SAFETY OVERVIEW OF LNG TERMINAL OPERATION INCLUDING LNG CARRIER UNLOADING

Presented By

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SAFETY & ENVIRONMENT PROTECTION IN OIL & GAS INDUSTRY

A strong concern since the beginning as Oil&gas are considered as hazardous products. Nevertheless major accidents have occurred: Mexico (LPG), Lyon (France, Raffinery), Sea pollution after various Oil Tankers accidents, IOC Storage Terminal Fire (Jaipur)

International regulations: OMI, SIGTTO, etc...

National regulations: (like OISD in India)

Oil & Gas companies policies

Insurance requirements
Safety Overview for LNG Terminal Operation

SAFETY REQUIREMENTS IN LNG INDUSTRY

Since accident in Cleveland (USA) in 1942, LNG has been considered as Hazardous product, various regulations have been developed:

Transport by sea: IMO rules, SIGTTO recommendations, OCIMF rules, Classification, Insurances requirements.

Plants & Storage: NFPA 59 A (USA) 49 CFR part 193 (USA) EN 1473 (Europe) J G A Rules

National regulations, safety and regulatory bodies, Environment protection bodies & Associations.

Companies Policies, Engg. Standards
SAFETY REQUIREMENTS IN LNG INDUSTRY

Safety and environment protection are considered since preliminary design studies. Codes and regulations mainly provide:

- **Design criteria**: Seismic design, impounding systems, etc...

- **Minimum safety distances**: considering accident scenarios and consequences: vapour clouds, fire radiation, Cold explosion, etc...

- **Hazardous areas classification**: fire-proof equipment, Electric & instrumentation equipment classification

- **Design & construction rules**: Min. safety systems, Min. protection, Fabrication, construction and control stds.
SAFETY REQUIREMENTS IN LNG INDUSTRY

Physical properties

• Liquefied Natural gas:
  • Colourless liquid,
  • Mainly CH4 (>80%),
  • Cold: temperature $\approx -160^\circ\text{C}$,
  • Density at 1 bar $\approx 450 \text{ kg/m}^3$

• Vapour of LNG:
  • Odourless and colourless,
  • Density at 1 bar and $20^\circ\text{C} \approx 0.8 \text{ kg/m}^3$
  • Flamability limits LFL: 5%, UFL: 15%

• Vapourization of LNG
  • 1 m$^3$ LNG $\Leftrightarrow$ 600 m$^3$ of gas at $20^\circ\text{C}$

What is LNG?
Properties of LNG

- Properties of LNG that have safety implications include auto-ignition temperature, low temperature, heat of vaporization, flammability limits, heat transfer rate of boiling liquid and specific gravity.
- The average auto-ignition temperature for pure methane at atmospheric pressure is 537°C, which is quite high.
- The lower and upper flammability limit of methane in air is 5% & 15% by volume respectively.
- In a closed tank, the percentage of methane is 100%, thus it cannot ignite.
- Methane leaking from a tank in a well-ventilated area is likely to rapidly dissipate to less than 5%, thus it is relatively safer as compared to other fuels.
Properties of LNG

• The most of Hazardous properties of LNG are due to extreme low temperatures
• The only danger from skin contact with LNG is freezing; there are no poisonous or toxic effects.
• Tissue damage from extreme cold is similar to damage from extreme heat.
• Unlike heat burns, a cryogenic burn victim will not feel pain until the injured part has begun to thaw.
• If the skin has surface moisture on it, contact with cold objects will result in freezing of the skin to the objects. Flesh will be torn when the victim tries to remove the affected area from cold surface
PROPERTIES OF LNG – REACTION ON WATER

Unlike other liquid petroleum products, LNG reacts vigorously with water and vaporizes very fast (leaving nothing behind) posing minimum risk for the marine life.
LNG PROPERTIES

• LNG VAPOUR CLOUD DISPERSION

- Continuous release
- Instantaneous release

Cloud height vs. Wind direction
- Subsidence by gravity
- Passive dispersion

Cloud radius vs. Wind direction
LNG PROPERTIES

- HEAVY GAS CLOUD DISPERSION FC TANKS

Calculation tools:

- Integral Model: EVANUM
- 3D: MERCURE HEAVY GAS
LNG RECEIVING TERMINAL
DESIGN HELP - SPECIAL CODES & STANDARDS

A SAFE & SMOOTHLY OPERATING FACILITY CAN BE GENERALLY ENSURED, IF THE APPLICABLE CODES & STANDARDS ARE FOLLOWED IN TRUE SENSE. Some of the special codes followed for LNG terminals are

- National Fire Protection Association (NFPA-59 A)
- British Standard (BS 7777)
- European Committee for Standardization (EN 1473):
- OCIMF (Oil Companies International Marine Forum):
- SIGTTO (Society International Gas Tanker & Terminal Operators):
- OISD STDS 116, 118 & 194
Safety Overview for LNG Terminal Operation

ISO ACCREDITATION

Certified by DNV on 21st Jan-05

ISO 9001: 2001 QMS

ISO 14001: 1996 EMS

OSHAS 18001: 1999
DAHEJ MARINE FACILITIES
FACILITIES : JETTY

2.4 K.M Long; 536 Steel piles average depth 50 m; Water depth max 16 m from chart datum; Tidal variation 10.4 m; segregation of hydrocarbon & non-hydrocarbon pipelines
FACILITIES : SECTION OF JETTY DESIGN

11 expansion loops for the unloading lines 4 passing bays for Vehicle

Passing bays for safety of vehicular traffic & Exp loops for thermal expansion

Port Control Room with Latest equipment for safe operation
MARINE HAZARDS /RISKS

- Major Causes identified for Marine hazards are
  - Striking
  - Collision
  - Impact & Grounding
  - Fire
  - Cargo Transfer Failure
  - Foundering / Capsizing, Structural Failure
  - Domino Accident
MITIGATION OF MARINE RISKS

• Traffic Separation scheme in consultation with Port Management
• Ship maneuvering to be regulated – (other ships to be disallowed in the vicinity during berthing of LNG ships)
• Environmental limits for wind, waves & visibility as per SIGTTO guidelines
• Navigational aids such as Docking assistance unit.
• Ship/jetty to be fitted with gas / fire detection system
• Design of ship with a double hull, and double bottom.
• Water curtain system between Jetty and ship
JETTY AND MOORING AT DAHEJ
Fender/Flat Body

Fender contact area

Flat Body
Reaction Force of Fenders

Strength of Side shell

Interference between Fittings on the Side and a Fender

The characteristic curve

Reaction Force

Energy Absorption

Displacement of a Fender
Mooring Force Calculation

OCIMF recommendation

**Current Force + Wind Force**

Under the following condition:

- **Wind**: All directions, 60 knots
- **Current**:
  - 0 & 180 deg, 3 knots
  - 10 & 170 deg, 2 knots
  - 90 deg, 0.75 knots

Wind Force Concerned with a projection area above water

Current Force Concerned with Length*draught
Safety Overview for LNG Terminal Operation

**Gangway**

- **Position**
- **Elevation**
FACILITIES FOR SHIP BERTHING

• State of the Art ship mooring system including
  • Electrical Motor winches
  • Mooring Hook stress Measurement
  • Ship Docking assistance Unit Including:
    o Sensors (sea current sensor, Wave & tide sensor, Wind sensor )
    o Radars
    o Display Units
    o Portable Display Units
    o Tension Monitoring arrangement
MOORING TENSION & WEATHER CONDITION MONITORING SYSTEM
QUICK RELEASE MOORING HOOK & LOCAL DISPLAY PANEL
QUICK RELEASE MOORING HOOKS
Loading Arm/Manifold

Manifold

Loading Arm

Loading Arm Reach Envelope
FACILITIES : UNLOADING ARMS

Unloading Arms designed following OCIMF guidelines, which ensures compatibility with most of the ships & safe operation.

One of the significant feature is installation of PERC.
Un-loading Arm – During Testing
PERC REACTIVATION – DURING TESTING
Unloading Arms Cool down – Normal scheme for long jetties
Unloading Arms Cool down – Scheme based on site specific risk analysis
## TANK SAFETY

### Results of Consequence Modeling

<table>
<thead>
<tr>
<th></th>
<th>Containment Type</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Single</td>
<td>Double</td>
</tr>
<tr>
<td><strong>Heat flux due to LNG Fire</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At Luvara</td>
<td>Acceptable (0.9 Kw/m2)</td>
<td>Acceptable (nil)</td>
</tr>
<tr>
<td>At GCPTCL</td>
<td>Acceptable (1.2 Kw/m2)</td>
<td>Acceptable (0.1 Kw/m2)</td>
</tr>
<tr>
<td>5 Kw/m2 distance</td>
<td>700 m</td>
<td>300 m</td>
</tr>
<tr>
<td>3 Kw/m2 distance</td>
<td>1200 m</td>
<td>700 m</td>
</tr>
</tbody>
</table>

| **Hazardous Vapour Cloud Spread** | Unacceptable (2500 m to 5600 m) | Unacceptable (1100 m to 1200 m) | Acceptable (57 m) | LEL not to spread outside battery limit |

*** PLL has selected fully contained tanks to ensure **MAXIMUM SAFETY** ***
LNG STORAGES TANK-PLL

Full containment above ground LNG Tank

Boil Off rate: 0.08% capacity/day
FACILITIES : LNG TANKS

Two nos. – 160,000 m³ capacity
Type: Full Containment
Design codes: BS 7777, API 620, EN 1473, NFPA 59A
Dia: 81 m; Height – 55 m
LNG Regasification

For ORVs Sea water characteristics not acceptable

For SCVs high operating cost & high exhaust gas mission

Open Rack Vapourizer (ORV)

Submerged Combustion Vapourizer (SCV)
FACILITIES: AIR HEATERS & STVs

7 STVs / Air Heaters with 112 fans-16.4 MW each

Close loop system with no exhaust

Only ambient air heat

No external firing

Most environment friendly system
SAFETY ISSUES

PROJECT IMPLEMENTATION

Safety studies

HAZID
Hazard Identification

HAZAN
Hazard Analysis:
Potential Hazards & consequences

HAZOP
Hazard and operability analysis:
Systematic approach to identify hazards and operability problems

Project Technical reviews

SAFETY CONCEPT

QRA
Quantitative Risk Assessment
Numerical calculation of Risk level
IDENTIFICATION OF RISKS

• External Origin
  • Natural Risks (Earthquakes, flooding, wind, typhoons and lighting)
  • Non Natural Risks (from other industry, Marine traffic, Aircraft crash)

• Internal Origin
  • Release of LNG
    o Release from tanker, Spill from un-loading arms
    o Failure of transfer line, Inner / outer tank failure
    o Overfilling of storage tanks, Send out pump failure
  • Release of NG
    o Tank safety valves, Vapouriser safety valves, Flare stack
  • Process upsets like equipment failure, utility failure, roll over are not included as these are covered under ESD system
RISK / HAZARD CONTROL

- Measures to avoid the cause of release
- Measures to reduce the consequence of a release.
- LNG Spill Action Plan
  - Prevent spill
  - Detect spill, if it happens
  - Keep the spill volume minimum
  - Control the Vapours
  - Detect the fire quickly, if it happens
  - Control the fire immediately, if it is detected
  - Protect the other facilities
  - Extinguish the fire
MAJOR STUDIES CONDUCTED

- Rapid Risk Analysis for Tank Type Selection
- Marine Risk Analysis for design of marine facilities
- Integrated Quantitative Risk Analysis (QRA) for layout selection
- Modeling studies for berthing, mooring & navigation for finalization of design for the marine facilities
- HAZOP studies for design & operability of the terminal facilities.
- Shipping Logistic study for finalizing the tank age requirement
- Marine & Terrestrial Environment Impact Assessment studies for studying the impact on environment (as a part of statutory requirement)
- Land Survey, soil investigations & seismic analysis for design of civil foundations & structures
SAFETY MEASURES INCORPORATED IN THE DESIGN

- State-of-the-Art Technology.
- Automatic Safety Shutdown System Have Been included in the Plant Control System.
- System for early detection of leakage / spillage of LNG or regasified LNG.
- Plant Design and Equipment Layout as per International & Domestic Safety Standards.
- Dedicated team to ensure adherence to safety measures.
- Safety Audits & Mock Drills
- Regular Safety Trainings (Internal & External)
- Incident Reporting & Analysis
EQUIPMENT LAYOUT
REGASIFICATION TERMINAL EQUIPMENT LAYOUT

• EN 1473 & NFPA 59 A provides guideline
• Layout to ensure LNG piping is minimized
• Layout to ensure risk does not extend beyond the plot
• Main Control room to be in non-hazardous area.
• Hazardous area classification may be decided based on dispersion calculation from possible spills.
The required safety distance from leakage point for HP & LP source are 190m and 168m which could be accommodated within the Allocated plot.
The required safe distances from leakage point from HP & LP source are 141 & 105 m, which could not be accommodated within the allotted plot. PLL had to use water curtains to resolve this problem.
LNG Spill Prevention Methods

• Release From Un-loading Arms
  • Powered Emergency Release Coupling with two step ESD System
    o Step 1: - Close the NG / LNG valves
    o Step 2: - Disconnect the NG / LNG un-loading Arms
  • Failure of both the steps only can cause the LNG spill.

• LNG Transfer Lines
  • Pipes are protected against corrosion, overpressure, Vehicle crash, equipment fall by design features & mostly being welded pipes

• Inner Tank Failure
  • Design Features (e.g. metallurgy, welding procedures, earthquake factor, low temperature detectors, no nozzle on side or bottom of tank, provision of VRV etc.) make the failure chance almost rare.

• Outer Tank Failure
  • Pre-stressed concrete outer tank designed to with stand cold LNG & external aggression due to LNG leak, earthquake, projectile attack etc.
HANDLING OF LNG LEAKS & SPILLS

• Elaborate Leak detection system
  • Thermal Sensors
  • Gas Detectors

• procedures to protect personnel from contact with leaking liquid or cold vapor and minimize the chance for vapor contact with potential source of ignition

• Equipment such as barricades, Warning signs and combustible gas indicators are available at the plant

• Elaborate Emergency Shut Down (ESD) system & System isolation
  • ESD1: - Stop Ship Un-loading
  • ESD2: - Stop Send out system
  • ESD3: - Stop Complete facility
ACTIVE EMERGENCY / FIRE PROTECTION MEASURES

• Fire Water System: Ring Main, Hydrants, Tower Monitors, Remote / manual operated spray system, Water Curtain
• High Expansion Foam System
• Clean Agent (Inergen) system
• Potable Fire Extinguisher
• Mobile Fire Fighting triple purpose (Water/Foam/DCP) Tender
• Personal Protection Gears & Breathing Apparatus
• Oil Spill Handling Equipment
SAFETY - DOCUMENTATION

• A Comprehensive set of Documentation is in Place for Safe & Reliable Operation:
  • Disaster Management Plan
  • Oil Spill Contingency Plan
  • Port Administration
  • Port Operations
  • Health, Safety and Environment (HSE)
  • Maintenance of Tugs and Support Craft & Jetty
  • Training
  • Terminal Information & Regulations & Operation Books
Concluding Remarks

• Follow the Codes & Standards leads to safe design & operation

• Studies like HAZOP, QRA, SIL, Risk Analysis etc. during the design phase help in ensuring the safety during construction & operation.

• For Key to Success remember
  • Engineering is easy
  • Environmental issues, public safety & public perception are difficult
  • Carryout detailed modeling studies to establish compliance with environmental / regulatory requirements in project development process from the very beginning
REDUCING THE RISKS AT DAHEJ TERMINAL

DESIGN & CONSTRUCTION

Full containment Storage Tanks

Emergency Release Coupling

Cold and Gas Detection

Lay-out: safety distances

Some examples
LNG IS A MATURE INDUSTRY ENJOYING A VERY HIGH LEVEL SAFETY RECORD WORLDWIDE

THANK YOU FOR YOUR ATTENTION

160,000 m3 LNG tanks under construction
Petronet LNG Ltd  LNG Terminal DAHEJ -Gujarat
Constant Tension Winches
Berthing Aids
Data Monitoring – While Ship at Berth

Using standard interfaces, environmental data can be integrated with load monitoring and docking systems to display all essential mooring information on one screen. This creates a clear understanding of the interaction between wind, current and vessel mooring dynamics.
MOORING HOOK TENSION MONITORING