Design Ships

The terminals are designed to accommodate vessels of between 87,000 m^3 and the largest designed vessels to date, designated the Q-Max vessels (265,000 m^3). The largest scheduled to be to be in service in 2007 is the Al Qattara class (216,000 m^3). (*Lloyd's Register-Fairplay*, May 2007) The *Al Qattara* was launched 9 December 2006, and commenced outfitting.

Smaller LNG carriers than the design ships may be utilised, but economics and efficiency, and the end users' port facilities dictate that the 87,000 m^3 is the optimum smallest to be used by the project.

Existing Fleet

The world fleet of LNG carriers consists 369 vessels in service or on order, of which 148 vessels are on the books and not due for delivery until 2007 or later, 33 are thirty years old or older.

The world fleet in service in May 2007 numbered 135 vessels.(*Lloyd's Register-Fairplay* May 2007). These vessels ranged in capacity from 1,078 m^3 to the largest, 153,000 m^3.

The two larger design vessels of the one hundred and forty-eight LNG carriers due for delivery are the Q-Flex vessels, 210,000 m^3 to 216,000 m^3 and the Q-Max vessels 250,000 m^3 to 265,000 m^3.

Grassy Point LNG Terminal is designed to berth ships and handle LNG cargo from and to vessels from 87,000 $m^3$to 265,000 $m^{3.}$ Table 1 below shows the numerical breakdown of the proposed and existing world fleet;

Table 1 Existing and Proposed World Fleet by Capacity

Capacity in cubic metres	**No. of vessels**
250,000 to 265,000	10
210,000 to 217,000	27
150,000 to 177,000	55
140,000 to 150,000	96
120,000 to 140,000	142
80,000 to 88,000	4
50,000 to 80,000	15
< 50,000	20

LNG carriers are large vessels with a comparatively shallow draft, large air draft and surface areas susceptible to wind loading. The hull form on LNG carriers is relatively fine, enabling the vessels to operate at comparatively high speeds.

Table 2 World Fleet Principal Dimensions of vessels 87,000 to 265,000 m^{3}.

Dimension	**Range in metres**
Length Overall	239 to 345
Beam	34 to 54
Draft	11.8 to 13.5
Depth	23 to 27
Engines and Machinery	
Total Power, kW	20,000 to 46,000
Service Speed, knots	18.5 to 20.5

Manoeuvrability of LNG Carriers

Conventional LNG carriers are powered by steam turbine engines driving single propellers. The steam will be produced in boilers powered by gas which has been boiled off from the cargo during the transit, collected and burned in the boilers. These vessels are not fitted with re-liquefaction plants. On the ballast voyage, the boilers will be fuelled by MFO. Because these vessels were required to use the services of tugs in most ports of the world, these carriers are fitted with single acting rudders, and some have no bow thrusters, relying on the tugs to assist in the manoeuvring alongside the berths, and departing from them. The power train provided a powerful motive force, but comparatively slow in changing direction when manoeuvring. The above water surface areas of the vessels make the vessels susceptible to sheer wind forces at slow speeds. Manoeuvrability is affected, but with the assistance of the tugs, berthing and departure are carried out with a high degree of safety, and are mitigated by the high degree of caution utilised by the bridge team on approach to and departure from the berth.

Recognising the value of delivering the LNG to the market, modern design of the main power plant, is developing on three options:

- slow speed diesel fuelled by low sulphur diesel oil and low viscosity low sulphur marine fuel oil. This necessitates having a re-liquefaction plant on board to return the boil-off gas to the cargo tanks,
- diesel electric plants powered by either forced boil-off gas, or natural boil-off gas plus heavy fuel oil,
- gas turbine electric power with waste heat recovery, utilising forced boil-off gas or natural boil-off gas with intermediate fuel oil.

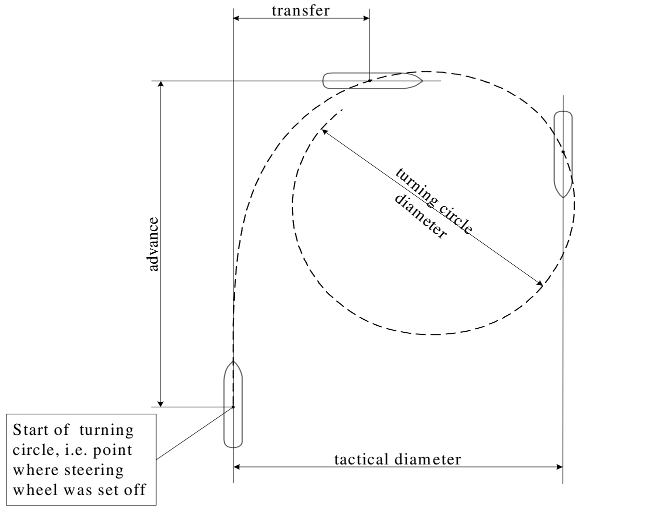
The modern design also has recognised the need for greater manoeuvrability and new LNG carriers are being developed with twin propellers, some variable pitch; high lift rudders (eg. Becker type); and thrusters, bow (and stern.) This increases the manoeuvrability of the vessels, and reduces the reliance on tugs, or provides the additional mitigation in the event of mechanical failure. This increase in manoeuvring machinery is in no way brought about by the lack of confidence in the conventional carriers' manoeuvrability, rather the economics of requiring large numbers of powerful tugs for berthing and departure.

Because of the geometry in developing large capacity spherical tanks while keeping the vessels' external dimensions within port operational capability, membrane tanks are the norm for the larger vessels, and are being increasingly utilised in the smaller vessel. The membrane tanks have less of a profile above the main deck, and thereby minimise the windage. There is no doubt that the windage is a major force to overcome when berthing; and the vessels are being developed to manoeuvre using their own machinery.

On the main sea voyage, the vessels have an average service speed of approximately 19.5 knots, (10.04m/sec), and following time to reduce the engine temperatures, will reduce to full manoeuvring speed of approximately 12 knots (6.17m/sec) to 15 Knots (7.71m/sec) , effective 'dead slow' ahead speed will be approximately 6 knots, (3.08m/sec). When manoeuvring astern, the effective power of the propellers will be approximately 70%

Stopping distances will vary, but in a 'crash stop' scenario, not using tugs or rudder, a Moss type LNG carrier with a displacement of approximately 90,000 tonnes, making way through the water at full sea speed (21 knots) will take approximately 10 to 12 minutes to reduce speed through the water to less than 1 knot, and the advance will be approximately 3,500 metres. (Existing vessels and models, Konsberg)
Utilizing the rudder, and reducing cavitation by stepping the engine speeds from full ahead to full astern may reduce the advance and the time. In the operating area of interest, the LNG Carriers will not be proceeding at full sea speed, but at the maximum, full speed manoeuvring, or approximately 12 to 15 knots, if a crash stop is required, which will reduce the time and advance significantly.

The vessels' turning circles will vary. This information relates to an LNG Carrier of approximately 90,000 tonnes displacement. The carrier, proceeding in deep water at 12 knots, puts its helm hard a' starboard, (45^{o}).



Probable Turning Distances at 12 Knots (Initial Speed)

Tactical diameter	850 metres
Turning circle diameter	600 metres
Advance	830 metres
Transfer	370 metres

Cargo Carriage and Tank Design

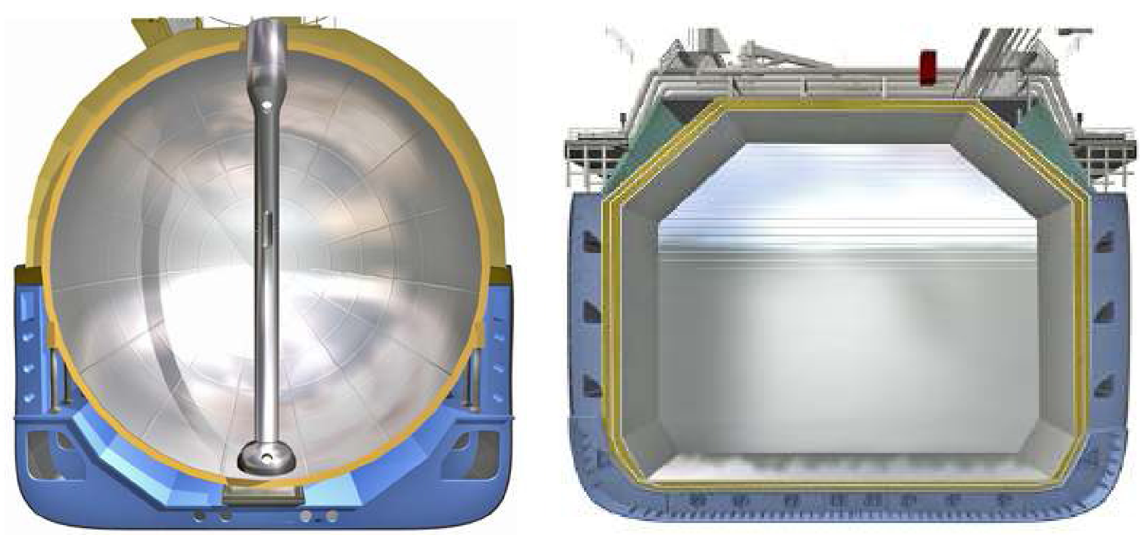
LNG carriers are of two basic designs. The Kvaerner-Moss spherical tank type and the membrane tank type. The spherical tanks have proven to be the most suitable for vessels up to approximately 140,000 m^3 cargo capacity, but the geometry precludes the use of the spheres for the larger vessels. The membrane tank enables better usage of the ship hull design.

Figure 1

Kvaerner-Moss spherical tanks (left) *(Intertanko/Qatargas)* and membrane tanks in an LNG carriers *(Qatargas)*

Figure 2 below shows the principal differences between the two types of tank construction that are utilised in LNG carriers.

Figure 2 Schematics of Spherical tank and Membrane tank design vessels



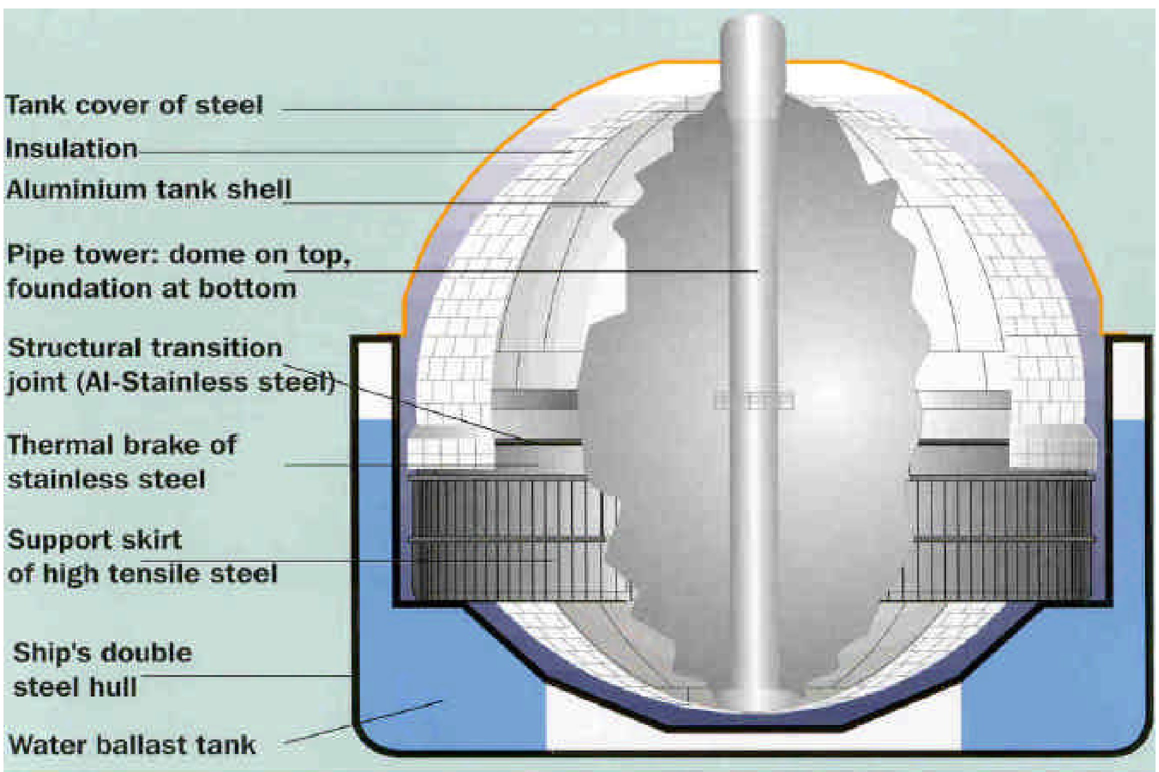
Kvaerner-Moss spherical tank (left) and the Gaz Transport or Tecnigaz Membrane tank

The tanks are constructed with material capable of withstanding the cryogenic temperatures, (eg, alloys of nickel steel or aluminium) and the shaping of the tanks has been developed to reduce the possibility of damage due to sloshing forces of the liquid. Limitations are placed on the movement of the membrane tank carrier, when the tanks are partially discharged (or loaded) due the prospect of sloshing damage.

Spherical Tank LNG Carriers – Tanks and Containment

The mid-range capacity and smaller LNG carriers were developed with spherical tanks which provided the suitable and safe system for the carriage of the LNG. The tanks are constructed of nickel steel, aluminium or other alloy suitable for containing the cryogenic liquid, surrounded by insulation and an outer steel shell. No part of the primary containment comes into contact with the carrier hull. There is a limit to the capacity of the carriers using spherical tanks, as the geometry precludes the use of this system for the larger capacity vessels.

Figure 3 Containment and insulation in Spherical Tanks Construction



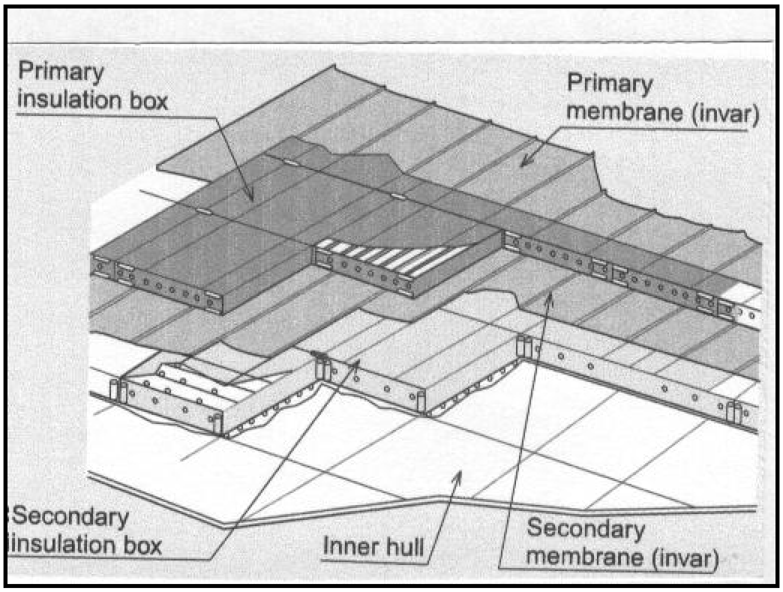
Containment and insulation within the hull of a Moss design carrier

Membrane Tank LNG Carriers – Tanks and Containment

The Gaz Transport system uses two such membranes constructed of ‘Invar’ (36% nickel-iron low expansion alloy). The primary barrier, inner tank membrane, and the secondary barrier are separated by plywood boxes of insulation. Similar boxes are fitted between the secondary barrier and the inner hull.

Loads are transmitted through the membranes and insulation to the ship hull. This construction is not capable of supporting a centreline bulkhead. Technigaz has developed a similar system with a stainless steel membrane as the primary barrier while the secondary barrier is included in the insulation, which consists of load bearing balsa and mineral woods.

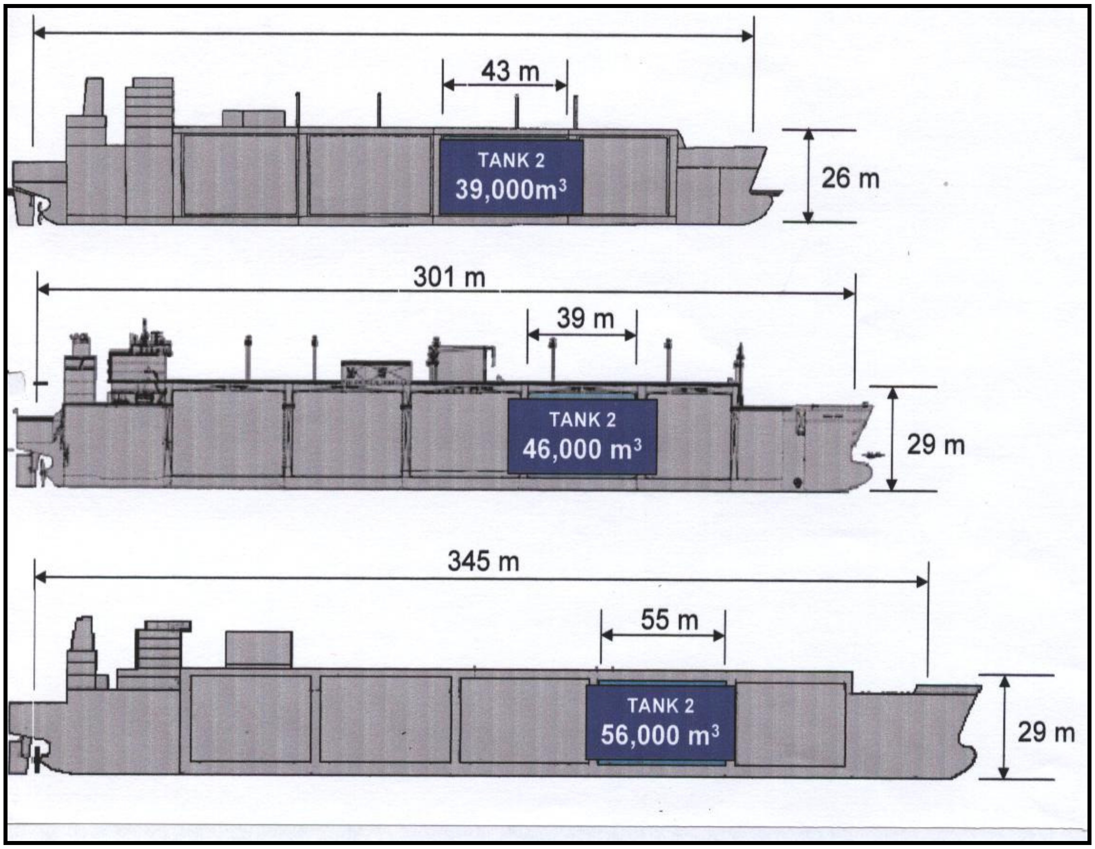
Figure 4 Containment and insulation in Membrane Tank Construction



Membrane tank in a Gas Transport No 96 LNG Carrier.

Figure 5 Membrane tanks in LNG Carriers

138,000 m^3 (top) 205,000 m^3 (middle) and the outline design for the 265,000 m^3 (bottom).



With the increase in demand for natural gas the LNG carriers have evolved and have modified the tank structure in order to provide the capability of carrying large quantities of LNG. Figure 5 above shows the development of the Membrane tank carriers with capacities of 138,000 m^3 (top) 205,000 m^3 (middle) and the outline design for the 265,000 m^3 (bottom).

With the development of the large LNG carriers, the cost for development with spherical tanks was impractical and overly expensive. Membrane tanks were submitted for industry, and the safety, economy and practicality were accepted. The membrane tank system is lighter, and more of the internal volume of the hull can be used for the carriage of LNG. The membrane surface is supported by the insulation, and the load is transferred to the hull through the insulation. The membrane ensures the liquid-tightness of the containment.

One drawback with the membrane system is that “sloshing” of the liquid in the tanks can cause damage to the membrane. For this reason the vessels should not be in a seaway when the tanks are between 10% and 80% full.

The specific gravity of LNG is about half that of water (0.46) the ships are therefore of large capacity, light in draught, and large in air draft. The vessels’ hulls are designed to accommodate the cargo tanks the insulation, outer tank shells, void spaces and ballast tanks. No part of the cargo tank comes into contact with the hull. The overall dimensions of the vessels are, of necessity, large; the largest design vessel will be: length over-all 354 m, beam 55 m, draught 12.5m and depth 27m. The tanks will protrude above the main deck approximately 4 to 6 metres.

Propulsion and manoeuvring machinery varies from ship to ship. The smaller vessels are equipped with a single propeller, a balanced rudder, and a bow thruster. This is primarily because all terminals for both loading and discharge require the use of tugs. Fuel for the steam propulsion units when loaded with LNG was the gas which boiled off from the cargo during the freight earning part of the voyage, and marine fuel during the ballast voyage. The new designed vessels are diesel or diesel electric main power plants: equipped with twin propellers, a "high-lift" rudder and bow thrusters. Fuel for the motor ships is diesel fuel or marine fuel oil on both legs of the voyage. (Some research is being undertaken to identify if the boil-off gas can be utilised in the propulsion units.) The newer vessels are equipped with re-liquefaction plants to return the boil-off gas to the cargo tanks.

Vessels to be used in the project will range between those of 87,000 m^3 up to 265,000 m^3 capacity and may be of either spherical tank construction or membrane tank construction. The dimensions of the smaller and larger vessels are given in Table 3 below:

Table 3 Dimensions of LNG Carriers

Note: No Q-Max carriers are to be delivered until 2008, and the information relating to them is that identified in LR- Fairplay data base.

	Typical small capacity Carrier, *("Polar Eagle")*	**Q-Max LNG Carrier *(Samsung 1675)***
Length over-all	239 metres	345 metres
Beam	40 metres	53.8 metres
Draught	11.02 metres	12 metres
Depth	26.8 metres	27 metres
Deadweight	48,817 tonnes	125,600 tonnes
Liquid Capacity	88,100 cubic metres	266,000 cubic metres
Gross Tonnage	66174	162,400
Speed at Sea	19.5 knots	19.5knots

Natural Gas and Liquefied Natural Gas (LNG)

Liquefied natural gas is natural gas cooled to -163 °C. The principal content of the natural gas is methane, although traces of ethane, propane and heavier hydrocarbons may be present along with nitrogen, helium, carbon dioxide, sulphur compounds and water. When liquefied, the pre-treatment removes the impurities; nitrogen, helium, carbon dioxide, sulphur compounds and water. Natural gas, at normal temperature and pressure, when cooled to its liquefied state is reduced in volume by a factor of 600:1. At a temperature of approximately -100 °C, natural gas is lighter than air. LNG is a clear, odourless, non-toxic, non-corrosive liquid. It is a cryogenic liquid not carried under pressure, and the small pressure in the tanks is as a result of the boil-off gas, which is released to be either burned or re-liquefied. LNG needs to be reduced to a gas before it becomes active. Natural gas (methane) has a flammable range of between 5% and 15% in air. Natural gas when not confined is not explosive, and if ignited will burn back to the source at a point where the gas become too rich to burn (15% in air) (University of Houston, Institute of Energy, Law and Enterprise, October 2003)