LIQUEFIED GASES

A liquefied gas is the liquid form of a substance which, at ambient temperature and at atmospheric pressure, would be a gas.

Most liquefied gases are hydrocarbons and the key property that makes hydrocarbons the world's primary energy source — combustibility — also makes them inherently hazardous. Because these gases are handled in large quantities it is imperative that all practical steps are taken to minimise leakage and to limit all sources of ignition.

The Gas Carrier Codes

The overall layout of a gas carrier is similar to that of the conventional oil tanker from which it evolved. The cargo containment system and its incorporation into the hull is, however, very different due to the need to carry cargo under pressurised, or refrigerated conditions; or under a combination of pressure and refrigeration.

Gas carriers designed for pressurised cargoes can usually be identified by cylindrical or spherical tanks which may project through the deck. Similarly the LNG carrier with spherical tanks protruding above the main deck can be easily recognised by its distinctive profile and much larger size. Gas carriers designed to carry their cargo at atmospheric pressure in prismatic tanks are not easily distinguishable from oil tankers except by their freeboard which is significantly greater. This greater buoyancy results from cargoes of a much lower density than most oils and the requirement to have totally segregated tanks for ballast. To examine the design of these ships in greater detail, readers should consult the Gas Codes and the rules of the major ship classification societies which give guidance on the requirements of the Gas Codes.

The Gas Codes, developed by IMO, apply to all gas carriers regardless of size. There are **three** Gas Codes and these are described below.

Gas carriers built after June 1986 (the IGC Code)

The Code which applies to new gas carriers (built after 30th June 1986) is the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. In brief, this Code is known as the IGC Code. The IGC Code, under amendments to Safety of Life at Sea Convention (SOLAS), is mandatory for all new ships. As proof that a ship complies with the Code, an International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk should be on board.

In 1993, the IGC Code was amended and the new rules came into effect on 1st July 1994. Ships on which construction started on or after 1st October 1994 should apply the amended version of the Code but ships built earlier may comply with previous editions of the IGC Code.

Gas carriers built between 1976 and 1986 (the GC Code)

The regulations covering gas carriers built after 1976 but before July 1986 are included in the Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. It is known as the Gas Carrier Code or GC Code in short. Since 1975, IMO has approved four sets of amendments to the GC Code. The latest was adopted in June 1993. It should be noted that all amendments are not necessarily agreed by every government. Although this Code is not mandatory, many countries have implemented it into national law. Accordingly, most charterers will expect such ships to meet with Code standards and, as proof of this, to have on board a Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

Gas carriers built before 1977 (the Existing Ship Code)

The regulations covering gas carriers built before 1977 are contained in the Code for Existing Ships Carrying Liquefied Gases in Bulk. Its content is similar to the GC Code, though less extensive.

The Existing Ship Code was completed in 1976 after the GC Code had been written. It therefore summarizes current shipbuilding practice at that time. It remains as an IMO recommendation for all gas carriers in this older fleet of ships. The Code is not mandatory but is applied by some countries for ship registration and in other countries as a necessary fulfillment prior to port entry. Accordingly, many ships of this age are required by charterers to meet with Code standards and to have on board a Certificate of Fitness for the Carriage of Liquefied Gases in Bulk.

Some of the **factors** to be taken into consideration which affect the design of gas ships are:

- Types of cargo to be carried
- Condition of carriage (fully pressurised, semi-pressurised, fully refrigerated)
- Type of trade and cargo handling flexibility required by the ship
- Terminal facilities available when loading or discharging the ship

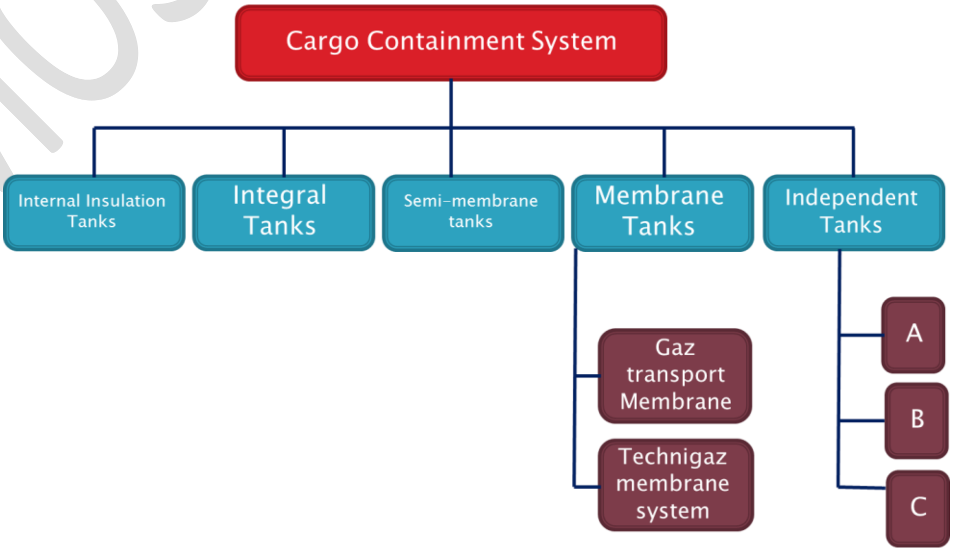
Perhaps more than any other single ship type, the gas tanker encompasses many different design philosophies. Nowhere is this more apparent than in considering the different types of cargo containment system which have been adopted.

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 ship'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 utilized on board gas carriers are in accordance with the list below:



Independent tanks

Independent tanks are completely self-supporting and do not form part of the ship’s hull structure. Moreover, they do not contribute to the hull strength of a ship. 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 bar; this means cargoes must be carried in a fully refrigerated condition at or near atmospheric pressure (normally below 0.25 bar). Figure 3.1 shows a section through this type of tank as found on a fully refrigerated LPG carrier.

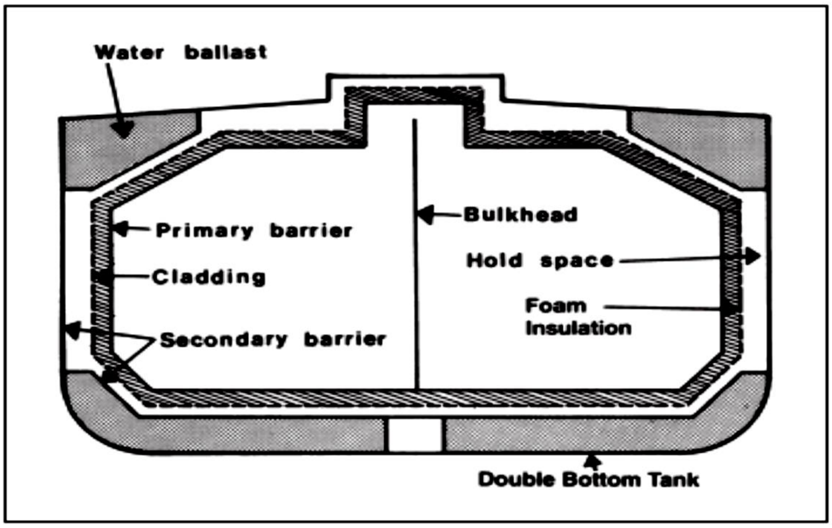


Figure 3.1 Prismatic self-supporting Type ‘A’ tank — fully refrigerated LPG carrier

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. 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 ships 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 ship’s hull, as shown in the figure. In general, it is this design approach which is adopted. By this means appropriate parts of the ship’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 ships, 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 3.2(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 ships; seldom featuring in the LPG trade. 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 ship 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 bar. A drawing of a self-supporting prismatic Type ‘B’ tank is shown in Figure 3.2(b).

Type ‘C’ tanks

Type ‘C’ tanks are normally spherical or cylindrical pressure vessels having design pressures higher than 2 bar. 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 ships 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.

In the case of a typical fully pressurised ship (where the cargo is carried at ambient temperature), the tanks may be designed for a maximum working pressure of about 18 bar. For a semi-pressurised ship the cargo tanks and associated equipment are designed for a working pressure of approximately 5 to 7 bar and a vacuum of 0.5 bar. Typically, the tank steels for the semi-pressurised ships 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 3.3 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 ship. This is a common arrangement in semi-pressurised ships as shown in Figure 3.4.

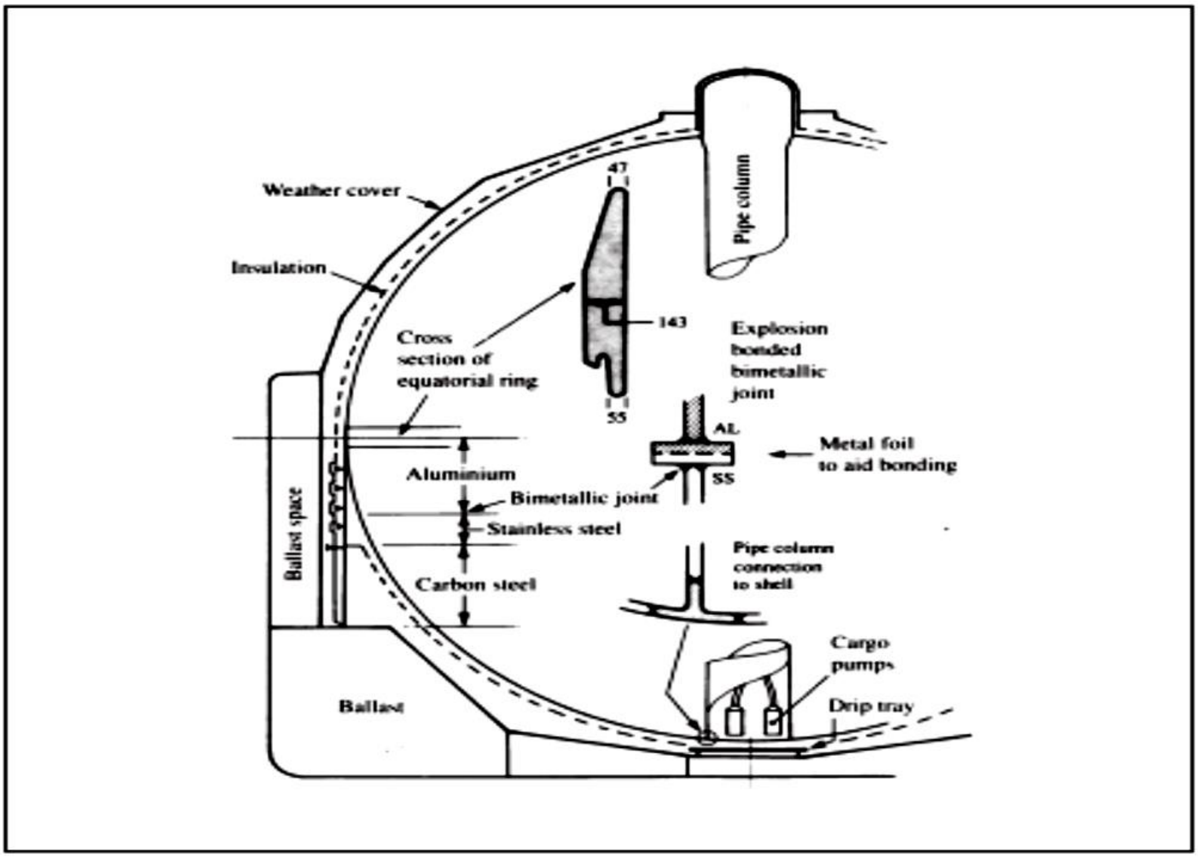


Figure 3.2(a) Self-supporting spherical Type 'B' tank

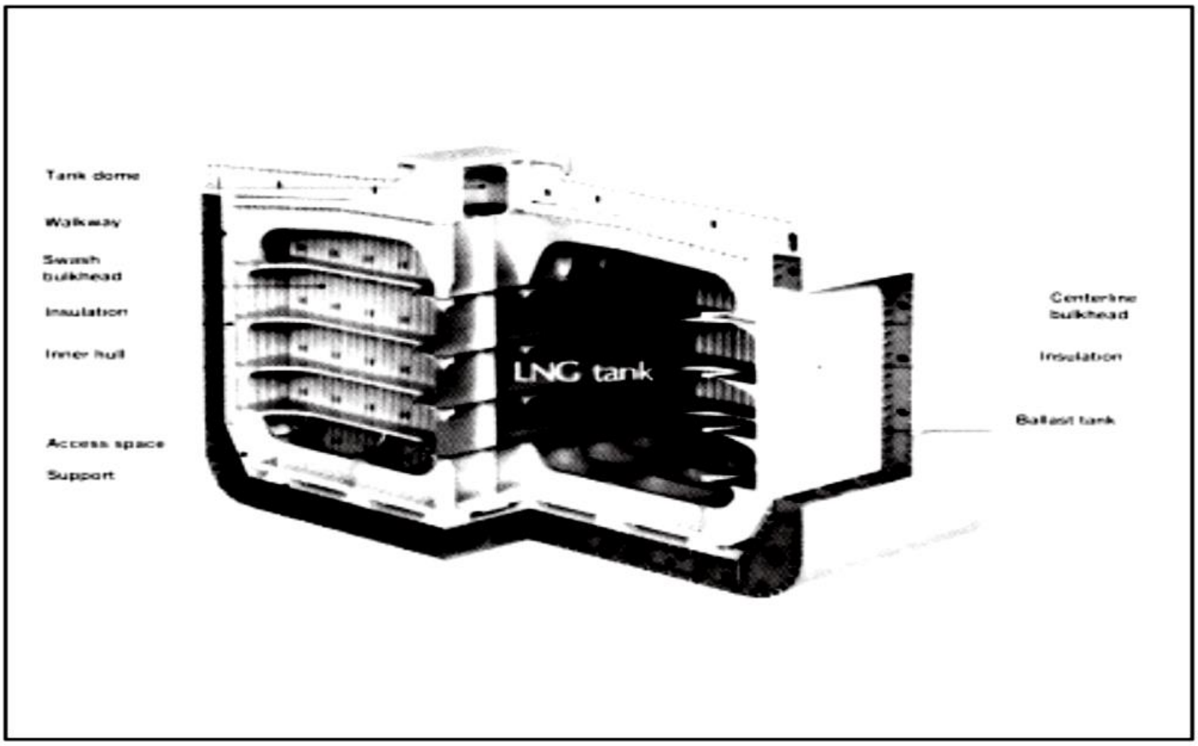


Figure 3.2(b) Self-supporting prismatic Type 'B' tank

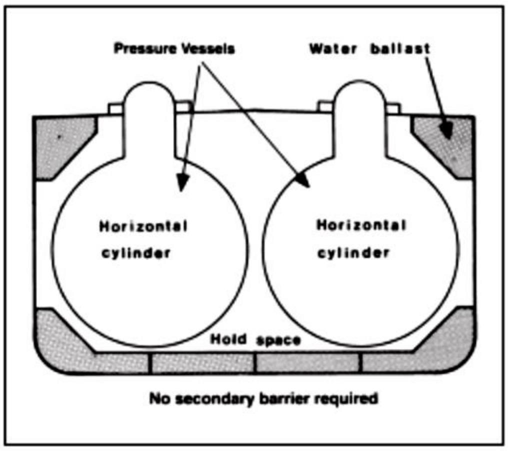


Figure 3.3 Type 'C' tanks — fully pressurised gas carrier

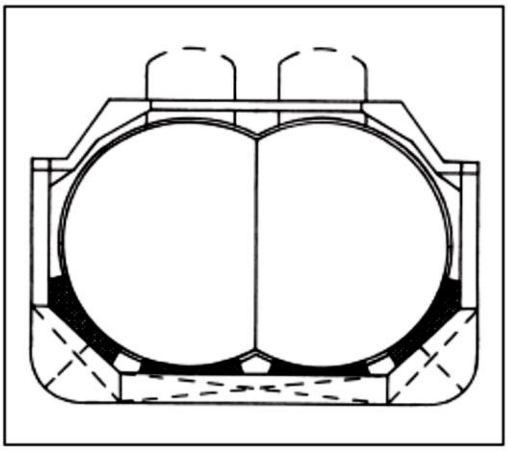


Figure 3.4 Type 'C' tanks — semi-pressurised gas carrier with bi-lobe tanks

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; 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. Gaz Transport membrane system
Figures 3.5(a) and 3.5(b) show the Gaz Transport system comprising a thin Invar primary barrier. Invar is a stainless steel alloy containing about 36 percent nickel and 0.2 percent 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 millimeters. 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

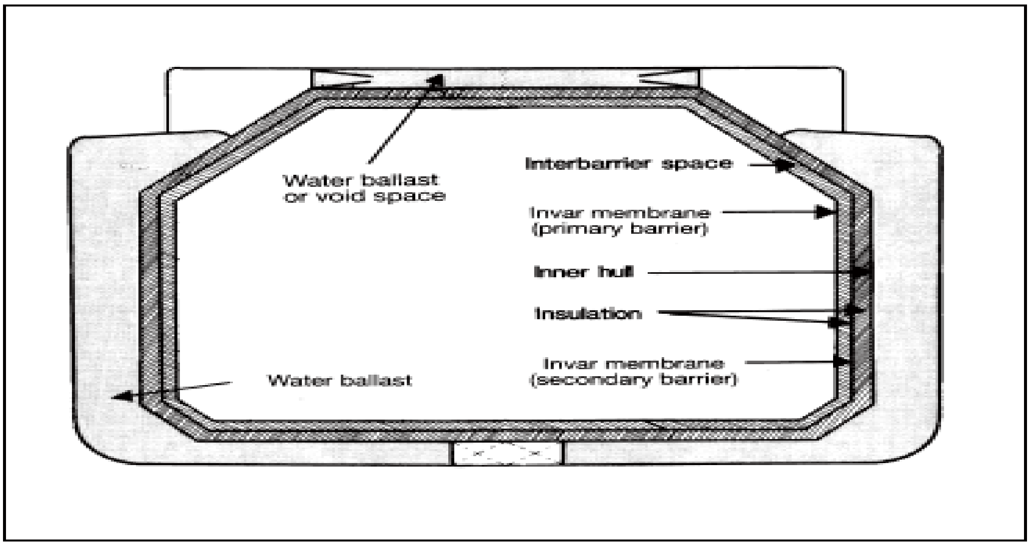


Figure 3.5(a) Gaz Transport membrane containment system — larger LNG carriers

Figure 3.5(a) Gaz Transport membrane containment system — larger LNG carriers 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 Gaz Transport system utilize Invar membranes of 0.7 millimeters thickness in strakes of 0.5 meters 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 3.5(b) shows a section through the basic Gaz Transport containment system.

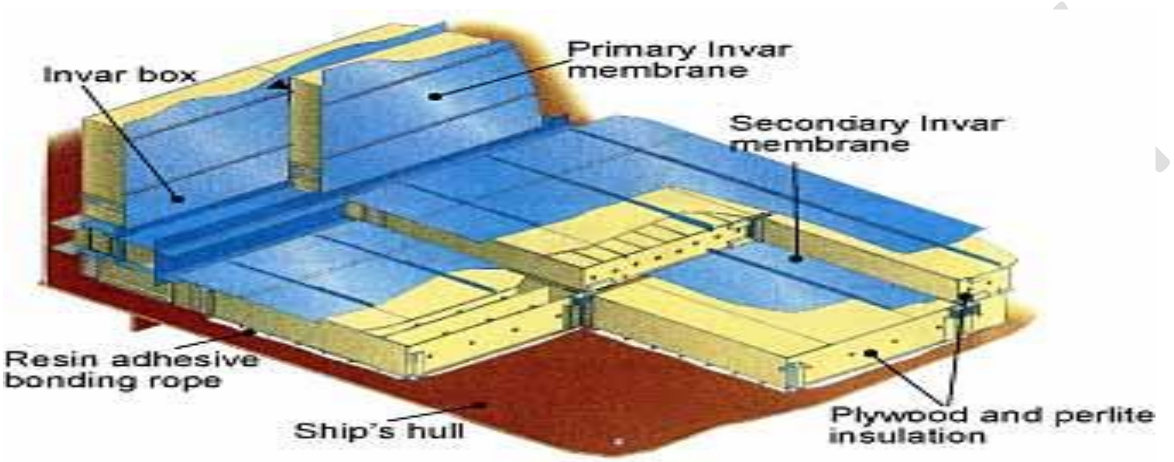


Figure 3.5(b) Construction of the Gaz Transport Membrane System

Technigaz membrane system

The Technigaz system, shown in Figure 3.6(a), features a primary barrier of stainless steel (1.2 millimeters 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 ship by wooden grounds

In the latest design (Mark lll) the balsa wood insulation is replaced by reinforced cellular foam. Within the foam there is a fibre glass cloth/aluminium laminate acting as secondary barrier. Figure 3.6(b) shows a cutaway section through the Mark lll Technigaz containment system.

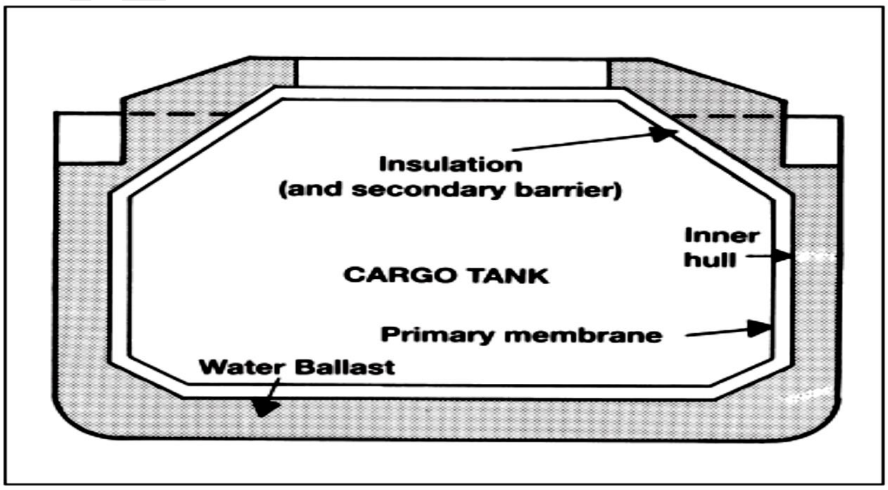


Figure 3.6(a) **Technigaz membrane containment system — larger LNG carriers**

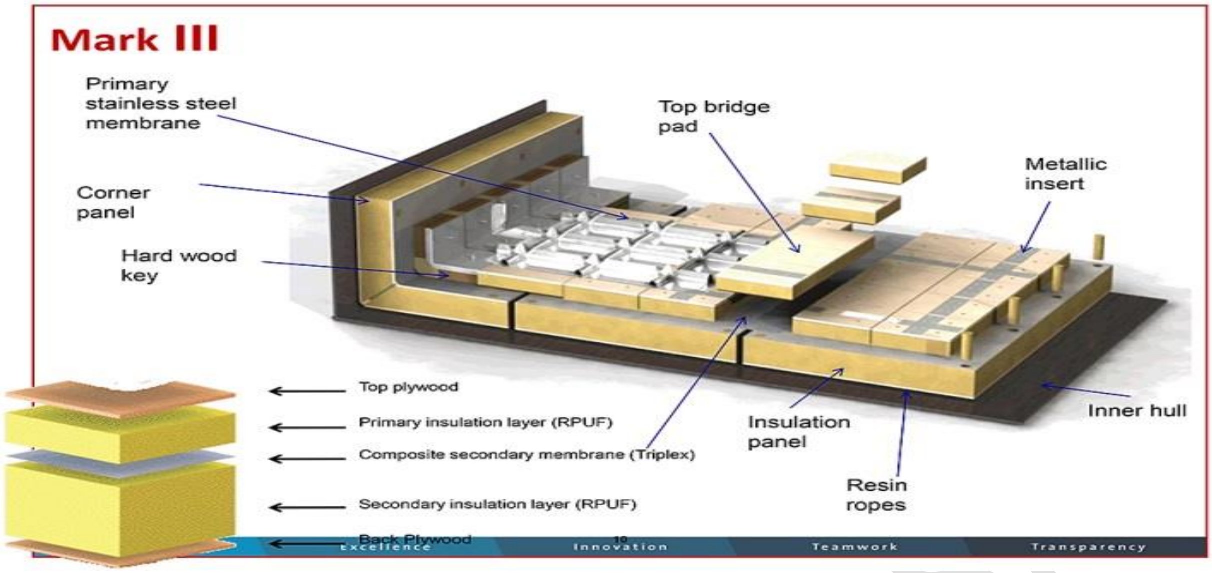


Figure 3.6(b) Construction of Technigaz membrane system- MARK-III

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 ships and several Japanese-built fully refrigerated LPG carriers have been delivered to this design.

Integral tanks

Integral tanks form a structural part of the ship’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.

Internal insulation tanks

Internally insulated cargo tanks are similar to integral tanks. They utilize insulation materials to contain the cargo. The insulation is fixed inside ship’s inner hull or to an independent load-bearing surface. The non-self-supporting system obviates the need for an independent tank and permits the carriage of fully refrigerated cargoes at carriage temperatures as low as –55°C. Internal insulation systems have been incorporated in a very limited number of fully refrigerated LPG carriers but, to date, the concept has not proved satisfactory in service.

MATERIALS OF CONSTRUCTION AND INSULATION

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, ships carrying fully refrigerated LPG cargoes may have tanks capable of withstanding temperatures down to –55°C. Usually, the final temperature is chosen by the ship-owner, 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 percent nickel, are used. Where a ship 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.

Tank insulation

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

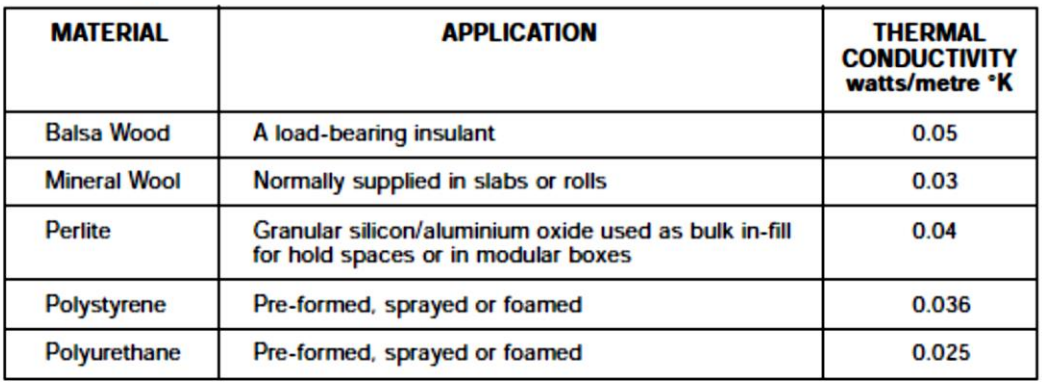
- To minimise heat flow into cargo tanks, thus reducing boil-off.
- To protect the ship structure around the cargo tanks from the effects of low temperature.

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.

Table 3.1 Typical insulation materials



MATERIAL	APPLICATION	THERMAL CONDUCTIVITY watts/metre °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 3.1 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.

Gas Carrier Types

Gas carriers can be grouped into five different categories according to the cargo carried and the carriage condition. These are as follows:

- Fully pressurised ships
- Semi-pressurised ships
- Ethylene ships
- Fully refrigerated LPG ships
- LNG ships

The first three ship types listed are most suitable for the shipment of smaller-size cargoes of LPG and chemical gases. This is normally accomplished on short-sea and regional routes. Fully refrigerated ships are used extensively for the carriage of large size cargoes of LPG and ammonia on the deep sea routes.

Fully pressurised ships

Fully pressurised ships are the simplest of all gas carriers. Their containment systems and cargo handling equipment have been established for many years. They carry their cargoes at ambient temperature. They are fitted with Type ‘C’ tanks (pressure vessels) fabricated in carbon steel having a typical design pressure of about 18 bar. Ships with higher design pressures are in service and a few ships can accept cargoes at pressures of up to 20 bar. No thermal insulation or reliquefaction plant is necessary for these ships and cargo can be discharged using either pumps or compressors.

Because of their design pressure, the cargo tanks are extremely heavy. As a result, fully pressurised ships tend to be small having cargo capacities of about 4,000 to 6,000 m3, and are primarily used to carry LPG and ammonia. Ballast is carried in double bottoms and in top wing tanks. Because these ships are fitted with Type ‘C’ containment systems, no secondary barrier is required and the hold space may be ventilated with air.

Figure 3.3 shows a section through a typical fully pressurised ship. These ships carry cargo at ambient conditions and, as such, cargo temperatures may be different at each end of the voyage. When equipped with a loading heater these ships can load from a fully refrigerated terminal.

Semi-pressurised ships

Semi-pressurised ships are similar to fully pressurised ships in that they have Type ‘C’ tanks — in this case pressure vessels designed typically for a maximum working pressure of from 5 to 7 bar. Compared to fully pressurised ships, a reduction in tank thickness is possible due to the reduced pressure but this is at the cost of refrigeration plant and tank insulation. This type of gas carrier has evolved as the optimum means of transporting a wide variety of gases such as LPG, vinyl chloride, propylene, and butadiene. They are most frequently found in the busy coastal trades around the Mediterranean and Northern Europe. Today, this type of ship is the most popular amongst operators of smaller-size gas carriers due to its cargo handling flexibility.

Semi-pressurised ships use Type ‘C’ tanks and, therefore, do not require a secondary barrier (cargo capacities can vary from 3,000 to 20,000 m3). The tanks are usually made from low temperature steels to provide for carriage temperatures of –48°C which temperature is suitable for most LPG and chemical gas cargoes. Alternatively, they can be made from special alloyed steels or aluminium to allow for the carriage of ethylene at –104°C (see also ethylene ships). The ship’s flexible cargo handling system is designed to load from (or discharge to) both pressurised and refrigerated storage facilities.

Ethylene ships

Ethylene ships are often built for specific trades but will also operate carrying LPGs or Chemical Gases. They normally have capacities ranging from 1,000 to 12,000 m3. Ethylene is normally carried in its fully refrigerated condition at its atmospheric boiling point of –104°C. Normally Type 'C' pressure vessel tanks are used and no secondary barrier is required. Thermal insulation and a high-capacity reliquefaction is fitted on this type of ship. Ballast is carried in the double bottom and wing ballast tanks. A complete double hull is required for all cargoes carried below –55°C, whether the cargo tanks are of Type 'A', 'B' or 'C'.

Fully refrigerated ships

Fully refrigerated ships carry their cargoes at approximately atmospheric pressure and are designed to transport large quantities of LPG and ammonia. Four different cargo containment systems have been used for these ships. They are as follows:—

- Independent tanks with single hull but double bottom and hopper tanks
- Independent tanks with double hull
- Integral tanks (incorporating a double hull), and
- Semi-membrane tanks (incorporating a double hull)

For this class of ship the most widely used arrangement is the first listed above. (The other systems have not found general favour with ship operators). Here, the tank itself is a Type 'A' prismatic free-standing unit capable of a maximum working pressure of 0.7 bar (Figure 3.1). The tanks are constructed of low-temperature steels to permit carriage temperatures of about –48°C. Fully refrigerated ships range in size from about 20,000 to 100,000 m3. There are relatively few fully refrigerated ships between 55,000 m3 and 70,000 m3.

Trading patterns in the 1990s show that ships smaller than 55,000 m3 tend to be used in general tramping routes where cargo changes are frequent. Such ships may switch into the ammonia trade from time to time and in exceptional circumstances, if properly certificated as an oil tanker, they have been known to carry petroleum products. On the other hand ships of 70,000 m3 and above tend to be on long-haul bulk trades carrying similar grades between a limited numbers of regular ports.

A typical fully refrigerated ship has up to six cargo tanks. Each tank is fitted with transverse wash plates, while a longitudinal bulkhead on the centre line is provided to reduce free surface so improving ship stability. The tanks are usually supported on wooden chocks and are keyed to the hull to allow for expansion and contraction as well as to prevent tank movement under static and dynamic loads. The tanks are also provided with anti-flotation chocks to avoid lifting in case of ballast tank leakage.

Because of the low-temperature carriage conditions, thermal insulation and reliquefaction equipment must be fitted. To improve a fully refrigerated ship's operational flexibility, cargo heaters and booster pumps are often fitted to allow discharge into pressurised storage facilities. This will normally be accomplished at reduced discharge rates. Where Type 'A' tanks are fitted, a complete secondary barrier is required, the hold spaces must be inerted when carrying flammable cargoes. Ballast is carried in double bottoms and in top side (saddle) tanks or, when fitted, in side ballast tanks.

LNG ships

LNG carriers are specialised types of gas carriers built to transport large volumes of LNG at its atmospheric boiling point of about –162° C. These ships are now typically of between 125,000 and 135,000 m3 capacity and are normally dedicated to a specific project. Here they often remain for their entire contract life, which may be between 20-25 years or more. Apart from a few notable exceptions during the early years of LNG transport, the containment systems on these ships are mainly of four types:

- Gaz Transport membrane (Figures 3.5(a) and 3.5(b))
- Technigaz membrane (Figures 3.6(a) and 3.6(b))
- Kvaerner Moss spherical — independent Type 'B' (Figure 3.2(a)), and
- IHI SPB Tank — prismatic (Figure 3.2(b))

These systems have already been described above. The newest containment system is the self supporting, prismatic Type 'B' (SPB) design developed by the Japanese shipbuilder IHI and this is based on the earlier Conch system. This design incorporates an aluminium tank.

All LNG ships have double hulls throughout their cargo length which provide adequate space for ballast. Ships fitted with the membrane systems have a full secondary barrier and tanks of the Type 'B' design have drip-pan type protection.

A characteristic common to all LNG ships is that they burn cargo boil-off as fuel. Hold spaces around the cargo tanks are continuously inerted, except in the case of spherical Type 'B' containment where hold spaces may be filled with dry air provided that there is an adequate means for inerting such spaces in the event of cargo leakage. Continuous gas-monitoring of all hold spaces is required.

In general, reliquefaction plants have been little used on LNG ships but it should be noted that a very small number of LNG ships have been fitted with reliquefaction plant suited to cater for limited boil-off. However these were never successfully operated. Being much colder than LPG, the necessary equipment is much more costly and it is currently more economical to burn the boil-off gas in the ship's main boilers.

Most LNG carriers have steam turbine propulsion plants. Two medium size ships are equipped with low speed, low injection pressure, dual fuel diesel engines. Although technology exists to introduce gas-burning diesel engines the perceived greater reliability of the steam turbine has so far prevented any serious development in this direction.

Gas Carrier Layout

Gas carriers have many features which are not found on other types of tanker. Some unique features can be identified from the general arrangement of gas carriers. Some specific features are outlined below.

It is not permitted for a cargo pump room to be placed below the upper deck, nor may cargo pipelines be run beneath deck level; therefore, deep well or submersible pumps must be used for cargo discharge. Pipelines to cargo tanks must be taken through a cargo tank dome which penetrates the deck.

Where ships are fitted with a reliquefaction plant, this is located in a compressor house on deck. Adjacent to the compressor house is an electric motor room which contains the machinery for driving the reliquefaction compressors. The electric motor room and compressor room must be separated by a gastight bulkhead (see Figure 3.7).

The Gas Codes detail the requirements for mechanical ventilation of these rooms. Positive pressure ventilation must be provided for the electric motor room and negative pressure ventilation for the cargo compressor area. This ensures an appropriate pressure differential between the rooms. An airlock entrance to the electric motor room from the ship's deck, with two gastight doors at least 1.5 meters apart, prevents loss of air pressure on entry. To ensure that both doors are not opened simultaneously they must be self-closing with audible and visual alarms on both sides of the airlock. (However an airlock is required only where access to the motor room is within 2.4 meters of the ship's main deck).

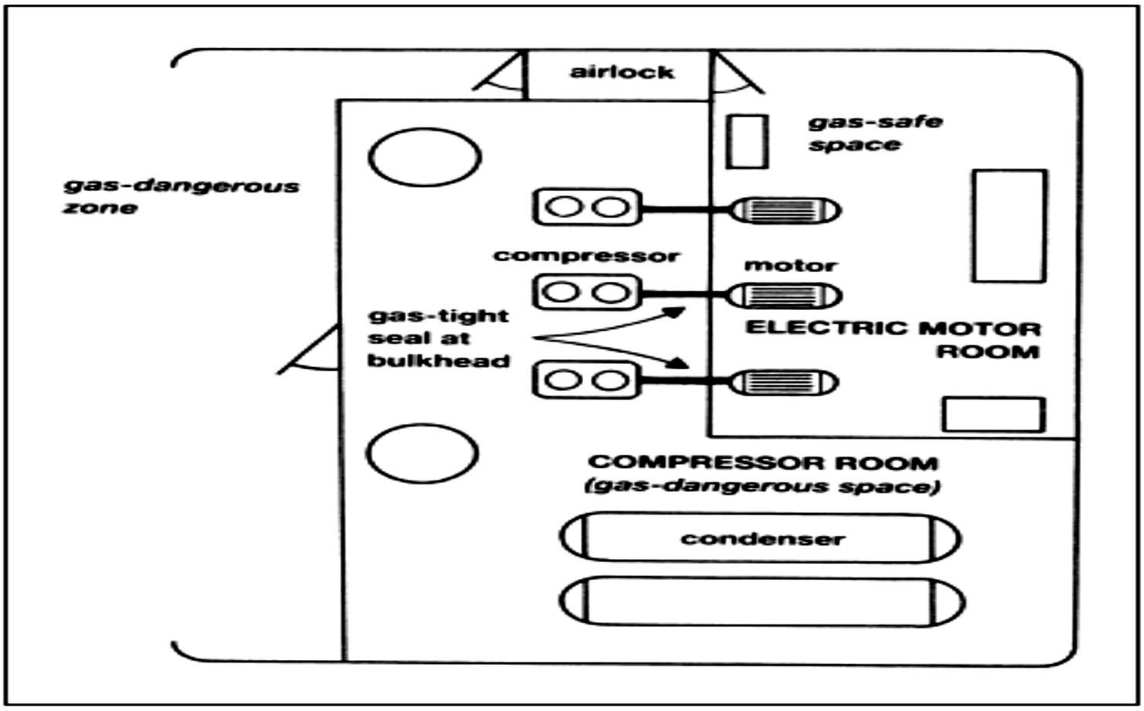


Figure 3.7 Compressor room/electric motor room on a gas carrier

In addition, loss of over-pressure in the motor room should trip the electric motors within. Another safety feature associated with the compressor room area concerns the sealing of the drive-shafts penetrating the gas-tight bulkhead between the compressor and motor room and this is discussed further in Chapter Four.

The cargo containment and handling systems must be completely separate from the accommodation and machinery spaces. A cofferdam, or other means of gas-tight segregation, is required between the cargo area and the engine room and fuel tanks. The Gas Codes also give specific advice for positioning doors leading from accommodation spaces into cargo areas. In addition, air intakes for accommodation and engine spaces must be sited away from cargo vent risers. All air intakes into accommodation and service spaces should be fitted with closing devices. Gas tankers are fitted with a fixed water spray system for fire protection purposes. This covers areas such as:

- Cargo tank domes
- Cargo tank areas above deck
- Cargo manifold areas
- The front of the accommodation including lifeboat boarding areas, and
- Control room bulkheads facing the cargo-deck

Minimum water flow rates of 10 liter/m2 per minute for horizontal surfaces and 4 liter/m2 per minute for vertical surfaces must be achieved. In addition to the fixed water spray systems, all gas tankers must be fitted with a fixed dry powder installation capable of fighting fires in the cargo area. At least two hand-held hoses and a minimum of one fixed monitor must be provided to cover the deck area. The dry powder installation is activated by nitrogen pressure which is stored in cylinders adjacent to the powder containers. Finally, cargo tanks cannot be used for ballast purposes and separate ballast tanks are required.