Tikrit University

College of Petroleum Processes Engineering

Department of Petroleum and Gas Refining Engineering

Gas Technology

Forth Class

Lecture 17

By

Jasim I. Humadi

Liquefied Natural Gas Transportation & Storage

LNG Transportation

- ### Ships

Typical ships are shown in the next two figures 1&2. The concept of membranes is based on the idea that the forces exerted by the LNG cargo are transmitted by a metallic membrane to the ship's inner hull (these are double hull ships). The Norwegian company Moss Rosenberg introduced the concept of spherical tanks. The capacity of these ships is between 100,000 to 140,000 m^3. The ships are powered with a medium speed 4-stroke diesel engine, which is capable of providing fuel efficiency and operates on burning low pressure gas. It consumes 0.15% of the cargo through what vaporizes of the LNG and that adds up to consuming 2 % of the LNG produces over the life of the project.

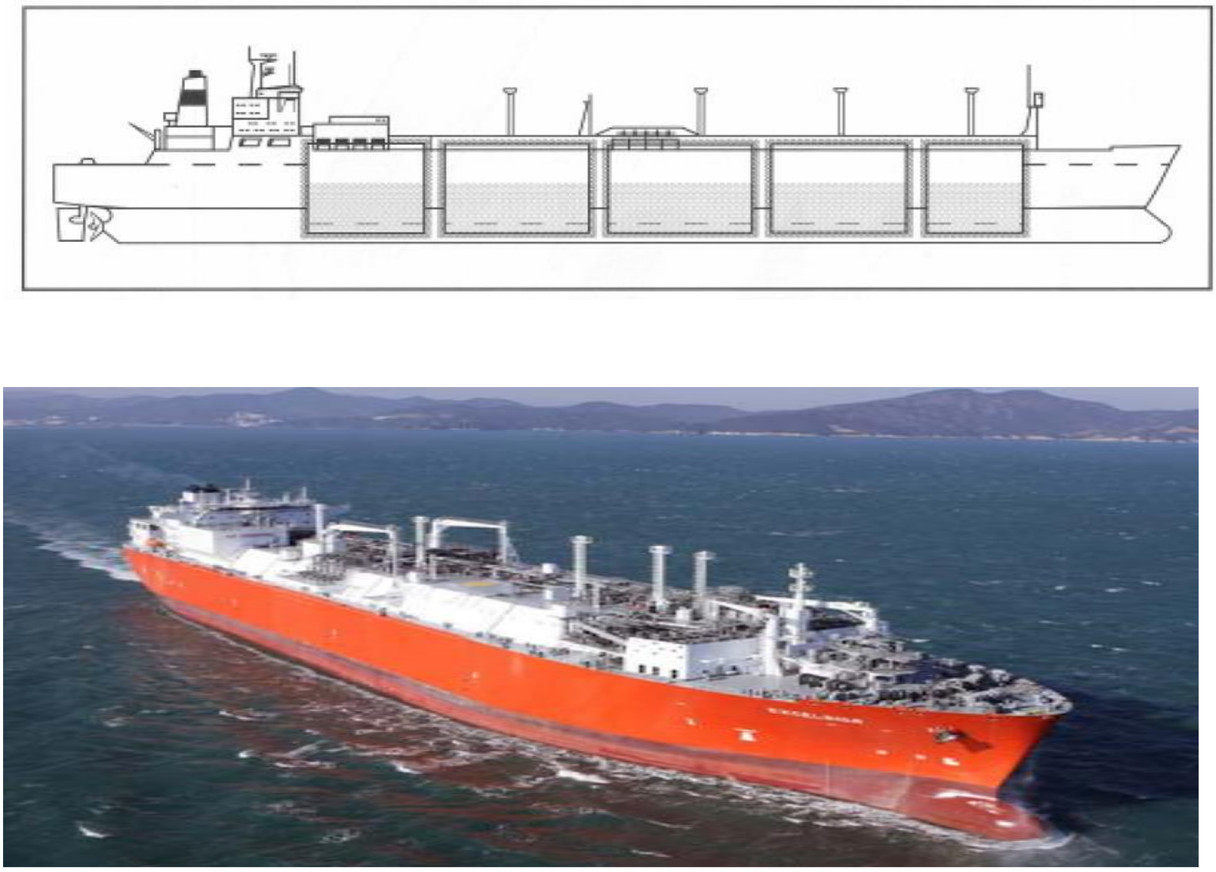
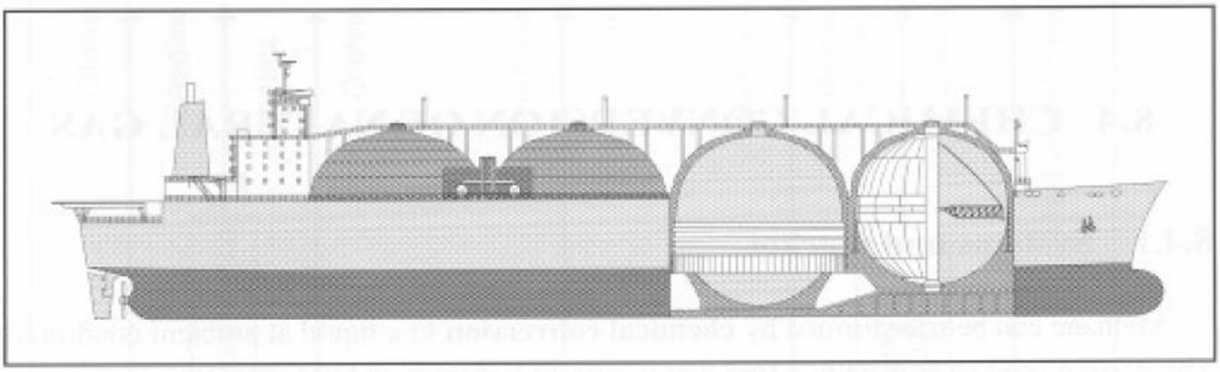


Figure 1: Schematic and photo of LNG carrier with GAZ Transport Membrane



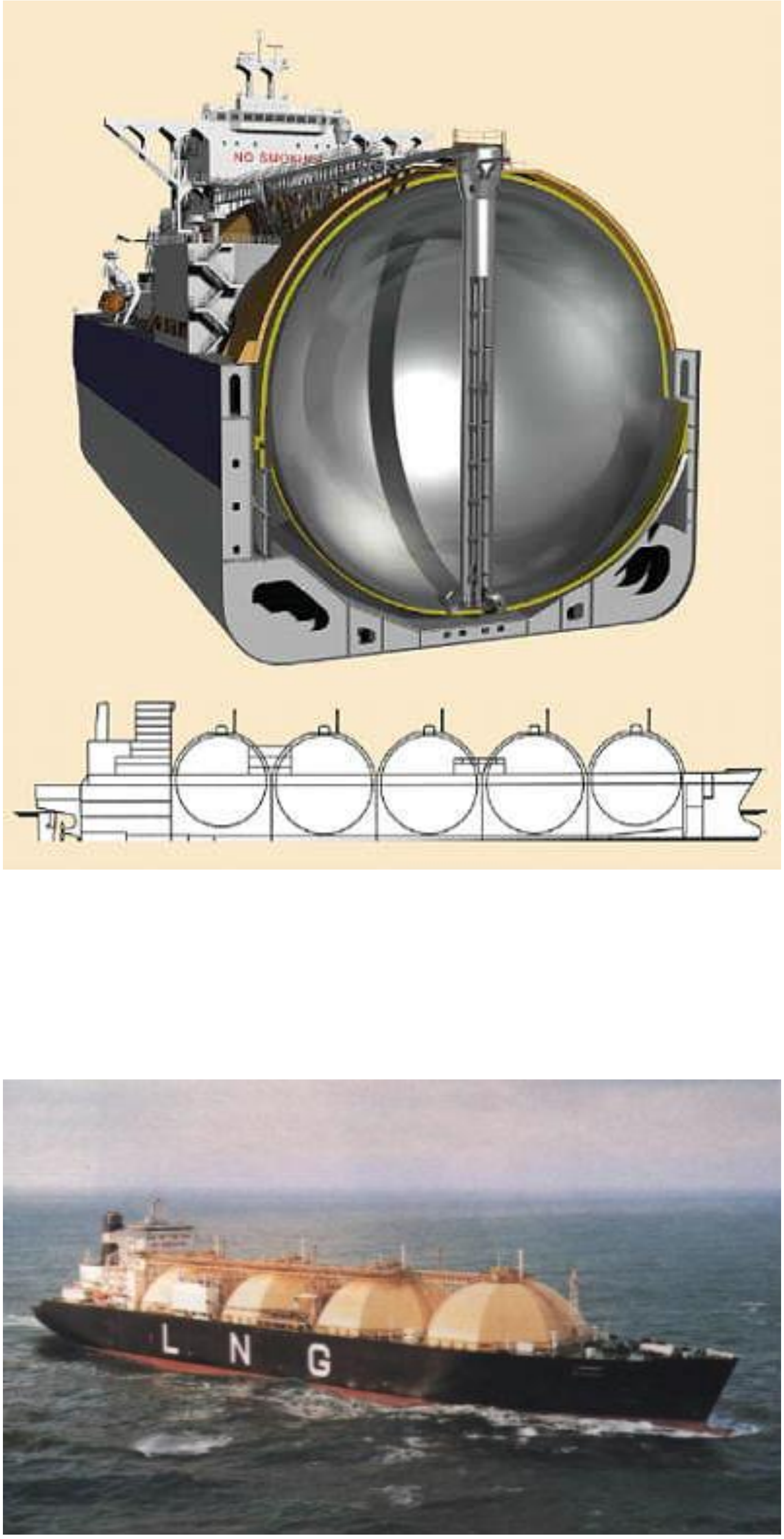


Figure 2: Schematic and photo of LNG carrier with Moss Rosenberg self-supporting tanks

LNG Storage

All field erected LNG storage tanks have a primary and a secondary containment system. The primary container is for normal operation and the secondary containment is for the highly unlikely event of a leak in the primary container. World wide a variety of storage tank types have been developed and constructed over the years. Those that have been successful can be categorized into the following types:

- Single containment types have a cylindrical metal primary tank and an earthen dike wall secondary containment. Single containment tanks were the first type developed and are now used mainly in remote locations.
- Double containment types have a cylindrical metal primary tank and an independent metal or reinforced concrete, open top secondary containment outer tank. This type was developed for small sites; however few have been built because the full containment type, below, was soon developed.
- Full containment type tanks have a cylindrical metal inner primary tank and metal or pre-stressed concrete outer secondary containment tank structurally independent but combined into one structure. Today full containment tanks are the most common type used.
- Full containment membrane type has a cylindrical thin metal membrane primary container structurally supported by an outer pre-stressed concrete cylindrical tank. The outer concrete tank also serves as the secondary leak containment. Applications of membrane tanks have been far less than the other types of tanks except in Japan and Korea.
- Even though all of the above listed structures can be built in-ground, only membrane tanks, type 4, have been regularly built below grade. The outer wall of an in-ground tank is not pre-stressed. The outer wall is held in

compression by soil pressure which in turn also supports the LNG's hydrostatic load.

The approximate number of field erected LNG tanks operating worldwide is summarized in the following list:

- Single Containment Type 320
- Double Containment Type 15
- Full Containment Type 110
- Membrane Containment Type 30
- Membrane In-ground Containment Type 50

Full Containment Tanks

A liquefied Modern LNG storage tanks are typically full containment type, which has a pre-stressed concrete outer wall and a high-nickel steel inner tank, with extremely efficient insulation between the walls. The common characteristic of LNG Storage tanks is the ability to store LNG at the very low temperature of -162°C. Large tanks are low aspect ratio (height to width) and cylindrical in design with a domed steel or concrete roof. LNG storage tanks can be found in ground, above ground or in LNG carriers. Storage pressure in these tanks is very low, less than 10 kPa (1.45 psig). Sometimes more expensive underground tanks are used for storage. Smaller quantities (700 m^3 and less), may be stored in horizontal or vertical, vacuum-jacketed, pressure vessels. These tanks may be at pressures anywhere from less than 50 kPa to over 1,700 kPa (7 psig to 250 psig). LNG must be kept cold to remain a liquid, independent of pressure. Despite efficient insulation, there will inevitably be some heat leakage into the LNG, resulting in vaporization of the LNG. This boil-off gas acts to keep the LNG cold. The boil-off gas is typically compressed and exported as natural gas, or is re-liquefied and returned to storage. Figure 3 illustrates the full containment cryogenic tank internals.

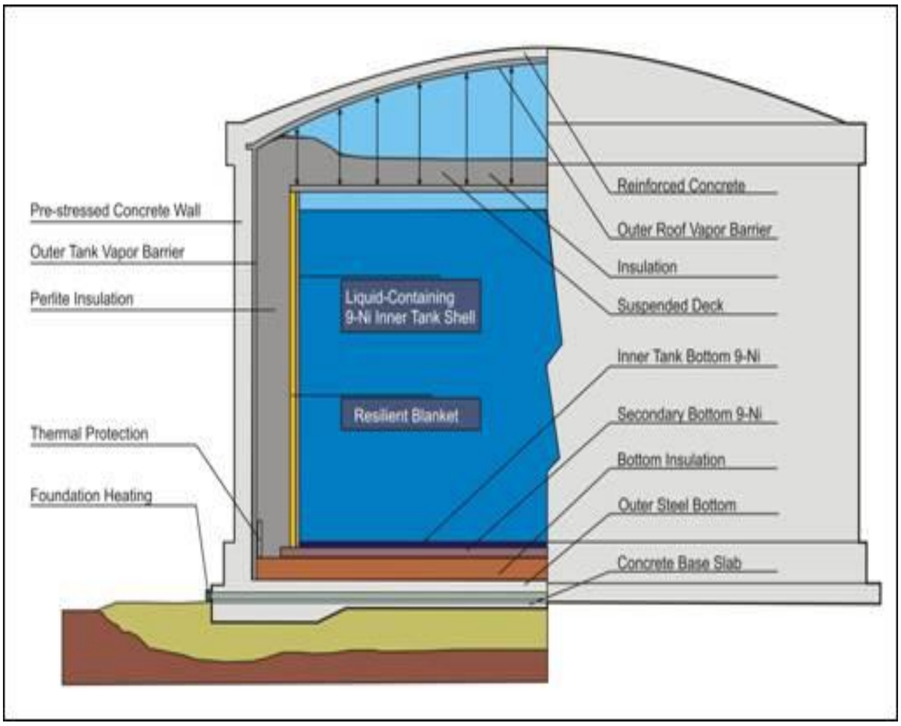


Figure 3: Full Containment Tank Internals.

COMPARISON OF FULL CONTAINMENT AND IN-GROUND TANKS

Economics

- The capital cost of constructing an in-ground LNG tank is over twice that of a full containment tank.
- In-ground tanks consume more electrical energy for increased boil-off compression, soil and foundation heating and ground water pumping. The extra power consumption is approximately a constant 1,500 kW load.

Design and Safety

- When LNG tanks are located in areas of possible aircraft impact full containment tanks have a higher chance of impact than in-ground tanks.
- Structures that are built into the ground generally have reduced acceleration loads generated from seismic events. This is because motions of in-ground storage system follow the seismic ground shaking and are not amplified through the structure of the tank as is the case for an above ground storage system. In addition, sloshing responses of LNG tanks resulting from seismic activity are lower for underground tanks. This however does not mean that an in-ground tank is safer than an above ground tank. It means that an aboveground tank is designed to higher seismic loads than an in-ground tank. In all cases LNG tanks are designed to maximum seismic activity for each tank type and its location.
- Based on the seismic hazard studies, the Hong Kong region is an area of low seismic activity. For example, seismic loading is not explicitly considered for general building design in Hong Kong. Hence, the design driver for selecting underground tank system to lower seismic loads is not applicable and the aboveground storage tanks are an appropriate choice for this location.

- Ground water can be very problematic for in-ground LNG tanks. The density of LNG is less than one-half that of water. If for some reason ground water was to rise around an in-ground tank or leak into it, buoyant forces could lift the tank or displace LNG over the tank wall. However such an event is considered highly unlikely.

Operation and Maintenance

- The soil heating cables on an in-ground tank are located such that they are almost impossible to repair. Redundant heating cables will be installed to lessen the possibility of failure.
- Since most equipment and piping is located on the roof of an LNG tank, access to this equipment is generally easier for in-ground tanks.
- Above-ground LNG tanks do not require the operation and maintenance of dewatering pumps.

Because much on an in-ground is covered with soil, tank inspection and monitoring is difficult and possible problems may go unnoticed. When problems do occur, it is much harder to repair them. For example, the in-ground tanks in Yung-An (Taiwan) have been leaking for years, but due to the difficulty in pinpointing the leak location and accessibility, have elected not to try to repair the leak.

Figure 4 shows a variety of design in installation of LNG storage tanks.

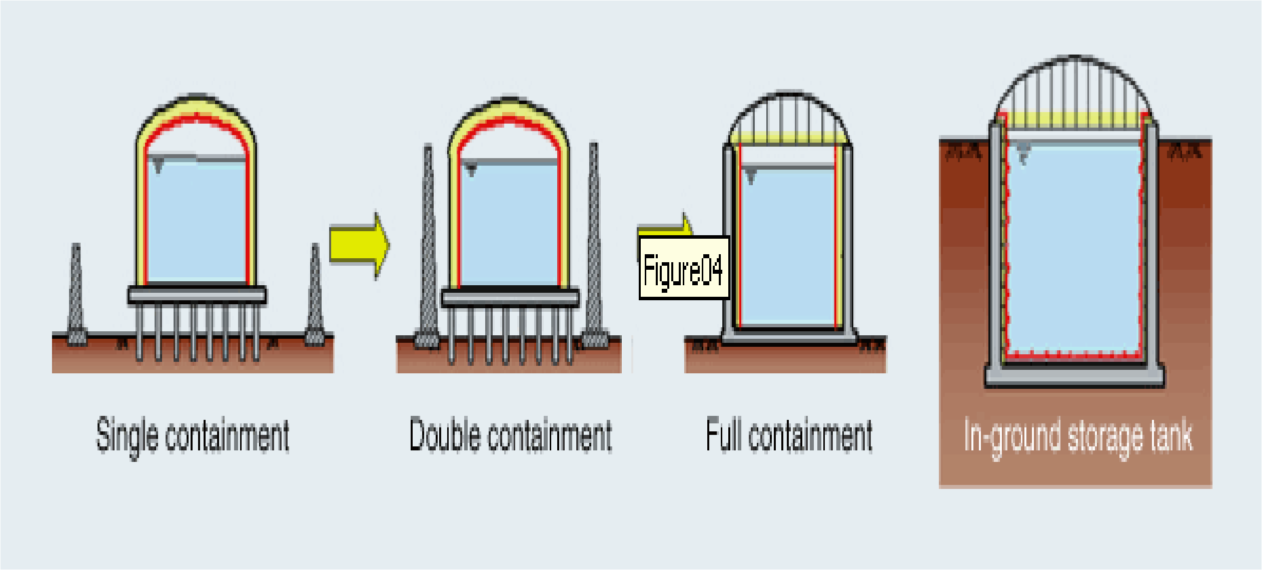


Figure 48: LNG Tank designs