UK P&I CLUB

Carefully to Carry

Liquefied natural gas

Background

It was as far back as 1959 that the Methane Pioneer carried the first experimental LNG cargo, and 40 years ago, in 1964, British Gas at Canvey Island received the inaugural cargo from Arzew on the Methane Princess. Together with the Methane Progress these two ships formed the core of the Algeria to UK project. And the project-based nature of LNG shipping was set to continue until the end of the 20th century. LNG carriers only existed where there were projects, with ships built specifically for employment within the projects. The projects were based on huge joint ventures between cargo buyers, cargo sellers and shippers, all in themselves large companies prepared to do longterm business together.

The projects were self-contained and operated without much need for outside help. They supplied gas using a purpose built fleet operating like clockwork on a CIF basis. Due to commercial constraints, the need for precisely scheduled deliveries and limited shore tank capacities, spot loadings were not feasible and it is only in recent years that some projects now accept LNG carriers as cross-traders, operating more like their tramping cousins – the oil tankers. Doubtless the trend to spot trading will continue. However, the co-operative nature of LNG's beginnings has led to several operational features unique to the ships. In particular there is the acceptance that LNG carriers burn LNG cargo as a propulsive fuel. They also retain cargo onboard after discharge (the 'heel') as an aid to keeping the ship cooled down and ready to load on arrival at the load port. Thus matters that would be anathema to normal international trades are accepted as normal practice for LNG.

Again, looking back to the early days, there was also great interest in this new fuel in the USA and France. Receiving terminals sprouted. However, gas pricing difficulties in the USA saw an end to early American interest while Gaz de France consolidated rather than expanded. Indeed, the American pricing problems, and the failure of an early US-built shipboard Conch contain-ment system on newbuildings, blanketed any spectacular progress in the Atlantic basin until the regeneration of interest initiated by the Trinidad project in 1999.

At that time, the stifling of European interest was also due to the discovery of natural gas in the North Sea, so quantities to replace town gas were available in sufficient volume on the doorstep without the need for imports. This being so, the first LNG project from Algeria to UK eventually faltered, with the receiving terminal at Canvey Island switching to other interests. The stagnation of LNG in the 70s and 80s applied the world over, with the singular exception of imports to Japan and Korea. Here interest in LNG's potential as an environmentally-friendly fuel stayed vibrant; as it does today.

LNG projects are massive multi-billion dollar investments. Major projects in the Far East included Brunei to Japan, Indonesia to Japan, Malaysia to Japan and Australia to Japan, comprising some 90% of the LNG trade of the day. Consequently, the Japanese defined much of what is seen best today in way of safety standards and procedures. It is worthy of note, however, that some early safety standards and practices are being questioned today in the light of experience in a more mature industry.

"The carrier shall properly and carefully load, handle, stow, carry, keep, care for and discharge the goods carried."

Hague Rules, Articles iii, Rule 2

Carefully to Carry Advisory Committee

This report was produced by the Carefully to Carry Committee – the UK P&I Club's advisory committee on cargo matters. The aim of the Carefully to Carry Committee is to reduce claims through contemporaneous advice to the Club's Members through the most efficient means available.

The committee was established in 1961 and has produced many articles on cargoes that cause claims and other cargo related issues such as hold washing, cargo securing, and ventilation.

The quality of advice given has established Carefully to Carry as a key source of guidance for shipowners and ships' officers. In addition, the articles have frequently been the source of expertise in negotiations over the settlement of claims and have also been relied on in court hearings.

In 2002 all articles were revised and published in book form as well as on disk. All articles are also available to Members on the Club website. Visit the Carefully to Carry section in the Loss Prevention area of the Club website www.ukpandi.com for more information, or contact the Loss Prevention Department.

LNG as a fuel

Because the ships, terminals and commercial entities were all bound together in the same chain, advantages could be seen in limiting 'unnecessary' shipboard equipment, such as reliquefaction plant, and allowing the boil-off to be burnt as fuel. One way or another the ship would need fuel, be it oil or gas and, if gas, it was only then a matter to quantify usage and to direct the appropriate cost to the appropriate project partner.

Interestingly, this concept was recognised in the IMO's Gas Codes from the very earliest days, and with the appropriate safety equipment in place the regulations allow methane to be burnt in ship's boilers. This is not the case for LPG, where reliquefaction equipment is a fitment, but specifically because the LPGs are heavier than air gases and use in engine rooms is thereby disallowed.

LNG quality

LNG is liquefied natural gas. It is sharply clear and colourless. It comprises mainly methane but has a percentage of constituents such as ethane, butane and propane together with nitrogen. It is produced from either gas wells or oil wells. In the case of the latter it is known as associated gas. At the point of production the gas is processed to remove impurities and the degree to which this is achieved depends on the facilities available. Typically this results in LNG with between 80% and 95% methane content. The resulting LNG can therefore vary in quality from loading terminal to loading terminal or from day-to-day.

Other physical qualities that can change significantly are the specific gravity and the calorific value of the LNG, which depend on the characteristics of the gas field. The specific gravity affects the deadweight of cargo that can be carried in a given volume, and the calorific value affects both the monetary value of the cargo and the energy obtained from the boiloff gas fuel.

These factors have significance in commercial arrangements and gas quality is checked for each cargo, usually in a shore-based laboratory by means of gas chromatography. LNG vapour is flammable in air and, in case of leakage, codes require an exclusion zone to allow natural dispersion and to limit the risk of ignition of a vapour cloud. Fire hazards are further limited by always handling the product within oxygen-free systems. Unlike oil tankers under inert gas, or in some cases air, LNG carriers operate with the vapour space at 100% methane. LNG vapour is non-toxic, although in sufficient concentration it can act as an asphyxiant.

Gas quality is also significant from a shipboard perspective. LNGs high in nitrogen, with an atmospheric boiling point of -196°C, naturally allow nitrogen to boil-off preferentially at voyage start thus lowering the calorific value of the gas as a fuel. Towards the end of a ballast passage, when remaining 'heel' has all but been consumed, the remaining liquids tend to be high on the heavier components such as the LPGs. This raises the boiling point of the remaining cargo and has a detrimental effect on tank cooling capabilities in readiness for the next cargo.

The good combustion qualities attributed to methane make it a great attraction today as a fuel at electric power stations. It is a 'clean' fuel. It burns producing little or no smoke and nitrous oxide and sulphur oxide emissions produce figures far better than can be achieved when burning normal liquids such as low sulphur fuel oil. Natural gas has thus become attractive to industry and governments striving to meet environmental targets set under various international protocols such asthe Rio Convention and the Kyoto Protocol. The practice of firing marine boilers on methane provides the further environmental advantage of lesser sootblowing operations and much fewer carbon deposits.

Cargo handling

The process of liquefaction is one of refrigeration and, once liquefied, the gas is stored at atmospheric pressure at its boiling point of -162°C. At loading terminals any boil-off from shore tanks can be reliquefied and returned to storage. However, on ships this is almost certainly not the case. According to design, it is onboard practice to burn boil-off gas (often together with fuel oil) in the ship's boilers to provide propulsion. In the general terms of seaborne trade this is an odd way to handle cargo and is reminiscent of old tales of derring-do from the 19th century when a cargo might have been burnt for emergency purposes. It is nevertheless the way in which the LNG trade operates. Boil-off is burnt in the ship's boilers to the extent that it evaporates from its mother liquid. Clearly cargo volumes at the discharge port do not match those loaded.

Accounting however is not overlooked and LNG carriers are outfitted with sophisticated means of cargo measurement. This equipment is commonly referred to as the 'custody

LNG carrier with Type-B tanks (Kvaerner Moss system).

transfer system' and is used in preference to shore tank measurements. These systems normally have precise radar measurement of tank ullage while the tanks themselves are specially calibrated by a classification society to a fine degree of accuracy. The system automatically applies corrections for trim and list using equipment self-levelled in drydock. The resulting cargo volumes, corrected for the expansion and contraction of the tanks, are normally computed automatically by the system.

Cargo tank design requires carriage at atmospheric pressure and there is little to spare in tank design for over or under pressures. Indeed, the extent to which pressure build-up can be contained in a ship's tanks is very limited in the case of membrane cargo tanks, although less so for Type-B tanks. Normally this is not a problem, as at sea the ship is burning boil-off as fuel or in port has its vapour header connected to the terminal vapour return system. Clearly, however, there are short periods between these operations when pressure containment is necessary. This can be managed. So taken together, shipboard operations efficiently carried out succeed in averting all possible discharges to atmosphere, apart that is from minor escapes at pipe flanges, etc. Certainly this is part of the design criteria for the class as it is recognised that methane is a greenhouse gas.

Boil-off gas (BOG) is limited by tank insulation and newbuilding contracts specify the efficiency required. Usually this is stated in terms of a volume boil-off per day under set ambient conditions for sea and air temperature. The guaranteed maximum figure for boil-off would normally be about 0.15% of cargo volume per day.

While at sea, vapours bound for the boilers must be boosted to the engine room by a low-duty compressor via a vapour heater. The heater raises the temperature of the boil-off to a level suited for combustion and to a point where cryogenic materials are no longer required in construction. The boil-off then enters the engine room suitably warmed but first passes an automatically controlled master gas valve before reaching an array of control and shutoff valves for direction to each burner. As a safety feature, the gas pipeline through the engine room is of annular construction, with the outer pipe purged and constantly checked for methane ingress. In this area, operational safety is paramount and sensors cause shutdown of the master gas valve in alarm conditions. A vital procedure in the case of a boiler flameout is to purge all gas from the boilers before attempting re-ignition. Without such care boiler explosions are possible and occasional accidents of this type have occurred.

Cargo care

The majority of LNG shippers and receivers have a legitimate concern over foreign bodies getting into tanks and pipelines. The main concern is the risk of valve blockage if (say) an old welding rod becomes lodged in a valve seat. Such occurrences are not unknown with a ship discharging first cargoes after newbuilding or recently having come from dry-dock. Accordingly, and despite discharge time diseconomies, it is common practice to fit filters at the ship's liquid manifold connections to stop any such material from entering the shore system. The ship normally supplies filters fitting neatly into the manifold piping.

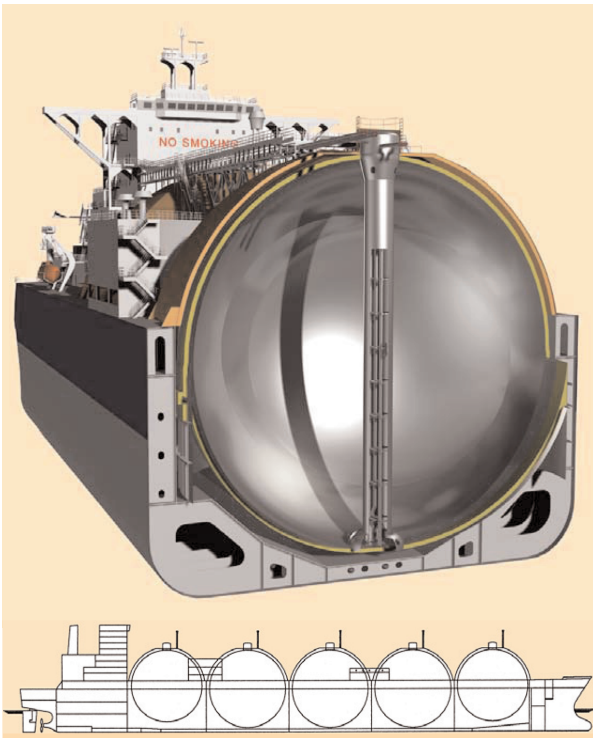
In a similar vein, even small particulate matter can cause concerns. The carryover of silica gel dust from inert gas driers is one such example. Another possible cause of contamination is poor combustion at inert gas plants and ships tanks becoming coated with soot and carbon deposits during gas freeing and gassing up operations. Subsequently, the contaminants may be washed into gas mains and, accordingly, cargoes may be rejected if unfit. Tank cleanliness is vital and, especially after drydock, tanks must be thoroughly vacuumed and dusted.

A cargo was once rejected in Japan when, resulting from a misoperation, steam was accidentally applied to the main turbine with the ship secured alongside the berth. The ship broke out from the berth, but fortunately the loading arms had not been connected. This action was sufficient however for cargo receivers to reject the ship, and the cargo could only be delivered after a specialised ship-to-ship transfer operation had been accomplished. The ship-to-ship transfer of LNG has only ever been carried out on a few occasions and is an operation requiring perfect weather, great care and specialist equipment.

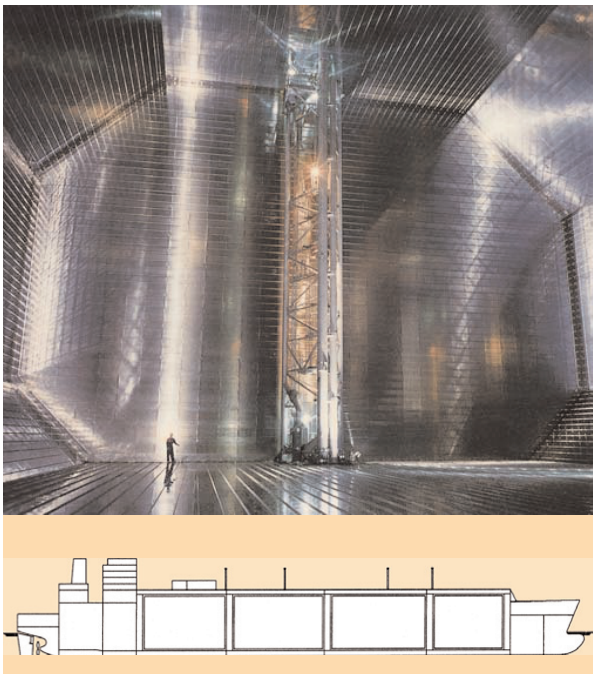
Another case of cargo rejection, this time resulting in a distressed sale, involved a shipment to Cove Point in the USA, where the strict requirements which prevail on in-tank pressures on arrival at the berth were not adhered to. The ship had previously been ordered to reduce pressure for arrival.

This is a difficult job to perform satisfactorily and, if it is to be successful, the pressure reduction operation must progress with diligence throughout the loaded voyage by forcing additional cargo evaporation to the boilers. This cools the cargo and hence reduces vapour space pressure. The process of drawing vapour from the vapour space at the last moment is ineffective, because the cargo itself is not in balance with that pressure and once gas burning stops the vapour space will return to its high equilibrium pressure. This process is known in the trade as 'cargo conditioning'.

Moss design (courtesy of Moss Maritime).



Membrane design (GTT).



Ship care

A temperature of -162°C is astonishingly cold. Most standard materials brought into contact with LNG become highly brittle and fracture. For this reason pipelines and containment systems are built from specially chosen material that do not have these drawbacks. The preferred materials of construction are aluminium and stainless steel. However these materials do not commonly feature over the ship's weatherdecks, tank weather covers or hull. These areas are constructed from traditional carbon steel. Accordingly, every care is taken to ensure that LNG is not spilt. A spill of LNG will cause irrevocable damage to the decks or hull normally necessitating emergency drydocking. Accidents of this nature have occurred, fortunately none reporting serious personal injury, but resulting, nevertheless, in extended periods off-hire.

LNG carriers are double-hulled ships specially designed and insulated to prevent leakage and rupture in the event of accident such as grounding or collision. That aside, though sophisticated in control and expensive in materials, they are simple in concept. Mostly they carry LNG in just four, five or six centreline tanks. Only a few have certification and equipment for cross trading in LPG. The cargo boils on passage and is not re-liquefied onboard – it is carried at atmospheric pressure. Although there are four current methods to construct seaborne LNG tanks, only two are in majority usage. There are the spherical tanks of Moss design and the membrane tanks from Gaz Transport or Technigaz (two French companies, now amalgamated as GTT). Each is contained within the double hull where the water ballast tanks reside. The world fleet divides approximately 50/50 between the two systems.

Regarding spherical tanks, a very limited number were constructed from 9% nickel steel, the majority are constructed from aluminium. A disadvantage of the spherical system is that the tanks do not fit the contours of a ship's hull and the consequent 'brokenstowage' is a serious diseconomy. In general terms, for two LNG ships of the same carrying capacity, a ship of Moss design will be about 10% longer. It will also have its navigating bridge set at a higher level to allow good viewing for safe navigation. On the other hand the spherical tanks are simple in design and simple to install in comparison to the membrane system, with its complication of twin barriers and laminated-type construction.

Tank designs are often a controlling factor in building an LNG carrier. Shipyards usually specialise in one type or the other. Where a yard specialises in the Moss system, giant cranes are required to lift the tanks into the ships and limits on crane outreach and construction tooling facilities currently restrict such tanks to a diameter of about 40 metres.

Early LNG carriers had carrying capacities of about 25,000 m3. This swiftly rose to about 75,000 m3 for the Brunei project and later ships settled on 125,000 m3. For some years this remained the norm, giving a loaded draught of about 11.5 metres, thus stretching the port facilities of most discharge terminals to their limits. Since then, however, there have been some incremental increases in size, usually maintaining draft but increasing beam, resulting in ship sizes now of about 145,000 m3. That said, one of the newest in class is the Pioneer Knudsen, trading at only 1,100 m3 capacity from a facility near Bergen to customers on the Norwegian west coast. At the end of 2004 the first orders were placed for LNG carriers of more than 200,000m3 and ships to carry over 250,000m3 are expected to be delivered by the end of 2008.

Large modern LNG carriers have dimensions approximately as follows:

Capacity (m3)	145,000	215,000
Length	295m	315m
Beam	48m	50m
Loaded draft	12m	12m

LNG having a typical density of only 420 kg/m3 allows the ships, even when fully laden, to ride with a high freeboard. They never appear very low in the water as a fully laden oil tanker may do. Ballast drafts are maintained close to laden drafts and, for a ship having a laden draft of 12 metres, a ballast draft of 11 metres is likely. This means that for manoeuvring in port in windy conditions the ships are always susceptible to being blown to one side of the channel, and restrictions on port manoeuvring usually apply with extra tug power commonly specified.

Another salient feature of the LNG class is the propensity to fit steam turbine propulsion. This is an anachronism brought about by a reluctance to change over the years, together with a fear that a system as yet untried on LNG carriers may not find favour with the principal charterers – the Japanese. Most other ship types of this size have diesel engines and the engineers to run diesel equipment are plentiful and suitably trained. On the other hand, engineers knowledgeable in steam matters are few and their training base is the ship itself. This situation is changing though, with both diesel electric dual fuel systems and slow speed diesels now finding favour.

LNG carrier with membrane tanks.

With slow speed diesel propulsion, reliquefaction plants will be required onboard to handle boiloff gas, and all diesel systems will require back-up gas disposal facilities – also known as 'gas combustion units' (GCUs) – for when either the reliquefaction plants or the duel fuel diesel engines are not available to process boil-off gas.

LNG ships are expensive to build. They comprise very valuable assets: generally far too good to let rust away. Shipowners and ship managers alike recognise this and, together with inspection regimes, the overall quality of LNG tonnage is kept to a high standard. Age for age, they are probably the best maintained ships in the world. Of course some of these ships are now old and only a few have ever been scrapped; some are over 30 years old. This is very old for a large tanker trading all its life in salt water, when 25 years is already considered by many as a cut-off date. On termination of their original projects we are now seeing many of the older ships as surplus to requirements. Sometimes the project wishes to continue but only with new ships. So the older ships are laid-off.

In the past this would have been their death knell but today this is not necessarily the case. The slow development of a spot market has allowed the shipowner to consider life extension programmes of considerable cost; all this set against the value of a very expensive newbuilding. Today life extension programmes are common with old ships making handsome profits in the spot market.

SIGTTO

Valuable assistance in the preparation of these articles has come from the Society of International Gas Tanker and Terminal Operators (SIGTTO).

SIGTTO is the leading trade body in this field and has over 120 members covering nearly 95% of the world's LNG fleet and 60% of the LPG fleet. SIGTTO members also control most of the terminals that handle these products.

The Society's stated aim is to encourage the safe and responsible operation of liquefied gas tankers and marine terminals handling liquefied gas; to develop advice and guidance for best industry practice among its members and to promote criteria for best practice to all who have responsibilities for, or an interest in, the continuing safety of gas tankers and terminals.

The Society operates from its London office at
17 St. Helens Place EC3.
Further details on activities and membership is available at www.sigtto.org

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The aforementioned publications are available from Witherby & Company Ltd, London.

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