Hazards within LNG Floating Facilities Topside Design

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The Floating LNG unit is a particular innovation of LNG FPSO combination whom global ship newbuilds attract sustainable technology and specific LNG supply chain. These latter unique characteristics force stakeholders to provide high quality of safety engineering design and providers of huge performance of reliable innovative process equipments.

Principles of Safety Onboard

Most of the time, safety management system of liquefied/flammable/petroleum products transport's shipping is based on risk analysis approach determined with prescriptive recommendations & regulations (SOLAS, IMO, OCIMF, FSS).

Most of the case, the safety philosophy and mitigation measures are efficient and sufficient enough to avoid escalation of hazards (as fire & explosion, leakage, toxic cloud, etc…) with well established technique used throughout industry for hazard identification and risk assessment. In the matter of fact, since FLNG is a new concept, additional considerations have been taken in order to optimize the arrangement of the FLNG facilities in an effective way to reduce the probability and the consequences of major accidental events, and limit the potential of escalation.

The FLNG facility is designed to remain on-site for the entire design service life of thirty (30) years recently without need for dry-docking and for sales production capacity of LNG comprising the following main key elements:

- Process Facilities Topsides
- Utility and Miscellaneous Facilities
- Storage and Offloading Facilities
- Hull
- Turret, Mooring and Swivel
- Risers, SURF
- Living Quarters and Building
- Helideck
- Marine System Facilities

New FLNG Hazard Analysis

Otherwise, floating offshore construction which processes hydrocarbons and refrigerates gas to produce LNG will be termed as an LNG FPSO (LNG floating production, storage and offloading unit) has created new hazards analysis such as the combination of prescriptive, probability, qualitative & quantitative reviews, alongside research & development of new generation of calculation softwares.

In the other hand, the Safety discipline appears as one of the most important key features in the design development. The concept of Floating Unit with topside Natural Gas Liquefaction process had never been implemented so far in the world as today. However several companies have developed numerous design concepts, that constitute background information which can be helpful in the development of this particular concept.

Therefore FLNG's safety design seems exceed all these previous considerations, because the Topside Safety Design of FLNG facilities becomes more complicated & challenged with risks of liquefaction process equipments & any modularized units: as fire & explosion and mitigate hazards (electrical, electrostatical, mechanical, chemical, overpressure, leakage, cryogenic spills) seem overwhelming for safety designers. The objective of the FLNG safety design phase ensures that the hazard, impact control systems identified, impact management process through the residual hazard are implemented into the design so that they will achieve their intent for the lifecycle of the FLNG Project.

Types of risk analysis

Using qualitative and quantitative safety risk assessments, we performed to demonstrate that risks are both tolerable and ALARP. Safety hazards and their effects on people, the environment, assets and reputation shall be systematically identified for the full lifecycle of assets and operations.
Hazards and Effects Management Process is undertaken to include the identification and further assessment of potential risk reduction measures for implementation during any stage of the FLNG Project in order to further drive down the Project risk to ALARP levels. Various relevant hazard identification (HAZID) or HAZAN (Hazard Analysis) methods will be used as applicable to identify hazards. In this addition workshop type sessions will be held to identify all significant hazards in key installation and operating regimes.

Developing a successful FLNG technical project involves concept updates, the latest in design, engineering and construction with safety and risk management study to reach a great challenge and solutions of managing safety of FLNG.

Typical main hazards of FLNG

The hazards analysis intends to identify the main hazards associated to any area of the FLNG Unit, from the turret assembly for feed gas import to the flexible cryogenic hose coupling for product offloading.

Definition

The main hazards on a detailed basis associated with the materials processed or handled within FLNG Unit and evaluating the possible consequences of accidental events which can result in damages to personnel, asset, environment or image of the Company.

Hazards related to LNG

Include flammability, embrittlement and rapid vaporization:

- Flammability hazards:

  Hazardous scenarios induced by LNG vapors flammability include a pool fire, an UVCE, or a jet fire.

- Rollover:

  Considered for LNG handling equipment and storage tanks.

- *E*mbrittlement hazards:

  In case on LNG release on material not protected against cryogenic temperature, those will suffer thermal stress which induce embrittlement of the surface and connection points in the vicinity of the release source.

- Rapid vaporization hazards:

  The physical expansion due to vaporization is such that one volume of LNG can generate 600 volumes of gas. In case of an important release rate over water, LNG can undergo rapid expansion phenomena, called RPT (Rapid Phase Transition) with hazardous overpressure.

Other Hazards

Include Liquefied Petroleum Gas (LPG):

- *LPG vapours flammability which properties will depend on the exact composition of the mixture but will be in the same range of value as the propane and butane properties (pool fire, UVCE). BLEVE risks are also to be considered for LPG handling equipment and storage tanks.*

Flammability hazards:

- *Flammable gas as methane, ethane, propane, butane.*

Hazards related to Condensates:

- *Hazardous scenarios induced by the flammability of the vapours include a pool fire and an UVCE.*

Hazards related to Ethanol:

- *Highly flammable fluid, in storage tanks, in case of leak if the released ethanol is ignited, the ethanol spill can induce a pool fire.*

Potential Accidental Events

- **Pool fires**

  A pool fire occurs when a flammable liquid spills onto the ground or onto water and finds an ignition point. Flammable liquids handled on the FLNG UNIT that potentially induce a pool fire are Hot Oil, Condensates, Ethanol, LNG and LPG.

- **Jet fires**

  Jet fires arising from the release of pressure liquefied gases giving rise to a jet of flashing fuel droplets are usually of low velocity.

- **Explosions**

An UVCE (Unconfined Vapour Cloud Explosion) is a gas explosion in free air with or without rain-out. In case of a mix of vapours from flammable liquid, this explosion leads to thermal effects and pressure effects. An UVCE often occurs according to the following steps:

- *atmospheric release of flammable gas;*
- *vaporization of the spilled pool;*
- *mix with air to produce flammable gas cloud;*
- *cloud ignition;*
- *propagation of a flame front through the flammable gas cloud. This flame front pushed by the expansion of waste gases, acts as a piston and can lead to a pressure wave.*

- **BLEVE**

  A BLEVE (Boiling Liquid Expanding Vapour Explosion) is the catastrophic failure of a vessel containing a superheated liquid. This type of explosion can occur when a pressure vessel contains a liquid at a temperature substantially above its boiling point at the atmospheric pressure. The conditions for a BLEVE to occur are:

  - *The liquid is superheated (generally because of a fire in the surroundings),*
  - *The pressure inside the tank suddenly decreases (generally because of a rupture in the tank wall),*
  - *The spontaneous nucleation phenomenon suddenly occurs.*

- **Cryogenic spill (Methane and Propane mainly)**

  Cryogenic spills are defined as release of LNG, refrigerants or other fluids with a low boiling point at atmospheric pressure, resulting in low temperatures. Cryogenic generally refer to liquids with a temperature below -150°C although there is no well-defined temperature where refrigerants end and cryogenics begin with some bodies referencing temperatures less than -71°C.

- **RPT**

  A Rapid Phase Transition (RPT) consists in the rapid evaporation of a liquid resulting from contact with another liquid that is at a temperature significantly above the boiling temperature of the evaporating liquid.

  Rapid Phase Transitions occur when the temperature difference between a hot liquid and a cold liquid is sufficient to drive the cold liquid rapidly to its superheat limit, resulting in spontaneous and explosive boiling of the cold liquid. In particular, when a cryogenic liquid such as LNG is suddenly heated by contacting a warm liquid such as water, explosive boiling of the LNG can occur, resulting in localized overpressure releases. In fact, the hazard potential of rapid phase transitions can be severe, but is highly localized within or in the immediate vicinity of the spill area

- **Roll-over**

  The LNG roll-over phenomenon occurs under certain conditions as stratified LNG comes to equilibrium.

  Stratification occurs when the product in the tank forms in layers with different densities and different temperatures. It occurs when liquid of a different composition than that which is already in the tank is introduced into the tank, or it can come from a process referred to as "autostratification".

Other External Hazards

- *Ship collision with LNG or LPG carriers or supply boat during import or export of hydrocarbons,*
- *Loss of containment from subsea line and/or loss of mooring system (failure of turret),*
- *Helicopter crash, Dropped object during load transfer from / to supply boat,*
- *Weather conditions,*
- *Human factors (piracy, material handling, shipping traffic,…).*

General arrangement of the FLNG Unit facilities

The FLNG is a Floating Unit with topside Natural Gas Liquefaction Plant. The FLNG units will have facilities to receive, pre-treat and liquefy the incoming gas, store and offload the valorised products (LNG, Liquid Refrigerated Propane, Liquid Refrigerated Butane and Condensates). The General Arrangement philosophy is based on the segregation of the three main components of the UNIT (namely LQ (Living Quarter), Turret and Topside Units including LNG/LPG Offloading System) and to have a logic sequence of Production as described hereafter:

- FLNG Unit being weathervaning around an internal Turret, LQ has been located forward of Turret and Processing Facilities aft of Turret : this will place LQ most of the time upwind from turret and topsides facilities and avoid as much as possible any gas migration or fire smoke dispersion towards the living areas;
- Turret is located aft the LQ (or downwind) to avoid routing gas inlet lines through LQ area, to ease maintenance and protection of the swivel stack, and to reduce motions at risers connections;
- Processing Facilities are installed on Topsides Modules above cargo area;
- LNG/LPG Offloading Systems are at aft of the ship;
- Flare stack and Knock-Out Drums are also located at aft end of the ship, to have tilting of the flame due to wind as much as possible away from Processing Facilities and LQ/Evacuation Facilities.

  The FLNG topside arrangement and processing facilities are designed to minimize accidents with Hazard analysis, and for example:

- The living quarter, accommodations, control rooms i.e. shall be located considering the prevailing wind and determines the flare location
- Due to the proximity of the turret, LQ aft wall will be provided as a Fire and Blast Wall.
- The layout will be arranged so that sources of flammable products are segregated from sources of ignition and from non hazardous areas.
- A safety gap between the axis of the internal turret and the fire and blast wall of the living quarter could be created.

Safety Design Review to evaluate & control hazards

The analysis provide an overview of the main hazards, their potential to escalate to adjacent equipment and structures and the prevention, control and mitigation measures deemed necessary to limit hazardous exposure of personnel or escalation potential to facilities. The review of accidental release scenarios will provide as an input to the selection of the cases to be CFD modelled.

The results of different analysis will provide as input to the design of:

- Process Hazards
- Unit Layout Principles
- Hazardous Area Classification
- HAZard Analysis
- Fire Zoning, Fire & Gas Detection
- Cryogenic Spill Protection, drainage
- Passive Fire Protection
- Active Fire Protection
- EER System
- Flare Study and Vent Mast Study
- Noise & Vibration

Risk Assessment Studies

In addition to safety in design, specifications, the following Risk Assessment studies will be performed at further engineering stage for the overall facilities:

- Quantitative Risk Assessment (QRA) including also risks linked to cryogenic spills
- Fire and Explosion Risk Analysis (FERA)
- Specific studies including risks analysis related to main structures, dropped object reports, offloading, ship collisions report, helicopter, etc.
- Cryogenic Risk Analysis, Cryogenic Spill Assessment Study
- Safety Critical Elements (identification and management).

The Quantitative Risk Assessment (QRA) comprises of a suite of safety studies where the overall objectives are to:

- Comply with the risk assessment requirements defined at the project.

- Demonstrate that the FLNG meets the project risk criteria, based on a benchmark of the risk against similar facilities;
- Communicate the results to all relevant parties and highlight key factors that influence/drives the risk level.

Software overview

Hazard analysis software tools which is applicable to all stages of design and operation across a wide range of process industries and in particular for FLNG studies are PHAST, CFD and advanced tool for the modelling of ventilation, gas dispersion, vapour cloud explosions and blast in complex process areas as FLACS.

Conclusion

The challenge for the future of FLNG's construction is to deliver an innovative design concept to minimize risk level as low as reasonably practicable and complies with project risk criteria and new technologies of LNG supply chain.

Although that FLNG's are novel, we should enable to eliminate the conservatism in risk determination and provide good approach of engineering practices with risk reduction and cost effective measures to be efficicient.