Loss Prevention Through Risk Assessment Surveys of LNG Carriers in Operation, Under Construction, Conversion and Repair

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Loss Prevention Through Risk Assessment Survey of LNG Carriers

- LNG Properties (Physical and chemical properties)
- LNG Carrier
- LNG FPSO (New - Floating Production Storage and Offloading)
- LNG FSRU (New - Floating Storage Regasification Unit)
- Shipyards (Building and Repairing Ship Yards in the world)
- Risks of LNG Carrier
- Loss Preventions of LNG Carriers
- LNG Production and Receiving Terminals in the world
Steel mills, Industries and Power Station

Domestic Gas

LNG FPSO for Smaller Reserves at sea

Processing, Liquefaction & Storage at LNG Production Terminal

LNG tankers

LNG Receiving terminal

Regasification

LNG FSRU for temporary sites or flexibility

LNG Receiving terminal

Distribution pipelines

Steel mills, Industries and Power Station

Domestic Gas
LNG Exporting Countries (LNG Loading Terminals)

- LNG export from countries with gas reserves.

- More natural gas reserves are found in Russia, Europe, Iran and other countries.

- Russia has the biggest Gas reserves supplying Europe by piped GNG

- LNG export is faster and more flexible than pipeline gas.

A very rough estimates
The major LNG importing countries are in Asia.

Europe and USA are increasing the import of LNG.
Processing and Liquefaction LNG Terminal

- Processes and liquefies GNG (Natural Gas) to LNG and NGL (Natural Gas Condensates – Production of 60% of world LPG).
- LNG is stored in LNG/LPG tanks for loading onto a LNG/LPG Carrier.
- Transport to overseas by LNG/LPG Carriers.
LNG Receiving and Regasification Terminal

- LNG receiving terminals:
- Receive LNG cargo from LNG Carriers.
- Storage in LNG tanks.
- Regasifies LNG to GNG. (1:620)
- GNG supply to Steel Mills, Power Stations, Industries and Homes.
### Type of LNG Carriers

**Membrane type of LNG Carrier (GTT Mark III, NO 96 and CSI)**

- **Standard:** 125-150,000m³
- **Q-Flex:** 210-217,000m³
- **Q-Max:** 250,000m³

**Moss - Spherical type of LNG Carrier**

- **Sizes:** 125-145,000m³

- **No. of Crew:** About 30 per Ship
- **Life Span:** About 40 years or more
- **Construction period:** About 2 to 2 ½ years from signing of contractor

*Image of a Membrane type LNG Carrier and a Moss type LNG Carrier*
LNG Containment Systems

**SPB Type**
- Only two LNG Carriers of this type in operation
- No filling restrictions
- Extensive internal structural stiffeners
- Prone to structural fatigue
- Aluminum Alloy
- IHI Design (Japan)
- Only two ships built

**Spherical Type**
- Long experience from LNG carriers
- Excellent track record
- Not affected by sloshing
- No filling restrictions
- No internal stiffeners
- Aluminum Alloy (25 mm to 100 mm)
- Moss Design (Norway)
- Smaller Loading Capacity
- Longer time in dry dock
- Higher construction cost

**Membrane Type**
- Long experience from LNG carriers
- Good track record
- Affected by sloshing
- Filling restrictions
- Invar steel or stainless (0.7 to 1.5 mm)
- GTT Design (France)
- NO 96, Mark III, CSI
- Bigger Loading Capacity
- Shorter time in dry dock

*BMT Marine & Offshore Surveys*
Number of LNG Carriers in operation

A very rough estimates
Number of New Buildings of LNG Carriers

A very rough estimates

Membrane Type
Spherical Type
Spherical Type of LNG Carrier

• Almost 40% the LNG carriers in the world are of the Spherical type.
• 80% of LNG carriers coming to Japan are of the Spherical type.
Spherical Type of LNG Carriers

- Aluminum Alloy Spherical tank.
- 40m in diameter.
- “Self Supporting”
- 40% of the world’s LNG carriers are of this type.
Aluminum spherical tank of about 40m - 45m in diameter
Thickness of Moss Tank
MEMBRANE Type of LNG Carrier

- Primary membrane holds cargo.
- Secondary membrane prevents leakage.
- Primary & secondary insulation to maintain cargo temperature at –161 C
- Ship’s hull to support tank.
- 80% of the world’s LNG carriers under construction are of membrane type.
- Most MISC LNG Carriers are this type
- Almost 60% of the LNG Carriers in the World.
NO.96 Membrane System of LNG Cargo Tank – Shinning and Flat Surface
NO.96 Membrane System

- Two layers of membranes made of 36% nickel-steel (invar) 0.7 mm to 1.5 mm thick.

- Two layers of insulation boxes made of plywood filled with expanded perlite (Volcano rock).

- Cargo tank is supported by tank top of double bottom of the ship.
MARK III System of LNG Cargo Tank – Less Shinning and Corrugated Stainless Steel Surface
MARK III Membrane System

Only one layer of Primary Barrier of Corrugated Stainless-steel of about 1.2-1.5 mm thickness

Secondary Barrier of “Triplex” Membrane
“Triplex” is made of glass cloth/aluminum foil/glass cloth bonded by glue. This section is installed on site and this is the problem area

Prefabricated Polyurethane Insulation Panels with “Triplex” from workshop
Prefabricated Polyurethane Boards

Primary Insulation

Secondary Barrier “Rigid” Triplex

Secondary Insulation
Installed Prefabricated Boards

Primary Barrier:
Corrugated Stainless-steel

Secondary Barrier:
“Flexible” Triplex
CS1 Membrane System

- New Design (Two ships in operation)
- Combination of Mark III & No. 96.
  - Nickel-steel (invar) (0.7 to 1.5 mm) primary membrane.
  - Glass cloth/Aluminum foil/Glass cloth Aluminum/glass “Triplex” secondary membrane.
  - Fabricated Polyurethane insulation panels with “Triplex” from workshop
OFFHIRE Statistics of LNG Carriers (Up to 2006)
Current Shipyards Building LNG Carriers

- **China (NO 96)**
  - Hudong Zhonghua Shipyard

- **Japan (Moss, GTT- NO 96, Mark III and SPB)**
  - Kawasaki Shipbuilding
  - Koyo Shipyards, Imabari
  - Mitsubishi Heavy Industries
  - Mitsui Engineering
  - Universal Shipbuilding
  - Ishikawajima-Harima Heavy Industries

- **Korea (Moss, GTT NO 96 and Mark III**
  - Daewoo
  - Hyundai Heavy Industries
  - Samsung Heavy Industries
  - Hanjin Heavy Industries
  - STX Shipbuilding
  
  (80% of world’s LNG carriers are under construction in Korea.)

- **France (GTT NO 96, Mark III and CS1)**
  - Aker Shipyard (Chantier's de L'Atlantique Shipyard)

- **Spain (GTT NO 96 and Mark III)**
  - Puerto Real Shipyard

- Special Trainings and licensing required.
LNG Ship Repair Yards

The current boom of shipbuilding has also brought forth an expansion of ship repair yards mainly under home port or home doctor concept.

– Japan
  • Mitsubishi Heavy Industries
  • Kawasaki Heavy Industries
  • Ishikawajima-Harima Heavy Industries
  • Universal Shipyards
  • Mitsui Engineering and Shipbuilding

– Singapore
  • Sembawang Group of shipyards
  • Keppel Group of shipyards

– Malaysia
  • Malaysia Shipbuilding & Engineering (MHHE)

– European Yards.
  • Sobrena-France.
  • Izar Carenas-Spain.
  • Blohm & Voss-Hamburg.
  • CMR-Italy.
  • San Giorgio del Porto-Italy.
  • Lisnave-Portugal.

– Middle East.
  • Dubai Dry-docks.

• Special Trainings and Licensing are required.
Risks of LNG Carrier due to Perils at Sea

- Accidents during sea voyage:
  - Grounding – Navigation error
  - Striking a fixed object or a wreck – Navigation error
  - Collision (with vessel or object) – Navigation error
  - Unloading/Loading
    - Sudden pull-away and damage of loading/discharging arms and human injury
    - Cracking of ship steel hull due to spill of LNG (super cold shock of -161°C)
  - Terrorism – Missile attack, boat based explosive and hijacking.
  - Cargo machinery and cargo containment failures
  - Natural risks – Lightning, typhoon, hurricanes, and tsunami.
  - Other hull/machinery accidents, such as fire in engine room on bridge and in accommodation, boilers, steam turbines, main reduction gears, diesel engine damages, and hull structural failures

Note: Apart from the above risks we must aware of the high costs (millions of $) and long repair period (months) arising from ordinary damage on LNG Carrier involving cargo containment system.
Past Losses of LNG Carriers

- Major and Minor Casualties on LNG Carriers experienced by the speaker over the last 30 years.
  - 1979 LNG “X” grounding in Japan due to weather - 2,000 tons of steel, 4 months of repair and Millions $
    - 1979 LNG “X” water ballast tank leak to insulation space of a cargo tank – ½ year of repair
    - 1979 LNG “X” over pressure of insulation spaces causing building of membrane – 9 months of repair
    - 1980 LNG “X” grounding in Gibraltar – 2,500 tons of steel and deformation of cargo tanks: 1 ½ years of repair and ship-ship transfer of LNG
    - 1989 LNG “X” broke away from LNG Terminal due to very strong gale damaging to No. 1 cargo tank, deck deformation and loading arms – 10 months of repair
  - 2004 LNG “X” grounding in Korea due to navigation error– 200 tons of steel, 8 months of repair and Millions of $$$
  - 2005 LNG “X” sloshing damage in a LNG tank due to heavy weather, and with partially loaded LNG tank – 6 months of repair and Millions of $$$
    - 2006 LNG ”X” sloshing damage during ballast voyage with minimum LNG, 4 months repair
  - Main Boiler damage – chemical carry over and thermo fatigue due to gas burning and ……
  - Main Reduction Gear damage-pitting and broken teeth and …..
  - Main and Auxiliary Turbine damage due to chemical carry out and wet steam and ……..
  - Main Propeller shaft broke due to porosity– Resulted in the 2nd Ship to Ship transfer of LNG in the history
  - Cargo Machinery damage (Cargo Pumps and etc.)
  - Cargo Pipe damages – movement of vessel at LNG terminal due to natural risks and machinery failures
  - Hull Structure Failures due to design, vibration and fatigues…….
A Minor Grounding Damage on LNG Ship at Bow
A minor crack (less than 1 meter) due to grounding impact on the steel bulkhead in a cofferdam between No. 1 and No. 2 cargo tanks caused sea water ingress into the No. 1 cargo tank.
Result: Seawater ingress into cargo tank and LNG Cargo Pumps Immersed in Seawater
Resulted Rust on the Primary and Secondary Invar Steel Membranes of the Cargo Tank after Soaked in Seawater and Moisture
Resulted primary and secondary insulation boxes soaked in seawater
Sloshing Phenomena of a Partially Filled Cargo Tank

The sloshing phenomena occur when the ship motions coincide with the natural frequency of the liquid motion in the tanks. The build-up of violent motion is due to frequency, not amplitude.

- Filling Restriction: Allowable minimum level of LNG in a membrane type of cargo tank is 10% of the height of the cargo tank

The sloshing phenomena takes place in partially filled tanks.
Heavy weather and partially loaded LNG tank resulted sloshing damage in a LNG tank – 6 months and Millions $$
Another close-up view of sloshing damage in a LNG tank
Secondary barrier “Triplex” failure on the on site installed insulation panels (N2 leak detected during operations)

Separation due to failure of “Glue”

“Triplex” Membrane-made of (glass cloth/Aluminum foil/glass cloth) as secondary barrier
Special stage (12 levels) from bottom to top of a cargo tank for repairs (Thousands pieces of special stage materials similar to the stages in the building construction)
Actual Losses during construction

Major construction casualties (Millions of $$ $$ $)

- 2005 – Fire in cargo tank. Due to welding of reinforcement on Pump column.
- Bulging of primary and secondary barriers during tests.
- Risk Assessment Surveys: JH 143 by BMT Surveys
JH 143
Shipyard Risk Assessment Surveys of Chinese LNG Carriers
Major Casualties in both Loading and Receiving LNG Terminals

Four Major accidents over 60 years of LNG usage

- **Cleveland, Ohio-1944.**
  - Shortage of stainless steel leading to poor quality tanks after WWII.
  - 128 fatalities, damage to facilities
- **Staten Island, New York-1973.**
  - Construction accident.
  - 37 fatalities, damage to facilities
- **Cove point, Maryland-1979.**
  - LNG leakage ignited by faulty electrical circuit.
  - 1 fatality, damage to facilities
- **Algeria-2004.**
  - LNG liquefaction plant.
  - Due to leaking gas drawn into a boiler fan.
  - 27 fatalities, damage to facilities

There have been other accidents leading to injuries, delays in production and damages to facilities.
## Sample of Risks on LNG Carrier

### Example of identified Risks:

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>Structural failure to hull</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Structural damage due to incorrect loading</td>
<td>17</td>
</tr>
<tr>
<td>3a</td>
<td>Overfilling of tanks</td>
<td>18</td>
</tr>
<tr>
<td>3b</td>
<td>Overpressure of tanks</td>
<td>19</td>
</tr>
<tr>
<td>4</td>
<td>Unignited leak in the cargo system</td>
<td>20</td>
</tr>
<tr>
<td>5</td>
<td>Release of Nitrogen</td>
<td>21</td>
</tr>
<tr>
<td>6</td>
<td>Release of bunker oil</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>Fire in engine room</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>Accommodation fire</td>
<td>24</td>
</tr>
<tr>
<td>9</td>
<td>Fire on open deck</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>Fire in cargo handling module</td>
<td>26</td>
</tr>
<tr>
<td>11</td>
<td>Fire in void spaces around LNG tanks</td>
<td>27a</td>
</tr>
<tr>
<td>12</td>
<td>Fire in void spaces like ballasting tanks</td>
<td>27b</td>
</tr>
<tr>
<td>13</td>
<td>Fire in forward storage area</td>
<td>27c</td>
</tr>
<tr>
<td>14a</td>
<td>Explosion in engine room due to fuel gas</td>
<td>28</td>
</tr>
<tr>
<td>14b</td>
<td>Explosion in engine room due crank house failure</td>
<td>29</td>
</tr>
<tr>
<td>15</td>
<td>Boiler explosion</td>
<td>30</td>
</tr>
<tr>
<td>16</td>
<td>Explosion in accommodation</td>
<td>31</td>
</tr>
<tr>
<td>32</td>
<td>ESD not functioning</td>
<td>33</td>
</tr>
<tr>
<td>34</td>
<td>Loss of emergency powers</td>
<td>35</td>
</tr>
<tr>
<td>36</td>
<td>Loss of hydraulic system- compressed air</td>
<td>37</td>
</tr>
<tr>
<td>38</td>
<td>Unignited leak from tank</td>
<td>39</td>
</tr>
<tr>
<td>40</td>
<td>Loss of navigational or manoeuvring capabilities</td>
<td>41</td>
</tr>
<tr>
<td>42</td>
<td>Hitting the quay</td>
<td>43</td>
</tr>
<tr>
<td>44</td>
<td>Man over board</td>
<td>45</td>
</tr>
<tr>
<td>46</td>
<td>Piracy/hijacking</td>
<td>47</td>
</tr>
<tr>
<td>48</td>
<td>Illness or epidemics</td>
<td>49</td>
</tr>
<tr>
<td>50</td>
<td>Gas freeing</td>
<td>51</td>
</tr>
</tbody>
</table>
Fire Risk on LNG Carrier due to LNG leak

Conclusion: unlikely

Scenario sequence:
1. Leak
2. Pool formation
3. Cloud dispersion
4. Flash fire back
5. Pool fire

Figure 1. LNG Event Sequence for Consequence Modelling
Risks of LNG Carriers

- Gas cloud
- Collision events
- Fire in engine room, accommodation and navigation bridge
- Release of bunker oil
- Collisions, groundings of any kind
- Man overboard, or piracy
- Contact with Quay/cargo tank releases of LNG
Measures to Reduce Risk and Loss Prevention on LNG Carriers in Operation, Under Repair and Construction

• Safe Operations: To reduce spill, sloshing, overpressure, vacuum and accidental leaks

• Improved Cargo Containment Systems

• Fighting Firing and Gas Detection Systems: Gas detection, safety and firefighting equipments: Manual and automatic gas detections, foam, powder, water curtain and fire hydrants

• Safety and Operational Inspection/Audit by crew/shipmanagers: Daily/Every arrival

• Safety and Operational Inspection/Audit: Yearly by ship managers

• Safety, Security, Operational and Management Inspection/Audit: Every 2 ½ years by external surveyors during scheduled dry docking and maintenance in a shipyard

• Home Doctor (Designated Shipyard) Concept, Standard Specification and Pricing, Crew Preventive Maintenance Plan and Master Maintenance Plan on All Vital Machineries and Systems

• Longevity Studies for LNG Carriers at 20 years for 25 years Time Chartered
Measures to Reduce Risk and Loss Prevention on LNG Carriers in Operation, Under Construction and Repair

• Use of Manufacturer’s Service Engineers for All Vital Machineries and Systems
• Water Ballast Tank Re-Coating (after 15 to 20 years)
• Pre-employment crew security screening, medical tests, training and licensing
• Continuous Crew and ship managers training
• Proper exclusion and buffer zones (Remote area) between public areas, ships, and LNG terminals.
• Terrorist Risk Prevention, ISPS (International Ship Port Security): Security checks at main gate, berth and on ship
• Entry and Routine Condition Surveys on behalf of P&I Clubs
• JH115A/JH 722 general condition/structural survey on behalf of Hull Insurers
• JH2006/010 A, B,C, Engine room and office management and condition surveys on behalf of Hull Insurers
• JH143 Risk Assessment and Loss Prevention Surveys- construction/conversion
Risks on New Technologies

• LNG Carriers have proven experience of steam turbines propulsion system.

• New propulsion system is introduced
  Dual Fuel Diesel Engine Propulsion Systems (in operation)
  Dual Fuel Diesel Engines + Electric Motors propulsion system
  (Under construction)
  Reliqefication Plant (in operation)
  Re-gasification plant (in operation)

  New Cargo Containment System (CS I and so on....)
  LNG FPSO (Floating Production Storage and Offloading)
  LNG FSRU (Floating Storage Regasification Unit) (in operation)

• We are going into new technologies accompanying with New Risks.
• Risk Assessment Surveys are Recommended: Condition Survey of LNG Carriers on behalf of Hull Insurers and P & I Clubs
We monitor casualty trends.

Types of Marine Casualties – Particular Average (PA) Numbers and Costs

Particular Average Claims (By Casualty Type)

Proportion of Total (%)

- ER Machinery
- Collision
- Fire/Explosion
- Grounding
- Heavy Weather
- Flooding
- Ice
- Structure
- Capsize/Sink
- Paint
- Prop/Rud/SG
- Other

Legend:
- PA Numbers
- PA Costs

BMT Marine & Offshore Surveys
Risks to Underwriters

• Untested Technologies

• More shipyards are building of LNG Carriers.

• Shortage of skill and trained workers

• Use of Sub-contractors

• Poorly targeted Risk Assessment and Unrealistic Emergency Response.

• Ship Owner and Shipyard Project Teams Skill Base makes a Big Difference in the Risk Profile and Quality during construction of LNG Carriers

Risk Assessment Survey: JH 143 Surveys
Risk Due To Shortage Of Experienced LNG Crew

- In year 2000 the number of LNG were about 130.
- In year 2007 it increased to 250.
- In year 2010 the number of LNGC increase to about 300.
- 6 experienced senior officers per LNGC are required. (Master, Chief Officer, Chief Engineer, 1st Engineer, Cargo Engineer, Electrical Engineer)
  - 2000: 1,000 Experienced senior officers
  - 2007: 3,000 Experienced senior officers
  - 2010: 3,600 Experienced senior officers
- In addition, due to increase in the construction of LNG Carriers, LNG FPSO, and LNG FSRU more experienced seafarers are employed as owner’s construction and operations superintendents and project managers of the shipyard.
- There is a great shortage of experienced LNG senior officers in the marine industries.
- Training, licensing, security screening and better financial rewards and benefits are essential in order to attract seafarers to this industries.
New: LNG FPSO - Floating Production Storage Offloading (Under Design/ Construction Stage for Smaller Reserves)

<table>
<thead>
<tr>
<th>LNG storage</th>
<th>180 - 250,000 m³</th>
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<tbody>
<tr>
<td>LNG production:</td>
<td>2 - 5 MMTPA/</td>
</tr>
<tr>
<td></td>
<td>290 - 730 MSCFD</td>
</tr>
<tr>
<td>Length:</td>
<td>300 - 450 m</td>
</tr>
<tr>
<td>Breadth:</td>
<td>50 - 70 m</td>
</tr>
<tr>
<td>Design life:</td>
<td>40 years</td>
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<tr>
<td>Raw Natural Gas</td>
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</table>
New: LNG FSRU (In Operation, Under Conversion and Construction)

- No. of Crew on board: About 30
- Life Span: About 40 years
- Conversion from existing LNG Carrier in Sembawang Shipyards
- New construction of LNG FSRU
- Temporary Sites
Floating Storage and Re-gasification Unit (LNG FSRU) For Temporary Sites

SHIP-TO-SHORE LNG PIPE LINE

Storage Tanks  Vaporizers  Mooring Turret  Pipeline Tie-in
Flexible Riser  PLEM  Subsea Pipeline
Over View of Offshore LNG Facilities
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  No. 96 System
  CS 1 System
Moss Systems engineering brochures
IHI-SPM Brochures

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KS Wang after a survey of exhaust gas manifold of a main engine wearing PPE, safety helmet, safety goggles, mask, gloves, boiler suit, safety shoes and explosion proof torch light and a spare torch light in the pocket.
Thank You and Arigatogozaimasu!

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