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GASEOUS FUELS SAFETY ASPECTS

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1. REGULATORY CONTEXT
2. USE OF GAS FUEL ENGINES ON SHIPS
3. CLASS RULES FOR GAS FUEL ENGINES PROPELLED SHIPS

1. **REGULATORY CONTEXT**

2. USE OF GAS FUEL ENGINES ON SHIPS

3. CLASS RULES FOR GAS FUEL ENGINES PROPELLED SHIPS

AIR POLLUTION REGULATIONS (MARPOL ANNEX VI)

- MARPOL Annex VI on air pollution is in force since 19 May 2005
- The revised MARPOL Annex VI was adopted at MEPC 58 (October 2008).
- Aim => to control the air pollution from ships, in particular to:
  - Limit noxious gases from ships' exhausts (sulphur oxide and nitrogen oxide emissions)
  - Prohibit the deliberate release of ozone depleting substances (halons and chlorofluorocarbons (CFC))
- The revised MARPOL Annex VI will be entering into force on 1st July 2010

AIR EMISSIONS: CAP ON NOX *(MARPOL ANNEX VI REG 13)*

Engine fitted on a ship built at date D*	Outcome of MEPC58	
1/1/2000 ≤ D < 1/1/2011	Tier I	
1/1/2011 ≤ D < 1/1/2016	Tier II	
1/1/2016 ≤ D	Tier III in ECA**	Tier II elsewhere
"existing engines" 1/1/1990 ≤ D < 1/1/2000 cylinders ≥ 90 l & power > 5,000kW	Tier I	

Engine rpm	N < 130	130 ≤ N < 2000	N ≥ 2000
Tier I Current Reg 13(3)(a)	17 g / kWh	$45\ N^{-0.2}$ g / kWh	9.8 g / kWh
Tier II ~ 80% Tier I	14.4 g / kWh	$44\ N^{-0.23}$ g / kWh	7.7 g / kWh
Tier III ~ 20% Tier I	3.4 g / kWh	$9\ N^{-0.2}$ g / kWh	2 g / kWh

* MARPOL: construction date = keel laying date

** ECA = NOx Emission Control Area

Note: Exhaust gas cleaning systems are acceptable

AIR EMISSIONS: CAP ON SULPHUR CONTENT OF FUELS *(MARPOL ANNEX VI REG 14)*

- The sulphur content (by mass) of any fuel oil used on board ships shall not exceed the following concentrations:
  - 4.50% prior to 1 January 2012;
  - 3.50% on/after 1 January 2012; and
  - 0.50% on/after 1 January 2020 (*).

  (*) Subject to review of fuel oil availability in 2018.

- For ships operating within an Emission Control Area (ECA), the sulphur content of fuel oil has to be below:
  - 1.50% prior to 1 July 2010;
  - 1.00% on/after 1 July 2010; and
  - 0.10% on/after 1 January 2015;

  However, in ECAs, Exhaust Gas Cleaning Systems provide an alternative to using two fuel standards.

- In addition, the EU has introduced a requirement that ships at berth use 0.1% Sulphur fuel from 2010. EGCS can be used as an alternative.

GREENHOUSE GAS EMISSIONS FROM SHIPS

- Shipping not covered by the Kyoto Protocol created by the UN Framework Convention on Climate Change (UNFCCC) which fixes limitation or reduction of GHG emissions through an ETS (Emission Trading Scheme)
- COP 14 (Conference of the Parties to the Climate Change Convention) in Dec. 2008 : IMO mandate = to find technical and operational solutions to reduce GHG
- Difficulty to reach an agreement between the countries
  - EU and Australia in favour of a ETS for shipping
  - Developing countries + India + China + Panama against commitments
  - USA propose an ETS within the shipping community only
  - Proposal for a fuel levy : to pool money into a fund to be managed by IMO
- Next step : COP 15, Copenhagen, Dec. 2009 : a possible new Kyoto Protocol including shipping
- EU Commission wants shipping to be covered by GHG regulations as aviation and pushes IMO to adopt global rules
  - Deadline : end 2010
  - If IMO fails, EU will take its own measures

A POSSIBLE SOLUTION

- The use of natural gas as fuel can offer an interesting solution to reduce exhaust gas emissions in air in terms of NOx, SOx and CO2 as well as of particulate emissions compared to fuel oils:
  - Tier III requirements (NOx) are met,
  - NG does not normally contain sulphur,
  - Reduction of 20% of CO2 emissions.

	NOx ($NO - NO_2$)	SOx ($SO_2 - SO_3$)	CO_2
Steam plant	▪ 1 to 3 g/kWh ▪ 5 to 10 g/kg of fuel	depends on the sulphur content of the fuel	1 kg of fuel produces: ▪ 2,7 kg of CO2 for gas ▪ 3,2 kg of CO2 for fuel oil 1 MJ of calorific value produces: ▪ 47,8 g CO2 for gas ▪ 74,8 g CO2 for fuel oil
Low speed engine with reliquefaction	15 g/kWh		
dual fuel engine (Wärtsilä 50DF) ▪ gas operation ▪ fuel operation	▪ 1 g/kWh ▪ 10 g/kWh		
gas turbine (GE LM2500) ▪ gas operation ▪ fuel operation	▪ 0.5 g/kWh ▪ 5 g/kWh		According to the efficiency of the propulsion plant, CO2 level ranges between 500 and 700 g/kWh

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GAS FUEL ENGINES ONBOARD SHIPS

- Until a recent past LNG carriers have been the only ships currently equipped with gas burning propulsion systems using the cargo boil off as fuel.
- LNG carriers used to be equipped with boilers and steam turbines until the “Gaz de France EnergY” in 2004 where a dual fuel diesel electric propulsion system was installed for the first time.
- Since this first application, more than 50 additional LNG carriers have been ordered with dual fuel diesel electric propulsion. We have also seen the delivery in 2009 of one LNG carrier with single gas fuel engines.

GAS FUEL ENGINES ONBOARD SHIPS

- Nowadays, gas burning engines are envisaged for a broader range of ships, in particular ferries (Ro-Ro / Ro-Pax), cargo and and supply ships. NG is also seriously considered for other vessel’s types such as container vessels and ships involved in “short sea shipping”. Spark ignition or pilot fuel injection are possible options depending of the required propulsive power.

- We have also seen projects of LPG carriers where cargo vapours can be used as fuel (in conjunction with FO) for diesel generators (e.g. Lauritzen Kosan “Isabella Kosan” delivered from 2008).

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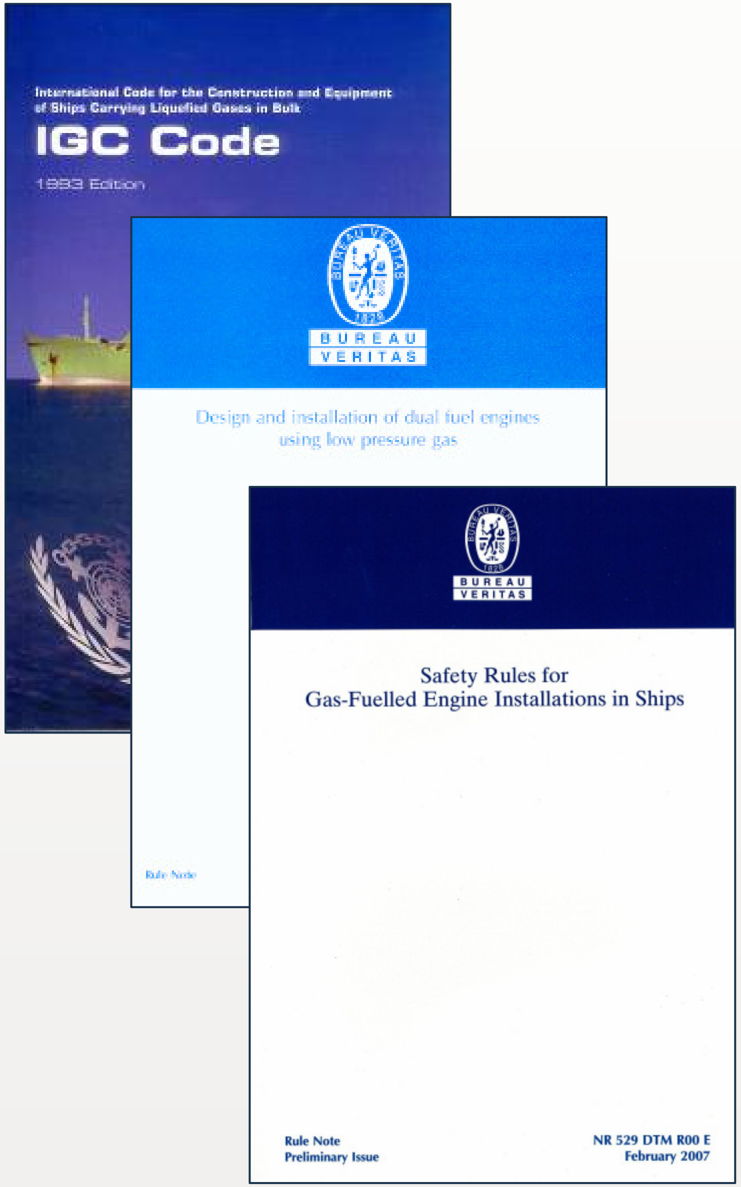
IMO REGULATION AND CLASS RULES



- IMO has addressed the use of natural gas as fuel in their "Interim guidelines on safety for natural gas fuelled engine installations in ships" (IMO Res. MSC.285(86) adopted on 1st June 2009).
- The IMO IGC code, applicable to liquefied gas carriers, also covers the use of boil off gas as fuel.
- However, the developments of the industry have been quite fast and some class societies have been able to timely introduce classification rules for gas fuel engines.
- This has been the case of Bureau Veritas with two specific documents:
  - NR481: "Design and installation of dual fuel engines using low pressure gas",
  - NR529: "Safety rules for gas-fuelled engine installation on ships".

IMO REGULATION AND CLASS RULES

The main objectives of the rules are to set acceptable basic prescriptions and criteria so that the gas fuelled propelled ships could have the same degree of safety and of reliability as the ships using liquid fuels.

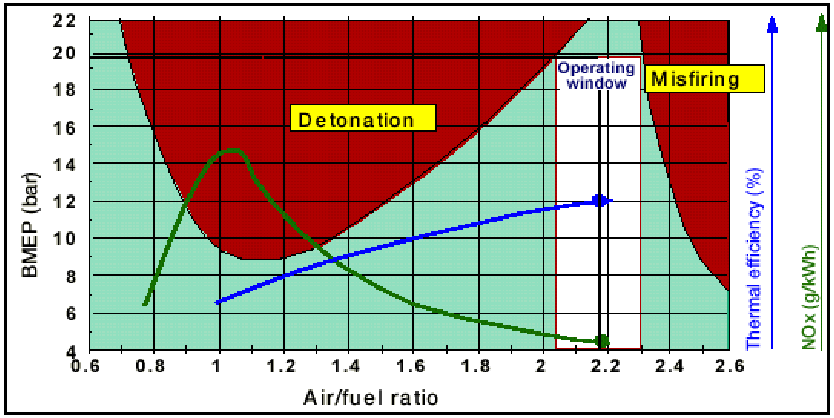
In other words,

- There should be a safe and reliable gas combustion in the engines,
- Gas plant storage (including refueling facilities) and distribution systems should not create a substantial risk of gas leakage or spillage leading to brittle fracture, fire and / or explosion,
- Machinery space should be designed and arranged for gas burning engines,
- Gas fuelled propulsion systems should have the same level of reliability as conventional fuel propulsion systems.

Depending of the type of ships, hence of their type of operations (e.g. supply vessel or passenger ferry), these objectives may imply slightly different technical responses.

SAFE GAS COMBUSTION

- The engine should be so controlled as to avoid detonation or misfiring.
- Good operation of gas engines to be monitored through a number of safety parameters.
- Engine exhaust duct to be protected against overpressure.



Parameter	Alarms	Automatic safety actions			
		Activation of the block-and-bleed valves	Activation of the master gas valve	Switch over to oil fuel mode	Engine shut down
Gas supply - pressure	L+H	x		x	
Gas supply - temperature	L+H	x		x	
Gas admission valve(s) - failure	x	x		x	
Pilot injection system - failure	x	x		x	
Air inlet manifold - gas concentration reaching 60% LFL (1)	H	x		x	
Exhaust gas at each cylinder outlet - temperature	H	x		x	
Exhaust gas at each cylinder outlet - temperature deviation from average	H	x		x	
Combustion in each cylinder - misfiring	x	x		x	
Combustion in each cylinder - knocking	x	x		x	
Crankcase - pressure	H	x			x
Crankcase - temperature (2)	H	x			x
Crankcase - oil mist concentration	H	x			x
Engine stop from any cause	x	x			

(1) Required only when gas is introduced directly in the gas manifold
(2) High temperature of cylinder liners or bearings.

SAFE STORAGE AND DISTRIBUTION

- Design of “bunker gas” containment system:
  - Type C (pressure tanks) with suitable design pressure,
  - Protection against spillages,
  - Possible heating / cooling systems.

- Location and segregation of spaces (storage compartments, machinery spaces, compressor room, …)
  - Storage above of under deck,
  - Protective distances against risks of collision and grounding,
  - Segregation of the accesses, ventilation, drainage, etc.
  - Safety equipment (gas / fire detection),
  - Passive and active fire protection,
  - Definition of hazardous area and selection of certified electrical equipment,
  - Gas safe engine room / ESD protected engine rooms,
  - Distance / segregation between storage compartments and manned area (crew / passengers).

ENGINE ROOM

- Arrangement of machinery space
  - Efficient ventilation (no dead space, effective in way of electrical, equipment, avoid recycling, …)
  - Ventilation exhaust location,
  - Gas detection.

- Gas supply to the engine room
  - Double wall piping,
  - Passage of gas duct to engine room,
  - ESD system.

ENGINE ROOM / GAS SUPPLY SAFETY SYSTEMS (BV RULES)

Parameter	Alarms	Automatic safety actions			
		Activation of the block-and-bleed valves	Shutdown of the master gas valve	Engine switch over to oil fuel mode	Engine shut down
Double-walled gas pipes with inert gas pressurisation - pressure in the double-wall space.	L		x	x	
Double-walled gas pipes with ventilated pipe or duct - gas detection in the double-wall space or at the air intake	x (1)		x (2)	x	
Double-walled gas pipes with ventilated pipe or duct - air flow through the double-wall space.	L		x	x	
Double-walled gas pipes with ventilated pipe or duct - gas detection in the machinery space.	x				
Safeguarded machinery spaces - loss of ventilation underpressure.	x		x	x	
Safeguarded machinery spaces - gas detection					
• before gas concentration reaches 30% LFL	x	x	x	x	
• before gas concentration reaches 60% LFL	x				x (3)
Failure of the block-and-bleed valve control actuating medium.	x	x		x	
Failure of the master gas valve control actuating medium	x		x	x	
Ventilation hood or casing - low air flow (4).	x		x	x	
Engine exhaust systems - opening of the safety devices	x	x			x

(1) The alarm is to be activated before the gas concentration reaches 30% of the LFL.
(2) The master gas valve is to be shut down before the gas concentration reaches 60% of the LFL.
(3) In addition, the non-safe electrical equipment located in the machinery compartment is to be de-energized.
(4) Required only when the ventilation hood or casing and the double-wall space are served by separate exhaust ventilation fans.

RELIABLE GAS PROPULSION SYSTEMS

Risk analyses (FMEA / HAZOP) are to be conducted to cover the following points:

- Gas operation of the engine,
- Boil-off management (when relevant),
- Possible presence of gas in the piping systems connected to the engine (e.g. lubricating oil, water cooling systems, …)
- Possible presence of gas in the machinery spaces,

in order to substantiate the adequate safety and dependability levels of the propulsion system of the vessel.

The HAZOP addresses in a formal manner the processes of the propulsion system with the objective of demonstrating that its globally design is adequate for all possible scenarios including normal, abnormal and emergency operating conditions.

CONCLUSION

- NG appears to be a quite interesting fuel, in particular for short sea shipping, due to its reduced emissions in air, thus its ability to meet the most stringent environmental regulations gradually implemented by the IMO and by several national or international bodies like the EU.

- Technical solutions to install gas fuel engines in various types of vessels are in place, demonstrating the feasibility of this alternative to liquid fuels.

- Safety and dependability aspects of NG as fuel have been studied by engine designers, design / engineering offices and shipbuilders, while IMO and class societies have developed rules and regulations to address NG propulsion of ships.

- Logistics of NG bunkering stations should be developed.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