LNG INFORMATION PAPER

#5

2019 Update

Managing LNG Risks
Containment

contents

GIIGNL's Technical Study Group introduces a series of Information Papers that provide factual information about Liquefied Natural Gas (LNG). 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.

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 either reloaded on trucks/LNG ships or 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 only 1 or over 10 tanks).

Storage tanks are a critical component of LNG terminals. The minimum construction time is 32 to 40 months. Storage tanks require substantial capital expenditures.

LNG can also be stored at a floating terminal (Floating Liquefaction Unit, Floating Storage Unit (FSU), Floating Regas Unit (FRU) or Floating Storage and Regas Unit (FSRU), Floating Units (ships or barges) which generally require lower capital expenditures than onshore terminals but may entail higher operating costs. Floating terminals must comply with all relevant regulatory requirements, including those of the International Maritime Organisation (IMO), International Gas Carriers (IGC) and the US Coast Guard (USGC). For additional information on floating units, please refer to **Information paper N°3.** This paper focuses primarily on the onshore terminals.

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 evapo-ration, and protect the structure from cryogenic tempera-tures 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. Some countries have constructed partly or fully below ground. For LNG storage different concepts are applied depending on individual process or local requirements.

While flat-bottom tanks are operated at pressures below 0.5 barg, in spherical and bullet tanks the product is stored at 2.0-3.0 barg to which the LNG supply chain systems (LNG trucks, ships, etc.) are compatible.

Atmospheric storage is well established and compre-hensively regulated by codes, applicable for large tanks. Spherical and bullet tanks are more applicable for small terminals or satellite stations.

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. 6**); 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 or stainless steel which is self-supporting (**Figures 1 & 2**; 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 that provides a secondary containment volume of at least 100% of that of the inner tank in the event of a complete failure of the inner tank. This type has an excellent history of reliability but the need for a containment dyke 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 dyke there is an outer wall usually made of post-stressed concrete (**Figure 3**; page 4). 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 4**; page 4). The majority of large LNG storage tanks built in the last 20 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 of a large tank is generally made of pre-stressed concrete and the roof is usually reinforced concrete, although under EN 1473 metal roofs may be allowed.

The membrane type of storage tank is a full containment post-stressed concrete tank with a layer of internal load-bearing insulation covered by a thin stainless-steel corrugated membrane (**Figure 5**; 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

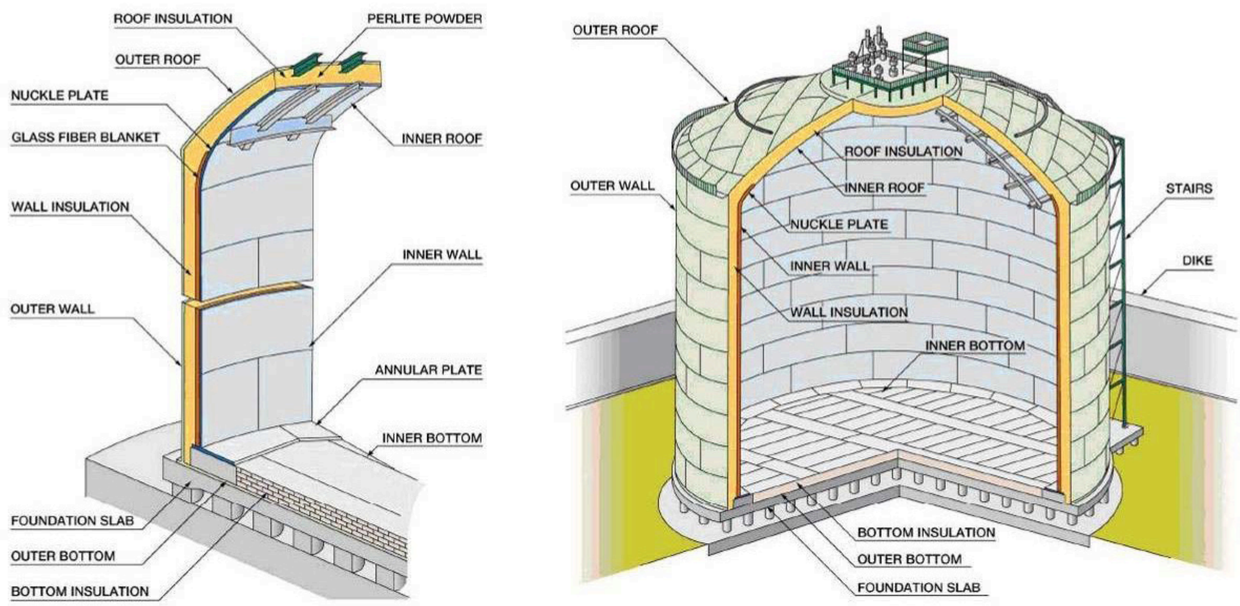


Figure 1. Single containment tank *(Source: Kawasaki Heavy Industries, Ltd.)*

self-supporting). The membrane is able to shrink and expand with changing temperatures. These tanks were constructed primarily in France, Korea and Japan in the 1970s and 1980s.

An LNG bullet or spherical tank is defined as full integrity when the inner and the outer container of the vessel are constructed from cryogenic steel being able to hold the LNG. In case of inner tank leakage the cryogenic liquid is contained in the outer tank and the structural integrity of the complete bullet is maintained. An example for a full integrity LNG bullet is given in **Figure 6.**

In-ground Tanks

In-ground LNG tanks are obviously less visible in their surroundings (**Figure 7**; 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.

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.

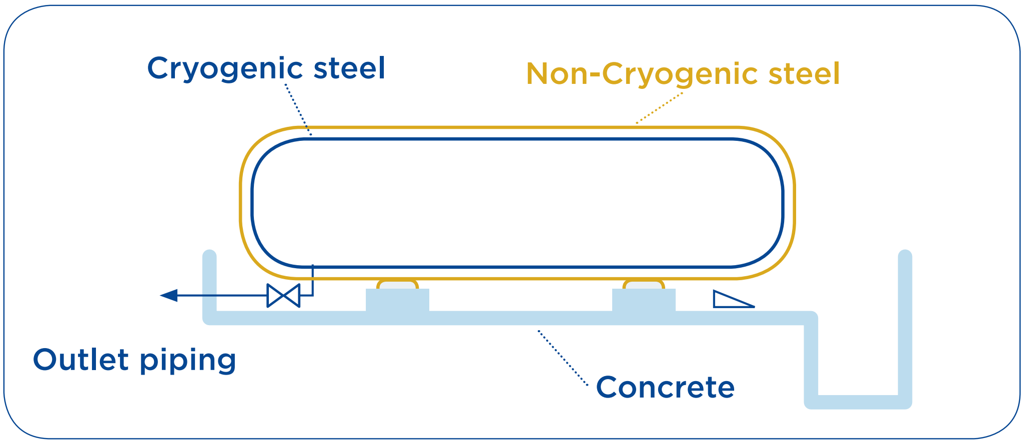


Figure 2 : Single integrity LNG bullet, surrounded by a dike.

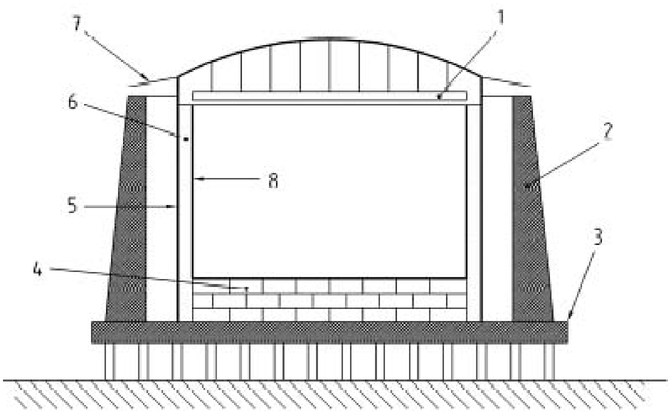


Figure 3 : Double containment tank *(Source: EN 1473)*

Key

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

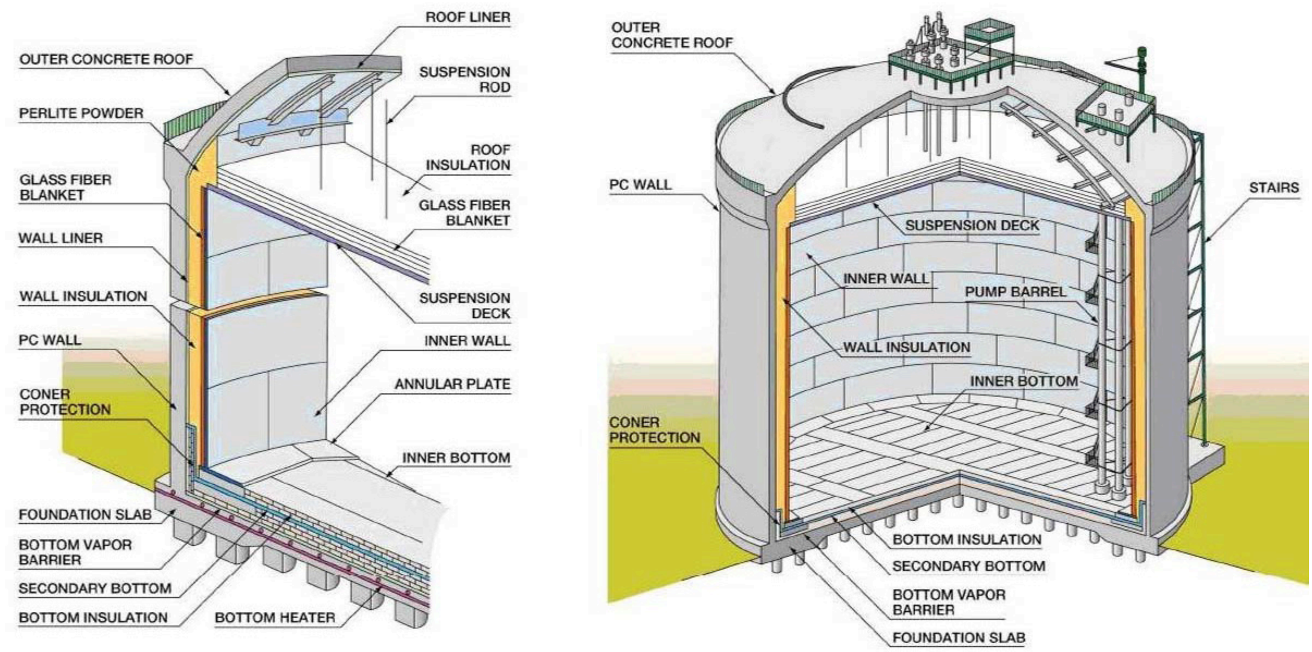
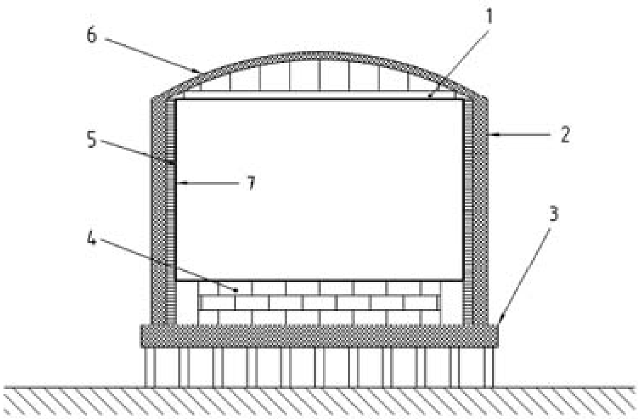


Figure 4. Full containment tank *(Source: Kawasaki Heavy Industries, Ltd.)*



Key

1. suspended deck (insulated)

2. post-stressed concrete secondary container

3. elevated concrete raft

4. base insulation

5. loose fill insulation

6. reinforced concrete roof

7. primary container membrane

Figure 5. Membrane tank *(Source: EN 1473)*

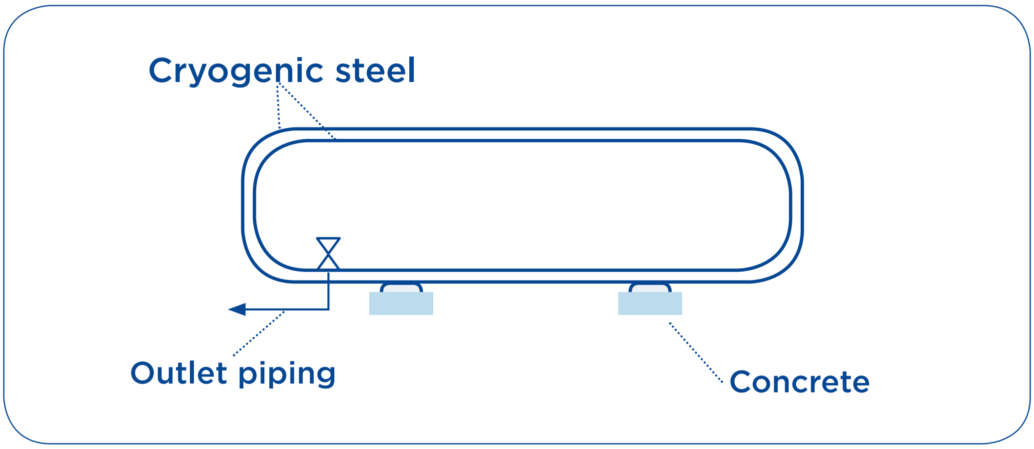


Figure 6 : Full integrity LNG bullet

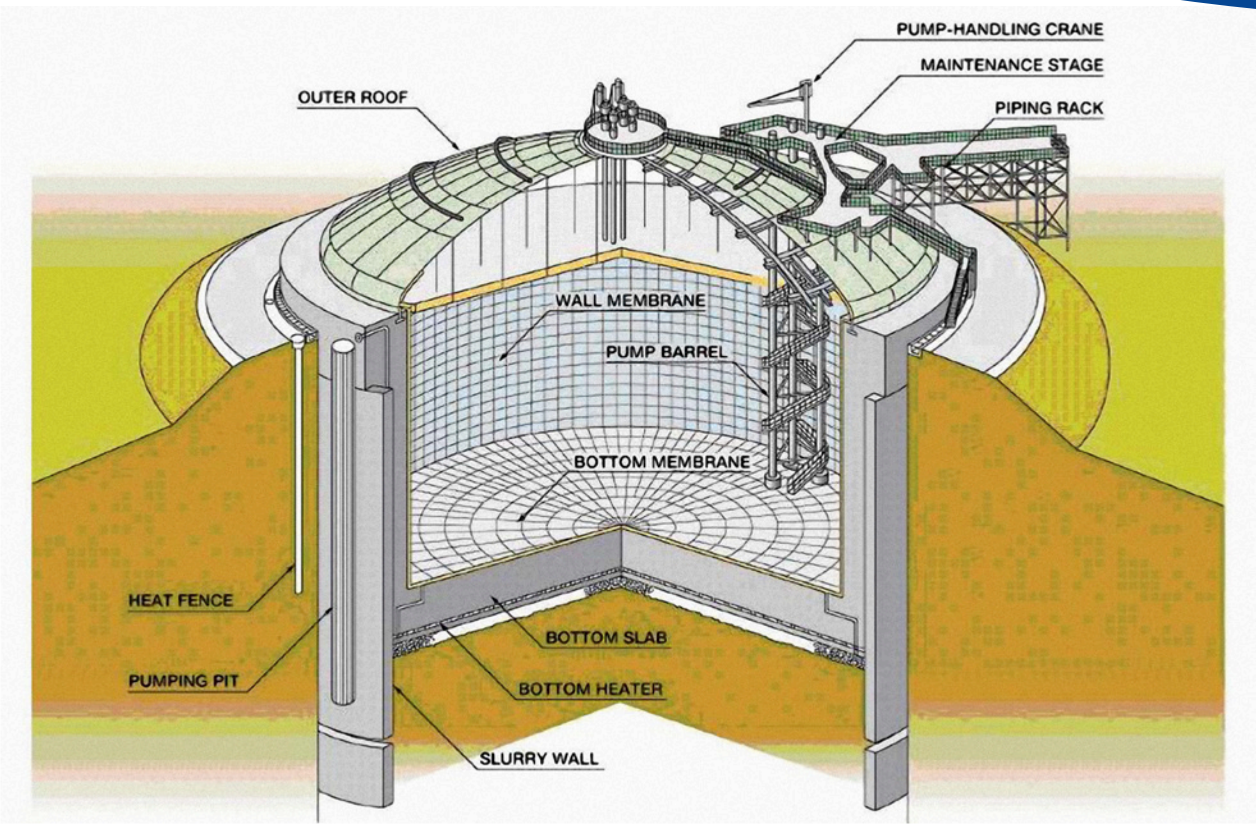


Figure 7 : In-ground storage tank *(Source: Kawasaki Heavy Industries, Ltd.)*

LEAK AND SPILL CAPTURE

In over 50 years, there have not been any incidents concerning LNG tanks which have had any impact beyond the terminal boundary.

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 approximately -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;
- 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. Dykes 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 key points of this information paper are:

1. In an industry in which safety considerations are paramount, containment is the primary requirement for LNG safety. This is underscored by the degree to which related codes, equipment, regulations, procedures and systems permeate all of our efforts.

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.

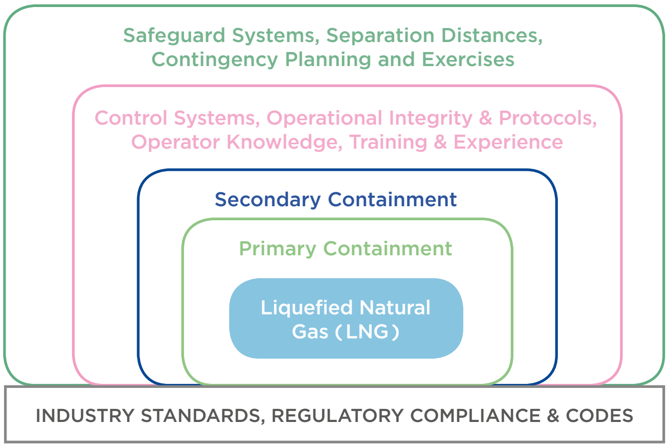
3. Various kinds of tanks are used around the world, including Single Containment Tanks, Double Containment Tanks, Full Containment Tanks, Membrane Tanks and In-ground Tanks.

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 detection devices and response systems 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.

As reflected in the illustration below, the Multiple Safety Layers for LNG are all firmly based on a foundation of solid Industry Standards, Regulatory Compliance and Codes, many of which are developed by the foregoing associations and regulatory bodies. These "safety layers" include several key components of the industry's Risk Management framework. Included among them are 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 further enhances the safe management of LNG.

Multiple Safety Layers Manage LNG Risk



For more information about these and other topics, or to obtain copies of this report series contact:

GIIGNL
8 rue de l'Hôtel de Ville
92200 Neuilly-sur-Seine (France)
Telephone: +33 (0)1 56 65 51 60 Email: central-office@giignl.org
Web address: https://giignl.org