STANDARD FOR UNLOADING, STORAGE AND REGASIFICATION OF LIQUEFIED NATURAL GAS (LNG)

OISD – STD –194
First Edition, August, 2000
Draft

OIL INDUSTRY SAFETY DIRECTORATE
Government of India,
Ministry of Petroleum & Natural Gas,
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FOREWORD

Oil industry in India is more than 100 years old handling variety of hydrocarbon material, natural gas, crude oil and petroleum products. With the technological advances and need for transportation of bulk energy carrier and natural gas over the years a variety of practices have been in vogue because of collaboration/association with different foreign companies and governments. Standardisation in design, operation and maintenance practices was hardly in existence at a national level. This lack of uniformity, coupled with feedback from some serious accidents that occurred in the recent past in India and abroad, emphasised the need for the industry to review the existing state of art in designing, operating and maintaining oil and gas installations.

With this in view, the Ministry of Petroleum & Natural Gas in 1986 constituted a Safety Council assisted by the Oil Industry Safety Directorate (OISD) staffed from within the industry in formulating and implementing a series of self regulatory measures aimed at removing obsolescence, standardising and upgrading the existing standards to ensure safer operations. Accordingly, OISD constituted a number of functional committees comprising of experts nominated from the industry to draw up standards and guidelines on various subjects.

The present document on the storage and handling of Liquefied Natural Gas (LNG) Terminals was prepared by Functional Committee constituted amongst the nominated members by the industry. This document was prepared based on the accumulated knowledge and experience of industry members and the various national and international codes and practices.

This document will be reviewed periodically for improvements based on the additional experience and better understanding.

Suggestions from industry members may be addressed to:

The Coordinator, Committee on
‘Unloading, Storage and Regasification of Liquefied Natural Gas (LNG)’

OIL INDUSTRY SAFETY DIRECTORATE,
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FUNCTIONAL COMMITTEE
(Second Edition --- 2012)

ON

STORAGE AND HANDLING
OF
LIQUEFIED NATURAL GAS (LNG)

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1.0 INTRODUCTION

1.1 LNG trade is more than 30 years old, and the technology associated with LNG projects is considered proven and mature. This applies to all the components of LNG chain – Gas Liquefaction, transportation, receipt, storage and re-gasification facilities.

1.2 The LNG industry over the years has gained experience in design, construction and operation of LNG terminal facilities and has been improving standards for the operational integrity of LNG facilities.

1.3 Indian Petroleum industry over the years has also gained experience in design and operations of gas processing and petroleum handling and has been updating design and plant safety aspects.

1.4 In doing so, the Committee has utilised the experiences of operations of oil and gas installations in India, the available international standards on LNG and applicable standards developed by the Indian Industry over the years.

1.5 This standard provides for safety and design aspects of all the major components of LNG receiving terminal facility including unloading, storage and re-gasification of LNG. This standard also outlines the operating practices for protection of persons & property and provides guidelines to all the persons concerned with the operation of LNG receiving, storage, re-gasification and other associated facilities.

1.6 A number of international codes and standards exist to take care of design, operations and safety of LNG terminals including operating and design experience of gas processing and petroleum handling in Indian context. It is recognised that this standard dealing with design and operating practices for LNG handling may differ from those specified in the available standards.

1.7 In the interest of safety, it is important that persons engaged in handling LNG, understands the properties of this product and that they be thoroughly trained in safe practices for its handling.

2.0 SCOPE

2.1 This standard lays down minimum requirements of layout within the plant boundary for Unloading, Storage, Vaporisation, Transfer & Handling and road loading facilities of LNG Terminals.

2.2 This standard covers safety in design and operational aspects of process systems, above ground tanks, vaporisation facilities, ship shore interlock, berthing conditions for the ship, receiving facilities including jetty and port.

2.3 In-ground, cryogenic concrete and spherical LNG storage tanks are not covered in this standard.

2.4 Satellite stations for re-gasifying the LNG at the gas end user or as source for local pipeline network are not covered in the scope of this standard.

2.5 This standard also to some extent covers engineering considerations in design and installations including fire protection and safety systems.

2.6 Upstream gas gathering, treating system and natural gas liquefaction facilities and LNG re-export through ship tanker loading are not covered in the standard.

3.0 DEFINITIONS

BOG: Boil off gas – The gas generated by the process of vaporisation of LNG in the storage tank by the heat ingress through, the insulation, from the surrounding atmosphere and connected piping, barometric pressure changes and also due to Vapor displaced due to pump in & flashing of the incoming liquid to the tank.

Bunkering: The loading of a ship’s bunker or tank with liquid fuel for use in connection with propulsion of auxiliary equipment.
**Container :**
A vessel for storing liquefied natural gas. Such a vessel may be above, partially below, or totally below ground and may consist of an inner and outer tank.

**Container, Frozen Ground :**
A container in which the maximum liquid level is below the normal surrounding grade and that is constructed essentially of natural materials, such as earth and rock, is dependent upon the freezing of water-saturated earth materials, and that has appropriate methods for maintaining its tightness or is impervious by nature.

**Container, Pre-stressed Concrete :**
A concrete container is considered to be pre-stressed when the stresses created by the different loading or loading combinations do not exceed allowable stresses.

**Deriming :**
Deriming, synonymous with defrosting or de-icing refers to the removal, by heating/evaporation/sublimation/solution, of accumulated constituents that form solids, such as water, carbon dioxide, etc. from the low-temperature process equipment.

**Design Basis Earthquake(DBE) / Operating Basis Earthquake(OBE) :**
Maximum earthquake event for which no damage is sustained and the restart and safe operation can continue. This event should result in no loss to the operational integrity of the facility.

**Design Pressure :**
The pressure used in the design of equipment, a container, or a vessel for the purpose of determining the minimum permissible thickness or physical characteristics of its different parts. Where applicable, static head shall be included in the design pressure to determine the thickness of any specific part.

**Dyke :**
A structure used to establish an impounding area.

**ERC :**
Emergency Release Coupler – The coupler fitted in each hard arm together with quick – acting flanking valves so that a dry-break release can be achieved in emergency situations.

**ERS :**
Emergency Release System

**ESD :**
Emergency Shutdown System – A system that safely and effectively stops whole plant or individual units before an unrecoverable incidents occurs.

**Failsafe :**
Design features which will maintain or result in a safe operating conditions in the event of a malfunction or failure of power, instrument air, components or control devices.

**Fired Equipment :**
Any equipment in which the combustion of fuels takes place. Included among others are fired boilers, fired heaters, internal combustion engines, certain integral heated vaporisers, the primary heat source for remote heated vaporisers, gas-fired oil foggers, fired regeneration heaters and flared vent stacks.

**Fixed-Length Dip Tube :**
A pipe that has a fixed open end fitted inside a container at a designated elevation that is intended to show a liquid level.

**Hazardous Fluid :**
LNG or liquid or gas that is flammable or toxic.

**Hazardous Liquid :**
Means liquid that is flammable or toxic including LNG.

**Ignition Source :**
Any item or substance capable of an energy release of type and magnitude sufficient to ignite any flammable mixture of gases or vapours that could occur at the site.

**Impounding Area :**
An area that may be defined through the use of dykes or the topography at the site for the purpose of containing any accidental spill of LNG or flammable refrigerants.
Liquefied Natural Gas:
A fluid in the liquid state composed predominantly of methane (CH4) and which may contain minor quantities of ethane, propane, nitrogen, or other components normally found in natural gas.

LNG:
An abbreviation for "liquefied natural gas"

LNG Terminal Facility:
LNG terminal facility is a group of one or more units/facilities i.e. unloading, storage, receiving facilities LNG re-gasification & pipeline transfer and liquid dispatch through road tankers, associated systems like utilities, blow down, flare system, fire water storage and fire water network, control room and administration service buildings like workshop, fire station, laboratory, canteen etc.

Maximum Allowable Working Pressure:
The maximum gauge pressure permissible at the top of an equipment, a container or a pressure vessel while operating at design temperature.

(Maximum Considered Earthquake(MCE) /Safe Shutdown Earthquake (SSE) -
Maximum earthquake event for which the essential fail-safe functions and mechanisms are designed to be preserved. Permanent damage can be accepted, but without the loss of overall integrity and containment. The LNG tank would not remain in operation without a detailed examination and structural assessment.

Primary Components:
Primary components include those whose failure would permit leakage of the LNG being stored, those exposed to a temperature between (-51°C) and (-168°C) and those subject to thermal shock. Primary components include, but are not limited to the following parts of a single-wall tank or of the inner tank in a double-wall tank; shell plates, bottom plates, roof plates, knuckle plates, compression rings, shell stiffeners, manways, and nozzles including reinforcement, shell anchors, pipe tubing, forging, and bolting. These are the parts of LNG containers that are stressed to a significant level.

Process Plant:
The systems required to condition, liquify or vaporise natural gas in all areas of application.

Secondary Components:
Secondary components include those which will not be stressed to a significant level, those whose failure will not result in leakage of the LNG being stored or those exposed to the boil off gas and having a design metal temperature of (-51°C) or higher.

Shall:
Indicates a mandatory requirement.

Should:
Indicates a recommendation or that which is advised but not mandatory.

Storage Tank:
A container for storing a fluid.

Transfer Area:
That portion of an LNG plant containing piping systems where LNG, flammable liquids, or flammable refrigerants are introduced into or removed from the facility, such as ship unloading areas, or where piping connections are routinely connected or disconnected. Transfer areas do not include product sampling devices or permanent plant piping.

Transition Joint:
A connector fabricated of two or more metals used to effectively join piping sections or two different materials that are not amenable to usual welding or joining techniques.

Transfer System:
Includes transfer piping and cargo transfer system.

Vaporisation:
Means an addition of thermal energy for changing a liquid or semi-solid to vapour or gaseous state.

Vaporiser:
Means a heat transfer facility designed to introduce thermal energy in a controlled manner for changing a liquid or semisolid to vapour or gaseous state.
4.0 TERMINAL PROCESS SYSTEM

4.1 LIQUEFIED NATURAL GAS (LNG)

4.1.1 Natural gas is liquefied at a temperature in the range of at (-) 162°C to (-)168°C and atmospheric pressure to facilitate transportation in the form of LNG in cryogenic tankers across the sea. After vaporisation the same can be used to meet the gas demand. LNG is a colourless, odourless, low density and slightly viscous liquid. The main characteristic of LNG is that its specific volume is nearly 600 times less than that of natural gas in the gaseous state. Owing to this characteristics, greater quantities can be stored / transferred in liquid state than in gaseous phase.

4.1.2 Upon release from containment to the atmosphere, LNG will vaporise and release gas which, at ambient temperature, will have about 600 times the volume of liquid vaporised. Generally at temperature below approximately (-112 °C), this gas is heavier than ambient air at (15.6 ° C). However as its temperature rises, it becomes lighter than the air.

Note: The critical temperature for methane is (-) 112° C. The predominant component of LNG is methane and hence this value is referred.

Typical LNG Composition Range (mole %)

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<tr>
<td>C&lt;sub&gt;1&lt;/sub&gt;</td>
<td>0.3 to 12.0</td>
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<tr>
<td>C&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.2 to 3.6</td>
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<tr>
<td>C&lt;sub&gt;3&lt;/sub&gt;</td>
<td>0.1 to 1</td>
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<tr>
<td>C&lt;sub&gt;4&lt;/sub&gt;</td>
<td>0 to 0.1</td>
</tr>
<tr>
<td>N&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.03 to 1.40</td>
</tr>
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Typical values of Molecular weight and calorific value of LNG

| Molecular Weight | 16 to 20 |
| Gross Calorific value | 8800 kcal/ scm to 10800 kcal/ scm |

4.1.3 Liquefied natural gas chain consists of

- Production of natural gas from fields and transportation to liquefaction plant.
- Natural Gas Liquefaction Plant and ship loading facility.
- Ships for carrying LNG between the liquefaction plant & receiving terminal.
- LNG receiving and storage terminal in the consumer’s area.
- Regasification & dispatch into Pipeline systems including distribution network.
- LNG road loading facility.

4.2 LNG RECEIVING TERMINAL:

The purpose of LNG receiving terminal is to unload LNG ship tankers, store, re-gasify and send it out through the pipeline transmission network. LNG terminals can also have the facility to re-load the LNG. The LNG receiving terminal facilities are divided into three sections namely receiving, storage and send out sections. (Refer typical flow scheme at the Annexure – I)

- RECEIVING SECTION
- STORAGE SECTION
- SEND OUT SECTION

In addition to the above, the terminal consists of various utilities, flare system, fire fighting facilities and other associated infrastructures.
4.3 RECEIVING SECTION

Conceptual studies should be undertaken to evaluate geotechnical, navigation manoeuvring and mooring operations to determine the risks and provide for safeguards while finalizing the siting of the LNG jetty facility.

The LNG ship tankers are moored and berthed along the jetty specially designed for LNG handling. LNG is pumped out of the ship tanks to the land based storage with the help of unloading arms connected to the ship, through an insulated cryogenic pipeline.

4.3.1 THE JETTY

The jetty consists of berthing facility, unloading arms and other associated facilities.

4.3.2 BERTHS

i) The number and size of the berths are determined by the quantity of LNG delivered, the size of the ships, time intervals between two ships & site conditions. The berths may be installed either parallel or perpendicular to the bank at the end of the jetty. A docking aid and piloting system helps aid the pilot and vessel master to monitor speed and distance accurately so as to manoeuvre safely alongside the jetty terminal.

ii) The berth normally includes breasting and mooring dolphins and unloading platform having unloading arms and other facilities such as drain vessels, fire and gas detection and fire fighting systems etc. Land access to the moored ships shall be provided.

iii) Breakwater, if required, based on the model studies and downtime analysis shall also be provided.

iv) Exclusion of ignition Sources: No uncontrolled ignition source should be within a predetermined safe area, centred on the LNG carrier’s cargo manifold. The minimum area from which all ignition sources must be excluded should be determined from the design considerations and dispersion studies envisaged in the risk analysis report.

v) Mooring layout: The jetty should provide mooring points of a strength and in an array which would permit all LNG carriers using the terminal to be held alongside in all conditions of wind and currents. Facility for mooring line load monitoring is recommended to ensure that loads are balance and vessel safely secured.

vi) Quick Release Hooks: All mooring points should be equipped with quick release hooks. Multiple hook assemblies should be provided at those points where multiple mooring lines are deployed so that not more than one mooring line is attached to a single hook. A remote release system helps to release each hook from a safe location.

vii) The design of approach trestle, shall cover the following:-

   a) Deflection for the piles
   b) Placement of different pipes (e.g. fire water piping to be separate)
   c) Gap between approach road and process piping

4.3.2.1 UNLOADING ARMS

i) Unloading arm consist of pipe length connected to each other by swivel joints, moved by hydraulic actuators. The connection of the arm end to the ship crossovers flange shall be provided with a special automatic ERC device.

ii) During emergency this automatic device will come into operation and de-coupling system gets activated.

iii) Emergency Release System (ERS): Each unloading arm shall be fitted with an ERS system, able to be interlinked to the ship’s ESD system. This system shall operate in two stages; the first stage stops LNG pumping and closes block valves in the pipelines; the second stage
entails automatic activation of the dry-break coupling at the ERC together with its quick-acting flanking valves. The ERS System should conform to an accepted industry standard. The volume between flanking valves should be as low as possible. Site specific drift study shall be taken into consideration for finalizing timings for each stage.

iv) No drain shall be open to atmosphere. Provision should be given to collect the LNG from the unloading arm and associated piping to a closed system by way of providing adequately sized blow down vessel or any other suitable arrangement. Facility to send the liquid from the blow down vessel to unloading line shall be provided.

v) The size of the arms depends on the unloading flow rate. Usual sizes are 10” and 12” for LNG tankers up to 75,000 m³ capacity and 16” to 20” for larger vessels of 120,000 m³ to 263,000 m³ (Qmax) capacity.

4.3.2.2 GENERAL:

i) General cargo, other than ships’ stores for the LNG tanker, shall not be handled within 30 m of the point of transfer connection while LNG is being transferred through piping systems. Ship bunkering shall not be permitted during LNG unloading operations.

ii) Vehicle traffic shall be prohibited on the berth within 30 m of the loading and unloading manifold while transfer operations are in progress. Warning signs or barricades shall be used to indicate that transfer operations are in progress.

iii) Prior to transfer, the officer in charge of vessel cargo transfer and the officer in charge of the shore terminal shall inspect their respective facilities to ensure that transfer equipment is in the proper operating condition. Following this inspection, they shall meet and determine the transfer procedure, verify that adequate ship-to-shore communications exists, and review emergency procedures.

iv) Interlocking between ship and terminal control room to be established and the control of unloading operations shall be monitored from the terminal control room.

v) Terminal Security: An effective security regime should be in place to enforce the designated ignition exclusion zone and prevent unauthorised entry of personnel into the terminal and jetty area, whether by land or by sea.

vi) Operating Limits: Operating criteria, expressed in terms of wind speed, wave height and current should be established for each jetty. Such limits should be developed according to ship size, mooring restraint and loading arm operating envelope. Separate sets of limits should be established for (a) berthing, (b) stopping cargo transfer, (c) loading arm disconnection and (d) departure from the berth.

vii) The ships should be berthed in such a way that in case of emergency the ship can sail out head-on immediately. All other instructions and procedures of Port Regulatory Authority are to be observed.

4.3.2.3 UNLOADING LINE

i) The unloading and transfer lines for LNG should have minimum number of flange joints. Consideration should be given to provide cold sensors for flanges of size 200 mm and above as well as where there are clusters of flanges.

ii) Length of the unloading line is to be kept to a minimum. In case it is not feasible, alternative options available are:

- To have additional line running parallel
- To have booster pump
- Increase size of line

iii) The unloading line need to be kept in cold condition to avoid stress and cyclic fatigue due to frequent warm-up and cooling down operation. This is done by one of the following methods.

- Continuous circulation of LNG (LNG goes through the unloading line and sent back to the vaporisation section through a special small diameter line).

- Alternatively two unloading lines are installed. When unloading is not taking place, this loop is used for re-circulation for keeping the lines in chill down condition.
- Line is fully filled with LNG and the boil-off formed is sent to the tank or to the vaporiser section.

- The unloading shall not be commenced till the healthiness of ERS and ESD is ensured. The Hot and Cold ESD testing should be carried out prior to unloading every time.

4.4 STORAGE SECTION

The storage section consists of LNG storage tanks, in-tank pumps, BOG system and BOG re-liquefaction facility.

4.4.1 Storage Tank:

The primary function of storage is to receive, hold and stock LNG for providing continuous supply to the send out section. An LNG tank is designed to ensure the following functions:

4.4.1.1 LIQUID RETENTION

The storage tank shall be capable of withstanding the hydrostatic load of the liquid and low temperature of LNG. In order to meet these conditions, cryogenic materials such as low carbon austenitic stainless steels, aluminium magnesium alloy, 9% Nickel ferritic steel, Invar (36% Ni steel) and pre-stressed concrete (as outer tank) can be used.

4.4.1.2 GAS TIGHTNESS

Tanks should be tight enough to prevent any evaporation losses and also to avoid ingress of air and moisture.

For concrete outer tanks, a seal coating is generally provided, to prevent natural porosity of the concrete.

4.4.1.3 THERMAL INSULATION

Thermal insulation shall be provided to:

- Limit boil-off rates (usually between 0.06% and 0.1 % of total volume per day).
- Avoid condensation and cold spots on the outer shell.

4.4.1.4 THERMAL STRESSES

Under normal operating conditions, the tank is subjected to variation in the temperatures. Also during start up, tank temperature is required to be brought down from ambient to cryogenic temperatures. Sometimes the tank may require de-riming for various reasons like repair of internals, modifications etc. Hence, the tanks shall be capable of withstanding the temperature variation.

4.5 PIPING

4.5.1 All Nozzles for the Piping requirements for an LNG tank shall be from the top. Side penetration is to be avoided to minimise risk of serious leakage. The piping requirements are:

- Fill lines
- Withdrawal line (Intank pump column)
- Boil-off line to remove LNG vapour.
- Cool down line for initial cooling of tanks during commissioning of the tank.
- Nitrogen purge lines to purge the inner tank and annular space.
- Nitrogen purging line for pump column and foot valve sealing.
- Instrument nozzles.
- Pressure make-up line.
• Pump re-circulation line.
• Purge release vent line.
• Pressure relief valve line
• Vacuum relief line

4.5.2 LNG lines are normally fully filled lines. However, during specific operating conditions could result in differential temperatures at the top and bottom of the pipe causing bowing of pipes and potential spills. Piping design should include stress analysis, expansion loops and supports as well as proper piping and equipment cool down procedures should address differential contraction covering all anticipated operation and upset conditions. Use of bellows expansion joints should be avoided in LNG lines.

4.5.3 Physical phenomenon such as surge pressure in LNG receipt and transfer lines, flashing and two phase flow shall be addressed in the piping and equipment design. ESD valves shall be fail-safe and fire safe.

4.5.4 Piping loads and thermal expansion / contraction of piping transferred to the Tank nozzle connections should be within the maximum allowable loads, as recommended in the applicable design code/Manufacturer. Bellows expansion joints should be avoided.

4.5.5 Valves shall be designed and manufactured for Cryogenic service. Extended bonnet valves are used in cryogenic service with stems in the vertical position.

4.5.6 LNG heats up and expands, if confined to a fixed volume. Hence any potentially blocked piping or equipment should be provided with thermal expansion relief valves with discharge to closed system.

4.5.7 Inlet piping shall be designed to minimize stratification/ layering of LNG [Stratification occurs when heavier LNG has been added at the bottom of a tank with partially filled lighter LNG or lighter LNG added at the top of the heavier LNG or due to ageing (storing for long duration ) of LNG. This leads to sudden and rapid release of vapour, called Roll-over].

This can be prevented by having two fill lines one ending at the top of the tank and other extending to the bottom, to inject denser LNG at the top and lighter LNG at the bottom. Mixing nozzles may also be used to avoid stratification.

Rollover conditions shall be prevented by active management of stored LNG which includes monitoring temperatures and densities, mixing the tank contents by appropriate top and bottom filling or by circulation.

4.5.8 Vaporiser piping involves high flow rates, pressures as well as transition from cryogenic piping materials to carbon steel material. This could result in embrittlement failure if cold gas or liquid were to come in contact with carbon steel, in case of failure of process interlocks.

Other features of the LNG tanks are covered under Section – 6.0

4.6 BOIL OFF GAS & RELIQUEFACTION

4.6.1 Boil of Gas (BOG) primarily comprises of the gas produced by the process of vaporisation of LNG in the storage tank by the heat ingress through the insulation, from the surrounding atmosphere, connected piping, pumping energy, displaced vapour due incoming liquid, on account of run down liquid flashing due to pressure changes and due to barometric pressure changes. BOG system consists of boil – off gas recovery from the tanks (compressor and re-condenser) and to divert it into the LNG send out system or inject it into the pipeline transmission network. BOG is also used for vapour return to the ship tanks during unloading thereby avoiding pressure drop in the ship tanks. If vapour return to the ship tanks is not considered, the BOG system should be designed to handle this additional quantity also. BOG system includes provision to route BOG to flare also.

4.6.2 During roll-over condition, the instantaneous boil of gas generation is substantially high and necessary provision shall be provided to protect the tank from overpressure as well as to take care of the safe discharge.
4.6.3 BOG Recovery/Utilisation Options:

i) Re-liquefaction & Recycle to Storage: Liquefaction process used in the LNG production plant may be used for re-liquefaction. Re-liquefaction process is less favourable compared to other facilities due to higher energy consumption.

ii) Pressurisation & Mixing with gas discharged from the Terminal: The boil-off gas is compressed to the network pressure and mixed with the re-gasified product. But while mixing, low calorific value of the boil-off gas may reduce the heating value of the network gas.

iii) Re-condensation & Incorporation into the re-gasified LNG: The re-condensation is carried out using LNG cold released during vaporisation. Pressurisation of boil-off gas in the liquid phase instead of gaseous phase leads to energy savings, safer operation.

iv) As a fuel gas in power generation process or internal use.

v) The receiving terminal shall be provided with flare system to enhance the plant safety. The flaring of BOG should be done only as a final solution when the normal BOG handling system is not available.

4.7 LNG PUMPING

4.7.1 IN-TANK PUMPS

The tanks are provided with in-tank submerged pumps, which are also known as primary pumps. These are provided in storage tanks nozzles only at the top. Pumps as well as the electric motor are submerged in LNG. Lubrication and the cooling of the pump are done by LNG itself. These pumps are installed in wells, equipped with foot valves, which can be isolated to enable pump removal for maintenance. Arrangement for foot valve seal purge, well purge, well draining and venting should be provided. The pumps are supplied by electrical power through nitrogen purged glands at the top of the tank. The tank should have necessary facility to lift / handle the in tank pump at the tank top (Jib crane, Hoist etc)

4.7.2 If the network pressure is not too high, in tank pumps alone may be sufficient to bring up to the network pressure through vaporisers. If the pipeline network pressure is high, two stage pumping may be needed which also helps in BOG re-liquefaction at intermediate pressure instead of compressing BOG vapours to the line pressure.

4.7.3 The discharge pressure of the in tank pump is usually guided by the re-condenser pressure wherever provided. The design pressure of the pump would also consider the chill down requirements of the ship unloading line.

4.8 SEND OUT SECTION

In send out section, LNG is pumped and brought to a pressure slightly higher than the network pressure through secondary pumps and vaporised & warmed to a temperature above 0°C and metered before it is sent for distribution.

4.8.1 Secondary Pumps:

These Pumps are used for pumping the LNG from the intermediate pressure to the network pressure through vaporisers. These are generally either horizontal or vertical, multistage turbine / submersible pumps.

4.8.2 VAPORISATION

4.8.2.1 Vaporisation is accomplished by the transfer of heat to LNG from water / ambient air / process stream. In the vaporisation process, LNG is heated to its bubble point, vaporised and then warmed up to the required temperature.
4.8.2.2 LNG vaporisers are to be designed based on the quantity of heat to be exchanged with LNG for its vaporisation, maximum LNG flow rate, amount of heat available in the heating medium, lowest temperature of the heating medium.

4.8.2.3 Vaporiser tubes are generally fitted with fins for better heat transfer. Owing to the light weight, good conductivity, corrosion resistant strength of aluminium alloy, fin tubes are generally made of aluminium alloy.

4.8.2.4 Regasified LNG outlet temperature should be monitored and controlled carefully in order to avoid any LNG or cold vapour passing into the network.

4.8.2.5 In case of vaporisers, where water is used as a medium, water outlet temperature should be maintained higher than water freezing point.

4.8.2.6 Major types of vaporisers are:

i) **HEATED VAPORISER**  
These vaporisers derive heat from the combustion of fuel, electric power, or waste heat.  
   a) **INTEGRAL HEATED VAPORISER**  
   They are classified as those heated vaporisers in which the heat source is integral to the actual vaporising exchanger. Submerged combustion vaporisers come under this classification.  
   b) **REMOTE HEATED VAPORISERS**  
   In these type of vaporisers, the primary heat source is separated from the actual vaporising exchanger and an intermediate fluid (e.g. water, steam, iso-pentane, glycol, etc.) is used as the heat transport medium.

ii) **AMBIENT VAPORISERS**  
These are classified as those vaporisers, which derive heat from naturally occurring sources such as atmosphere, seawater or geothermal water.

iii) **PROCESS VAPORISERS**  
These vaporisers derive heat from another thermodynamic or chemical process or in such a fashion as to conserve or utilise the refrigeration from the LNG.

4.8.2.7 The three types of vaporisers which are predominantly used in LNG Terminals are:

a) **OPEN RACK VAPORISER**  
It is a heat exchanger that uses water as the source of heat. They are generally constructed out of finned aluminium alloy tubes. Corrosion protection is provided for surfaces that come in contact with water that is sprayed on the outside of the finned tubes.  

The minimum water flow for ORV should be ensured as per design during running of the ORV. The well designed safeguarding system shall be provided to protect downstream carbon steel piping from cold break thru.

b) **Intermediate Fluid Vaporizers (IFV)**  
Intermediate fluid vaporizer uses an Intermediate Heat Transfer Fluid (IHTF) in a closed loop to transfer heat from a heat source to the LNG for vaporization. Heat transfer for LNG Vaporization occurs in a shell and tube exchanger. Typically Intermediate HTFs can be Glycol-water, Methanol-water, etc.

Intermediate Heat Transfer Fluid flows through the intermediate fluid vaporizers (shell and tube exchanger) where it rejects heat to vaporize LNG. Cooled IHTF is circulated using pumps. Surge drum
placed upstream of the circulating pumps is used to account for system volume contraction and expansion.

There are several options to warm the IHTF solution for recycling back into the shell and tube vaporizer, for example, a waste heat recovery system, air heater etc. These intermediate fluid vaporizers have a very compact design due to high heat transfer coefficients thus reducing space requirements.

c) SUBMERGED COMBUSTION VAPORISER

In this type, LNG flows through a tube coil fabricated from stainless steel that is submerged in a water bath. Water contained in the bath is heated by direct contact with hot effluent gases from submerged gas burner.

Submerged combustion vaporiser shall not be located in an enclosed structure / building to avoid accumulation of hazardous products of combustion.

4.8.2.8 SAFETY FEATURES OF VAPORISERS AND CONNECTED PIPING.

a) Vaporisers shall be designed for working pressure at least equal to the maximum discharge pressure of the LNG pump or pressurised container system supplying them, whichever is greater.

b) Manifold vaporisers shall have both inlet and discharge block valves at each vaporiser.

c) The outlet valve of each vaporiser, piping components and relief valves installed upstream of each vaporiser outlet valve shall be suitable for operation at LNG temperature.

d) Suitable automatic equipment shall be provided to prevent the discharge of either LNG or vaporised gas into a distribution system at a temperature below the minimum design temperature of the send out system. Such automatic equipment shall be independent of all other flow control systems and shall incorporate shut down valves used only for contingency purposes.

e) Isolation of an idle manifold vaporiser to prevent leakage of LNG into that vaporiser shall be accomplished with two inlet valves with safe bleed arrangement in between.

f) Each heated vaporiser shall be provided with safety interlock to shut off the heat source from a location at least 15 m distant from the vaporiser. The device shall also be operable at its installed location.

g) A fire safe shutoff valve to be installed on the LNG line inlet to a heated vaporiser to be at least 15 m away from the vaporiser. This shutoff valve shall be operable either at installed location or from a remote location and the valve shall be protected from becoming inoperable due to external icing conditions.

h) If a flammable intermediate fluid is used with a remote heated vaporiser, shutoff valves shall be provided on both the hot and cold lines of the intermediate fluid system. The controls for these valves shall be located at least 15 m from the vaporiser.

i) The vaporisers shall be fitted with local as well as control room indications for pressure and temperature of both fluid streams at inlet and outlet.

j) Instrumentation for storage, pumping and vaporisation facilities shall be designed for failsafe condition in case of power or instrument air failure.

4.8.2.9 RELIEF DEVICES ON VAPORIZERS

a) Each vaporiser shall be provided with safety relief valves sized in accordance with the following as applicable:
i) The relief valve capacity of heated or process vaporisers shall be such that the relief valves will discharge 110 percent of rated vaporiser natural gas flow capacity without allowing the pressure to rise more than 10 percent above the vaporiser maximum allowable working pressure.

ii) The relief valve capacity of ambient vaporisers shall be such that the relief valves will discharge at least 150 percent of rated vaporiser natural gas flow capacity without allowing the pressure to rise more than 10 percent above the vaporiser maximum allowable working pressure.

b) Relief valves on heated vaporisers shall be so located that they are not subjected to temperature exceeding 60 °C during normal operation unless designed to withstand higher temperature.

c) The discharges from the relief valves should be routed to the Flare. If not connected to flare, vapours may safely be disposed to atmosphere, provided that this can be accomplished without creating problems like, formation of flammable mixture at ground level or on elevated structure where personnel are likely to be present. The height of release to be based on the dispersion analysis and risk analysis so that the integrity of the facility is maintained.

4.9 LNG COLD RECOVERY

4.9.1 LNG cold recovery system may be optional in an LNG Terminal. It aims at recovering the part of the potential cold energy available in LNG so as to use it effectively in cold utilising plants.

4.9.2 LNG cold utilisation process is divided into:

i) Cold is used directly to cool down another element, by simple heat transfer. Some of the schemes under this class are:
- Re-liquefaction / re-condensation of BOG
- Cooling of industrial fluids
- Air Liquefaction plants
- Food Freezing
- Power plant cooling
- Cold warehouse
- HVAC of plant buildings

ii) Only a portion of the cold is utilised in the receiving terminal for boil – off gas re-liquefaction / re-condensation. Remaining cold may be utilised in the nearby industries for heat exchange with industrial fluids or for power generation unit.

iii) In case of LNG cold recovery facility at the terminal, all the safety features provided on the LNG vaporisers shall be applicable.

4.10 LNG TRUCK LOADING FACILITY

4.10.1 BRIEF DESCRIPTION

The purpose of LNG road loading system is to transfer LNG from the storage tanks to tank truck to deliver LNG to other sites via road transportation. The LNG road loading shall be manually operated system, where all activities shall be done in presence of trained personnel. LNG for loading into the tank trucks shall be tapped off from the LNG In-tank Pump discharge. LNG vapour return from the tanker shall be routed to the BOG suction header. When no loading will be in progress the recirculation will be maintained in the LNG filling line, through a recirculation line for maintaining chilled condition. The loading facility to be provided with the LNG liquid loading arm and vapour return arm. For monitoring of uniform chilling of the LNG feed line during no-loading situation, suitable number of skin temperature indications with alarm shall be provided in the control room.
The LNG road tanker shall be double walled vacuum insulated cryogenic vessels suitable for transport at cryogenic conditions. The tank truck for road movement shall be designed, constructed and tested in accordance with the Static and Mobile Pressure Vessels (Unfired) Rules, 1981 as amended from time to time.

Typical Truck Loading facility consists of the following:
- LNG filling line, Vapor return line & a recirculation line with adequate instrumentation
- Liquid/Vapour Loading arm, Batch Flow meter & Control Valve
- Weigh Bridge/ Flow meter for Custody transfer
- Sick Tanker unloading facility

4.10.2 DESIGN CONSIDERATIONS OF LNG LOADING/ UNLOADING FACILITIES

a) Loading Facility
Each loading station shall consist of the following:
- Excess flow protection device or suitable mechanism meeting similar functional requirements & non return valve shall be provided in LNG loading lines.
- A vapour return line with an isolation valve connected back to the storage vessel/ BOG line with NRV.
- The proper tanker earthing connection shall be provided.
- Properly designed loading arm shall be provided at the end of filling and vapour return lines for connecting to the tank truck. The loading arm end connection type shall be CGA LNG 300. The loading arms shall be provided with breakaway couplings. These arms shall be of approved type and tested as per OEM recommendations.
- Weigh bridges of suitable capacity for tanker weighment shall be provided.

b) Sick Tanker Unloading Facility
The sick tanker unloading facility shall be provided. The tanker unloading shall be done by vapors using pressure differential method of liquid transfer by any of the following methods:
- Utilising vapours from BOG compressors discharge.
- Utilizing the gas from the pressurized gas (send out) network with proper pressure control.
- Utilizing tanker pressure building coil.
- Dedicated unloading compressors/pumps.
A suitable protection shall be considered for tanker / system over-pressurization and due considerations of impact of high temperature.

c) Others
All drains, vents and safety valve discharges shall be routed to the closed system/flare system. In case of non-availability of flare system, the discharge from safety valve shall be vented to atmosphere at a safe location minimum at an elevation of 3 meter above the nearest working platform for effective dispersion of hydrocarbons. The dedicated drain and vent connections to be provided for the loading and vapour arms. Operational requirement is that after every loading operation, before disconnection, the liquid holdup in the LNG liquid and vapor arms are required to be drained, depressurized and purged. The provision of Drain Pipe can be considered. The liquids collected in the Drain Pipe would gradually vaporize. Nitrogen connection can be provided to facilitate the vaporization process.
4.10.3 SAFETY SYSTEM AND SAFETY PRECAUTIONS

a) Safety System

The gantry shall have gas and spill detector at potential spillage and gas emission locations. There shall be flame detectors which shall cover the entire gantry and detect any fire. In addition, there shall be manual call points at appropriate locations.

The fire and gas detection shall be considered as follows:

- Fire detectors
- Gas detectors
- Low temperature (spill) detector

The signals generated from the detectors shall be integrated with the ESD system.

The shutdown valves to be provided for all the process incoming and outgoing lines to/from loading gantry and shall be located at least 15 meters away from the loading gantry at an easily accessible location.

The Emergency Shutdown (ESD) philosophy shall be designed to initiate appropriate shutdown action on detection of any emergency situation or through detector signal.

Emergency push button or hand switch shall be provided in Control room and also in field at safe location for manual actuation of ESD system and fire water spray system by operator in case of emergency. The field related button/switch to be provided on either end of the gantry at easily accessible locations.

ESD shall be caused in case of either of the following:

- Signals from two detectors of different types of gas or spill or flame
- Initiation of manual call points
- Hand switches provided in the field as well as in the Operator Console & Control Room.

In addition, the following logic shall also be performed to stop individual tanker filling operation:

- Gas detection will stop filling operation.
- Earth relay contact indicating inadequate earthing of the truck will stop filling operation.

For the loading arm excessive moment limit switches are provided which cause the ESD in the gantry.

In addition to above, fire water spray with deluge system shall also provided in the gantry which is activated either automatically (either Flame/Fire detector or Quartzoid bulb assembly) or manually by manual switches.

b) Safety Precautions

Following precaution should be taken due to associated hazards during transfer of LNG to or from a tank truck.

1. No source of ignition must be allowed in the area where product transfer operations are carried out.
2. Fire extinguishers shall be placed near the tank trucks during transfer operations.
3. The first operation after positioning the truck should be to provide proper earthing connection of the tanker. Earthing shall be disconnected just before the release of the truck.
4. While disconnecting arm, connections shall be loosened only slightly at first to allow release of trapped pressure, if any.

5. Always use personal protective equipment while making or breaking the connections to avoid cold burns.

6. The master switch shall be put off immediately after parking the truck in position. No electrical switch on the truck shall be turned “on” or “off” during the transfer operation.

7. No repairs shall be made on the truck while it is in the loading area.

8. Availability of wheel chokes.

9. Filling/transfer operations should be stopped immediately in the event of -
   (i) Uncontrolled leakage occurring
   (ii) A fire occurring in the vicinity
   (iii) Lightning and thunder storm

**4.10.4 PROCEDURES FOR LOADING OPERATION**

(a) PREFILLING ACTIVITIES

1. Verification of the truck is necessary as per standard procedure before it is allowed to enter its premises and check for following in a tanker:
   - Provision of two safety valves, level gauge, Excess flow protection and control valve on liquid and vapour lines, pressure gauge, on the vessel / bullet.
   - Fire screen between cabin and vessel is provided. For this purpose, cabins with metallic back cover with suitable view glass will be considered as fire screen.
   - Provision of 2 nos. of 10 Kgs. DCP Fire Extinguishers.
   - Fitment of Spark arrestors of approved quality.
   - No leakage in exhaust silencer pipe exists.
   - Manufacturer's name plate with date of testing with next due date of testing is fitted on the vessel.
   - Valid Explosive Licence and RTO registration certificate is available.
   - Blind flanges/caps are provided on vessel.
   - Availability of earthing cable.
   - Bonding between vessel and chassis and between flanges is satisfactory.
   - Earthing / bonding point is available.
   - Third party inspection/test certificates for vessel/fittings are available.
   - Liquid / vapour line valves are in good condition.

2. Move truck to the loading bay/weigh bridge and record the weight of the empty tank truck.

3. When the truck enters the loading bay, following shall be checked by the Truck Filling Operator:
   i) Check for residual positive pressure and LNG (Heel) in the truck tank. If the heel is present then the tank is considered ready for filling. Then proceed iv).

   ii) If the heel is not present, then the vapour space shall be checked for moisture content and oxygen with portable analysers. The moisture content should be such that the dew point shall be less than -20 deg C and oxygen less than 1000 ppm.
iii) If the any of the parameters mentioned at point no i) and ii) above, are not complied, then the truck needs to be purged with Nitrogen.

iv) Once the oxygen and moisture are within limit, the operator shall prepare a 'Filling Advice' as per procedure. The purpose of the Filling Advice is to advise the operator about the amount of LNG to be loaded, empty weight of the truck, destination, vehicle identification number, driver's particulars and other relevant details.

v) After issuing the filling advice, the truck shall be grounded.

vi) The filling arm is connected to the tanker-truck and the vapour return arm is connected to the vapour return line.

It shall be ensured that the valve downstream of flow control valve is closed. The Nitrogen line shall be slowly opened and oxygen and the moisture content shall be checked at the vents. The procedure for venting and purging shall be individually developed meeting all the safety requirements.

b) FILLING OPERATION

Before starting the filling operation, following shall be checked by the Truck Filling operator:
- The truck is in right location on the ramp.
- The wheels are choked, ignition is off and the key is with the Truck Loading Operator.
- Truck is grounded.
- The filling and vapour return arm is under positive nitrogen pressure.
- All arms and the valves are as per operating condition.
- None of the thermal relief valves are relieving and do not show any sign of tampering
- All instrumentation is in the normal condition and there is no alarm present.
- Truck cabinet door is open and secured and all components are in working order.
- Start the filling operation as per the standard operating procedure to be individually developed for each filling.
- Filling the tanker can be simultaneously monitored and confirmed by level instrument on the tanker and batch flow controller.
- Recirculation should be started after the filling is complete.

c) POSTFILLING OPERATION

- The line between arms and the nearest ball valve in the filling line shall be drained into the drain header for both filling and vapour return line. Once all the liquid is drained, both the arms should be allowed to warm up first near about ambient.
- The liquid arm shall be purged with nitrogen and vented out through the vent valve.
- Once all the vapour is purged out, then the filling arm should be disconnected from the tanker and stowed at its original position.
- Start the draining and filling operation as per the standard operating procedure to be individually developed.
• Chokes should be removed from the truck and the keys handed over to the driver.
• The driver signs and takes a copy of the ticket and drives away.

4.10.5 BLACK START
The black start will be applicable when the truck loading system is starting up first time or after a long shutdown. The important precaution for the black start is to maintain the slow rate of cooling to bring down the temperature of the pipe from ambient to -160 °C.

The line from the tanks to the truck loading gantry shall be flushed and purged with nitrogen prior to the black start. The black start procedure shall be individually developed meeting the entire safety requirement.

4.10.6 DRAIN AND VENTS
Drain and vents shall be provided to meet all the requirement of draining, purging, venting etc. Appropriate system shall be provided to handle the discharge from the TSV's also.

5.0 TERMINAL LAYOUT

5.1 PHILOSOPHY
Terminal lay out philosophy must consider location of the facilities at a site of suitable size, topography and configuration with a view to designing the same to minimise the hazards to persons and property due to leaks and spills of LNG and other hazardous fluids at site. Before selecting a site, all site related characteristics which could affect the integrity and security of the facility shall be determined. A site must provide ease of access so that personnel, equipment, materials from offsite locations can reach the site for fire fighting or controlling spill associated hazards or for the evacuation of the personnel.

OISD–STD-118 covers the layout consideration for the oil and gas installations. The above standard is also generally applicable for consideration of layout of LNG Terminal. However specific points related to LNG Standards are brought out here.

5.2 BASIC INFORMATION

5.2.1 Information on following items should be collected before proceeding with the development of overall plot plan.

- Terminal capacity
- Process units and capacities
- Process flow diagram indicating flow sequence
- Utility requirements
- Unloading system along with tanker berthing system with capacity
- LNG storage tanks, sizes and type of storage tanks
- Other storage tanks
- LNG transfer and vaporisation
- No. of flares
- Provision for spill containment and leak control
- Inter distances between the equipment
- Operating and maintenance philosophy for grouping of utilities
- Plant and non-plant buildings
- Environmental considerations
- Scrap yards and dumping ground
- Fire station
- Chemical storage
- Ware house and open storage areas.

5.2.2 Information related to each item should include, but not limited to, following:

- Extreme temperatures and pressures for normal operations as well as emergency conditions.
Concrete structures subject to cryogenic temperatures
- Fail safe design
- Structural requirement
- Requirement of dike and vapour barrier.
- Shut off valves and relief devices.

5.2.3 Data on following infrastructure facilities should be identified and collected before detailed layout activity is taken up. Due consideration should be given for the same while deciding/finalising terminal layout.

- Site location map
- Seismic characteristics and investigation report.
- Soil characteristics
- Prevailing wind speed and direction over a period
- Meteorological data including corrosive characteristics of the air and frequency of lightening
- Area topography contour map
- High flood level in the area and worst flood occurrence.
- Source of water supply and likely entry / exit point
- Electric supply source and direction of entry point
- LNG entry point/ Gas exit point
- Minimum inter distances between facilities as well as between facilities & boundaries
- Storm water disposal point and effluent disposal point
- Approach roads to main Terminal areas
- Surrounding risks
- Air routes and the proximity of the Airports.

5.3 BLOCKS

5.3.1 In addition to points indicated in OISD-STD-118, as applicable, containment of potential spills of LNG or other hazardous liquid, especially in case of LNG storage and jetty area should also be considered.

5.3.2 LAY OUT OF BLOCKS / FACILITIES

The LNG may consist of the following basic blocks / facilities.

- The Jetty for berthing of ship and unloading of LNG.
- Unloading line from Jetty to shore terminal.
- LNG Storage
- Re-gasification consisting of pumping and vaporisation.
- Utility Block
- Fire Station
- Flare system
- Control Room
- Administrative Block
- Workshop
- Warehouse
- Electrical Substation.
- Laboratory
- Road Loading

5.4 ROADS

OISD-STD-118 is to be followed as applicable. In addition land access to the moored ships shall be provided. If necessary, a separate road may lead to the berths in order to provide the crew with a free access to the ship.

5.5 LOCATION

OISD-STD-118 shall be followed as applicable. In addition the receiving terminal should be as close as possible to the unloading jetty.
5.6 ERECTION & MAINTENANCE

OISD-STD-118 shall be followed as applicable.

5.7 FUTURE EXPANSION

Future expansion requirement shall be assessed and provision of space for the same should be made.

5.8 GENERAL CONSIDERATIONS

Following points should be considered:

OISD-STD-118 shall be followed as applicable with following additional requirement for LNG.

The Lay out shall consider Two specific zones i.e. Gas Zone and Non-Gas Zone and identify the applicable blocks within each zone. Minimum inter-distances between blocks / facilities shall be maintained as per Table-1 of OISD-STD-118 or as per the risk analysis studies whichever is higher. Inter distances between specific equipment as mentioned below are to be maintained.

5.9 SPACING REQUIREMENTS OF LNG TANKS AND PROCESS EQUIPMENT

5.9.1 LNG TANK SPACING

LNG tanks with capacity more than 265 M³ should be located at minimum distance of 0.7 times the container diameter from the property line but not less than 30 meters. Minimum distance between adjacent LNG tanks should be 1/4 of sum of diameters of each tank. The distance between tanks should be further reviewed in accordance with Hazard assessment, but in no case it shall be less than the criteria mentioned above.

This standard does not consider inter distances between LNG Storage tank below 265 M³ capacities. However any LNG storage / process equipment of capacity more than 0.5M³ shall not be located in buildings.

5.9.2 VAPORIZER SPACING

Vaporisers and their primary heat sources unless the intermediate heat transfer fluid is non-flammable shall be located at least 15 m from any other source of ignition. In multiple vaporiser installations, an adjacent vaporiser or primary heat source is not considered to be a source of ignition. Integral heated vaporisers shall be located at least 30 m from a property line that may be built upon and at least 15 m from any impounded LNG, flammable liquid, flammable refrigerant or flammable gas storage containers or tanks. Remote heated, ambient and process vaporisers shall be located at least 30 m from a property line that can be built upon. Remote heated and ambient vaporisers may be located within impounding area. The inter distances in multiple heated vaporisers a clearance of at least 2 m shall be maintained. The types of heaters are as mentioned in Section 4.5.2.

5.9.3 PROCESS EQUIPMENT SPACING

i) For Process equipment spacing Table 2 of OISD-STD-118 as applicable shall be followed.

ii) Fired equipment and other sources of ignition shall be located at least 15 m from any impounding area or container drainage system.

5.9.4 CONTROL ROOM AND SUBSTATION:

i) Control Room shall be constructed as per OISD-STD-163.

ii) The minimum distance of 60 m shall be maintained between LNG Storage Tank and Substation.
5.9.5 UNLOADING FACILITY SPACING

i) A pier or dock used for pipeline transfer of LNG shall be located so that any marine vessel being loaded or unloaded is at least 30 m from any bridge crossing a navigable waterway. The loading or unloading manifolds shall be at least 60m from such a bridge.

ii) LNG and flammable refrigerant loading and unloading connections shall be at least 15 m from uncontrolled sources of ignition, process areas, storage containers, control room and important plant structures. This does not apply to structures or equipment directly associated with the transfer operation.

5.9.6 LNG ROAD TANKER LOADING /UNLOADING FACILITIES

The layout of the LNG facilities including the arrangement and location of plant roads, walkways, doors and operating equipment shall be designed to permit personnel and equipment to reach any area affected by fire rapidly and effectively. The layout shall permit access from at least two directions.

LNG tank lorry loading gantry shall be covered and located in a separate block and shall not be grouped with other facilities.

Adequate space for turning of tank Lorries shall be provided which is commensurate with the capacities of the tank trucks. However, the space for turning of tank Lorries with minimum radius of 20 M to be provided.

Maximum number of LNG tank lorry bays shall be restricted to 8 in one group. Separation distance between the two groups shall not be less than 30 M.

The layout of the loading location shall be such that tank truck being unloaded shall be in drive out position.

The weigh bridge of adequate capacity shall be provided and proper manoeuvrability for vehicles.

The consideration to be given for the dedicated parking area for LNG tank trucks with controlled access of other vehicles. The parking area shall be located in a secured area and provided with adequate no. of hydrants / monitors to cover the entire parking area. The suitable arrangement for safe venting of vapor generated during waiting period in the parking area, preferably to a closed system should be considered.

Escape routes shall be specified and marked in LNG sheds for evacuation of employees in emergency. Properly laid out roads around various facilities shall be provided within the installation area for smooth access of fire tenders etc. in case of emergency.

5.9.7 ELECTRICAL CLASSIFICATION

Classification of areas for Electrical Installations in LNG Terminal shall be as per OISD-STD-113 as applicable.

5.9.8 BUILDINGS AND STRUCTURES

Buildings or structural enclosures in which LNG, flammable refrigerant and gases are handled shall be of lightweight, non-combustible construction with non-load-bearing walls.

6.0 LNG STORAGE TANK

The Liquefied Natural gas is stored at about -158°C to –168°C. LNG tanks are required to be designed to ensure proper liquid retention, gas tightness, thermal insulation and environment safety.

6.1 CLASSIFICATION OF STORAGE SYSTEM

6.1.1 GENERAL

The most common type of refrigerated storage tanks were of “Single Containment Tank” meaning it is having a single retaining compartment, surrounded by a low bund wall. The failure of a single containment tank would result in an immediate release of liquid as well as vapour to the surrounding environment and the resulting possible major hazard. To decrease the probability of failure of a single containment tank more stringent requirements for material selection, design, construction, inspection and testing were considered.
6.1.2 Even though the probability of failure reduces to a very low level with the above requirements, the consequences of a failure may be considered so serious that a secondary protection system is required to eliminate the risk of large inventory release around the tank in case of leakage or failure of the primary/inner container/tank. This can be achieved by double containment or full containment tanks. Membrane type tanks are also considered to reduce the risk; however, external/internal damage scenarios should be carefully examined for membrane type tanks as part of risk analysis as internal membrane is not designed for independent mechanical/structural integrity.

Four types of LNG Storage Tanks are considered here.

- Single Containment
- Double Containment
- Full Containment
- Membrane

The selection of storage tanks shall be decided based on the location, adjacent installations, habitation on the surrounding, operational, environmental, safety and reliability considerations.

6.1.3 SINGLE CONTAINMENT TANK

The single containment storage for liquefied natural gas is usually dome roof, flat bottomed tanks. In the past the most common type of storage system consisted of a tank with a single liquid retaining container – referred as “Single Containment tank” – surrounded by a bund wall / dyke. (Ref. Figure – 1). The outer wall (if any) of a single containment storage system is primarily for the retention and protection of insulation and is not designed to contain liquid in the event of product leakage from the inner container.

A single containment tank shall be surrounded by a bund wall / dyke to contain any leakage.

6.1.4 DOUBLE CONTAINMENT TANK

A double containment LNG storage tank is designed and constructed so that both inner and outer wall shall be independently capable of containing the LNG stored. The LNG is normally stored within the inner tank but the outer tank shall be able to contain the LNG product leakage from the inner tank. The outer tank is not designed to contain product vapour in the event of liquid leakage from the inner tank. (Ref. Figure – 2). The outer tank if it is made of metal it shall be of cryogenic grade. If outer tank is made of pre-stressed concrete the same shall be suitable for withstanding temperature and hydrostatic head. To minimise the pool of escaping liquid in case of failure of inner tank the outer tank should not be located at a distance exceeding 6 Mtrs from the inner tank.

6.1.5 FULL CONTAINMENT TANK

A full containment storage tank is one meeting all the requirements of a double containment storage plus the additional requirement of that it shall avoid the uncontrolled release of product vapour in the event of liquid leakage from the inner tank. (Ref. Figure – 3).

6.1.6 A pre-stressed concrete outer tank with / without an earth embankment can be used as the secondary liquid container for a double, full containment and membrane tank. The construction of a full height retaining wall of concrete has the added advantage of protection against blast overpressure and impact of projectiles. (Ref. Figure – 4). If the outer tank is made of metal it shall be of cryogenic grade. If outer tank is made of pre-stressed concrete the same shall be suitable for withstanding temperature and hydrostatic head.

6.1.7 MEMBRANE TANK:

Membrane tank technology has predominantly been used in LNG carriers (ships) and for in-ground LNG tanks. Membrane tanks have also been used for above ground LNG storage in some cases.
The in-ground membrane tanks have been in use for LNG storage and are also considered as acceptable option. However, the design of the in-ground membrane tanks to be as per the available international standards and the same are not covered in this standard.

Though membrane tank technology is propriety in nature, design of membrane shall be governed by applicable standards. This standard covers only above ground Membrane tanks.

i) The main characteristic of this type of tank is the separation of the tightness and mechanical strength functions. Tightness is ensured by a membrane not subjected to any stress. Stresses are taken up by the concrete wall through the load bearing insulation provided between membrane and concrete wall.

ii) The primary container, constituted by a membrane together with thermal insulation and a concrete tank jointly forming an integrated, composite structure. This composite structure shall provide the liquid containment. The concrete tank shall have special provisions so that in case of a major leak through the membrane & insulation system, it is capable of containing the liquid LNG & vapor both, till controlled venting of vapor.

iii) The vapour of the primary container is contained by a steel roof liner which forms with the membrane an integral gas tight containment.

iv) The insulation space between the membrane and the concrete tank is isolated from the vapour space of the tank. A nitrogen breather system operates on the space to control the pressure of the nitrogen within normal operating limits and to monitor the gas concentration in order to check continuously the integrity of the primary container. In case of a methane leak, the nitrogen sweeping mode is activated to maintain the resulting gas concentration within normal operating limits.

6.2 SELECTION CRITERIA

6.2.1 Safety and reliability are the most important aspects for LNG storage tanks holding large inventory of flammable gas. Majority of technical improvements on LNG storage tanks to date have therefore been directed towards improvements in both safety and reliability.

6.2.2 The following list summarises a number of loading conditions and considerations that have influence on the selection of the type of storage tank.

i) The factors which are not subjected to control:
   • Earthquake
   • Wind
   • Cyclone, floods, tsunami
   • Snow, Climate
   • Objects flying from outside the plant.

ii) The factors that are subjected to limited control
   • In plant flying objects
   • Maintenance Hazards
   • Pressure waves from internal plant explosions
   • Fire in bund or at adjacent tank or plant.
   • Overfill, Overpressure (process), block discharge
   • Roll over
   • Major metal failure e.g. brittle failure
   • Minor metal failure e.g. leakage
   • Metal fatigue, Corrosion
   • Failure of pipe work attached to bottom, shell or roof
   • Foundation collapse.

iii) The factors that are subjected to full control
   • Proximity of other plant
   • Proximity of control rooms, offices and other buildings within plant
   • Proximity of habitation outside plant
   • National or local authority requirements
   • Requirements of the applied design codes.
6.2.3 The main criteria for selection of the type of tank shall be decided based on the risk analysis study and the level of risk it is posing on the surrounding.

6.2.4 There is no limit on the height of the tank envisaged other than engineering considerations.

6.2.5 No capacity restriction for LNG tank is envisaged considering the technological developments in this area.

6.3 BASIC DESIGN CONSIDERATIONS

This section describes the basic design considerations for single, double, or full containment and membrane tanks.

6.3.1 Pressure:

Maximum allowable working pressure should include a suitable margin above the operating pressure and maximum allowable vacuum.

6.3.2 Material of construction:

The parts of LNG container which will be in contact with LNG or cold vapour shall be physically and chemically compatible with LNG. Any of the materials authorised for service at (-) 168°C by the ASME Boiler and Pressure Vessel Code shall be permitted. Normally, for single containment tank, improved 9% Ni steel / Austenitic stainless steel / Aluminium Magnesium alloy are used. For double, or full containment tanks, 9% Ni steel with impact testing is used. In case of membrane tanks, normally austenitic stainless steel is used as material of construction for membranes.

6.3.3 Liquid loading:

i) The maximum filling volume of LNG container must take into consideration the expansion of the liquid due to reduction in pressure to avoid overfilling.

ii) For double containment and full containment, the primary container shall be designed for a liquid load at the minimum design temperature specified. The design level shall be the maximum liquid level specified or the level 0.5 m below the top of the shell, whichever is lower.

iii) The outer tank for Double containment, Full containment and membrane tanks shall be designed to contain the maximum liquid content of the primary container at the minimum design temperature specified. Outer concrete tank shall have 9% nickel steel secondary bottom and 9% nickel steel insulated ‘Thermal Corner Protection’ (TCP). These are linked together. The top of the TCP is anchored into pre-stressed concrete wall, approximately 5 meters above the base slab.

6.3.4 Insulation:

i) The refrigerated storage tanks for LNG shall be adequately insulated in order to minimise the boil off gas generation due to heat leak from ambient. The extent of insulation depends on boil-off considerations for which the storage tank is designed. Normally boil-off rate of 0.06 to 0.1 % of hold up liquid volume per day is considered. Proper insulation shall be ensured in tank base, tank shell, tank roof, suspended deck etc.

ii) The possibility of an adjacent tank fire must be taken into consideration when designing insulation for LNG storage tanks. Tank spacing, water deluge systems, quantity and hazard index of LNG contents must be considered when specifying insulating materials.

6.3.5 Soil protection:

i) The soil under the LNG storage tank shall not be allowed to become cold. If the soil becomes too cold, frost penetrates into the ground, ice lenses form in the soil (mainly in clay types of soil) and the growth of these ice lenses result s in high expansion forces which lift and damage the tank or parts of the tank. To prevent such occurrence heating system needs to operate in the foundation. An automatic on/off switch system activates the electrical heating system and
ensure that the tank foundation at its coldest location within acceptable temperature range i.e.
+5°C to +10°C.

ii) As an alternative to electrical bottom heating system free ventilated tank bottom by elevated
structure is also used. Also slope shall be ensured for the paved portion below the tank from
centre to periphery to avoid accumulation of liquid. Gas detector shall be provided for detection
of any leakage and accumulation below the tank.

iii) Electrical heating system shall consist of a number of independent parallel circuits so designed
that electrical failure of any one circuit does not affect power supply to the remaining circuits.
Electrical heating shall be so designed that in the case of electrical failure of a main power
supply cable or a power transformer, sufficient time is available to repair before damage occurs
due to excessive cooling. Alternatively, provision for connecting a standby heating power
source should be made.

6.3.6 Leak Detection in annular space:

i) Leak detection facility shall be provided in the annular space between primary container and
secondary container. Liquid may be present in the annular space due to spillage from inner
tank or leak of the inner tank. If liquid is detected in the annular space it should be removed
carefully. For tanks with a perlite filled annular space, liquid can be removed by evaporation.
Temperature sensors may be used for leak detection. A system alarm may be provided if there
is a malfunction in the monitoring system.

ii) Provision for Nitrogen purging of the annular space should be considered. This will also be
useful in leak detection by monitoring hydrocarbons levels in the Nitrogen purge.

6.3.7 Pressure and Vacuum relief system

The following guidelines for the design of pressure and vacuum relief system of cryogenic LNG tanks
shall be provided:

1) Pressure relief valve shall be entirely separate from the vacuum relief valve. Pressure relief
valve shall relieve from inner tank. In order to take care of mal-function of any of the relief
valves due to blockage in the sensor line, one extra relief valve (n+1) shall be installed. Further
sensor lines for each relief valve can form a common ring and with individual tapping from the
sensor ring for each of the pilots. Pilot operated pressure relief valves are preferred over pallet
operated relief valves.

2) Vacuum relief valves (n+1 philosophy) shall relieve into the space between the outer roof and
suspended roof. Pilot operated vacuum relief valves are not acceptable for vacuum protection
as the valve action is not fail safe against main valve diaphragm or bellows rupture. Conventional pallet type vacuum relief valves shall only be used.

3) Relief valves to atmosphere should be adequately sized to relieve the worst case emergency
flows, assuming that all outlets from the tank are closed, including the outlet to flares and also
boil off gas. Vapours may safely be disposed to atmosphere, provided that this can be
accomplished without creating problems like, formation of flammable mixture at ground level or
on elevated structure where personnel are likely to be present.

4) Provision shall be made to inject nitrogen or dry chemical powder at the mouth of pressure
safety relief valve discharge.

5) Vacuum relief should be based on: withdrawal of liquid at the maximum rate, withdrawal of
vapour at the maximum compressor suction rate, variation in atmospheric pressure etc.

6) A flare shall be provided for cryogenic storage tank(s). The flare stack should be continuously
purged in order to avoid air ingress and shall be provided with pilot burner.

7) Provision shall be made to maintain the internal pressure of LNG container within the limits set
by the design specification by releasing to flare via a pressure control valve installed in the
BOG line from tank to compressor. Factors that shall be considered in sizing of flare system
shall include the following:
Operational upsets, such as failure of control device / BOG compressor tripping etc.

- Loss of refrigeration
- Vapour displacement and flash vaporisation during filling
- Drop in barometric pressure
- Depressurisation load from Emergency depressurisation vents from vaporisers/RLNG headers.

8) Safety relief system shall suitably be designed to take care of pressure rise in annular space due to leakage from inner tank and subsequent vaporisation of the liquid. One of the following two options shall be considered to allow safe venting and relief:
   a) Independent safety hatch/rupture disc on outer tank.
   b) Safety relief valves connected to inner tank including the suspended deck vents and perlite retaining barrier to be adequately sized and specified.

9) For the pressurised systems, the safety relief valve vent shall be so positioned to release the hydrocarbon at safe height.

10) Relief from tank PSV shall not form a cloud on the tank and the PSV discharge shall be routed to safe height in accordance with dispersion study and risk analysis.

6.3.8 Tank Roll Over

Under certain conditions "roll over" of the liquid in the LNG tank can occur resulting in the rapid evolution of a large quantity of vapour with the potential to over pressurise the tank. Stratification can occur in an LNG tank if the density of the liquid cargo charged to the tank is significantly different from the left over LNG in the tank. Inlet piping must be designed to avoid stratification of LNG. This can be done by having top and bottom fill lines to inject denser / lighter LNG at the top / bottom. Mixing of in tank LNG by providing re-circulation facility may be considered. Mixing may also be done by providing distribution holes along the fill line extending to the bottom. Temperature sensors are put to monitor the temperature of the liquid throughout the liquid height at regular intervals. Provision for density measurement on tank shall be provided for the entire height of the tank.

The boil off due to a roll-over shall be calculated appropriately. Alternately, the flow rate during roll-over shall be conservatively taken as 100 times of the boil off rate.

For taking care of over pressurisation due to roll over, one of the following options shall be provided:
   a) Sizing of inner tank pressure relief valves releasing to flare in case the flare system is designed for such loads.
   b) Sizing of inner tank pressure relief valves releasing to atmosphere.
   c) Rupture disc or equivalent device to be provided on the tank with isolation valve (lock open condition) releasing to atmosphere.

- Means to check rupture disc integrity should be provided. Fragments of the rupture disc should not fall into the tank.
- Failure of the rupture disc shall trip all the boil off gas compressors automatically.
- Following failure, the rupture disc replacement should be possible during operation.

6.3.9 Over-Fill of Inner Tank

a) Two independent type level measuring instruments shall be provided. The level instrument shall be equipped to provide remote reading and high level alarm signals in the control room. In addition, an independent transmitter for high level alarm and high - high level alarm with cut off shall be provided. The high - high level should be hard wired directly to close the liquid inlet valves to the tank.

b) The tank shall not be provided with overflow arrangement.
6.3.10 DYKE

a) Dyke shall be provided for the following

- Single containment tank
- Double containment with metallic outer tank
- Full containment with metallic outer tank
- Membrane tank

b) The containment volume of the dyke shall be equivalent to 110% capacity of the largest tank within the dyke and on the requirement that the trajectory of a leak at the upper liquid level does not overshoot the edge of the dyke.

c) No restriction of the dyke height is envisaged.

d) High volume foam generators shall be provided for the dykes.

6.3.11 OTHER SAFETY CONSIDERATIONS

i) Where refrigerated storage tanks are located near process plants with a likelihood of exploding process equipment, the impact of a flying object on the tank, one 4" valve travelling at 160 km/h (object of 50 kg weight with a speed of 45 m/sec) shall be considered.

ii) For the tank located within the flight path of an airport, the impact of a small aircraft or component shall be taken care of.

iii) Impact of explosion wave due to major leak from a nearby natural gas pipeline or a major spill of LNG may also be considered.

iv) Failure of inner tank: Where a sudden failure of inner tank is considered, the outer tank shall be designed to withstand the consequent impact loading.

v) Earthquakes: The risk level is determined on the basis of the seismic classification of the location. The data pertaining to the seismic activity level having been ascertained, the structure is to be designed based on IS-1893 and other relevant codes.

vi) Rainfall runoff from the tank roof should be directed to a curbing and collecting system around the outer edge of the roof. Collected rainwater should be carried by a drainage piping system that directs the rainwater away from any LNG spill carrying surfaces and to graded drainage areas that are beyond (outside) the ring road.

6.3.12 Nozzles (also refer 4.5.1)

There shall be no penetrations of the primary and secondary container base or shell walls for LNG tanks to ensure fluid tightness.

In addition to the nozzles used for regular operations like liquid inlet, pump outlet, vapour outlet and instrument connections the following provision shall also be provided.

i) Nitrogen connections for:
   - Inertisation of inner tank
   - Outer tank and insulating material.

ii) Chill down connections for the inner tank.

iii) Depressurisation and purging of the in-tank pump column.

6.4 Instrumentation and process control for tanks:

The instrumentation shall be suitable for the temperature at which LNG is stored. All instrumentation shall be designed for replacement or repair under tank operating conditions in a hazardous gas zone area. Instrumentation for storage facilities shall be designed in such a way that the system attains fail-safe condition in case of power or instrument air failure.
The Level instrumentation for ESD function shall be separate and independent of the device for monitoring.

6.4.1 Level: LNG containers shall be equipped with two independent types of liquid level gauging devices to monitor tank levels.

Each system shall have High and High High Level alarms.
Local Level indication should be available at grade apart from remote indication in the control room.
Refer Para 6.4.6. Density variation shall be considered in the selection of gauging devices.

6.4.2 Pressure: The storage tank shall be provided with pressure transmitters to continuously monitor and control pressure with an indication in the control room. Indication in field at grade level should also be provided.

Instrument for detecting High Pressure shall be independent of the tank pressure monitoring instrument.

The sequence for over pressure control and protection shall be as follows:

1. High pressure alarms
2. Increasing the BOG system to the full load.
3. Further increase in pressure shall be controlled by releasing to Flare.
4. Further increase in pressure shall be controlled by closing of inlet automated valve.
5. The final over pressure protection shall be PSV and tank design pressure.

All the above pressure control and actuation shall be on independent pressure transmitters.

Independent Pressure transmitters shall be provided for low pressure detection that will trip the boil off gas compressors.

In the event of continued drop in tank pressure, two layers of protection against vacuum shall be provided.

1. Automatic admission of natural gas from outside source into the tank vapour space (From vaporiser outlet). The trip of the pumps shall be envisaged after admission of natural gas and before admission of nitrogen for protection against vacuum.
2. In the unlikely event this is not sufficient; a set of vacuum breakers installed will admit air into the space between the suspended deck and outer roof to prevent permanent damage to the tank.

Automatic admission of Nitrogen from an outside source into the tank vapour space before admission of air through vacuum breakers should also be considered as a layer of protection.

The independent pressure transmitters shall be provided for the natural gas and nitrogen gas admission for vacuum protection.

6.4.3 Temperature: As LNG is a product of varied compositions, it would be necessary to measure temperature of liquid and vapour over the full tank height; the sensors being located at 2 meter intervals or every 10% interval of the tank height, whichever is less.

Measuring and recording the formation of layers of liquid with different temperatures should warn the operator of a possible roll over phenomenon.

In addition, for monitoring of the initial chill down operation, temperature elements are required to be provided at tank base and shell of both the primary and secondary containers.

These temperature elements must be provided at various heights and at various locations of the base to ensure monitoring and proper chilling of the tanks.

6.4.4 Gas Detectors: Automatic gas detection system for monitoring leakage of LNG to be installed. Adequate number of gas alarm sensors shall be placed on the tank roof in the vicinity of roof nozzles and places where the possibility of gas or liquid release exists including below elevated tanks. The facility shall be equipped with Emergency shutdown system. The ESD should be able to
operate remotely / locally. Need for any automatic actuation of ESD may be assessed based on risk perceptions.

6.4.5 **Leak Detectors (See para 6.3.6 also):** Monitoring leaks through the primary container in double containment systems shall be provided by one of the following means:

1. Temperature measurement sensors in annular space.
2. Gas detection
3. Differential pressure measurement

The arrangement shall have redundancy to prevent spurious alarms.

Tank external leak / spillage detection shall be installed at every location where leaks are credible. These detectors may activate appropriate process shutdowns or isolation, activate remote operated fire protection systems or initiate emergency actions by Operators.

The following leak detection devices shall be considered:

1. Low temperature sensors for LNG spills.
2. Flammable gas detection of IR type. Battery limit fences shall have open path type detectors.
3. Flame detectors of the UV/IR type
4. Heat temperature detectors for protection of tank relief valve fires and activation of tail pipe extinguishing packages, if provided.
5. Smoke detectors of the ionisation type
6. CCTV systems in unmanned areas and unloading Jetty, capable of detecting vapour clouds, fitted with motion sensor alarms.
7. Communication system between field operators, Jetty terminal and pipeline dispatching centre.

6.4.6 **Density Meters:** Density Meters shall be provided on the storage tanks to check the homogeneity of LNG.

The density of LNG in the Tank shall be monitored at all levels and analysis performed to alert the operator of any density layering.

6.4.7 **Linear and Rotational Inner Tank Movement Indicator**

Linear and Rotational inner tank movement indicator should be located with recorder between inner container and outer shell to record the relative movement of the liquid container with respect to outer tank.

6.4.8 A provision in the tank for endoscopic inspection (through insertion of camera) shall also be considered. This will be helpful to know the health of the tank in the absence of visual inspection of the tank.

6.4.9 An Uninterruptible Power Supply (UPS), with battery back-up shall be provided to all critical instrumentation control and safety (F&G) systems so that plant may be kept safe in case of emergencies.

7.0 **INSULATION**

7.1 **CONTAINER INSULATION**

7.1.1 Any exposed insulation shall be

- noncombustible
- contain or inherently shall be vapor barrier
- moisture free
- resist dislodgment of fire water
7.1.2 Where an outer shell is used to retain loose insulation, the shell shall be constructed of steel or concrete. Exposed weather proofing shall have a flame spread rating not greater than 25.

7.1.3 The space between the inner tank and outer tank shall contain insulation that is compatible with LNG. The insulation shall be such that a fire external to the outer tank cannot cause significant deterioration to the insulation thermal conductivity by means such as melting or settling.

7.1.4 The load bearing bottom insulation shall be designed and installed in such a manner that cracking from thermal and mechanical stresses does not jeopardize the integrity of the container.

7.1.5 Material used between the inner and outer tank only shall not be required to meet the combustibility requirements, provided the material and design of the installation comply with all the following:

i) The flame spread rating of the material shall not exceed 25, and the material shall not support continued progressive combustion in air.

ii) The material shall be of such composition that surfaces that would be exposed by cutting through the material on any plane shall have a flame spread rating not greater than 25 and shall not support continued progressive combustion.

iii) The combustion properties of material do not deteriorate significantly as a result of long-term exposure to LNG or natural gas at the anticipated service pressure and temperature.

iv) The material in the installed condition shall be capable of being purged with natural gas or inert gas (Nitrogen). The natural gas remaining after purging shall not be significant and shall not increase the combustibility of the material; this is not applicable when insulation space is maintained under inert gas (i.e. Nitrogen).

7.2 PIPING INSULATION

7.2.1 Piping systems shall be insulated to minimize energy loss, protect against condensation/frost and for personnel protection.

7.2.2 Insulating materials shall be specified in accordance with relevant codes and standards considering boil off limitations and control of surface condensation. Low chloride insulation should be used to avoid corrosion of stainless steel piping.

7.2.3 Insulation materials should be water proof and have an effective vapour barrier, coating and cladding.

7.2.4 Monitor and inspect piping for corrosion damage under insulation.

8.0 FIRE PROTECTION, SAFETY AND EMERGENCY SYSTEMS

8.1 GENERAL

8.1.1 This chapter covers equipment and procedures designed to minimise the consequences from released LNG, flammable nature of refrigerants, liquids and gases related to facilities constructed and arranged in accordance with this standard. These provisions augment the leak and spill control provisions provided for in other sections. This chapter also includes basic plant security provisions.

8.1.2 Fire protection shall be provided for all LNG facilities. The extent of such protection shall be determined by an evaluation based upon sound fire protection engineering principles, analysis of local conditions, hazards within the facility and exposure to or from other property. The evaluation shall determine as a minimum:

8.1.3 The type, quantity and location of equipment necessary for the detection and control of fires, leaks and spills of LNG, flammable refrigerants or flammable gases all potential fires non process and electrical fires.

8.1.4 The methods necessary for protection of the equipment and structures from the effects of the fire exposure.

8.1.5 Fire protection water system (refer section 8.5)
8.1.6 Fire extinguishing and other fire control equipment's (section 8.6)

8.1.7 The equipment's and process systems to be operated with the emergency shutdown (ESD) system.

8.1.8 The type and location of sensors necessary for automatic operation of the emergency shutdown (ESD) systems or its subsystems.

8.1.9 The availability and duties of individual plant personnel and the availability of external response personnel operating an emergency.

8.1.10 The protective equipment and special training necessary by the individual plant personnel for their respective emergency duties.

8.1.11 A detailed emergency procedure manual shall be prepared to cover the potential emergency conditions. Such procedure shall include but not necessarily be limited to the followings:

   a) Shutdown or isolation of various equipment in full or partial and other applicable steps to ensure that the escape of gas or liquid is promptly cut off or reduced as much as possible.
   b) Use of fire protection facilities.
   c) Notification of public authorities.
   d) First aid and
   e) Duties of personnel.
   f) Communication procedure in case of emergency

8.1.12 An updated emergency procedure manual shall always be available in the operating control room.

8.1.13 All personnel shall be trained in their respective duties contained in the emergency manual. Those personnel responsible for the use of fire protection or other prime emergency equipment shall be trained in the use of equipment. Refresher training of personnel shall be conducted at least on annual basis.

8.1.14 The planning of effective fire control measures be co-ordinated with the authority having jurisdiction and emergency handling agencies such as fire and police departments who are expected to respond to such emergencies.

8.2 IGNITION SOURCE CONTROL

8.2.1 Smoking within the LNG terminal is not allowed. All hot and cold work shall be carried out as per OISD -STD – 105.

8.2.2 Vehicle and other mobile equipment that constitute potential ignition sources shall be prohibited within impounding areas or within 50 ft (15 m) of containers or equipment containing LNG, flammable liquids or flammable refrigerants except when specifically authorised and under constant supervision.

8.2.3 No vehicle or other mobile equipment without flame arrester at the exhaust should be permitted within impounding areas or within 50 ft. (15 mts.) of containers or equipment containing LNG.

8.2.4 Electrical equipment, switches, plug, wiring etc. used within the impounding areas of within 15 mts. Of container or equipment containing LNG must be of flameproof type either as per BIS standard or appropriate OISD standard.

8.2.5 To avoid formation and accumulation of static charge all the equipment, storage tank, pipeline containing LNG should be properly bonded and earthed. Continuity of earthing and bonding should be checked as per OISD-STD-110 on regular interval.
8.3 EMERGENCY SHUTDOWN SYSTEMS

8.3.1 Each LNG facility shall incorporate an emergency shutdown (ESD) system that which when operated:
- Isolates or shutoff a source of LNG, flammable refrigerant or flammable gases.
- Shuts down equipment which as continued operation may add to an emergency.

8.3.2 When equipment shutdown result in an additional hazard or substantial mechanical damage to the equipment, the shut down of such equipment or its auxiliaries shall be omitted from the ESD system, provided that continuous release of flammable or combustible fluid are controlled.

8.3.3 Vessel containing liquids that are subjected to metal overheating and catastrophic failure from fire exposure and not otherwise protected shall be depressurised by the ESD system.

8.3.4 Initiation of ESD system shall be either manual, automatic, or both manual and automatic, depending upon result of evaluation performed in accordance with fire protection facilities. Manual actuator shall be located in an area accessible in an emergency and shall be located at least 15 meters away from the equipment and marked distinctly and conspicuously with their design function.

8.3.5 The emergency shutdown system (ESD) or systems shall be of failsafe design. It should be installed, located or protected for its ease of operation in the event of an emergency or failure of the normal control system. Emergency shutdown systems that are not of failsafe design shall have all components that are located within 15 m of the equipment to be controlled either:

   i) Installed or located where they will not be exposed to a fire or
   ii) Be protected against failure due to fire exposure of at least 10 minutes duration.

8.3.6 The emergency shutdown system shall consider process safety as well as leakage of gas, fire, smoke as well as cold detection and linear detection. Depending on seriousness, the level of shut down is required to be graded and considered. This could be by way of section isolation or total complex shut down.

8.3.7 Communication and interlock to be provided between ship and terminal control room. Provision shall be given in the jetty for the above facility. During unloading operation, the terminal operator shall take control of the unloading. In addition to automatic shutdown system (ESD) the terminal operator shall be in a position to initiate shut down of unloading.

8.4 FIRE AND LEAK DETECTION SYSTEM

8.4.1 Those areas including enclosed buildings that have a potential for flammable gas concentrations of LNG or spilling of flammable refrigerant and fire shall be monitored.

8.4.2 Continuously monitored low temperature sensors or flammable gas detection systems shall sound an alarm at the plant site and at a constantly attended location. Flammable gas detection systems shall initiate this alarm 20 percent as well as 40% of lower flammable limit of the gas or vapour being monitored.

8.4.3 The Fire detectors shall initiate an audio and visual alarm at the plant site and at a constantly attended location.

8.4.4 Fire detectors may activate appropriate portions of the emergency shutdown system with a voting system.

8.4.5 The detection system determined shall be designed, installed and maintained in accordance with the OISD/NFPA standards.

8.4.6 All identified gas zones shall be provided with linear gas detection and hooked up with the ESD
8.5 FIRE PROTECTION SYSTEM FOR LNG TERMINAL

The primary source of fire and explosion hazard is from a leak or spill from the LNG storage or transfer systems.

a. Fire fighting system for the LNG terminal shall be as per the provisions laid down in OISD STD 116 as applicable. The Fire protection facilities for the LNG terminal shall be designed to fight two major fires simultaneously anywhere in the LNG terminal.

b. Fire fighting system of the port/jetty area shall be designed as per OISD STD 156.

c. LNG terminals which also cater to jetty fire water demand, shall be designed to fight two major fires simultaneously anywhere in the LNG terminal including the jetty area.

In addition to OISD STD 116 following shall also apply.

8.5.1 WATER SPRAY SYSTEM:

i) For the storage tanks, water sprays shall be provided on the tank shell including the roof and the appurtenances on the tank. For single containment tanks, water application rate for the tank roof and walls shall be calculated using method detailed in Appendix 5 of IP Model Code of Safe Practice, Part 9 of NFPA 15. The water application rate on the appurtenances shall be 10.2 lpm / m² as per this code. For double/full containment metallic tanks, the water application rate for the tank roof and walls shall be 3 lpm/m², required for cooling the outer shell of tanks adjoining to the one on fire. Water spray for shell of pre-stressed concrete double/full containment LNG tanks is not considered necessary. However, water spray shall be provided on roof for all the LNG tanks regardless of the construction material used.

ii) The water application rate applicable to other equipment shall be as follows:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Water Application Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessels, structural members</td>
<td>10.2 lpm / m²</td>
</tr>
<tr>
<td>Piping &amp; valves manifolds</td>
<td>10.2 lpm / m²</td>
</tr>
<tr>
<td>Pumps</td>
<td>20.4 lpm / m²</td>
</tr>
</tbody>
</table>

iii) The water spray shall be divided into subsystems to provide protection to the different sections of the tank, i.e. one system to cover each segment of vertical wall, one to cover the dome roof and the tank appurtenances. The roof section shall be provided with duplicate 100% risers.

iv) The deluge valves on the water spray systems on the tanks as well as the pumps, compressors, vessels etc. shall be actuated automatically through a fire detection system installed around the facilities with provisions of manual actuation from Control Room or locally at site.

v) For single containment tanks, double containment / full containment tank having metallic outer tank and membrane tanks which are having a dyke, high expansion foam systems shall be provided as per NFPA 11A. Water turbine powered high expansion foam generators shall be located on the impounding area around the storage tanks. Foam units comprising storage facilities and pumps shall be provided in a safe area removed from the protected risk and shall be accessible in an emergency.

Portable high expansion foam generators should be considered, suitable for coupling to hydrant hose lines for isolated LNG spills.

vi) Fixed dry chemical powder or nitrogen snuffing systems shall be provided for each relief valve outlet of the LNG storage tanks. Each set shall provide two shots of dry chemicals in the event of ignition during venting.
vii) Fire hydrants shall be provided along the main fire header at suitable intervals in the process and storage areas. Fixed foam/water monitors may be provided around the process areas based on requirement.

8.6 FIRE EXTINGUISHING AND OTHER FIRE CONTROL EQUIPMENT

8.6.1 Portable wheeled fire extinguishers suitable for gas fires, preferably of the dry chemical type shall be made available at strategic locations.

8.6.2 Fixed fire extinguishing and other fire control systems that may be appropriate for the protection of specific hazards, are to be provided.

8.6.3 A automotive and trailer mounted fire apparatus shall not be used for any other purpose, other than it is designated for.

8.6.4 Plant assigned automotive vehicles shall be provided with a minimum of one portable dry chemical extinguisher having adequate capacity.

8.6.5 Water curtains should be considered to mitigate gas releases, dilute the LNG vapour and facilitate its dispersion.

8.6.6 Vessels, equipment, structures, cables, safety critical instruments etc. that are likely to be exposed to LNG fire radiation shall be provided with a passive fire protection (PFP) in the form of fire proofing insulation or/and water deluge for the duration of the hazard. Fire proofing shall be executed as per OISD STD 164. PFP being considered for LNG service shall be suitably tested for cryogenic liquid side of the test followed by a hydrocarbon pool and/or jet fire test according to the fire scenario. Typical application of PFP are:

Buildings:
- Fire barriers or doors between enclosures.
- Protection of escape routes in buildings

LNG facilities:
- Protection of critical structural members in process areas
- Protection of critical equipment (e.g. ESD valves and actuators)
- Protection of critical control cabling
- Protection of process equipment
- Protection of tanks
- Protection of vessels and vessel supports
- Containment pits
- Run off channels

8.6.7 Embrittlement Protection: Equipment and structures shall be protected by insulation or appropriate metallurgy selection against cold shock and failure due to a spill of LNG.

8.7 PERSONNEL SAFETY

8.7.1 Personnel shall be advised of the serious danger from frostbite that can result upon contact with LNG or cold refrigerant. Suitable protective clothing and equipment shall be made available.

8.7.2 Presence of personnel in the vicinity of ERC during cooldown/bulk unloading should be restricted so as to avoid any injuries due to accidental release of Emergency Release Coupling (ERC).

8.7.3 Those employees who will be involved in emergency activities shall be equipped with the necessary clothing and equipment.

8.7.4 Self contained breathing apparatus shall be provided for those employees who may be required to enter an atmosphere that could be injurious to health during an emergency.

8.7.5 A portable flammable gas indicator shall be readily available because LNG and hydrocarbon refrigerants within the process equipment are usually not odorised and the sense of smell cannot be relied upon to detect their presence.
9.0 SHIP TANKER RECEIVING FACILITIES AND MINIMUM PORT FACILITIES AND BERTHING CONDITIONS:

The design of ship tanker receiving and port facilities does not form part of this standard. However, these paragraphs have been included for the general guidance and information of the users of this standard. For detailed study, reference should be made to information paper no. 14 - Site Selection and Design for LNG Ports and Jetties by SIGTTO. (Society of International Gas Tankers and Terminal Operators Ltd.)

PORT DESIGN

i) **Approach Channels.** Harbour channels should be of uniform cross sectional depth and have a minimum width, equal to five times the beam of the largest ship.

ii) **Turning Circles.** Turning circles should have a minimum diameter of twice the overall length of the largest ship to be received where current effect is minimal. Where turning circles are located in areas of current, diameters should be increased by the anticipated drift.

iii) **Tug Power.** Available tug power, expressed in terms of effective Bollard pull, should be sufficient to overcome the maximum wind force generated on the largest ship using the terminal, under the maximum wind speed permitted for harbour manoeuvres and with the LNG carrier’s engines out of action.

iv) **Traffic Control.** A Vessel Traffic Service (VTS) System should be a port requirement and this should be able to monitor and direct the movement of all ships coming within the operating area of LNG carriers.

v) **Operating Limits.** Operating criteria for maximum wind speed, wave height and current should be established for each terminal and port approach. Such limits should match LNG carrier size manoeuvring constraints and tug power.

vi) **Speed Limits.** Speed limits should be set for areas in the port approach presenting either collision or grounding risks. These limits should apply not only of LNG carriers but also to any surrounding traffic.

A separate jetty shall be earmarked for LNG unloading. A minimum distance of 500 metres from other cargo jetties should be kept.

Minimum depth of the sea (water depth) required to accommodate the large LNG tankers is of the order of 13 - 14 metres w.r.t. the CD (i.e. Chart Datum).

The size of the tankers, which are currently in use, vary from 40,000 M$^3$ to 263,000 M$^3$ having compartments varying between 3-5 numbers. This LNG from the ship *should be* unloaded by minimum two liquid and one vapour arm depending on the unloading rate and spill considerations. One of the unloading arm should be designed for the use of both liquid and vapour.

All these unloading arms are provided with an emergency shut-off arrangement (ESD valves and ERS) which shall operate in case of any emergency so that no liquid/vapour is passed through to the LNG ship.

Basic criteria needs to be looked into its approach channel to the terminal, traffic control and the berthing facilities apart from interface with the shore for communication, mooring system etc.

Each gas terminal requires a unique risk management system and mere application of guidelines/criteria may be insufficient. The approach channel specification turning circle radius, power required by tug, operating limits, need to be looked into before arriving at the final specification for port facilities.

The water current in the turning areas should be less than 1 knot and the wind speed with the assistance of tug would be in the order of 25 knots. The design criteria for mooring is

i) Wind speed 60 knots from any direction.

ii) Water current 3 knots.
Wind speed on the berth is to the extent of 27 knots however the unloading operations can take place up to 30 - 35 knots and the arms to be disconnected at 35 knots wind speed subject to manufacturer’s specification.

The vessels lie alongside the jetty and the discharge operation takes place at 1 to 1.5 metre height of the bay. With specialised mooring arrangements, the height may go up to 2 metre. The ship can be discharged during the day or night if managed effectively.

The traffic control management is to ensure that no credibility risk of breach in cargo containment and such limits are synergies with vessel size and manoeuvring. The ships shall be berthed normally with head out to sail off in the event of any emergency

The design policies and standards need to take care of port safety and environment in regard to

i) Coast line assessment
ii) Environmental impact assessment
iii) Risk conditions
iv) Policy development.

The security of supply is based on the physical assessment, sparing philosophy, reliability of equipment's and operation.

The normal distance between the jetty and shore is between 25 to 500 metres.

The design safety and commercial criteria for ship operations generally require that a ship should be unloaded in 12 hours so that it can turn around in 24 hours. With larger ships the unloading rates shall increase which in turn will result in larger unloading lines on the jetty and into the terminal. The development in the LNG ship design has reduced the boil off from 0.25% of the contents per day to a value of 0.1%. Generally the boil-off is used for the following:

d) In the boiler for generating the steam which in turn is being used for power generation,
e) As a fuel in dual fuel for diesel electric propulsion.
f) Small Re-liquefaction plant

Safety
The LNG Jetty Provision shall have emergency escape routes from a fire or liquid spill as per OCIMF guidelines.
Jetty elevated monitor streams shall be capable of reaching the fire hazard area (ship manifold and loading arms)

10.0 REFERENCERS
1) OISD-STD-112 Safe Handling of Air Hydrocarbon Mixtures and Pyrotheric Substances.
2) OISD-STD-114 Hazardous Chemical Data
4) OISD-STD-118 Layout for Oil and Gas Installations- Rev 1
5) OISD-STD-155 Personnel Protective Equipment.
6) OISD-STD-156 Fire Protection Facilities for ports handling hydrocarbons
8) NFPA - 59 (A), 2009 Standard for production, storage and handling of LNG.
9) EEMUA - Publication no. 147 (THE ENGINEERING EQUIPMENT AND MATERIAL USERS ASSOCIATION)
10) API - 620, Appendix - Q Design and construction of large, welded, low-pressure storage tanks
12) Cryogenic storage of liquefied gases - Hydrocarbon Asia, 1996
13) LNG receiving terminal design is different-DB Crauford and CA Durr, Hydrocarbon Processing.
15) IS:1893 : 2002 Criteria for earth quake resistant design of structures.
16) EN 14620 : 2006 Design and manufacture of site built,vertical,cylindrical,flat bottomed steel tanks for the storage of refrigerated,liquefied gases with operating temperatures between 0°C and -165°C
Vacuum Relief valve is designed to allow air ingress in the extreme case of vacuum formation in the tank.

Annexure-1
Single Containment

Double Containment
Figure 3
Full Containment Tank

Figure 4
Full Containment Tank with earth embankment
Membrane Tank (above ground)
CRYOGENIC CONCRETE TANK (Ref EN 1473)

Key

1 susended deck (aluminium deck) 9 reinforced concrete roof
2 pre-stressed concrete secondary container 10 bottom heating
3 elevated slab 11 concrete outer raft
4 base insulation 14 carbon steel liner
6 loose fill insulation 15 9 % Ni steel base
7 outer steel roof 16 cryogenic pre-stressed concrete primary container
8 primary container 17 cryogenic pre-stressed concrete secondary container
Key
1 outer shell
2 primary container
3 secondary container