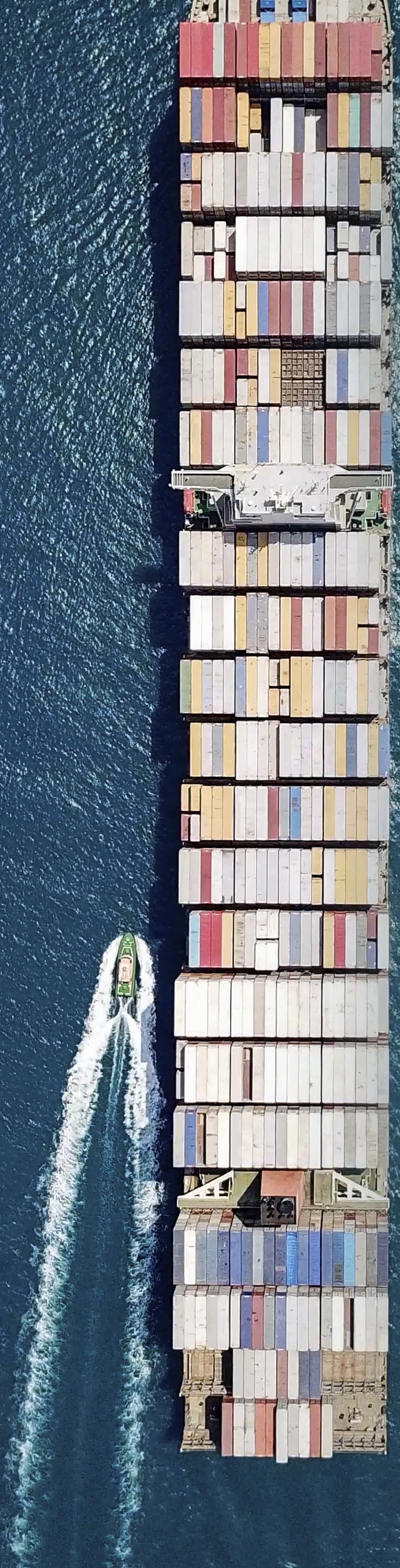

LNG-fuelled shipping goes large scale

Adnan Ezzarhouni, GTT, China, and Martial Claudepierre, Bureau Veritas, China, discuss the main technical features of the world's largest dual-fuel vessel program: the ultra large LNG-fuelled container vessels and their bunkering counterparts.

Tightening environmental regulations and limits set on worldwide shipping emissions have increased the attractiveness of gas as a marine fuel, and LNG has emerged as the principal alternative fuel option being adopted today.

Up to now, the use of LNG as fuel has been limited to small and mid-size ships, and it was originally adopted by LNG carriers. With a few exceptions, for larger vessels, only 'LNG ready' ships have been developed, such as for tankers, large container carriers and very large ore carriers. The main reasons being the uncertainty of the availability of LNG supply infrastructure, ensuring affordable LNG supply compared to other fuels, as well as extra CAPEX for dual-fuel (DF) propulsion and auxiliaries. However, on the large container carrier market, the constantly moving economic and environmental pressure forces owners to innovate in order to comply and maintain profitability.

With that in mind, CMA CGM, one of the world's largest container liner operators, has adopted a disruptive innovation by the use of LNG as fuel for its largest newbuild container ships. This breakthrough project is crucial for the entire industry as it will demonstrate that compliance with stringent environmental constraints and increased economic advantages are possible.

The project includes nine LNG-fuelled ultra large container vessels (ULCVs), each with a capacity of 22 000 TEU, to be built in Shanghai at the CSSC Hudong Zhonghua (HZ) and Jiangnan (JN) shipyards, featuring GTT's Mark III containment system. The supply chain also includes a 18 600 m³ LNG bunker ship to deliver 0.3 million tpy of LNG fuel.

GTT and Bureau Veritas are in the process of reviewing the existing LNG fleet and the available LNG bunkering infrastructure in an attempt to evaluate the available options that meet the new IMO emissions regulations, as well as the rationale behind the choice of LNG as fuel for large container liners which have fixed routes and tight schedules.

The technical challenges presented by the world's first LNG-fuelled ULCVs, as well as the associated LNG bunkering vessels (LBVs), are numerous.

LNG as fuel market development

Using LNG as marine fuel means full compliance with any environmental regulation ahead. This statement is, however, subject to specificities depending on technologies (2 or 4 stroke, low pressure or high pressure gas injection).

Initially, the LNG as fuel initiative was limited to vessels operating all year in Emission Control Areas (ECAs) on dedicated routes where state funds were encouraging the use of low NO_x technologies. This was particularly the case for Norway where, in the 2000s, the first fjord ferry (gas-only) was put into service with a relatively low power propulsion system and small LNG storage onboard.

In parallel, the LNG carrier industry experimented in 2006 with the first ever DF engine to be installed onboard a vessel. The first ever DF engine was certified by Bureau Veritas, opening the way for future application of EIAPP MARPOL clean engines.

From 2006 to 2014, the industry has seen a steady and slow evolution of the market of LNG fuel vessels, mainly composed of short sea shipping and ferries. The reason behind this was mainly the presence of ECAs, as already mentioned, in the Baltic and North Sea in Europe and the second in North America, with allocated funding. Other factors include the lack of or limited LNG bunkering infrastructure, mainly composed of truck-to-ship bunkering convenient for short voyage ferries and short sea shipping embarking with only a limited amount of LNG, and the relatively high cost of construction, approximately 20 – 30% more compared to a liquid fuel version (CAPEX), and high fuel cost (OPEX) compared to heavy fuel oil (HFO) or marine gas oil (MGO) on an equivalent energy basis. In addition to these costs, an extra price to pay was the waste of cargo space due to the poor integration of LNG storage tanks and the lower density and energy content of the LNG compared to HFO or MGO.

There was a sharp change in the LNG as fuel market in 2017 with the adoption of LNG as fuel by ocean-going UCLVs. The fleet in service currently numbers more than 132 units (aggregate diverse fleets), with a further 140 units under construction. The regions receiving the most coverage at present are Northern Europe and North America, which is not a surprise in light of ECA presences. Other emerging areas such as Asia, Australia and South America still have a limited number of units.

Figure 1. Typical trade route for an ultra large container vessel (ULCV) between Asia and Europe.

LNG bunkering infrastructure development

When we look back to the development of LNG-fuelled vessels, it is clear that the key to the wider development of LNG as fuel was the LNG bunker delivery logistic chain. The first age of LNG as fuel was satisfied with LNG bunkering from trucks, but rapidly it appeared no longer viable to multiply the number of trucks to deliver the larger requested quantities of LNG as fuel. It became obvious that greater investments were necessary, involving many stakeholders globally.

Shell, ENGIE and Total were the first LNG suppliers to understand the new market development requirements and to bring an appropriate answer in terms of a large scale bunkering solution. MOL's LBV, chartered by Total Marine Fuels, features 18 600 m^3 of LNG bunker capacity, thanks to Mark III membrane tanks, and the appropriate auxiliaries to transport, store and deliver the LNG, and treat vapour return from client vessels. It is the top of its class, and offers a model for new designs of LBV.

In Asia, whilst being a bit late to the market due to a traditional high price of LNG and absence of environmental regulations in place, rapid progress is now being made to implement local emission controlled areas, such as in China, induced by the Maritime Safety Administration (MSA), enabling the region to catch up with the demand of international and local LNG fuel markets.

LNG ship-to-ship (STS) bunkering is the way forward for developing the market, mimicking the HFO and MGO markets, and offering flexibility and opportunities to use LBVs as short sea LNG carriers to meet other demands. Amongst other advantages, the simultaneous commercial operations (SIMOPS) is a must to achieve such innovative clean propulsion, since it allows cargo loading and unloading at the same time as the LNG transfer operations, side by side with the LBV.

But there is a price to pay, as a typical LNG bunker vessel will cost up to five times more than a basic HFO/MGO bunker barge (investors are at stake, and many of them have taken action by vacillating local regulations, delivering financial support and learning from other front runners).

The world's largest LNG bunker vessel

The main challenge presented by LNG as fuel is to maintain comparable profitability with standard fuels, such as HFO or MGO. When it comes to LNG bunkering, the authorisation to bunker LNG as fuel during commercial operations is requested by the end-user. This implies that the bunkering operation will not take place in a dedicated remote area, but in the container terminal, ships side-by-side, container loading and unloading by cranes, 'business as usual'.

The story of the CMA CGM LNG-fuelled vessels project

The CMA CGM project is the conclusion of a long lasting investigation process that started in 2010, when the first collaboration with DSME & CMA CGM was established. Back then, environmental regulation was already encouraging consumers to find alternative ways of being sustainable whilst maintaining profitability. However, due to the lack of an LNG bunkering chain and the lack of visibility in terms of LNG fuel costs, it was not found relevant to derive the 'approval in principle' (AIP) for a real project. Type B tank and high pressure DF 2 stroke engine propulsion systems were assessed; ship structure, LNG fuel storage and economics were also studied.

In 2013, a 16 000 TEU vessel with MARIC & Shanghai Jiangnan Changxing Heavy Industry was assessed. Membrane type fuel storage tanks were also studied. Meanwhile, other AIPs and joint development projects (JDPs) were approved and agreed, paving the way to a clear mutual understanding of such designs.

In 2017, CMA CGM made its groundbreaking decision to request shipyards propose designs for a ULCV with a DF option. HZ Shipyard was finally selected to construct the vessel. It was also agreed that the associated LBV would be constructed in the same shipyard.

Initially, the project was targeting two bunkering operations in the sailing loop, as usually the case for HFO bunkering, one bunker stop in Malacca Strait-Singapore area and one in the Amsterdam-Rotterdam-Antwerp (ARA) region. Unfortunately, due to the uncertainty of the availability of the LNG bunker fuel back in 2017 and the differences in prices, it was decided that the vessel would be operated along the route from Northern Asia to Northern Europe with one bunkering stop in Europe only, almost doubling the required onboard LNG fuel storage capacity.

The outcome of the project was an ultra large container carrier (22 000 TEU), the largest in the world at the time the contract was signed, featuring a DF propulsion system, a large Mark III membrane tank, gas handling preparation technology and a gas fuel supply system. The vessel is an ocean going, single screw, DF diesel engine driven, fully cellular container vessel, suitable for carrying dry cargo containers. It also has five tiers of lashing bridges.

The vessel has a raked stem with straight bow, a transom stern and a continuous deck. The accommodation, including the navigation bridge, is located semi-fore and the engine room is located semi-aft.

The membrane LNG storage tank, featuring GTT's Mark III reinforced system, is installed below the accommodation, under

Figure 2. Artist's impression of a 22 000 TEU DF vessel, equipped with GTT's Mark III LNG containment system (image courtesy of: CMA CGM).

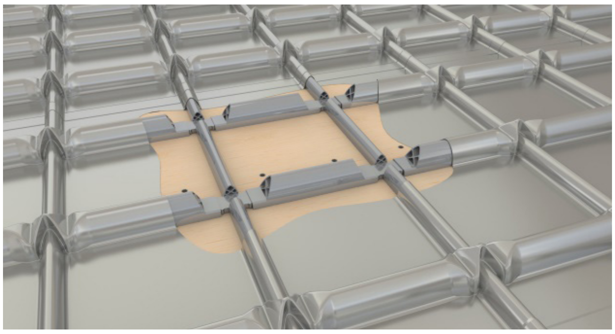

Figure 3. Artist's impression of the aluminium wedges below the primary membrane corrugations.

deck in accordance with the IGF Code. The double bottom and side area around the LNG storage tank are arranged as void space. Double hull construction is provided from the N°1 to N°11 cargo holds, and covers the engine room. Double bottom will extend from the aft peak bulkhead to as far forward as practicable, subject to strength consideration. Double bottom will be approximately 2.6 m.

Lessons learnt

Contrary to conventional LNG carriers, the LNG fuel tanks for this project have additional features:

- All filling levels, as it is a fuel tank.
- Large and single fuel tank.

In order to design a proper solution, specific design considerations were taken into account in order to cope with the exceptional requirements of the vessel. The key changes included the following:

- Insulation reinforcement: the insulation panels need to withstand the loads derived from LNG sloshing. Heavier densities on foam panels up to 210 Kg/m^3 need to be introduced in some parts of the tanks. GTT has already implemented similar reinforcement on very large ethane carriers (VLECs), which are designed to carry heavier cargoes, such as ethane and LPG.
- Primary membrane reinforcement below corrugation: like the insulating panels, the primary membrane also faces the sloshing loads of LNG cargoes, and needs to have proper reinforcement underneath the corrugations with so called 'wedges'. For this particular project, the material used was aluminium, in order to avoid deformations of the primary membrane.
- Inner hull reinforcement: as the membrane tank is non-self-supported and employs load bearing material, the inner hull needs to also be designed to withstand the hydrodynamic pressures from the fuel tank. Therefore, a specific assessment combined with sloshing tests has been carried out to define a minimum thickness for the hull. Under these conditions, the deformation of the hull as a result of sloshing remains similar to that of traditional LNG carriers.
- Protection of the pump tower: due to the higher sloshing loads and because only fuel gas pumps are applied, GTT has revisited the design of the pump tower in order to limit the exposure of the equipment to sloshing.

This project features the largest LNG fuel supply chain so far, and has doubled the total LNG fuel volume contracted. As a world first in a nascent LNG fuel industry, the nine ULCVs and their dedicated LBV have been a key development project for the LNG as fuel industry.

We will see more and more LNG-fuelled vessels in the near future, thanks to the growing development of the LNG bunker fleet all over the world. The supply and economics of LNG will play a significant role in that development, and containers transported by such clean and efficient ships will remain, more than ever, the cleanest and most cost-effective mode of transport, thanks to LNG as fuel.

GTT, Bureau Veritas, CMA CGM, MOL and Total have proven not only the feasibility of LNG as fuel, but more importantly, the viability of the economic model thanks to this disruptive decision for a cleaner future. **LNG**