Classification Rules: safety requirements & special risk based studies for LNG risk mitigation

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Martial CLAUDEPIERRE
R&D Project Manager

Environmental impact of shipping

The contribution of shipping to worldwide air emissions is significant.

<table>
<thead>
<tr>
<th>Total shipping emissions</th>
<th>Amount</th>
<th>% of global emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in million tonnes</td>
<td></td>
</tr>
<tr>
<td>CO2 (International shipping)</td>
<td>1,046 (870)</td>
<td>3.3 (2.7)</td>
</tr>
<tr>
<td>NOx</td>
<td>20</td>
<td>20 to 30</td>
</tr>
<tr>
<td>SOx</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>PM</td>
<td>1.5</td>
<td></td>
</tr>
</tbody>
</table>

Estimated air emissions from shipping in 2007
Regulations for NOx and SOx emissions

- IMO and other Regulations for NOx and SOx emissions are more and more stringent.

- Regulations limits for SOx emissions:

<table>
<thead>
<tr>
<th>Regulations</th>
<th>Sulphur Content</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>IMO - Global</td>
<td>4.5%</td>
</tr>
<tr>
<td>IMO - ECA</td>
<td>1.5%</td>
</tr>
<tr>
<td>EU ports</td>
<td>0.1%</td>
</tr>
<tr>
<td>California (&lt; 24 nm)</td>
<td>1.5% (MGO)</td>
</tr>
</tbody>
</table>

(*) Subject to a feasibility study on LSFO use and availability to be completed by 2018.
(**) Danish proposal to postpone ECA 0.1% cap to a later date.

Regulations for NOx emissions:

- Regulations for NOx emissions:

<table>
<thead>
<tr>
<th>Regulations</th>
<th>NOx emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2010</td>
</tr>
<tr>
<td>IMO – outside ECA</td>
<td>Tier I</td>
</tr>
<tr>
<td>IMO - ECA</td>
<td>Tier I</td>
</tr>
</tbody>
</table>
**Emission Control Areas (ECA)**

- An Emission Control Area (ECA) may be designated for:
  - NOx, SOx and particulate matter, or
  - all three types of emissions.

- **Existing ECAs for SOx emissions include:**
  - Baltic Sea: adopted in 1997 / entered into force in 2005
  - North Sea: adopted in 2005 / entered into force in 2006
  - North America coastal waters (200 n miles from the US and Canadian coasts) designated for the control of SOx, particulate matters and NOx

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**A tricky situation…**

- However, there are solutions!

- And gas fuelled propulsion is one of them!
Reduction of Emissions

► NOx emissions are reduced by more than 80% (for lean burn engines).
► SOx emissions eliminated (no sulphur in LNG).
► Particulate matters are close to zero.
► What about GHG reduction? It depends on the technology used, given the CH4 combustion (thermal efficiency) with unburned methane (slip).
► Considering an incomplete combustion (methane slip), we know that the Global Warming Potential (GWP) factor of methane = 20 x CO2, which means that 1g methane going to the atmosphere is equivalent to 20 g of CO2.

\[
\text{GHG emitted by CH4 engines} = \text{CO2 (g)} + [\text{methane(g)} \times 20]
\]

► For memory, Cs GO=175g.kWh. And Cs CH4= 7410kJ/kWh with LHV=50MJ/kg, thus CsCH4 = 7410/50=150g.kWh. CsGO=3.2 and CsCH4=2.75.

Different technologies of gas engines

<table>
<thead>
<tr>
<th>Technology</th>
<th>Lean Burn Engine</th>
<th>Dual fuel low pressure</th>
<th>Dual fuel high pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>High energy efficiency at high load</td>
<td>High energy efficiency at high load</td>
<td>Diesel cycle and performances maintained</td>
</tr>
<tr>
<td>Methane slip</td>
<td>Yes, efforts are on minimising up to 50% of existing ratio</td>
<td>Yes, efforts are on minimising up to 50% of existing ratio</td>
<td>No, as per publication</td>
</tr>
<tr>
<td>Meeting IMO tier III NOx reduction targets</td>
<td>Yes</td>
<td>Yes</td>
<td>No, need additional NOx reduction devices</td>
</tr>
</tbody>
</table>
Rules & Regulation

IMO Regulations & Existing Class Rules

- Historically the IMO gas codes were the first regulation authorizing and ruling the use of boil off gas as fuel (on LNG carriers).

- In response to the demand of the industry, the CS have introduced classification rules for gas fuel engines and gas fuelled ships. For example BV did:
  - NR481 in 2002: Design and installation of dual fuel engines using low pressure gas,
  - BV Guidance Note for LNG ship to ship transfer
  - With dedicated class notations

- The 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 in June 2009)

- The IMO has started the development of the International Code for Gas Fuelled Ships (IGF code) in 2009
**IMO Regulations & Existing Class Rules**

- Main objective of rules is to set acceptable basic prescriptions and criteria in order to achieve an equivalent degree of safety and reliability for ships with gas propulsion as compared to conventional ships using fuel oil
  - Safe and reliable gas combustion in the engines
  - LNG storage (including re-fuelling facilities) and distribution systems should not create any substantial risk of gas leakage or spillage leading to brittle fracture, fire and/or explosion
  - Machinery spaces 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 on the ship type, and hence the nature of their operations, (e.g. supply vessel or passenger ferry), these objectives may imply slightly different technical responses

**Progress & Scope of IGF Code Development**

- Development of the IGF code is being performed by correspondence group with the target for a draft to be available for submission at either the BLG sub-committee in Feb 2012 in order to implement the code within the 2015 SOLAS amendments
- The future IMO IGF code will not be limited to natural gas fuel but will address several more options, in particular:
  - Natural gas
  - Other gases (LPG)
  - Low flash point fuels (FP < 60°C):
    - Methanol – ethanol – hydrogen – synthetic fuels
  - Storage: liquid or compressed
  - All energy converters types:
    - Low and high pressure internal combustion engines, gas turbines, boilers, fuel cells
**Key Design Considerations And Challenges**

**A challenging design**

<table>
<thead>
<tr>
<th></th>
<th>Methane</th>
<th>HFO</th>
<th>MDO</th>
<th>MGO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>450 (LNG)</td>
<td>920 - 1060</td>
<td>900</td>
<td>850 - 890</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>50</td>
<td>39 - 41</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>LHV (GJ/m³)</td>
<td>22.5 (LNG)</td>
<td>39 - 40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- At same energy content, LNG has a volume of about **1.8 larger** than that of fuel oil. Therefore the main challenges to be overcome for the use of natural gas as fuel for ships are:
  - Find sufficient space for the LNG storage
  - Provide the necessary heating / cooling arrangements
  - Location and segregation of spaces
  - Provide protection against spillages/leakages
  - Bunkering arrangements
**Sufficient Space for LNG Storage**

- Storage above or under deck
- Pressurized tanks (type C) with suitable design pressure (for short sea shipping)
  - Allow gas to be supplied to the engines at the required pressure (approx. 5 bar) without pumps
  - Allow the accumulation of boil-off gas by accepting pressure build up
  - Vacuum insulation with outer shell acting as secondary barrier
- Type B tanks
  - Partial secondary barrier fitted
- Membrane tanks
  - The partial filling capability is to be demonstrated and consequences of sloshing are to be investigated
  - Arrangements are to be made to deal with boil-off gas in excess
- Protective distances against risks of collision and grounding

**Design of portable LNG storage tanks and equipment**

- Assessment of EN 13530-1/3 standard against IGC code requirements
- Resistance to ship accelerations and shocks (collision)
- Tank pressure control and boil-off gas management
- Partial filling levels
- Discharge capacity of the safety valves
- Vacuum-insulated tanks: consequences of a failure of the external shell
- Classification and inspection
- Connections between portable tanks and fixed shipboard piping systems: LNG supply to vaporizer, safety valve discharge line, etc.
- Qualification of LNG flexible hoses (EN 12434) or equivalent.
- Compatibility between tank equipment and shipboard equipment to be addressed (electrical equipment, control, monitoring, alarms, ESD, etc.)
- Monitoring of tanks parameters: pressure, temperature and level, vacuum in vacuum insulated tanks.
**Location & Segregation of Spaces**

- Safety equipment (gas / fire detection)
- Passive and active fire protection
- Segregation of the accesses, ventilation, drainage etc.
- Definition of hazardous areas and selection of certified electrical equipment,
- Gas safe engine room / ESD protected engine rooms,
- Distance / segregation between storage compartments and manned area (crew / passengers),
- Distance between vent outlets and openings or ventilation inlets / outlets to gas safe spaces (in particular for small ships)

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**Protection against LNG spillages / leakages**

- The space containing the tank, pumps, heaters and piping should act as the secondary barrier. The material of the space bulkheads should be compatible with LNG temperature. Ordinary steels should not be exposed to unacceptable cooling. This space is to be designed to withstand the maximum pressure build-up.

- For vacuum-insulated type C tanks, the outer shell may be extended to enclose the heaters, valves, piping, etc. (cold box).
**Bunkering Arrangements**

- For small capacities, non-fixed tanks located onboard the ship may be considered, such as containerized tanks or vehicle-tanks.
- Bunkering from land based LNG storage facility may also be considered.
- For larger capacities, bunkering from a dedicated bunker ship will be used. Alternatively, bunkering from LNG terminals may also be considered subject to relevant agreements and safety analysis.
- Devices are to be fitted on the manifold to prevent hose break in case of unexpected extreme ship movement or emergency (such as break-away couplings with quick-closing shut-off valves).

**Safe Machinery Space**

- 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 in case of accidental gas explosion.

- **Safety of the crankcase**
  - Presence of gas in normal operations. Issue to be clarified with engine makers.

- **Operation of dual fuel engines at low loads**
  - Inability of dual fuel engines to run at low load (< 15% of the nominal load).

- Efficient ventilation in Machinery Space (no dead space, effective in way of electrical equipment,) and in terms of ventilation exhaust location - Effective Gas detection.
- Gas supply to the engine room fitted with Double wall piping - Passage of gas duct to engine room - ESD system.
Risk Analysis

Reliable Gas Propulsion Systems

► Risk analyses (FMEA / HAZOP / HazId) 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 overall design is adequate for all possible scenarios including normal, abnormal and emergency operating conditions
Hazard categories and guidewords:

<table>
<thead>
<tr>
<th>Number</th>
<th>Hazard Category</th>
<th>Hazard guidewords</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Natural Disasters</td>
<td>High winds – typhoons, hurricane, extreme wave, extreme current, extreme temperature, lightning, fire, dry season, seismic events</td>
</tr>
<tr>
<td>2</td>
<td>Impact from External Effects</td>
<td>Dropped object, ship / floating object collision, helicopter impact, flexed road visibility, sabotage/terror, grounding, capsizing, shipping route hazards, shuttle barker list, loss of buoyancy</td>
</tr>
<tr>
<td>3</td>
<td>Impact on the Environment</td>
<td>Wastewater treatment, Ballast water disposal, oily water treatment/discharge, underwater noise and vibration, air quality, marine ecology</td>
</tr>
<tr>
<td>4</td>
<td>Impact on the Surroundings</td>
<td>Proximity to adjacent industrial installations, proximity to centres of population, adjacent land use, proximity of the bunkering ship</td>
</tr>
<tr>
<td>5</td>
<td>Normal Operations</td>
<td>Proximity to transport corridors, crane operations</td>
</tr>
<tr>
<td>6</td>
<td>Emergency Operations</td>
<td>Mustering, escape, evacuation and rescue, helicopter availability, ESD command and control, emergency disconnection of the bunkering vessel during loading</td>
</tr>
<tr>
<td>7</td>
<td>Human Factors</td>
<td>Occupational accidents, improper/inadequate training, weather monitoring, striker, shipping traffic monitoring, material handling, manning level, crew training</td>
</tr>
<tr>
<td>8</td>
<td>Loss of Containment</td>
<td>Release of hydrocarbons, fatigue cracking, structural failure, cargo tank leak, leak into ballast tank, drains, rupture due to over / under pressure, rupture due to over / under temperature</td>
</tr>
<tr>
<td>9</td>
<td>Loss of Function</td>
<td>Equipment failure, rollover in cargo tanks, drains, excess / zero level</td>
</tr>
<tr>
<td>10</td>
<td>Impact from Adjacent areas</td>
<td>Engine room fires, accommodation fires, electrical spaces fires, container fires</td>
</tr>
</tbody>
</table>
A preliminary Hazid workshop is set up

- to confirm the understanding of the risks present to a specific arrangement
- To assess the general layout, the specific installation and the safety systems
- To identify all major accidental events and other hazards which are relevant to the ship with respect to the fuel gas system and its operation;
- to ensure that the risks are eliminated or reduced to as low as reasonably practicable (ALARP) by the application of mitigating and preventative safeguards; and
- To identify any action opportunities for risk reduction (such as safety or consequence assessment studies to be performed in future phases of engineering) and responsibilities
The first step is the hazard identification, which is done by a group of experts, having met with the ship designers and crew experts.

Second step is to analyze and assess the risk mitigation when detection and prevention are in place and after protection barriers efficiency.

A final level of risk is noted by the HazId experts and approved by the team.

A final list of recommendations is then made available for the designer.
**Risks – Complementary simulation studies**

- Calculation of the consequences on the structure using software simulation tools giving gas concentration and flame propagation.

**Complementary Explosion Simulation Studies**

- Elaboration of different scenarios of dispersion of a mix of gas and air onboard and on deck
- Analysis of the consequences of an explosion with the shock wave intensity and propagation.
Some on going projects... & Conclusions...

Selected Ship Projects with LNG fuel

- **Ultra Large Container Ship**
  - 2-stroke dual fuel propulsion engine supplied with high pressure gas
  - Auxiliary engines supplied with low pressure gas
  - Storage in type B tanks (~20,000 m³ LNG)

- **Passenger Vessel:**
  - Dual fuel propulsion plant supplied with natural gas for operation in port
  - Storage in type C tanks
**Other Selected Projects with NG Fuel**

**Handy size Oil Tanker:**
- 2-stroke dual fuel propulsion engine supplied with HP gas or DFDE propulsion
- Storage in type C tanks (2 x 1,500 m³ LNG) or type B tanks

**Ro-ro Passenger Ship:**
- Dual fuel propulsion plant supplied with low pressure gas
- Storage in cryogenic tank-vehicles stowed on ro-ro deck

**Conclusions....**

- LNG is a very promising and challenging fuel!! It gives the possibility to meet the most stringent environmental regulations from IMO, EU, US, however, it must be kept in mind that:
  - Price of LNG is going up on Asian market due to shortage and nuclear cease by Japan
  - The technology is still a bit more expensive that traditional fuel. LNG fuelled ships have a higher building cost.
  - The methane slip may decrease sometime the benefit from using LNG as fuel, it is under strong mitigation by the technology.
  - Logistics of LNG bunkering stations and ship to ship LNG transfer procedures should be improved.
  - Flag and Port Authorities should consider more optimistically
  - Crew members operating gas-fuelled installations are to be suitably trained, in accordance with the Flag Administration requirements.
Tack så mycket!