Petronet LNG Ltd.,
India

LNG Terminal Design- Major Design Considerations

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OVERVIEW

1. What is LNG and LNG Chain
2. Project Development & Site Selection
3. Studies Required
4. Marine Facilities
5. Storage Tanks
6. Regasification & Sendout
7. Terminal Layout
8. New Development

What is LNG?

Liquefied Natural Gas (LNG)

LNG is a natural gas that has been cooled to the point that it condenses to a liquid, which occurs at a temperature of approximately -162°C at atmospheric pressure. Liquefaction reduces the volume of gas by approximately 600 times thus making it more economical to store natural gas, and transport gas over long distances for which pipelines are either too expensive or not feasible. Thus, LNG technology makes natural gas available throughout the world. LNG is a cold, transparent, odorless, non-corrosive, non-toxic and has low viscosity. LNG is safer than other liquid fuels. Typical LNG composition are as below:

Methane [CH4]	82.0% - 94.0%		Inert Nitrogen Gas [N2]	Trace
Ethane [C2H6]	3.0% – 6.0%		Carbon Dioxide [CO2]	NIL
Propane [C3H8]	0.1% - 2.0%		Oxygen [O2]	Trace
Butane [C4H10]	0.1% – 0.7%		Hydrocarbon Liquids & Water	NIL
Pentane [C5H12]	Trace		Sulphur [S]	10 ppm of H2S and not more than 15 ppm of total sulphur
Hexane-plus [C6H14+]	Trace		Gross Heating Value:	Not less than (35.39 MJ/scm)

PROJECT DEVELOPMENT AND SITE SELECTION

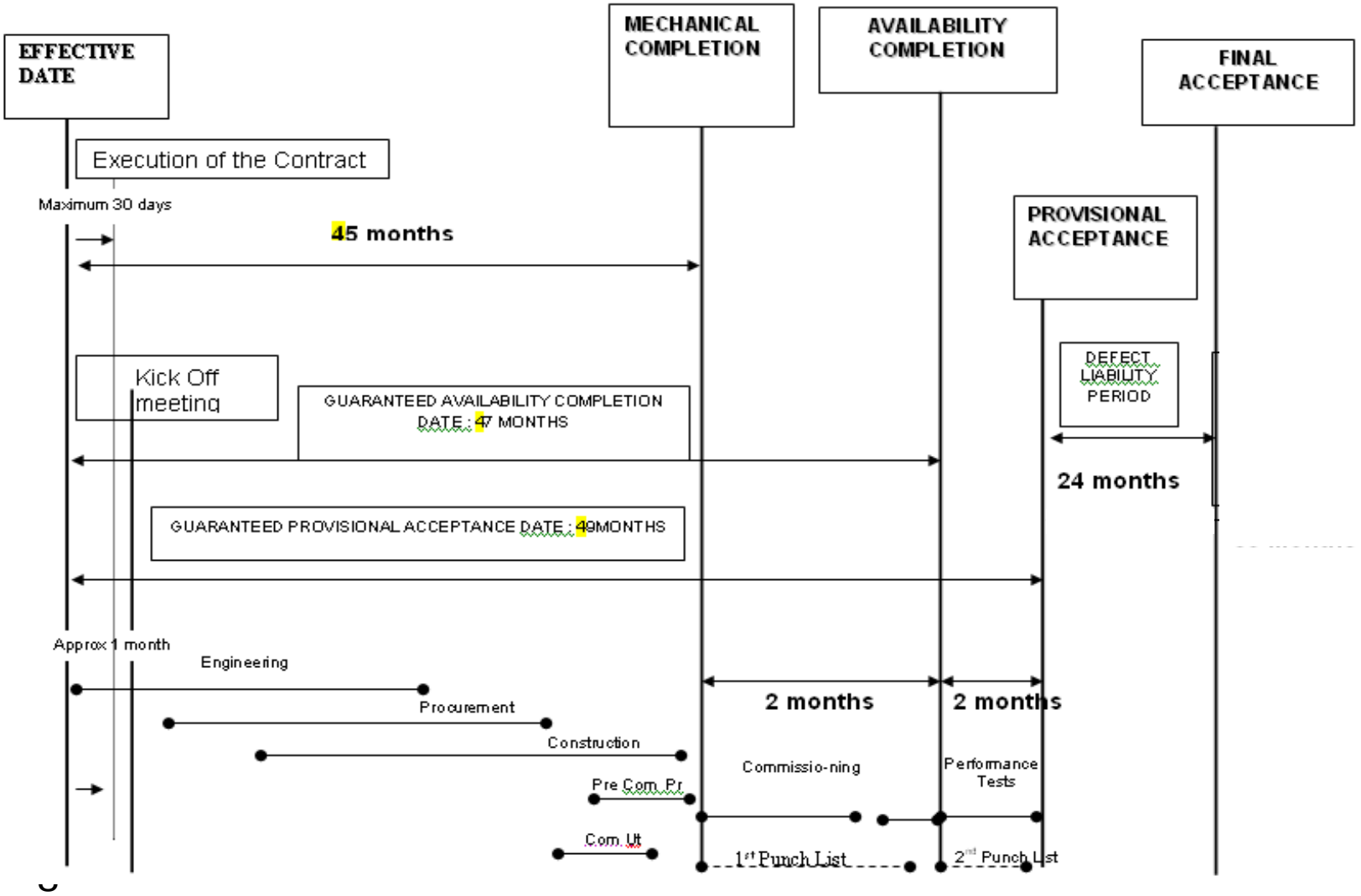
Typical Design Steps & Studies Required

- Pre-feasibility – Feasibility study
- BEP : Basic Engineering Package
- FEED : Front End Engineering Design
- RFP : Request for Proposal and Bids Evaluation
- EPC (Engineering Purchase and Construction) award
- Detailed Engineering, Purchase and Construction
- Commissioning and delivery

Typical project schedule : 60 months (5 years)

S No.	Description	Time (Months)
1	Pre feasibility (Market Data) & Detailed feasibility Studies	6 to 9
2	Front End Engineering Design	6 to 8
3	Request for proposal and bid evaluation	4 to 6
4	Engineering, procurement, and construction (Storage Tanks)	36 to 42
5	Commissioning and delivery performance tests)	2 to 6

Schedule


EFFECTIVE DATE
MECHANICAL COMPLETION
AVAILABILITY COMPLETION
FINAL ACCEPTANCE
Execution of the Contract
Maximum 30 days
45 months
PROVISIONAL ACCEPTANCE
Kick Off meeting
GUARANTEED AVAILABILITY COMPLETION DATE : 47 MONTHS
DEFECT LIABILITY PERIOD
24 months
GUARANTEED PROVISIONAL ACCEPTANCE DATE : 49MONTHS
Approx 1 month
Engineering
Procurement
Construction
Pre Com Pr
Com Ut
2 months
2 months
Commissio-ning
Performance Tests
1st Punch List
2nd Punch List

PROJECT DEVELOPMENT AND SITE SELECTION

- Need of LNG terminal
- Project identification and formulation
- Feasibility studies to analyse the technical, environmental, commercial and marketing factors
- Site - Permitting conditions

ECONOMICS OF LNG IMPORT FACILITIES FOR NEW GAS MARKETS

- Sufficient demand for gas for next 15-20 years
- Pipelines alternatives impractical
- High load factor
- LNG imports Government policy
- Suitable import site
- Avail infrastructure for gas distribution

SITE SELECTION

- Suitable Port
- Land Availability & Soil Condition
- Consumer
- Infrastructure
  - Gas Pippeline
  - Water
  - Power

– Present and future availability of gas

– Nearby center of population

STUDIES REQUIREMENT-SITE SELECTION

- Soil
  - Type of soil
  - Extent of soil filling required
  - Availability of soil
- Type of storage tanks
- Marine facilities
- Requirement of breakwater
  - Type of breakwater (island type, shore based)
  - Length & No. of breakwater
- Length of Jetty Trestle
- Local Environment
- Weather Condition
  - Heavy Monsoon
  - High Wind speed

FEASIBILITY & RANKING OF SITES

- Eliminate obviously unsuitable sites
- Compare suitability of met-oceanic and land parameters
- Define typical feature and estimate costs
- Evaluate Opex
- Rank sites in cost-risk terms
- Revisit best site: plan plant layout & berth

KEY FACTORS GOVERNED BY SITE DATA

- Navigation of LNG tankers & turn around times
- Construction schedule
- Safety and security of operation
- Expandability of design
- Regas methodology
- Method of power generation
- Air Emissions & water quality
- Pipeline route feasibiltiy
- Perception of safety (to Population)

ENGINEERING STUDIES DURING THE CONCEPTUALIZATION STAGE

LIST OF INVESTIGATIONS & STUDIES REQUIRED

Investigations	Physical features	Influence on Design
Bathymetry & Tidal Survey	Sea bed levels/ Water depth, tidal variation, Low, Mean & High tidal levels	Approach of ship Location & Level of jetty head
Side Scan Sonar	Profile, obstacles, wrecks.	Wreck Removal Requirement
Meteorological Investigations	Wind, Currents & Waves - frequency distribution of wind/ current speed/ wave height/, direction & wave period Storm surge, Past storm track, storm surge	Orientation of facilities Need for Breakwater Structural design Mooring Requirements Input to model studies
Marine Geo-technical Investigations	Geology & Subsoil properties Seismic sounding of subsoil strata	Design of port structures and Assess need of geotextile

LIST OF INVESTIGATIONS & STUDIES REQUIRED

Investigations	Physical features	Influence on Design
Analysis of water Properties	Physical chemistry of the water Salinity Pollution Turbidity	• Assessment of suitability of Open Rack Vaporizers • Assessment of Sedimentation in port area • Design of ship Ballast Management System • Design of Cathodic Protection System
Environmental impact Study	Marine fauna and flora Coastline	• Effect of port construction & operation activities on • aquatic species, mangroves etc. • Interference with fishing • Impact of works on beach, historic sites and Monuments

HYDRAULIC MODEL STUDIES

- Prediction of changes
- Movement of water & its effect on ships.
- Movement of soil & its effect on navigation areas.
- Effect of Marine environment on stability and safety of structures.
- Design Optimization
- Maintenance cost.

HYDRAULIC MODEL STUDIES

- **Mathematical Model Studies**
  - Investigate the flow pattern and the resulting morphological changes.
  - Wave propagation and wave penetration in the harbour.
  - Estimation of shore line drift and evolution.
  - Navigation aspects of approach channel.
  - Forces acting on moored tanker.
- **Physical Model Studies**
  - Examine the change in flow pattern.
  - Orientation of proposed berth.
  - Stability & Tranquility at berth

LNG Import Terminal

Project Execution

- Tie-up of LNG long term contract
- Shipping arrangement
- Preparation of DFR / Design of facilities
- Preparation of Front End Engineering Design (FEED)
- Selection of EPC Contractor
  - Lump sum
  - Cost plus basis
  - Split into no. of packages, each package on turnkey basis.
- Selection of Project Management Consultant.

Project Execution

- Base line data requirement
- Approval requirement of State / Central Government such as
  - Exemption for Coastal Regulatory Zone
  - Clearance from State Environment Department
  - NOC from Ministry of Environment & Forest (MOEF), Government of
  - India
  - NOC from State Pollution Control Board
  - Clearance from Chief Controller of Explosives
  - Clearance from Civil Aviation Authority
  - Clearance from Naval Authorities
  - Clearance from State Department of Forest & Wildlife
  - NOC from Fisheries Department

Project Execution

Define Design parameter

- Capacity of Terminal
- Send out rate
- LNG Storage Volume
- Gas delivery profile
- Battery Limit Conditions
- Size of LNG Carrier
- Location of LNG loading port
- Design of Jetty

COST OPTIMISATION

- Highly capital intensive projects
- Optimization of costs to increase returns
- Identify and analyze alternatives
- Design is the driver that influences project life cycle cost
- Project costs and revenues are largely fixed during DFR stage

Marine Facilites

Marine Facilities

- Mooring Dolphins
- Breasting Dolphins
- Jetty Head
- Trestles
- Unloading Arms
- LNG Unloading Lines

Unloading system : Sizing Parameters

- **Number of berth :**
  - Number of carriers per year
  - Port of call and unloading duration
- **Number and diameter of arms**
  - Duration and flow rate of unloading
  - LNG flow speed and pressure drop
  - Arms reliability
- **Number and diameter of unloading line(s)**
  - Geometrical height between carrier flanges and tank top
  - LNG flow speed, line length and pressure drop
  - Carrier pump rated head
  - Gas pressure difference between carrier and storage tank

SHIP

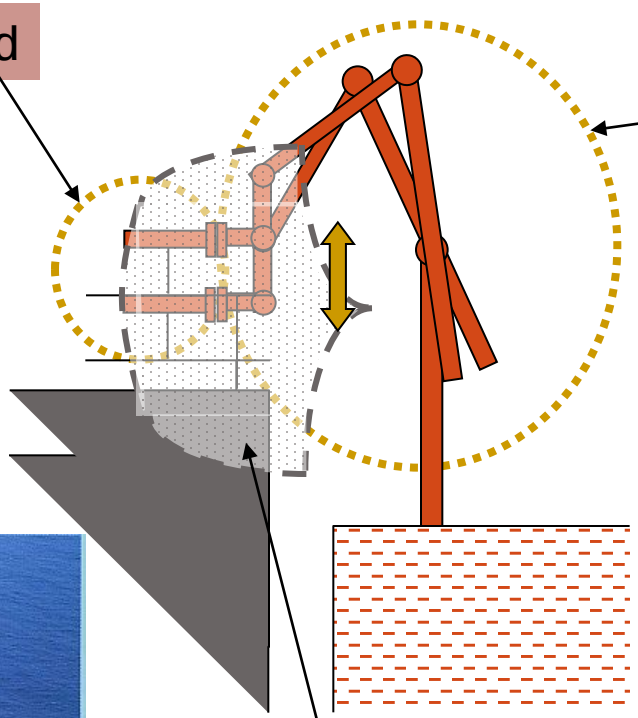
MOSS TYPE SHIP

MEMBRANE TYPE SHIP

Turning and berthing at Dahej LNG Terminal

Loading Arm/Manifold

Manifold

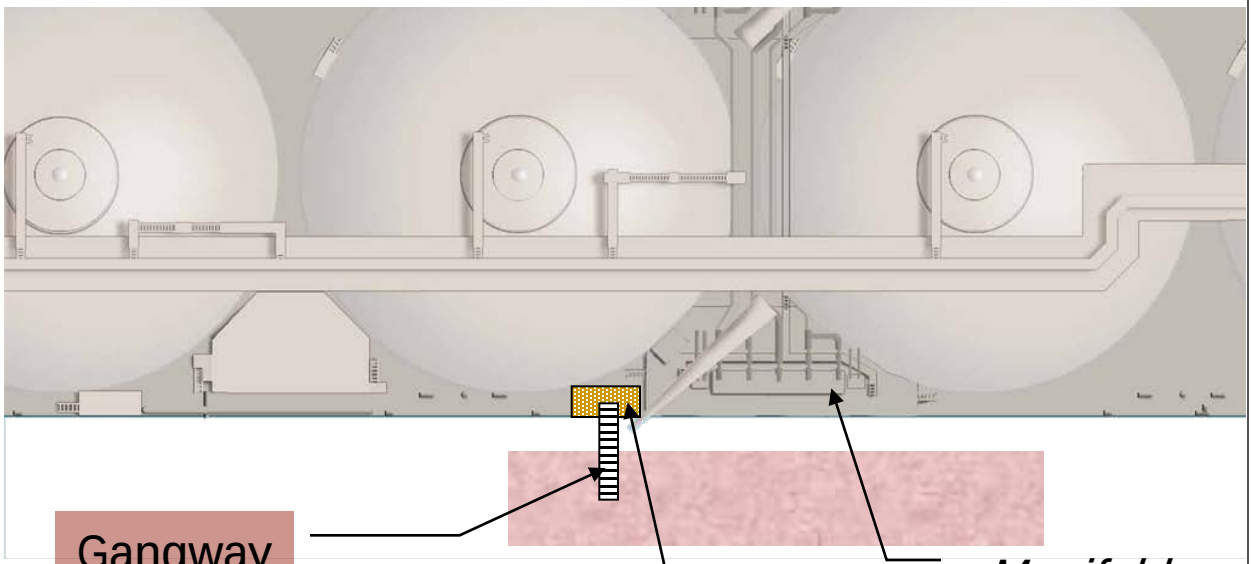


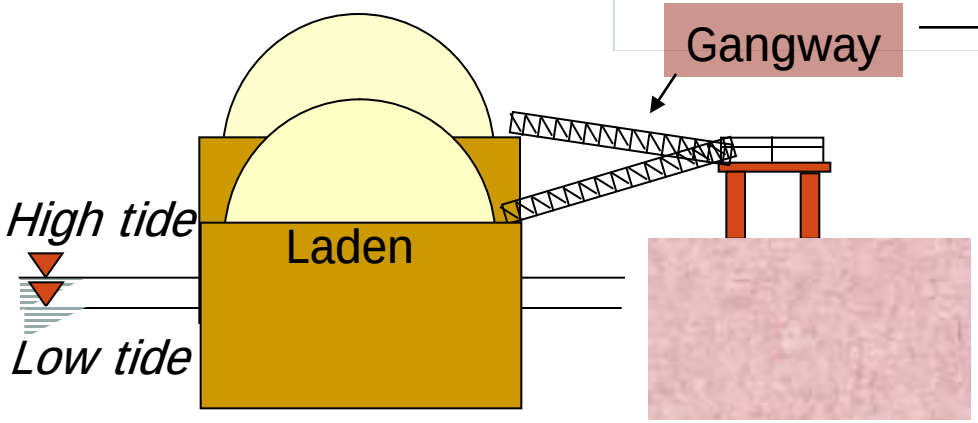
Loading Arm

Loading Arm Reach Envelope

Gangway

- Position
- Elevation





STORAGE TANKS

Storage capacity : General Needs

- LNG storage : buffer role between cargo unloading and continuous send out

- Total storage requirement depends on:
  - Capacity of the largest LNG carrier
  - Maximum ship arrival delay
  - Corresponding send out flow rate

Storage system : sizing parameters

- **Buffer storage capacity = C + (Tr - Td) Q + B + S**
  - C : largest carrier capacity
  - Tr : maximal delay
  - Td : unloading duration
  - Q : reliable flow rate
  - B : unpumpable
  - S : strategic stock

- **Number of tanks and capacity**
  - Technological limits
  - Seismic,
  - Available surface
  - Environmental Impact
  - Specific requirements of the owner

TYPES OF STORAGE TANKS

REGASIFICATION & SEND OUT FACILITIES

REGASIFICATION

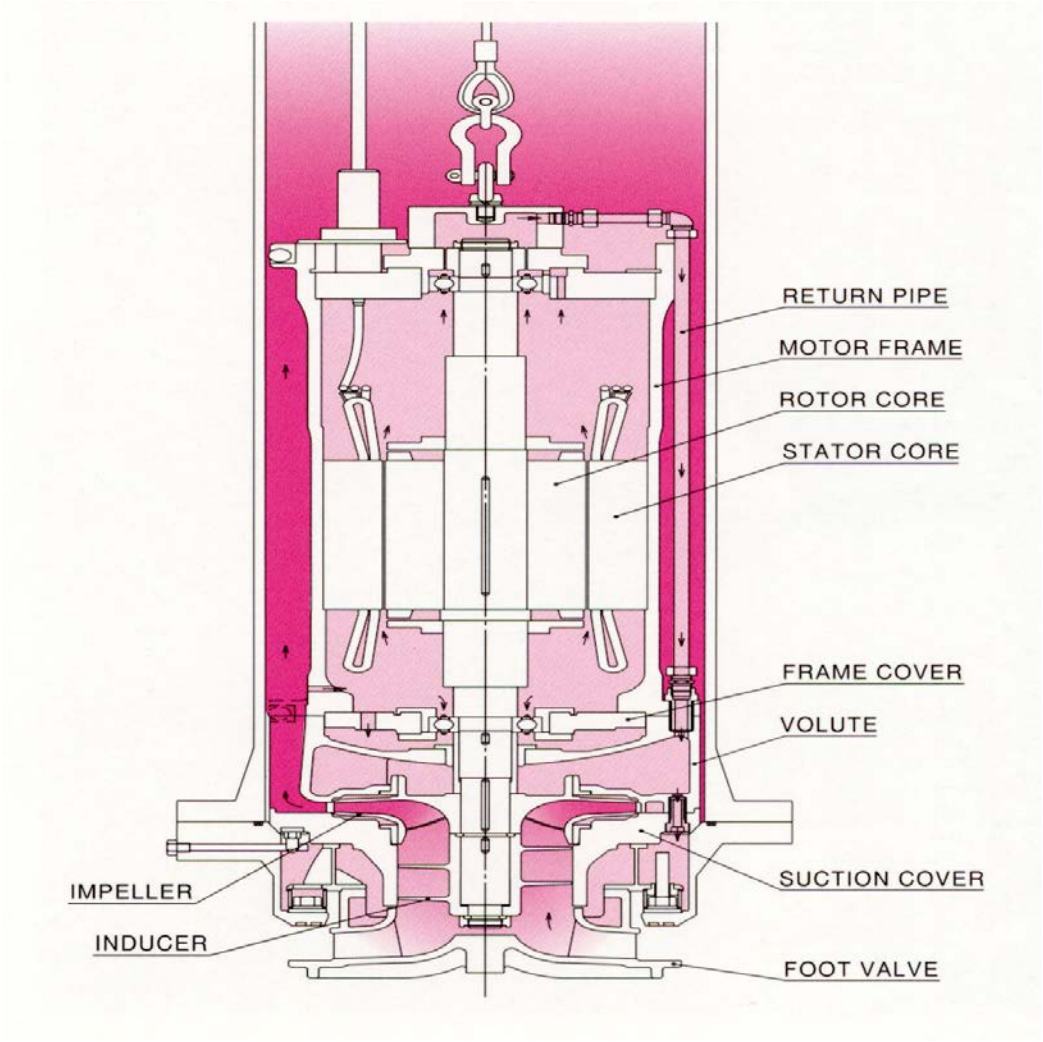
Send out system : Sizing parameters (1)

- **Send out flow rate**
  - **Annual average flow rate (LNG receiving annual quantity, operating duration, equipment reliability)**
  - **Maximum flow rate (m3/h)**
  - **Minimum flow rate (m3/h)**
  - **Send out pressure**
  - **Flow rate modulation**

Send out system : Sizing Parameters (1)

- **Number and characteristics of LP pumps**
  - Recondenser pressure
  - Storage tank height
  - Pressure drop in LP lines
  - Trunk loading
- **Cool down system**
  - HP, LP and unloading lines

Lp Submerged Pump In Tank



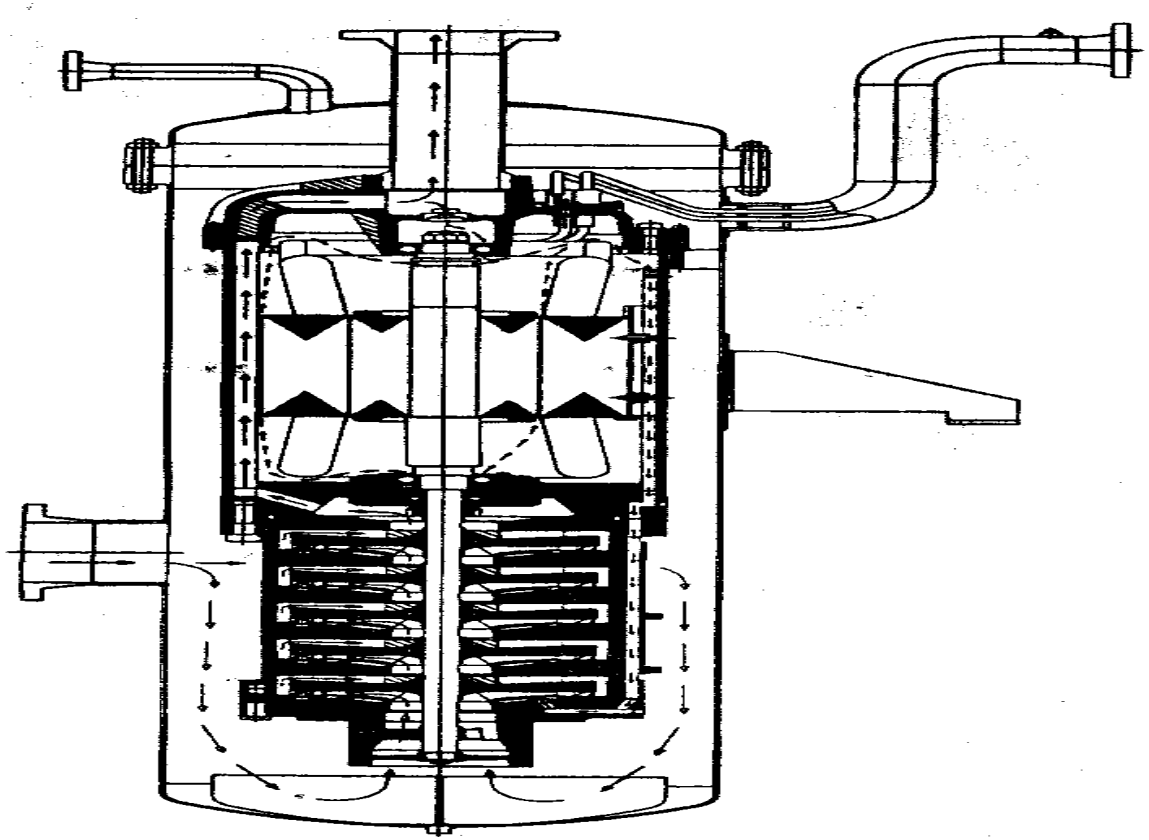
Send out system : Sizing Parameters (2)

- **Number and characteristics of HP pumps**
  - **NPSH and geometrical height between recondenser and HP pump inlet , pressure drop safety margin to send out point**
  - **Shut off head**
  - **Technological limits**

Send out system : Sizing Parameters (2)

- Vaporization
  - General
    - Gas Grid and pressure
    - Send out modulation
    - Reliability and operating costs
    - Cogeneration
  - Sea water
    - △T Cooling down and annual temperature range

Pot Mounted HP Pump



Send out system : Sizing Parameters (3)

- LNG and NG HP piping
  - Shut off head
  - Pressure and pressure drop at maximum flow rate
  - « Dead » end and depressurising system
- Pressure control and metering,
  - Pressure reducer
  - Type of metering (diaphragm, turbines, ultrasonic)
- Gas composition and odorization
  - Gross Calorific Value and Wobbe index (chromatography)
  - Odorant storage (THT, mercaptan)
  - Odorant injection (flow ratio control)
  - Measurement of odorant ratio (chromatography)

Boil off gas recovery system : Sizing Parameters (4)

- Flare and Boil Off Gas (BOG) lines
  - Operating pressure
  - Gas return to tanker flow rate
  - Tanker cooling down
  - Roll-over
  - Flare implementation
  - Relief valve collection (storage tanks, vaporizers)

- Boil off gas compressors
  - Recondenser pressure range
  - Normal evaporation flow rate (storage tank, cooling down,…)
  - Unloading LNG flash
  - Pressure control of storage tanks
  - Number of compressor, flow rate and range control

EQUIPMENT LAYOUT

REGASIFICATION TERMINAL EQUIPMENT LAYOUT

- EN 1473, NFPA 59 A, OISD-194, OISD-156 provides guideline
- Layout to ensure LNG piping is minimized
- Layout to ensure risk does not extend beyond the plot
- Main Control room to be in non-hazardous area.
- Hazardous area classification may be decided based on dispersion calculation from possible spills.

New Developments

LNG Satellite Terminal

NG → Power Plant

NG → Industrial users

NG → Residential users

LNG Satellite terminal

Small LNG vessels

LNG Terminal

Further Opportunities

LNG Trucking

LNG

Direct LNG Filling

LNG/CNG Hub

CNG

CNG Filling

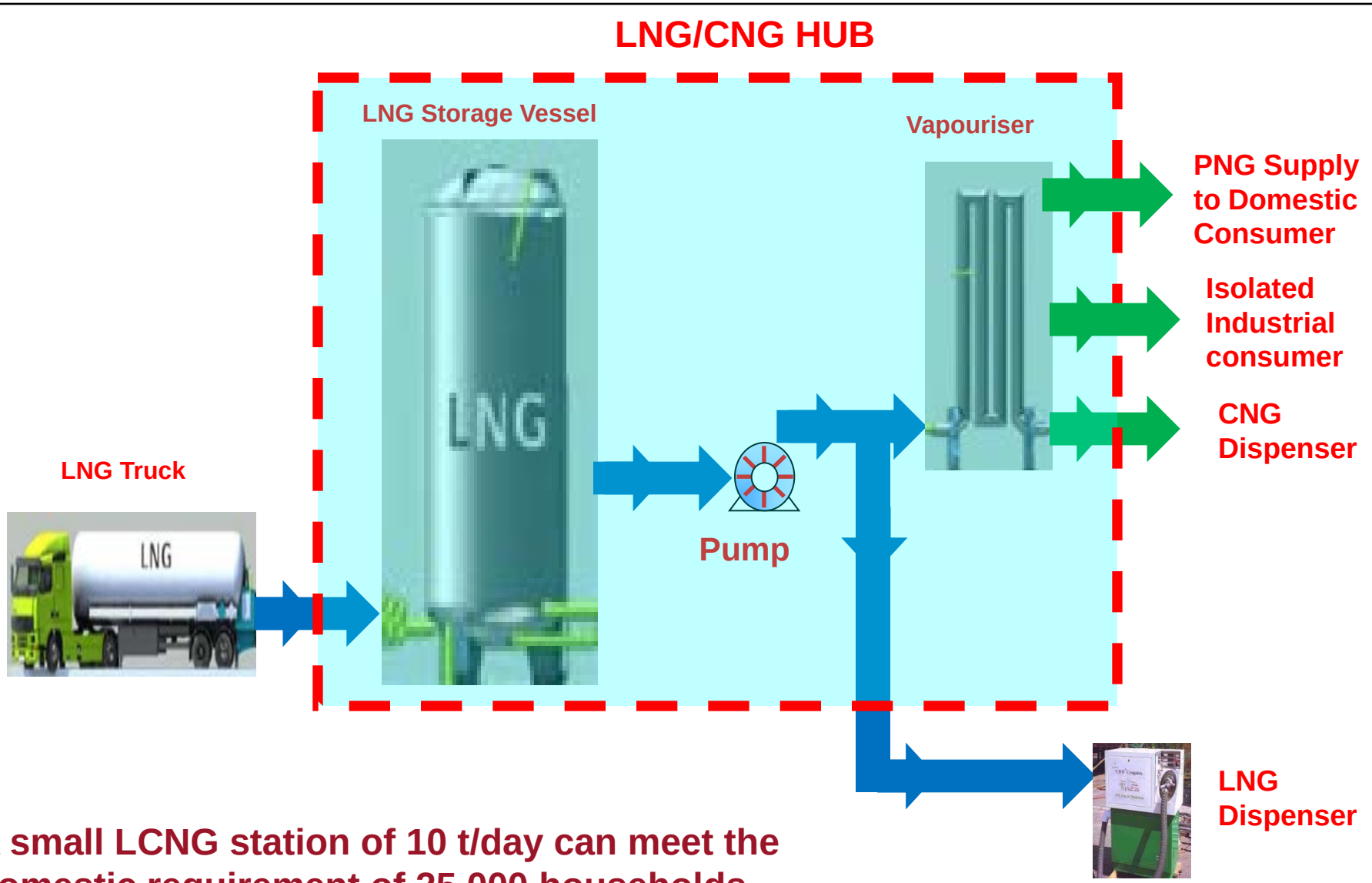
PNG

PNG Supply to Domestic Consumer

NG

Isolated Industrial consumer

L-CNG HUBS



A small LCNG station of 10 t/day can meet the domestic requirement of 25,000 households.


THANK YOU