Activity 6.1 Risk assessment of parallel LNG bunkering and passenger/cargo handling on a ferry.

Workshop presentation Stockholm 21 May 2013

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Objective - Safety assessment regarding bunkering of LNG

Bunkering must be performed without unnecessary time loss to make LNG operations competitive. Bunkering processes are aimed to take place in parallel with passenger and cargo operations.

The study will identify critical parts of the operation and try to find ways to handle the involved risks. Based on the risk assessment and with input from other activities on safe bunkering best practices for bunkering in parallel with passenger/cargo operations will be suggested. These will include organisational and technical recommendations for equipment and standby systems. This work will also lead to recommendations for training the operators.
Activity expected results

- Identification of risks associated with parallel bunkering and passenger operations.
- Identification of possible technical solutions to reduce risks and make operations efficient.
- Suggested best practices for safe bunkering in parallel with passenger operation. This will include suggestions for instruction for, and education of, the crew on board the vessels.
- Identify the changed risk profile imposed by parallel bunkering of LNG in port.
- Prioritise and order risks. Describe the critical passages and the critical operations
- Identify appropriate risk control options
Limitations

No port specific case studies
• Tend to be more detailed on local features and phenomena.

Generic port case studies
• Tend to be general in identification of hazards and estimation of accident probabilities and consequences
• The risk-based rule-making must be general and applicable for all ports

To be addressed:
• Scaling of potential accident consequences with respect to the quantities of LNG handled
• Strategic planning considerations with regard to other activities in the port, its location, distance to residential areas, exposure of third parties.
Methods and Approach

- FSA as suggested for activity 1.1 and 6.2 with parallel HAZID meeting
- Establish baseline risk profile
- Analysis of relevant risk analyses, projects, safety distances and restrictions of existing and planned ferry lines (Fjord1, Viking Line, Fjordline, etc)
- Recommendation for risk assessments for new establishment of ferry lines
- Training requirements for crews
- Follow up Viking Line and Sirius/ AGA
Risk analysis methods
Traffic pattern bunkering vessel
Traffic pattern bunkering vessel
# Traffic pattern bunkering vessel

<table>
<thead>
<tr>
<th>Location</th>
<th>Average time</th>
<th>Maximum time</th>
<th>Counts</th>
<th>Average/vessel</th>
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</thead>
<tbody>
<tr>
<td>Skarvik</td>
<td>03:30:25</td>
<td>12:04:45</td>
<td>2806</td>
<td>180</td>
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<tr>
<td>Brofäste</td>
<td>04:42:39</td>
<td>09:25:40</td>
<td>941</td>
<td>98</td>
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<tr>
<td>Ankar C</td>
<td>03:34:30</td>
<td>06:54:20</td>
<td>890</td>
<td>62</td>
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<tr>
<td>Rya</td>
<td>01:02:34</td>
<td>01:53:56</td>
<td>764</td>
<td>53</td>
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<tr>
<td>RIVÖ</td>
<td>02:10:28</td>
<td>04:38:22</td>
<td>472</td>
<td>33</td>
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<tr>
<td>Skandia</td>
<td>02:22:12</td>
<td>09:16:52</td>
<td>286</td>
<td>20</td>
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<tr>
<td>Stena</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Danmark</td>
<td>02:23:37</td>
<td>04:33:23</td>
<td>185</td>
<td>22</td>
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<tr>
<td>Stena</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tyskland</td>
<td>02:33:29</td>
<td>04:47:41</td>
<td>126</td>
<td>21</td>
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<tr>
<td>Torshamn</td>
<td>02:38:33</td>
<td>05:43:29</td>
<td>122</td>
<td>9</td>
</tr>
<tr>
<td>DANA</td>
<td>02:47:44</td>
<td>06:55:44</td>
<td>107</td>
<td>9</td>
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<tr>
<td>Frihamnen</td>
<td>01:50:28</td>
<td>03:59:12</td>
<td>88</td>
<td>6</td>
</tr>
<tr>
<td>Ankar B</td>
<td>02:53:17</td>
<td>04:28:24</td>
<td>66</td>
<td>5</td>
</tr>
<tr>
<td>Ålvsborg</td>
<td>01:40:12</td>
<td>03:16:41</td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Ankar A</td>
<td>02:59:47</td>
<td>05:04:19</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Arendal</td>
<td>03:28:17</td>
<td>06:51:36</td>
<td>19</td>
<td>3</td>
</tr>
</tbody>
</table>
Future traffic estimation – LNG – Impact?

Figure 50: Sensitivity of LNG price, investment horizon and fuel burden on uptake of LNG fuelled vessels. Scenario D+ denotes increased investment horizon and fuel burden. Source: DNV, 2012.

Figure 51: Ships with smaller or de-rated engines. Sensitivity of fuel price on uptake of smaller or de-rated engines. Scenario D+ denotes increased investment horizon and fuel burden. Source: DNV, 2012.
### LNG bunker volumes – Impact?

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Density [kg/m³]</th>
<th>LHV [MJ/Kg]</th>
<th>Energy density [MJ/1000 m³]</th>
</tr>
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<tbody>
<tr>
<td>LNG</td>
<td>442</td>
<td>~54.7</td>
<td>~24.17</td>
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<tr>
<td>MDO</td>
<td>900</td>
<td>~42.7</td>
<td>~38.43</td>
</tr>
<tr>
<td>HFO380 (ISO8217)</td>
<td>991</td>
<td>~40.9-41.2</td>
<td>~40.5-40.8</td>
</tr>
</tbody>
</table>

Heavier tanks, more space required, location more restricted:

LNG could require up to 2.5/ 3.5 times as much space as MDO for the same amount of energy onboard

→ Bunkering will take place more often
LNG bunkering, where are we?

“Old” system: Experience from normal operations increases the number of regular and predictable events.

The number of unpredictable events is so large that changes are insignificant.

New system: New operating practices reduces the number of regular and predictable events.
Accident Frequencyies: "Occupation"

- Anchor handling
- Other
- Other maintenance
- Towing, icebreaking
- Mooring/unmooring
- Working with fishing equipment
- No activity
- Loading/Unloading, bunkering
- Normal sailing
- Unknown
- Cleaning of tanks/cargo spaces
- Safety drills
- Maintenance or service in machinery
Frequency of bunkering accidents

Statistics from the Mediterranean Sea (REMPEC, 2011): The database is based on data from 1977 to 2010 and contains 772 accidents, 12 of which have been made in connection with the bunkering. Most common cause of oil spills, as it is known, was the overfilling of the tank. Hose rupture occur in two cases.

- Ship-to-ship transfer (Lightering)?
- Truck loading/ unloading?
- Norway LNG statinary bunkering?
- LNG carriers?
- Effect of break-away couplings? (62% according to OGP)
Accidents while bunkering

- SSPA has analyzed data from the English accident database MAIB:
  - Safety - 63.6%
  - Human Factor - 45.5%
  - Technical factor - 30.9%
  - Procedures - 45.5%
  - Practice - 40.0%
  - Environment - 18.2%
  - Equipment - 7.3%.

Most often occurs accidents on deck, but also on the bridge and in the engine room.
### Causes of Operations

<table>
<thead>
<tr>
<th>Operations</th>
<th>Loading/ Discharging</th>
<th>Bunkering</th>
<th>Other Operations</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allison/Collision</td>
<td>4</td>
<td>0</td>
<td>38</td>
<td>308</td>
<td>350</td>
</tr>
<tr>
<td>Grounding</td>
<td>0</td>
<td>0</td>
<td>22</td>
<td>251</td>
<td>273</td>
</tr>
<tr>
<td>Hull Failure</td>
<td>36</td>
<td>4</td>
<td>11</td>
<td>48</td>
<td>99</td>
</tr>
<tr>
<td>Equipment Failure</td>
<td>143</td>
<td>6</td>
<td>17</td>
<td>38</td>
<td>204</td>
</tr>
<tr>
<td>Fire/Explosion</td>
<td>8</td>
<td>0</td>
<td>13</td>
<td>24</td>
<td>45</td>
</tr>
<tr>
<td>Other</td>
<td>96</td>
<td>14</td>
<td>33</td>
<td>26</td>
<td>169</td>
</tr>
<tr>
<td>Unknown</td>
<td>103</td>
<td>9</td>
<td>16</td>
<td>82</td>
<td>210</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>390</td>
<td>33</td>
<td>150</td>
<td>777</td>
<td>1350</td>
</tr>
</tbody>
</table>

### Other Operations

<table>
<thead>
<tr>
<th>Operations</th>
<th>Loading/ Discharging</th>
<th>Bunkering</th>
<th>Other Operations</th>
<th>Unknown</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allison/Collision</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>166</td>
<td>182</td>
</tr>
<tr>
<td>Grounding</td>
<td>2</td>
<td>0</td>
<td>14</td>
<td>226</td>
<td>242</td>
</tr>
<tr>
<td>Hull Failure</td>
<td>324</td>
<td>10</td>
<td>47</td>
<td>196</td>
<td>577</td>
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<tr>
<td>Equipment Failure</td>
<td>1124</td>
<td>104</td>
<td>251</td>
<td>202</td>
<td>1681</td>
</tr>
<tr>
<td>Fire/Explosion</td>
<td>50</td>
<td>5</td>
<td>35</td>
<td>83</td>
<td>173</td>
</tr>
<tr>
<td>Other</td>
<td>842</td>
<td>289</td>
<td>517</td>
<td>163</td>
<td>1811</td>
</tr>
<tr>
<td>Unknown</td>
<td>814</td>
<td>154</td>
<td>404</td>
<td>1806</td>
<td>3178</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3157</td>
<td>564</td>
<td>1281</td>
<td>2842</td>
<td>7844</td>
</tr>
</tbody>
</table>

#### 7-700 tonnes

Smaller amounts more frequent

Accidents LNG carriers

• Good safety record:
  – over 60,000 Shipments
  – eight marine incidents worldwide, involving the accidental spillage of liquefied natural gas
  – three major grounding incidents, but none resulted in loss of cargo

• Loading/unloading accident/ incident frequency:
  $2.47\times10^{-3}$ per ship year (1984-2008) -> vapour released, no LNG, no ignition

• Applicable?
Hazard identification workshop

Objectives

• Identify hazards associated with LNG bunkering activities conducted in parallel with handling of passengers and cargo on a ferry.

• Ranking of probability and severity of consequences of identified hazards.

• Follow the gas from the delivering bunker vessel to the tanks of the receiving vessel in generic technical systems with defined key components and optional layout.

• Follow the operational phases and human factor related procedures regarding communication, responsibilities, qualification requirements, training and complacency

• The output; structured documentation of discussion, forms input for further analysis of identified high ranked hazards.

• Not repeat previous hazids, focus on project specific issues.

• Bow-Tie approach:
  – All levels of safety barriers addressed
  – All causes of failures addressed
Hazid documentation

<table>
<thead>
<tr>
<th>No.</th>
<th>HAZARD</th>
<th>Cause</th>
<th>Direct and final consequence</th>
<th>Probability(1-3)</th>
<th>Consequence(1-3)</th>
<th>Preventive measure</th>
<th>Consequence reducing measure</th>
<th>Comparative scenario</th>
<th>Comments</th>
</tr>
</thead>
</table>

- **What could go wrong?**
- **Why does it go wrong?**
- **How often does it go wrong?**
- **What are the consequences?**
- **How can they be prevented?**
- **How can the consequences be mitigated?**
• **Types of accidental events:**
  Collision/contact, mooring failure, leakages, fire/explosion, structural failure, falling objects, occupational...

• **Causes of accidental events:**
  Technical failure of critical components, human error, external factors, weather, other ship, sabotage, organizational, lack of competence...
Identified risks

- Human error
- ESD system fails, handling of equipment
- Emergency release couplings fail, e.g. accidental triggering, hose breaks instead of coupling, buckling
- Risks associated with parallel processing of other fuels eg. discharge of fuel
- Damage to bunker hose
- Emergency systems on bunker boat is not working, e.g. hose crane, sprinklers, monitoring, control
- Leakage not detected
- Backfilling gas to the bunker boat
- Gas in confined spaces
- Sparking (Technical, third party, thunder)
- Wake wash, mooring arrangement, mooring line damage
- Pleasure boat too close to vessels

Surge pressure
Specific aspects regarding ferries, cruise vessels:

1. Gas zone size (IGF)
2. Safety zones, no unauthorized access bunkering/normal
3. Separation of passenger areas and bunker station
4. Separation of ro-ro areas and bunker station
5. Loading ramps ro-ro doors adjacent to bunker station
6. Connections between p and sb bunkering stations
Specific aspects regarding ferries, cruise vessels:

7. Cabin windows or balconies near/above bunker station
8. Passenger fear of visible frost smoke, preventive info
9. Passengers in no smoking areas
10. Enforcement of safety zones on board
11. Enforcement of safety zones in surrounding water area
12. Passenger evacuation in case of gas cloud formation
Risk assessment – risk control options

Causes
- Human error
- Technical failure
- External factors
- Organisational

Operation
- Prevent deviation from normal operation
- Detect
- Restore

Accident event
- Release of LNG

Emergency
- Detect the consequences of the accident
- Control
- Mitigate

Final consequences
- Fatalities
- Injuries
- Losses
- Pollution

Causal chain
LNG bunker vessels for supply of LNG fuel

- Volume: typical 1200-4000 cbm acc to needs (possible w L<70m)
- Pat.pend. For LNG cooling plant reducing boil off
- Can also engage in coastal transportation of LNG
- L = 60-99m
- min Manning
- Short engine room
- Boil off as fuel

White Smoke WS1 700/1000/1400 m³ LNG

LOA 80m, B 13 m, T 4 m DWT 1400 tonnes

SEAGAS 170 m³ LNG

LOA 50 m, B 11,3 m, DWT(LNG) +70 ton, Crew: 3
Regulations, Operational bunkering box charts
LNG bunkering system

- LNG bunker vessel/truck
  - Recirc. loop
  - LNG pump
  - CH₄ purging
  - N₂ inerting
  - Vapour return hose
  - ESD valve
  - ESD link

- LNG receiving vessel
  - ESD valve
  - DDC
  - ERC
  - VPU
  - Grounding
System design,
STX LNG Diesel Electric Machinery
Break-away couplings

• Safety break away couplings are designed to prevent pull-away/tow-away accidents when loading or unloading tank trucks, railcars, vessels etc.

• Shall initiate ESD when pulled away
Dry Disconnect Couplings

To connect
Push and turn - it's coupled
- full flow

To disconnect
Turn and pull - it's released
- no spillage

LNG bunkering components examples of couplings
Consequences, Safety distances with regard to localisation and parallel cargo/pax handling

• Consequence a function of
  – Transfer rate (volume, time)
  – Hose diameter
  – Equipment

• Credible spill scenario for safety zone

• Distance bunkering station – public

• Uncontrolled sources of ignition, risk object vs object to be protected

• EX zones
Differences compared with today’s bunkering

- Training
- Procedures
- The monitoring systems for transfer, equipment, links
- Responsibilities
- Fire protection
- **Test of LNG quality**? Procedures for sampling of LNG, Continuous/ Discontinuous? Contaminated LNG

- **Ventilation**: The LNG tanks have their purging, filling and emptying systems. The enclosed space, where the tank/s are placed together with compressor and/or fuel preparation room will have their own forced ventilation system separated from that used for the ventilation of non-hazardous spaces.

- For the transfer of LNG, there is no implemented **standardized** system in respect of sizes or design/interface of couplings and hoses. The hoses and couplings must be designed and constructed for products with temperature of -196ºC.
What to choose, hose or arm?

Failure frequencies

<table>
<thead>
<tr>
<th>Hose</th>
<th>Loading Arm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage:</td>
<td>Leakage:</td>
</tr>
<tr>
<td>( 5.4 \times 10^{-6} )</td>
<td>( 3.0 \times 10^{-7} )</td>
</tr>
<tr>
<td>( d_{eq} = 0.1 \times D, \text{ max. 50 mm} )</td>
<td>( d_{eq} = \text{equivalent leak diameter (mm)} )</td>
</tr>
<tr>
<td>( D = \text{loading arm or hose diameter (mm)} )</td>
<td>( D = \text{loading arm or hose diameter (mm)} )</td>
</tr>
<tr>
<td>Rupture:</td>
<td>Rupture:</td>
</tr>
<tr>
<td>( 5.4 \times 10^{-7} )</td>
<td>( 3.0 \times 10^{-8} )</td>
</tr>
</tbody>
</table>

Source:
Handbook Failure Frequencies 2009, Flemish Government, Belgium
Questions?

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