If the insulation efficiency should deteriorate for any reason, the effect may be a lowering of the inner hull steel temperature, ie a cold spot and an increase in boil-off from the affected tank.

If it is outside of the capability of the LNGC's cargo handling system, excess gas may be vented via the vent mast. The inner hull steel temperature must be maintained within acceptable limits to prevent possible brittle fracture.

Thermocouples are distributed over the surface of the inner hull, but these only serve as a general indication of steel temperature.

Note: On a loaded voyage, the primary method of detecting cold spots is by frequent visual inspection of the ballast and cofferdam spaces. An alternative method involves the use of a thermographic camera by specialist subcontractors.

The grade of steel required for the inner hull of the ship is governed by the minimum temperature the steel would reach if the primary barrier fails causing LNG to come into contact with the secondary barrier.

In addition to failure of the membrane, cold spots might occur due to localised failure of the insulation.

Prolonged operation at steel temperatures below 0°C may cause ice build-up on the inner hull plating. This, in turn, may lower the steel temperature further due to the insulating effect of the ice. To avoid this, glycol heating coils are fitted in each cofferdam space and these are of sufficient capacity to maintain the inner hull steel temperature at 5°C under the worst conditions.

If a cold spot is detected, either by the inner hull temperature measurement system or by visual inspection, the extent and location of the ice formation should be recorded. Small local cold spots are not critical and, provided a close watch and record are kept as a check against further deterioration and spreading of the ice formation, no immediate action is required. If the cold spot is extensive, or tending to spread rapidly, flooding of the ballast space should be carried out. The thermal capacity of the water, plus the improved heat transfer from outside, should maintain the steel temperature at, or near, the ambient sea water temperature.

3.3.3 Interbarrier and insulation space (IBS/IS) N_2 pressurisation and control system

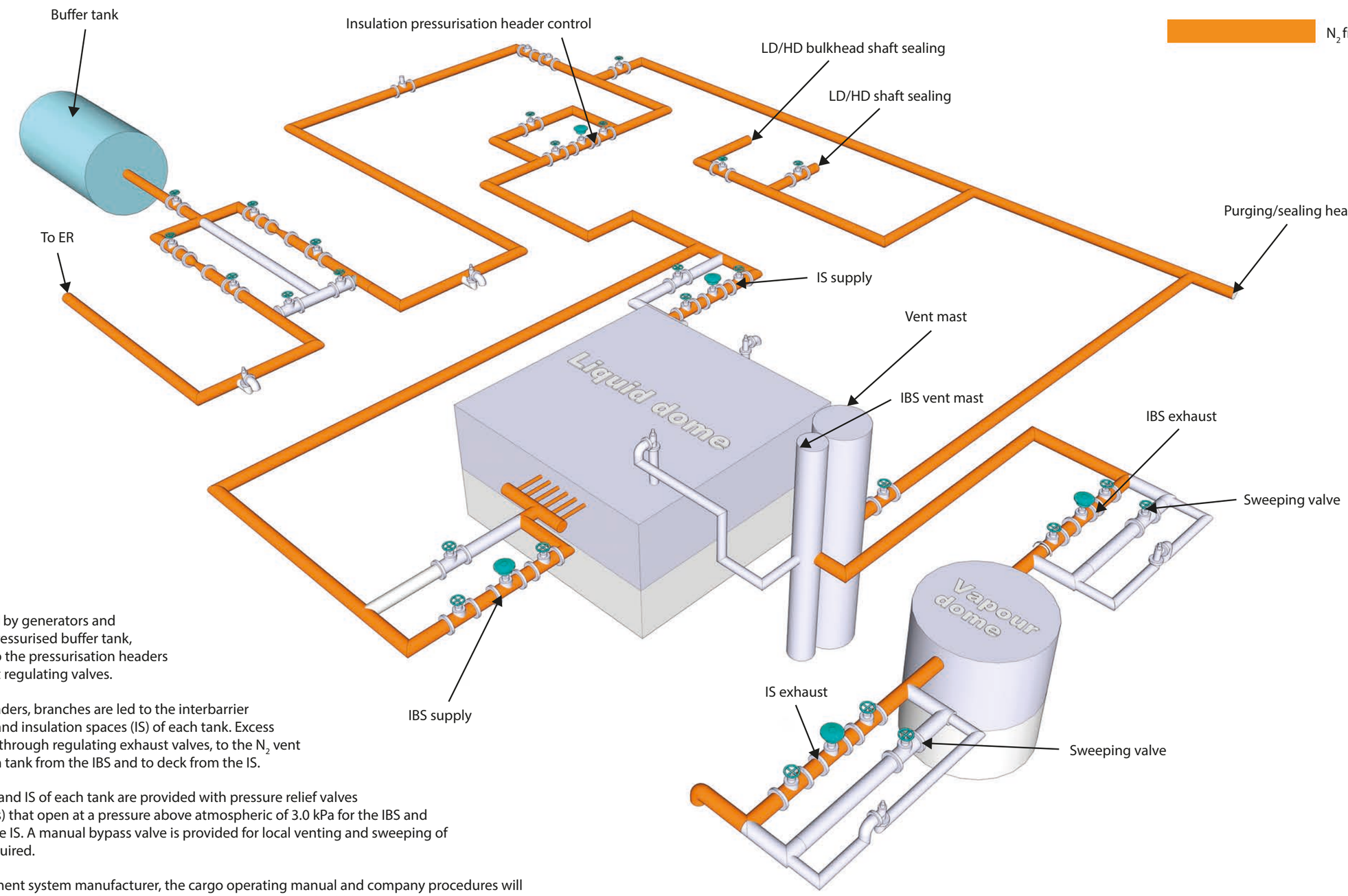


Figure 3.5 IBS/IS N_2 pressurisation and control system

N_2, produced by generators and stored in a pressurised buffer tank, is supplied to the pressurisation headers through inlet regulating valves.

From the headers, branches are led to the interbarrier spaces (IBS) and insulation spaces (IS) of each tank. Excess N_2 is vented, through regulating exhaust valves, to the N_2 vent mast on each tank from the IBS and to deck from the IS.

Both the IBS and IS of each tank are provided with pressure relief valves (safety valves) that open at a pressure above atmospheric of 3.0 kPa for the IBS and 3.5 kPa for the IS. A manual bypass valve is provided for local venting and sweeping of a space if required.

The containment system manufacturer, the cargo operating manual and company procedures will provide specific instructions for the N_2 pressurisation system and IBS/IS pressure settings.

Typical settings are as follows:

- IBS – 0.5 kPa
- IS – 1.0 kPa or differential pressure (DP) 0.5 kPa (settings for IS pressure will usually be expressed as differential pressure between IS and IBS, where IS pressure is always higher in normal operational condition).

3.4 NO96 (GTT)

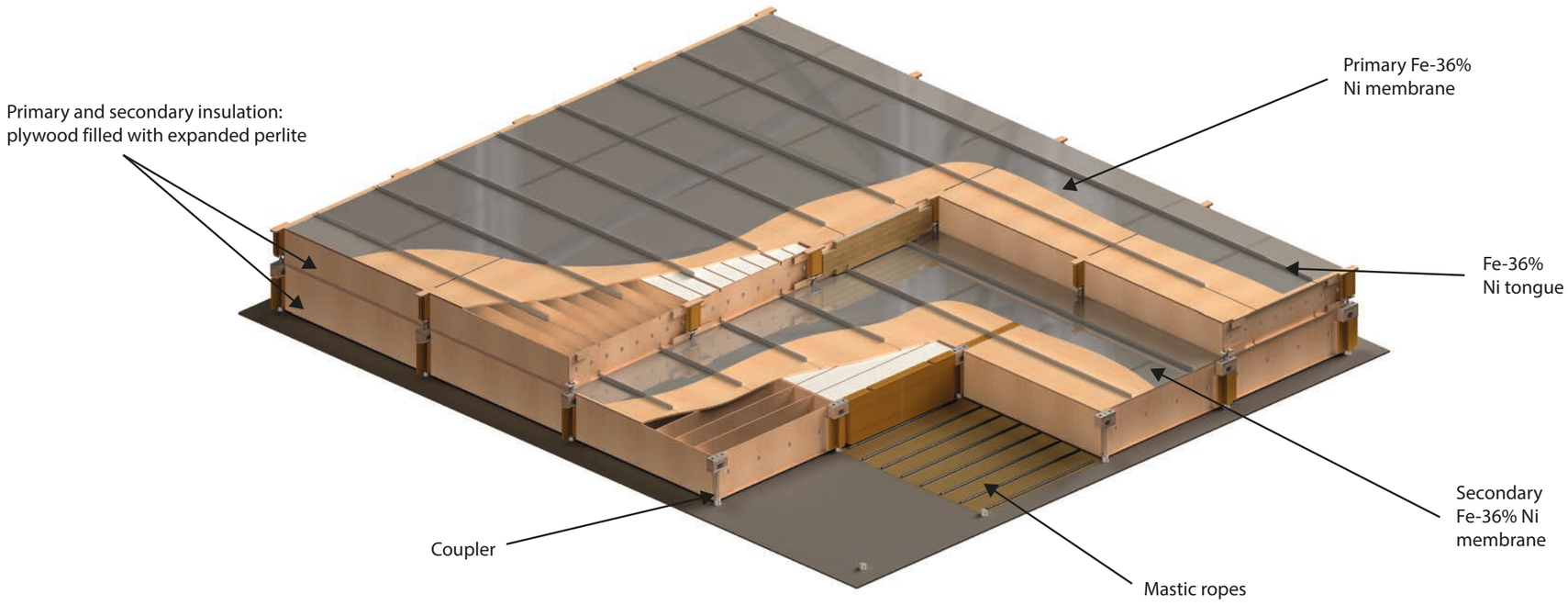


Figure 3.6 NO96 cargo containment system (GTT)

The GTT NO96 cargo containment system consists of a thin, flexible membrane that is in contact with the cargo and is known as the primary membrane. Layers of plywood boxes filled with perlite form the primary and secondary insulation spaces, in addition to the flexible secondary membrane. This insulation system allows free circulation of N_2 and, therefore, permits gas freeing or inerting to be carried out in the barrier spaces without difficulty.

The primary and secondary barriers are identical and are fabricated from cryogenic Invar (36% nickel steel, with a very low coefficient of thermal expansion, 0.7 mm thick). Perlite is obtained from a vitreous rock of volcanic origin and its water repellence is increased by a silicon treatment.

The double membrane system meets the requirement of the relevant regulations of the IGC Code to provide two separate 'barriers' to prevent cargo leakage. The system ensures that the whole of the cargo hydrostatic loads are transmitted through the membranes and insulation to the inner hull plating of the ship. The secondary membrane, sandwiched between the two layers of insulation, provides a safety barrier and reduces the convection currents within the insulation.

The primary and secondary insulation spaces are under a pressure controlled N_2 atmosphere. The primary space's pressure must never exceed the cargo tank pressure as this could result in the primary membrane collapsing inwards. In the event of leakage from the tank into the primary insulation space, it is recommended that the pressure in the primary insulation space is maintained at 0.2 kPa above the secondary insulation space pressure. This prevents the primary membrane from collapsing inwards.

The insulation is distributed over the hull in two specific areas:

- Reinforced area located in the upper part of the tank and covering approximately 30% of the total tank height (including the tank ceilings). This area is fitted with reinforced type boxes
- standard area (or non-reinforced area) covering approximately 70% of the tank height (including the tank bottom). This area is fitted with normal boxes.

The primary and secondary boxes in the reinforced area have thicker internal stiffeners to resist the impacts that can be created by the liquid sloshing inside the tanks. The primary reinforced boxes have two 12 mm thick plywood covers stapled on them.

The primary insulation is 230 mm thick and the secondary insulation is 300 mm thick.

The insulation dimensions have been determined to ensure that:

- The heat flow into the tank is limited to such an extent that the evaporation, or boil-off rate, is about 0.15% of total tank capacity per day or as per contractual requirements
- the inner hull steel does not attain a temperature below its minimum design value, even in the case of failure of the primary barrier
- any deflections resulting from applied strains and stresses are acceptable by the primary barrier.

3.4.1 Primary insulation space (PIS) and secondary insulation space (SIS) N_2 pressurisation and control system

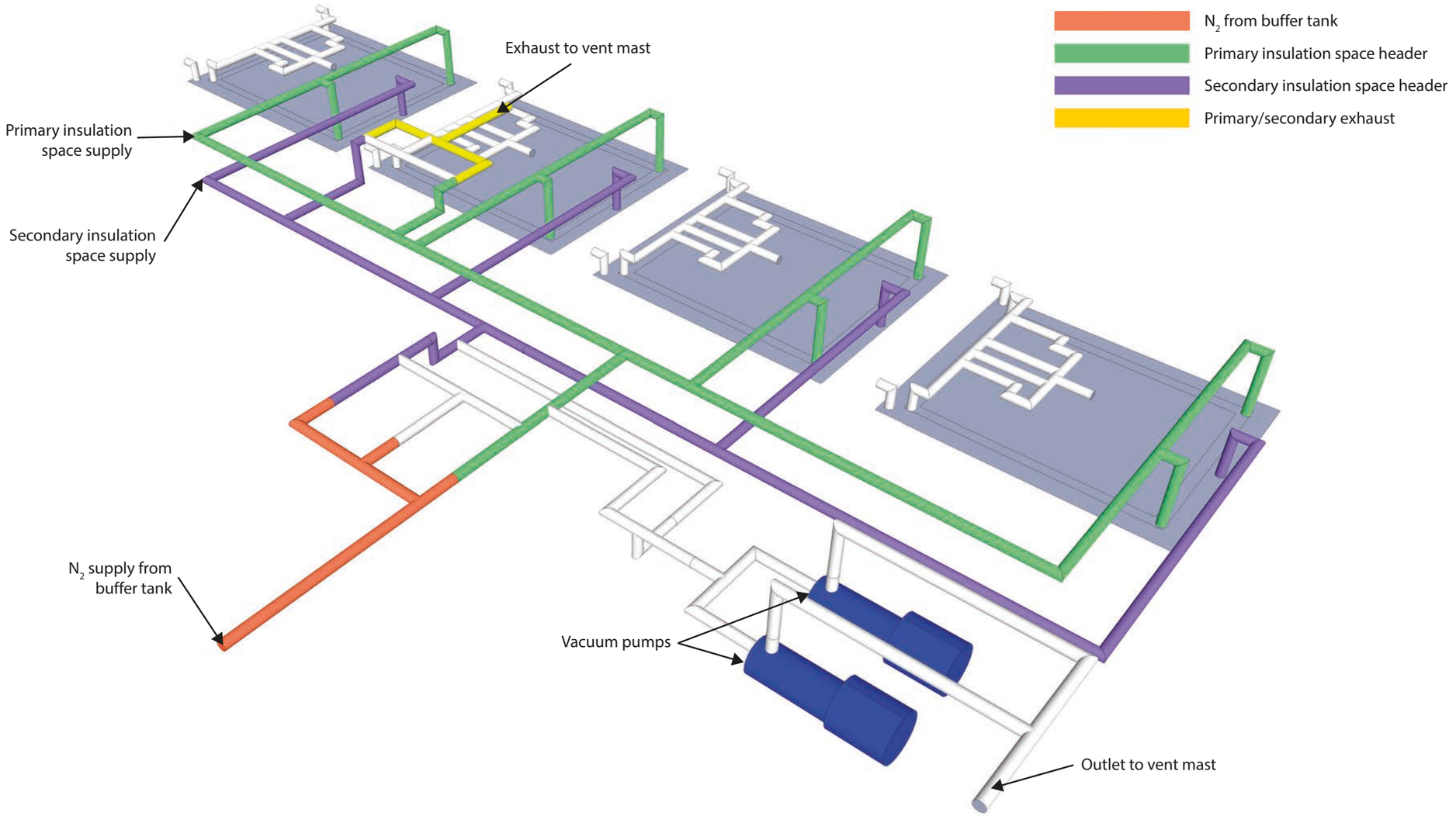


Figure 3.7 NO96 insulation spaces pressurisation system

N_2 produced by generators and stored in a pressurised buffer tank is supplied to the pressurisation headers through common inlet regulating valves. From the header, branches are led to the PIS and SIS of each tank. Excess N_2 from the common primary and common secondary space headers is vented through regulating outlet valves to the common vent mast.

Standby inlet and exhaust regulating valve arrangements are fitted and can be connected to either the primary or secondary header line.

Both PIS and SIS of each tank are provided with pressure relief valves that open at 1 kPa for PIS and 1 kPa for SIS (above atmospheric).

The discharge from the primary exhaust valves is directed to atmosphere via a dedicated vent mast associated with each tank.

The discharge from the secondary barrier relief valves is directed straight to atmosphere.

Where required, a manual bypass valve on the primary barrier relief line is provided for local venting and sweeping of the primary barrier space.

The containment system manufacturer, the cargo operating manual and company procedures will provide specific instructions for the N_2 pressurisation system and the IBS/IS pressure settings.

Typical settings are:

- PIS – 0.4 kPa inlet/0.6 kPa exhaust
- SIS – 0.2 kPa inlet/0.4 kPa exhaust.

4 Cargo Handling Equipment

4.1 Cargo Pump

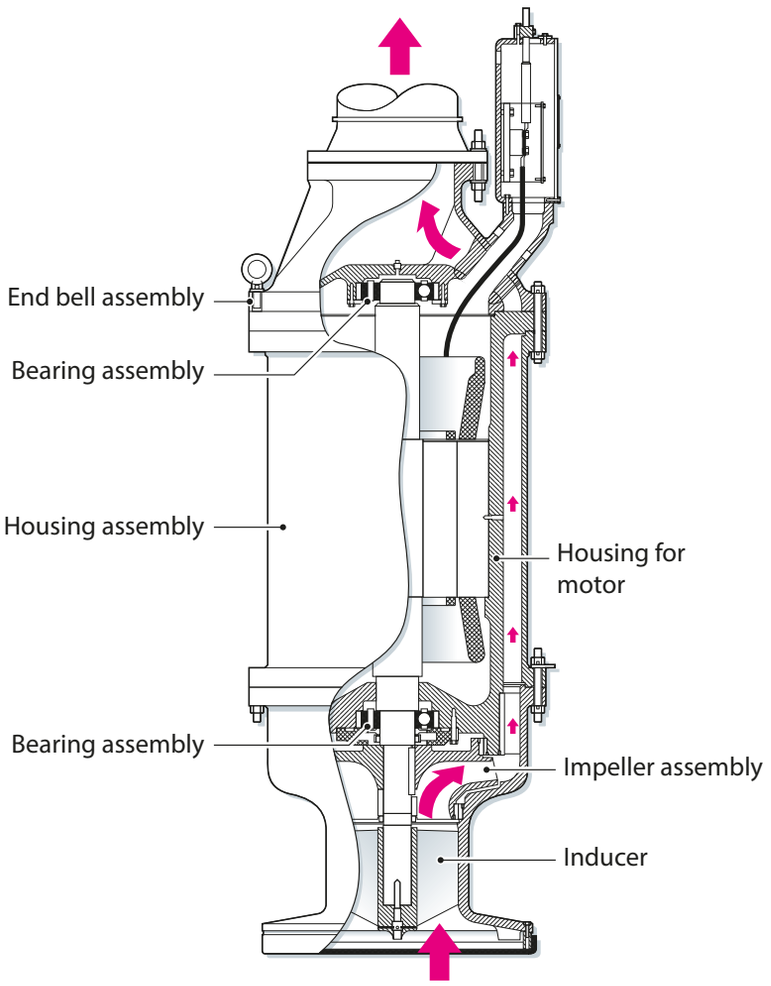


Figure 4.1 Typical main cargo pump and performance curve (WMT)

LNGCs are fitted with submerged electrically driven centrifugal pumps within their tanks. Each cargo tank is fitted with two main cargo pumps that are of the same capacity.

Pumps are specifically designed for the transfer of liquid at cryogenic temperatures.

The equipment manufacturer's manual, the cargo operating manual and the company procedures will provide clear instructions and the starting/re-starting procedure. LNG acts as the coolant and lubricant for the pump when it is running. For this reason, the pump is never started with the discharge valve in a fully closed position. Starting the pump with the discharge valve in an open position that is above the manufacturer's recommended value may cause pump motor overcurrent, resulting in operational failure.

It is essential to allow sufficient time to cool down the pump prior to starting or restarting. Mechanical parts are designed within a tolerance for clearance that is only achieved at a certain temperature. Warm starts can cause rubbing of internal parts and significant damage to the pump assembly.

Cargo pump starting is incorporated in the integrated automation system (IAS) and most LNGCs will have integrated interlocks related to cargo tank level, discharge valve position and restarting interval to prevent inadvertent operation of the pumps.

Best performance of a pump is achieved when it is running at its designed rated flow. If, for operational reasons (eg discharge rate requirement), this cannot be attained, then it is beneficial to run one pump close

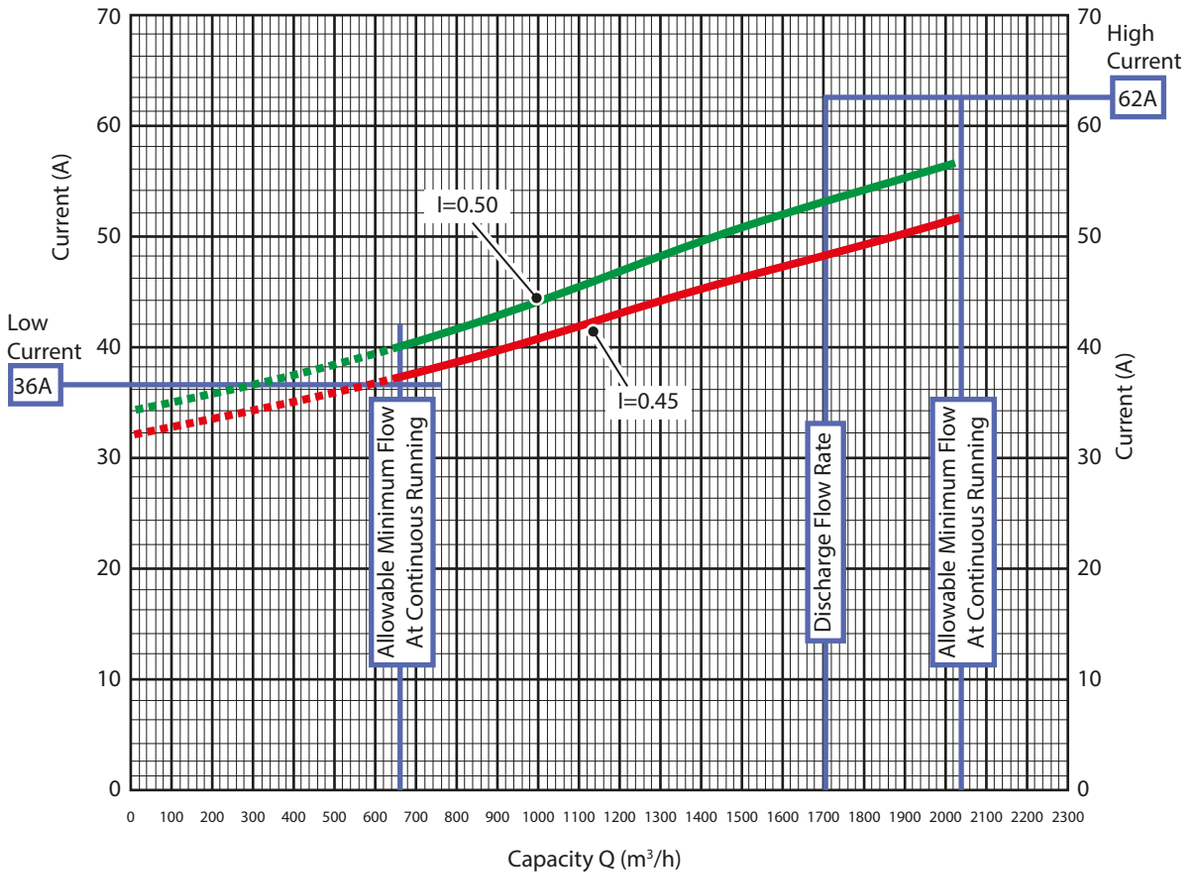


Figure 4.2 Q-A Curve (Pumping Capacity - Ampere Curve)

to the maximum continuous flow rather than running two pumps at minimum flow. The discharge rate is adjusted by the position of the discharge valve and observation of the pump amp meter. The pump amps are adjusted to attain the corresponding discharge rate to the pump performance curve.

Typical capacity of a main cargo pump at rated amps is 1,500 m^3/hr to 1,800 m^3/hr, depending on manufacturer's design.