Pressurised Natural Gas – A New Alternative for Natural Gas Transport

a report by
Knutsen OAS Shipping

Introduction

Compressed natural gas (CNG) has been evaluated for decades and several concepts have been introduced. So far, this has not been successful, mainly due to the huge weight of the containment system when standard codes have been applied for the containment design.

Several concepts have applied this combined pressure and temperature principle for new CNG designs. However, when temperature is reduced, other challenges appear that both add cost and introduce complexity into the design.

The Norwegian ship-owning company Knutsen OAS Shipping has selected another approach to make CNG a reality. The development strategy is as follows:

- apply known design principles as far as possible;
- combine the best from the pipeline industry with the shipping industry; and
- keep the system complexity to a minimum.

To meet this development strategy, Knutsen OAS Shipping has joined forces with the Det Norske Veritas (DNV) of Norway and Europipe of Germany. DNV is one of the leading experts on vessel design, pipeline design and safety assessment in the world. Europipe is the leading pipeline fabrication company in the world.

Knutsen OAS Shipping

Knutsen OAS Shipping is a privately owned shipping company with its main office in Haugesund, Norway. The company was founded at the end of the 19th century. The company was reorganised under the new owners in the early 1980s and currently owns more than 30 vessels including shuttle-tankers, chemical/product carriers and liquified natural gas (LNG) carriers. Besides being a company with focus on shipping services to first-class charterers and development of its own solution for CNG transport, the company has also developed environmental solutions for reduction of volatile organic compounds (VOC) and treatment of ballast water.

The Pressurised Natural Gas Solution

The new CNG concept with the designation pressurised natural gas (PNG®) carrier is a Knutsen OAS Shipping registered trade-mark. The gas is stored under normal pressure in vertical cylinders on-board the vessel. The concept is based on several patents pending solutions. PNG will not require sophisticated processing to maintain the gas stored in the containment system. Due to the operation under ambient temperatures, no isolation will be required to prevent heating during the voyage. The vertical cylinders will be prepared according to three main principles:

- design, material selection and testing regime for the cylinder is according to the recognised offshore pipeline code DNV-OS-F101 (similar to ISO/DIS 13623);
- end caps designed according to the International Gas Code (IGC) but with a minimum wall thickness not less than the cylinder wall; and
- all material used for cargo containment piping, cargo deck piping, valves and fittings is NV 316 or similar, complying with the requirements for manufacture survey and certification given by normal rules for classification of ships.

The vessel itself is straightforward vessel design. Some special vessel arrangement is required to ensure maximum safety and functionality for the new application.

Det Norske Veritas – CNG Rules

DNV helped Knutsen to identify the feasibility of the PNG design, giving input to the design of critical issues and failure modes and giving input to acceptance criteria and rules requirements.

Because the IGC was never intended to cover CNG cargo containment system (CCS), no existing rules

Figure 1: Full Scale Test Cylinder

The Cargo Containment System

- Maximum allowable operating pressure, 250 barg
- Pipe dimension, 42"
- Cylinder length, between 19–38m
- Material quality, X-80
- Cylinder wall and end cap wall thickness, 33.5mm.

apply for such concepts. According to International Maritime Organisation report MSC 72 and 74/19, formal safety assessment (FSA) principles have to be applied where existing rules do not cover new applications. The aforementioned work performed by DNV resulted in quantitative risk analysis (QRA) to document that the risk level is acceptable. This analysis was performed during 2002 and is the basis for the new rules issued by DNV.

The new rules for classification of CNG carriers were issued in January 2003. This is the first time a complete set of rules has been issued for CNG carriers. The rules are to some extent generic, but scope included the PNG design, although that may not apply for all CNG concepts. The DNV ambition is to further develop the rules to cover several other CNG concepts.

Scope of Delivery

Knutsen OAS Shipping has worked jointly with Europipe GMBH in Germany to qualify the containment system according to the new rules issued by DNV. Europipe has used the Mannesmann Research Institute and the CCS has been successfully qualified and approved by DNV according to the new DNV rules. This is an achievement that proves that CNG through the Knutsen PNG solution could become a reality.

Europipe has already performed a trial production of the X-80 pipes and end caps according to PNG specification and DNV rules. These have been used for the qualification testing. Both fatigue and burst test has been performed. The fatigue test will ensure a PNG carrier lifetime of 40 years based on 50 loading per year. The burst test verified that sufficient burst capability remains in the cylinder even after a fatigue exposure of 40 years.

Vessel

Knutsen OAS Shipping has performed the vessel initial design with input from DNV and independent naval architect expertise.

The vessels have been discussed with several of the major shipbuilding yards. The yard input together with the Europipe input for the CCS has given Knutsen the possibility to price the vessels to a detailed level necessary in order to be able to determine the unit cost for transportation of natural gas by PNG vessels.

Several different types of vessel have been considered such as the offshore loading and discharging type PNG vessel and terminal-to-terminal type PNG vessel.

The offshore loading type vessel is based on Knutsen's own experience with similar operation for oil. The vessel can apply the well-known submerged turret loading (STL) system from advanced production and loading (APL) systems. Other types of offshore loading systems are also being considered and detailed design and testing for a combined offshore/onshore loading and discharging system is on-going.

Several vessel sizes have been considered from small PNG carriers with gas carrying capacity down to 2–4MMSm^3 to large PNG carriers with carrying capacity more that 30MMSm^3.

The large size PNG carrier is capable of sailing with a speed of 17.5 knots and is very suitable for large volumes and/or long distance gas deliveries up to 3,000 nautical miles (nm). Similarly, smaller vessels can be built according to the volumes and distances required.

System Solutions

Gas transport using PNG vessels can be continuous if a minimum of three vessels is provided for gas transport from the gas source to the gas receiving part. More vessels can be added according to market demand, avoiding high initial tariff traditionally associated with other systems because of low utilisation.

Another advantage is that the gas quality that could be transported on PNG carriers are very similar to gas qualities allowed in pipeline systems. In fact, even richer gas could be transported in PNG carriers compared with pipelines, giving PNG carriers an advantage compared with LNG and even towards pipelines in some cases.

Compared with traditional LNG value chains, a PNG value chain would not require investments in

storage and liquefaction facilities upstream and storage and regasification facilities downstream. This would make PNG an interesting new alternative for certain volumes/distances where LNG was previously considered the only option. Case studies indicate that for distances up to 3,000nm PNG could be more economic than LNG.

PNG is the potential solution for stranded gas (gas that cannot be developed economically either since the volumes are too small to justify LNG or is too far from the market to justify pipeline). The large volumes of the stranded gas identified worldwide have, for many years, been one of the main incentives for CNG transport. With the PNG carrier, monetisation of stranded gas reserves would be close to reality since PNG transport is a gas transportation solution that fills the gap between pipeline gas and LNG.

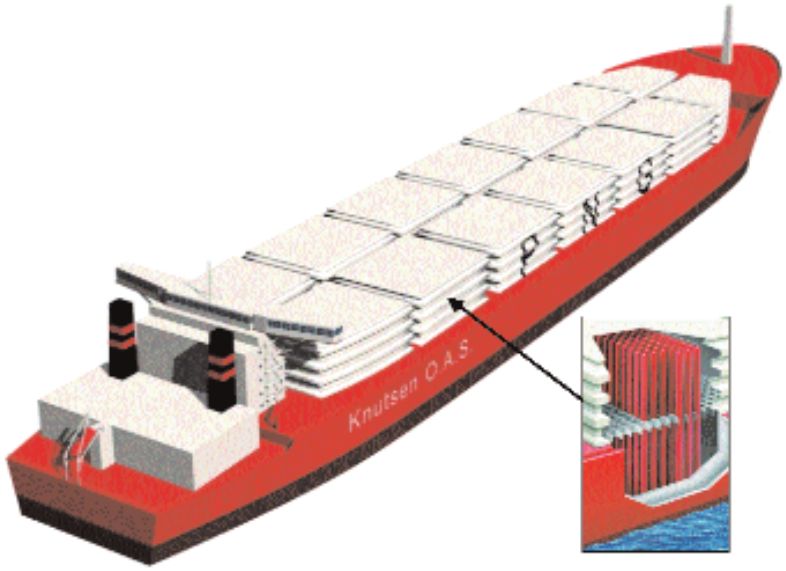
Environmental Benefits

PNG offers an environmentally interesting solution. The vessel could be fuelled using natural gas, a favourable fuel compared with heavy fuel oils normally used in shipping – reducing the emissions of nitrogen oxides, carbon dioxide, sulphur and dust to the environment. Total energy demands are much less for PNG compared with LNG, while PNG, compared with pipeline, is very similar or better. Due to the heavy containment system, ballast water discharge would not be required. For some trades, this could be a very important environmental issue.

Safety First

As part of the rule development, DNV performed a risk and safety assessment, that concluded that PNG transport is as safe as or even safer than comparable LNG transport – an important issue that must be considered when gas transport solutions are being established.

Figure 2: The PNG Vessel



Because PNG delivery is performed with natural gas in gaseous phase, discharging could be far away from existing population. Discharging could even be performed offshore some distance from the shoreline and piped to shore. For some areas, this could be an advantage because of political risk or social unrest.

The PNG vessel operates at full pressure at ambient temperatures. This means that the CCS cannot be pressurised due to heat received from the environment. It also simplifies the piping arrangement and minimises piping and valves dimensions and system complexity. This again contributes to an increased safety.

The PNG carrier is based on known technology elements arranged differently. The vessel is a combination of an ordinary crude oil tanker and a container vessel while the CCS is based on ordinary pipeline fabrication principles. The cargo handling system is small in diameter with material and pressure rating that is well-known in the shipping and offshore industry. ■