

Chapter 33

TYPES OF GAS CARRIERS

This Chapter provides an overview of the written standards covering gas carrier construction. It also discusses the essential elements of design such as cargo containment systems and tanker types. It is important to realise that apart from the written standards there are some aspects of gas carrier construction which are covered by the additional requirements of experienced shipowners.

33.1 Types of Gas Carriers

Gas carriers range in capacity from the small pressurised tankers of between 500 and 6,000 m³ for shipment of propane, butane and the chemical gases at ambient temperature up to the fully insulated or refrigerated seagoing tankers of over 100,000 m³ capacity for the transport of LNG and LPG. Between those two distinct types is a third tanker type – semi-pressurised gas carrier. These very flexible tankers are able to carry many cargoes in a fully refrigerated condition at atmospheric pressure or at temperatures corresponding to carriage pressure of between five and nine bar.

The movement of liquefied gases by waterways is now a mature industry, served by a fleet of many tankers, a network of export and import terminals and a wealth of knowledge and experience on the part of various people involved.

Gas carriers have certain features common with other tankers used for the carriage of bulk liquids such as oil and chemical tankers.

A feature almost unique to the gas carrier is that the cargo is kept under positive pressure to prevent air entering the cargo system. This means that only cargo liquid and cargo vapour are present in the cargo tank and flammable atmospheres cannot develop. Furthermore all gas carriers utilise closed cargo systems when loading or discharging, with no venting of vapour being allowed to the atmosphere. In the LNG trade, provision is always made for the use of a vapour return line between tanker and shore to pass vapour displaced by the cargo transfer. In the LPG trade this is not always the case as, under normal circumstances during loading, reliquefaction is used to retain vapour on board. By these means cargo release to the atmosphere is virtually eliminated and the risk of vapour ignition is minimised.

Gas carriers must comply with the standards set by the Gas Codes or national rules, and with all safety and pollution requirements common to other tankers. The safety features inherent in the tanker design requirements have helped considerably in the safety of these tankers. Equipment requirements for gas carriers include temperature and pressure monitoring, gas detection and cargo tank liquid level indicators, all of which are provided with alarms and ancillary instrumentation. The variation of equipment as fitted can make the gas carrier one of the most sophisticated tankers afloat today.

There is considerable variation in the design, construction and operation of gas carriers due to the variety of cargoes carried and the number of cargo containment systems utilised. Cargo containment systems may be of the independent tank type (pressurised, semi-pressurised or fully refrigerated) or of the membrane type.

Fully pressurised tankers

Most fully pressurised LPG carriers are fitted with a number of horizontal cylindrical or spherical cargo tanks and have capacities up to 6,000 m³. Fully pressurised tankers are still being built in numbers and represent a cost-effective, simple way of moving LPG to and from smaller gas terminals.

Semi-pressurised tankers

With the development of metals suitable for containment of liquefied gases at low temperatures, semi-pressurised tankers were developed. By installing a reliquefaction plant, insulating the cargo tanks and making use of special steels, the thickness of the pressure vessels, and hence their weight, could be reduced. These carriers, incorporating tanks either cylindrical, spherical or bi-lobe in shape, are able to load or discharge gas cargoes at both refrigerated and pressurised storage facilities.

Fully refrigerated tankers

Fully refrigerated tankers are built to carry liquefied gases at low temperature and atmospheric pressure between terminals equipped with fully refrigerated storage tanks. The tankers have prismatic-shaped cargo tanks fabricated from 3.5% nickel steel, allowing the carriage of cargoes at temperatures as low as -48°C, marginally below the boiling point of pure propane. Prismatic tanks enable the tanker's cargo carrying capacity to be maximised, thus making the fully refrigerated tanker highly suitable for carrying large volumes of cargo such as LPG, ammonia and vinyl chloride over long distances.

Liquefied natural gas (LNG) carriers

LNG is carried at its boiling point, being -162°C. LNG containment systems have developed considerably. LNG carriers are fitted with independent cargo tanks or with membrane tanks.

33.2 Cargo Containment Systems

A cargo containment system is the total arrangement for containing cargo including, where fitted:

- A primary barrier (the cargo tank);
- Secondary barrier (if fitted);
- Associated thermal insulation;
- Any intervening spaces, and
- Adjacent structure, if necessary, for the support of these elements.

For cargoes carried at temperatures between -10°C and -55°C the tanker's hull may act as the secondary barrier and in such cases it may be a boundary of the hold space.

The basic cargo tank types utilised on board gas carriers are in accordance with the list below:

- Independent Type 'A' (fully ref.)
- Independent Type 'B' (typical LNG tank)
- Independent Type 'C' (fully pressurised)
- Membrane (typical LNG tank)

Individual legislations may use differing definitions for tank types

33.2.1 Independent Tanks

Independent tanks are completely self-supporting and do not form part of the tanker's hull structure. Moreover, they do not contribute to the hull strength of a tanker. As defined in the IGC Code, and depending mainly on the design pressure, there are three different types of independent tanks for gas carriers: these are known as Types 'A', 'B' and 'C'.

Type 'A' tanks

Type 'A' tanks are constructed primarily of flat surfaces. The maximum allowable tank design pressure in the vapour space for this type of system is 0.7 barg; this means cargoes must be carried in a fully refrigerated condition at or near atmospheric pressure (normally below 0.25 barg). Figure 33.1 shows a section through this type of tank as found on a fully refrigerated LPG carrier. This is a self-supporting prismatic tank which requires conventional internal stiffening. In this example the tank is surrounded by a skin of foam insulation. Where perlite insulation is used, it would be found filling the whole of the hold space.

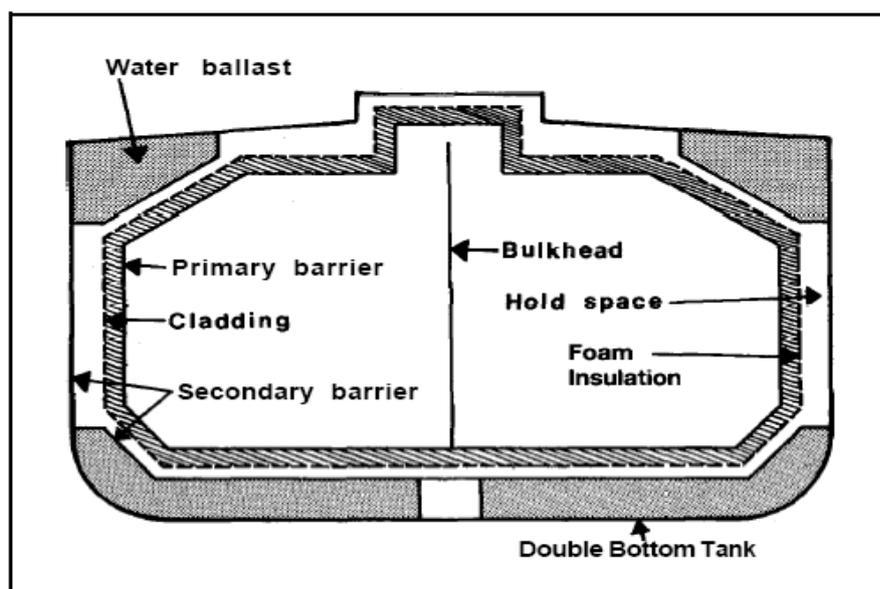


Figure 33.1 - Prismatic self-supporting Type 'A' tank - fully refrigerated LPG carrier

The material used for Type 'A' tanks is not crack propagation resistant. Therefore, in order to ensure safety, in the unlikely event of cargo tank leakage, a secondary containment system is required. This secondary containment system is known as a secondary barrier and is a feature of all tankers with Type 'A' tanks capable of carrying cargoes below -10°C .

For a fully refrigerated LPG carrier (which will not carry cargoes below -55°C) the secondary barrier must be a complete barrier capable of containing the whole tank volume at a defined angle of heel and may form part of the tanker's hull, as shown in the figure. In general, it is this design approach which is adopted. By this means appropriate parts of the tanker's hull are constructed of special steel capable of withstanding low temperatures. The alternative is to build a separate secondary barrier around each cargo tank.

The IGC Code stipulates that a secondary barrier must be able to contain tank leakage for a period of 15 days.

On such tankers, the space between the cargo tank (sometimes referred to as the primary barrier) and the secondary barrier is known as the hold space. When flammable cargoes are being carried, these spaces must be filled with inert gas to prevent a flammable atmosphere being created in the event of primary barrier leakage.

Type 'B' tanks

Type 'B' tanks can be constructed of flat surfaces or they may be of the spherical type. This type of containment system is the subject of much more detailed stress analysis compared to Type 'A' systems. These controls must include an investigation of fatigue life and a crack propagation analysis.

The most common arrangement of Type 'B' tank is a spherical tank as illustrated in Figure 33.2(a). This tank is of the Kvaerner Moss design. Because of the enhanced design factors, a Type 'B' tank requires only a partial secondary barrier in the form of a drip tray. The hold space in this design is normally filled with dry inert gas. However, when adopting modern practice, it may be filled with dry air provided that inerting of the space can be achieved if the vapour detection system shows cargo leakage. A protective steel dome covers the primary barrier above deck level and insulation is applied to the outside of the tank. The Type 'B' spherical tank is almost exclusively applied to LNG tankers; seldom featuring in the LPG trade.

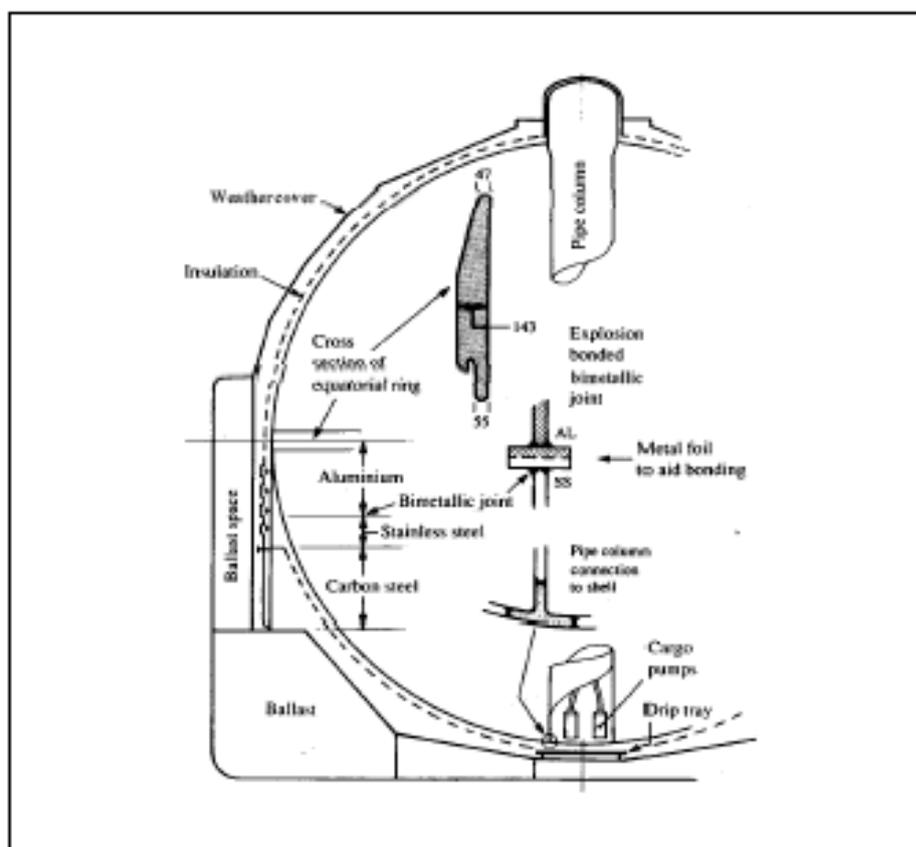


Figure 33.2(a) - Self-supporting spherical Type 'B' tank

A Type 'B' tank, however, need not be spherical. There are Type 'B' tanks of prismatic shape in LNG service. The prismatic Type 'B' tank has the benefit of maximising tanker-hull volumetric efficiency and having the entire cargo tank placed beneath the main deck. Where the prismatic shape is used, the maximum design vapour space pressure is, as for Type 'A' tanks, limited to 0.7 barg. A drawing of a self-supporting prismatic Type 'B' tank is shown in Figure 33.2(b).

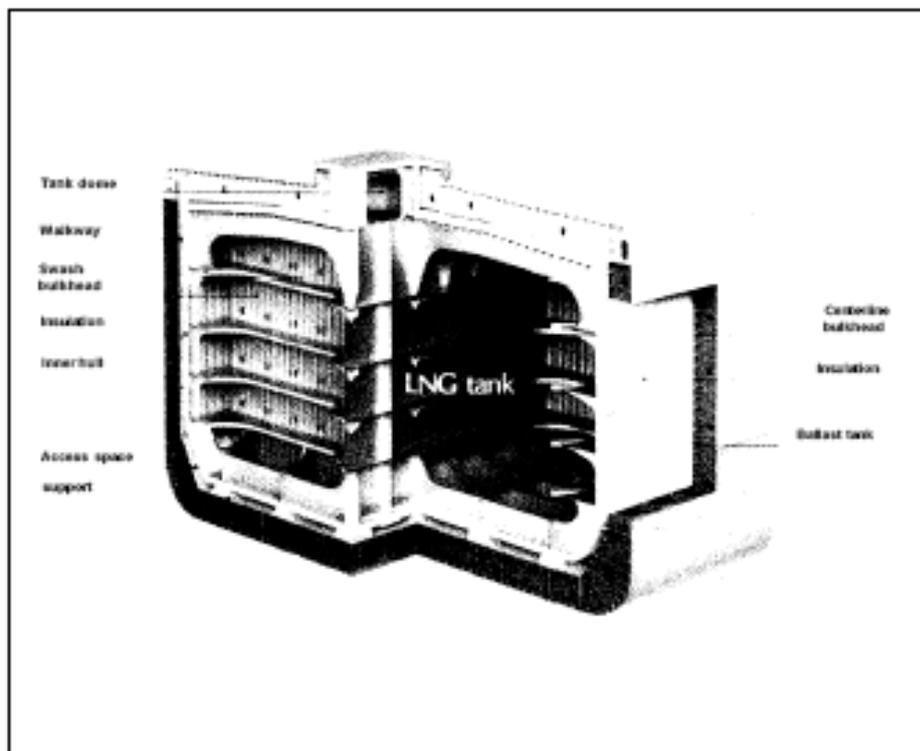


Figure 33.2(b) - Self-supporting prismatic Type 'B' tank

Type 'C' tanks (fully pressurised)

Type 'C' tanks are normally spherical or cylindrical pressure vessels having design pressures higher than 4 barg. The cylindrical vessels may be vertically or horizontally mounted. This type of containment system is always used for semi-pressurised and fully pressurised gas carriers. In the case of the semi-pressurised tankers it can also be used for fully refrigerated carriage, provided appropriate low temperature steels are used in tank construction. Type 'C' tanks are designed and built to conventional pressure vessel codes and, as a result, can be subjected to accurate stress analysis. Furthermore, design stresses are kept low. Accordingly, no secondary barrier is required for Type 'C' tanks and the hold space can be filled with either inert gas or dry air and for fully pressurised tankers normal air may be allowed.

In the case of a typical fully pressurised tanker (where the cargo is carried at ambient temperature), the tanks may be designed for a maximum working pressure of about 18 barg. For a semi-pressurised tanker the cargo tanks and associated equipment are designed for a working pressure of approximately 5 to 7 barg and a vacuum of 0.3 barg. Typically, the tank steels for the semi-pressurised tankers are capable of withstanding carriage temperatures of -48°C for LPG or -104°C for ethylene. (Of course, an ethylene carrier may also be used to transport LPG.)

Figure 33.3 shows Type 'C' tanks as fitted in a typical fully pressurised gas carrier. With such an arrangement there is comparatively poor utilisation of the hull volume; however, this can be improved by using intersecting pressure vessels or *bi-lobe* type tanks which may be designed with a taper at the forward end of the tanker. This is a common arrangement in semi-pressurised tankers as shown in Figure 33.4.

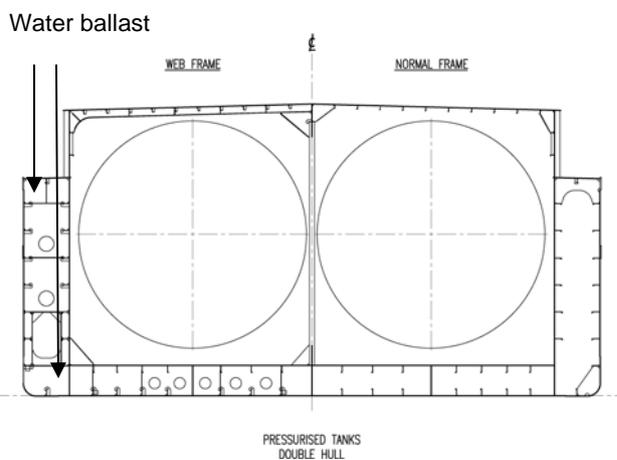


Figure 33.3.1 - Widely spread inland gas tanker-type, fully pressurised Double hull and double bottom

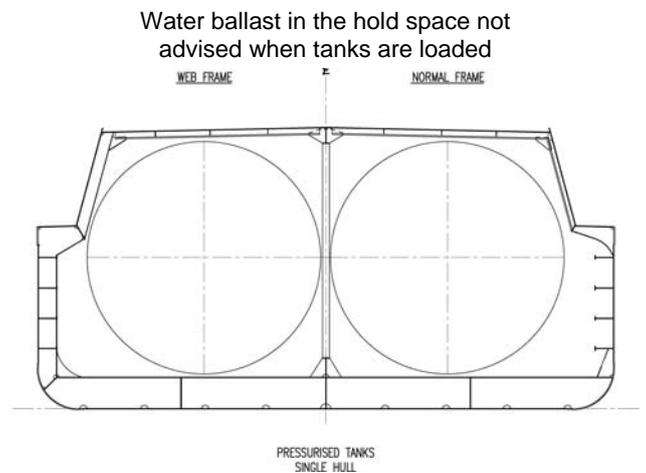


Figure 33.3.2 - Widely spread inland gas tanker-type, fully pressurised Single hull

33.2.2 Membrane Tanks (Membrane - 0.7 to 1.5 mm thick)

The concept of the membrane containment system is based on a very thin primary barrier (membrane - 0.7 to 1.5 mm thick) which is supported through the insulation. Such tanks are not self-supporting like the independent tanks outlined in 33.2.1; an inner hull forms the load bearing structure. Membrane containment systems must always be provided with a secondary barrier to ensure the integrity of the total system in the event of primary barrier leakage. The membrane is designed in such a way that thermal expansion or contraction is compensated without over-stressing the membrane itself. There are two principal types of membrane system in common use both named after the companies who developed them and both designed primarily for the carriage of LNG.

These two companies have now combined into one and future developments can be expected.

GTT 96 Membrane system

Figures 33.5(a) and 33.5(b) show the GTT 96 system comprising a thin Invar primary barrier. Invar is a stainless steel alloy containing about 36 per cent nickel and 0.2 per cent carbon. This is attached to the inner (cold) surface of perlite-filled plywood boxes used as primary insulation. These boxes have thickness of between 200 and 300 millimetres. These, in turn, are attached to an identical inner layer of Invar (the secondary barrier) and, finally, a further set of similar perlite-filled boxes is used for secondary insulation. Invar is chosen for the membranes because of its very low coefficient of thermal expansion, thus making expansion joints, or corrugation, in the barriers unnecessary. Newer designs of the GTT 96 system utilise Invar membranes of 0.7 millimetres thickness in strakes of 0.5 metres width and strengthened plywood boxes to hold the perlite insulation. The perlite is processed with silicon to make it impervious to water or moisture. The thickness of the insulation boxes can be adjusted to obtain the required amount of boil-off.

Figure 33.5(b) shows a section through the basic GTT 96 containment system.

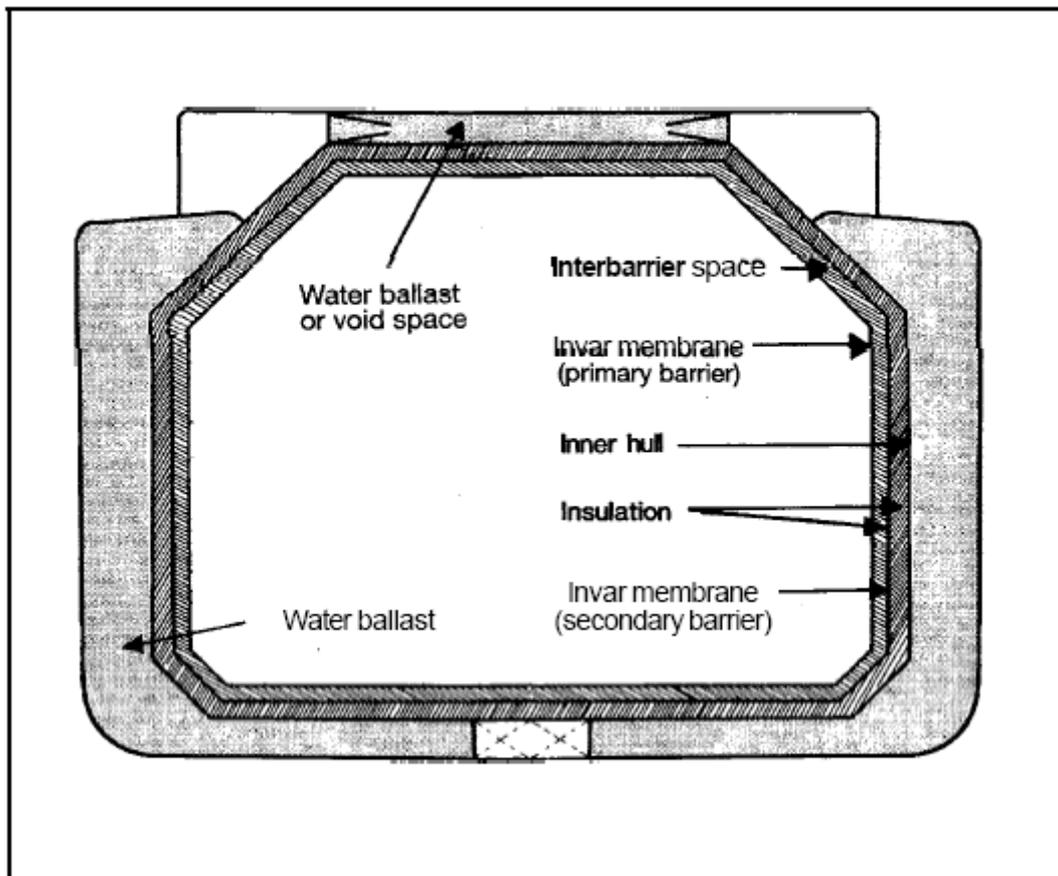


Figure 33.5(a) – GTT 96 Membrane containment system - larger LNG carriers

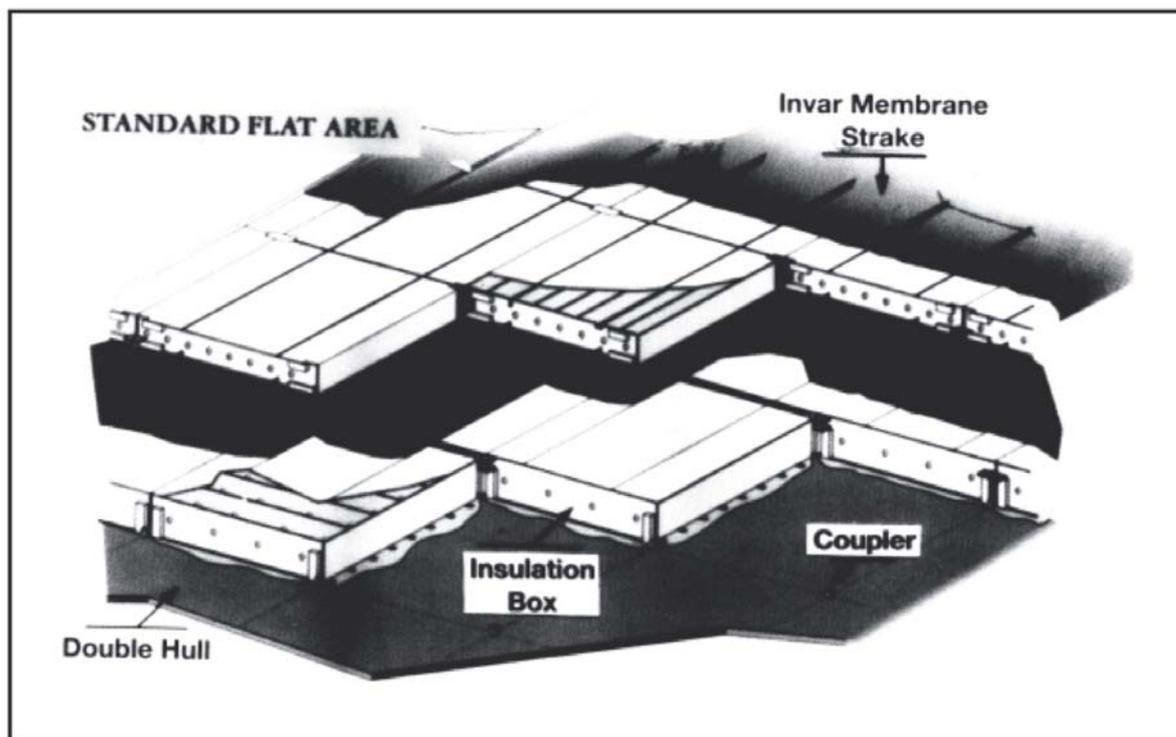


Figure 33.5(b) - Construction of the GTT 96 Membrane system

GTT Mk III

The GTT Mk III system, shown in Figure 33.6(a), features a primary barrier of stainless steel (1.2 millimetres in thickness) having raised corrugations, or *waffles*, to allow for expansion and contraction. In the original Mark I design, the insulation that supports the primary membrane consisted of laminated balsa wood panels held between two plywood layers; the face plywood formed the secondary barrier. The balsa wood panels were interconnected with specially designed joints comprising PVC foam wedges and plywood scabs and were supported on the inner hull of the tanker by wooden grounds.

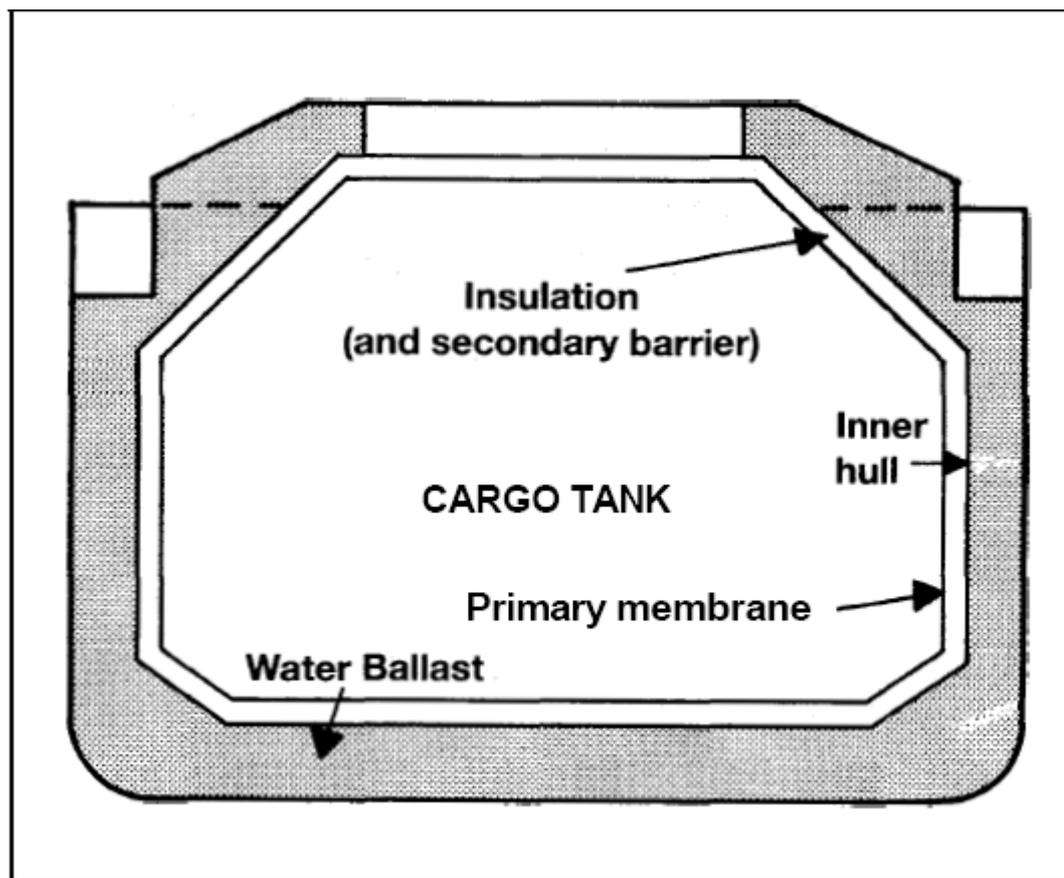


Figure 33.6(a) – GTT Mk III Membrane containment system - larger LNG carriers

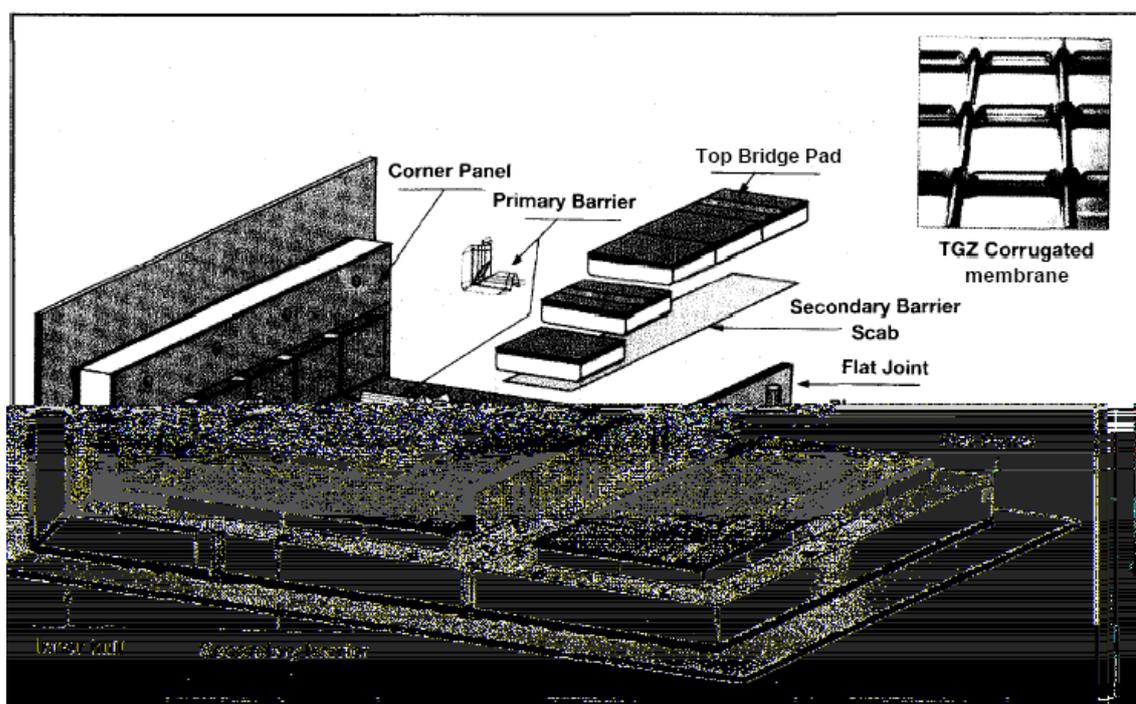


Figure 33.6(b) - Construction of the GTT Mk III Membrane

In the Mark III design the balsa wood insulation is replaced by reinforced cellular foam. Within the foam there is a fibreglass cloth/aluminium laminate acting as secondary barrier. Figure 33.6(b) shows a cutaway section through the GTT Mk III containment system.

33.2.3 Semi-Membrane Tanks

The semi-membrane concept is a variation of the membrane tank system. The primary barrier is much thicker than that in the membrane system, having flat sides and large radiused corners. The tank is self-supporting when empty but not in the loaded condition. In this condition the liquid (hydrostatic) and vapour pressures acting on the primary barrier are transmitted through the insulation to the inner hull as is the case with the membrane system. The corners and edges are designed to accommodate expansion and contraction. Although semi-membrane tanks were originally developed for the carriage of LNG no commercial-size LNG carrier has yet been built to this design. The system has however, been adopted for use in LPG tankers and several Japanese-built fully refrigerated LPG carriers have been delivered to this design.

33.2.4 Integral Tanks

Integral tanks form a structural part of the tanker's hull and are influenced by the same loads which stress the hull structure. Integral tanks are not normally allowed for the carriage of liquefied gas if the cargo temperature is below -10°C . Certain tanks on a limited number of Japanese-built LPG carriers are of the integral type for the dedicated carriage of fully refrigerated butane.

33.3 Materials of Construction and Insulation

33.3.1 Construction Materials

The choice of cargo tank materials is dictated by the minimum service temperature and, to a lesser degree, by compatibility with the cargoes carried. The most important property to consider in the selection of cargo tank materials is the low-temperature toughness. This consideration is vital as most metals and alloys (except aluminium) become brittle below a certain temperature.

Treatment of structural carbon steels can be used to achieve low-temperature characteristics and the Gas Codes specify low-temperature limits for varying grades of steel down to -55°C . Reference should be made to the Gas Codes and classification society rules for details on the various grades of steel.

According to the Gas Codes, tankers carrying fully refrigerated LPG cargoes may have tanks capable of withstanding temperatures down to -55°C . Usually, the final temperature is chosen by the shipowner, depending on the cargoes expected to be carried. This is often determined by the boiling point of liquid propane at atmospheric pressure and, hence, cargo tank temperature limitations are frequently set at about -46°C . To achieve this service temperature, steels such as fully killed, fine-grain, carbon-manganese steel, sometimes alloyed with 0.5 per cent nickel, are used.

Where a tanker has been designed specifically to carry fully refrigerated ethylene (with a boiling point at atmospheric pressure of -104°C) or LNG (atmospheric boiling point -162°C), nickel-alloyed steels, stainless steels (such as Invar) or aluminium must be used for the material of tank construction.

33.3.2 Tank Insulation

Thermal insulation must be fitted to refrigerated cargo tanks for the following reasons:

- To minimise heat flow into cargo tanks, thus reducing boil-off.
- To protect the tanker structure around the cargo tanks from the effects of low temperature.

Insulation materials for use on gas carriers should possess the following main characteristics:

- Low thermal conductivity.
- Ability to bear loads.
- Ability to withstand mechanical damage.
- Light weight.
- Unaffected by cargo liquid or vapour.

The vapour-sealing property of the insulation system, to prevent ingress of water or water vapour, is important. Not only can ingress of moisture result in loss of insulation efficiency but progressive condensation and freezing can cause extensive damage to the insulation. Humidity conditions must, therefore, be kept as low as possible in hold spaces. One method to protect the insulation is to provide a foil skin acting as a vapour barrier to surround the system.

Material	Application	Thermal Conductivity W/m K
Balsa Wood	A load-bearing insulant	0.05
Mineral Wool	Normally supplied in slabs or rolls	0.03
Perlite	Granular silicon/aluminium oxide used as bulk in-fill for hold spaces or in modular boxes	0.04
Polystyrene	Pre-formed, sprayed or foamed	0.036
Polyurethane	Pre-formed, sprayed or foamed	0.025

Table 33.1 - Typical insulation materials

Table 33.1 provides information on the insulation materials normally used in gas carrier construction, together with approximate values for their thermal conductivities at 10°C.

Thermal insulation may be applied to various surfaces, depending on the design of the containment system. For Type 'B' and 'C' containment systems, insulation is applied directly to the cargo tank's outer surfaces. For Type 'A' cargo tanks insulation can be applied either directly to the cargo tank or to the inner hull (if fitted) although its application to the cargo tank is more common.

As most insulation materials are flammable, great care is required at times of construction or refit to ensure that fires are avoided.

