Gas Carriers

Gas carriers take liquid which occupies about 1/600 of the volume it would occupy as a gas.

Two different forms are carried; Liquid Petroleum Gas which is mainly propane and butane, and Liquid Natural Gas which is mainly methane. Critical factors in the carriage of gas in liquid form are the boiling point tempo at atmospheric pressure and the critical tempo (this is the temperature above which the gas cannot be liquified no matter what the pressure.

The type of containment vessel used for the cargo will differ depending upon the desired tempo and pressure (the tempo must always be below the critical).

In general low pressures may be used if the tempo is kept low, alternately higher temperature may be used but higher pressures are required. LNG

LNG has a boiling point of -162^{o}C at atmospheric pressure and a critical tempo at 47 bar of -82^{o}C, suitable containment conditions allow the carriage of LNG at different tempo and pressure.

LPG

LPG comprises many different gases which have different boiling points and critical temperature, carriage requirements vary between atmospheric pressure and 18 bar and -100^{o}C to -5^{o}C

For smaller ships carrying LPG, pressurised systems are generally used, these employ spherical or cylindrical tanks. However, there is a considerable loss of space. With higher pressures (up to 18 bar) no reliquifacation plant is fitted and no insulation is required. Relief valves are used to protect the system.

Recompression of boil off gas may be employed.

Systems employing pressurised tanks may be partly or fully refrigerated thus requiring less strength in the cargo tanks. This reduces weight and cost. Insulation and reliquification plant is required. Partly refrigerated systems have a maximum pressure of about 8 bar and a temperature of about -10^{o}C. Fully refrigerated have a maximum pressure of about 8 bar but the temperature may be down to -45^{o}C thus increasing the range of petroleum gas cargoes that may be carried. These systems employ cylindrical or spherical tanks which must be self supporting.

Most shipments of LPG are carried at atmospheric pressure at theire respective boiling point. Some typical examples are ethylene -103^{o}C, propane -42^{o}C, ammonia -33^{o}C and butane 0^{o}C to- 5^{o}C

Lloyds register require that in cases other than for pressurised tanks, for carriage of cargoes below 10 ^{o}C the hold spaces should be segregated from the sea by a double bottom. For below 50^{o}C the ship should also have longitudinal bulkheads forming the tank sides.

Most gas tanks incorporate a method of detecting leakage. When the primary barrier is breached the secondary barrier should capable of confining the leakage for a minimum of 15 days.

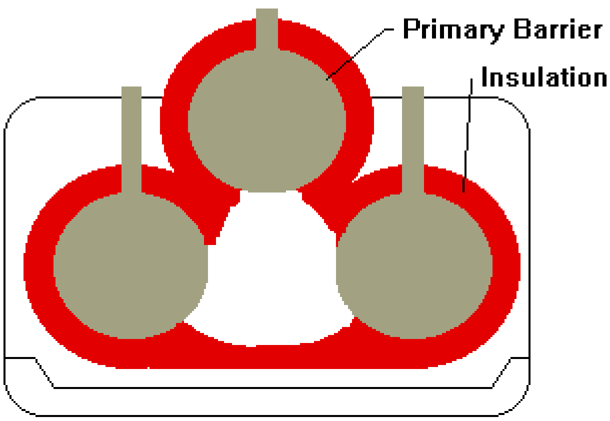
In addition, especially for LNG carriers, the inert gas contained in the barrier space is sampled and temperature probes fitted. Regular 'cold spot' inspections are carried out on the secondary barrier.

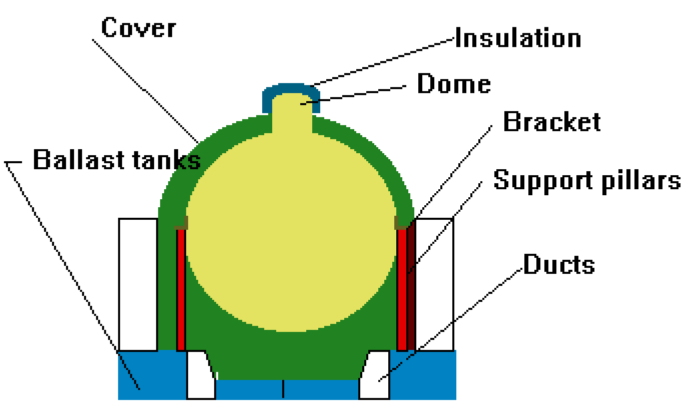
Before designing a gas tank certain criteria set down in the IMO code for ships carrying bulk gas must be met. These, by giving a set of figures determining a damage to the ship, ensure the ships survivability in a collision, grounding etc. The position of the tanks, determined by the type of cargo to be carried, are laid down to prevent the escape of cargo under similar conditions.

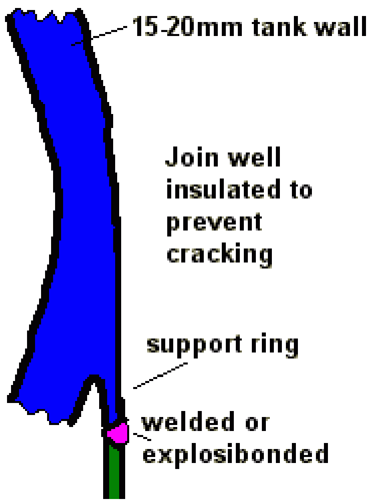
For systems other than fully pressurised a method of dealing with 'boil off' must be fitted. For LPG carriers this takes the form of an on board

Fully pressurised

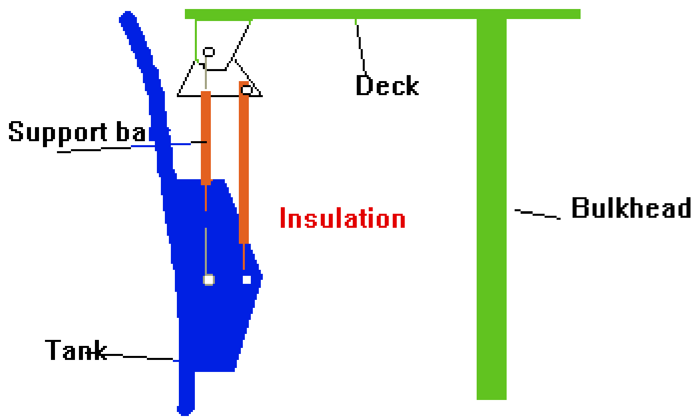
The tanks are internally stiffened and constructed of ordinary grade steels as the cargo is carried at atmospheric temperatures.







Alternative tank support arrangements



Tanks are in the form of pressure vessels, cylindrical or spherical.

Maximum pressure is about 18 bar and no reliquification plant is provided.

Apart from certain areas around the supports insulation is not usually fitted. Relief v/v's are required to safe guard against pressure build up due to boil off. A compressor is provided to keep the tank system pressurised.

Tanks are classed as self supporting, because of the loss of space the system is not popular and is usually applied to smaller ships

Semi-pressurised, partly refrigerated

These reduce the cost and weight; tanks are insulated and reliquifaction plant is fitted, max pressure is 8 bar and minimum tempo about -5°C. Tank arrangement is similar to the fully pressurised and so there is still the loss of space.

Semi-pressurised, fully refrigerated

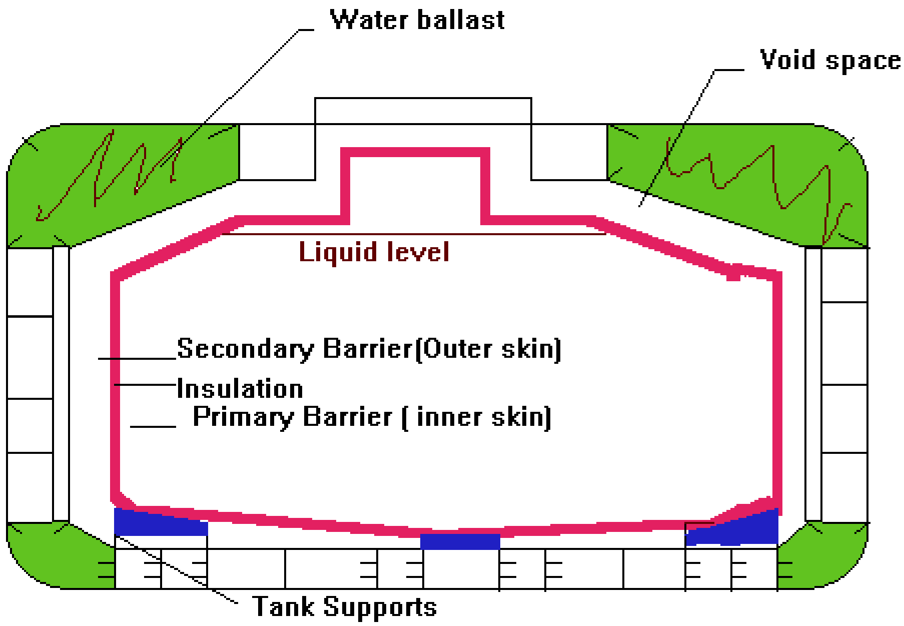
Pressure about 8 bar, and temperatures down to -45°C. Tanks well insulated and reliquification plant essential. Tank pressurised but it is possible to carry a range to cargoes at different pressures and temperatures.

Fully refrigerated

Cargoes are carried at atmospheric pressure but at a temperature below the atmospheric boiling point. Very suitable for LNG, but can also be used for LPG and ammonia (LNG carriers do not generally have a reliquification plant but LPG carriers may)

Prismatic tanks or membrane wall systems may be used. Prismatic tanks are self supporting but they must be tied to the main hull structure.

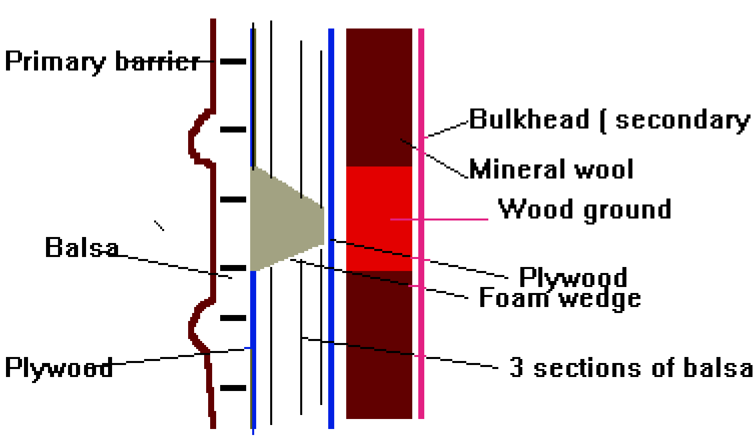
Prismatic tank



Membrane tanks

Membrane tanks are rectangular and rely on the main hull of the ship for strength.

The primary barrier may be corrugated in order to impart additional strength and to account for movement due to change of temperature. Systems vary but the arrangement shown is typical.



Primary barrier material must have the ability to maintain its integrity at the low temperatures. 36% Nickel steel(invar), stainless steel and aluminium are satisfactory at normal LNG temperatures.

Secondary barriers may be fitted depending upon the arrangements but it is not normally required as the ships hull may be used as the secondary barrier if the temperature of the barrier is higher than - 50 ^{o}C and construction is of arctic D steel or equivalent.

An independent secondary barrier of nickel steel, aluminium or plywood may be used provided it will perform a secondary function correctly.

Insulation materials may be Balsa, mineral wool, glass wool, polyurethane or pearlite. It is possible to construct a primary barrier of polyurethane's as this will contain and insulate the cargo.

Usually, secondary barriers are of low temperature steel or aluminium, neither of which becomes brittle at low temperatures.

Gas detection equipment needs to be fitted in the inner barrier and void spaces in cargo pump rooms and in control rooms.

The type of equipment depends upon the cargo being carried and the type of space involved measurement of inflammable gas vapours and toxic vapours as well as oxygen content should be monitored.

Visual and available warnings must be given when high levels are approached. Toxic gasses must be measured every four hours except when personnel are in the spaces when the interval is 30 mins.

Membranes are very thin (less than 2mm) and are therefore susceptible to damage, tanks are never partially loaded.

Boil off

With LNG reliquifaction is not economically viable. It is a requirement by class that a suitable method be installed for the handling of this gas

One common method is to utilise the gas as fuel for the propulsion plant. A suitable method of disposing with excess energy should be fitted. Typically for a steam powered vessel this would take the form of a steam dumping arrangement.

Alternately , the gas may be vented although port restrictions mean it may not always be possible.

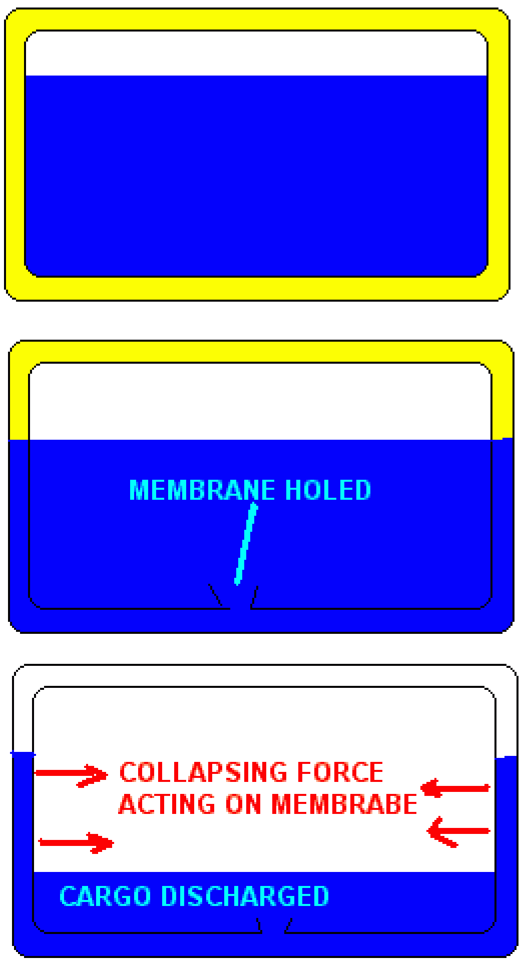
For LPG boil off can be reliquified or a suitable venting system clear of the ship may be used. Burning in the main engine can be very problematic, not least with the ensuring safe gas tightness on the engine. Combustion problems and the probable production of noxious gasses are also areas of concern.

Safety

During transit gas will boil off and venting may be employed to release pressure but methane is a green house gas and pollution regulations may restrict such venting. Any venting of gas must be vertical and away from the ship.

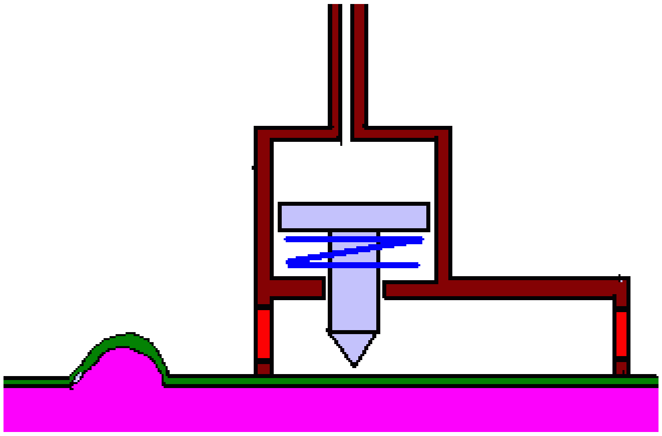
Spaces between the tank barriers or between the barrier and the ships side must be constantly inerted or there must be sufficient inert gas available to fill spaces. Tanks must be fitted with indicators for level, pressure and temperature. There must also be a high level alarm with visual and audible warning together with automatic flow cut off. Pressure alarms and gas monitoring points for detection equipment must also be provided in inter barrier spaces. Detection equipment is also required in void spaces, cargo pump rooms and control rooms. Measurements must be taken of flammable vapours, toxic vapours and oxygen content. For fire protection, the fire pump must be capable of supplying at least two jets or sprays which can reach all parts of the deck over the cargo tanks fixed dry chemical systems may also be required.

Automatic tank piecing (lng)



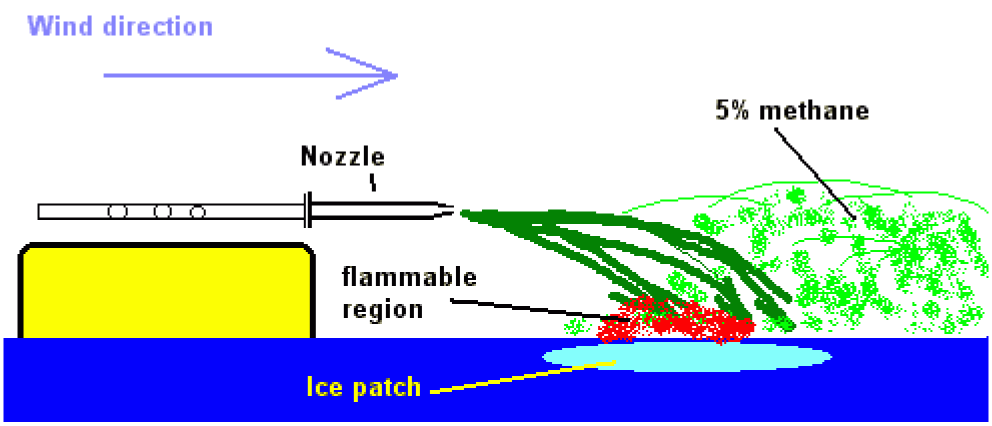
Should a leak be detected from the tank into the interbarrier space by either temperature probes or gas detectors during the loaded voyage the inter barrier space will fill to the level of the liquid in the tank. On discharge it is possible that the level in the tank will fall more rapidly than the liquid can drain from the inter barrier. The primary barrier, which has little mechanical strength will thus collapse.

To prevent this a nitrogen powered punch assembly is fitted to a low point in the tank, before start of discharge this punch may be operated to allow proper drainage. Once the cargo has been discharged both the original leak and the hole caused by the punch are repaired.



Jettison the cargo

Should a problem occur of such severity that it is required to jettison the cargo then a special nozzle arrangement is fitted to the manifold and the main cargo pumps started. The liquid is ejected down wind of the vessel forming a large gaseous ball. By carefull design and flow considerations the flammable region is kept to a minimum.



The author has witnessed videos of tests carried out on this system and can vouch for its effectiveness.

LNG vessel propulsion systems.

Although the amount of boil off from a modern LNG carrier represents a small percentage of the cargo it still is significant in terms of cost.

The traditional method of dealing with this boil off is to specify steam propulsion for the vessel and utilise the boil off as fuel in the boiler. The disadvantage of this is that initial cost is high and efficiency is low in comparison to reciprocating engines. The advantage is the proven design, low maintenance and high reliability

The growth in carrier size up to and above 200000m^3 has led to twin screw designs. This has favoured the use of slow speed and duel fuel burning engine designs There are alternatives available to this some of which are

Two stroke diesel electric propulsion plant- the boil off is burnt in a boiler which powers a turbo-alternator which supplies electricity for propulsion.- reached design stage but the proven track record of the steam turbine as held it at bay.

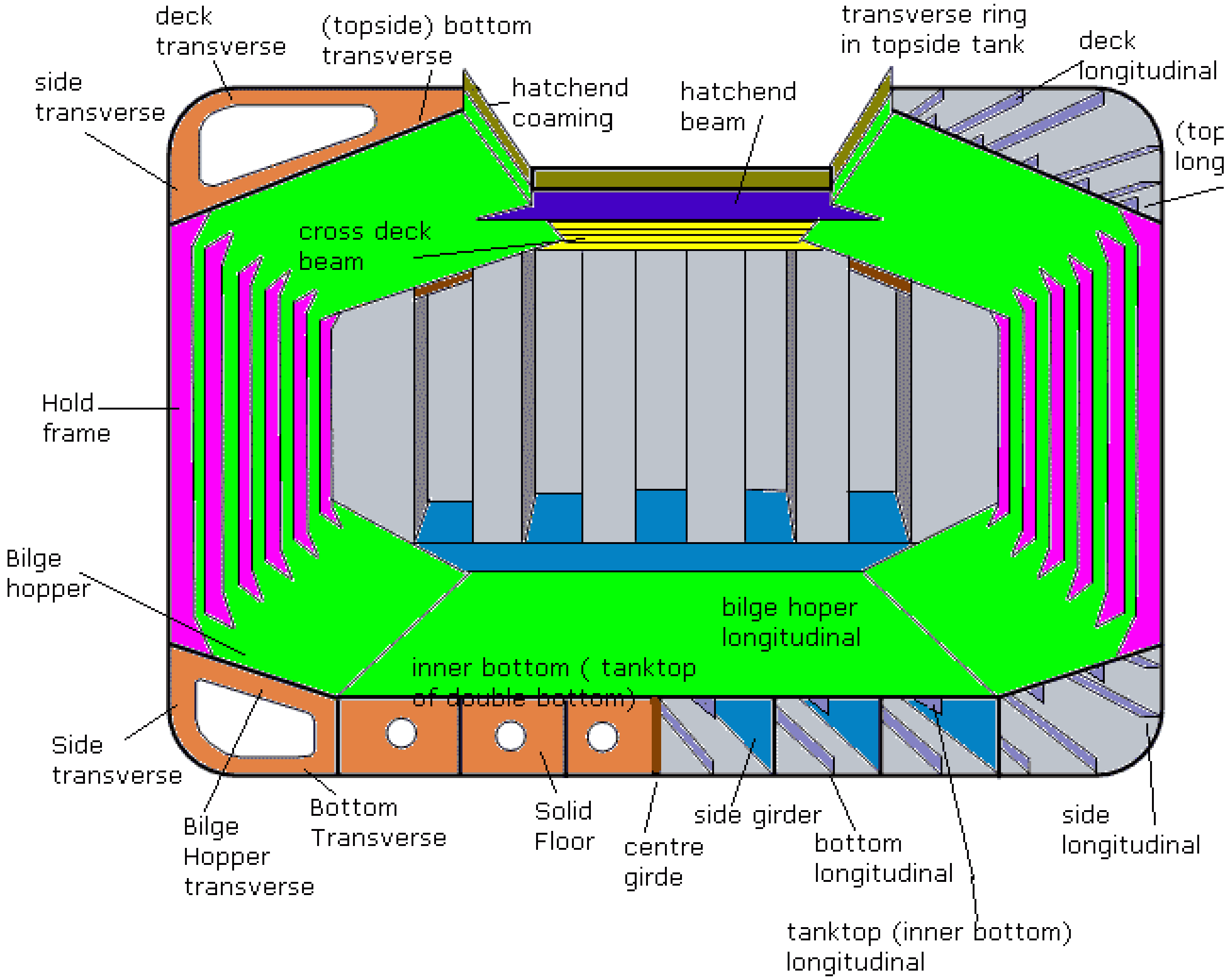
Slow speed engine and reliquificationconcerns over the initial cost, unproven reliability in the marine environment and high electrical power consumption has meant this is only a recent introduction

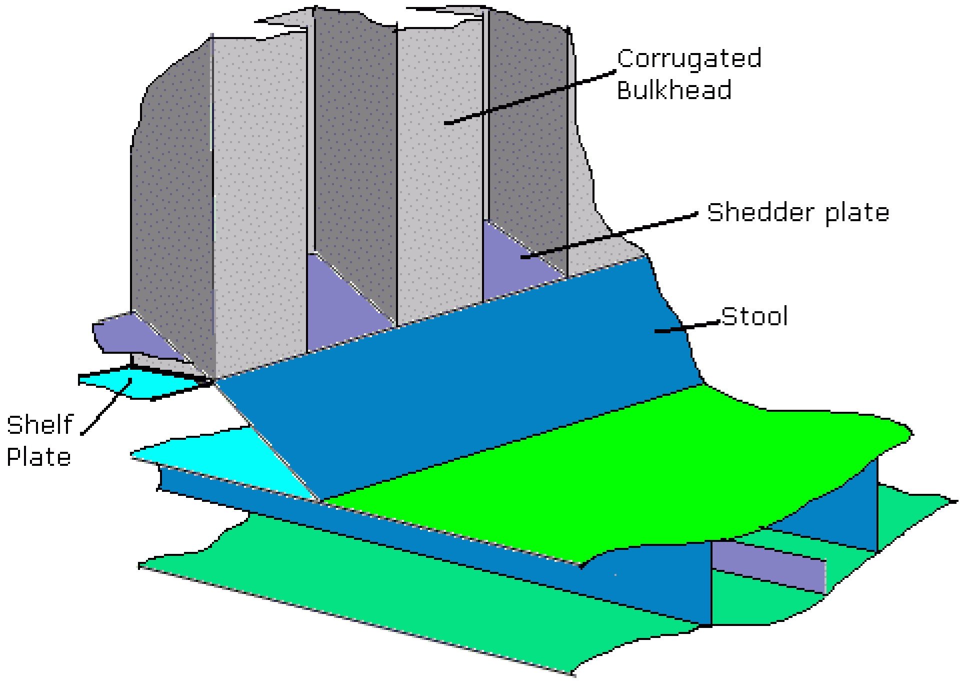
Duel burning diesel engines- question mark over reliability and effect on the near perfect safety record of the worlds LNG fleet. In this design gas is introduced either at low presure during the air suction stroke into the air inlet ducting. Alternately the gas may be injected at high pressure directly into the cylinder. In both designs a pilot fuel oil injector is used. The engine retains the ability to run on fuel oil only. Low NOx and CO_2 emissions at least equalt to steam plants are claimed

Gas Turbine

- in a turbolectric set up

Bulkers


deck transverse
(topside) bottom transverse
transverse ring in topside tank
deck longitudinal
side transverse
hatchend coaming
hatchend beam
(top
long
cross deck beam
Hold frame
Bilge hopper
bilge hoper longitudinal
inner bottom (tanktop of double bottom)
Side transverse
Bilge Hopper transverse
Bottom Transverse
Solid Floor
centre girde
side girder
bottom longitudinal
side longitudinal
tanktop (inner bottom) longitudinal



The bulk carrier is designed for the carriage of dry caro such as grain , iron ore etc. Upper ballast water hoppers aid stability to revent cargo shit and the bottom hoppers aid the collection of the cargo for discharge.

Relatively low density caros such as grain and coal would be carried in each hold. Heavy cargos such as iron ore may be carried in alternate holds. The internal tank design for bulkers is a clean one. The floor is absent of framing allowing ease of cargo discharge and cleaning.

Classification

Bulk carriers are generally classed into three catagories according to size.

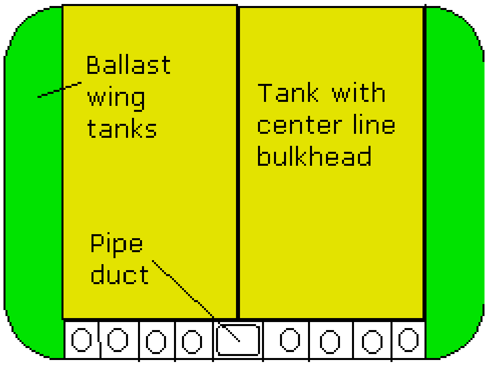
Handy type 30,000 to 45000 dwt, 5 holds

Panamax type breadth 32.2m and are the largest able to transit the panama canal. 50-60000 dwt and 7 holds

Capesize type- 100000 dwt, 9 or more holds

Vessels with there own carog handling gear , typically those carrying food products are termed **geared**

Chemical carriers



Chemical carriers are basically tanker type structures which are arranged to carry certain types of noxious substances. The structure will generally consist of central cargo tanks with the wing tanks and double bottoms used for dirty ballast. Restrictions will apply if the cargo being carried reacts with water and in these cases void spaces are required. Materials used for construction will depend upon the type of cargo being carried and these are grouped depending upon their properties.

Chemical carriers must be designed for the safe carriage of particular types of cargo and these are classed into 3 groups according to the potential hazard of that group.

In general a class A, ship could theoretically carry any class A, cargo, but particular cargoes react with certain materials used for tank pipe and pump construction. The carriage of such cargoes is therefore limited to those which will not react with the materials of construction. A ship designed for class A cargoes may also carry class Band C provided they will not react with the materials of construction. Similarly, class B vessels may carry class C cargoes.

Liquid sulphur must be maintained within a temperature range of 127-138^{o}C , and not exceeding 155^{o}C. Tanks should be insulated and the internal construction at the top of the tanks should not allow vapour pockets to form.

Hydrochloric acid presents difficulties (it reacts with most common metals) and special arrangements are required to line steel tanks with a material which will not react with the acid but is flexible enough to distort with the tank. A suitable material is rubber. Tanks must be separated from the main hull so that the stresses in the hull are not transmitted to the tank

Cargo classes

Class	Hazards	Examples
A,	Low flash point toxic Skin hazard Reactive with water	acetic acid Sulphuric acid Liquid sulphur Reactive with water Phenol
	These are listed and have a high rate of reaction with moisture or water. Tanks must be segregated from the ships side and pumps must be located in the tanks	

	or on deck. Cargo tank vent outlets are not to be closer than 15m to inlets to the accommodation. In general these cargos are unsuitable for carriage in mild steel tanks (generally acids and petrochemical substances)	
B	Low flash point e.g. Carbon tetrachloride Toxic Skin hazard	Formaldehyde Benzene
	Are not as restrictive as the type A although they are toxic and many have a low flash point their problems with relation to water are not as great. Mild steel is suitable for tanks but aluminium and copper are not.	
C	Low flash point	acetone Asphalt Caustic soda
	Are less dangerous and most are not toxic in general. Most engineering materials are suitable for tank construction. There is some risk of contamination through water but it is not great	

DP Systems

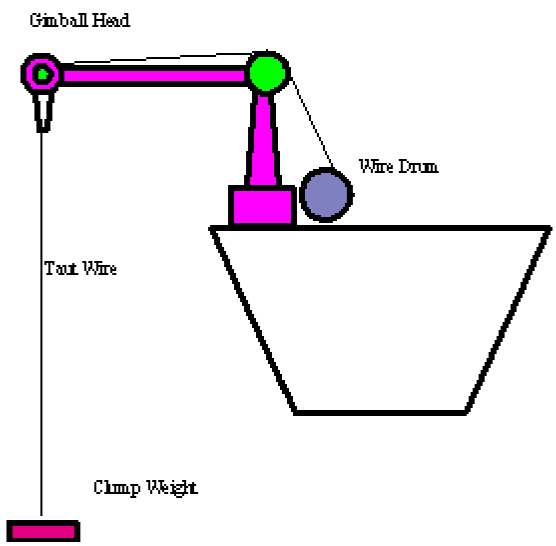
Dynamic Positionning systems allow a vessel to remain at a fixed point independent of the influences of the environment. This is achieved by a system of reference points, sensors and propulsive power units.
The reference points determine the vessels position relative to a datum, they do not necessarily determine the vessels exact location on the earths surface- only DGPS attempts to do this.
Sensors monitor the environmental effects on the vessel, such as the effects of swell and wind and use this to error compensate the reference systems.
Propulsive power units take the form of the main propulsion unit, thrusters and steeering gear system (in conjunction with propulsive unit). These units are mounted for and aft and may be either fixed or steerable.
The number of reference systems, sensors and propulsion units is determined by the required duties of the vessel

Types of reference systems

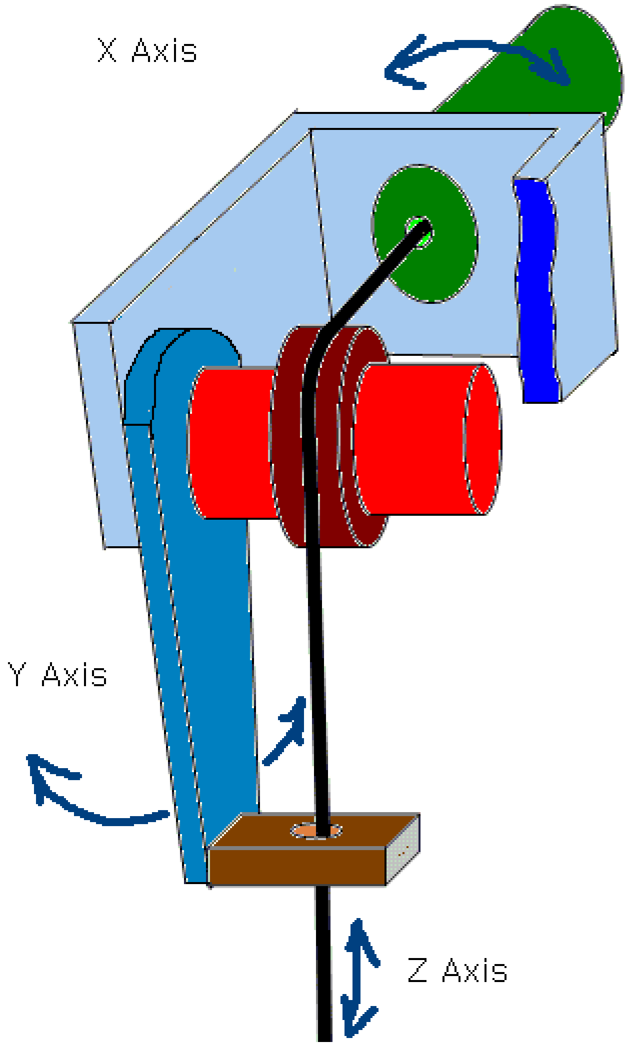
This is a non exhaustive list of the types of reference systems available;

- Differential GPS- The reliability of this system is very much dependent on the location and can range from good to very poor
- Microwave (Artemis)- Is limited in that it is a line of site only system, the advantage is that a communication link is available and emergency shut down systems are sometimes built in
- Laser (Fanbeam)- This cheap reference can be initially very reliable reducing as the target becomes dirty or due to atmospherics. It is a line of site reference
- Acoustic (HPR)-Can be reliable but is reliant on batteries in portable transponders (no limitation exists with fixed transponders)
- Taut Wire- Very reliable simple system. Can introduce movement restrictions when in use.

Taut Wire



A substantial weight is lowered to the sea bed attached by a high tensile steel wire or minimum diameter (reduces effect of current).



The wire passes through a Gimball head which is free to move in X and Y axis up to the mechanical limitations of the assembly. The angle the head is at relative to the vertical for the X axis and horizontal for the Y axis is measured by potentiometers and sent to the DP computer. The wire length is measured by a line out counter and sent to the DP computer. With the weight on the bottom contant tension is placed on the wire keeping it taut, this is achieved by having a constant rpm electric motor coupled to the wire drum via an electric clutch. The field current on the clutch determines the degree of coupling and thereby the degree of torque (note that this torque if far to small to lift the weight and a seperate hydraulic motor is provided).

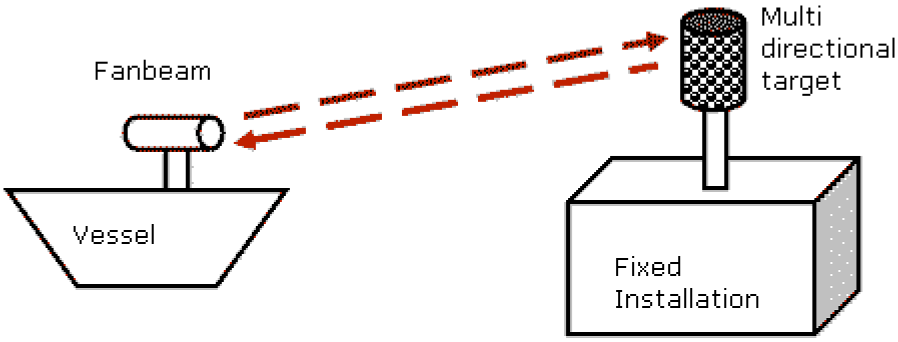
As the vessel moves the angle between the head and weight as well as the wire length will alter. A calculation is made by the DP computer which gives the vessels relative position to the weight. Vessel movement through wave action is measured by the accelerometers and factored in.

Shown is a system which is deployed from the ships side, a limitation is placed on the vessels movement towards the weight when the vessel is 'walked' (say moving into position or following an ROV). A second system would be mounted on the opposite side. Alternately a single system may be fitted operateing through a moonpool in the centre of the vessel.

The size of the weight (and corresponding wire diameter) is determined by the depth that the vessel operates and the operating conditions the vessel works in. Typically they would be not less than 350Kg

Described is a vertical taut wire system. Also avaible are horizontal taut wires which give the same degree of reliability without the need for the clump weight. The disadvantage is that they must be manually tethered.

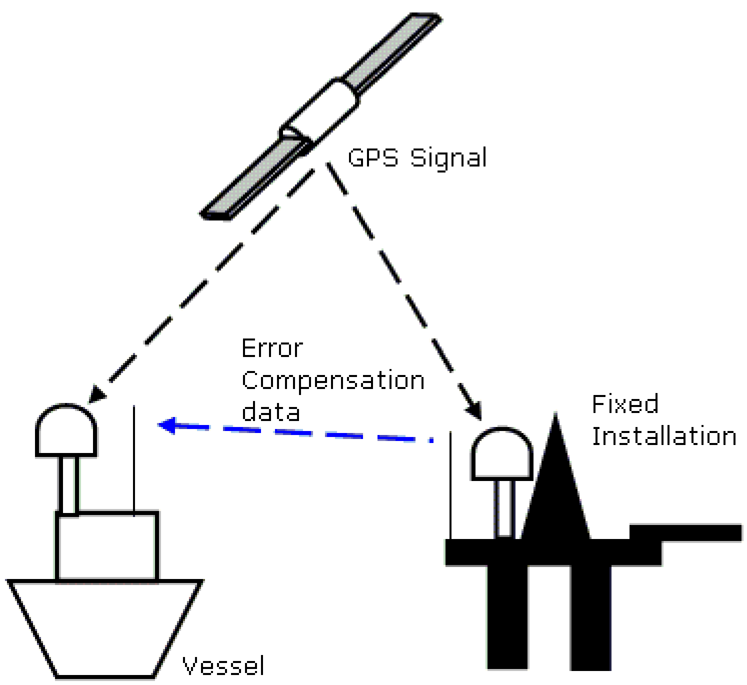
Laser (fanbeam)



This is an auto tracking system whereby a scanning head fires a laser beam through one lens and receives a reflecion of it through a second

The targets must be equiped with reflectors, reflective white tpae may be used but the range is very limited. Greater distance is achieved prisms. 360' coverage is achieved by mounting these prisms on a tube.

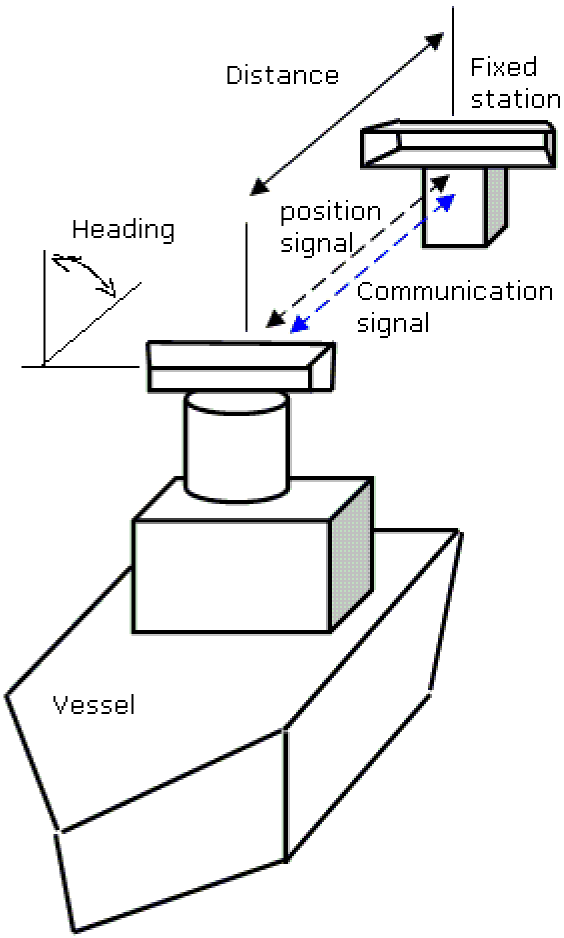
Position reference is by the laser (this is a class one low power unit similar to that found in CD players) scanning for the target. The bearing and range of the target is found and by calculation using error correction from the vertical reference units the movement between the two points is known. **Differential GPS**
The GPS signal from a satellite does not give the degree of accuracy required for a vessel positioning system. To improve accuracy differential GPS is used



A satellite signal is received by both the vessel and by an installation whose position is precisely known. Any error in the signal from the satelite is converted into and error correction signal which is then broadcast. This signal is received by the vessel, a calculation is made and a more precise position now known.

This system is inherently risky for vessels working in critical postions and it is often required that GPS be not used as both of the minimum two sources required. The gps signal is sometimes intermittent as is the error compenstion signal, they are effected by relection from nearby installations and by ionospheric variation. Multiple stations are used to improve accuracy

Microwave (Artemis)



This consists of two stations. One unit mounted on a fixed installation, a second unit mounted on the vessel. These units consist of a rotateing antenna. When initialised both units rotate untill they point at each other. Manual control is available to speed this up. Once they have acquired each other the antenna horns point continuously at each other
The fixed unit now knows the relative postion of the vessel to itself by measurement of the angle of the 'antenna relative to north. The microwave connection gives the relative distance of the vessel. This information is given to the vessel. As the vessel moves there will be alterations in the distance and the bearing between the units. An error correction is made for changes in the ships heading measured by the GYRO.

Hydro Acoustic (HPR)
This system consists of an acoustic transponder and a sensor mounted on the vessel. The transponder may be fixed to the sea bed or installation required , be lowered to the sea bed

as required from the vessel or be attached to a moving unit such as a diver or ROV to allow the vessel to 'watch' the know their location.

The sensor may be fixed so that it looks in one direction only, or tracking where it can move to locate several targets. To prevent interference from the vessels hull the sensors are normally mounted on a long pole which may be lowered through an isolation valve . The installation allows access to the sensor head for maintenance

The system is subject to variations in water temperature and salinity which effects the sound velocity. At water stratification layers a degree of refraction occurs to the wave.

Sensors

Wind- This measures both the wind speed and wind direction. A calculation based on parameters such as vessel topside area is made on the effect of the vessel. This signal is fed forward to the DP Computer so that action may be taken before the vessel moves off station

Gyro-Measures the vessels heading giving error correction for such reference systesm as artemis.

Vertical reference Unit-used to measure the vessels pitch and roll and used as error corrections on such reference systesm as taut wire, artemis etc.

Draught-Used on vessels sucha s heavy lift where ships operations may significantly effect the draught of the vessel

Draghead Force-Used on dredges where the vessels forward spped is governed by the loading of=n the draghead

There is generally no current measurement, instead the current is calculated by the DP computer which looks for a permenant off set in the thrust required to keep the vessel in position. Depending on the class of vessels all sensors may be duplicated

Functions of the DP system

Modes

Manual control- The vessel is operated by joystick but in built protection such as for black out are still available

Auto Position Control- The operator enters a position and the dp system moves the vessel

Auto track control -The vessel moves at slow speed between several waypoints

Auto sail Control-The vessel moves at high speed between several waypoints

Autopilot Control- The vessel follows a dtermined course using the functions of the DP system compensating for enviromental effects

Follow Target- The vessel follows a moving target such as an ROV or Diver.

Reliability and weighting

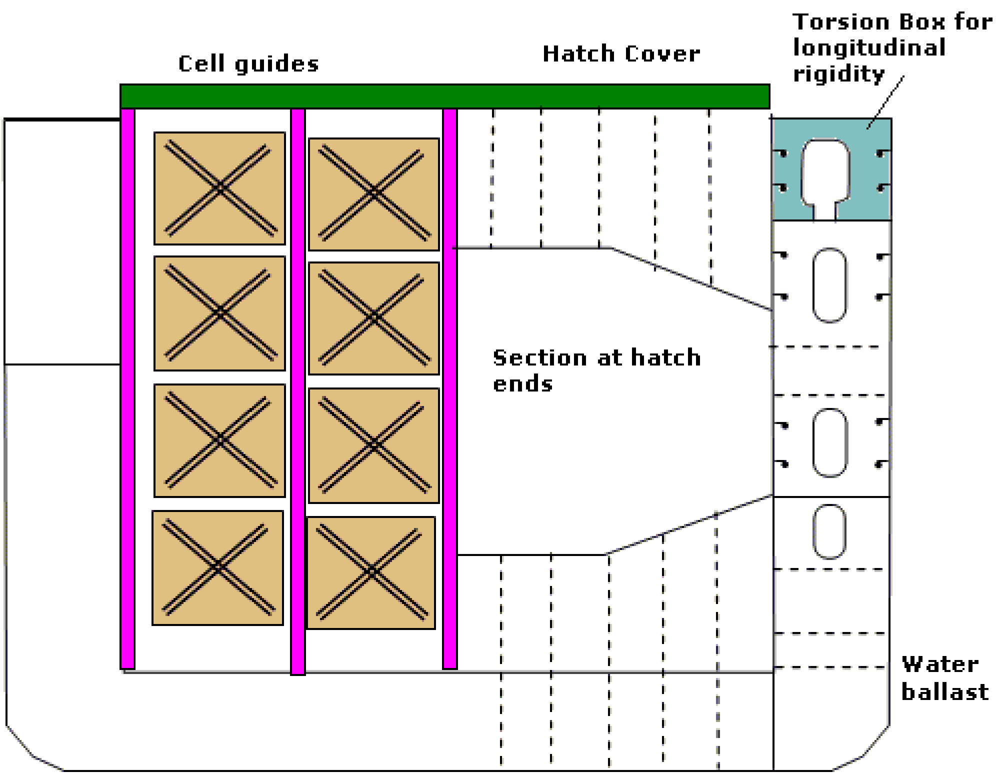
A minimum of three reference points is required for a diving operation. For example tautwire, DGPS and HPR.
Each of these systesm have a known reliability record. The DP computer 'weights' the measured position depending on the known reliability , say 60% for the taut wire, and 20% each for the other two. The position of the vessel determined by each system are unlikely to coincide exactly, the computers measured value position it uses in a combination of the determined positions suitably weighted. In this case it would hace the postion closer to where the taut wire believed it was.
Should a fault occur with the taut wire (say one of the potentiometers on the gimball heads begins tracking giving a noisy output signal), then this will be detected and the amount of weighting for that system reduced, below a certain value and the reference system will be automatically disconnected and a warning alarm sounded. A continuous read out of the positions from all three systems, the computer determined postion and the degree of weighting are all permenantly displayed.

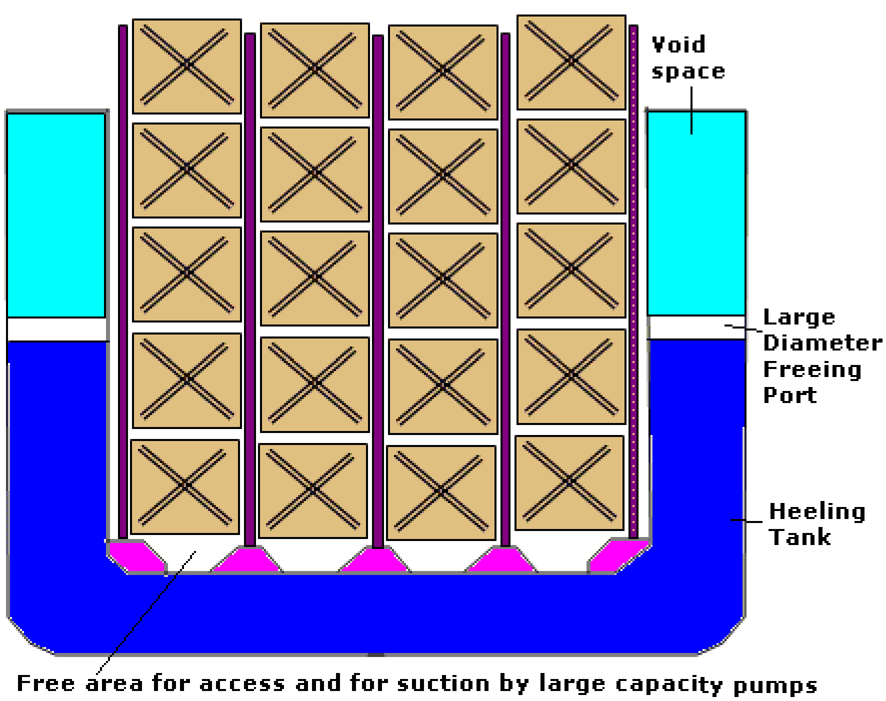
Black out protection

This takes the form of pitch reduction for the thrusters in the event that the reserve power on the main switchboard falls below a set value.

Container carriers

Hatchless carrier

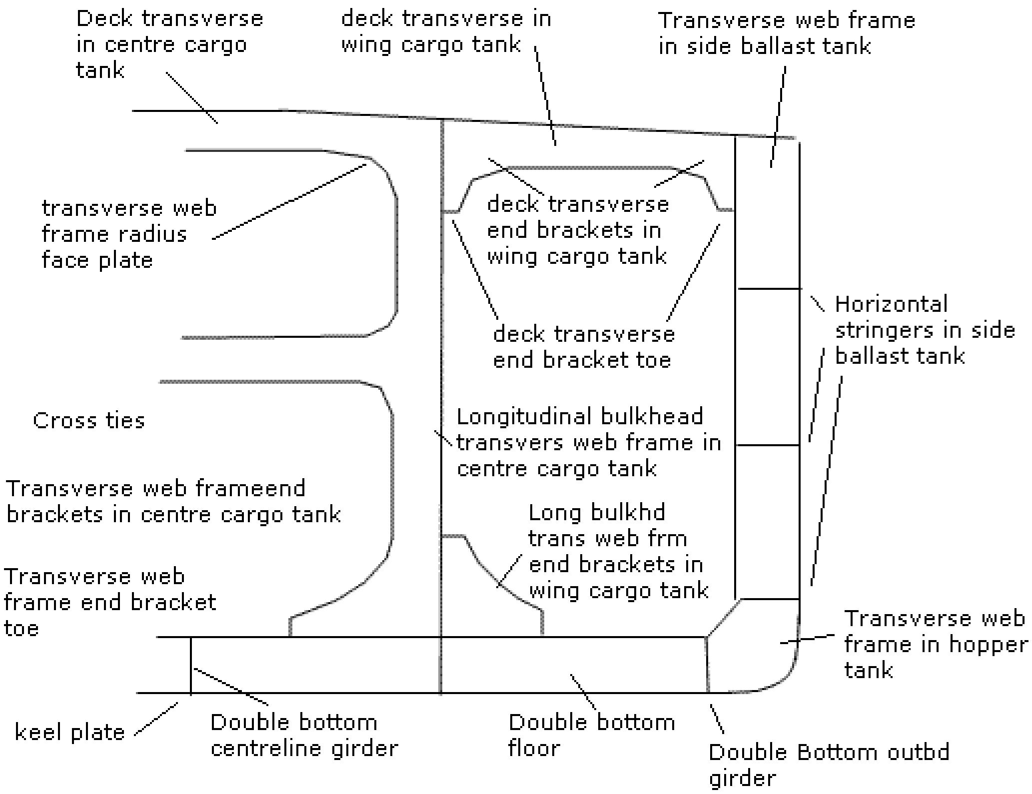


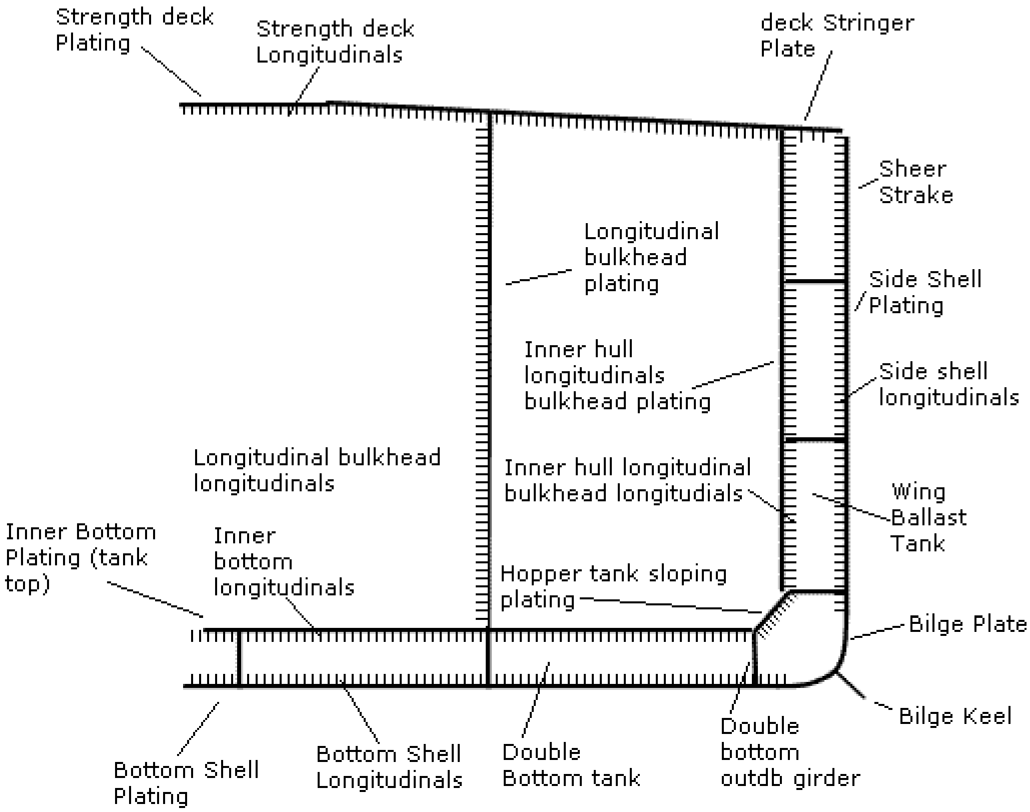


Box type girders are used extensively. These provide considerable strength and rigidity and they allow for a large central opens space.

Tankers

Double Hull- typical mid ships section




Strength deck
Plating
Strength deck
Longitudinals
deck Stringer
Plate
Sheer
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bulkhead
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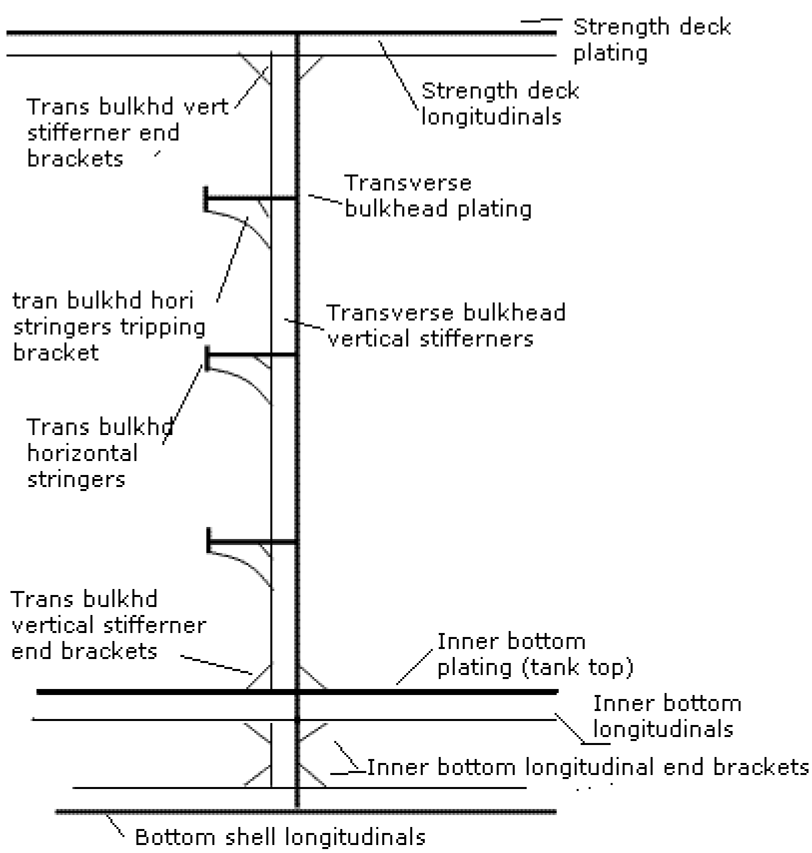
Side Shell
Plating
Inner hull
longitudinals
bulkhead plating
Side shell
longitudinals
Longitudinal bulkhead
longitudinals
Inner hull longitudinal
bulkhead longitudials
Wing
Ballast
Tank
Inner Bottom
Plating (tank
top)
Inner
bottom
longitudinals
Hopper tank sloping
plating
Bilge Plate
Bilge Keel
Bottom Shell
Plating
Bottom Shell
Longitudinals
Double
Bottom tank
Double
bottom
outdb girder


Strength deck
plating
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Transverse
bulkhead plating
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stringers tripping
bracket
Transverse bulkhead
vertical stifferners
Trans bulkhd
horizontal
stringers
Trans bulkhd
vertical stifferner
end brackets
Inner bottom
plating (tank top)
Inner bottom
longitudinals
Inner bottom longitudinal end brackets
Bottom shell longitudinals