LNG INFORMATION PAPER

#6

2019 Update

Managing LNG Risks
Industry Safeguard Systems

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 operational safeguards which the industry implements as standard practices to detect, control and minimize potential effects from a release of LNG.

SAFETY SAFEGUARDS IN MANY LAYERS

The safety of LNG worldwide is the result of high industry standards, effective regulations, and a fervent industry commitment to rigorous risk management. Regardless of the type of LNG facility, there are multiple layers of protection implemented to minimise the likelihood of an LNG release. **Information Papers No. 4 and 5** describe ways in which the industry maintains operational integrity through regulations, codes, standards and best practices, and how the LNG is contained in various types of storage tanks. This paper describes industry safeguard systems designed to immediately detect, control and mitigate the consequences if a release of LNG were to occur in the import terminal.

There are two types of safety features in an LNG facility: management systems and equipment/technology systems. Management systems include studies during the design process which first identify hazards and then review the design to ensure that these hazards can be controlled or mitigated. During the operational phases, procedures are written to ensure that safe working practices are encouraged, inspections and maintenance are conducted in an appropriate and timely manner and that the impact on the public and employees of any unexpected circumstance is minimised.

With regard to safety equipment and technology, LNG facilities have multiple levels of hazard detection, mitigation and intervention systems. There are two types of intervention systems: those based on passive technology, which require no interaction, and active systems, where action is either automatic or an operator is prompted to take action.

PREVENTION

LNG facilities and LNG carriers are viewed in the industry as the "top of the line". This view is justly predicated on their high quality, robust safety systems and overall attention to detail in design, solid construction and stringent operational practices. All of these factors collectively serve to prevent accidents, incidents and product releases of any kind. The excellent safety record of the industry is substantive evidence of this commitment. There was a (single) major tank failure incident, which occurred in Cleveland, Ohio, US in 1944 at the beginning of the LNG industry, resulting in a fire and a number of fatalities. This incident is discussed in detail in **Information Paper 9 (Q&A's).** At the time of the Cleveland incident, the safe storage practices required for cryogenic liquids were not fully understood. Since then, the LNG industry has implemented safety improvements to prevent situations which could lead to or cause such incidents. Examples of standard practices which are now established around the world to prevent leaks and their escalation include the following:

- Compliance with known and proven codes and standards for designing and siting new facilities;
- Siting new facilities a safe distance from adjacent populations based on risk assessments;
- Construction of special materials and inclusion of systems designed to safely insulate and store LNG at temperatures of -162°C (-259 °F);
- Various codes and standards for maintenance and inspection of equipment in LNG service;
- Overpressure protection (pressure controllers and relief valves);
- Leakage detection and spill control through temperature probes;
- Ignition source control;
- Fire zoning;
- Emergency depressurising;
- Passive fire protection, e.g., fireproofing, fire resistant barriers and coatings; and
- Active fire protection.

Additional standard devices and practices specifically for tanks include:

- Cool-down temperature sensors on the tank wall and base;
- Leak detection equipment, e.g., temperature sensors, and low temperature alarms, located in the annular space;
- LNG tank gauging systems to provide remote readings, with high/low level alarms which trigger emergency shut down systems; and
- Combined temperature and density sensors to detect rollover potential.

In Europe, the Seveso III Directive requires a complete Safety Management System for the control of major-accident hazards. This System must include a safety study with a risk analysis and relevant measures for the mitigation of consequences. The final risk level must be acceptable to the authorities.

In the US, the regulations generally require that these worst-case spill hazards are contained within the perimeter of the owner's property such that risk to the public is near zero.

In Japan, JGA (Japan Gas Association) published safety guidelines for aboveground and underground LNG tanks. It contains design layout (security distance etc.), disaster prevention facilities (safety valve, security electricity, etc.), monitoring (alarming) system, communication system, shutdown system and maintenance philosophy for these safety facilities. JGA also published safety guidelines for gas manufacturing facilities containing same contents as mentioned above. These guidelines were updated in 2017 based on the experience of 'The 2011 off the Pacific coast of Tohoku Earthquake' adding countermeasures against Tsunami.

Locating LNG facilities and vessels a safe distance away from adjacent industry, communities and other public areas provides the assurance of protecting citizens from potential hazards in case a serious incident occurs. In the current environment, where there is a threat of terrorism, the public is understandably concerned that bulk storage of a flammable energy source represents a risk. Separation of LNG from the public can take the form of exclusion zones for facility-siting or safety zones around LNG ships while underway. The separation distances used in codes, standards, and regulations are based on risk assessments and scientific analyses.

In addition to industry best practices and governmental requirements, financial institutions specify guidelines to assure that LNG facilities are safe and worthy of financing and insurance. The World Bank Group states in its guidelines that the layout of an LNG facility (and the separation distance between the facility and the public and/or neighbouring facilities outside the LNG plant boundary) should be based on an assessment of risk from LNG fire (entitled a "thermal radiation profile prediction"), vapour cloud ("flammable vapour cloud dispersion characteristic prediction"), or other major hazards. The results of such risk assessments define the recommended separation distance for a proposed facility. Generally in Europe, depending upon the design and storage capacity of the subject facility, risk assessments recommend a separation distance from residential, recreation areas, or other public built-up areas. In simple terms, separation distances ensure that the surrounding public is protected from the consequences of any credible LNG release at a terminal.

The industry standards and regulations described in **Information Paper No. 4** reduce the likelihood of a release. If a release were to occur, the consequence is minimised through the use of secondary containment and active safety mitigation systems described in this paper.

Figure 1 illustrates multiple layers of protective measures, for instance, to prevent the escalation of an LNG leak into a pool fire and to minimize the consequences of such an incident. The occurrence of a hazardous event, in this case, a pool fire, would require the simultaneous and very unlikely failure of several, independent layers of protection.

The layers of protection implemented at terminals include risk mitigation measures such as the following:

- **Spacing and design of pipes, equipment and storage tanks:** they must be made of specific materials in order to resist cryogenic temperatures and avoid LNG leaks. LNG tanks are equipped with integral impoundment.
- **Detectors:** Facilities are constructed with a variety of leak detection devices, including cameras, temperature sensors and various kinds of very specific detectors (for discovering fire, flame, gas, smoke or tank overfill). This detection equipment communicates to the control centre and can automatically trigger emergency shut-down systems (some examples are shown in Figure 2).

- **Emergency shut-down (ESD) valves**: In case of fault detection, ESD valves are automatically closed to prevent the further loss of LNG.
- **Impounding areas**: In the event of an LNG leak, the spill is contained in these areas to control its spread, vaporisation rate and, if a pool fire occurs, to minimise the consequence outside the terminal.
- **Fire control systems**: LNG fires can be mitigated with fire-fighting systems available throughout the terminal.
- **Vapour reduction systems**: if an LNG pool has formed, foam generators can be used to reduce the rate of vapour formation and movement.
- **Trained operators**: operators are always present in the terminal to control operations and ensure rapid response to any emergency condition, including making emergency notifications to agencies and responders, as well as an emergency broadcast to the community.

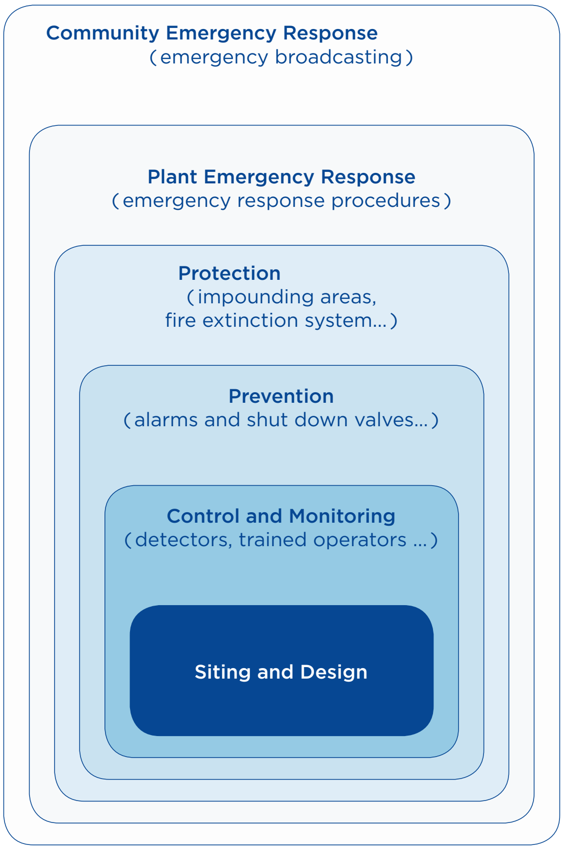


Figure 1. Layers of protective measures to prevent escalation of an LNG leak into a pool fire *(Source: BV 2009)*

Operations and maintenance personnel in LNG facilities are required to be trained, both initially and periodically thereafter, in:

- The hazards of LNG;
- The hazards of operation and maintenance activities;
- How to recognise breaches of security and execute security procedures;
- Understanding the potential causes, types, sizes and predictable consequences of fires and knowing and following fire prevention procedures;
- How to perform their assigned functions during both normal operations and emergencies; and
- How to provide first aid.

Verification of compliance with these requirements is performed by each national dedicated Authority.

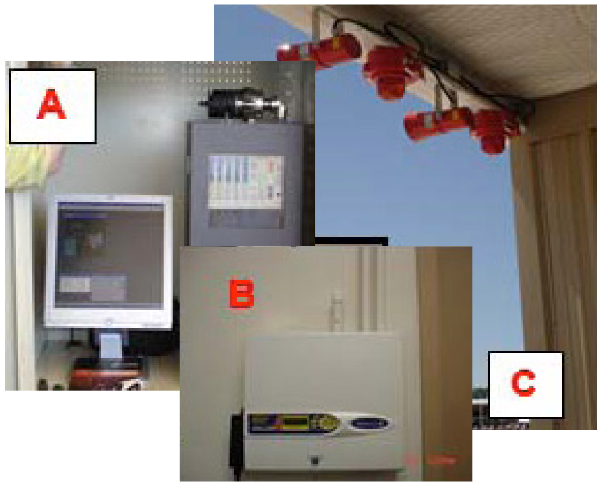


Figure 2. Detection and warning devices for LNG terminals: A) flame detection monitoring in a control room, B) aspirating smoke detector, and C) audible alarms
(Photos provided by A.H. Walker)

DETECTION

Several systems incorporate monitoring and control devices to detect deviation from acceptable parameters, thereby enabling corrective action to prevent unsafe conditions. Standards and codes require that combustible gas detectors and low temperature detectors are located at places where an LNG release might occur and where LNG or low temperature vapour might accumulate. In Europe, the code is: EN 1473. In the US, they are: NFPA 59A 49 CFR Part 193.2507, Subpart I and 49 CFR Part 127.201-3. These detectors are continuously monitored. They also have alarms set just above the detection levels and automatic shutdowns at hazard levels.

For facilities on land, monitoring systems are required by EN 1473 in Europe, 49 CFR Part 193 and NFPA 59A in the US and JGA-10 in Japan. Onboard ship, monitoring systems are required by the International Gas Carrier Code, the classification society's requirements and the USCG requirements of 46 CFR 153-154 and 33 CFR Parts 127, 160-169.

In addition to the code-required instrumentation specifically for leak detection, there is abundant normal process instrumentation which will alert an operator to an abnormal condition which may or may not be caused by leakage. Many areas are either covered by remote TV cameras or are visible to a plant operator or to a crew member from a ship's control room. An LNG release of any size is easily recognized visually, because of the condensation of water vapour from the atmosphere within any resulting cloud.

All LNG facilities have equipment to detect an LNG release and to initiate immediate notification so as to control the leak or spill. Vapour and liquid detection equipment is used to detect problems, set off alarms and monitor flammable vapours. Remote monitoring screens, e.g., in a control room, provide a means to instantaneously see the situation and manage the overall facility. Closed-circuit TV is used to monitor operational areas in the terminal and serve as a secondary visual system for the gas, flame, and fire detectors. Detection and initial response equipment includes:

- Cryogenic liquid detection.
- Leak detectors designed to detect low temperatures,
- Gas or vapour detection,
- Smoke detectors,
- Flame detectors,
- Safety alarms,
- Emergency shut down valves to limit the quantity of LNG released, and
- Secondary containment designed to mitigate the consequences of release.

Continuous improvements are made in detection systems.

CONTROL AND MITIGATION

A hazardous event (e.g., a pool fire) could only occur due to simultaneous failure of several independent layers of protection.

If a liquid spill is detected, emergency shut-down valves may be automatically activated depending upon the situation, e.g., size of the spill and the location. They can also be activated manually by push buttons at the jetty, control room, around the terminal and on the LNG ship (when it is at the jetty). The emergency shut-down system stops all pumps and closes off all piping so that the LNG stays either in the storage tanks or on the ship if there is a ship offloading. In many terminals, emergency-release couplings on the unloading arms or flexibles, used to transfer LNG between the ship and the shore, are quick break-away lines that shut the unloading system down and allow the ship to move away from the jetty.

If a leak is detected, actions are taken to:

- Prevent fire by securing the leak and the area, eliminating ignition sources, and monitoring vapours until no flammable vapours remain;
- Warn and shelter facility workers and notify authorities as required or appropriate;
- Control vapour dispersion with foam and/or water curtains;
- Use water spray to increase the vaporisation rate of the LNG (rapidly warm it), which will facilitate a more rapid mixing and dilution of LNG vapours to outside flammable limits, and help them warm more quickly to the temperature at which they will become buoyant and rise away from ignition sources and people on the ground (see Information Paper No. 1); and
- Control and manage/mitigate incidents if vapours are ignited, using dry chemical powder or foam, and applying water to plant equipment (not the LNG fire) to cool it down.

High-expansion foam and water-spray curtains help control LNG vapours in a proactive manner. The application of foam to LNG spills on land, or water spills that are contained, e.g., in a storm drain or small pond, is an effective hazard control technique. Applying and maintaining a “blanket cover” of high-expansion foam can help to minimise ignition risk and/or to manage vaporisation rates and vapour dispersion, when either of these actions is appropriate for the specific situation. The use of water curtain sprays to form water barriers between LNG vapours and potential ignition sources can also be an effective risk mitigation technique for a liquid spill. Dry chemicals can be applied to extinguish flames if the vapours in a contained area ignite. High-expansion foam has proven effective in reducing flame height and radiant heat.

In the event of a leak or spill, responders wear personal protective equipment (PPE) while undertaking control and mitigation actions. Common PPE equipment in industrial operations includes safety goggles, steel-toed boots, gloves, and hard hats. In an LNG facility, PPE for protection from cold liquids and vapours, e.g., face shields suitable for contact with cryogenic materials, are also standard. During an LNG incident, additional personal protective equipment might include a breathing apparatus (depending upon the magnitude of any gas release), since LNG vapours can displace oxygen and lead to asphyxiation, along with fire protection gear such as:

- Full protective clothing (coat and trousers),
- Anti-flash hood,
- Fire helmet with visor,
- Fire gloves, and
- Fire boots.

INSPECTIONS

Government agencies routinely inspect LNG facilities and ships to verify that safety measures have been correctly applied and maintained. Inspections vary among countries, or regions. For example:

- Europe The Safety Management System, required by the European Directive Seveso III and implemented by the operator, includes internal control loops for every safety activity. In addition, verification of compliance is made by oversight agencies and inspections are performed by local authorities.

- US Safety activities and inspections are under the jurisdiction of several agencies: the US Coast Guard, the Pipeline and Hazardous Materials Safety Administration (PHMSA) of the US Department of Transportation, and the Federal Energy Regulatory Commission (FERC). All of these agencies inspect terminal operations after start-up. Each agency will verify safety compliance with their respective jurisdictions through inspections. The inspection rate is chosen by the responsible agency and will vary by facility.
- Asia In Japan, the Ministry of International, Trade and Industry (MITI) prescribes inspection frequencies.

EMERGENCY RESPONSE PLANS

Being prepared for any emergency is an essential activity for LNG terminals and ships. A set of preparedness activities conducted before an incident helps assure that any incidents that do occur are well managed and mitigated. To be most effective, preparedness activities are conducted in a sequence, where the results of one activity leads into another, with the end result being that overall preparedness is constantly improving. This is referred to as the Preparedness Cycle (**Figure 3**). Preparedness is achieved and maintained through a continuous cycle of planning, organising, training, equipping, exercising, evaluating, and taking corrective action. Ongoing preparedness efforts among all those involved in emergency management and incident response activities ensure coordination during times of crisis.

A good emergency response plan helps assure that responders have optimal control over an incident. Beginning to plan response actions at the time of an incident is an extra but avoidable challenge. For this reason, LNG facilities prepare and maintain emergency response plans which identify potential credible incident scenarios and then develop specific actions to mitigate the consequences of such incidents.

The regulations of countries, including the US and Europe, and companies, specify the content of these plans. For example, emergency response plans for import terminals, which in the US are required by FERC and must be approved before the terminal even begins operations, must include scalable procedures for responding to:

- Emergencies within the LNG terminal;
- Emergencies that could affect the public near an LNG terminal;
- Emergencies that could affect the public along an LNG vessel transit route;
- Methods for notifying agencies and the public; and
- Training and exercises using the plan.

It is important to involve all response stakeholders (including adjacent facilities) in the planning process to develop the plan. The facility emergency response plan is prepared in consultation with appropriate local and national governmental agency representatives, including first responder representatives. The valuable benefit of a plan is the planning process of working through incident management issues.

Figure 3. Preparedness cycle *(Source: US FEMA)*

Another key component of emergency planning is the training of all emergency responders, which incorporates coordination, communication, drills and exercises. Hazards and mitigation scenarios are identified and used to develop responses and role assignments. Simulated emergencies, both table-top and full-scale, are used to validate the effectiveness and efficiency of both individual responders and responding organisations. Field exercises provide an opportunity to practice hands-on skills and cultivate expertise.

Participating in such training and exercises helps assure that the emergency response plan will be well understood by the organisations with responsibilities during an incident and that they are ready to respond effectively in the unlikely event of an emergency.

KEY POINTS AND CONCLUSIONS

In closing, the key points of this information paper are:

1. Industry safeguard systems are designed to immediately detect, control and mitigate the consequences of any LNG release in an import terminal.

2. There are two types of safety features in an LNG facility: equipment/technology systems and management systems. The former include multiple levels of hazard detection, mitigation and intervention systems. The subject intervention systems may be active systems, requiring an operator to act or being automatically started, or passive systems, requiring no interaction.

   Management systems, include, among other things, studies during the design process which first identify the hazards and then review the design to incorporate steps which eliminate or control/mitigate the hazards. They also include, for example, the drafting, refinement and implementation/dissemination of sound operating procedures and safe working practices.

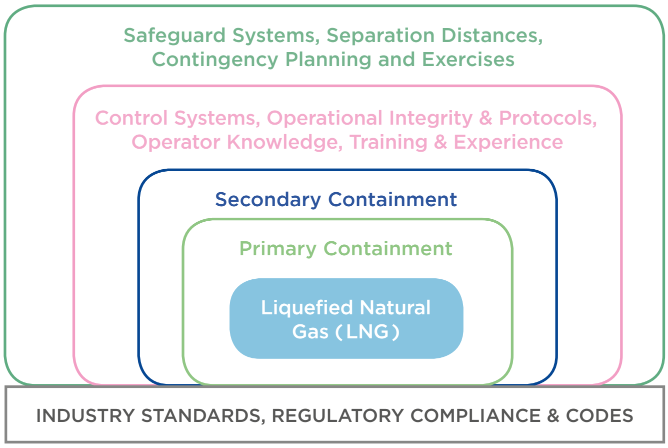
3. Safety design of facilities, systems, and equipment in the LNG industry are generally viewed as "top of the line", largely due to their high quality, robustness and implicit attention to detail.

4. The tragic accident in Cleveland, Ohio, US over 60 years ago, when LNG first became commercially viable, resulted in a fire and a number of worker and public fatalities. As a result of the exhaustive subsequent investigation, a comprehensive number of safety precautions have been implemented and are in effect throughout the industry.

5. Typical layers of protection implemented in modern LNG terminals are graphically illustrated in **Figure 1.** These layers begin, in a sense, with the Siting and Design of the terminal. The next layer reflects the Control and Monitoring features (including, for example, detectors and trained operators). Prevention components include alarms, shut-down valves, etc. Protection is provided by elements such as impounding areas and fire extinction systems. Company management of the incident is provided by implementing the Plant Emergency Response procedures. In addition, Community Emergency Response begins with notification about the leak or other incident, which activates governmental oversight, mobilizes additional response resources to reinforce the facility's response, and thereby protects the public and adjacent properties.

The goal of this series of papers has been to identify and describe the many components which comprise LNG safety along with providing a global sense of LNG risk management.

Multiple Safety Layers Manage LNG Risk



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