RISKS ASSOCIATED WITH THE MARINE ASPECTS OF LNG FPSO\textsubscript{es} (FLOATING PRODUCTION, STORAGE AND OFFLOAD) UNITS
Agenda

- Introduction to LNG what is it, what are the risks, what are the myths?
- Introduction to FLNG (Floating LNG Unit), what are they what do they do?
- Technical Risks associated with FLNG Units
  - Containment systems.
  - Mooring systems.
  - Transfer System.
  - FLNG Projects and Status.

NB The intent today's presentation is to address the Marine risks associated with LNG FPSOs and as such the presentation does not address the aspects of gas production and processing. Production risks will vary field to field similarly gas processes will vary field to field depending on specific gas make up.
What is LNG (Liquid Natural Gas)?

- LNG is primary liquid methane (CH$_4$) at a temperature of $-163^\circ$C at atmospheric pressure.
- It is a hydrocarbon fuel.
- It is lighter than air, it is colourless and odourless.

![Methane molecular structure](image)

**Tetrahedral E. P. G.**
**Tetrahedral Molecular Geometry**

C. Ophardt, c. 2003
What is LNG (Liquid Natural Gas)?
The Myths

Myth 1 LNG and LNG Carriers are floating bombs!!
Myth 2

- Leaking LNG will vaporise to form a vapour cloud that can become a BLEVE (Boiling Liquid Expanding Vapour Explosion) which will can ignite causing a major explosion.
- Alternatively the vapour cloud will ignite and burn as it disperses causing a large fire in city areas potentially causing huge damage!!
Myth 2

- Leaking LNG vapour cloud will ignite and burn as it disperses causing a large fire in city areas potentially causing huge damage!!
Fact

- LNG is a hydrocarbon and will burn BUT it is only combustible in free air at between 5 - 15% by volume.

- By comparison motor gasoline is combustible in free air between 1.4 - 7.6% by volume!
Fact

• Vapour will disperse rapidly and move down wind. As it moves down wind it will dilute and as such we once again have a situation where vapour density varies considerably.

• Some areas of the cloud will pass through the 5-15% flammability range as they do it is possible that, with a source of ignition, they could ignite but once out of this range fire will go out.
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Summary of LNG Characteristics

• LNG is hydrocarbon fuel so while LNG does not burn the vaporising methane will burn.

• Ignition is only possible at between 5-15% in free air so that rapid combustion across the cloud (explosion) is not possible!!

• It does not explode!

• 20 million residential users in the UK are connected to natural gas (methane) supplies and accidents are rare.

• LNG is stored and carried at - 163⁰C
What is FPSO (Floating Production Storage)?

• An LNG FPSO is a Floating Production Storage and Off-load Units so the unit is permanently moored over a gas well(s), gas is brought on board through a series of sea bed connections and risers to the Vessel.

• Once on board the gas is processed, dehydrated and liquefied for storage within the vessel. LNG is then transferred from the FPSO to LNG carriers for delivery to terminals around the World.

• The basic principle is identical to that for Oil and LPG FPSOs,
Typical Oil FPSO Arrangements
The Catch

• While Oil FPSOs are fairly common and there are two LPG FPSOs in service there are **NO LNG FPSOs** currently in service!!
What Do We Have Now?

• Today we have a number of concepts that have been developed to one degree or another.

• There are two cases where there are designs in place and orders have been placed with ship yards for two units.

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<tr>
<th>Project</th>
<th>Production MTPA</th>
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<tr>
<td>Shell Prelude</td>
<td>3.6</td>
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<td>Petronas Kanowit</td>
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What are Designs Based On?

• Currently the FPSO hull designs are based on experience gained in FPSOs and Offshore structures built over the last 30 years and marine LNG carrier experience over the last 40 years.
• Common sense says that with 30 years structural experience offshore and 40 years marine transport experience most aspects of risk must have been addressed?
• Sadly we do not believe that to be the full story.
So Where are the Risks?

- What we see as the major aspect of risk centres on the cryogenic nature of LNG, remember we are dealing with a liquid at -163°C. To deal with liquids at these temperatures we need to address two major points:-

1. LNG stored within the FPSO structure:-
   - The main concerns in this area are:-
     a) Steel structures must be isolated from these low temperatures as they will not withstand them.
     b) We need to be able to store liquids such that there is the minimum of heat ingress to reduce liquid boil off.
     c) Tanks need to be operable at any level of fill between empty and full

2. Transfer of LNG from FPSO to LNG Carrier
1. LNG Stored within the FPSO Structure

• If we look at points 1a) and 1b) how do we solve these problems in the marine industry now?

• We use what are called “containment systems”.

• So what are containment systems and how do they work?

• Simply put they are insulated tank systems within a ship that isolates LNG from ship structures.
Current Containment Systems

• There are three different types of containment systems currently in use:

  • Moss

  • Membrane - GTT MK III
    GTT No. 96
    CS 1

  • IHI SPB
The Moss System

- Is in essence, a spherical, aluminium tank supported within the vessel structure but isolated from it.
- The aluminium tank is insulated and then protected from the weather by a steel cover.
The Membrane Systems

• While there are three (3) different membrane systems in use, all designed and licensed by GTT, all 3 follow the same basic principle in that they provide two liquid tight layers, membranes, and two layers of insulation which line an LNG carriers hold spaces.
The Membrane No.96 System
IHI SPB System

- The IHI system is a self supporting (S), prismatic (P), Type B (B) tank.

- Essentially it is a separate, insulated aluminium tank within a ships hold supported on blocks top, bottom and side to prevent movement of the tank.
IHI SPB System
From this it is clear that in the marine sector we have successfully dealt with the issues in regard of liquid temperature and tank insulation.

What we haven’t dealt with entirely is the aspect of partial fill and how this translates sloshing issues into LNG FPSO use. Traditionally LNG carriers have been constructed for a specific trade and have been designed to operate either fully laden or empty.

An FPSO will spend the vast majority of its working life in the partial fill condition as it produces LNG then off-loads to an LNG Carrier and as such this becomes a critical area.
Each of the containment systems described above have different issues when it comes to partial fill.

- Moss System - will allow partial fill to any level BUT has problems re deck space to fit process and liquefaction equipment.

- Membrane
Partial Fill Issues - Membrane

- Membrane Systems - Operating requirements for membrane systems are generally that tanks are Operated with liquid levels below 10% of tank depth and above 80% of tank depth.
Partial Fill Issues

Not Permitted

Permitted
Partial Fill Issues — so how do we mitigate this
Partial Fill Issues

- IHI SPB - Will allow partial fill to any level and provides a relatively flat deck to allow fitting of process and liquefaction equipment BUT only two ships have ever been built with this system, a total of 8 tanks!

- Maximum tank built size has been around 25,000 cu.m.
2. Transfer of LNG from FPSO to LNG Carrier

• Currently there are two means of transferring LNG from LNG FPSO to LNG Carrier being discussed.

  a) Side by Side
  b) Tandem Systems
Side By Side Off Loading Systems

LNG production, storage and offtake barge
- Dumb barge
- Fixed heading
- Spread mooring
- Flowline reception porch

Side by side offtake
Cargo transfer system

Connecting Loading Arms
Side By Side Off Loading Systems

- **Advantages:**
  Well tried, well proven in land based operations.

- **Disadvantages:**
  Limited operating range limits use in some sea states.
  Not used offshore
Tandem Off - Loading Systems

D.P LNG offtake vessel positioning manifold under crane

Wind and/or current

A: Mooring footprint

Turret

B: Connecting arm footprint

D.P offtake vessel
Tandem Off - Loading Systems
Tandem Off Loading Systems

• Advantages:-
  Well tried, well proven in offshore oil and LPG operations.

• Disadvantages:-
  Not used in offshore LNG
Summary

• Floating LNG Projects are now going ahead and will be in service potentially as early as 2015

• Each LNG FPSO must be looked at in its totality and that detailed risk assessment studies must be undertaken for each project. These must include detailed review of wave and weather data in conjunction with assessments of proposed containment system and off load systems.
Thank You

Image Courtesy of Shell