Liquefied Natural Gas Operations

An Overview

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1. Introduction

Liquefied Natural Gas (LNG) operations require a high level of technical expertise, the implementation of rigorous safety protocols, and precise coordination between ship and shore personnel. This document provides an overview of the key aspects of LNG handling, including pre-shipment evaluation, some important operational challenges, cargo care, and monitoring procedures. It is developed with the intention of supporting safe, efficient, and compliant LNG transfer and carriage by outlining best practices, preventive measures, and essential documentation requirements for all stakeholders involved in LNG operations.

LNG is natural gas cooled to approximately -162°C, reducing its volume by about 600 times which enables efficient storage and transportation in specialized vessels equipped with insulated tanks to maintain cryogenic temperatures. The LNG trade has expanded significantly and requires strict operational protocols and highly trained personnel.

Composition of LNG

LNG is primarily composed of methane (CH_4), typically making up 85–95% of its volume. Other components include:

Ethane (C_2H_6): 1–10%
Propane (C_3H_8): <2%
Butanes (C_4H_{10}): trace amounts
Nitrogen (N_2): up to 1%

Other hydrocarbons: trace levels depending on source.

The exact composition varies depending on the origin of the natural gas and the processing method adopted. The presence of solids or heavier hydrocarbons can lead to freezing in cryogenic systems, blockages in pipelines or pumps, and operational challenges in LNG processing and storage.

2. Pre-Shipment Evaluation

LNG Terminal – Compatibility & Safety Checklist

Before arriving at any LNG terminal, it is essential to complete compatibility checks and proper preparation to ensure safe operations and cargo transfer. These checks should confirm:

- Secure mooring arrangements
- Safe and accessible ship boarding
- Proper gangway alignment, the landing area appropriate to the gangway footprint.
- Loading arm compatibility
- Reliable ship-to-shore communication systems, including radio and data links

Additional key checks to include:

- Emergency communication protocols aligned, and Emergency Shutdown (ESD) signal compatibility verified.
- Cargo transfer equipment such as:
    - Manifold alignment and Flange compatibility
    - Hose/loading arm specifications (pressure rating, diameter, material)
    - Quick Connect/Disconnect (QCDC) systems – tested for fit and functionality

- ESD interface testing to confirm that both ship and terminal systems can communicate and activate shutdowns, initiate pre-transfer ESD test to verify signal transmission and response time. (Warm / Cold as determined).
- Instrumentation and Control Systems (e.g. tank level gauges, temperature and pressure sensors) must be:
  - Calibrated
  - Compatible with terminal systems
- Custody Transfer Systems (CTS) must be synchronised and verified.
- Safety systems, including gas detection, operational and aligned with designated coverage zones.
- Fire suppression systems should be compatible in terms of activation zones and coordinated response.

Pre-Transfer Cargo Conference

Before operations begin, a cargo conference should be held to:

- Review and agree on loading/unloading procedures
- Confirm ramp-up and ramp-down rates
- Align on alarm protocols and emergency response plans
- Agree ESD test sequence, warm/cold
- Clarify roles and responsibilities of all personnel

2.1 Operational Issues in LNG Systems / Cargo Manifold Strainer Clogging

Cargo manifold strainer clogging can occur during loading or discharging due to entrained solids or heavy hydrocarbons and may lead to flow restrictions and operational delays.

Best practices to mitigate these issues include:

- Conducting pre-loading checks for cargo quality and composition.
- Perform routine inspection and cleaning of strainers and filters.
- Monitoring Boil Off Gas (BOG) composition to detect early signs of contamination.
- Ensuring crew training on emergency response and system diagnostics.

A structured guide for Onboard Troubleshooting and Fault Diagnosis, tailored to the vessel's specific design should be followed, particularly when dealing with cryogenic systems and BOG management.

Common Troubleshooting Areas

Component	Symptoms	Checks	Actions
Cargo Manifold Strainers	Reduced flow during loading/discharging	Differential pressure across strainers; visual inspection for waxes, ice or debris	Isolate and clean strainers; consider heating or flushing if waxes are present
BOG Compressors (PRS/FRS)	High inlet pressure, low flow, or compressor trips	Inlet filter/demister condition; vibration and temperature readings	Clean or replace filters; inspect demisters for icing or hydrocarbon buildup. Robust PMS.
Cold Box Strainers	Reduced reliquefaction efficiency or flow restrictions	BOG composition; cold box temperature gradients	If heavy hydrocarbons suspected, initiate N_2 warm-up procedure (16–18 hrs)
Fuel Gas Pump Strainers	Engine fuel starvation; pump cavitation	Suction pressure and flow rate	Clean strainers; check for wax or hydrate formation
Cargo Tank Cooling	Slow cooldown after ballast voyage	Tank temperature profiles; BOG availability and flow	Use controlled BOG flow or N_2 to assist cooldown; avoid rapid cooling to prevent thermal stress

Preventive Measures

Regular filter and strainer maintenance
Pre-loading cargo quality checks
System purging before and after extended idle periods
Crew training on emergency procedures and warm-up protocols

2.2 Documentation and Certification

Prior to any LNG operation, the following documentation and certifications should be reviewed and verified:

- Ship and terminal operational manuals: Ensure procedures are aligned and clearly understood by all parties.
- Certificates of fitness for LNG operations: Confirm validity and compliance with regulatory standards.
- Calibration records for critical equipment: Verify that instruments such as tank level gauges, temperature sensors, and pressure monitors are accurately calibrated.
- Tank inspection reports: Confirm readiness of cargo tanks.
- Cool-down procedures: In order to prevent thermal shock during initial loading.
- Custody transfer system verification: Ensure systems are synchronised and measuring instruments are properly calibrated.

- Cargo documentation: Examine LNG composition, boil-off rates, and any special handling requirements.

These checks are essential to ensure operational safety, regulatory compliance, and accurate cargo accounting during LNG transfer operations.

2.3 Rollover

LNG rollover is a hazardous phenomenon that occurs when stratified layers of LNG within a storage tank suddenly mix. This rapid mixing releases large volumes of vapour, which can lead to overpressure, triggering of emergency venting systems or, in extreme cases, a loss of containment and the formation of LNG liquid pools.

Stratification typically arises when, due to slow or uneven filling, LNG layers of differing densities and temperatures form. Studies have shown that even a small density difference—as low as 1 kg/m^3 (0.001 t/m^3)—can result in stable stratification, particularly when the LNG fill rate is very slow.

This hazard has been observed in shore terminals and is a potential risk for ships—especially Floating Storage Regassification Units (FSRUs) —that remain stationary for extended periods. In such cases, the lack of motion prevents natural mixing, allowing stratification to develop. Conversely, vessels underway at sea are less prone to rollover due to the sloshing effect induced by the vessel movement, which promotes mixing.

Once stratification becomes unstable, the layers can mix suddenly, releasing trapped thermal energy in the form of vapour. This can cause a rapid increase in tank pressure and compromise containment integrity.

Additionally, when the density of any LNG retained on board as ''heel[1]'' is lower than that of the incoming cargo, the potential risk of stratification can be high, and precautionary measures should be taken before loading

In light of the above the following procedure is suggested to mitigate the potential risk of stratification if identified prior to loading:

- Consolidate the heel into one tank.
- Partially load a second tank to a level such that there is room to transfer any remaining heel into the tank.
- Close the manifold liquid valves-leaving the vapour manifold open.
- Transfer the heel into the partially filled tank. This should be done using the ship's cargo pumps as fast as is safely possible, prudence and vapour generation permitting. The reason for speed is to promote turbulence in the bottom of the receiving tank to aid mixing.
- Do not load any further LNG into the tank containing the mixture.
- Complete loading the other tanks as per normal procedures.

Any necessity to adopt the above procedure is to be carefully discussed between ship and shore before the commencement of loading.

Heel is the small volume of cargo that may be retained in the cargo tanks upon completion of discharge. The heel is used to condition the cargo tanks in preparation for the next loading cycle, reducing the time in the loading port. Following the LNG loading process, the remaining ''heel'' will mix with the fresh cargo and stay blended throughout the voyage.

Should, against previous advice, a ship load and it is subsequently determined that there is a risk of stratification, the following may give some indication that stratification has occurred:

- Reduction in boil-off gas flow rate below normal.
- Tank level not decreasing at the anticipated rate; indeed, it may even increase.
- Careful monitoring of the CTS temperature probes shows the lower tank temperatures increasing whilst the upper temperatures remain substantially constant.

These indicators may be small and masked by other factors. If it is determined that a ship is at risk of rollover, the only remedy is to discharge all the cargo as soon as possible into a shore receiving tank that has the appropriate mixing arrangements. This can understandably have serious commercial and operational implications and it is therefore of paramount importance that the risk of rollover is carefully assessed before loading.

2.4 Stratification in LNG Tanks

Contributing Factors:

- Slow or uneven filling
- Temperature gradients
- Lack of tank agitation (e.g., in stationary vessels or terminals)

Associated Risks:

- Vapour release
- Overpressure
- Activation of safety systems
- Potential damage to containment systems

Preventive Measures:

- Monitor density gradients during loading
- Avoid slow fill rates
- Use tank mixing systems or rely on ship motion
- Conduct rollover risk assessments

The most effective stratification and rollover prevention is to avoid the need for mixing LNG and to load only into "empty" cargo tanks. SIGTTO Guidelines define an empty cargo tank as one that contains less than 800 m3 of LNG. The exact figure may vary depending on the type and size of the vessel and tank design. To acquire the exact figures, the manufacturer of the cargo tank should be consulted.

3. Carriage of Cargo

During transit, LNG naturally evaporates as Boil-off gas (BOG), even with the very efficient insulation systems that are now available. The BOG can be managed either by reliquefication or used as fuel, while tank pressure and temperature are continuously monitored. Specialised cargo containment systems such as membrane or Moss-type tanks preserve the structural integrity of the vessel as carriage involves transporting liquefied natural gas at cryogenic temperatures in vessels designed to maintain product integrity and safety throughout the voyage.

4. Cargo Care and Monitoring

Cargo monitoring involves continuous surveillance of tank parameters to ensure safety and operational integrity during LNG transport.

Key Monitoring Areas:

- Tank Levels, Pressure, and Temperature:
  - Continuous monitoring using tank radar or float-type level gauges to prevent overfilling and ensure accurate custody transfer.
  - Temperature maintained at approximately -162°C; any rise may indicate increased boil-off gas (BOG) generation.
  - Pressure monitored to remain within design limits; pressure relief valves and venting systems act as safeguards.
- Gas Detection Systems:
  - Integrated systems for early leak identification.
- Insulation and Inter-Barrier Spaces:
  - Regular checks for signs of overpressure, leaks, or fire.
  - Monitoring of inter-barrier spaces (IBS) and insulation spaces (IS) for anomalies:

- IBS (between primary and secondary barrier): pressure maintained at 0.5–1.0 kPa above atmospheric.
- IS (between secondary barrier and inner hull): pressure maintained at 0.5–1.0 kPa above IBS.

Use of SIGTTO IBS monitoring for proactive detection of insulation degradation or leaks. SIGTTO IBS (Inter-barrier spaces)

4.1 Safety and Alarm Systems

Robust safety infrastructure ensures immediate response to hazardous conditions.

System Components:

- Gas and Fire Detection:
  - Continuous monitoring in cargo and void spaces.
  - Immediate alarms for methane presence above threshold limits.
  - Flame detectors and heat sensors installed in cargo zones.
- Fire Suppression:
  - Systems include dry chemical and water mist technologies.
- Data Logging and Reporting:
  - Voyage Data Recorders (VDR) and Integrated Automation Systems (IAS) log:
    - Tank levels
    - BOG rates
    - Temperatures
    - Alarms and anomalies

    Daily reporting ensures traceability and operational awareness.

Conclusion

The safe and efficient handling of LNG cargoes demands unwavering attention to detail, robust operational discipline, and a proactive approach to risk management. By adhering to established protocols, maintaining rigorous checks, and fostering a culture of continuous learning, we can mitigate operational hazards and uphold the highest standards of safety.

Supportive Information

For further information on this or other Loss Prevention topics please contact the Loss Prevention Department, Steamship Insurance Management Services Ltd.

Tel: +44 20 7247 5490 Email: loss.prevention@simsl.com

References

LNG Operations – An Overview

SIGTTO Liquefied Gas Handling Principles

INTERTANKO LNG Operational Guidance

IMO STCW LNG Training Requirements

IMO guidelines-related-to-marpol-annex-vi.aspx

IMO ESD Cargo emergency shutdown (ESD) system Guidance

SIGTTO Recommendations for management of cargo alarm systems