.4.5.

16.9.5 In addition to the requirements of 16.4.3.2, both ventilation inlet and outlet shall be located outside the machinery space. The inlet shall be in a non-hazardous area and the outlet shall be in a safe location.

Risk assessment to show that LPG has equivalent level of safety as LNG fuel supports this.

MAN – LGIP – Gas fuel supply



Source: MAN

- The LPG fuel supplied to Engine room will be in liquid form with a pressure of approximately 50 bar.
- Engine room to have double wall piping to be carefully considered in the design, including arrangement.
- The ventilation of double wall pipe to be from cargo area.
- Ventilation arrangement and gas detection inside Engine room generally to consider LPG escape, even double wall piping is required.

Risk analysis

IGC Code 16.9 Alternative fuels and technologies

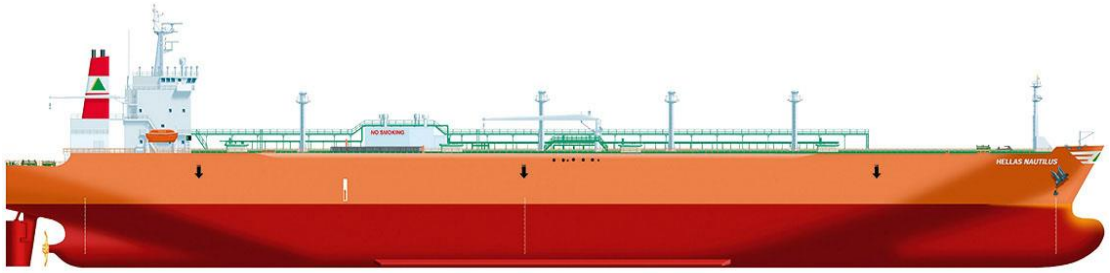
16.9.1 If acceptable to the Administration, other cargo gases may be used as fuel, providing that the same level of safety as natural gas in this (IGC) Code is ensured.

DNV Clarification in Rules Pt.5, Ch.7, Sec.16 (9.1.6)

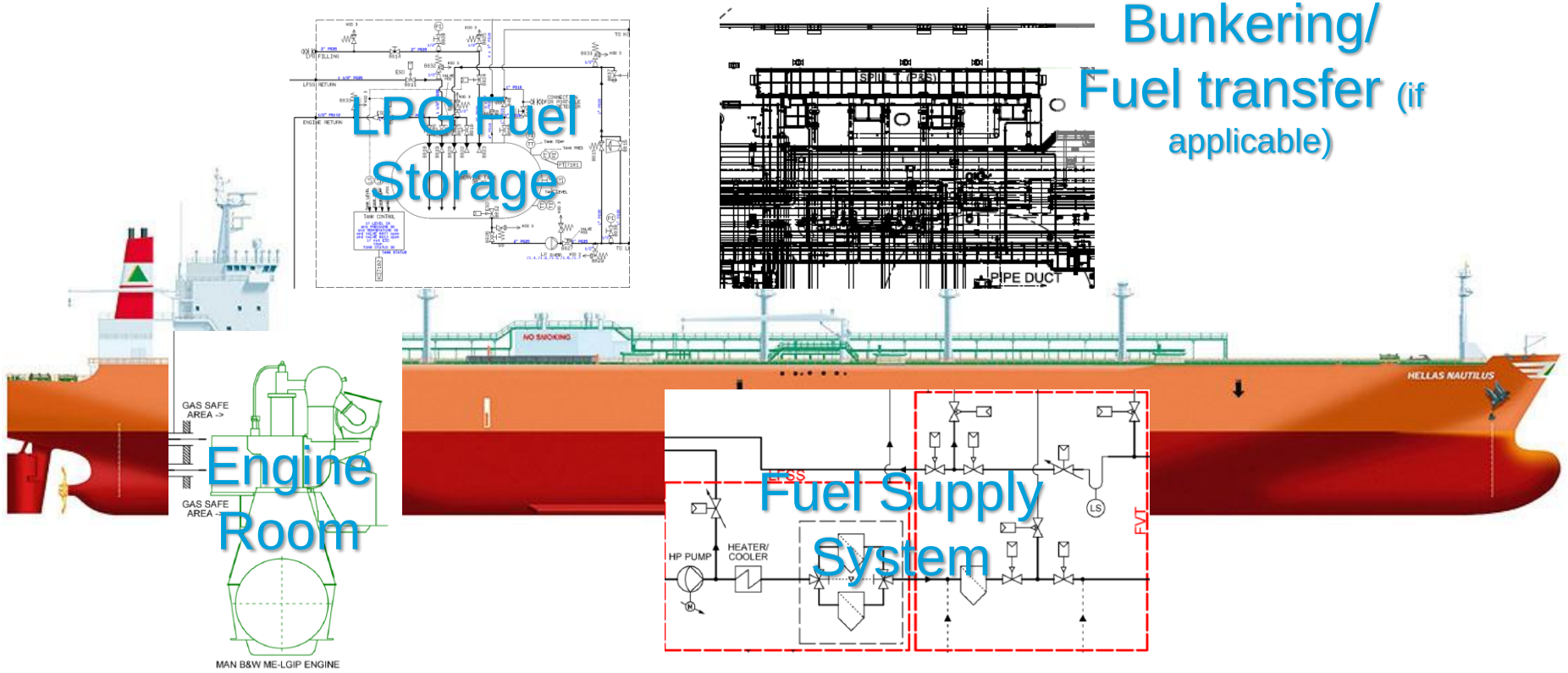
Equivalent safety for the alternative fuel product compared to methane as fuel shall be documented through a risk assessment.

HAZID objective

- *Identify hazards and hazardous events associated with the system*
- *Identify possible causes and consequences for each hazardous event*
- *Identify safeguards included in design for the management of the risks*
- *Semi-quantitatively assess the consequences by using a risk matrix*
- *Recommend any potential new safeguards based in ALARP principle*



Scope of Work – Risk assessment



Example of results from a workshop, recommendations and conclusions

Node: 1. Bunkering Stations / Fuel Transfer

Hazardous Events	Causes	Consequences	Preventive safeguards	Mitigating Safeguard	Current Risk S	L	RR	Recommendations	Remarks
	gaskets or valves							plan addresses LPG spill during bunkering	
	3. Manifold connection issues with the bunkering hose	3. Fire/explosions		3. Firefighting equipment				8. Ensure that certification and testing of LPG bunkering equipment is per STS requirements	"Equipment" here refers to the hoses for transfer. Hence, responsibility is for the Operator. Should the scope of "Equipment" include piping arrangements, responsibility should be shared with Yard.
	4. Interface compatibility issues (shore/ship side)	4. Personnel injury			4	2	M		
3. Uncontrolled LPG flow between fuel and cargo systems	1. Defect in the interface between fuel and cargo systems	1. Contamination of LPG cargo	1. LPG cargo ESD system	1. Firefighting equipment				7. Ensure that emergency response plan addresses LPG spill during bunkering	
	2. Human error	2. High level in LPG cargo tanks		2. Emergency response plan				9. Ensure piping design and integration of ESD control between LPG cargo tank and LPG fuel storage tank is such as to prevent uncontrolled flow between the two systems during LPG bunkering or LPG fuel transfer operations	
		3. Overpressure in LPG cargo tanks			5	3	H		
		4. Overfilled deck tanks							
4. Clogging of LPG bunkering system filters	1. Excessive amounts of particles in the LPG	1. Interruption of the LPG bunkering						4. Evaluate installation of manifold strainers on the LPG bunkering line, mesh sizing to be in line with LPG fuel system and main engine manufacturer's recommendation	
5. Damage to LPG	1. Off-spec LPG	1. Machinery	1. Engine					5. Ensure that LPG fuel	

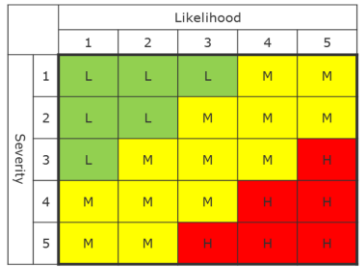


Figure 4 Risk Matrix

Table 3 Likelihood descriptions

Index	Description
1	Not expected ($p < 10^{-4}$)
2	Has occurred at least once in Company ($10^{-4} < p < 10^{-3}$)
3	Has occurred several times in Company ($10^{-3} < p < 10^{-2}$)
4	Happens several times a year in Company ($10^{-2} < p < 10^{-1}$)
5	Happens several times a year in one location ($10^{-1} < p$)

LPG vs LNG – Important considerations

LPG	LNG	Remark
LPG gas is heavier than air (1.5 : 1)	NG is lighter than air (0.5 : 1)	Natural gas is more easily dissipates in the event of leak, whilst LPG gas may settle in lower part.

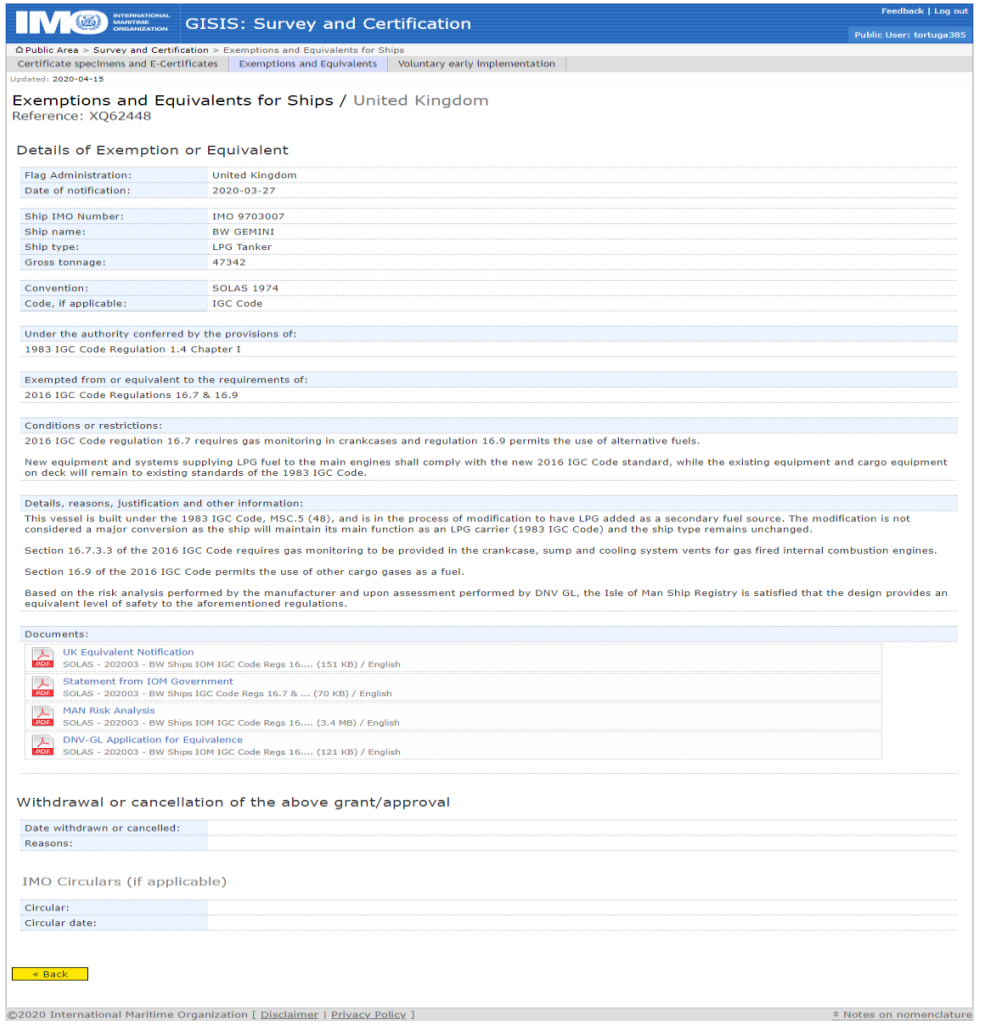
For LPG as fuel

- LPG as fuel is generally in liquid form at approximately 50 bar (Noted however as comparison that ME- GI is 300 bar NG).
- Gas detection shall be done at the lower part of the spaces concerned
- Ventilation (exhaust) from lower deck

Flag acceptance - IMO GISIS Equivalency register

- Equivalence:
  - Ref.# XQ62448
  - Flag Administration United Kingdom
  - Ship name BW Gemini
  - IMO Number IMO 9703007
  - dated 2020-03-27

- Contains attachments:
  - UK equivalent notification
  - Statement from IOM Government
  - MAN Risk Analysis
  - DNV Application for Equivalence



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Certificate specimens and E-Certificates | Exemptions and Equivalents | Voluntary early implementation

Updated: 2020-04-15

Exemptions and Equivalents for Ships / United Kingdom

Reference: XQ62448

Details of Exemption or Equivalent

Flag Administration:	United Kingdom
Date of notification:	2020-03-27
Ship IMO Number:	IMO 9703007
Ship name:	BW GEMINI
Ship type:	LPG Tanker
Gross tonnage:	47342
Convention:	SOLAS 1974
Code, if applicable:	IGC Code

Under the authority conferred by the provisions of:

1983 IGC Code Regulation 1.4 Chapter I

Exempted from or equivalent to the requirements of:

2016 IGC Code Regulations 16.7 & 16.9

Conditions or restrictions:

2016 IGC Code regulation 16.7 requires gas monitoring in crankcases and regulation 16.9 permits the use of alternative fuels.

New equipment and systems supplying LPG fuel to the main engines shall comply with the new 2016 IGC Code standard, while the existing equipment and cargo equipment on deck will remain to existing standards of the 1983 IGC Code.

Details, reasons, justification and other information:

This vessel is built under the 1983 IGC Code, MSC.5 (48), and is in the process of modification to have LPG added as a secondary fuel source. The modification is not considered a major conversion as the ship will maintain its main function as an LPG carrier (1983 IGC Code) and the ship type remains unchanged.

Section 16.7.3.3 of the 2016 IGC Code requires gas monitoring to be provided in the crankcase, sump and cooling system vents for gas fired internal combustion engines.

Section 16.9 of the 2016 IGC Code permits the use of other cargo gases as a fuel.

Based on the risk analysis performed by the manufacturer and upon assessment performed by DNV GL, the Isle of Man Ship Registry is satisfied that the design provides an equivalent level of safety to the aforementioned regulations.

Documents:

- UK Equivalent Notification — SOLAS - 202003 - BW Ships IOM IGC Code Regs 16.... (151 KB) / English
- Statement from IOM Government — SOLAS - 202003 - BW Ships IGC Code Regs 16.7 & ... (70 KB) / English
- MAN Risk Analysis — SOLAS - 202003 - BW Ships IOM IGC Code Regs 16.... (3.4 MB) / English
- DNV-GL Application for Equivalence — SOLAS - 202003 - BW Ships IOM IGC Code Regs 16.... (121 KB) / English

Withdrawal or cancellation of the above grant/approval

Date withdrawn or cancelled:	
Reasons:	

IMO Circulars (if applicable)

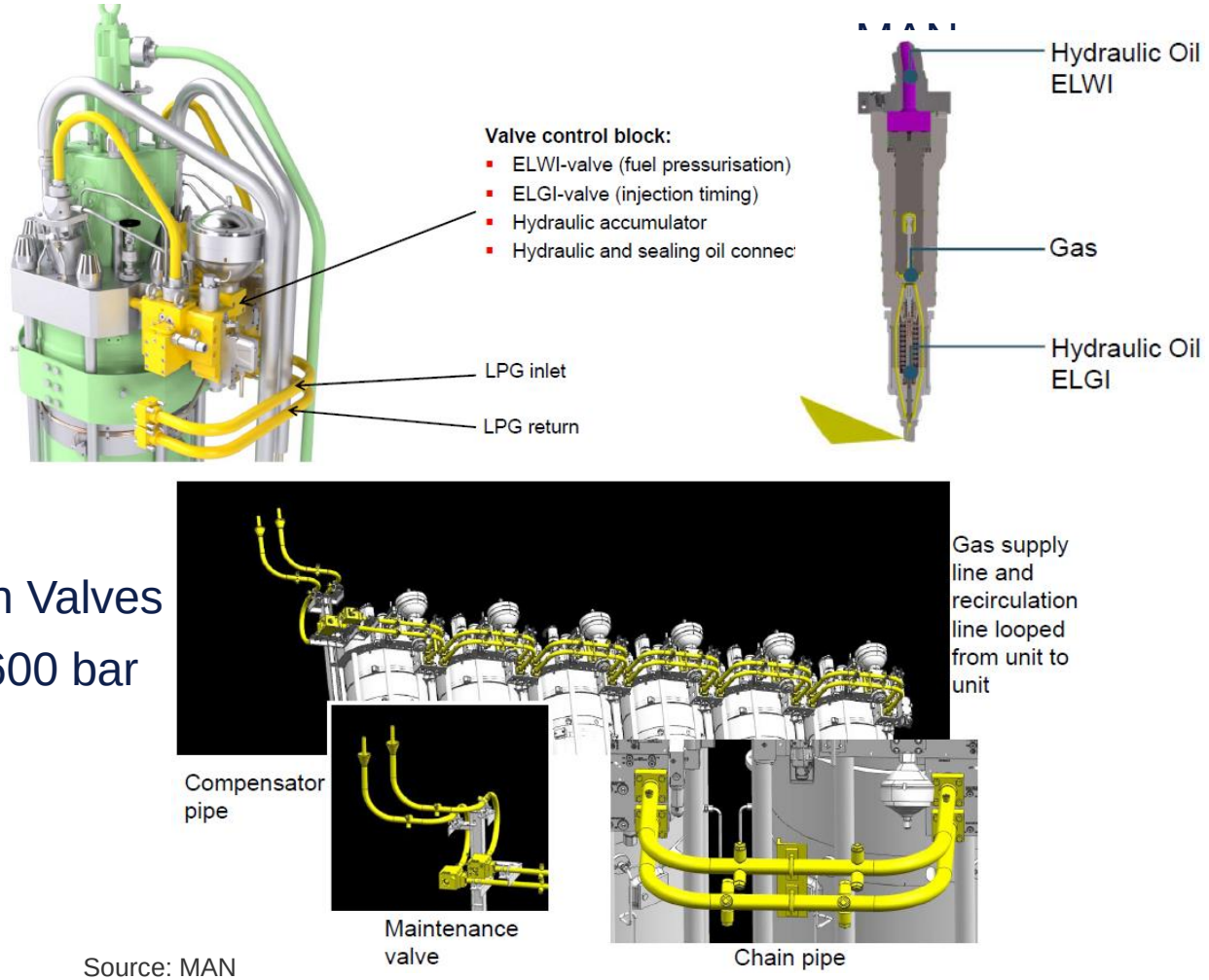
Circular:	
Circular date:	

« Back

‡ Notes on nomenclature

2-stroke LGIP engine - MAN B&W

- Produced ME-LGIP engines or upgrades of engines ME-C or ME-B series to MAN-LGI
- ME-LGI engine itself similar to ME-GI engine for LNG
  - Used for methanol and LPG
- Fuel supply piping pressure abt. 50 bar (liquid)
- Injection pressure is achieved by Fuel Booster Injection Valves
  - Hydraulic power raises fuel pressure for injection to 600 bar
  - Eliminates need for high-pressure fuel lines
- Pilot fuel oil is used for ignition



Source: MAN

Ammonia (NH3) as fuel on Gas carriers

Ammonia has lately been requested as potential fuel source on Gas Carriers.

1. DNV has experience related to Ammonia as cargo, but also as refrigerant.
2. DNV finds this possible, however following items must be addressed:
    1. Safety items and fuel need comply with IGC Code requirements. Gas Fuel supply principles follow code principles,
    2. Risk Assessment need to be made to ensure same safety level as methane fuel,
    3. Engines to be confirmed suitable,
    4. Gas Valve Unit spaces, fuel preparation rooms or other spaces containing equipment with Ammonia where the are enclosed pipes containing ammonia, should also comply with requirements in DNV rules for Ammonia as refrigerant. Hence DNV Rules Pt.4 Ch.6 Sec.6.
3. As 2016 IGC Code prohibits the use of toxic products as fuel, DNV proposes that preliminary flag acceptance is requested at an early stage, but noted an IGC Code amendment proposal is made which would permit the use Ammonia as fuel on a more general basis.

Engines for Ammonia as gas fuel

- Reciprocating Internal Combustion Engines
  - Two-stroke, slow speed under development, dual-fuel Diesel pilot – liquid gas injection, MAN-ES, as well as WINGD.
  - Four-stroke, under development, dual-fuel, with ammonia substituting initially 20% of diesel or LNG, and increasing up to 80% as experience is gained, Wärtsilä
- Installations will be more similar to LPG as a fuel than LNG
- Fuel cell development (Wärtsilä), to be installed to Offshore Supply Vessel by 2023 in Norway

Tank volumes required as per MAN

An interesting comparison is the needed tank volumes for the fuels as per MANs table, (Noted ME-GA and similar WINGD supply pressures are not reflected below).

Energy storage type	Supply energy	Energy density	Required tank volume	Supply pressure	Injection pressure	Emission reduction compared to HFO Tier II			
	MJ/kg	MJ/L	m^3 *1	bar	bar	%	%	%	%
HFO	40.5	35	1,000	7-8	950	SO_x	NO_x	CO_2	PM
Liquefied natural gas (LNG -162°C)	50	22	1,590	300 methane	300 methane	90-99	20-30	24	90
				380 ethane	380 ethane	90-97	30-50	15	90
LPG (including Propane / Butane)	42	26	1,346	50	600-700	90-100	10-15	13-18	90
Methanol	19.9	15	2,333	10	500	90-95	30-50	5	90
Ethanol	26	21	1,750	10	500				
Ammonia* (liquid -33°C)	18.6	12.7	2,755	70	600-700	90-95	Tier	95	90
Hydrogen (liquid -253°C)	120	8.5	4,117						
Marine battery market leader, Corvus, battery rack	0.29	0.33	106,060						
Tesla model 3 battery Cell 2170 *2	0.8	2.5	14,000						

Table 1: Physical and chemical fuel properties related to combustion in two-stroke engines, where *1 is based on a 1000 m^3 HFO tank, the additional space required for insulation is not included in the table. All pressure values are for high-pressure injection and *2 the values for the Tesla battery do not contain the energy/mass needed for cooling/safety/classification

Table from MAN Energy Solutions “Engineering the future two-stroke green-ammonia engine”

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Presentation in SIGTTO Regional Panel, London 2023-10

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