MAJOR MARINE VESSELS IN BRITISH COLUMBIA'S COASTAL WATERS

Topics Covered:
LNG Carriers - Their Nature, Products and Risks

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PART 1 – LNG PROPOSED PROJECTS & THEIR ROUTES
PART 2 – LNG CARRIER DESIGN AND OPERATIONS
PART 3 – ABOUT LNG AND AN ACCIDENTAL RELEASE
### Liquefied Natural Gas (LNG) Carriers

#### LNG PROJECTS IN THE NORTH COAST

<table>
<thead>
<tr>
<th>Project</th>
<th>Terminal Location</th>
<th>Companies</th>
<th>LNG Export Capacity</th>
<th>Vessel Traffic</th>
<th>Carrier Size</th>
<th>Planned Start*</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC LNG</td>
<td>Kitimat</td>
<td>Haisla, LNG Partners</td>
<td>~1.8 m tonnes/year</td>
<td>~2 per month</td>
<td>Standard</td>
<td>2015 or later</td>
</tr>
<tr>
<td>LNG Canada</td>
<td>Kitimat</td>
<td>Shell, Kogas, Mitsubishi</td>
<td>~12 - 24 m tonnes/year</td>
<td>Up to 35 per month</td>
<td>Q-Flex, Q-Max</td>
<td>2017 or later</td>
</tr>
<tr>
<td>Kitimat LNG</td>
<td>Kitimat</td>
<td>Apache, Chevron</td>
<td>~5 - 10 m tonnes/year</td>
<td>~15 per month</td>
<td>Q-Flex, Q-Max</td>
<td>2017 or later</td>
</tr>
<tr>
<td>Prince Rupert LNG</td>
<td>Prince Rupert</td>
<td>BG Group</td>
<td>~27 m tonnes/year</td>
<td>Up to 35 per month</td>
<td>Q-Flex, Q-Max</td>
<td>2018 or later</td>
</tr>
<tr>
<td>Pacific Northwest LNG</td>
<td>Prince Rupert</td>
<td>Progress, Petronas</td>
<td>~6 m tonnes/year</td>
<td>~1.5 per month</td>
<td>Q-Flex</td>
<td>2018 or later</td>
</tr>
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* *Start ups can be much later depending on approval times. Although not all projects may proceed, several other companies are kicking the tires on LNG export opportunities.*

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### PLANNED SHIPPING ROUTES

There are two port access approaches for major vessels arriving to or from Kitimat - a Northern and a Southern. The open-waters of Hecate Strait and the sounds are hazardous areas for all types of vessels. Caaman’o Sound in the south is subject to severe currents, winds, seas and swells during and after winter cyclonic storms. Often the sound can only be navigable during fair-weather summertime conditions.
Liquefied Natural Gas (LNG) Carriers

TYPES

LNG carriers are specialized ships transporting LNG at its atmospheric pressure at approximately -162 degree Celsius. LNG carriers were typically in the range 80,000 to 135,000 cubic meters (m³). In 2006, the first LNG ships of over 200,000 and 250,000 m³ were being constructed.

All the North Coast projects will utilize LNG tankers as large as 285 meters, and be in the upper range of world sizes.

Membrane: Cargo is contained by a thin stainless steel or nickel alloy flexible membrane. Two membrane systems in use. Insulation is fitted directly into the inner hull and the primary barrier consists of a thin metal membrane less than one millimetre thick.

Features: Affected by sloshing and filling restrictions. About 80% of new LNG construction is of the Membrane Type. The vessel’s hull provides the cargo compartment’s structural function.

Moss Tanks: Spherical tanks of aluminum or 9% nickel steel. The sphere is welded to a steel skirt that is connected to the hull of the ship. Insulation is fitted to the outside shell of the sphere but no secondary barrier.

Features: Not affected by product sloshing and no filling restrictions. Smaller loading capacity and high construction cost than membrane type. They currently represent about 40% of the world LNG carrier fleet. The LNG tanks provide the structure for the cargo, not the vessel’s hull.

SIZES AND CONSTRUCTION

<table>
<thead>
<tr>
<th>Name &amp; Percentage of World Fleet</th>
<th>Size – cubic metres</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (9%)</td>
<td>&lt;100,000</td>
</tr>
<tr>
<td>Standard (79%)</td>
<td>100,000 to 200,000</td>
</tr>
<tr>
<td>Q-Flex (8%)</td>
<td>200,000 to 217,000</td>
</tr>
<tr>
<td>Q-Max (4%)</td>
<td>&gt; 250,000</td>
</tr>
</tbody>
</table>

A membrane LNG carrier’s hull supports the tanks. Tanks are lined by two thin membranes of nickel-steel (invar) of 0.7 mm to 1.5 mm thick – the primary one holds the cargo, the secondary membrane prevents leaks. Layers wood and perlite provide insulation. There are other construction variations being used and/or considered, such as using glass cloths.

There are very high costs and vessel “down-time” associated with any LNG carrier repairs if there is any leakage or compromise of the storage containers. This includes any accidental entry of seawater or LNG cargo. A cargo compromise does not necessarily provide significant risk to the environmental unless undetected.

Video: Construction Overview Membrane Type of LNG Carriers
PART 2

Liquefied Natural Gas (LNG) Carriers

CONVENTIONS, CODES AND REGULATIONS

As with any major sea-going (convention) vessel, the maritime transport of LNG cargo is subject to a host of international and domestic conventions and laws.

The International Maritime Organization (IMO) is the United Nations specialized agency with the responsibility for the safety and security of shipping, as well as the prevention and marine pollution by ships. Canada subscribes to the IMO process and codifies the IMO conventions under the Canada Shipping Act and its regulations. This is because Canada – as any other vessel-based trading nation – does not want to impede shipping through inconsistent laws and other requirements.

PARTIAL LIST OF IMO CONVENTIONS THAT APPLY:

- The Convention on the International Regulations for Prevention of Collisions as Sea (COLREGs)
- International Convention on the Prevention of Pollution from Ships (MARPOL)
- The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW)
- Safety at Sea Convention (SOLAS)
- International Ship and Port Facility Security Code (ISPS Code)
- International Safety Management Code (ISM Code)
- Convention on Limitation of Liability for Maritime Claims (LLMC)

**The purposes of IGC code is to provide an international standard for the safe transport by sea in bulk of liquefied gases and certain other substances, by prescribing the design and construction standards of ships involved in such transport and the equipment they should carry so as to minimize the risk to the ship, its crew and to the environment, having regard to the nature of the products involved.**

PART 2

Liquefied Natural Gas (LNG) Carriers

INDUSTRY OVERSIGHT

The society (SIGTTO) was formed as an international organization through which all industry participants might share experiences, address common problems and derive agreed criteria for best practices and acceptable standards. The purpose of the society is to promote shipping and terminal operations for liquefied gases which are safe, environmentally responsible and reliable. To fulfill this mission the society:

- Proactively develop best operating practices and guideline
- Sustain a learning environment by sharing lessons learned
- Promote training and development of all within the industry
- Foster mutually beneficial relationships with regulatory authorities and other stakeholders

HISTORY: By the late 1970s, the international LNG business was set for rapid expansion. Companies required common standards for the industry to aid its expansion, underpin public confidence and avoid a proliferation of unilaterally defined regulations.

SIGTTO provides a large selection of technical guides for the LNG terminal and shipping industry.
PART 2

Liquefied Natural Gas (LNG) Carriers

LNG SHIPPING TRACK-RECORD

There has been less than ten incidents of LNG releases from LNG tankers – none have ever resulted in a thermal burn. This attests to a high level of safe design, practices, and oversight in the LNG industry to date.

LNG carriers have been a small part of the world fleet of major vessels with less than a 100 in operation in the early 1990, and reaching just over 300 by 2008. The number of new builds is rising by 50 or more a year since then. World-wide, the risk of accidental LNG cargo losses has and will continue to rise mainly do to increased number of carriers.

With new LNG construction design and materials, comes new risks from unforeseen integrity and maintenance issues. There is also a shortage of skilled officers and crew for manning LNG carriers.

There is a need for a high degree of international, national, and regional vigilance to monitor the growth of the LNG carrier Industry to foster on-going safe design and operation.

PART 3

Liquefied Natural Gas (LNG) Carriers

ABOUT LNG

Liquefied Natural Gas (LNG) is liquefied by refrigeration to -162°C and this process is carried out ashore, before the cargo is loaded onto the ship. LNG is a methane product. Liquefaction reduces volume by 600 times original. It is not pressurized.

LNG carriers are fully insulated. It is not cost effective to liquefy methane onboard or transport in its gas state. *

LNG is:

• A methane gas at ambient conditions: but a liquid when cooled and condensed.
• A vapour that is lighter than air at ambient temperatures, but initially denser when cold so sinks to water/ground levels until it warms up.
• Non-corrosive, non-toxic, colourless and odourless.

Most LNG carriers have no-board re-liquefaction capability.

When LNG warms back up, LNG becomes natural gas again and is used commercially for as fuel for gas stoves, home heaters, and electric power plants.

* In some vessels, “boil-off” vapours are burned as fuel gas in the engine room.

Video: Basic Properties of LNG

United States Department of Energy
Washington, DC 20585
Liquefied Natural Gas (LNG) Carriers

ABOUT LNG

LNG is a substance which, at ambient temperature and at atmospheric pressure, would normally be a gas. It is a hydrocarbon (methane) and the key property that makes hydrocarbons the world’s primary energy source – combustibility – also makes them inherently hazardous.

The Cryogenic Hazard of Released Freezing Liquid and Ensuing Vapour Cloud

Because LNG is maintained as liquid, a container breach provides an escape route for the liquid without necessarily further rupturing of the container’s wall. A vapour cloud results as the liquid turns to a gas. There are two “cold-related” consequences of a rapid, large LNG release:

1) There is potentially severe freezing of vessel hull, tanks, people or animals caught within the liquid/evaporation danger zone.

2) There is a rapid expansion of the gas – referred to as “rapid phase transition” – when a large amount of LNG is released and spills on to water.

Mostly, the cryogenic hazard is on-board and near the vessel. The main danger is to the crew and structural damage to the vessel itself.

ABOUT AN ACCIDENTAL RELEASE OF LNG

The Thermal Hazard of Ignited LNG

If the vapour above a “pool” of spilled LNG ignites, then there is potential for severe thermal damage and harm to the vessel, people and/or animals caught within the high-intensity heat zone – generally near the rupture source. This thermal – “fire ball” – hazard has the greatest public concern.

Some Technical Factors the Need to be Consider to Assess Risk and Consequences

A LNG’s vapour cloud mixes with air, but it will ignite only where it is mixed between 5% and 15% with air, and at the same time an ignition source needs to exist. Above 15%, there’s not enough air for it to burn, and below 5 percent, there’s not enough LNG vapor to burn. LNG vapor clouds burn when they are within this mixture range, but they don’t explode.

Nevertheless, a large thermal burn can result if all the correct conditions exist.
Sandia National Laboratories in the United States between May 2008 to 2011 conducted a series of large-scale LNG fire and cryogenic damage tests. The studies simulated the consequences large LNG spills and fires on water as if a LNG carrier was damaged.

Key study findings:

For a large breach and spill event as much as 40 percent of the LNG spilled from the LNG vessel's cargo tank is likely to remain within a LNG vessel’s structure, leading to extensive cryogenic fracturing and damage to the LNG vessel’s structural steel – this would quickly disable the vessel, and possibility cause it to sink.

LNG vessel and cargo tank design, materials, and construction practices are such that multi-cargo tank cascading damage and spill are unlikely. Should sequential cargo tank spills occur, they are not expected to increase the hazard distances resulting from an initial spill and pool fire. It could increase the duration of the fire hazards.

The fire would likely stay attached to the ship instead of floating away, meaning that wind will not carry the fire away, but it will cause more damage to the ship.

For very small breach events, which could occur from a number of credible accidental or intentional events, the spill rates are more than a 1,000 times less than that of potential larger breach events.
PART 3

Liquefied Natural Gas (LNG) Carriers

ACCIDENTAL RELEASE OF LNG CONTINUED…

Based on Sandia National Laboratories large LNG pool fire tests, publically safe distances from a LNG release that ignites ranges from about 900 to 1900 meters. Fire would burn for about 3 to 20 minutes. Actually, hazard distances from an LNG fire as burn durations will change depending on site-specific environmental conditions (wind speed and direction) and breach scenarios (collision, grounding, sabotage).

Interpretation LNG Public Risk: A hazard-zone model will help decision makers identify the areas at greatest risk, plan mitigation measures, and develop emergency response plans.

Zone 1: as the area within 500 meters (m) of an LNG vessel. Populations and structures within this zone would experience “severe negative impacts”.

Zone 2: as the area between 500 m and 1.9 km of an LNG vessel. The consequences of an LNG fire would be lower within this zone than in Zone 1, but injuries and property damage still could occur.

Zone 3: is the area farther than 1.9 km from an LNG vessel. The effects a LNG pool fire are significantly minimized. The chief danger is the possibility of a vapor cloud “burn back” to the source of a spill.

Safety zone models are used for existing and planned LNG terminals and shipping. Nevertheless, studies do not model conditions at any specific facilities or on specific routes. This leaves decision-makers to apply safety estimates and suggestions to individual projects and shipping corridors on a case-by-case basis depending on exposures – such as coastal communities.