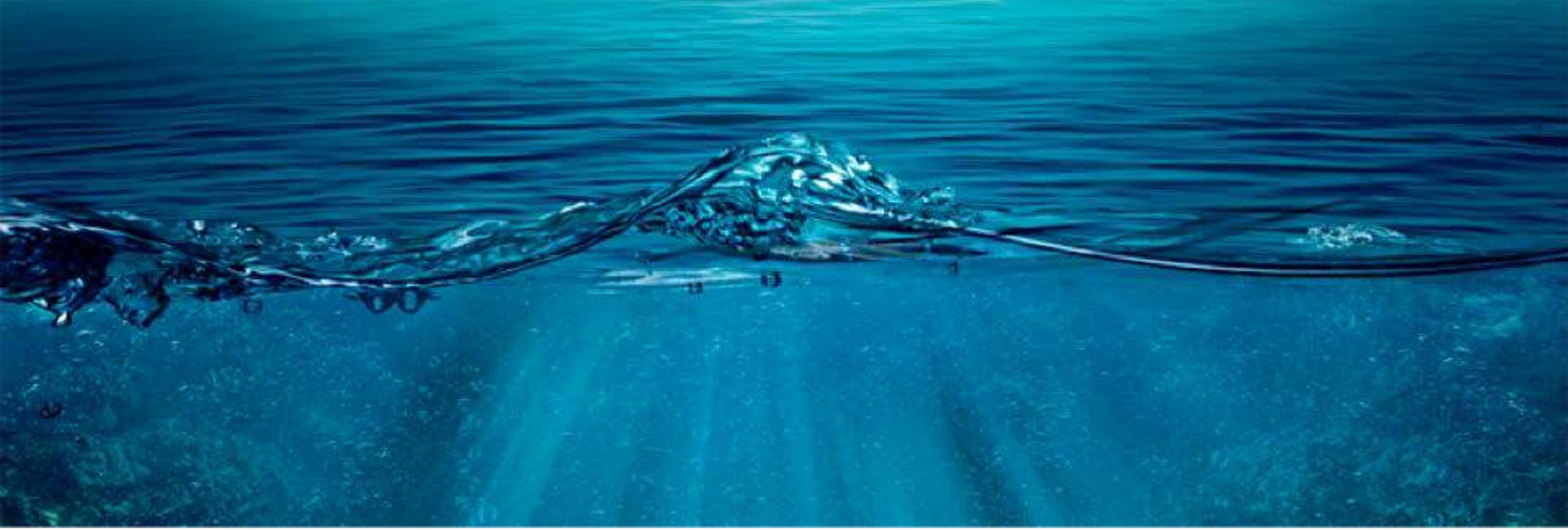


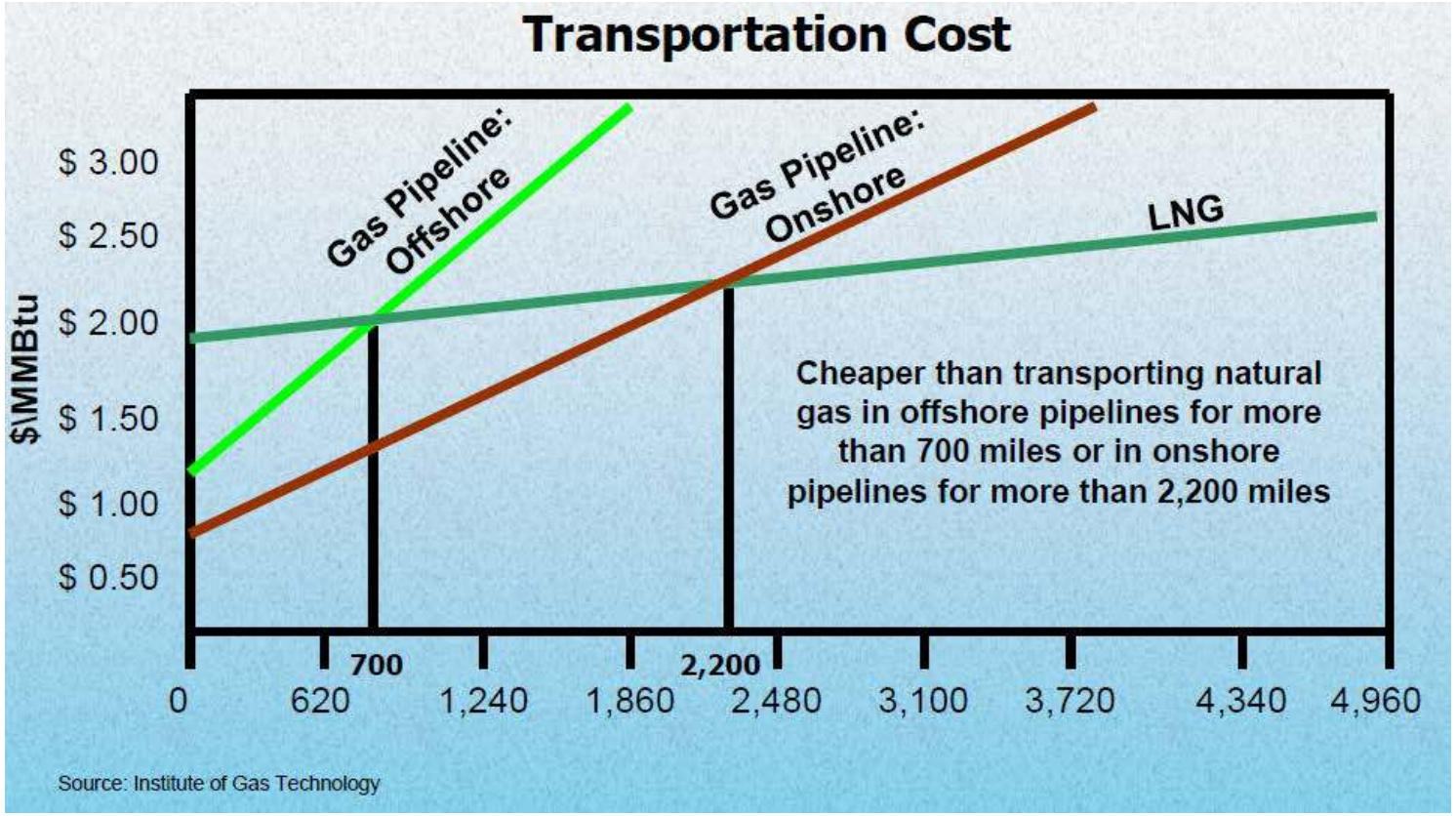
LNG Routes, IMO Code Categorization, Loading Discharge Methods

Isalos.net | Summer Shipping Courses | 09 July 2018

Capt. George Livanios
Fleet Manager, Operations, Maran Gas Maritime Inc.

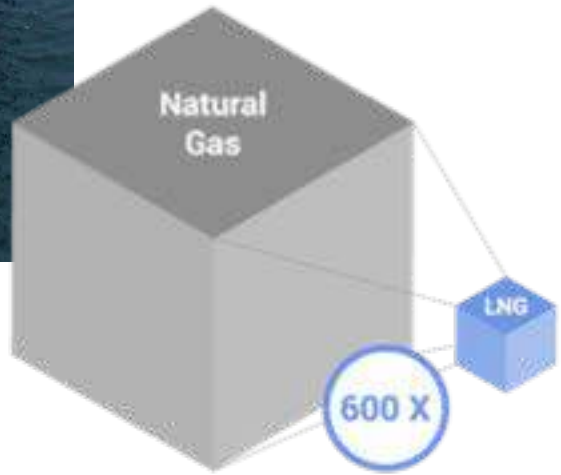
Introduction | What is LNG

- Natural gas is a hydrocarbon mixture composed primarily of methane (CH_4) which is in gaseous form at atmospheric temperature and pressure.
- Over large distances, gaseous methane is uneconomic to carry due to its very small density.



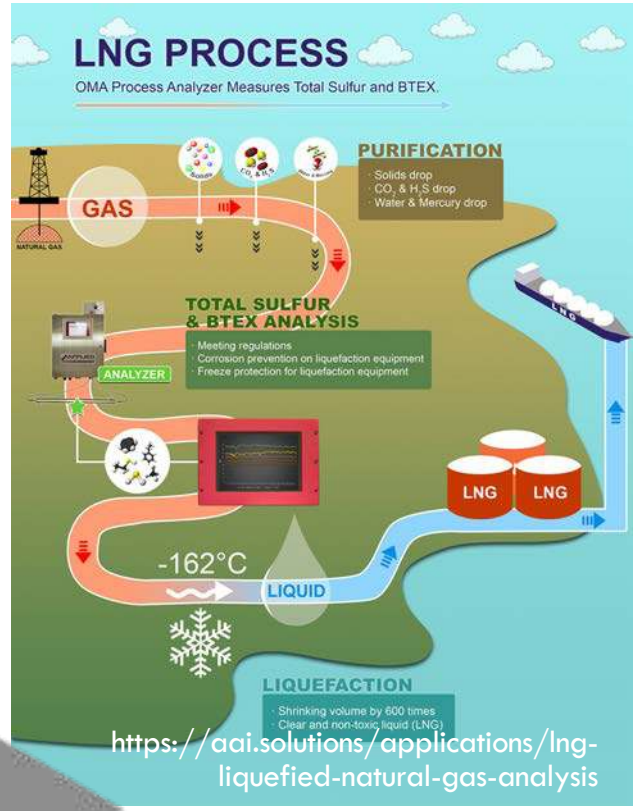
Introduction | What is LNG

- **In fact, 600 m^3 of gaseous methane have the same mass as just 1 m^3 of liquid methane.**
- Therefore, natural gas must be liquefied to be transported by ship.
- The phase shift from gas to liquid can be achieved either though compression or through cooling.

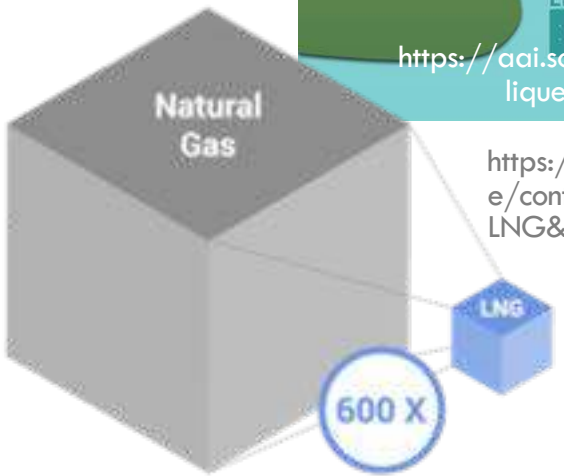


LNG | Natural boil-off

- Generally, the natural gas is liquefied through cooling at the LNG source.
- When loaded, it is at approximately atmospheric pressure, but **chilled to and transferred at its boiling point**, around -160°C with the exact temperature depending on the cargo source and composition.
- During transit: cargo is kept cold (at its boiling point) only by the effective thermal insulation of the cargo tanks (while re-liquefaction equipment is fit only on a minority of ships).
- However, even the best insulation, cannot completely stop heat transfer from the environment to the LNG. As a result, a small amount of cargo boils and becomes vapor every day. This vaporized cargo is called natural boil-off gas (NBOG).

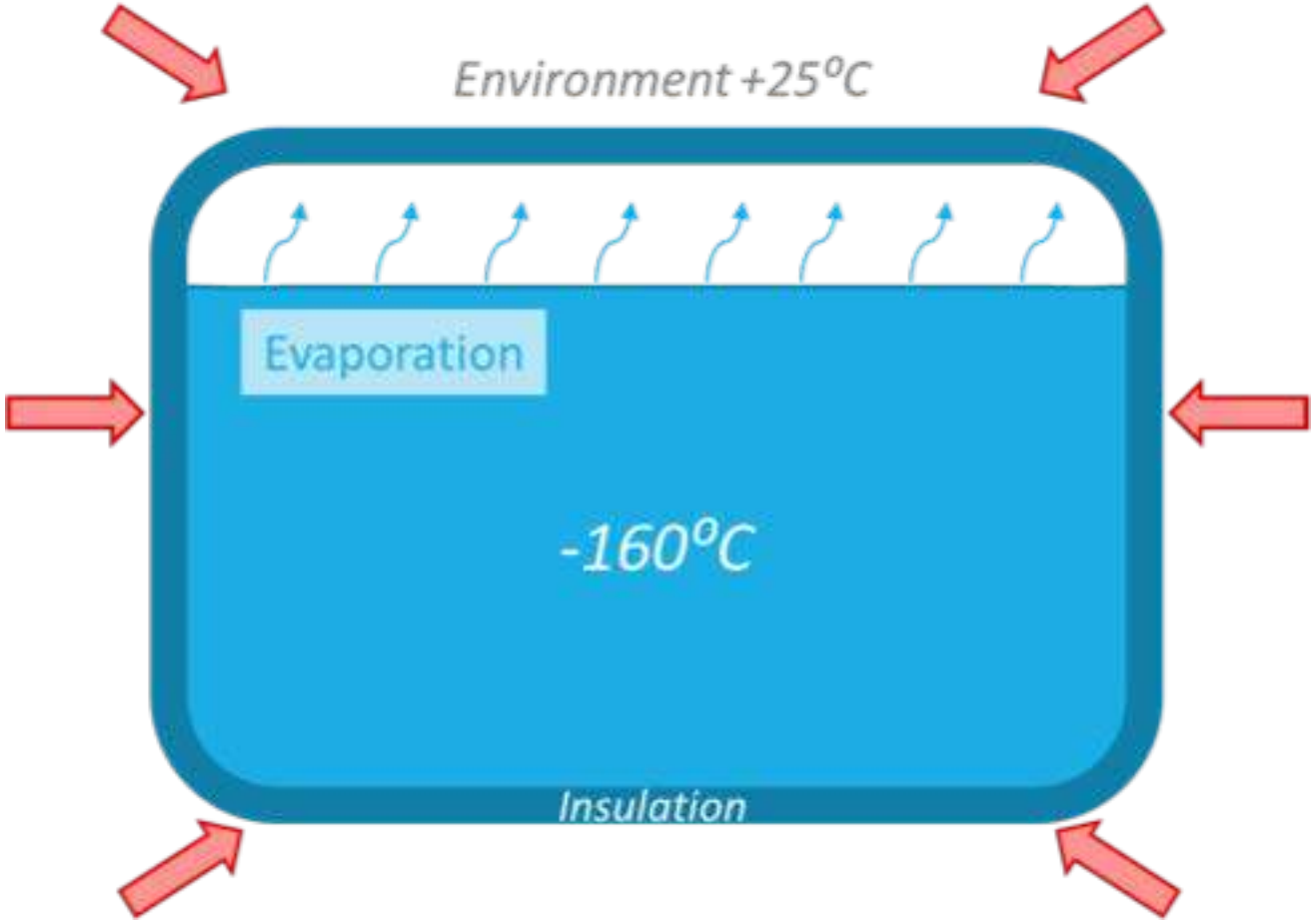


https://aai.solutions/applications/lng-liquefied-natural-gas-analysis



https://www.slng.com.sg/website/content.aspx?wpi=What+is+LNG&mmi=27&smi=118

LNG | Natural boil-off

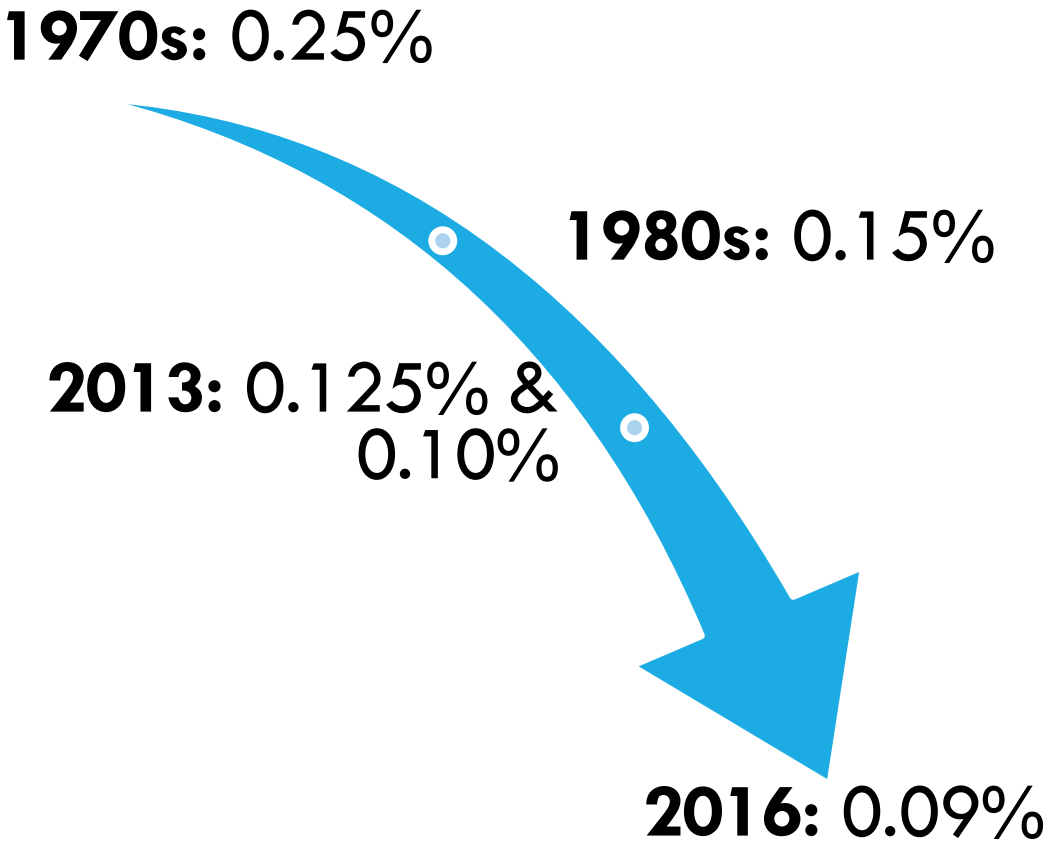


- The amount of the cargo which will naturally evaporate depends on the quality of the insulation.
- For every ship, a nominal **Natural Boil off Rate (NBOR)** is defined which gives the percentage of cargo evaporating each day.
- In order to keep the cargo cold and the pressure within allowable levels in the tanks, the produced NBOG must be removed. While, in the past, the boil-off gas was burned in the ship's mast, **today's energy prices have put this practice to an end**. Boil-off gas is directed to the engine, where it is burned as fuel.

LNG | Natural boil-off

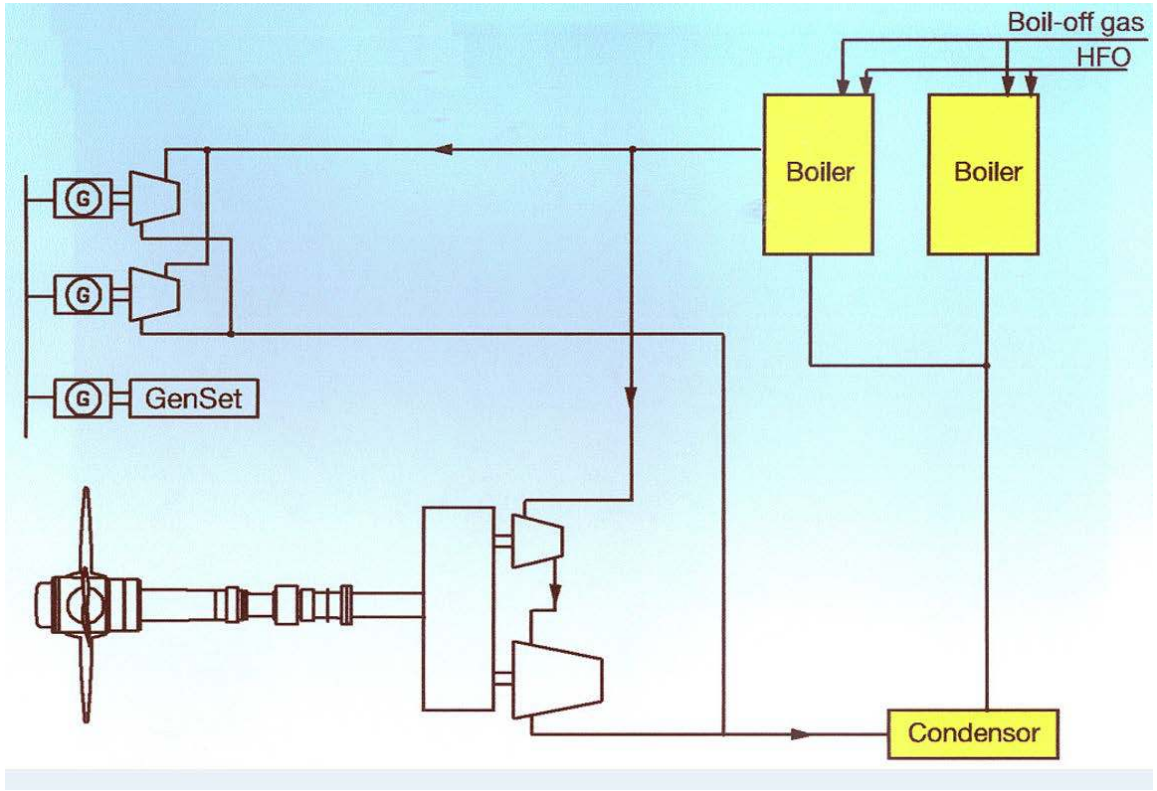
Natural boil-off is measured by "Natural boil-off rate", a number which expresses the percentage of total cargo capacity to boil-off every day.

Improved insulation has improved Natural boil-off rates through the years

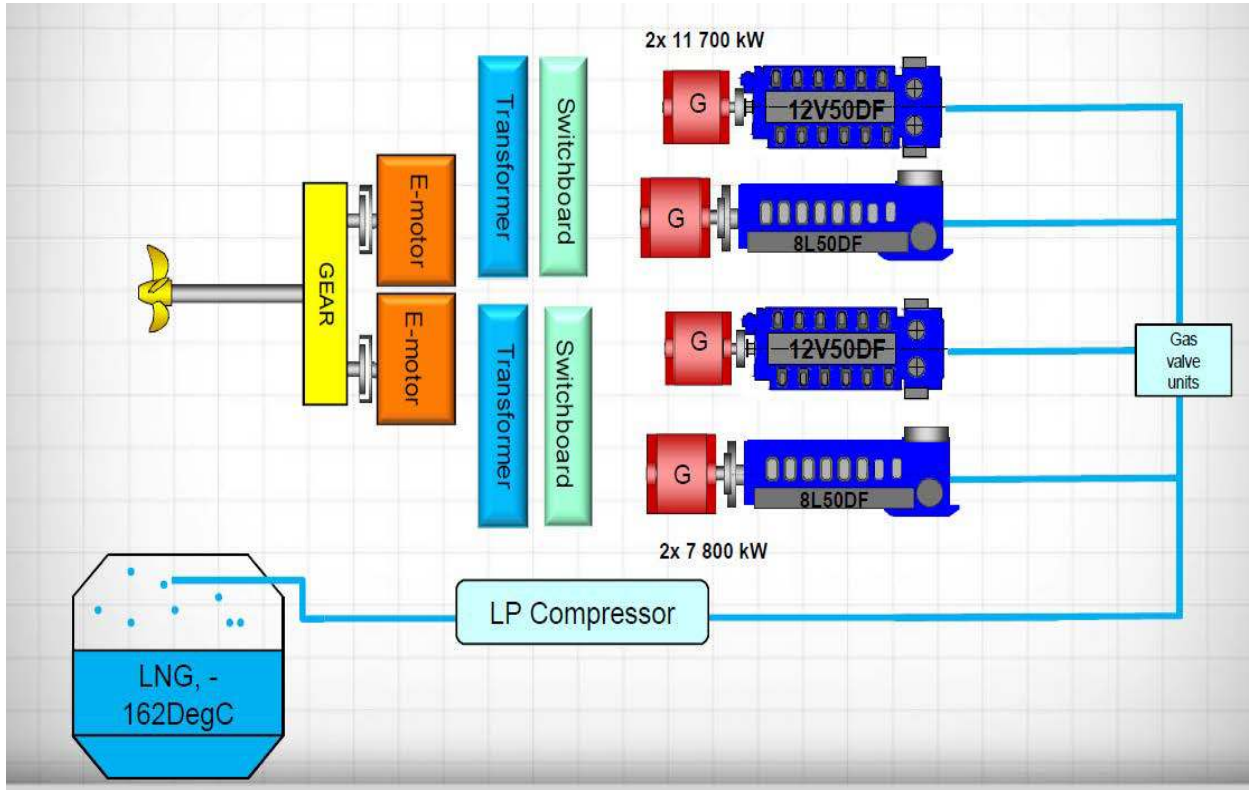


LNG | Natural boil-off for propulsion

- LNG vessels **propulsion plants** are designed configured to burn natural gas
- First generation LNG ships were fit with conventional steam plants
- Second generation ships were fit with 4-stroke, diesel-electric propulsion plants (DFDE)



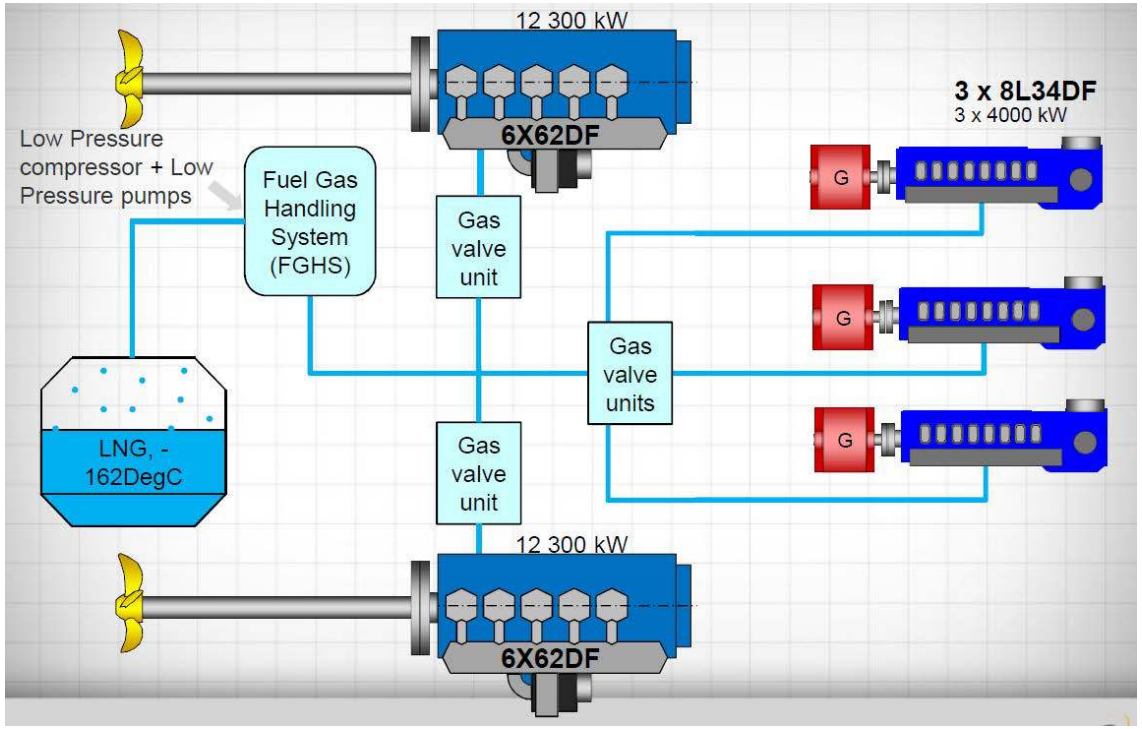
Conventional Steam Plant



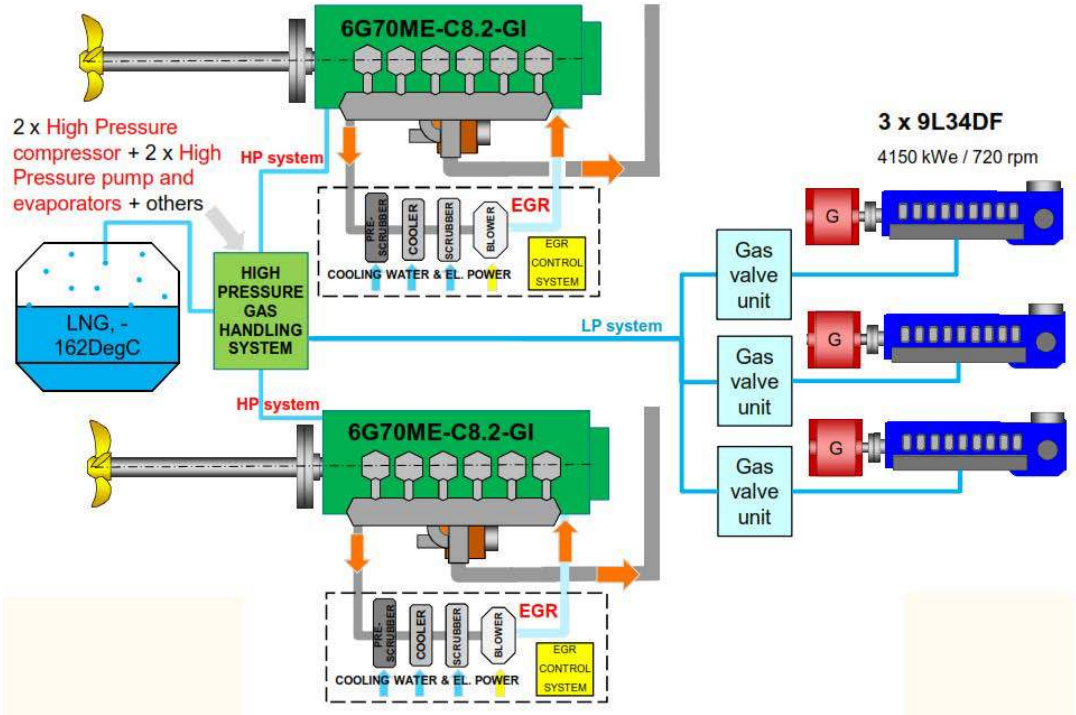
Dual-fuel Diesel Electric Plant

LNG | Natural boil-off for propulsion

- Recently, ships are being fit with 2-stroke, slow-speed, direct drive engines (MEGI, X-DF)



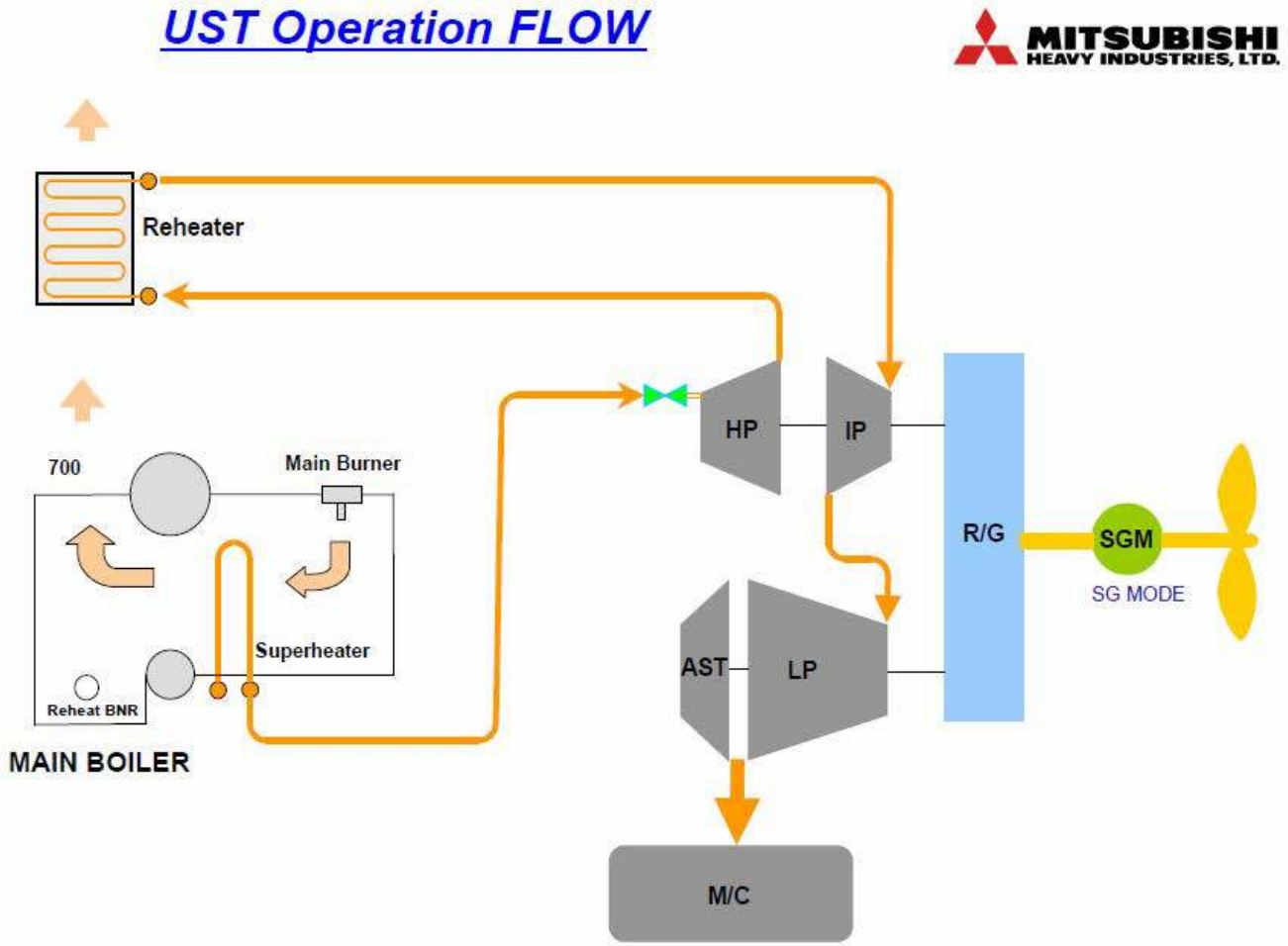
Slow speed dual fuel propulsion plant (X-DF)



Slow speed dual fuel propulsion plant (MEGI)

LNG | Natural boil-off for propulsion

- Improved steam-turbine arrangements have also been applied



LNG | Boil-off for cargo conditioning

- Many terminals require vessels to arrive with cargo at specific temperature and pressure conditions.
- As a result, it may be necessary to burn even more cargo than would be consumed to manage Natural BOG.
- This process is called “conditioning the cargo”

Peculiarities of LNG Shipping due to NBOG

- Due to the fact that LNG is constantly boiling off / burned, commercial requirements around accounting for cargo loaded, delivered and transferred are complicated.
- Bill of Lading quantity reflects loaded volume, not delivered volume as cargo is burned in transit.
- Some newer vessels are capable of reliquefying cargo in transit, making accounting for cargo even more complicated.
- Cargo is measured by volume (m^3) and not by tons as in the oil-tanker industry.
- All measurements are made by an automatic, closed system and not by manual measurement as on traditional tanker vessels.

Rosemount TankRadar® CTS

Before Loading Report

Trim	0.95	m	by Stern	Automatic
List	0.09	°	Stbd	Automatic
Average Liquid Temperature	-160.66	°C		
Average Vapor Temperature	-143.53	°C		
Average Vapor Pressure	1,078	mbar(a)		

Level Measurements (m)	TANK1	TANK2	TANK3	TANK4
No. 1	0.019	0.053	0.653	0.039
No. 2	0.020	0.054	0.644	0.039
No. 3	0.019	0.054	0.646	0.039
No. 4	0.019	0.053	0.653	0.038
No. 5	0.019	0.054	0.642	0.038
Average Level (m)	0.019	0.054	0.648	0.039
Trim Correction (m)	-0.006	-0.033	-0.071	-0.024
List Correction (m)	0.003	0.002	-0.002	0.003
Corrected Level (m)	0.016	0.023	0.575	0.018

Temperature Measurements (°C)	TANK1		TANK2		TANK3		TANK4	
99.5%	-110.31	V	-111.99	V	-106.10	V	-114.26	V
95%	-150.37	V	-145.20	V	-146.77	V	-146.35	V
80%	-152.71	V	-147.76	V	-150.12	V	-148.72	V
50%	-155.41	V	-149.80	V	-153.19	V	-150.40	V
10%	-155.99	V	-151.40	V	-154.72	V	-151.92	V
0%	-160.59	V	-160.63	L	-160.70	L	-160.65	L
Average Liquid Temperature (°C)	----------		-160.63		-160.70		-160.65	
Average Vapor Temperature (°C)	-147.56		-141.23		-142.18		-142.33	

	TANK1	TANK2	TANK3	TANK4
Vapor Pressure (mbar(a))	1,078	1,078	1,078	1,078
Volume (m^3)	10.894	34.351	876.426	27.528
Volume Summed (m^3)	949.199	(A)		

Flow Meter	MGE 1	MGE 2	MGE 3	MGE 4	GCU
Gas Flow (Kg)	1,060,969.088	1,117,672.576	1,024,002.176	1,419,545.600	1,191,55[illegible]
Summed Gas Flow (Kg)	5,813,743.360	(C)			

LNG | Tanker Safety Guide

Methane/LNG

Appearance	**Colourless**
Odour	**Very faint, nearly odourless**
UN Number	**1972/1971**
MFAG Table	**620**

SYNONYMS

Carburetted hydrogen
Firedamp
Hydrogen bicarbide
Liquefied natural gas
LNG
Marsh-gas
Methyl hydride
MTH

The Main Hazard
FLAMMABLE

EMERGENCY PROCEDURES

Fire	STOP GAS SUPPLY. Do not extinguish flame until gas or liquid supply has been shut off, to avoid possibility of explosive re-ignition. Extinguish with dry powder, halon or carbon dioxide. Cool tanks and surrounding areas with water spray.
Liquid in eye	DO NOT DELAY. Flood eye gently with clean fresh water. Force eye open if necessary. Do not rub affected area. Continue washing for at least 15 minutes. Obtain medical advice or assistance as soon as possible.
Liquid on skin	DO NOT DELAY. Remove contaminated clothing. Flood affected area with water. Handle patient gently. Do not rub affected area. Immerse frost-bitten area in warm water until thawed. Obtain medical advice or assistance as soon as possible.
Vapour inhaled	REMOVE VICTIM TO FRESH AIR. Remove contaminated clothing. If breathing has stopped or is weak or irregular, give mouth to mouth/nose resuscitation or oxygen, as necessary. Obtain medical advice or assistance as soon as possible.
Spillage	STOP THE FLOW. Avoid contact with liquid or vapour. Extinguish sources of ignition. Flood with large amounts of water to disperse the spill, and to prevent brittle fracture. Inform port authorities or coastguard of spill.

Health Data

TLV 1000 ppm
Asphyxiant

Odour threshold 200 ppm

Effect of liquid	**ON EYES** Tissue damage due to frost-bite.
	ON SKIN Tissue damage due to frost-bite.
	BY SKIN ABSORPTION Not absorbed through skin.
	BY INGESTION Not pertinent. No hazard in normal industrial use.
Effect of vapour	**ON EYES** No hazard in normal industrial use. May be tissue damage due to frost-bite.
	ON SKIN No hazard in normal industrial use. May be tissue damage due to frost-bite.
	WHEN INHALED *Acute effect* Vapour has narcotic effect. Because of very rapid evaporation rate, there is possibility of total air replacement and danger of asphyxiation. *Chronic effect* No chronic effect known.

Personal protection

Protective clothing covering all parts of the body, gloves, boats, goggles or face shield, all insulated against cold temperature attack.

LNG | Tanker Safety Guide

Methane/LNG

Fire and Explosion Data

Flashpoint -175°C approx.

Auto-ignition Temperature 595°C.

Flammable Limits 5-16% by volume.

Explosion Hazards Vapour can form a flammable mixture with air which, if ignited, may release explosive force causing structural damage.

Chemical Data

Formula CH_4.

Chemical Family Hydrocarbon.

Reactivity Data

Water, fresh or salt No dangerous reaction; may freeze to form ice or hydrates.

Air No reaction.

Other liquids or gases Dangerous reaction possible with chlorine.

Physical Data

Boiling Point at Atmospheric Pressure -161°C.

Vapour Pressure Bar (A) See graph in Figure A1.2.

Specific Gravity See graph in Figure A1.2.

Coefficient of Cubic Expansion 0.0026 per °C at -165°C.

Freezing Point -182°C.

Relative Vapour Density 0.55.

Molecular Weight 16.04Kg/Kmole.

Enthalpy (KJ/Kg)
Liquid 29.3 at -165°C 285.5 at -100°C.
Vapour 545.1 at -165°C 588.3 at -100°C.

Latent Heat of Vaporisation (KJ/Kg) See graph in Figure A1.2.

Electrostatic Generation

Conditions of Carriage

Normal Carriage Condition Fully refrigerated.

Ship Type 2G.

Independent Tank required No.

Control of Vapour within Cargo Tank Fully inerted with zero oxygen content.

Vapour Detection Flammable.

Gauging Closed or indirect.

Materials of Construction

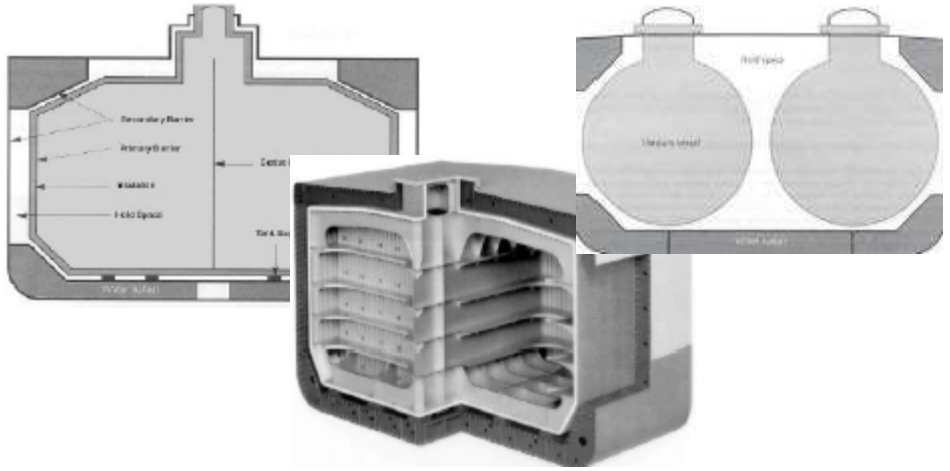
Unsuitable Mild steel.

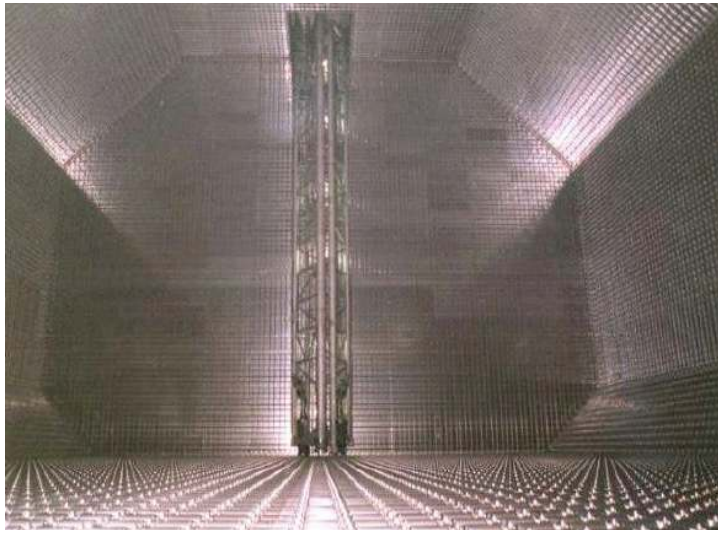
Suitable Stainless steel, aluminium, copper, 9% or 36% nickel steel.

LNGC Cargo Tanks

- Independent
  - Independent tanks are completely independent from the vessel's structure and capable of independently withstanding weight, pressure and sloshing loads of cargo.
  - There are three classes of independent cargo tanks, Type A, B and C.
- Membrane
  - Membrane tanks are not-self supporting.

    They consist of thin membrane layers supported by the hull via the insulation.





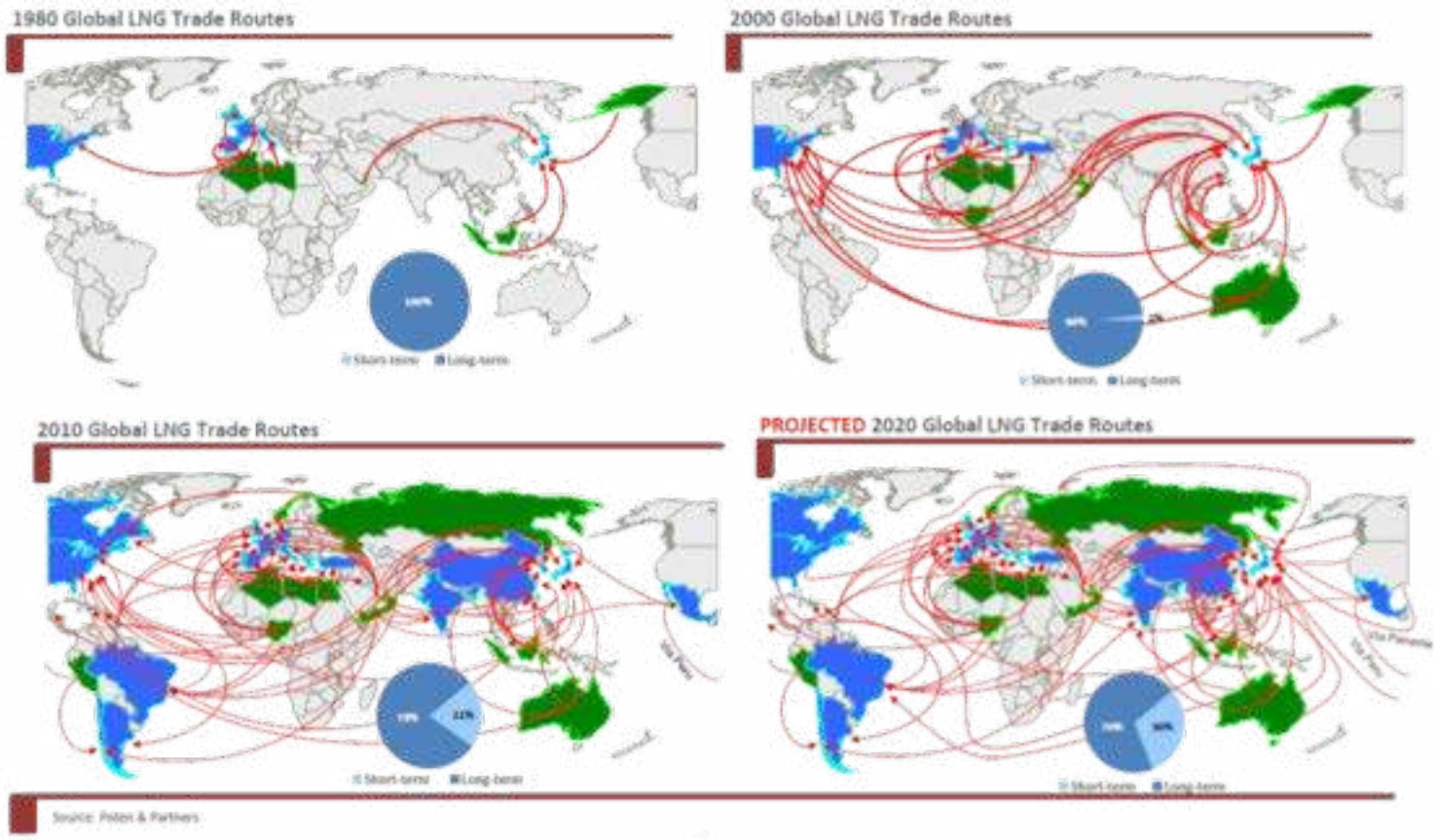
LNG Shipping | Trade Routes Then & Now

- Gas liquefaction technology has existed since the 19th century.
- The first LNG plant was built in 1912-1917, while the first commercial LNG plant was built in 1941.
- LNG was first transported by sea in the 1950s.

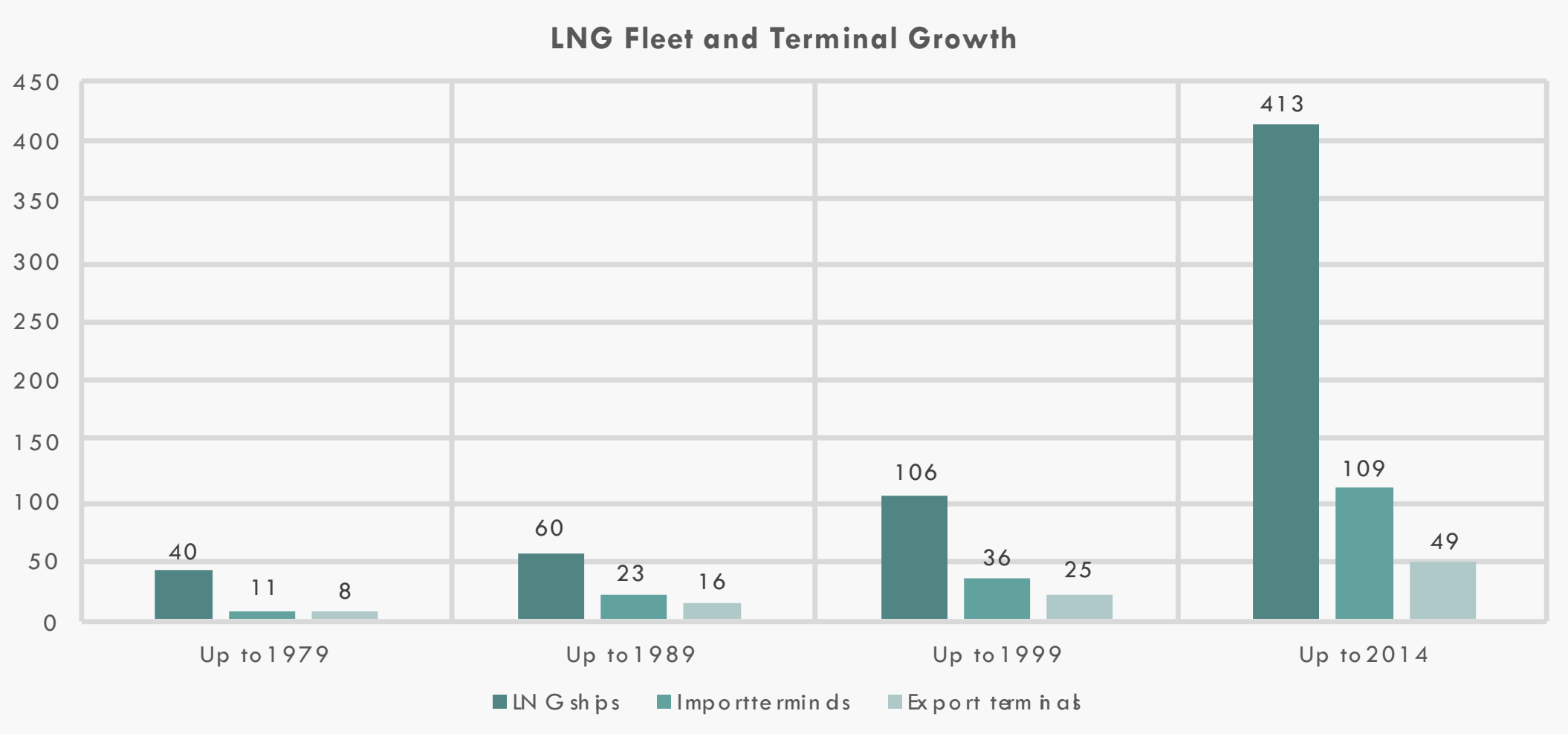
- The first oceangoing LNG vessel was the Methane Pioneer. Built in 1945 as a cargo ship named Marline Hitch, the vessel was renamed Don Aurelio and Nomarti before being rebuilt in 1958 for the purpose of transporting LNG and being operated between 1959 and 1972 as an LNG carrier.

LNG Shipping | Trade Routes Then & Now

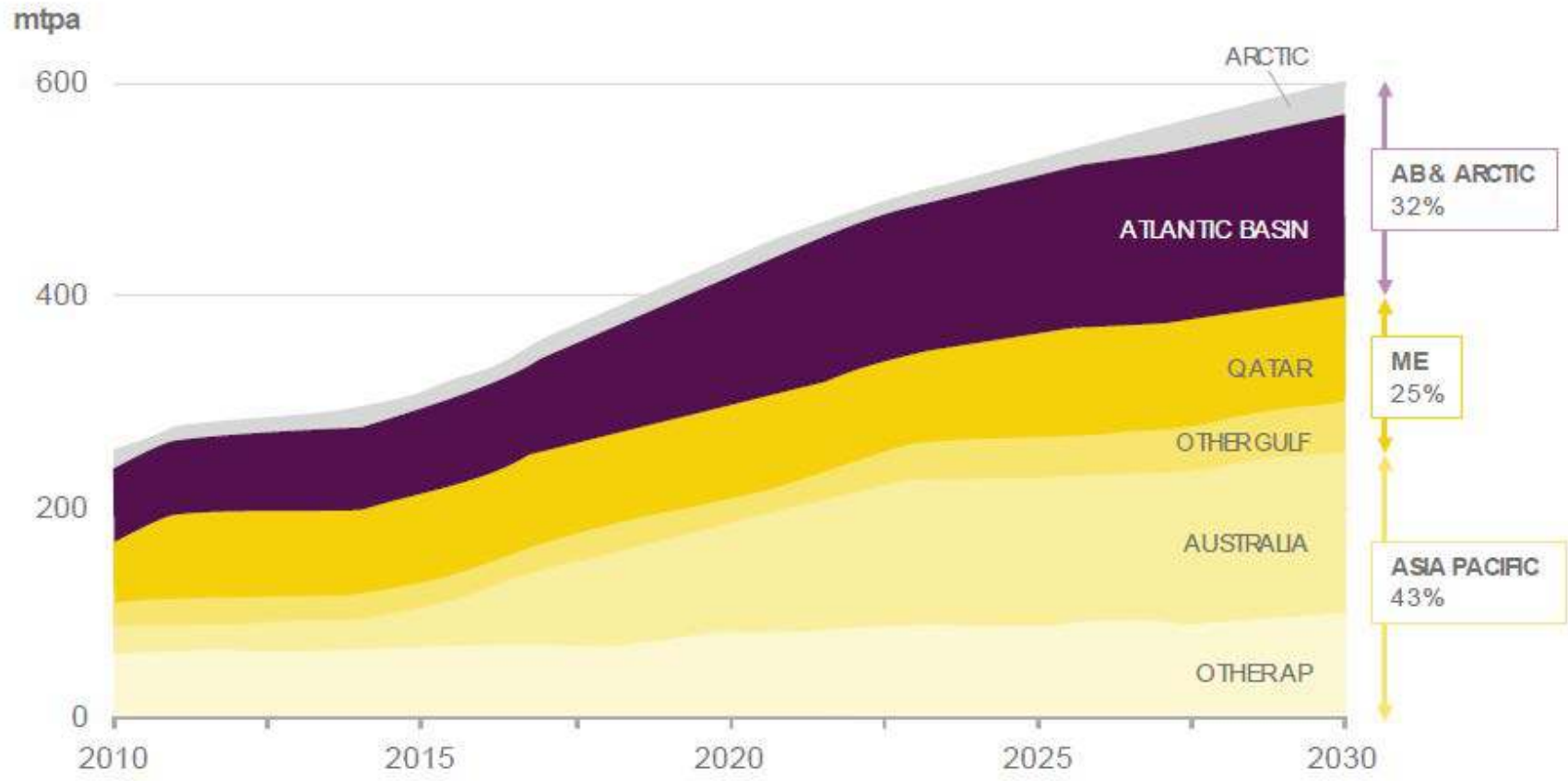
- The LNG industry has changed radically in the past few decades.
- The number of new ships and and new terminals is constantly increasing.
- Ships are no longer dedicated to terminals, so extra effort is required for familiarization with all necessary procedures.
- New terminals may lack the experience of established ports, and extra diligence is required.



LNG Shipping | Trade Routes Then & Now

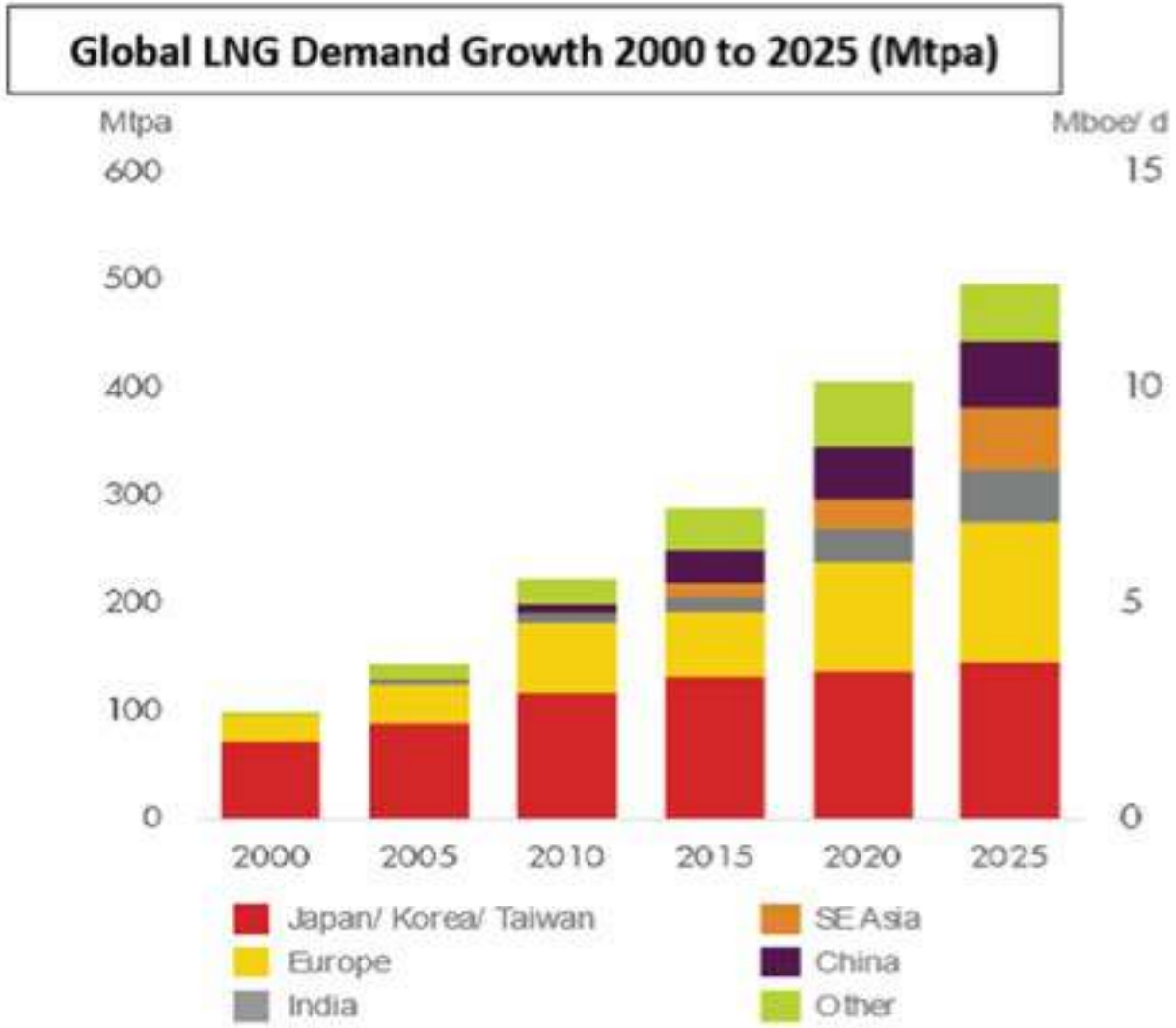


LNG Shipping | Trade Routes Then & Now

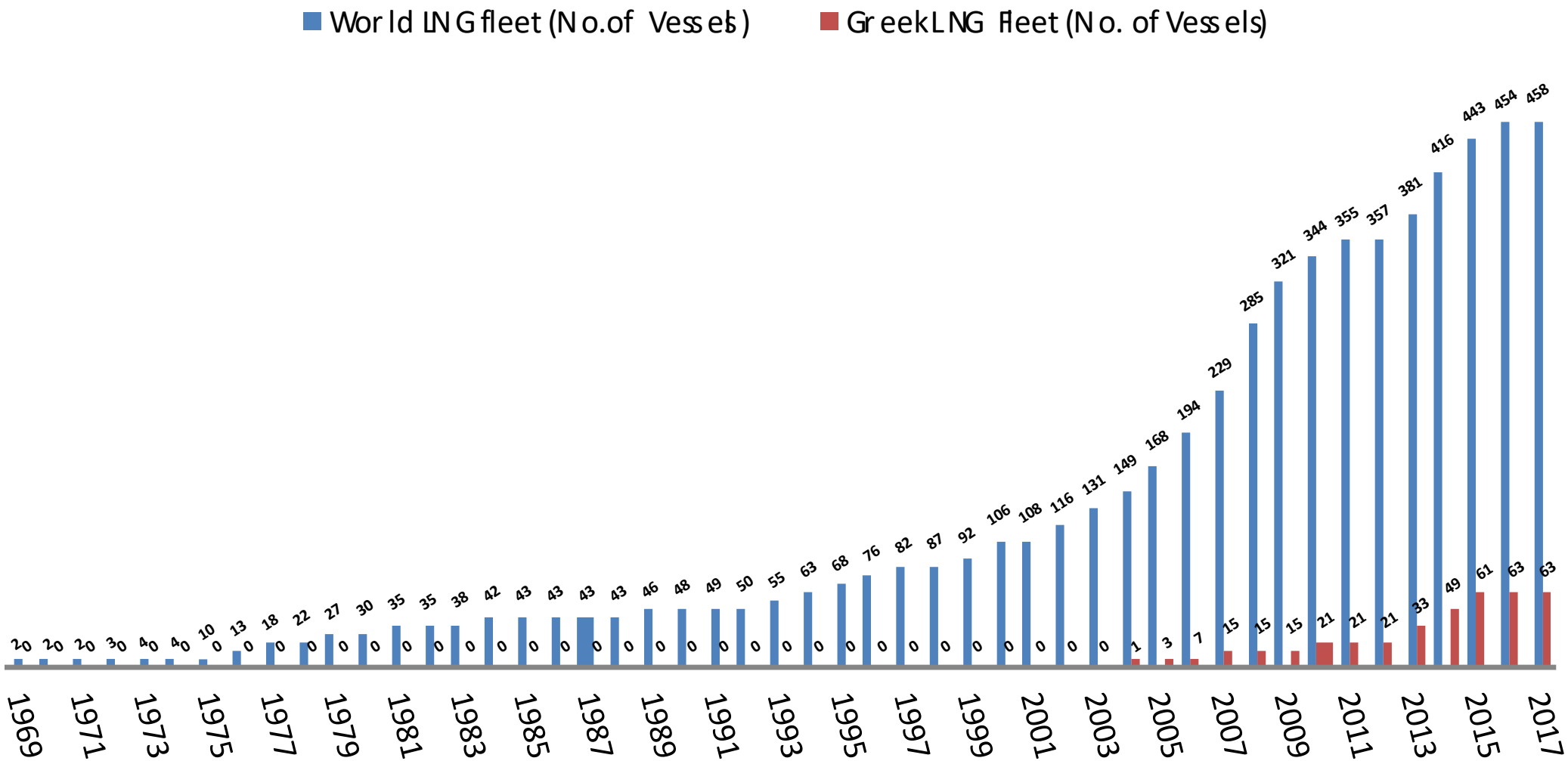


Global LNG Supply 2010 to 2030

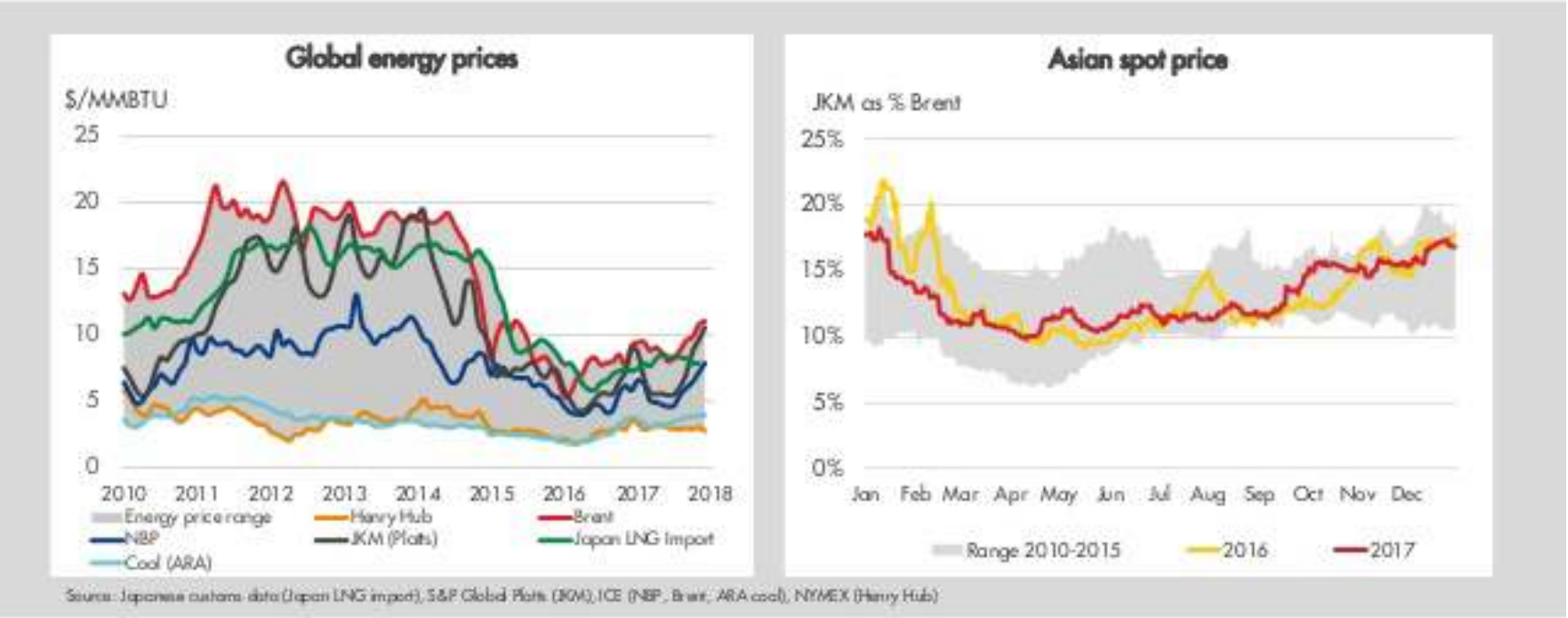
LNG Shipping | Trade Routes Then & Now



LNG Shipping | Greek LNG Fleet



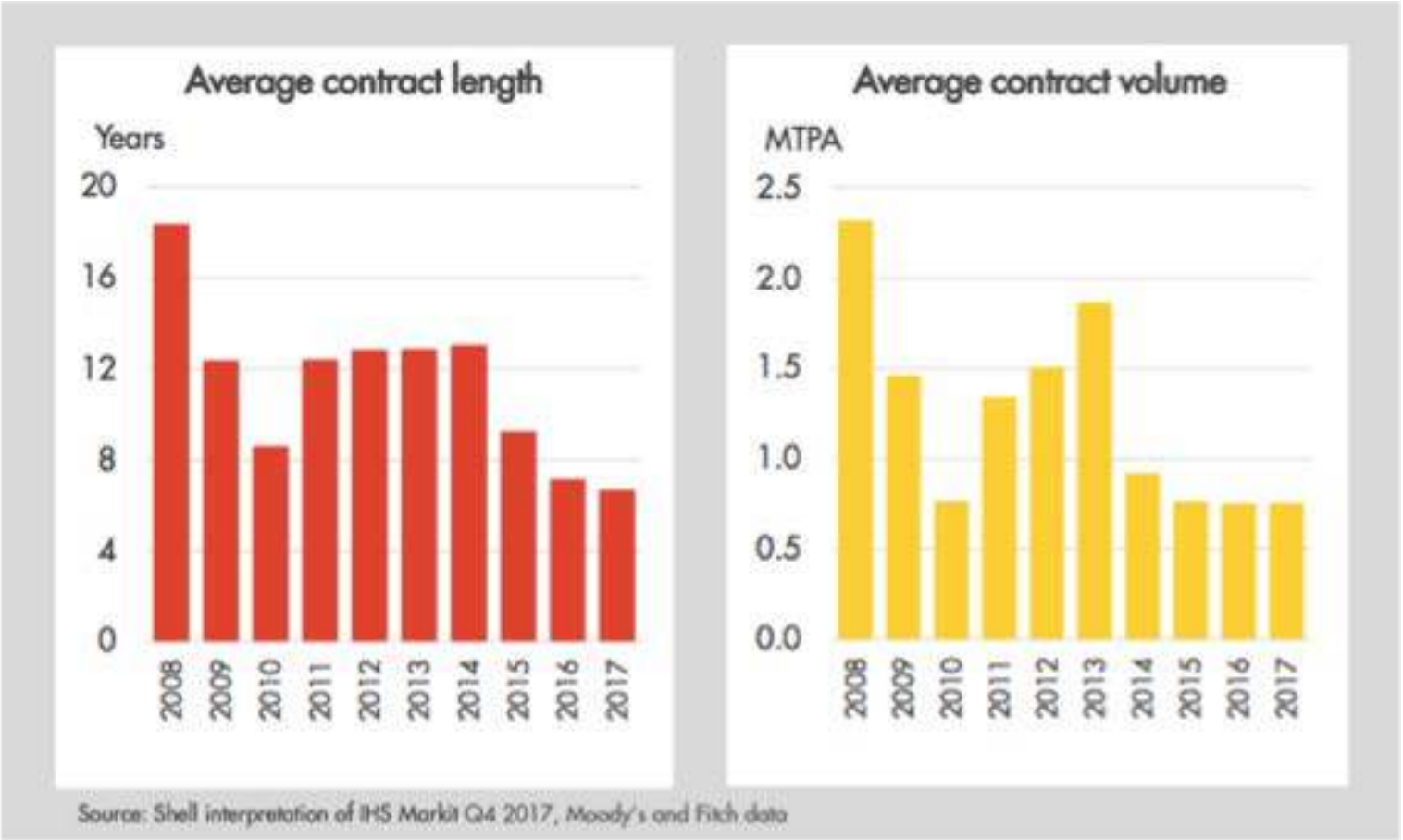
LNG Shipping | Evolution of the Spot Market



- Traditionally LNG vessels were chartered on **long term contracts** upwards of 20 years.
- Charterers generally had their own source of NG / reliquefaction terminals, and served specific consumers / regasification terminals through long term Sales Purchase Agreements (SPAs).
- Recent years have seen the emergence of **LNG commodity trading** and the a growing spot market.

LNG Shipping | Evolution of the Spot Market

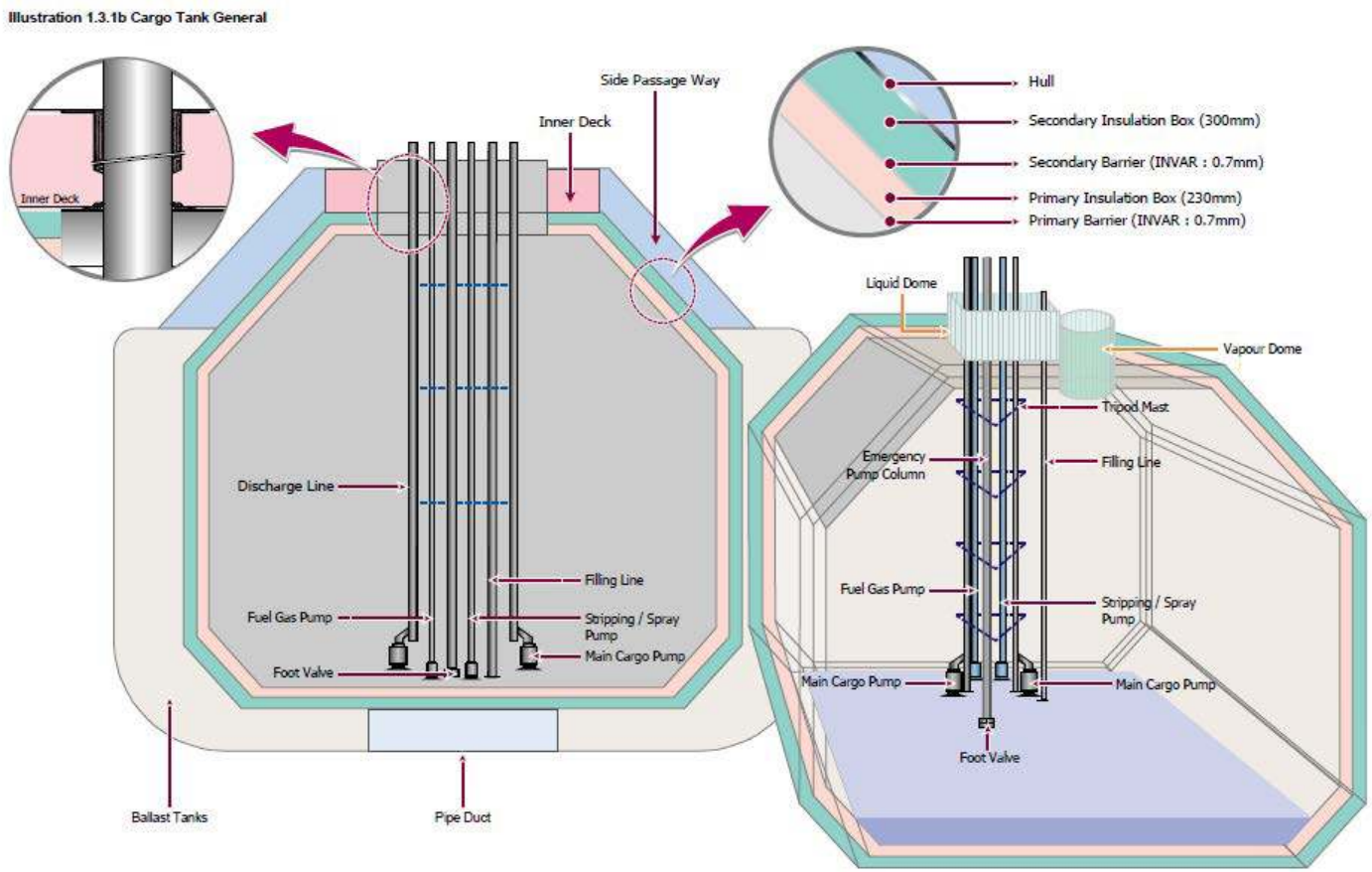
- New players in the industry do not have their own sources of NG, but buy and sell cargos on the market, looking for the best deal.
- These companies do not have stable, long-term needs for tonnage, so they charter vessels on short term contracts ranging anywhere from one voyage to one year duration.



Royal Dutch Shell plc

Loading / Discharging LNG

- Loading / Discharging LNG is completed with cryogenic, centrifugal pumps
- Average cargo parcel sizes are 145,000 to 174,000 m^3 of LNG
- The cargo loading / discharging call usually lasts 24 to 36 hours
- All aspects of the vessel call are carefully prepared for during the ship compatibility / terminal approval process

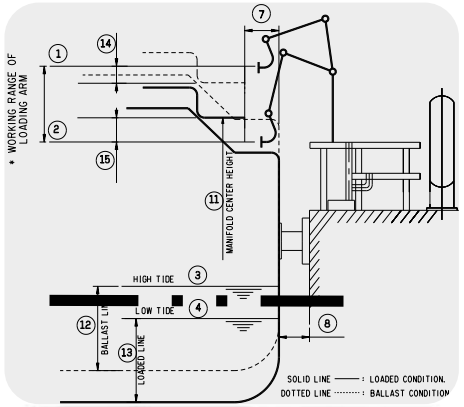


Terminal Requirements & Compatibility

SHIP-SHORE COMPATIBILITY

- Compatibility is the process of verifying that a loading or discharge terminal is physically and procedurally adequate to receive a certain ship and that the ship is physically and procedurally adequate to load or discharge at that terminal

- The compatibility process can be divided into three major parts:
  1. Ship-shore interface: Physical compatibility check
  2. Ship-shore cooperation: Agreement of procedures
  3. Ship-shore acceptance: Terminal and ship operator due diligence checks

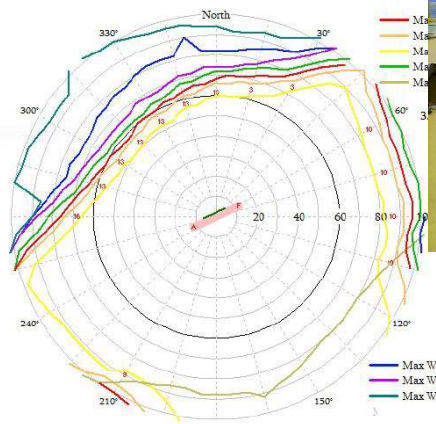


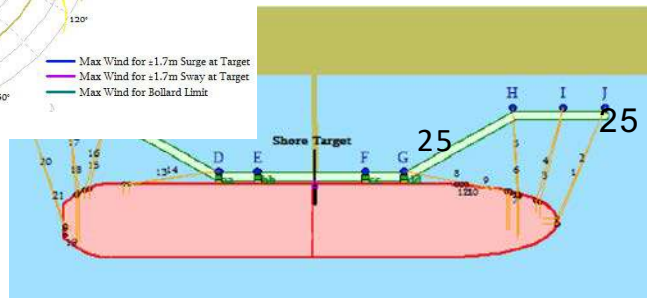
Terminal Requirements & Compatibility

1. SHIP-SHORE INTERFACE (PHYSICAL COMPATIBILITY)

WHAT DO WE CHECK?

- Navigation
  - Entry channel
  - Turning circle
  - Available tugs
- Mooring means
  - Terminal equipment (hooks, fenders)
  - Ship equipment (flat body, winches, mooring lines)
  - Mooring simulation (Optimoor)





Terminal Requirements & Compatibility

1. SHIP-SHORE INTERFACE (PHYSICAL COMPATIBILITY)

WHAT DO WE CHECK?

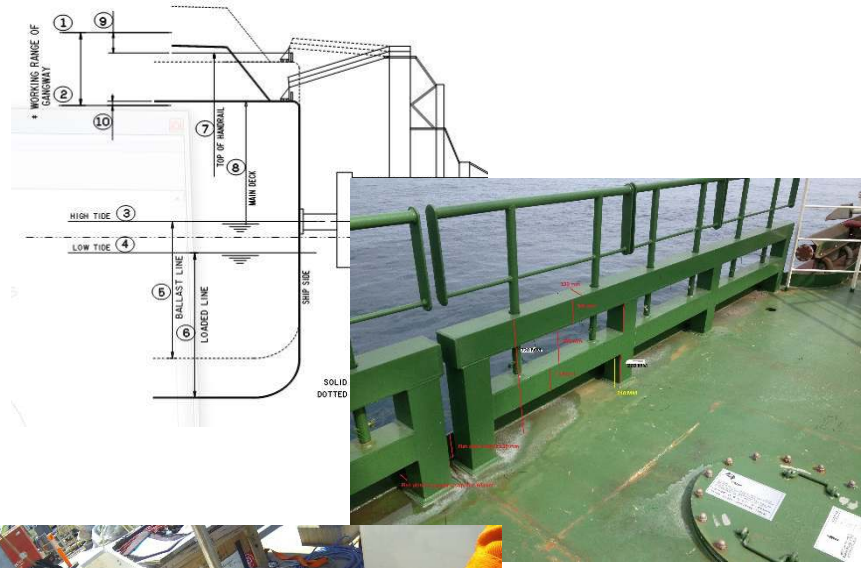
- Loading arms compatibility
  - Vertical range
  - Flanging details
    - Bolts or QCDC
    - Use of SDSP
  - Strainers

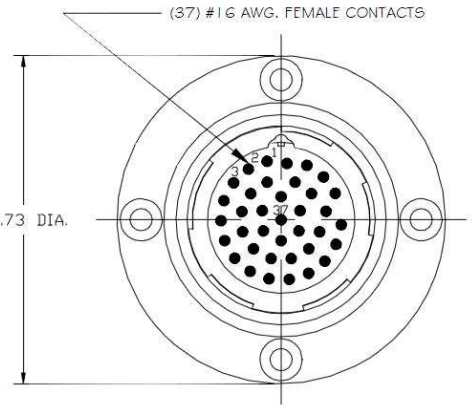
Terminal Requirements & Compatibility

1. SHIP-SHORE INTERFACE (PHYSICAL COMPATIBILITY)

WHAT DO WE CHECK?

- Gangway compatibility
  - Vertical range
  - Support type or lands on deck
- Communication equipment (ship-shore link)
  - Means: Electric, optical, pneumatic (ESD only), radio (audio only)
  - Provides:
    - Audio communication
    - Emergency shut down system
    - Tension monitoring



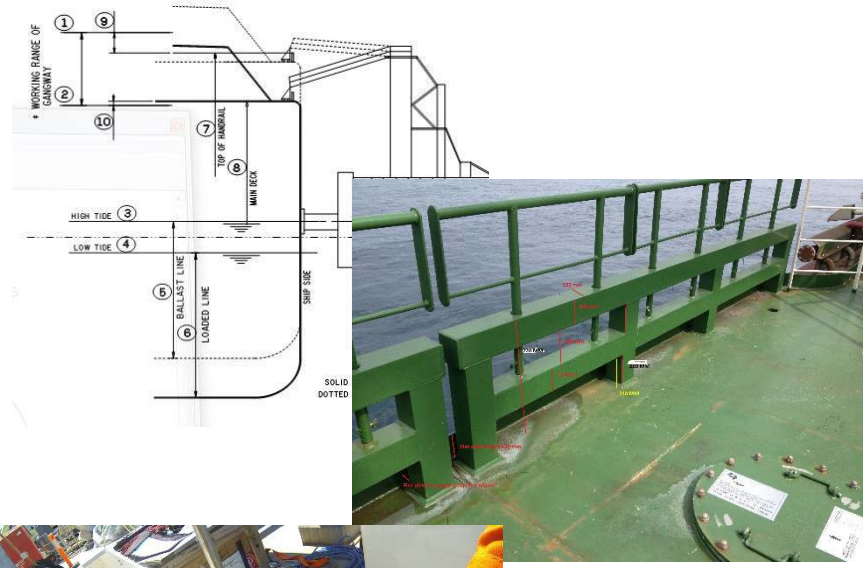


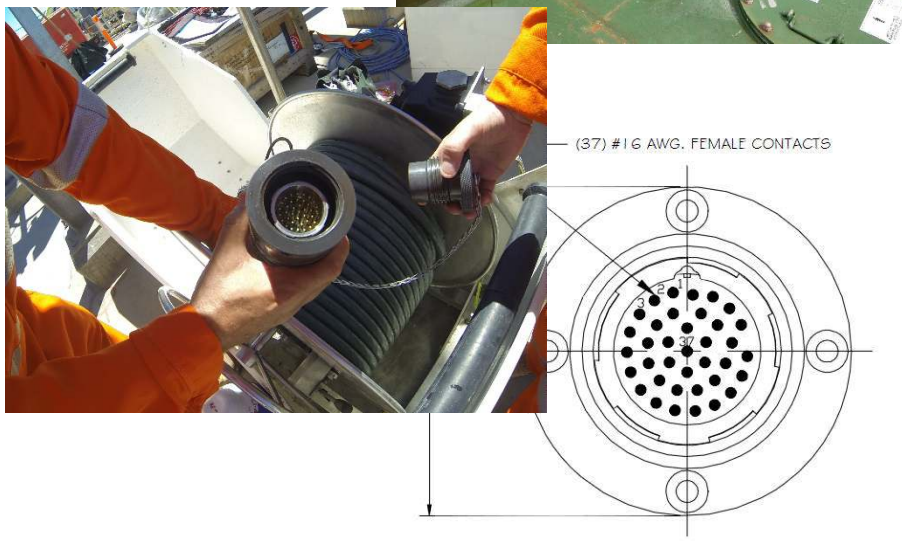
Terminal Requirements & Compatibility

2. SHIP-SHORE COOPERATION (AGREEMENT ON PROCEDURES)

WHAT DO WE CHECK?

- Mooring procedure
  - Weather restrictions for berthing / unberthing
  - Mooring with line boats or messengers
- Cargo transfer procedure
  - Manifolds connection and cooldown
  - Ramp up-down
  - Vapour handling equipment
  - Draining and purging
  - Custody transfer management
- Emergency procedure
  - Emergency communication
  - Emergency departure (e.g. for tsunami)





Terminal Requirements & Compatibility

3. SHIP-SHORE ACCEPTANCE (DUE DILIGENCE CHECKS)

WHAT DO WE CHECK?

On the terminal side

- Does the ship meet regulatory requirements?
- Are there any conditions of class?
- Are ship certificates in good order?
- Have inspections (SIRE, Port State Control, etc) been carried out without issue or serious observationsion

On the ship operator side

- Is the terminal equipment adequate?
- Are settings for key components correct (for example, ESD systems)?
- Are terminal procedures established, safe and clear?
- Has the terminal faced serious operational problems in the past?

SAFETY FIRST!

Physical compatibility confirmation is not sufficient for vessel or terminal acceptance. Vessels must be in properly maintained and operated. Terminals must meet all the qualifications of a safe port.