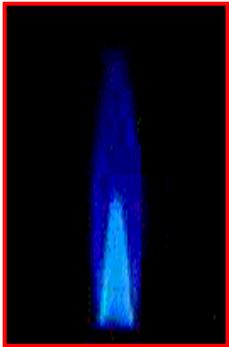




## LNG Information Paper No. 5



# Managing LNG Risks – Containment

GIIGNL's Technical Study Group has overseen the development of this Information Series of 7 papers to provide factual information about Liquefied Natural Gas (LNG), or GNL in French, Spanish, Portuguese, or Italian speaking countries. This paper describes the tanks used to store LNG, which should be viewed as the primary means for safely containing LNG and preventing the exposure of LNG's extremely cold temperatures and flammable vapours to facility workers or the public. Secondary containment, i.e., ways in which the tank contents will be captured on site in the unlikely event of a leak or spill, is also discussed. For more information on these topics, additional references and weblinks are provided at the end of this paper.

## Introduction

A primary safety requirement for the industry is to contain LNG. LNG is stored in large tanks at liquefaction facilities and import terminals. At an import terminal, LNG is stored until it is turned back into natural gas through regasification and then sent out to consumers in pipelines. A typical LNG import terminal has 2 to 4 LNG storage tanks (although a small number have over 10 tanks). LNG can also be imported and stored at an offshore receiving terminal.

LNG tanks have more than one means of containment. The first layer of containment is provided by the tank which holds the LNG. All LNG storage tanks are constructed with thermal insulation to prevent heat transfer, reduce evaporation, and protect the structure from cryogenic temperatures which could damage the structural integrity of the tank. Secondary containment is provided either by the use of dikes, berms and impoundment dams around storage tanks, or by building a second tank around the primary storage tank to contain the LNG in the unlikely event of a failure in the primary tank.

The decision to use a particular design is influenced by available space and local requirements. The vast majority

of LNG storage tanks are above-ground. Japan has constructed some tanks below ground to save expensive land, and there are some floating storage tanks at offshore receiving terminals. This paper focuses on onshore storage tanks.

## Storage Tanks

The tanks in which LNG is stored are the means for primary containment. Safe and secure containment is in part a function of the codes and standards which contribute to the operational integrity layer of protection (described in **Information Paper No. 4**); these codes and standards define suitable engineering designs and specify appropriate materials for constructing storage tanks and other equipment at LNG facilities. Several types of tanks are used to store LNG in the world today. In some places a reinforced concrete tank surrounds the inner tank. Types of onshore LNG storage tanks include:

- Single containment tank,
- Double containment tank,
- Full containment tank,
- Membrane tank, and
- In-ground tank.

## Single Containment Tank

A single containment tank is composed of an inner cylindrical container made of 9% nickel steel which is self-supporting (**Figure 1**; next page). This inner tank is surrounded by an outer tank made of carbon steel which holds an insulation material (usually an expanded mineral material called perlite) in the annular space. The carbon steel outer tank is not capable of containing cryogenic materials; thus the inner tank provides the only containment for the cryogenic liquid. However, single containment tanks are always surrounded by a dyke (bund or containment basin) external to the tank, either of which provides at least 100% secondary containment in the event of a complete failure of the inner tank. This type has an excellent history of reliability and represents the majority of tanks in the world but does require a relatively large area of land.

## Double Containment Tank

The double containment tank is similar to a single containment tank, but instead of a containment dike there is an outer wall usually made of post-stressed concrete (**Figure 2**; next page). Therefore if the inner tank fails, the secondary container is capable of containing all of the cryogenic liquid.

The outer concrete wall increases the cost of the tank, but less space is required because there is no need for a containment dyke. Should the inner tank fail, the liquid will be contained and vapours will escape through the annular gap, which is the space between the two tanks or the tanks and the concrete wall.

## Full Containment Tank

A full containment tank is a double containment tank in which the annular gap between the outer and inner tanks is sealed (**Figure 3**; page 4). The majority of LNG storage tanks built in the last 10 years worldwide have been designed as full containment tanks.

In this tank, the secondary container is liquid- and vapour-tight in normal operations. In case of leakage of the primary barrier, the secondary container remains LNG-tight. The secondary container wall is generally made of pre-stressed concrete and the roof is usually reinforced concrete, although under EN 1473 metal roofs may be allowed.

## Membrane Tank

The membrane type of storage tank is a post-stressed concrete tank with a layer of internal load-bearing insulation covered by a thin stainless-steel corrugated membrane (**Figure 4**; page 4). In this design, the

concrete tank supports the hydrostatic load (weight of the liquid) which is transferred through the membrane and insulation (in other words, the membrane is not self-supporting). The membrane is able to shrink and expand with changing temperatures.

These tanks were constructed primarily in France and Korea in the 1970's and 1980's.

## In-ground Tanks

In-ground LNG tanks are obviously less visible in their surroundings (**Figure 5**; page 5). They are mainly used in Japan and some other Asian countries. They were developed by Tokyo Gas Engineering (TGE) in the early 1970's based on earlier designs in the UK, the US and Algeria and subsequently used by other Japanese companies. As of 2005, there were 61 in-ground storage tanks in Japan. The record for the largest LNG tank in the world was first set by an in-ground (200,000 m<sup>3</sup>) although several above-ground tanks have recently been built with a similar capacity.

These tanks are more expensive and take longer to build than an above-ground tank – about 4 to 5 years compared to 3 years for a tank built above ground. The terminals with in-ground tanks are designed to harmonise with the surroundings and ensure safety at every stage of the lifecycle. These tanks do not need to be surrounded by a dyke or bund wall, so the separation distance from adjacent land is less than that of other types of tanks. This is especially important for countries such as Japan, Korea, and Taiwan. In 45 years, there have not been any incidents concerning LNG tanks which have had any impact beyond the terminal boundary.

## Leak and Spill Capture

LNG terminals are designed to detect any vapour leaks, as well as to detect and capture liquid leaks. LNG containment is a system which consists of the primary containment in the tank plus secondary containment, e.g., the impoundment around the tank to capture and keep in place any leakage of LNG. Storage tanks also incorporate the following measures to prevent leaks or detect leaks immediately at the source:

- Tank construction of special materials and equipment with systems designed to safely insulate and store LNG at temperatures of -162°C (-259 °F);
- Cool down temperature sensors on the tank wall and base;
- Leak detection temperature sensors located in the annular space to signal a low temperature alarm;
- LNG tank gauging systems to provide remote readings and high/low level alarms;

- Level temperature density gauge to detect rollover potential;

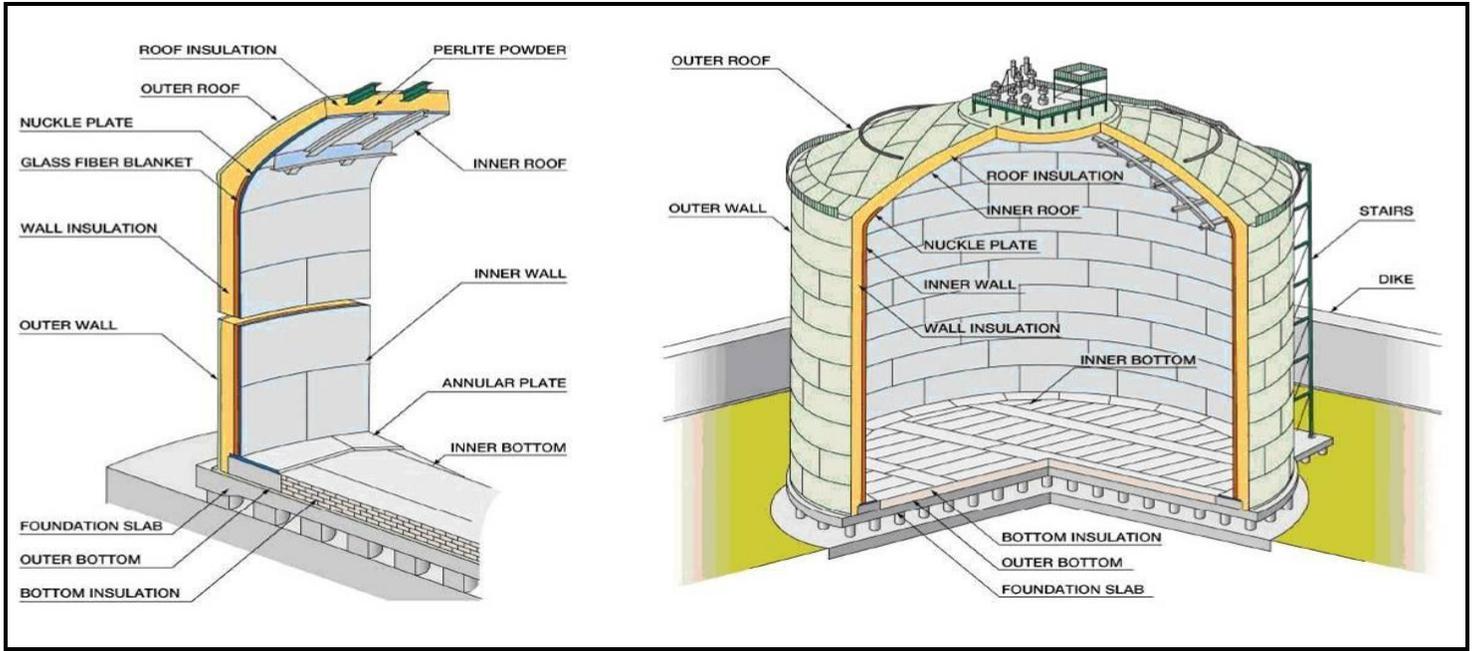
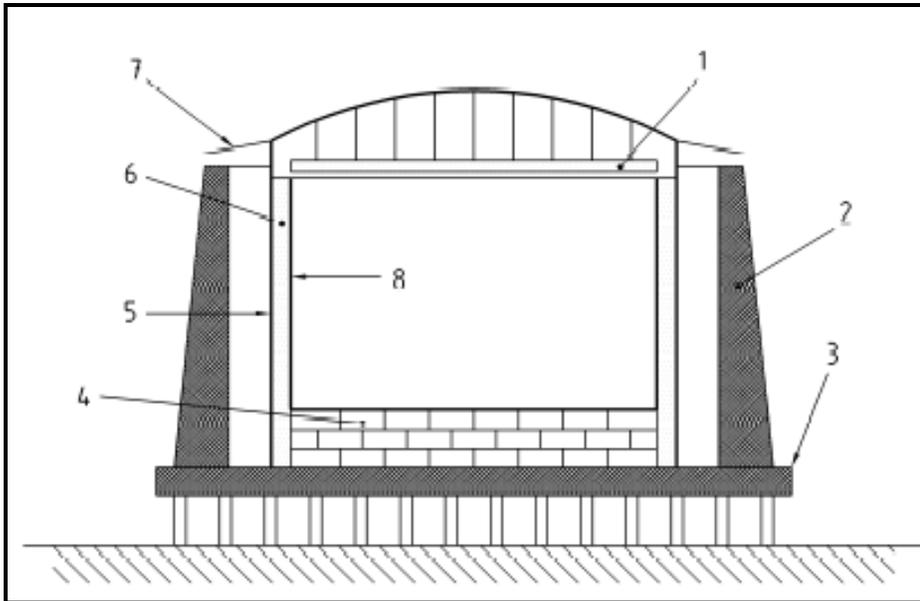


Figure 1. Single containment tank (Source: Kawasaki Heavy Industries, Ltd.)



Key

- |  |                          |
|--|--------------------------|
| 1 suspended deck (insulated)                 | 6 loose- fill insulation |
| 2 post-stressed concrete secondary container | 7 roof if required       |
| 3 elevated slab                              | 8 primary container      |
| 4 base insulation                            |                          |
| 5 outer shell (not able to contain liquid)   |                          |

Figure 2. Double containment tank (Source: EN 1473)

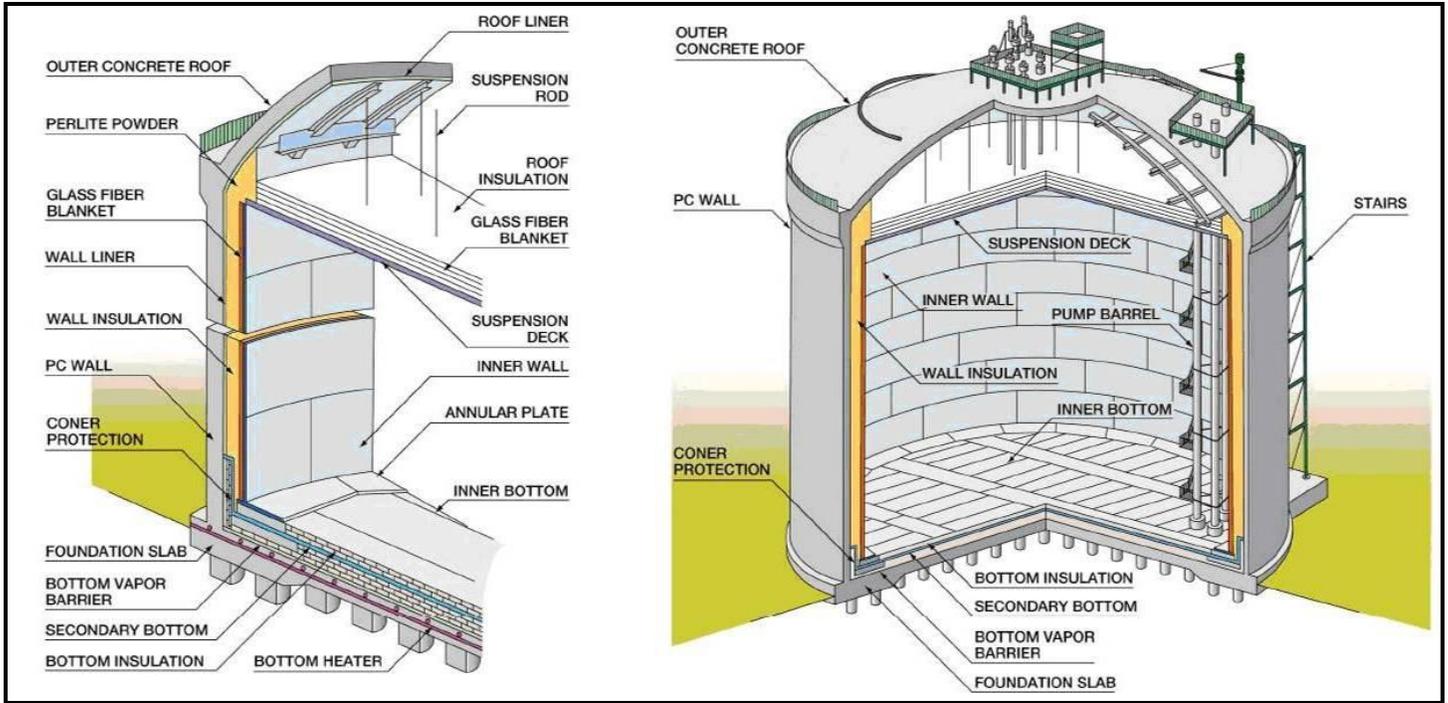
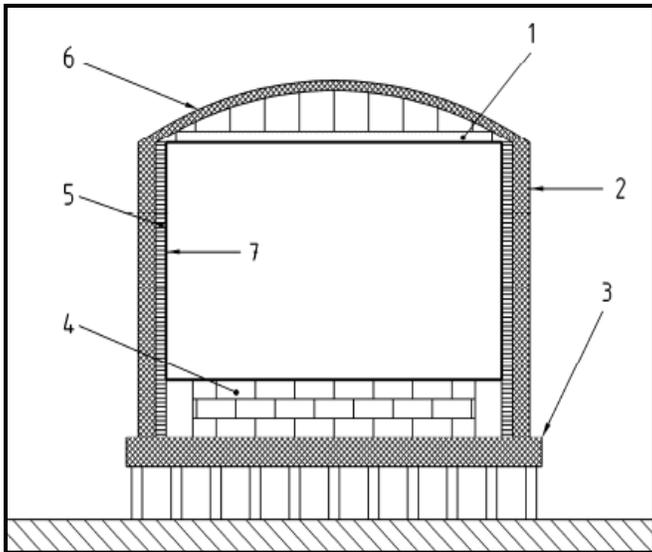


Figure 3. Full containment tank (Source: Kawasaki Heavy Industries, Ltd.)



Key

- |   |  |   |                            |
|---|--|---|----------------------------|
| 1 | suspended deck (insulated)                 | 4 | base insulation            |
| 2 | post-stressed concrete secondary container | 5 | loose fill insulation      |
| 3 | elevated concrete raft                     | 6 | reinforced concrete roof   |
|   |  | 7 | primary container membrane |

Figure 4. Membrane tank (Source: EN 1473)

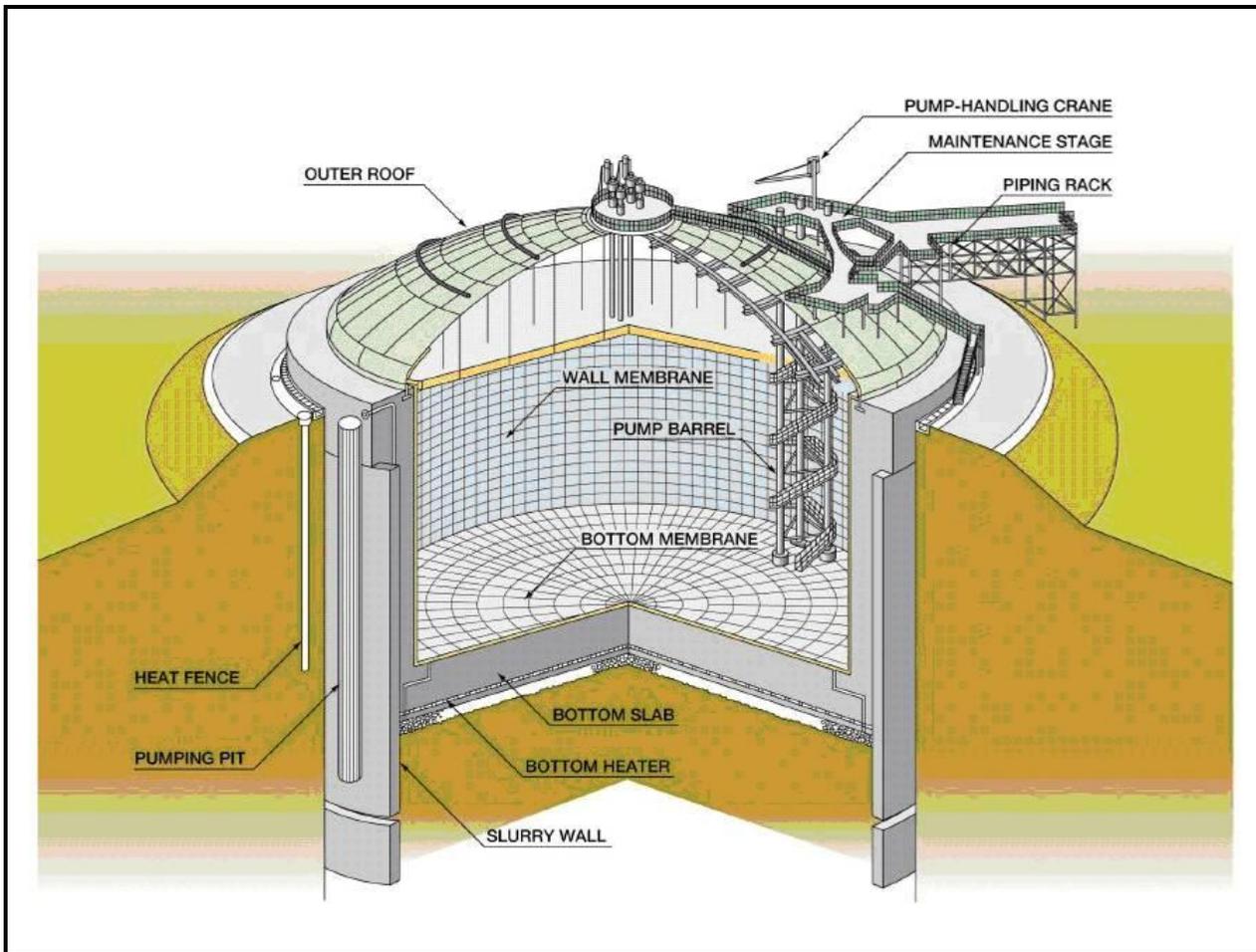


Figure 5. In-ground storage tank (Source: Kawasaki Heavy Industries, Ltd.)

- Pressure controllers and relief valves.
- Passive fire protection, e.g., fireproofing, fire resistant barriers and coatings; and
- Various codes and standards for maintenance and inspection of equipment in LNG service.

Many of these safety measures in tank design and construction were implemented to prevent a re-occurrence of the incident at a peak-shaving facility in Cleveland, Ohio, US in 1944, 20 years before LNG became a significant industry. Post-incident analysis clearly demonstrated that the size of the design of the capture basin was inadequate. Since then, codes and standards have been developed to require a second layer of protection around the primary containment (of single-containment tanks). Single-containment tanks now must be designed to prevent the spread of an LNG spill. Dykes, berms, and dam impoundments surround each single-containment storage tank to capture the LNG in case of a

spill. The size of impoundment areas must be able to capture a volume which exceeds that of the storage tank. Dikes are designed to contain 100-110% of the tank volume and to be high enough so the trajectory of a leak at the upper liquid level in the tank can not overshoot the edge of the dike. Impoundment areas often have concrete or earthen liners and employ some method for extracting rain and deluge water.

In the unlikely event of a leak of any kind, all LNG facilities have many types of equipment to detect a release, and initiate immediate notification and control of the leak or spill. Standard detection and initial response equipment in various areas of an import terminal include:

- Cryogenic liquid detection;
- Gas or vapour detection;
- Smoke detectors;
- Flame detectors;
- Safety alarms;

- Emergency shutdown valves on piping to stop the flow of LNG and limit the quantity of LNG released; and
- Secondary containment designed to mitigate the consequence(s) of release.

Vapour and liquid detection equipment is used to detect, set off alarms and monitor flammable vapours. Most devices have remote monitoring screens, e.g., in a control room, and provide a safe and secure way to monitor the situation and manage the overall facility. Continuous improvements are made in detection systems and there are vendors who specialise in systems just for LNG.

LNG facilities develop and maintain emergency response plans for the unlikely event of any leak. These plans identify potential credible incident scenarios and then develop specific actions to control and mitigate the consequences of these incidents.

## Key Points and Conclusions

In closing, the reader should remember the key points of this information paper:

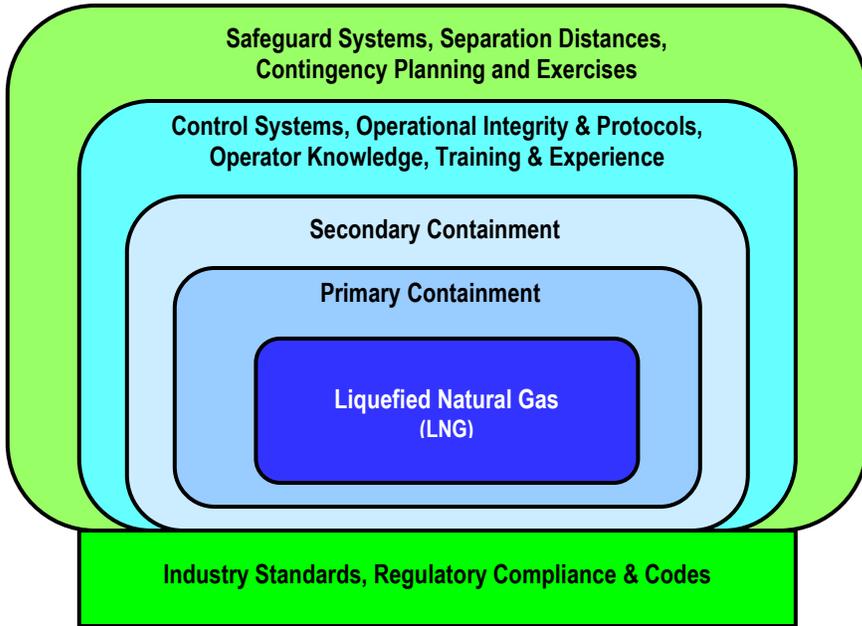
1. In an industry in which safety considerations are paramount, as underscored by the degree to which related codes, equipment, regulations, procedures and systems permeate all of our efforts, containment is the primary requirement for LNG safety.
2. LNG facilities and terminals have more than one means of containment. Beyond the first layer (the specifically-designed and constructed tanks), various methodologies (including berms, dykes, impoundment dams and secondary tanks) are used to provide another layer of protection.
3. Various kinds of tanks are used around the world, including Single Containment Tanks, Double Containment Tanks, Full Containment Tanks, Membrane Tanks and In-ground Tanks.
4. Liquid and gas/vapour leak detection and response systems incorporate a wide array of relevant devices and technologies, including alarms, emergency plans and shutdown valves, fireproofing/fire-resistant barriers and coatings, flame detectors, gauging devices, pressure controllers, relief valves, smoke detectors and temperature sensors.
5. Most devices have remote monitoring screens, e.g., in a control room, to provide a safe and secure way to monitor the situation and manage the overall facility.

Next, in **Information Paper No. 6: Industry Safeguard Systems**, we will review leak prevention and detection systems, emergency plans and emergency preparedness in greater detail. This paper will touch upon again the profound importance of safety considerations in every facet of the LNG industry. As graphically reflected in the “Multiple Safety Layers” figure on the last page, these layers assure LNG safety, and are firmly based on a foundation of solid Industry Standards, Regulatory Compliance and Codes. These safety layers include several key components of the industry’s Risk Management framework, including Primary and Secondary Containment, Control Systems which promote Operational Integrity; Protocols, Operator Knowledge and Experience (which are reinforced by comprehensive and ongoing training). A protective umbrella of Safeguard Systems, Separation Distances, and Contingency Planning, and Exercises further enhances the safe management of LNG.

## References and Additional Resources

- British Standards Institution (BSI) BS 7777: 1993 Parts 1: <http://www.hse.gov.uk/hid/land/comah/level3/5C39A0F.htm>
- Bureau Veritas, 2009
- Center for LNG - [www.lngfacts.org](http://www.lngfacts.org)
- Foss, Michelle Michot. October 2003. LNG Safety and Security. Available from: [http://www.beg.utexas.edu/energyecon/lng/documents/CEE\\_LNG\\_Safety\\_and\\_Security.pdf](http://www.beg.utexas.edu/energyecon/lng/documents/CEE_LNG_Safety_and_Security.pdf)
- Foss, Michelle Michot. Introduction to LNG. Updated January 2007. Center for Energy Economics. Available from: [http://www.beg.utexas.edu/energyecon/lng/documents/CEE\\_INTRODUCTION\\_TO\\_LNG\\_FINAL.pdf](http://www.beg.utexas.edu/energyecon/lng/documents/CEE_INTRODUCTION_TO_LNG_FINAL.pdf)
- GIIGNL - The International Group of Liquefied Natural Gas Importers website - [www.GIIGNL.org](http://www.GIIGNL.org)
- Society of International Gas Tanker and Terminal Operators (SIGTTO) website - [www.sigtto.org](http://www.sigtto.org)
- Tokyo Gas inground tanks. <http://www.tokyo-gas.co.jp/lngtech/ug-tank/index.html>
- World Bank Group International Finance Corporation. Guidelines for Liquefied Natural Gas (LNG) Facilities. [http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui\\_EHSGuidelines2007\\_LNG/\\$FILE/Final++LNG.pdf](http://www.ifc.org/ifcext/sustainability.nsf/AttachmentsByTitle/gui_EHSGuidelines2007_LNG/$FILE/Final++LNG.pdf)

# Multiple Safety Layers Manage LNG Risk



The GIIGNL Technical Study Group has developed this 7-paper series to provide public readers with factual information about the LNG industry's multiple layers of safety, as illustrated in the figure to the left.

The GIIGNL Study Papers include:

- No. 1 – Basic Properties of LNG
- No. 2 – The LNG Process Chain
- No. 3 – LNG Ships
- No. 4 – Managing LNG Risks – Operational Integrity, Regulations, Codes, and Industry Organisations
- No. 5 – Managing LNG Risks – Containment
- No. 6 – Managing LNG Risks – Industry Safeguard Systems
- No. 7 – Questions and Answers (Q&A's)



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