LNG Operations: safety issues and procedures

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Agenda

• Definitions
• LNG market overview
• LNG issues, properties and hazards
• Elements of safety
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  • Transfer procedures
  • Pre-bunkering operations
  • Bunkering operations
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• Regulatory framework
• Conclusions
Definitions

- Bunkering (Loading) Temperature: At atmospheric pressure, natural gas will liquefy at a temperature of about \(-162^\circ C \text{ (}-260^\circ F)\). As LNG increases in temperature, its vapor pressure increases and its liquid density decreases. These physical changes need to be considered because they may increase the required storage tank volume and pressure rating.

- Filling Limit: The filling limit of an LNG tank is the maximum allowable liquid volume in the tank, expressed as a percentage of the total tank volume. The filling limit is not the same as the loading limit. The maximum filling limit for LNG cargo tanks is 98 percent at the reference temperature. This same limit is expected to apply to LNG fuel tanks. A higher filling limit may be allowed on a case-by-case basis based on requirements from classification societies and regulatory bodies.

- Reference Temperature: The reference temperature is the temperature corresponding to the saturated vapor pressure of the LNG at the set pressure of the pressure relief valves. For example, if the LNG tank has a pressure relief valve set pressure of 0.7 barg (10.15 psig), then the reference temperature is \(-154.7^\circ C \text{ (}-246.4^\circ F)\), which is the temperature that natural gas will remain a liquid at 0.7 barg (10.15 psig).

- Loading Limit: The loading limit is the maximum allowable liquid volume to which the tank may be loaded, expressed as a percentage of the total tank volume. This limit depends on the LNG densities at the loading temperature and reference temperature.

- Heel: The volume of LNG that is normally left in the tank before bunkering is called the tank heel. This small volume of LNG keeps the LNG tank cold before it is refilled during bunkering. The required tank heel should be calculated with the assistance of the tank designer and fuel gas designer based on several variables such as tank size and shape, ship motions, heat inflow from external sources, gas consumption of the engines, and bunkering and voyage schedule. As a general rule of thumb, for initial design considerations a tank heel of 5 percent can be assumed. Usable Capacity: In general, the usable capacity of the LNG tank is equal to the loading limit minus the heel, expressed as a percentage of the total tank volume. The usable capacity is the consumable volume of bunkered LNG in the tank.
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LNG Market overview

- The LNG market remains buoyant as all of the major importing regions are seeing increases in LNG imports since 2011 accounting nearly to 10% on a year over year basis.
- An even greater growth in global LNG trade is largely-slowed down mainly due to constrained export capacity. So despite being in need of increasing volumes of LNG in the short term there will not be a major growth until gains from projects around the world (Australia) begin to come on-stream.
- Ship demand growth will continue to exceed fleet growth for the following years while the overall vessel supply surplus is moving roughly between the 10-20% range across the 2010-2015 horizon.

![LNG Carrier Supply and Demand Graph](image)
The majority of LNG trade is carried out through sea and mainly through the following countries:

From:
- Libya
- Algeria
- West Africa
- Alaska & Australia
- Borneo & Venezuela
- Persian Gulf
- Saudi Arabia

To:
- Italy & Spain
- France & UK
- Belgium & Netherlands
- USA & Japan
- USA & Japan
- USA & Japan
LNG trade routes

- Cove Point
- Lake Charles
- Algeria to Europe and USA
- Nigeria to Europe and USA
- Europe
- Turkey
- Oma
- Taiwan
- Malaysia
- South Korea
- Japan
- Australia
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Environmental impact

• One of the main reasons for building vessels fueled with LNG is their environmentally friendly profile both under normal operations and in the event of an accident. Using LNG instead of diesel is more environmentally friendly for the following reasons:

• Burning LNG as a fuel instead of diesel reduces the greenhouse gas emissions (CO2 and HC) due to the higher hydrogen ratio in LNG compared to diesel or HFO. The release of NOX, SOX and particles are reduced significantly (82-84 %, 100% and 67 %, respectively). The reductions are dependent on engine size and type.

• Methane gas might be released through the vent mast due to different reasons, such as pressure build up in the LNG tank. Methane is a more severe greenhouse gas than CO2 (greenhouse gas potential 20 to 25 times greater than CO2) and therefore methane releases should be kept to emergencies only. Running the engines or boiler on gas to lower the pressure in the LNG tank is better for the environment then lowering the pressure by releasing methane. The most likely source of methane releases will be due to purging of the gas pipes to ensure that no gas is trapped. This will be done when shutting down the engines or switching to diesel fuel. The amount of methane gas released in these scenarios will most likely be minor as well as the frequency thereof.

• Accidental spills of LNG to the marine environment would result in a relatively small and thin film, which is so volatile it would only affect the immediate surroundings. The majority of the fuel would evaporate immediately and be removed from the sea. Comparatively, a diesel oil release of the same magnitude (same mass of fuel) would result in an oil slick about 1000 times larger, more persistent and much more detrimental to sea-mammals, birds, and aquatic wildlife.

• Releases of sub-surface LNG (a worst-case scenario for releases to the aquatic environment during e.g. capsizing) would result in a gaseous flow to the surface of methane and ethane, which could saturate the surrounding waters with these gases. The concentrations are not, however, considered sufficiently high to cause long-term effects on the affected environment. The components that may be liquid at deeper waters (butanes and pentanes) have such a low density that these too are expected to flow rapidly to the surface if released after e.g. capsizing or sinking of the vessel. Rapid dilution of these components, to concentrations well below acute and chronic effect levels, ensures that negligible environmental effects are expected from such a spill.
Issues for LNG operations

• The LNG industry has an excellent safety record. This strong safety record is a result of several factors.

• First, the industry has technically and operationally evolved to ensure safe and secure operations. Technical and operational advances include everything from the engineering that underlies LNG facilities to operational procedures to technical competency of personnel.

• Second, the physical and chemical properties of LNG are such that risks and hazards are well understood and incorporated into technology and operations.

• Third the standards, codes, and regulations that apply to the LNG industry further ensure safety. While we in the U.S. have our own regulatory requirements for LNG operators, we have benefited from the evolving international standards and codes that regulate the industry.
LNG industry considerations and risk mitigation

- The LNG industry is subject to the same routine hazards and safety considerations that occur in any industrial activity.
- Risk mitigation systems must be in place to reduce the possibility of occupational hazards and to ensure protection of surrounding communities and the natural environment.
- As with any industry, LNG operators must conform to all relevant national and local regulations, standards, and codes.
- Beyond routine industrial hazards and safety considerations, LNG presents specific safety considerations.
- To consider potential LNG hazards, we must first understand the properties of LNG and the conditions required in order for specific potential hazards to occur.
LNG properties

- LNG is an extremely cold, non-toxic, non-corrosive substance that is transferred and stored at atmospheric pressure.
- It is refrigerated, rather than pressurized, which enables LNG to be an effective, economical method of transporting large volumes of natural gas over long distances.
- LNG itself poses little danger as long as it is contained within storage tanks, piping, and equipment designed for use at LNG cryogenic conditions.
- However, vapors resulting from LNG as a result of an uncontrolled release can be hazardous, within the constraints of the key properties of LNG and LNG vapors – flammability range and in contact with a source of ignition.
Potential hazards

- The potential hazards of most concern to operators of LNG facilities and surrounding communities flow from the basic properties of natural gas are:
  1. Explosion.

An explosion happens when a substance rapidly changes its chemical state — i.e., is ignited — or is uncontrollably released from a pressurized state. For an uncontrolled release to happen, there must be a structural failure — i.e., something must puncture the container or the container must break from the inside. LNG tanks store the liquid at an extremely low temperature, about -256°F (-160°C), so no pressure is required to maintain its liquid state. Sophisticated containment systems prevent ignition sources from coming in contact with the liquid. Since LNG is stored at atmospheric pressure — i.e., not pressurized — a crack or puncture of the container will not create an immediate explosion.
Potential hazards

2. Vapor Clouds. As LNG leaves a temperature-controlled container, it begins to warm up, returning the liquid to a gas. Initially, the gas is colder and heavier than the surrounding air. It creates a fog – a vapor cloud – above the released liquid. As the gas warms up, it mixes with the surrounding air and begins to disperse. The vapor cloud will only ignite if it encounters an ignition source while concentrated within its flammability range. Safety devices and operational procedures are intended to minimize the probability of a release and subsequent vapor cloud having an affect outside the facility boundary.

3. Freezing Liquid. If LNG is released, direct human contact with the cryogenic liquid will freeze the point of contact. Containment systems surrounding an LNG storage tank, thus, are designed to contain up to 110 percent of the tank’s contents. Containment systems also separate the tank from other equipment. Moreover, all facility personnel must wear gloves, face masks and other protective clothing as a protection from the freezing liquid when entering potentially hazardous areas. This potential hazard is restricted within the facility boundaries and does not affect neighboring communities.

4. Rollover. When LNG supplies of multiple densities are loaded into a tank one at a time, they do not mix at first. Instead, they layer themselves in unstable strata within the tank. After a period of time, these strata may spontaneously rollover to stabilize the liquid in the tank. As the lower LNG layer is heated by normal heat leak, it changes density until it finally becomes lighter than the upper layer. At that point, a liquid rollover would occur with a sudden vaporization of LNG that may be LNG Safety and Security - 19 – too large to be released through the normal tank pressure release valves. At some point, the excess pressure can result in cracks or other structural failures in the tank. To prevent stratification, operators unloading an LNG ship measure the density of the cargo and, if necessary, adjust their unloading procedures accordingly. LNG tanks have rollover protection systems, which include distributed temperature sensors and pump-around mixing systems.
Potential hazards

5. Rapid Phase Transition. When released on water, LNG floats – being less dense than water – and vaporizes. If large volumes of LNG are released on water, it may vaporize too quickly causing a rapid phase transition (RPT). Water temperature and the presence of substances other than methane also affect the likelihood of an RPT. An RPT can only occur if there is mixing between the LNG and water. RPTs range from small pops to blasts large enough to potentially damage lightweight structures. Other liquids with widely differing temperatures and boiling points can create similar incidents when they come in contact with each other.

6. Sloshing. The advent of LNG offshore terminals implies certain risks associated with tanks only partially filled with LNG. Carrying LNG in partially filled tanks could lead to sloshing - a violent motion of the fluid. Sloshing could lead to an increased high pressure of LNG on the tank walls, especially in an abnormally harsh wave environment. Possible sloshing effect might require additional modifications to LNG cargo systems, especially taking into account increasing size of LNG carriers. Several engineering organizations, including Det Norske Veritas (DNV) and Norwegian Marine Technology Research Institute, have projects underway, researching this important safety issue.

7. Earthquakes and Terrorism. The unexpected risks of earthquakes and terrorism
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Elements of safety

- Beyond routine industrial hazards and safety concerns, LNG presents specific safety considerations. Safety in the LNG industry is ensured by four elements that provide multiple layers of protection both for the safety of LNG industry workers and the safety of communities that surround LNG facilities. Additionally, these critical safety conditions are all integrated with a combination of industry standards and regulatory compliance.
Elements of safety

• Primary Containment is the first and most important requirement for containing the LNG product. This first layer of protection involves the use of appropriate materials for LNG facilities as well as proper engineering design of storage tanks onshore and on LNG ships and elsewhere.

• Secondary containment ensures that if leaks or spills occur at the onshore LNG facility, the LNG can be fully contained and isolated from the public.

(The term “containment” is used to mean safe storage and isolation of LNG)
Elements of safety (cont.)

- **Safeguard systems**: In the third layer of protection, the goal is to minimize the release of LNG and mitigate the effects of a release. For this level of safety protection, LNG operations use systems such as gas, liquid, and fire detection to rapidly identify any breach in containment and remote and automatic shut off systems to minimize leaks and spills in the case of failures. Operational systems (procedures, training, and emergency response) also help prevent/mitigate hazards. Regular maintenance of these systems is vital to ensure their reliability. LNG operations use technologies such as high level alarms and multiple back-up safety systems, which include Emergency Shutdown (ESD) systems.

  - ESD systems can identify problems and shut off operations in the event certain specified fault conditions or equipment failures occur, and which are designed to prevent or limit significantly the amount of LNG and LNG vapor that could be released. Fire and gas detection and fire fighting systems all combine to limit effects if there is a release. The LNG facility or ship operator then takes action by establishing necessary operating procedures, training, emergency response systems, and regular maintenance to protect people, property, and the environment from any release.

- **Separation Distance**: LNG facility designs are required by regulation to maintain separation distances to separate land-based facilities from communities and other public areas. Safety zones are also required around LNG ships.
Element of safety (cont.)

- Industry Standards/Regulatory Compliance. No systems are complete without appropriate operating and maintenance procedures being in place and with insurance that these are adhered to, and that the relevant personnel are appropriately trained.

- Organizations such as: the Society of International Gas Tanker and Terminal Operators (SIGTTO), Gas Processors Association (GPA) and National Fire Protection Association (NFPA) produce guidance which results from industry best practices.

- Industry standards are written to guide industry and also to enable public officials to more efficiently evaluate safety, security, and environmental impacts of LNG facilities and industry activities. Regulatory compliance should ensure transparency and accountability in the public domain.
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The LNG value chain

- The major components of the value chain include the following:
  - Natural gas production: the process of finding and producing natural gas for delivery to a processing facility.
  - Liquefaction: the conversion of natural gas into a liquid state so that it can be transported in ships.
  - Transportation: the shipment of LNG in special purpose ships for delivery to markets.
  - Re-gasification: conversion of the LNG back to the gaseous phase by passing the cryogenic liquid through vaporizers.
  - Distribution and delivery: of natural gas through the national natural gas pipeline system and distribution to end users.
  - Storage: is a major focus for safety and security. Once natural gas is liquefied, it is stored before shipment or loaded directly into the ship. LNG ships are required to have double hulls by regulation (International Maritime Organization) to facilitate safe transportation by sea. LNG receiving terminals and re-gasification facilities store LNG before it is re-gasified for pipeline transportation.

![Diagram of the LNG value chain](image)
Further on, information on the critical features of major LNG facilities as they relate to safety and security are provided.

- A typical, onshore LNG receiving terminal and re-gasification facility, like those that currently exist and ones that are planned or proposed, consists of marine facilities, LNG receiving and storage facilities, and vaporization facilities.
Description of LNG facilities

• Marine Facilities.

The LNG dock facilities are designed to berth and unload LNG from ships. Tugboats provide assistance when berthing. The dock is designed to accept a specified size range of LNG ships.

• LNG Receiving and Storage Facilities.

Once the LNG ship is moored and the unloading arms on the dock have been connected, the ship's pumps will transfer LNG into the onshore LNG storage tanks. Offloading generally takes about 12 hours depending on cargo size. Double-walled tanks store LNG at atmospheric pressure. LNG is a cryogenic fluid, and it is not stored at high pressures, so an explosion of LNG from overpressure is not a potential hazard. The issues regarding LNG storage tanks apply both to the liquefaction and re-gasification facilities because the storage tanks are of the same design. New technologies enabled offshore LNG storage and re-gasification.
Description of LNG facilities

• LNG Vaporization Facilities.
  Each LNG storage tank has send-out pumps that will transfer the LNG to the vaporizers. Ambient air, seawater at roughly 59°F (15°C), or other media such as heated water, can be used to pass across the cold LNG (through heat exchangers) and vaporize it to a gas.

• Typical types of vaporizers that have been used worldwide for LNG regasification are:
  • Open Rack Vaporizers (ORV)
  • Submerged Combustion Vaporizers (SCV)
  • Ambient Air Vaporizers (AAV)
  • Intermediate Fluid Vaporizers (IFV)
Types of vaporizers used in LNG facilities

- Open rack vaporizers (ORV) and submerged combustion vaporizers (SCV) are the most common vaporization methods in existing regasification terminals, which have generally been located in the subequatorial region.

- Recent LNG receiving terminal activities have been shifting to the equatorial region where the weather is warmer, and the use of intermediate fluid vaporizers (IFV) is found to be attractive.

- Important factors that should be considered in the LNG vaporizer selection process are:
  - Site conditions and plant location
  - Availability and reliability of the heat source
  - Customer demand fluctuation
  - Emission permit limits
  - Regulatory restrictions with respect to the use of seawater
  - Vaporizer capacity and operating parameters
  - Safety in design
  - Operating flexibility and reliability
  - Capital and the operating cost
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LNG Operational transfer procedure

• The bunkering procedures should aim at establishing a safe and time efficient truck to ship bunkering procedure for LNG, encompassing the entire bunkering operation, both the operational bunkering process and the technical solutions needed. Therefore certain Conditions and requirements are needed:

1. Approval: Before commencing any bunker operations it is necessary to have the Coast Guard’s approval for LNG bunkering.

2. Ship and supplier compatibility: It must be clarified that mooring and bunker equipment are compatible in design so that the bunker operation can be conducted in a safe way before commencing any operations.

The following points are to be confirmed by communication:

• Possibility for safe and effective mooring/immobilizing of the trucks

• The relative freeboard difference

• Type and size of hose connections and manifold flanges

• Connection order of the manifolds • Compatibility of ESD and communication systems

• Operational envelope (motions, weather, visibility)

• Ex-zone, hazardous zoning and ventilation

• Spill protection systems; drip tray arrangements and water sprays for ships with different draft

• Compatibility of safety management systems
LNG Operational transfer procedures

3. Transfer Area: The transfer area is determined and approved by the Coast Guard. Points to be considered are:
   - Safety zone
   - Waves, current, swell and weather conditions
   - Tidal conditions
   - Maneuvering space
   - Simultaneous operations during LNG bunkering

4. Weather Conditions: Weather and current forecast for the area are to be studied before commencing a bunkering operation.

5. Light Conditions: The bunkering operation will be accomplished during the shutdown period overnight without passengers or vehicles on board the vessel. The shutdown occurs after dark. Intrinsically safe light is provided at each terminal where bunkering will occur. Sufficient light is required in all hazardous and safety zones on board and onshore as well as for all the open air transfer lines which requires monitoring during the filling operations.

6. Warning Signs: There shall be warning and instruction signs posted around hazardous areas of the vessel. The signs are to be placed clearly visible and according to an accepted guideline for placement of warning signs. The warning signs are to cover the risks of handling cryogenic liquid, fire and safety issues and show restricted areas.
LNG Operational transfer procedures: safety issues

• The Chief Engineer is at all times responsible for the bunkering operation and should not allow safety issues to be influenced by the actions of others. They are to ensure that correct procedures and check-lists are followed and that safety standards are maintained and that the ship system and procedures are according to approved rules and regulations.

• EX-Zone and hazardous zone: The bunkering area is to be an EX-classified and restricted area during bunkering. Only authorized personnel are allowed in these areas during bunkering. The terminal must establish a prohibited zone with warning signs to secure the bunker operation area. The size of the EX-zone shall be according to the IGF Code for Zone 1. Special attention must be given to existing equipment such as high voltage cables and their insulation and protection. The Zone 1 is within 3m (9.8 ft) of any bunker manifold valve, flange or gas tank outlet. Use of EX-proof tools is decreed while in the EX-zone. It should be clearly communicated that storage of combustible waste within the EX-Zone and hazardous zone is prohibited. There should be adequate means (marking of equipment, fences and EX signs) such that safety of the operation cannot be affected by unauthorized personnel. Inside these zones (including Zone 1, 2 and exclusion zone) all electrical equipment is required to be intrinsically safe. Vessel and terminal staff should not carry any lighters, cell phones or other portable electronic devices. Recommended protective equipment generally concerns face shield, hearing equipment, gloves, protective overall, protective footwear and other equipment (i.e. VHF) which are intrinsically safe.
LNG Operational transfer procedures: safety issues

• ESD-System: In the case that a hazardous situation (e.g. operation mal-function or security violations) occurs, appropriate safeguards shall be implemented in order to detect that a release has occurred, reduce immediate consequences and prevent escalation. Each truck and ferry shall have an independent Emergency Shut-Down system for a quick and safe shutdown of the transfer pump and all bunkering system valves in case of an emergency.

• The ESD system shall be appropriate for the size of and type of facility and shall be activated by some or all of the following:
  - Gas detection
  - Fire detection
  - Manual activation from ship and facility
  - Ship drift/movement of supply vehicle
  - Power failure
  - High level in receiving tank
  - Abnormal pressure in transfer system
LNG Operational transfer procedures: safety issues

- Check-Lists: Each ship is to have internal individual check-lists for before, during and after bunkering. For the bunkering operation there shall be a common check-list which is to be filled out and signed by responsible operators on the truck and the ferry before any operation is commenced.

- Instructions (Routines): There shall be written detailed instructions for the bunkering process with regards to responsibility and actions to be made in case of malfunction or emergency. The instructions are to be quickly available at all times and all personnel involved in bunkering operations are to be familiar with the content and location of the instructions. The instructions should cover the following areas:
  - Loss of communication or control system (ESD)
  - Loss of power
  - Handling of cryogenic products including the use of personal protection equipment and EX-proof tools, ice formation and awareness of sharp edges.
  - Waves and weather conditions
  - Collision and impacts from ships or trucks
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Pre-bunkering operations

1. Preparations: The following steps shall be made prior to start of the operation and noted on the Before Bunker Check-list:
   • The bunkering operators should ensure that the drip trays are not damaged and properly positioned
   • Safety zone on ferry activated and checked
   • EX-zone and hazardous zone is safe and clear
   • Fire equipment on trailer and ship checked and ready for use
   • Personal protection equipment on trailer and ship checked and prepared for use
   • ESD system on the ship and trailer checked and ready for use
   • Where operations permit, it should be best practice not having the gas engines running at any time during bunkering of LNG.
   • Lighting installations to be checked and cleared

2. LNG Tank System Check: Liquid level, temperature and pressure for the fuel tanks of the receiving vessel should be checked from the Integrated Automation System (IAS) in prior to bunkering and noted on the pre-transfer bunker checklist. If the temperature of the receiving tank is significantly higher than the bunker tank, there will be an initial vaporization when starting to transfer the LNG. This will increase the tank pressure and can trigger the pressure relief valve to open if the pressure exceeds the set limit. The pressure of both tanks must be reduced prior to the bunkering in case of a high receiving tank temperature. The trailer operator and CE are to confirm that both ship and trailer LNG tanks combined temperature and pressure range are within the safety limits before commencing transfer.
Pre-bunkering operations

3. Mooring Equipment Check: Lines, fenders, winches and other mooring equipment are to be visually checked for wear or damages. Equipment should be replaced or the transfer aborted if there are any doubts about equipment quality and safety.

4. Bunker Hose Check: Bunker hoses are to be visually checked for wear or damages and that the hose markings are correct for the actual transfer operation. Bunker hoses should be replaced if there are any doubts about equipment quality and safety. Pressure testing of the transfer equipment should be commenced on reasonable regular intervals.

5. Check-List for “operations before bunkering”: Both the LNG truck and the Ferry are to have a checklist (declaration of inspection) which contains the steps to be made and documented specific for each ship before the bunkering process commences.
Pre-bunkering operations

6. **Call** The CE shall notify the port of the time schedule of the bunkering and location by the normal VHF contact channel. Also, the working channel for VHF communication, emergency signal, contingency plan and terms of the operational envelope is to be agreed upon.

7. **Arrangement Plan** The ferry shall supply, if requested, a sketch with information about placement of the trailer and transfer pump in relation to the bunker station and storage tanks. The Arrangement Plan shall show the number of lines and dolphins and their locations with respect to the transfer span and location of the shore side approach.

8. **Mooring Operation** The ferry shall be moored in a safe manner with respect to weather conditions such as wind, tide and current. The bunker station should be placed on the forward section of the curtain plate to ensure a good access on the No 1 End between the transfer span and the bow of the boat, additional lines should be ready for use if needed.

9. **Mooring Lines Supervision** Mooring lines are to be under supervision during the total bunkering operation. Special attention is to be given when bunkering during heavy weather or when other vessels are in the area.

10. **Connection of Communication Link** Optionally, there can be a separate communication link which is located at the bunkering station. This panel would contain a wired communication system with the following:
    - Have a direct line phone system
    - View the level, temperature and pressure of the receiving tanks
    - Monitor alarms.
    - Include the emergency stop control instead of a separate box
11. Connection of Hoses: The hoses are to be supported over their entire length from the vessel to the transfer pump and from the transfer pump to the bunkering station.

All connections and handling of hoses shall be accomplished by trained personnel from the ferry, before operation commences. Each manifold shall be equipped with an insulating flange near the coupling to prevent a possible ignition source due to electrostatic build-up. The hoses with couplings should not touch any un-grounded part before connection to avoid possible electrical arcing.

The bunker hose should be connected by emergency release couplings (ERC) or dry break away couplings. Dry break away couplings will decrease the LNG spill in case of an emergency where a hose decoupling is required and also increase the safety profile of the vessel as the time for full retraction of the vessel decreases.

The hose connections can, if possible, be of different sizes for increased safety reason to eliminate the possibility of error in the connection point. Proper marking by color is also recommended to avoid mix-up.

12. LNG Bunker Hose: The LNG bunker hoses are to be clearly color-marked so that there will be no risk of using an incorrect hose type. The hoses must be in good condition, have suitable length for the actual transfer and supported to avoid overstressing or chafing during transfer.

13. Pre-Transfer Bunker Declaration of Inspection: The pre-transfer checklist is a mutual document with steps to be made on the trailer and vessel, and signed by authorized persons to confirm that all points are addressed. The operator is responsible for the checklist to be properly filled in and signed before delivery to the receiving ship. The Chief Engineer will accept the checklist and issue the order to proceed after alerting the pilothouse that the bunkering is to commence.
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Operations during bunkering

1. Return of Documents:
   - Signed Declaration of Inspection: The declaration of inspection is to be filled out, signed by the CE on the vessel and returned to the trailer operator before starting any transfer. A copy of the signed declaration of inspection is to be kept on board the vessel for a minimum of one month (ref. 33 CFR 127.317(b)). No bunker operations are to begin until this declaration of inspection is signed by both parties.
   - Signed document with Agreed Amount and Transfer Rate: A document, clearly stating the quantities of fuel to be transferred, the transfer rate, start and topping up rate and maximum pressure at manifold, is to be filled out and signed by the CE and truck operator. This document can be combined with the pre-transfer checklist mentioned above. The signed document is to be kept on board the ferry for three months.

2. Inerting the Transfer Lines:

   Inerting with Nitrogen is performed in order to remove moisture and Oxygen in the piping and hoses. This is to reduce the risk of explosion and clogging of the lines by hydrate formation. Nitrogen is usually supplied from a bank on board the vessel. The person responsible for the inerting sequence should note level and pressure of Nitrogen bottles in prior to inerting. In general the inerting is stopped after a certain number of minutes controlled by the IAS and based on experience of when piping and hose conditions are satisfactory. The inerting sequence may also be controlled by visual condition monitoring of the bunker lines.
Operations during bunkering

3. Purging the Liquid Filling Line:

The pipelines are purged with NG after the inerting sequence due to engine specifications on Nitrogen tolerance.

There are different handling designs and practices for the purged amount of NG from the vessel’s cold tank.

Venting of the purged gas to the atmosphere will be restricted in future regulations and measures are taken to prevent gas emissions during bunkering. The IGF Code states that the bunkering system should be so arranged that no gas is discharged to air during filling of the storage tanks. Measures that are common for prevention of purging to the atmosphere are LNG system and design dependent

4. Open Manual Bunker Valves:

The trailer operator may close the road relief valve set at 30 psig. The main relief valve is set at 75 psig. Pressure is built in the trailer by allowing LNG from the bottom of the tank to flow and vaporize through a pressure build-up coil on the underside of the trailer.

Once the pressure in the trailer and the receiving tanks are within 10 psig, the operator shall open the manual bunkering valves (line up the transfer path). It is important to check that the remote controlled bunker valves are closed, by visually checking the valve indicator, prior to opening the manual valves. There shall be one engineer at the bunkering station and transfer pump and a second engineer at the storage tanks to monitor the tanks. The chief engineer shall oversee the operation and will monitor the situation at the communication panel at the bunkering station.
Operations during bunkering

5. Ready Signal:

When the manual valves are confirmed to be opened and the personnel are confirmed to be outside the safety zone, the operator and the ferries’ engineers confirm that they are ready to commence bunkering by giving a ready signal by VHF or optional communication link. The CE will initiate the bunkering.

6. Pump Start Sequence:

After ready signals are given and personnel are out of the bunker area, the transfer pumps can be started and ramped up in a controlled manner until the agreed start transfer rate is achieved. This sequence is to be closely monitored on both ship and truck for possible leaks, hose and equipment behavior and system functions.

The party responsible for operation, control and monitoring of the pump shall be defined and clearly communicated in prior to instigating operations. If any problems or suspicions of problems are detected, transfer is to be shut-down immediately and not started again until satisfactory checks and actions are performed. The start sequence transfer rate is to be upheld for an agreed time, giving time for monitoring and also cooling down of the system before the transfer rate is increased.
7. Bunkering:

When the pump start sequence is completed the transfer pumps can continue to ramp up in a controlled manner until the agreed rate is achieved under constant supervision and monitoring of the equipment and the system. This rate can be withheld during the transfer until the agreed amount is almost reached. The transfer is to be continuously monitored with regards to system pressure, tank volume and equipment behavior.

The actual working pressure relative to the maximum allowable working pressure, 130 psig, of the receiving vessel’s bunker tank is generally automatically controlled by sequential filling. Sequential filling is encountered by sequentially spraying of LNG in from the top of the tank and pumping of LNG into the bottom of the tank. Spraying on top gives a condensing of the accumulated vapor in the tank which results in a pressure decrease. Pumping in at the bottom of the tank increases the pressure.

If the tank pressure exceeds the limit for maximum allowable working pressure, the filling will be aborted and the pressure relief valves will open to vent automatically. In any case of this event, the cargo pump should be stopped to avoid cavitations.

The delivery pressure should be controlled during bunkering. A too high delivery pressure will jeopardize personnel and equipment safety, whilst a too low delivery pressure can result in flow reversals. The system pressure is monitored in the IAS and visually by pressure gauges coupled to the system and filling lines at all times during the filling sequence. Pressure relief and venting is to be arranged for at all times in case of trapped liquid between two valves.
Operations during bunkering

All loading control is with the receiving vessel. Tank pressure and liquid level is to be monitored and noted from the IAS for bunkering control. On shore personnel is to respond accordingly through the communication channels that are set up (i.e. VHS).

The filling sequence may be aborted at all times during the operation by three redundancy systems:

a) The IAS
b) The ESD system
c) Manual shut down procedures upon closing of the safety valves

Activating a stop or hold in the IAS or ESD will automatically give a reactive response to pneumatic valves. When a stop order has been given, the bunker hose is to be held open until the hose is manually confirmed empty.

The cargo pump shall have pressure gauges on suction and discharge that will quickly shut down the pump in case of leakage during transfer.
Operations during bunkering

8. Pump Stop Sequence:

The cargo pumps shall be ramped down to an agreed topping up rate when the total transfer amount is almost reached. The final filling requires special attention on the receiving ship to watch the tank level and pressure. The maximum level for filling the LNG tanks is 86% of total volume to allow for cooling the tank to accept the residual LNG in the line.

The receiving ship operator is to signal, by VHF or optional communication link to the bunkering station when the required amount of fuel is reached. The engineer will then secure the transfer pumps. The ESD system will automatically stop the bunkering sequence at a maximum liquid level in the fuel tanks.
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Operations after bunkering

1. Stripping of the transfer lines:

   The liquid that remains in the bunker hoses, after the pumps have stopped, must be drained before disconnection. Heated LNG-vapor from the trailer is to be blown through the hose in order to purge the hose. The valves at the transfer pump are to be closed when the purging is completed.

   When the bunkering is complete, the vapor return line is closed as well as the liquid fill line at the truck. The remaining LNG will be pushed up the line by a build-up of pressure on the truck side with a simultaneous reduction of pressure in the storage tank. The maximum operating pressure of the trailer is 67 psig. The differential pressure required to purge the line of LNG is approximately 18 psi from the bunkering station to the storage tank.

   A temperature sensor should be clamped on the liquid filling line in the cold box to indicate and transmit an approximate liquid temperature. During stripping, the temperature can be monitored in the IAS for phase and state control.

2. Close Manual and Remote controlled valves:

   Once the line is purged of LNG, the valves at the storage tank are to be closed. First the remote controlled valves are to be closed and then the manual valves.

3. Purging of the transfer lines:

   The bunkering line purge valve is opened and the line is purged with nitrogen to remove any NG left in the transfer lines in prior to disconnecting. The vapor return line purge valve is opened and charged with nitrogen. The bunkering line can be purged with nitrogen from either the transfer pump trailer or from the bunkering station. The vent return line is purged from the bunkering station.
Operations after bunkering

4. Disconnection of Hoses:

The bunker lines and vapor return, on the LNG trailer, can be disconnected after the lines have been purged from NG and valves are closed.

The ERC couplings are to be disconnected with attention to possible dripping of fuel. If a second LNG trailer load will be delivered, the hoses between the transfer pump and trailer shall be purged with nitrogen before the first LNG trailer is moved. When the second trailer is in position, a second Pre-bunkering Checklist will be completed prior to the transfer of fuel. There should not be any sharp edges in the hose handling area.

5. Disconnection Communication Link:

The communication link, if available, is to be disconnected and returned to the EOS
Operations after bunkering

6. Delivery Bunker Document:
   The LNG trailer is to deliver a document, in 2 copies, clearly stating the quantity and quality of fuel transferred, signed by the responsible officer. Both copies are to be signed by the receiving ship personnel. One signed document is to be kept by the driver and the other document on board the ferry for three (3) months.

7. Inerting of Bunker Lines:
   The vessel must inert the bunker line and vapor return line before departure on board the vessel, which means that the inerting sequence is to start as soon as the hoses are disconnected from the manifold and run until the lines are gas free. The trailer does not need to inert before departure since the hoses are stored on the trailer and are ventilated. To avoid the risk of forgetting to inert the bunker hoses, there shall be an inerting section in the After Bunker Check-list to be checked out within 10 minutes after departure and an alarm signal on the main switchboard if inerting valve has not been activated within 60 minutes from stopping the cargo pumps.

8. Check-list After Bunker:
   Both the trailer and the receiving ship are to have a checklist which contains steps to be made in order to safely shut down the bunkering system. The checklist shall specifically document the ship and bunkering event after the bunkering process is completed.
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Bunkering with LNG is a new process that presents a number of unique risks and hazards not seen with oil fuel bunkering. For that reason, most regulatory organizations having jurisdiction over vessel design, operation, and bunkering are focusing their attention on it. Many new regulations and requirements are being developed and implemented, so keeping abreast of the regulatory framework is important to anyone involved with LNG bunkering.

The primary organizations that will be involved with reviewing LNG bunkering system designs and arrangements, as well as possibly the fueling procedures, are as follows.

- **Classification Societies**: Classification societies, such as ABS, will have a major role in reviewing the design and construction of LNG bunkering systems on board gas fueled vessels (receiving ships) and any LNG bunker vessels. Besides reviewing the design and surveying construction according to its own Rules and standards, class societies may be the reviewing organization for compliance with national and international regulations on behalf of the flag Administration and some port States.

- **Flag Administrations**: Flag Administrations, such as the USCG, the UK Maritime and Coastguard Agency (UK MCA), and other national maritime agencies, have primary responsibility for enforcing international and national regulations related to the bunkering systems, processes, and procedures. International regulations are primarily those issued by IMO. National regulations apply to vessels registered in that country. Most of the nations where LNG fueled vessels will be actively operating have developed or are in the process of developing national regulations. National regulations can be more restrictive than class Rules or international regulations. Some flag Administrations may delegate all or part of their review and approval process to classification societies, while others will carry out the review and approvals themselves.

- **Port States**: Port States are actively involved in the LNG bunkering process because they are the locations where the actual bunkering process will take place and, thus, any of the risks to life, environment, and property will be borne in their waters. The port State will have primary jurisdiction over any land-based facilities that may be part of the LNG bunkering process. Port State regulations will likely cover more parts of the bunkering process than either class Rules or flag Administration regulations. For example, port States could include requirements on the actual bunker procedure, locations where bunkering is permitted, restrictions on bunkering times and weather conditions, simultaneous cargo operations, bunkering supply facility, training, required documentation, acceptability of risk assessments, permits, etc. Since port States (and local jurisdictions within the port State, such as port authorities, harbor masters, and local and regional governments) can have a broad authority over the bunkering process it is important to determine early on which ones will be involved, particularly at the local or port level.
Regulatory Framework: Regulatory Organizations and Required Approvals

- Required Approvals:

Classification societies, flag Administrations and port States will likely each require review and approval of some aspects of the receiving gas fueled vessel and/or the bunker supplier. The flag Administration and port States are also likely to require the review and approval of the LNG bunkering procedures.

The approval process has the potential to be far more extensive than for oil fuel bunkering because of the additional complexity and hazards encountered with LNG. In order to reduce the risks for major design changes and delays, it is critical that the approval process be initiated early on in the development of a project involving an LNG fueled vessel or an LNG bunkering supply facility or vessel.

Design details and operating procedures may be specific to a variety of different bunkering scenarios, bunkering vessel types and bunkering locations, so the preparations for the approval process may need to be quite comprehensive.

Detailed consultation and collaboration with the classification society and the regulatory organizations are recommended. All parties involved in the project development should be prepared to submit detailed designs, reports, analyses and procedures to the multiple reviewing organizations.

Approvals may need to be revisited or applied for anew because regulations are in the process of being finalized and, thus, there may be a need to re-apply when final regulations are issued. As bunkering scenarios and bunker suppliers change overtime, new approvals also will likely be required.
Overview of Regulations

• There are a wide variety of regulations and requirements applicable to an LNG bunkering operation because of the multiple organizations with jurisdiction over it.
• This section will highlight some of the major ones:
• International Maritime Organization (IMO) The IMO has the primary responsibility for the development of requirements for ships involved in international voyages. There are specific references that apply to LNG fueled vessels in the two primary IMO regulations applicable to vessels – SOLAS and MARPOL. But the primary regulations addressing vessels that have LNG on board are found in the IMO Codes and Guidelines identified as follows.
IMO Codes and Guidelines

- IGC Code: The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) is the primary code for LNG carriers. The IGC Code is applicable to any internationally trading bunker supply vessel to which SOLAS is applicable or when required to be applied by class, national or port regulations. It is not applicable to vessels that carry LNG as engine fuel only. However, it provides criteria for LNG carriers using LNG cargo boil-off as fuel and has been used as guidance in the development of rules and regulations intended to be applied to LNG fueled vessels. The IGC Code has been in effect for many years and reflects the knowledge gained from years of safe and reliable LNG transport across the oceans.

- MSC.285(86): In June 2009, IMO issued resolution MSC.285(86) as an interim measure to provide guidance for the first LNG fueled vessels. The resolution is voluntary and may or may not be utilized by flag States. Pending the adoption of the IGF Code, it is the pertinent IMO guidance. It contains criteria on the design, construction, arrangement, safety, and operation of LNG fueled vessels for use by flag Administrations. There are no specific requirements for the LNG bunkering operation, but the hardware and systems used for bunkering are covered.

- IGF Code: The International Code of Safety for Ships using Gas or Other Low Flashpoint Fuels (IGF Code) is currently being developed by IMO. The IGF Code will replace the current IMO guidance document (MSC.285(86)).
  - IMO’s Maritime Safety Committee’s 94th session, which met from 17 to 21 November 2014 approved, in principle, the IGF Code as well as two amendments to SOLAS Chapter II-1:
    - One amendment introduces a new Part G which mandates the application of the IGF Code to cargo ships ≥ 500 gt and passenger ships using natural gas as fuel; and
    - A second amendment revises Part F Regulation 55 to account for the IGF Code requirement that ships using other low-flashpoint fuels (methanol, propane, butane, ethanol, hydrogen, dimethyl ether, etc.) need to comply with the functional requirements of the Code through the alternative design regulation based on an engineering analysis. Operationally dependent alternatives are not permitted.
Industry Standards & National regulations

• ISO/TS 18683:2015: An ISO technical specification titled Guidelines for Systems and Installations for Supply of LNG as Fuel to Ships was released in January 2015. It describes the properties of LNG, the safety hazards, the risk assessment process, and the functional requirements for LNG bunkering systems. While ISO/TS 18683:2015 is not specifically a standard or regulation, it is expected to be cited in many national and local regulations. Under direction from IMO, ISO has indicated that a standard for LNG bunkering connectors will be developed for publication at the same time the IGF Code enters into force.

• While with regards to National Regulations: Some nations are in the process of issuing their own regulations covering the LNG bunkering process. Most are still in the draft stage and are subject to change as the regulatory framework for LNG bunkering evolves. Some of the key regulations are as follows.
The European framework

• The use of LNG as vessel fuel in non-LNG carriers was developed first in Europe, particularly in Norway. Regulations and requirements for LNG bunkering in the early projects in Norway were developed on a case by case basis. Reference was made to the guidelines and standards for LNG cargo transfer and to risk assessments for the planned bunkering operation.

• Currently, in some places in Northern Europe LNG bunkering is a daily occurrence, including bunkering taking place with simultaneous cargo and passenger operations, and in these instances an appropriate safety and regulatory framework was developed for that particular port, but it is well recognized in the European Union (EU) and countries outside the EU, such as Norway, that a more comprehensive regulatory framework is needed.

• In anticipation of the growing use of LNG as a fuel in Europe, the European Maritime Safety Agency (EMSA), national governments, port authorities and regional planning groups have carried out studies on what regulations and standards are currently applicable to LNG fuel use and bunkering and what gaps exist that should be filled by new regulations and standards. One key study issued in 2012 was a final report based on an EMSA commissioned study on standards and rules for bunkering gas-fuelled ships. It provides a comprehensive overview and gap analysis of the regulatory framework for LNG bunkering in Europe. Table 1 in the next slide from the EMSA study is a summary of the different approaches being taken to the regulation of LNG bunkering in the primary LNG bunkering nations.
National approaches to LNG in Europe

Table 1: National Approaches to LNG Bunkering in Europe

<table>
<thead>
<tr>
<th>No.</th>
<th>Country</th>
<th>Regulation of gas fueled ships</th>
<th>Regulation of bunkering LNG</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Belgium</td>
<td>Interim Guidelines MSC.285(86): not transposed in Belgian law</td>
<td>No regulation on national level; ports are responsible</td>
<td>MSC.285(86) was not implemented in Belgian law. The final IGF Code will be implemented.</td>
</tr>
<tr>
<td>2</td>
<td>France</td>
<td>MSC.285(86) is implemented in national law</td>
<td>Not regulated</td>
<td>–</td>
</tr>
<tr>
<td>3</td>
<td>Germany</td>
<td>MSC.285(86) is implemented in national law</td>
<td>Not regulated; it’s possible based on special permission and cargo handling procedures</td>
<td>Based on the GL study “Bunkering of liquefied gases within German ports,” further rule development activities are expected.</td>
</tr>
<tr>
<td>4</td>
<td>Norway</td>
<td>National approval procedure based on MSC.285(86)</td>
<td>National approval procedures are available</td>
<td>–</td>
</tr>
<tr>
<td>5</td>
<td>Sweden</td>
<td>National approval procedure based on MSC.285(86)</td>
<td>No regulation on national level; several port specific procedures available</td>
<td>Existing bunker guidelines on port level (Port of Gothenburg and Port of Stockholm) are available</td>
</tr>
<tr>
<td>6</td>
<td>The Netherlands</td>
<td>National approval procedure based on MSC.285(86)</td>
<td>National approval guidelines are under development</td>
<td>–</td>
</tr>
</tbody>
</table>
The European framework (cont.)

• The EMSA study identified many gaps that exist in the regulations for LNG bunkering.

• It advised that many of the existing regulations and best practices for LNG cargo transfer from ship-to-shore and from ship-to-ship, such as ISO 28460, Installation and Equipment for Liquefied Natural Gas – Ship-to-shore Interface and Port Operations and SIGTTO’s publication, LNG Ship-to-Ship Transfer Guidelines, plus some applicable standards and national regulations, can be used as references, but specific regulations and standards for bunkering of LNG fueled vessels should be developed. The ISO/TS 18683:2015 document fills in some of the gaps. EMSA plans to develop uniform European-wide regulations and standards.

• Based on the extensive efforts currently underway in many nations and ports in Europe and at EMSA, it is expected the regulatory framework for LNG bunkering in Europe will be completed in the next few years.
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Conclusions

• LNG technology makes natural gas available throughout the world.
• It is important for citizens, industry and government to develop and communicate appropriate understandings of relative risks associated with LNG facilities and shipping.
• LNG as fuel is an environmentally friendly and commercially attractive way of ship’s propulsion
• Technical solutions for LNG supply infrastructure and on-board storage and processing are available
• Demand for LNG is growing.
• LNG carriers are part of an existing and quick developing market, driven by LNG supply to remote areas and LNG as ships fuel
• Excellent safety record of LNG business and proven safety systems are limiting risks
• Development of bunkering infrastructure and regulatory framework is the main challenge
End of Session

Thank you for your attention!

Q&A