

# **LNG Storage Solutions: A Key Consideration and Element in LNG Terminal Operation**

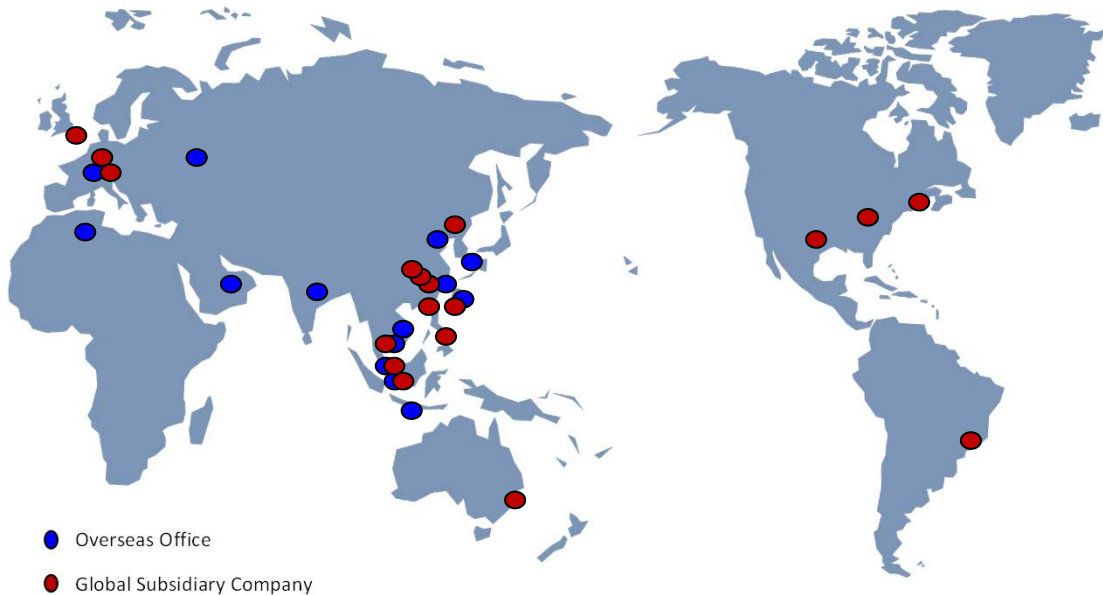
Presented by:

Hal Bouknight – Senior Vice President of Business Development

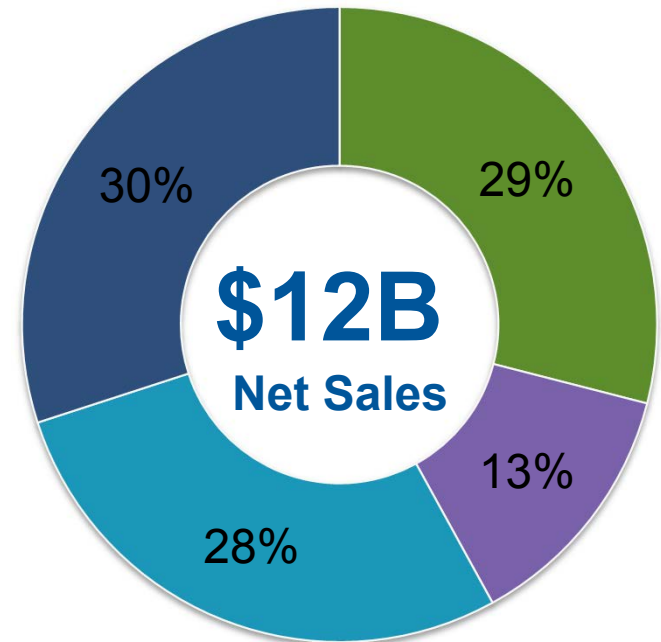
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# IHI Overview

*IHI can stand behind your project through its financial strength and support network of 10 major manufacturing centers in Japan plus multiple world wide locations in key industrial segments.*

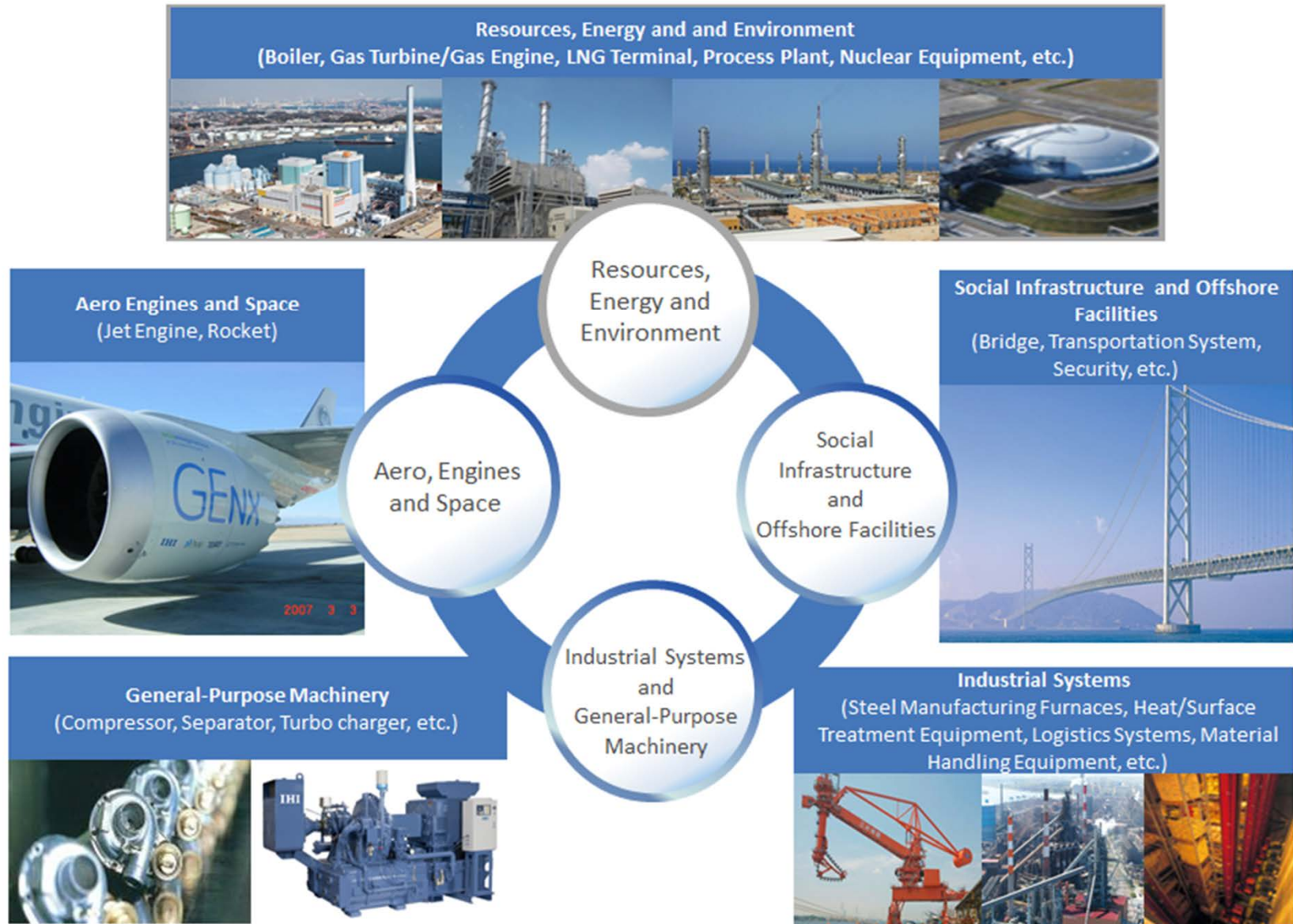


<b>Established</b>	<b>1853</b>
<b>Employees</b>	<b>27,000+</b>
<b>Offices</b>	<b>33</b>
<b>Factories</b>	<b>10</b>
<b>R&amp;D Facility</b>	<b>1</b>



- Resources, Energy & Environment
- Social Infrastructure & Offshore Facilities
- Industrial Systems & General-Purpose Machinery
- Aero Engines, Space & Defense

*For over 160 years, IHI has helped customers solve their most challenging problems.*





*We combine process expertise and technology know-how to deliver Full EPC solutions successfully.*

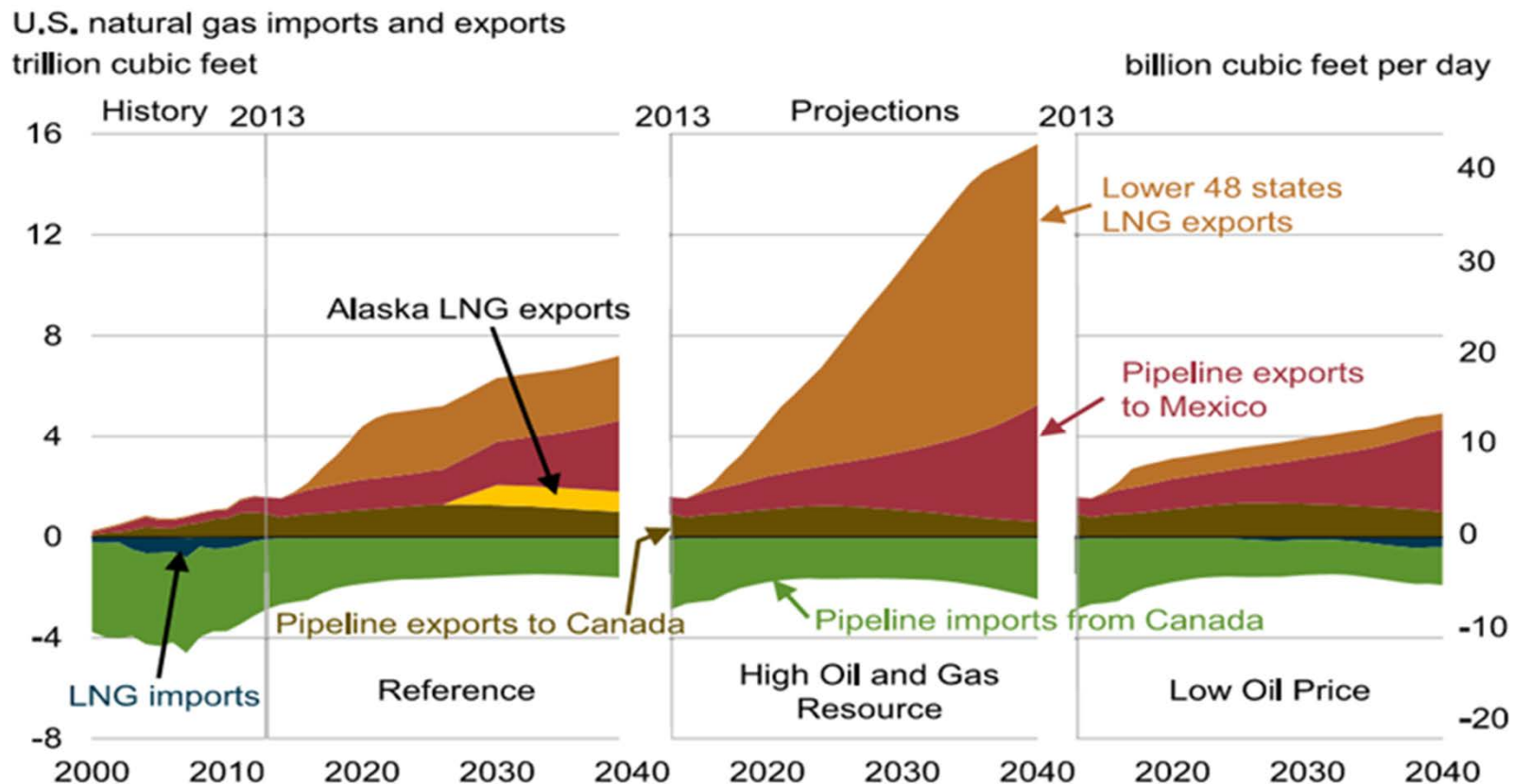
- HSE performance is a top priority
- Proven project delivery model
- Full service EPC/CM capabilities
- Direct-hire Construction
- Commissioning and Start-Up services
- Ability to leverage HVEC resources
- Global procurement reach



1080 Eldridge Parkway, Houston, TX

# Perspective

*Projected U.S. natural gas exports reflect the spread between domestic natural gas prices and world energy prices*



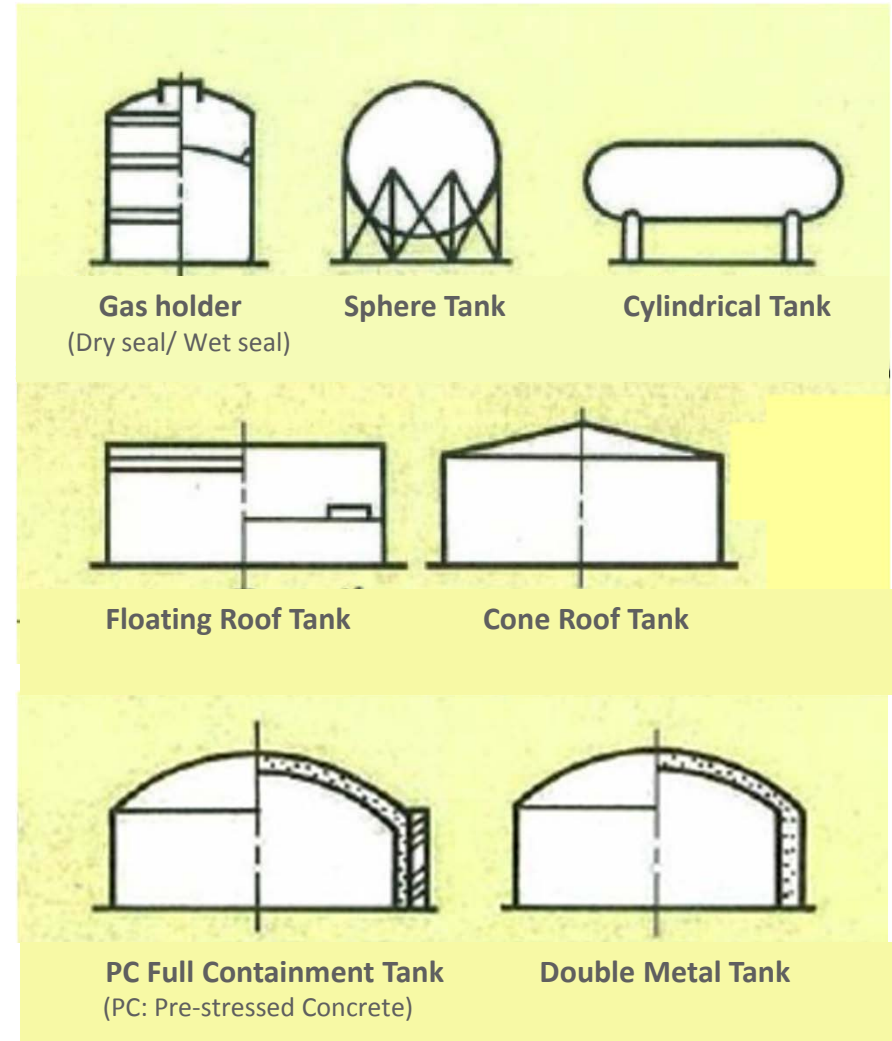
Source: EIA, Annual Energy Outlook 2015

*The United States transitions from being a net imported of natural gas to a net exported by 2017 in all cases*



# Variation of Storage Tanks for Oil and Gas

- Gas Storage  
Propane, Butane, Nitrogen & Various Industrial Gas
- Liquid Storage  
Crude Oil, Heavy Oil, Water
- Liquefied Gas Storage  
LNG, LPG, Ethylene, Ammonia, etc.



# Tank Material for Low-Temperature Application

## Steel Material Property

Carbon Steel



Ductile Behavior at  
Low Temperature



Brittle Fracture

Liquid Temperature	°C	° F	Steel Material
Butane (i)	-12	-10	High Tensile Steel, Carbon-Manganese Steel
Ammonia	-33	-27	
Propane	-45	-49	
Propylene	-48	-54	
		-60	API 620 Appendix-R
Ethane	-88	-126	3.5% - 5.5% Ni Steel
Ethylene	-104	155	
Methane/ LNG	-163	-261	7% - 9% Ni Steel
Argon	-186	-303	9% Ni steel
Nitrogen	-196	-315	
		-325	API 620 Appendix-Q

*Use low temperature steel with suitable fracture strength.*

## Typical Property for Liquefied Gas

- Main component: Methane (CH<sub>4</sub>)
- Liquid at -162° C (-260° F).
- Volume of LNG reduced to 1/600 of gaseous state
- Colorless, odorless, clean
  - Liquefaction process involves removal of certain components, such as dust, acid gases, helium, water, and heavy hydrocarbons
- Density of LNG is roughly 0.42 to 0.48 kg/L
  1. Ocean Transportation

The reduction in volume makes it much more cost-efficient to transport over long distances where pipelines do not exist.
  2. Large-Volume Storage

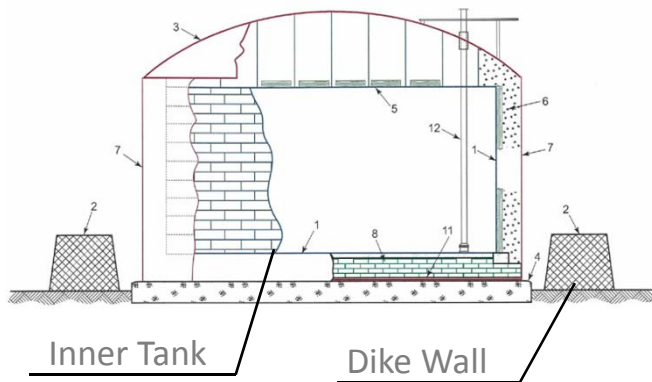
Where large volume natural gas storage is not economical, it can be stored as LNG in specially designed cryogenic tanks.



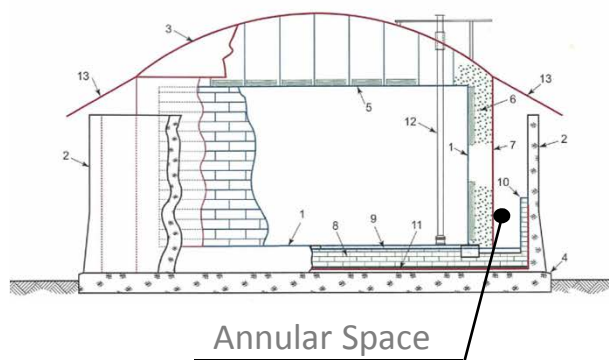
# Storage Concept

THREE DIFFERENT MAIN CONCEPTS FOR LNG			
Type	Single Containment	Double Containment	Full Containment
Property	Only Inner Container Contain Liquid	Both Inner And Outer Container Contain Liquid Annular Space Shall Not Be More Than 6 M (20 Ft)	Both Inner And Outer Container Contain Liquid The Secondary Container Is Capable To Contain Both Liquid And Vapor
Inner Tank	Liquid Tight Container	Liquid And Vapor Tight Container	Liquid Tight Container
Outer Tank	Vapor Tight Container	Liquid Tight Container	Liquid And Vapor Tight Container
Dike Wall	Require As Secondary Liquid Container	Not Required * Except as may be required by Fire Safety codes or FERC/PHMSA	Not Required

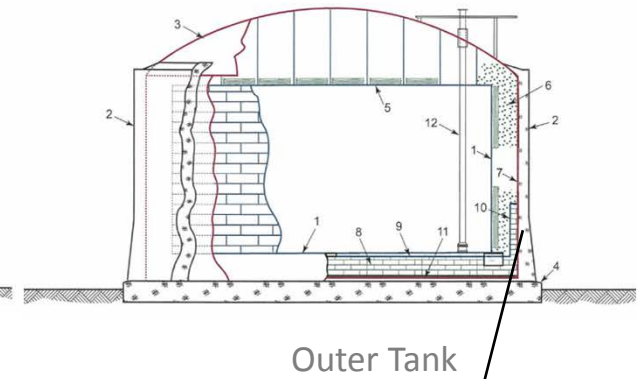
**Single Containment**



**Double Containment**

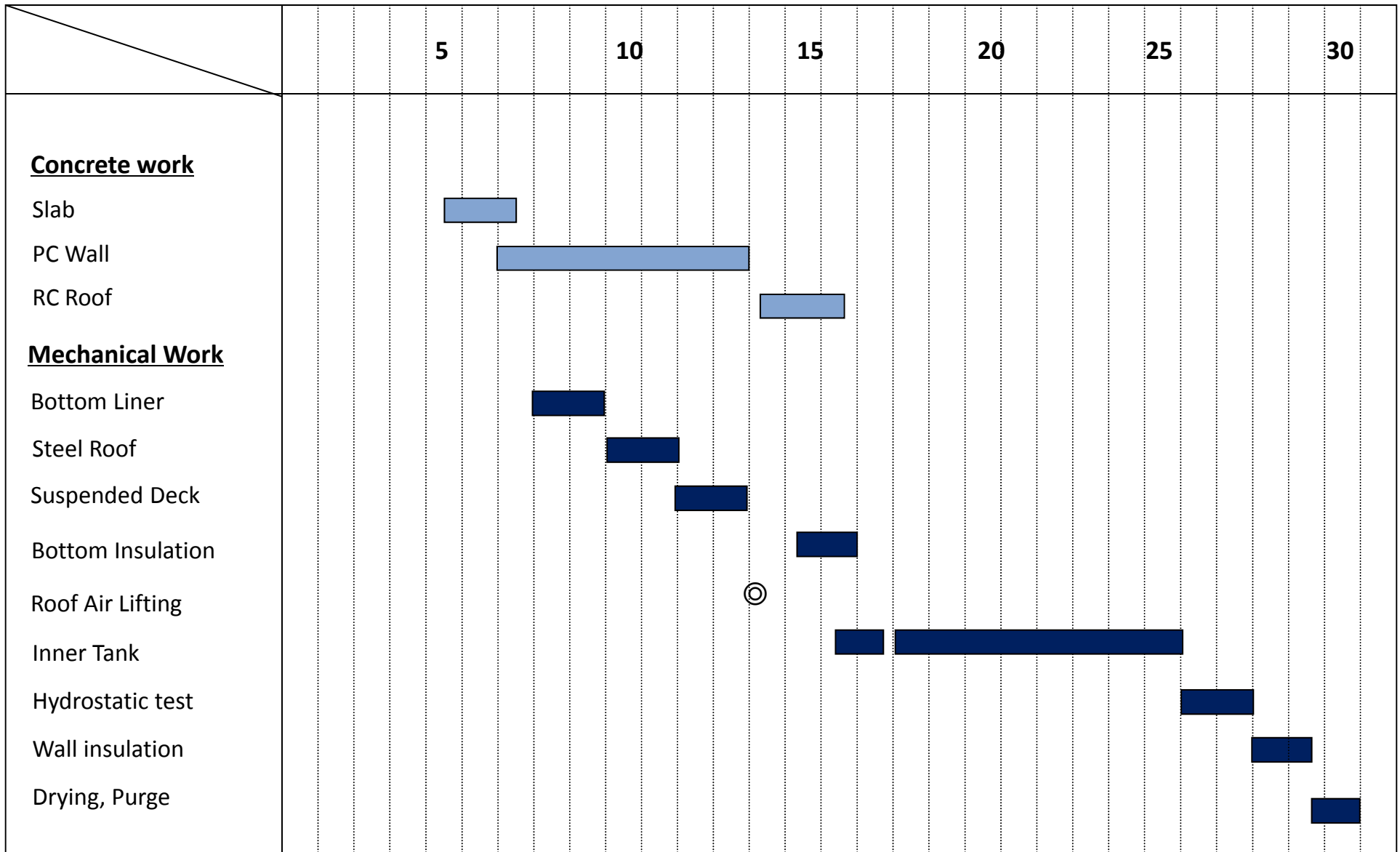


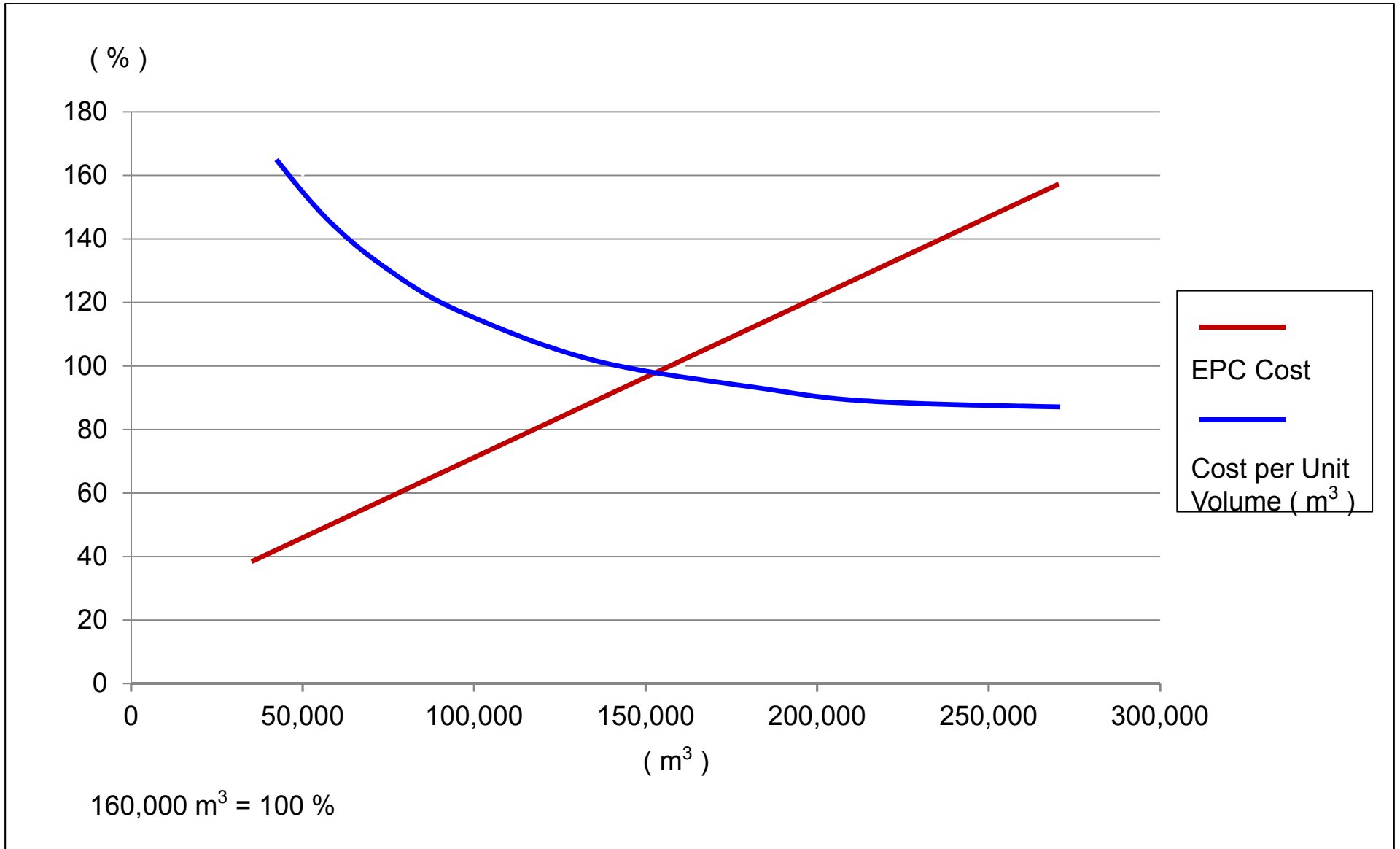
**Full Containment**



## Full Containment Type Tank

# Typical Schedule (160,000m<sup>3</sup>)

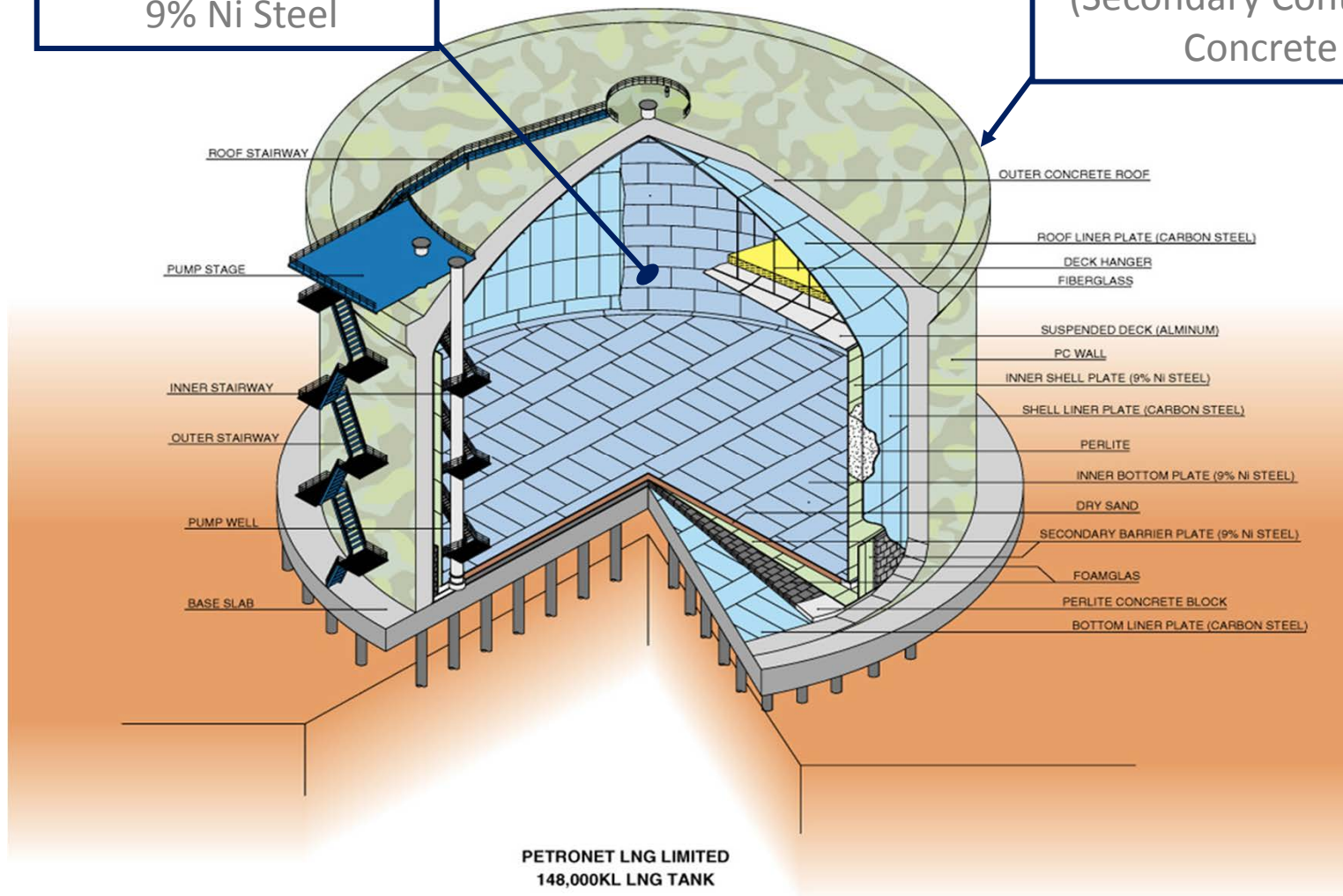




## Conceptual Diagram Of Tank

Inner Tank  
(Primary Container)  
9% Ni Steel

Outer Tank  
(Secondary Container)  
Concrete











# Concrete Outer Wall





# Bottom Liner Plate (Outer Tank)



# Steel Roof (Outer Tank)











# Suspend Deck







# Inner Tank Shell (9% Ni Steel)









# Completion of Full Containment Tank





# Conversion of Import to Export or Bidirectional Terminal – Considerations



- Current state of the existing LNG storage tank(s)
- Assuming conversion from import to export (LNG side)
  - LNG loading and unloading rates (reversed)
  - Generally new larger or additional pump(s) required
  - Existing well with changes in pump discharge nozzles or
  - Additional well(s) with new larger nozzles on the tank(s)
  - Use of spare well requiring additional piping, instruments
  - Overall in-tank pumps pumping rate changes will generally leads to
  - Roof-top piping, instruments, structural changes due to the larger pumps or in the worst case scenario additional nozzle(s)/well(s)
  - Safety considerations for the Pressure/Vacuum conditions at the LNG tanks



2010/01/20

# Finished Concrete Roof









# Finished Tank Tops



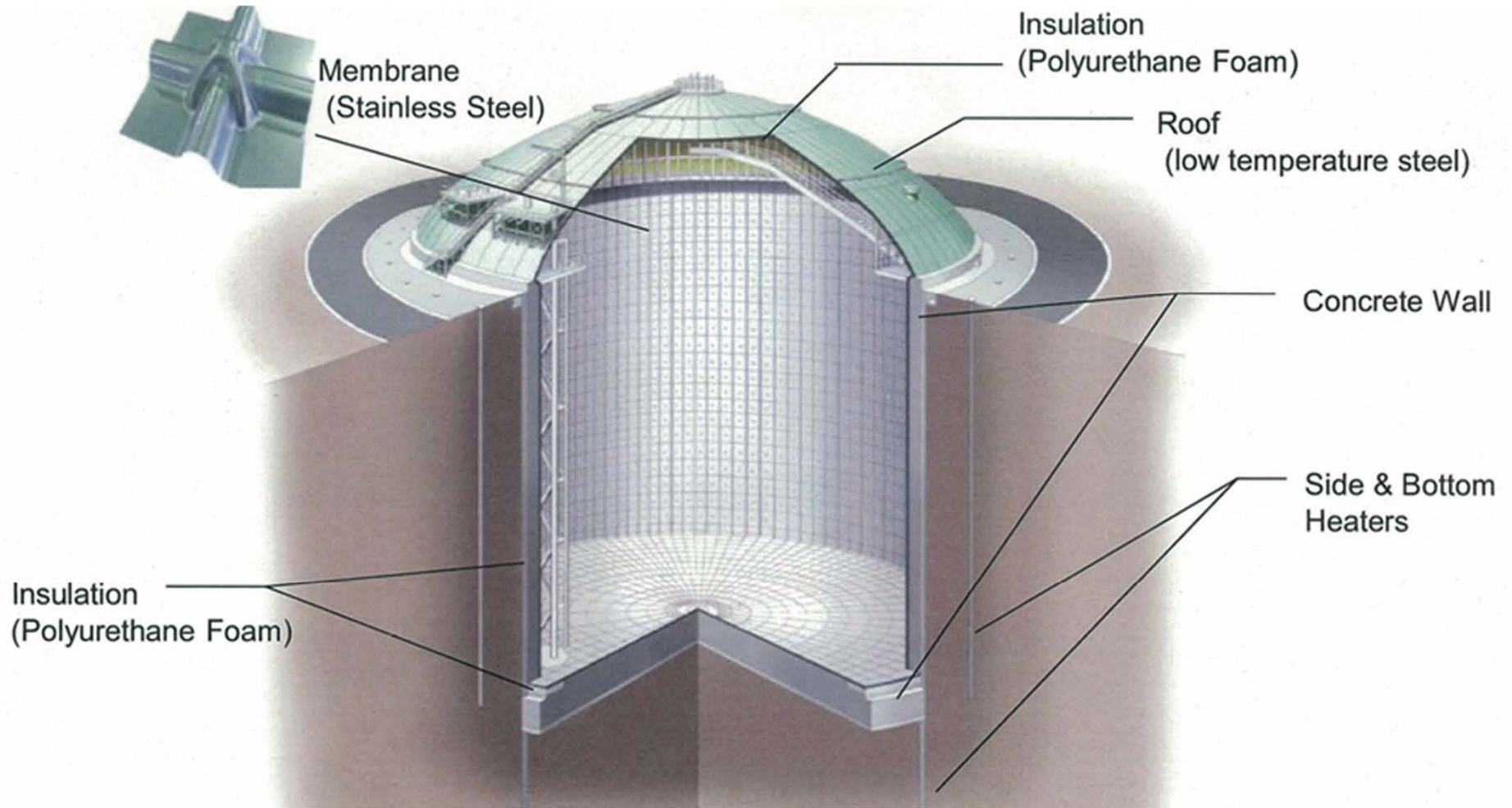
## Existing LNG storage tank(s) reconfiguration

- Possible changes to the tank or tank roof top
  - Modification requirement – major/minor
  - Is tank entry required? i.e likely major changes
  - Where structural or other major changes required:
    - ✓ Perform structural analysis including FEA analysis for the roof-top
  - Construction methods varies depending on:
    - ✓ Existing tank type (single/double/full containment)
    - ✓ Changes to the roof top only, internal, or both
- If major reconfiguration – requiring tank-entry
  - Tank warm-ups or re-cooling analysis
  - Decommissioning of the tank(s)
  - Inspections
  - Modifications / testing / commissioning
- Schedule and cost considerations if reconfiguration required

# In-ground Storage Tank

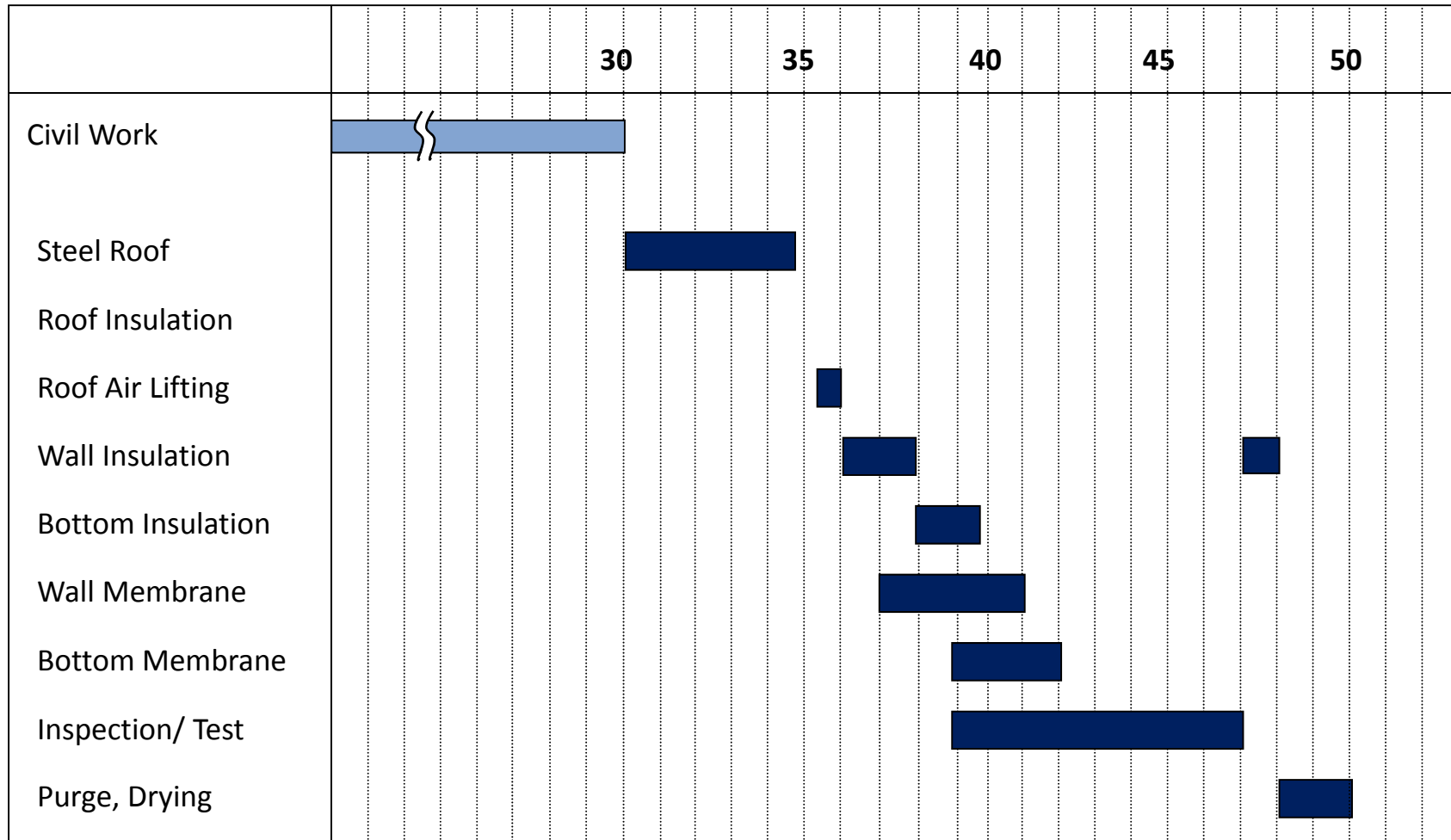


## Structure of In-Ground LNG Storage Tanks





# Typical Schedule (200,000m<sup>3</sup>)









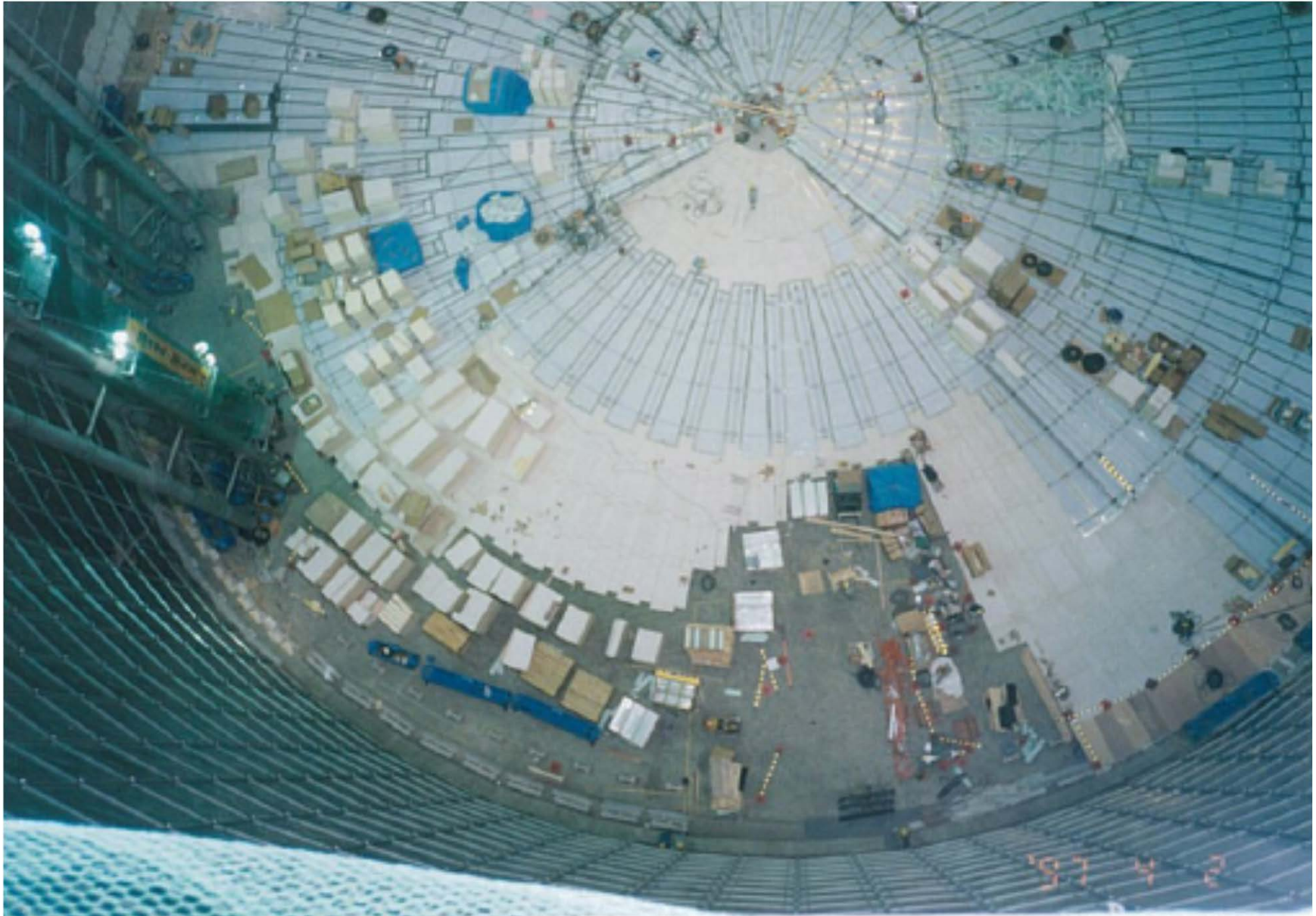




# Wall Membrane (SS 304)







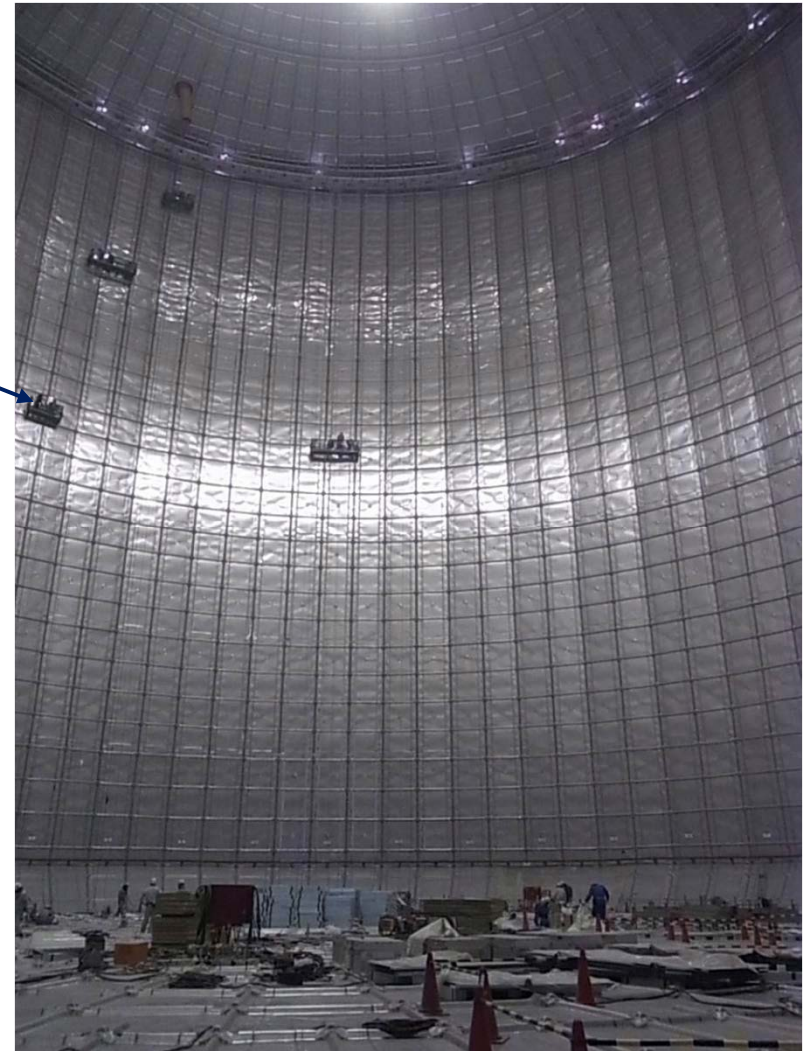
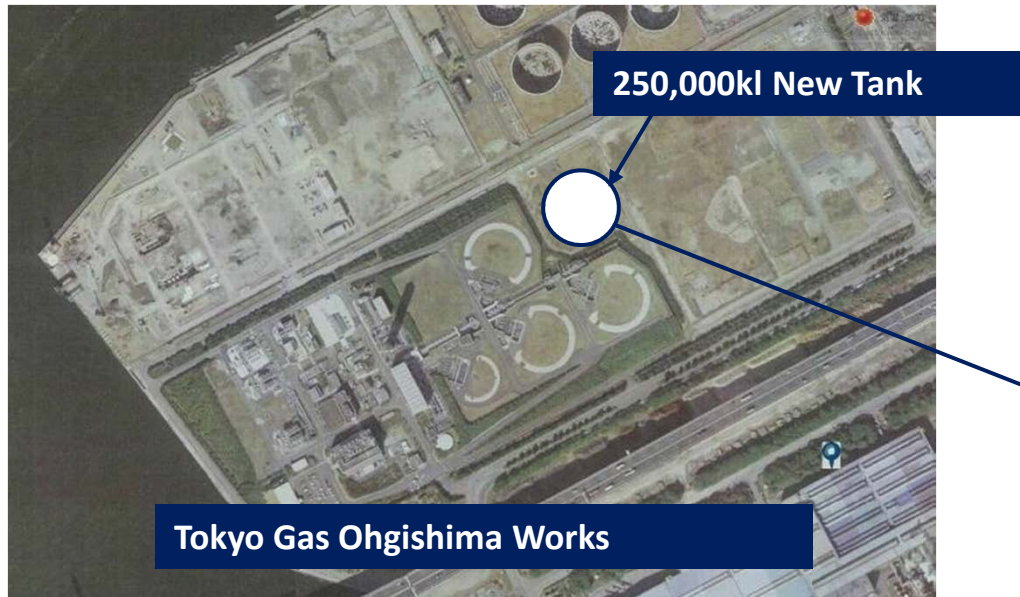
# Ammonia Leak Test





# Approach for 250,000kl World Largest LNG Storage Tank

## Inside view of 250,000kl tank



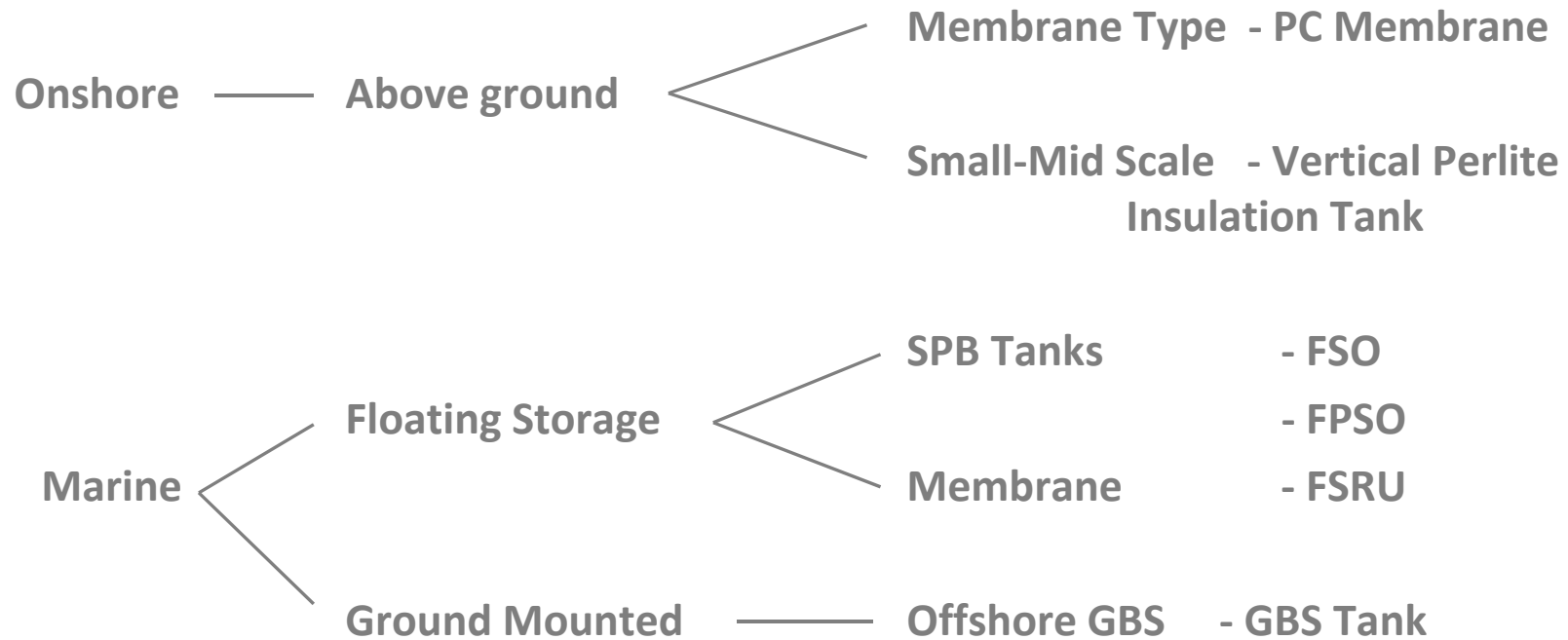
Capacity	250,000 m <sup>3</sup>
Inner Diameter	72m (236 ft)
Liquid Height	61.7m (202 ft)

### CONCEPT

1. Same Diameter for the Land District
2. Construction Of Maximum Volume

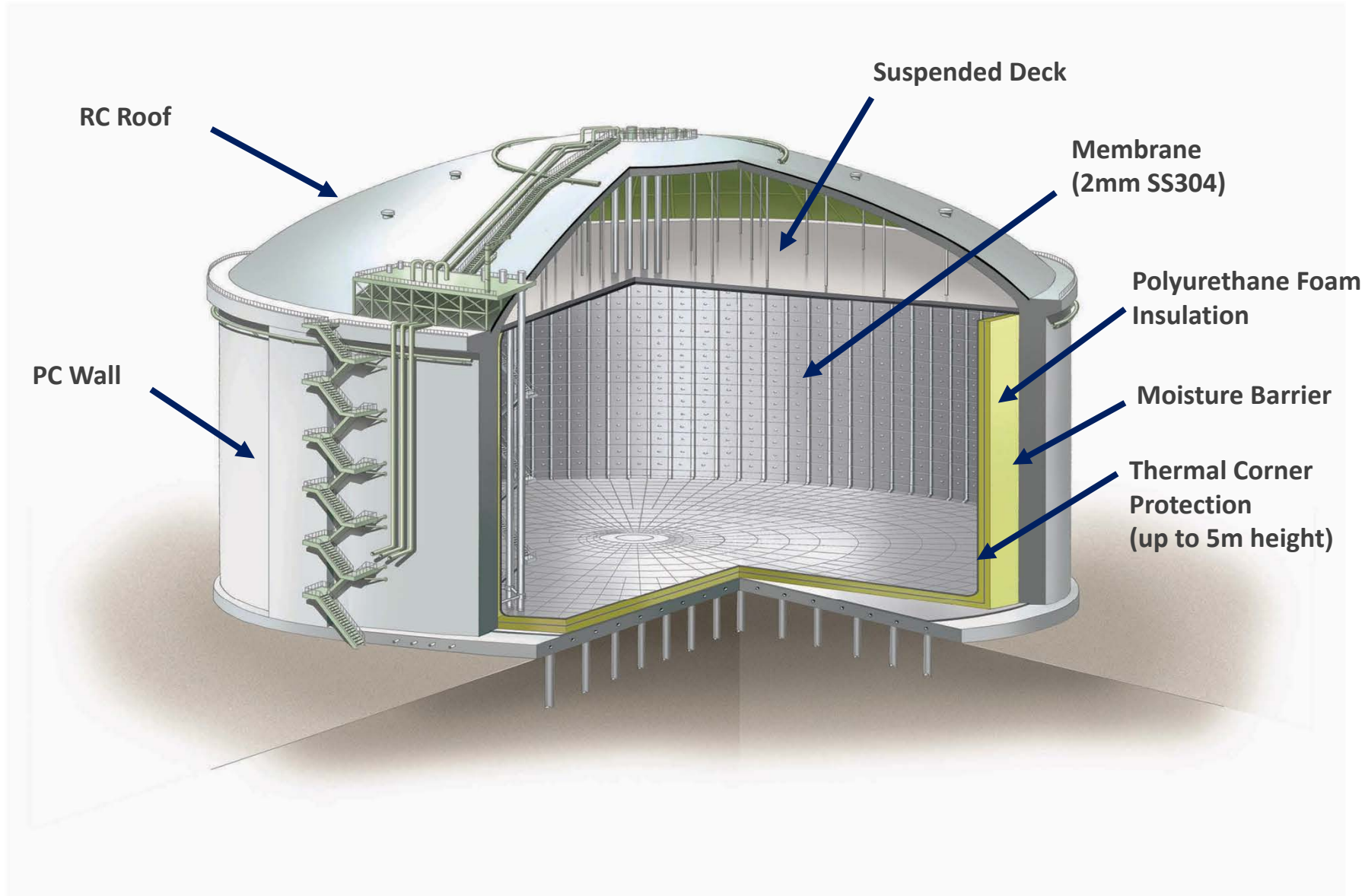


# Variations for Cryogenic Storage Concepts

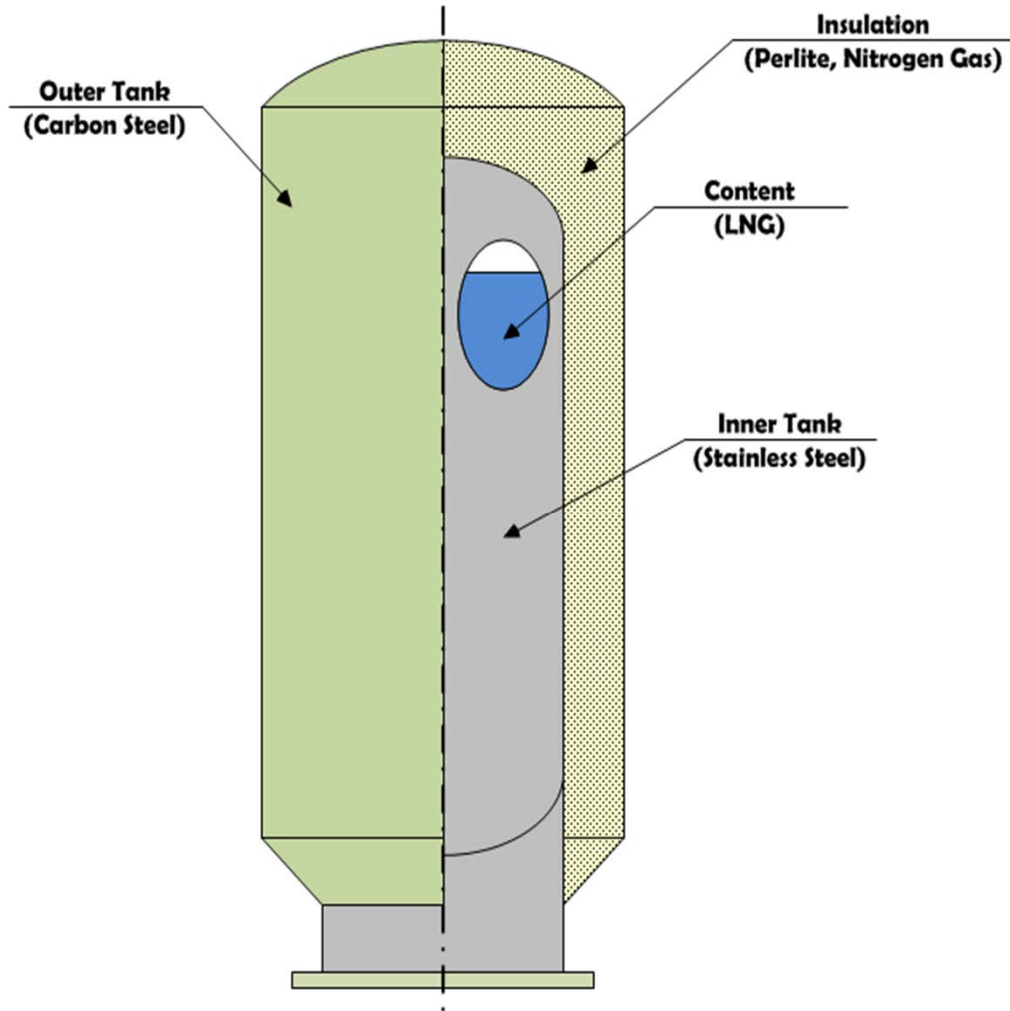


Note: SPB – Self - Supporting Prismatic IMO Type B  
GBS – Gravity Base Structure  
FPSO – Floating Production, Storage and Offloading Unit  
FSRU – Floating Storage and Regasification Unit

# LNG PC Membrane Tank



## Outline Drawing



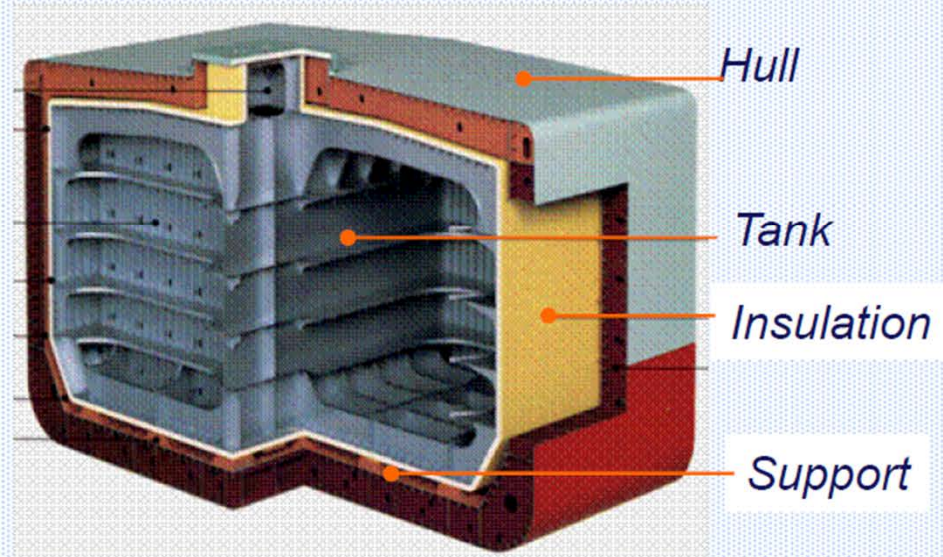


## Outline of SPB Cargo Tank System

**S**elf-supporting, **P**rismatic-shape IMO type **B**

**Structural concept based on long history and experiences in marine technology**

- Robust
- Best fit to hull form
- Restricts motions of cargo liquid inside





# Floating Storage/Floating Terminal

LNG-FSO



FLNG



FLPG



IHI-SPB®



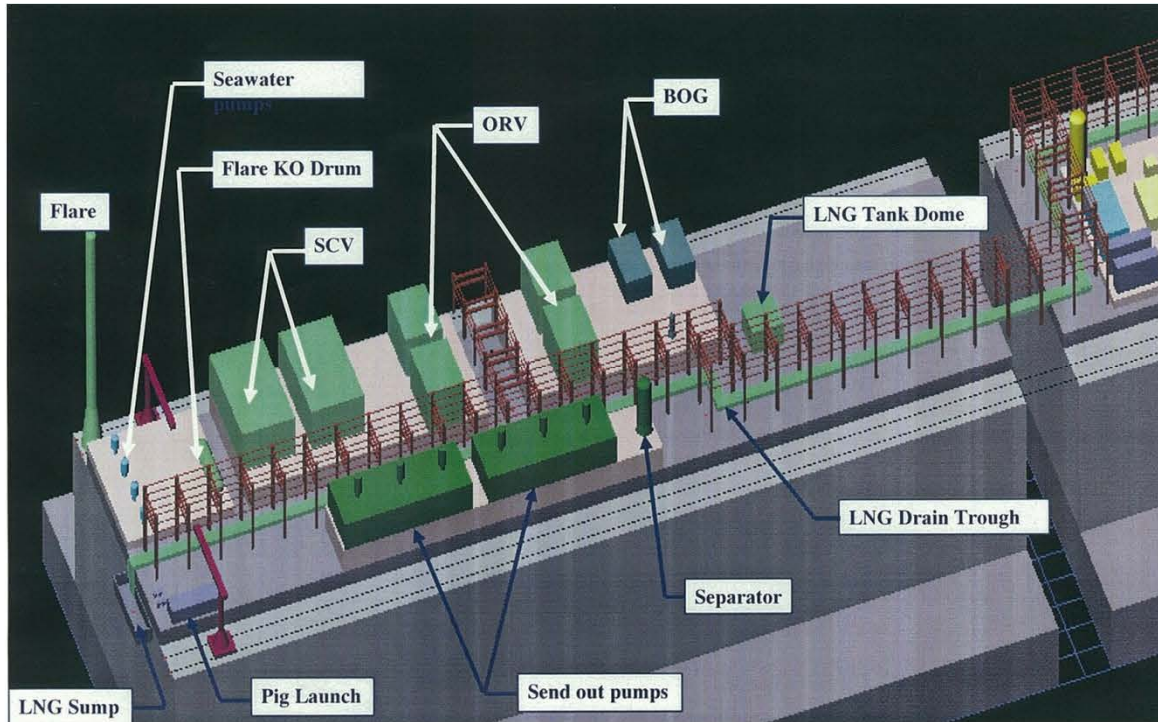
LNG Carrier



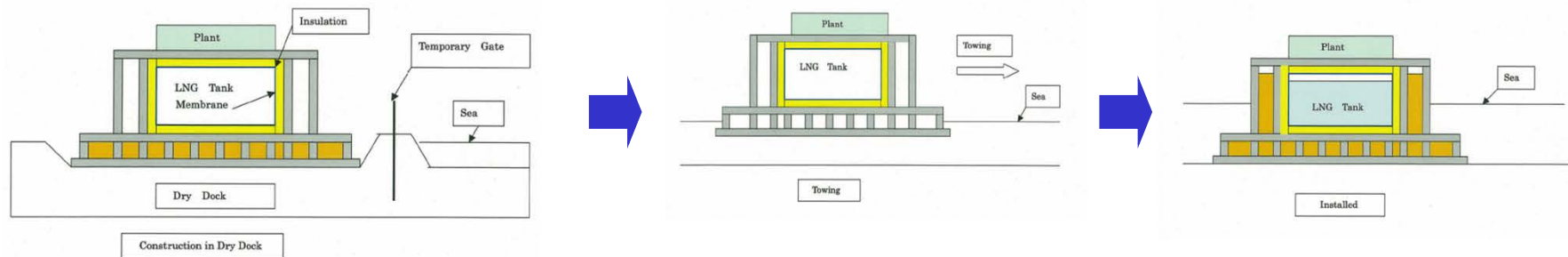
LNG FSRU

Note: FPSO – Floating Production, Storage and Offloading Unit  
FSRU – Floating Storage and Regasification Unit

# GBS Membrane Type



GBS Membrane Tank Construction Procedure





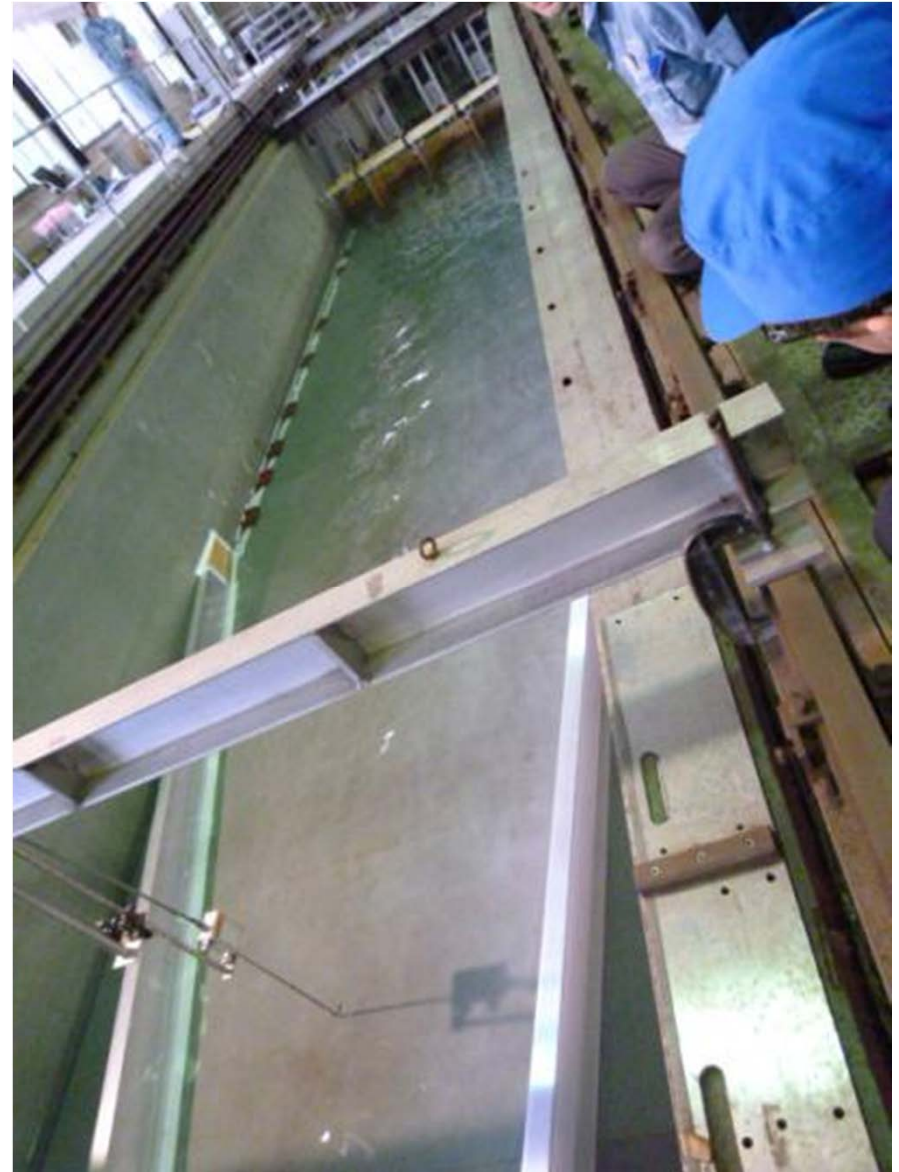
# Improving Tank Technology

*IHI has executed LNG tank seismic test by METI in 1996 to 1999.  
Large scale model of 8.0m diameter tank has been shaken on the test bench.*





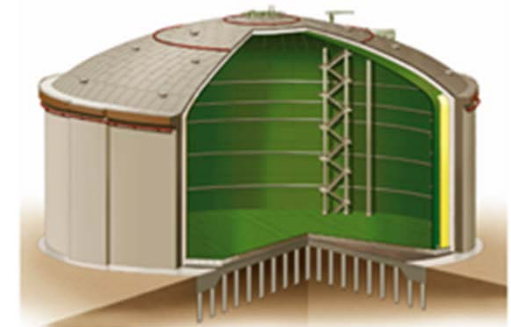
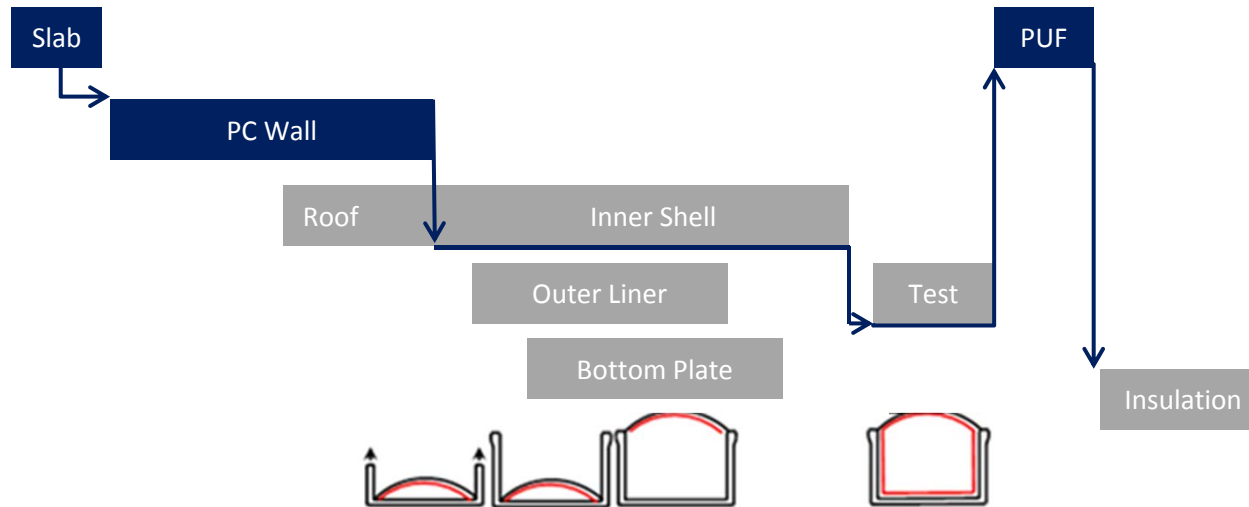
## *IHI Yokohama R&D Center*



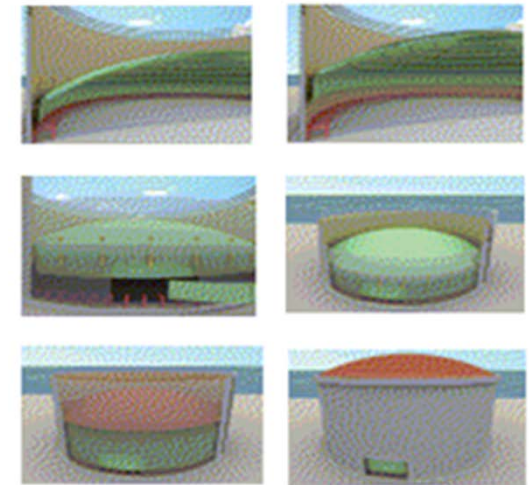
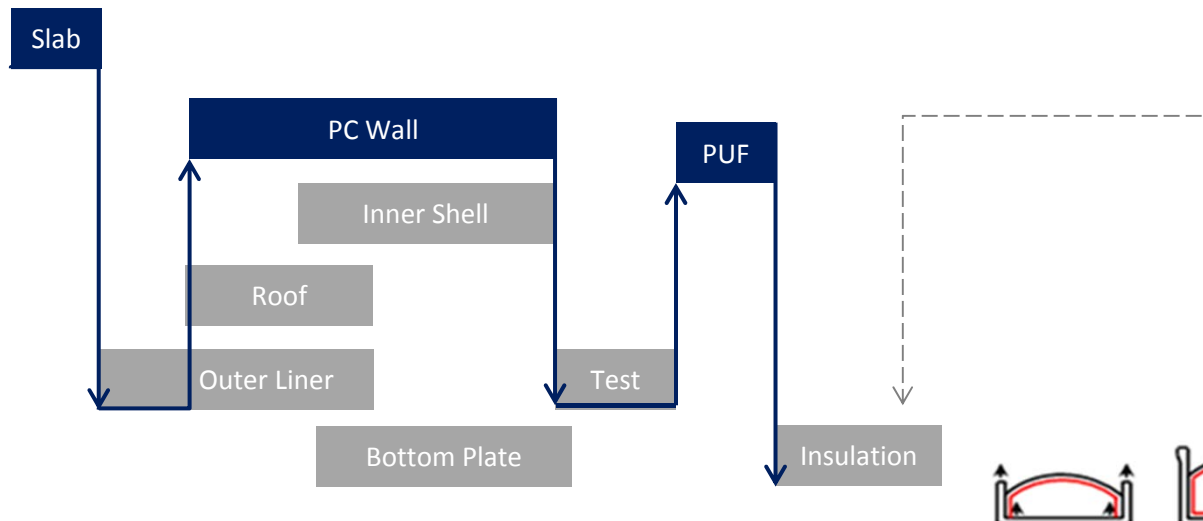


## Focus on Shorter Tank Construction Period

Conventional Roof Air Lift Method: 39 Months



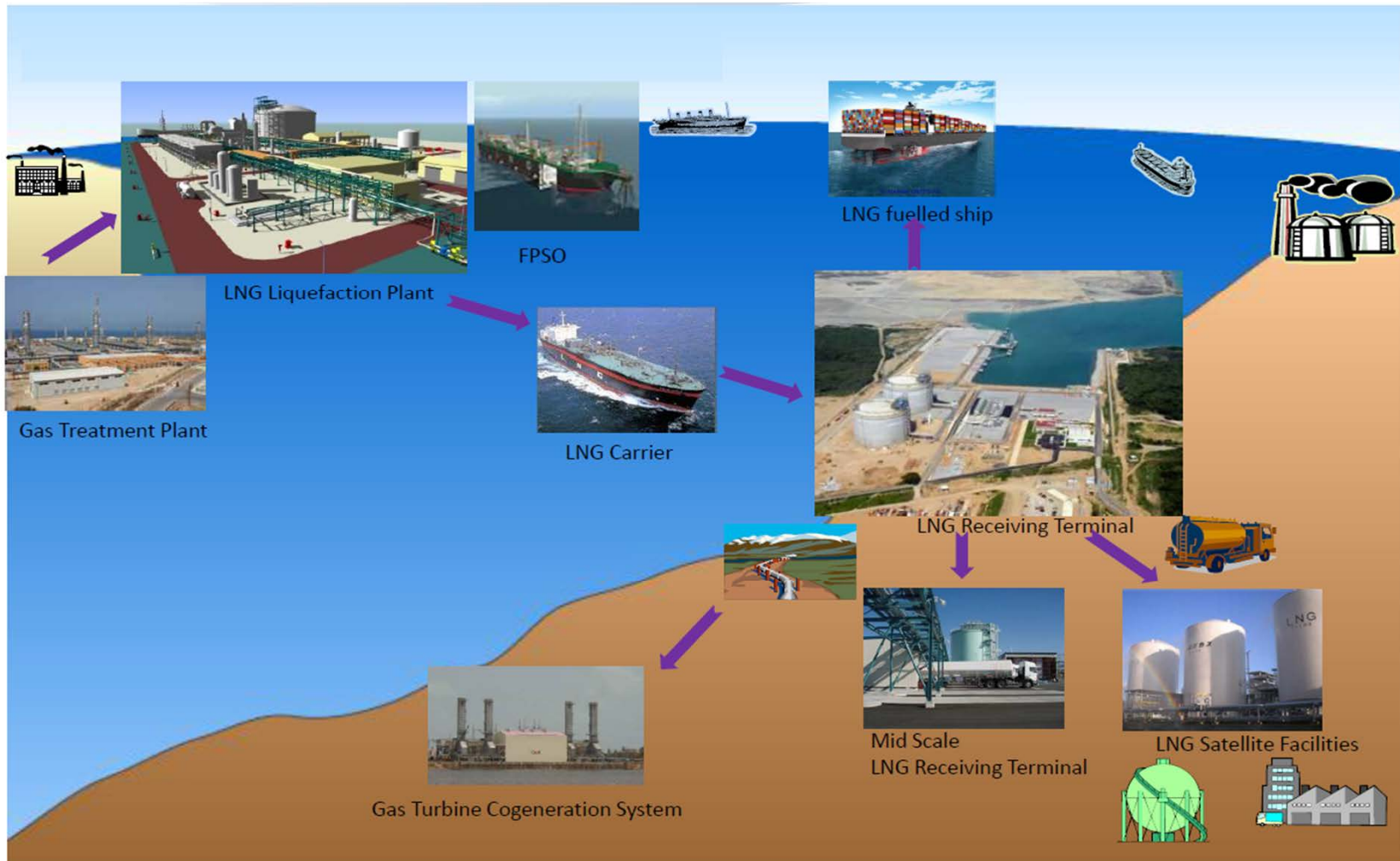
J.C. Method (Jack Climbing Method): Potentially Reduce up to 14 Months



## Total Solution in LNG Value Chain

# Total Solution in LNG Value Chain

*IHI has over the 40 years of experience in developing numerous LNG Import Terminals, Liquefaction Projects, LNG Storage Tanks, and LNG carrier projects. IHI has the proven experience to provide the total LNG Solutions.*





# IHI

## Realize your dreams



**Contributing to  
the development of  
society through technology**