Bunkering for a More Sustainable Future

Understanding LNG Technologies

A technology report from Bureau Veritas Marine & Offshore

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TECHNOLOGY REPORT

CONTENTS

LIST OF ACRONYMS

BOG	Boil-Off Gas
CAPEX	Capital Expenditure
CCS	Cargo Containment System
CFD	Computer Fluid Dynamics
EMSA	European Maritime Safety Agency
ERS	Emergency Release Systems
FLNG	Floating Liquefied Natural Gas
FSRU	Floating Storage Regasification Unit
GCU	Gas Combustion Unit
GHG	Greenhouse Gas
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HSEQ	Health Safety, Environment and Quality
IGC	International Gas Carrier (Code)
IMO	International Maritime Organization
LFL	Lower Flammability Limit
LNG	Liquefied Natural Gas
LNG BB	LNG Bunkering Barge
LNG BV	LNG Bunkering Vessel
LNGC	LNG Carrier
QRA	Quantitative Risk Assessment
RPT	Rapid Phase Transition
SIMOPS	Simultaneous Operations
SOx	Sulfur Oxides
STS	Ship-to-Ship
TEU	Twenty-foot Equivalent Unit
TTS	Truck-to-Ship
UFL	Upper Flammability Limit
VLCC	Very Large Crude Carrier

LNG AT THE HEART OF THE TRANSITION TOWARD A GREENER MARITIME INDUSTRY

The shipping industry is making the transition to a lower carbon future. One of the key steps being taken to make that transition is the development of LNG-fueled shipping.

So far, gas as a marine fuel has primarily been used for ferries, OSVs and other relatively small-scale ship types and sectors. This is now changing, and the biggest and most important challenge for deep-sea shipping - reducing emissions - is now being addressed. In November 2017, Rodolphe Saadé, Chairman and CEO of CMA CGM Group, a world leader in shipping and logistics, made the pioneering choice to equip its future series of nine 23,000 TEU mega ships with LNG-powered engines - a first in the history of shipping for Ultra Large Container Vessels and a first step towards energy transition of the maritime transport. Ships such as these show that two-stroke engines are ready to help ship owners meet IMO targets for 2030 and eventually 2040.

The increased size of this new breed of LNG-fueled ships is driving bunkering needs well beyond the capacity of LNG trucks previously used for smaller bunkering operations at bunkering terminals. This has led to the development of LNG Bunkering Vessels (LNG BVs). Although a fairly recent development within the LNG value chain, LNG BVs are quickly gaining a prominent role, offering higher volume potential as well as significant flexibility, effectively removing barriers related to port infrastructure and draft limitations.

With every emerging technology, however, comes the challenges of adapting to a regulatory framework that is constantly evolving. Bureau Veritas, a leading classification society for these new LNG-fueled ships and the development of large LNG BVs, has been working closely with the industry to understand and address the risks and challenges clients and stakeholders face. Our unique position across the whole LNG value chain has allowed us to actively participate in and accompany the development of LNG BVs. This report is an opportunity for us to share our expertise and support our clients in their decision-making for LNG bunkering and their transition towards a greener future.

"Bureau Veritas has been working closely with the industry leaders to understand and address the challenges of LNG-fueled shipping and LNG bunkering. Our unique position across the whole LNG value chain has allowed us to actively participate in and accompany the development of LNG BVs."

Matthieu de Tugny
President of Marine & Offshore
Bureau Veritas


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SUPERSIZE ME

ADDRESSING GROWING LNG BUNKERING NEEDS

In the past decade, LNG-fueled ships have not only grown in number, but also in terms of capacity. Today, these ships range from small tugboats to large VLCCs. The *CMA CGM JACQUES SAADE*, the new flagship of CMA CGM and the first 23,000 TEU containership to be powered by LNG, is a great example of such growth. The first containership of such size, the project also includes the development of an LNG BV, built by MOL and chartered by Total Marine Fuels, featuring 18,600 m³ LNG bunkering capacity.

However, with greater capacity also comes greater constraints. As noted in the European Maritime Safety Agency's (EMSA) 'Guidance on LNG bunkering to Port Authorities and Administrations', published in 2018, "very large containerships, that potentially make use of LNG for longer voyages, will naturally require larger bunker volumes and, inevitably higher bunker rates". Ultra large containerships such as the *CMA CGM JACQUES SAADE* need the largest volumes of LNG bunkering, and therefore stay at berth for the shortest time interval possible and need to be able to carry out SIMOPS – that is, bunkering should not interfere with cargo handling operations.

LNG BV's and LNG BB's IN SERVICE - WORLD FLEET (July 2020)

Ship Name	Type	New-built / Conversion	Ship owner	Class	CCS / Capacity (m³)	Reliq/ Subcooling	Delivery
SEAGAS	LNG BV	Conversion	AGA GAS AB	DNV GL	Type C – 180	-	2013
HAI GANG XIN 01	LNG BB	New Built - China	Jiangsu Haiqi Ganghua GAS DEV.	CS	Type C – 500	-	2013
GANG QIANG 01 HAO	LNG BB	New Built - China	Gangqian LNG LTD	CS	Type C – 500	-	2014
ZHU GANG XI 01	LNG BB	New Built - China	Yunfu Zhugang	CS	Type C – 200	-	2015
XIJIANG ENN 01	LNG BB	New Built - China	ENN	CS	Type C – 200	-	2015
GANG QIANG 02 HAO	LNG BB	New Built - China	Gangqian LNG LTD	CS	Type C – 500	-	2016
HAI GANG XIN 02	LNG BB	New Built - China	Jiangsu Haiqi Ganghua GAS DEV.	CS	Type C – 500	-	2016
CHANG LUNG 01	LNG BB	New Built - China	Sinopec Changjiang Fuel	CS	Type C – 500	-	2017
GREEN ZEEBRUGEE	LNG BV	New Built – Hanjin H.I.	NYK	BV	Type C – 5,000	-	2017
CORALIUS	LNG BV	New Built – Royal Bodewes	Sirius Veder AB	BV	Type C – 5,800	-	2017
CARDISSA	LNG BV	New Built - STX	Shell	LR	Type C – 6,500	Air Liquide	2018
CHANG LUNG 02	LNG BB	New Built - China	Sinopec Changjiang Fuel	CS	Type C – 500	-	2018
CORAL METHANE	LNG BV	Conversion	Anthony Veder	BV	Type C – 7,500	Air Liquide	2018
OIZMENDI	LNG BV	Conversion	Itsas Gas Bunker Supply	BV	Type C – 642	-	2018
CLEAN JACKSONVILLE	LNG BB	New Built – Conrad Orange	Tote	ABS	Mark III – 2,200	Stirling	2018
BUNKER BREEZE	LNG BV	New Built - ZAMAKONA	Suardiaz	BV	Type C – 1,200	-	2018
KAIROS	LNG BV	New Built - HMD	Babcock Schulte Energy	LR	Type C – 7,500	-	2019
FLEXFUELER 001	LNG BB	New Built - Europe	Titan LNG BV	BV	Type C – 1,480	-	2019
LNG LONDON	LNG BV	New Built – INEC BV	LNG Shipping	BV	Type C – 3,000	Stirling	2019
GAS AGILITY	LNG BV	New Built – HUDONG-Z.	MOL	BV	Mark III – 18,600	Air Liquide	2020
SM JEJU LNG 2	LNG BV	New Built - SHI	Korea Line	KR	KC-1 – 7,500	-	2020
AVENIR ADVANTAGE	LNG BV	New Built - Keppel O&M	Avenir	DNV GL	Type C – 7,500	-	2020
KAGUYA	LNG BV	New Built - Japan	Central LNG Shipping	NK	Type C – 3,500	-	2020

N.B: Chinese built LNG BB are acting as LNG fueling pontoons in rivers, harbors or estuaries. SEAGAS, CLEAN JACKSONVILLE, FLEXFUELER 001 and LNG LONDON are registered for inland navigation or restricted sea trade. BUNKER BREEZE LNG tanks are not yet installed on board.

Type
LNG BV LNG Bunkering Vessel
LNG BB LNG Bunkering Barge

Class
ABS American Bureau of Shipping
BV Bureau Veritas
CS China Classification Society
DNVGL Det Norske Veritas Germanischer Lloyd
KR Korean Register
LR Lloyds register

LNG BV's and LNG BB's ON ORDER - WORLD FLEET (July 2020)

Ship Name	Type	New-built / Conversion	Ship owner	Class	CCS / Capacity (m³)	Delivery
DSIC / G8500-I	LNG BV	New Built - China	ENN	CS	Type C – 8,500	2020
OPTIMUS	LNG BV	New Built - China	Elenger	BV	Type C – 6,000	2020
EK H.I.	LNG BV	New Built - Korea	Ministry of Oceans and Fisheries	KR	Type C – 500	2020
ECOBUNKER TOKYO BAY	LNG BV	New Built - Japan	Eco Bunker Shipping	NK	Type B – 2,500	2020
FUELNG BELLINA	LNG BV	New Built - China	Fuel LNG	ABS	Type C – 7,500	2020
KEPPEL NANTONG / 414	LNG BV	New Built - China	Gazpromneft	RS / BV	Type C – 5,800	2020
FLEXFUELER 002	LNG BB	New Built - Europe	Titan LNG	BV	Type C – 1,480	2020
OSLO TANK	LNG BV	Conversion - Norway	Bergen tankers	BV	Type C – 850	2020
VT HALTER MARINE	LNG BB	New Built - USA	QLNG Transport	ABS	Type C – 4,000	2020
FINCANTIERI BAY	LNG BB	New Built - USA	NorthStar Midstream	ABS	Type C – 5,400	2020
HMD / 8298	LNG BV	New Built - Korea	Korea Line	LR	Type C – 18,000	2021
HUDONG-Z / 1870A	LNG BV	New Built - China	MOL	BV	Mark III – 18,600	2021
SEMBCORP / 09J420004	LNG BV	New Built - Singapore	MOL	BV	Mark III – 12,000	2021
ROSETTI	LNG BB	New Built - Europe	Rimorchiatori Riuniti Panfido	RINA	Type C – 4,000	2021
ARMON	LNG BV	New Built - Europe	Knutsen	BV	Type C - 5,000	2022

Type
LNG BV LNG Bunkering Vessel
LNG BB LNG Bunkering Barge

Class
ABS American Bureau of Shipping
BV Bureau Veritas
CS China Classification Society
DNV GL Det Norske Veritas Germanischer Lloyd
KR Korean Register
LR Lloyds Register
NK Nippon Kaiji Kyokai
RINA Registro Italiano Navale
RS Russian Maritime Register

Bureau Veritas experts inspect the GTT Mark III tank during the construction of the CMA CGM JACQUES SAADE, *the largest LNG-powered containership in the world.*

SUPERSIZE ME – ADDRESSING GROWING LNG BUNKERING NEEDS

What is an LNG BV?

LNG BVs are small ships used for the direct supply of LNG fuel to ships inside or at port. During bunkering, LNG is pumped from the bunker vessel's cargo tanks directly into the fuel tanks of the ship being supplied. LNG BVs typically have a capacity of 500-20,000 m³.

STS bunkering is already the solution of choice for other fuels. Bunkering ships facilitate SIMOPS and have a large delivery capacity, as well as higher transfer rates than other options such as TTS. Moreover, because bunkering takes place alongside with the receiving vessel either moored, at anchor or at station, they also offer operational flexibility. As such, STS for LNG bunkering is naturally the most fitting solution for the growing size of LNG-fueled ships.

While the technology that allows for high delivery capacity and accommodates varying types of LNG-fueled ships is relatively new and still evolving, there already exists significant experience building LNG BVs on which to capitalize. Since the first STS bunkering activities started in Sweden in 2013, several LNG BV and LNG BB have been delivered and are currently in operation.

The great differences in size, capacity and operations of LNG-fueled vessels therefore require the LNG BV market to be flexible. These ships need to be able to meet the challenges specific to each project.

Chronology of significant LNG BV and LNG BB projects


© Open source

CARDISSA
TYPE C - 6,500 m³
2017


© Sirius Shipping

CORALIUS
TYPE C - 5,800 m³
2017


© Engie

GREEN ZEEBRUGGE
TYPE C - 5,000 m³
2017


© Open source

XIJIANG ENN 01
TYPE C - 200 m³
2015


© Open source

SEAGAS
TYPE C - 180 m³
2013


© Anthony Veder

CORAL METHANE
TYPE C - 7,500 m³
2018


© Itsas Gas bunker

OIZMENDI
TYPE C - 642 m³
2018


© Opensource

CLEAN JACKSONVILLE
Mark III - 2,200 m³
2018


© Open source

KAIROS
TYPE C - 7,500 m³
2019


© MOL

GAS AGILITY
MARK III – 18,600 m³
2020

HIGH TECH

LNG BV TECHNOLOGY OPPORTUNITIES & RISKS

Many European countries, as well as the USA, China, Singapore, Japan and South Korea, have been involved in LNG bunkering activities for quite some time now. This has brought about the development of a wide variety of technical solutions available to ship operators and shipyards, particularly in terms of types of containment systems and tank capacity, compatibility with LNG terminals and LNG-fueled ships, boil-off gas handling and LNG transfer systems.

Cargo Containment Systems

Four main types of technologies, referred to as CCS, have been developed and approved for the containment of LNG onboard LNG BVs, although only two – membrane Mark III and Type C – have already been installed onboard in-service LNG BV or LNG BB:

- Type A, prismatic cargo tanks with low design pressure (<0.7 bar)
- Type B, prismatic or spherical cargo tanks with low design pressure (<0.7 bar)
- Type C, spherical, cylindrical or bilobe pressure tanks designed to withstand higher pressures (<5 bar)
- Membrane, designed with a thin layer (membrane) supported through insulation by the adjacent hull structure and with low design pressure (<0.7 bar)

While type A, B and C cargo tanks are built independently from the ship, membrane tanks are integrated into the ship structure. All cargo tanks have to be designed and built in accordance with the IMO IGC Code (International Code for the Construction and Equipment of Ships Carrying Liquified Gases in Bulk).

Each technology brings its own advantages and disadvantages, and as such needs to be considered in terms of two key factors: cargo volume capacity requirements and operational profile.

Cargo Volume Capacity Requirements

The first factor to be considered when choosing the type of CCS to be integrated on an LNG BV is the required cargo volume capacity. With CAPEX reductions concerning LNG BV ship dimensions, certain types of CCS may be more appropriate for ships designed to provide higher volumes of natural gas to LNG-fueled ships without necessarily increasing the size of the ship.

For LNG BVs designed to carry more than 10,000 m³, the prismatic shape is generally favored, because it optimizes the total dimensions of the ship. Prismatic Type A tanks have thus far not been selected for an LNG BV, since it is

IGC Code Tank Classification

INDEPENDENT TANKS
Type A
Pr < 700 mb
Full Secondary Barrier


© CSSC Jiangnan

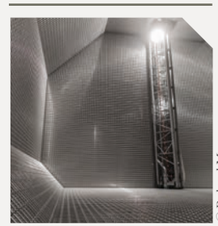
INDEPENDENT TANKS
Type B
Pr < 700 mb
Partial Secondary Barrier


© Wison

INDEPENDENT TANKS
Type C
Pr > 2 bar
No Secondary Barrier


© Wison

MEMBRANE TANKS
Membrane
Pr < 700 mb
Full Secondary Barrier


© Roland Mouron

a quite novel technology. Type B tanks are prismatic as well. They require a spill tray to be added at the bottom of the tank to protect from leakage, as opposed to Type A, which requires a full secondary barrier to protect hull structure from leakage. To date, the Type B tank has only been considered for a small unit currently under construction in Japan.

Membrane tanks are continuously evolving and are currently less common in LNG BVs. Yet they are starting to prove their efficiency for high cargo volumes, and they should progressively become more common as cargo capacity grows.

For LNG BVs designed to carry less than 10,000 m^3 the cylindrical shape is well suited. Although the prismatic shape would be just as suitable for ships, type C tanks are generally the preferred option, because they are designed and built according to the conventional pressure vessel IGC Code. This makes them eligible for accurate stress analyses, and ensures much attention is paid during the design phase to eliminating possible stresses to tank material.

The developers of LNG BV projects have followed the trends of small-scale LNG carriers in terms of reliable and most used cargo containment systems. The charts below show the breakdown of containment system types for the ocean-going, small scale LNG fleet, including LNG BVs (ships below 40,000 m^3).

Operational Profile

LNG BVs are specifically designed and built to deliver LNG to other ships at suitable bunkering locations – typically at ports or at anchor. This requires cargo operations to be carefully scheduled to optimize the time between the loading of LNG fuel onto the LNG BV at the terminal and the bunkering operation, in order to limit the amount of idle time for a laden LNG BV.

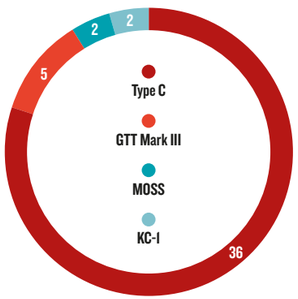
When an LNG BV is idle, the LNG continues to boil inside the CCS, producing BOG, which is normally used onboard to produce energy by means of dual-fuel or gas-fuel engines or boilers. It can also be used to produce electricity in generator sets. There are different ways to handle BOG so as to reduce the pressure and temperature of the cargo tanks. One option is to use boilers to burn excess BOG, however this is rather inefficient, especially if boilers are not producing any energy but instead operating in a closed loop (known as 'steam dump'). Another option may be to use a gas combustion unit (GCU), which burns gas but does not produce energy. The best option may be to install BOG handling systems such as re-liquefaction or sub-cooling. The selection of the onboard CCS has an impact on BOG handling.

One of the key advantages of Type C tanks is that they are usually designed for a service pressure of maximum 5 bar, and the holding time for large Type C tanks until the pressure inside the tank equals the pressure release valve may be more than 30 days. As it is rare for an LNG BV to keep its cargo for longer than 30 days, pressure accumulation can be considered a method of handling BOG with Type C tanks, although it is not the preferred option. In fact, it is not uncommon to see LNG BVs fitted with Type C tanks and also equipped with BOG handling systems. This achieves a higher degree of flexibility and efficiency, while maintaining low temperatures for the cargo. This is particularly important before starting LNG bunkering operations, as the density of LNG will be higher at lower temperatures.

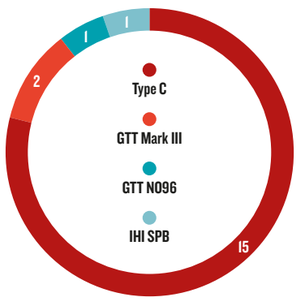
Type A, B and membrane tanks have much lower design pressure (<0.7 bar), which means that holding time is shorter than for Type C tanks with similar capacity, an equivalent ratio between surface and tank volume, and similar insulation performance. Consequently, LNG BVs fitted with these types of tanks will have to also feature (re)-liquefaction or sub-cooling systems to handle BOG, in order to maintain low cargo temperatures, and therefore low pressure.

Today, the vast majority of LNG BVs are equipped with type C tanks. This is hardly surprising, given their pressure capacity and the fact that LNG-fueled ships have lower bunkering requirements. The fact that Type C tanks are built independently, and are subsequently fitted onto the ship, also makes them particularly attractive for shipyards that prefer to have a turnkey scope delivered by a single company. However, as the worldwide fleet of larger LNG-fueled ships increases, thus creating constraints in terms of cargo capacity onboard LNG BVs, it is expected that technologies such as membrane tanks will gain more traction.

CCS fleet by number of ships



CCS orderbook by number of ships



LNG Transfer Systems

The traditional method of LNG transfer used for ship-to-shore operations by means of loading arms is widely used in LNG terminals. Full rigid arms are fitted with rigid insulated pipe sections for pumping LNG to the receiving vessel. Associated couplings, dimensions, communication links – for shore-to-ship and ship-to-shore – are also well known by the different stakeholders involved in these conventional cargo transfer operations.

STS LNG bunkering operations are more recent and therefore have required the development of new transfer technologies to adapt to a new set of challenges.

Safe Transfer

Indeed, a key issue for the assessment of an STS LNG transfer system is the relative motions of the two floating units. Excessive wind conditions will lead to significant wave heights and, consequently, additional stress on the mooring or berthing lines and fender systems (if any). This puts added stress on the transfer system components.

Easy and safe emergency disconnection of the LNG transfer system is therefore essential if harsh conditions emerge. Emergency Release Systems (ERS), such as drip-free, breakaway couplings that give way before any excessive pressure risks damaging the hose, are therefore fitted on transfer systems to ensure safety. Assessment of risk must also include the activation of emergency shutdown and disconnection of the whole system to avoid LNG spill.

Operational Requirements

Besides safety, the operational requirements of an LNG BV also need to be taken into consideration. How will an LNG BV be able to supply clients with variable configurations? What are the compatibility aspects to be considered? What is the transfer rate required for an LNG BV?

Depending on the type of operational profile associated with the LNG BV, communication aspects between the feeder and the receiving ship, and the relevant standardized equipment are key issues to address for the right assessment of the complete transfer system. This will avoid operational issues further down the line.

A full rigid arm enables high flow-rates, which makes them particularly attractive to ship operators who need to maintain short bunkering times. It also requires less handling from the crew, thus reducing the level of risk they are exposed to during bunkering operations. Rigid arms do, however, present the disadvantage of needing more maintenance compared to hoses.

Flexible hoses are more likely to be the transfer system of choice for harbor operations or for transfers in mild environments. However, while they may be easier to maintain, they do require more handling from the crew and take longer to cool down – hence increasing the risks they are exposed to and the transfer time.

Hybrid options, which combine flexible and rigid systems, may also be chosen for additional flexibility.

Ship-to-Ship LNG bunkering to crane vessel, Singapore.

Standards for LNG transfer systems design:

ISO/TS 18683
Guidelines for systems & installations for supply of LNG as fuel to ships

ISO 20519
Specification for bunkering of gas-fueled ships. Superseding the above

ISO 16904
LNG Marine Transfer arms for conventional onshore terminal

ISO 21593
Quick Connect/Disconnect coupling standard (QC/DC) for marine LNG bunkering

PSA Marine's first dual-fuel LNG harbour tug, PSA Aspen, refueling in Singapore.

LNG BUNKERING IN SINGAPORE

Singapore is one of the largest fuel bunkering hubs in the world as a result of its location on several major shipping routes, the efficiency of its bunkering operations, the attractiveness of prices and the availability of products. To be ready and maintain this competitive edge in LNG as fuel, Singapore launched a program in 2015 as a means of testing protocols, safety and operational procedures.

Over the past four years, Bureau Veritas has been closely involved in that ecosystem, firstly by being involved in the development of the national LNG bunkering standard for Singapore.

Bureau Veritas also worked with one of the two licensed LNG providers selected by the Singapore Port Authority (MPA) to provide risk assessments – first for Truck-to-Ship, then for Ship-to-Ship – in order to ensure Singapore's port is as safe as possible for LNG bunkering operations.

To this end, Bureau Veritas organized HAZID and HAZOP workshops with all stakeholders – ship owners, port operators, terminal facility owners, licensed LNG provider – to identify all possible risks, and define safety zones and draft operation procedures. This included the development of Quantitative Risk Assessments (QRA), Operation Procedures and a Joint Operation Plan, which were submitted to and approved by the MPA in 2018 and 2019, respectively. Also in this context, Bureau Veritas participated in the first Ship-to-Ship LNG bunkering operation in Singapore and Southeast Asia, which took place in April 2019 between a small-scale LNG carrier and a large crane vessel.

Finally, Bureau Veritas is also involved in the classification of one of the LNG BV that will operate in Singapore and some of the LNG-fueled ships currently in operation in Singaporean waters (port tugs and an oil bunker tanker; see photo). Bureau Veritas also provides training to several ship operators in Singapore.

SAFETY FIRST

RISK ASSESSMENT FOR BUNKERING VESSELS & OPERATIONS

In addition to standard risk assessment methods for bunkering operations, which focus on the safety of transfer systems, STS bunkering requires taking into consideration additional risks associated with LNG BVs navigating with partial loads and with the ability to carry out SIMOPS.

Sloshing – A Calculated Risk

While some LNG BVs might be designed in connection with one specific project, they are all eventually used to provide LNG bunkering to other types of ships as well.

As such, an LNG BV can provide a certain amount of LNG to one ship, then travel to another area to refuel another ship, carrying on until its LNG cargo is empty, at which point it will travel to a terminal.

Because it is in the owner's financial interest to be able to refuel several ships before having to load again, LNG BVs will cover varying distances at partial load capacity. This leads to sloshing. Sloshing can be defined as the violent behavior of the liquid contents of tanks that are subjected to forceful external motions of the sea.

If the risk of sloshing is not properly addressed, direct consequences will depend on the intensity of impact conditions, which can induce large structural loadings, possibly damaging the CCS, the inner hull and pump mast structures.

Although LNG BVs' tanks are far smaller than LNG carriers', therefore misleading people to believe that the sloshing impact pressures would be lower and less risky, the sloshing loads within LNG BVs can be larger than the ones encountered for standard LNGCs because:

- LNG BVs need to operate at all filling levels (including partial fillings), as opposed to standard LNGCs that are restricted to standard filling operations during navigation.
- The smaller size of LNG BVs results in higher acceleration than that expected for standard LNGCs.

Thus, LNG BVs are potentially subject to heavy sloshing conditions when partially filled. However, proper assessment, calculations and, if required, adjustments to the design of the tank, can address the risks of sloshing.

Bureau Veritas has a methodology to assess loads and determine appropriate design responses, requiring strengthened CCS and reinforcements of the inner hull and pump mast structures. Bureau Veritas does, nevertheless, offer certain flexibility. In the event that, for instance, a given design does not allow for the strengthening of the CCS, Bureau Veritas' sloshing assessment helps define the operational limitations for which all filling operations are feasible (*e.g.,* restriction of operation to a given geographical zone or limitations in terms of Hs).

Bureau Veritas' sloshing assessment, already applied to many LNGC, FSRU, FLNG and LNG-fueled ships projects, is comprised of the following three steps:

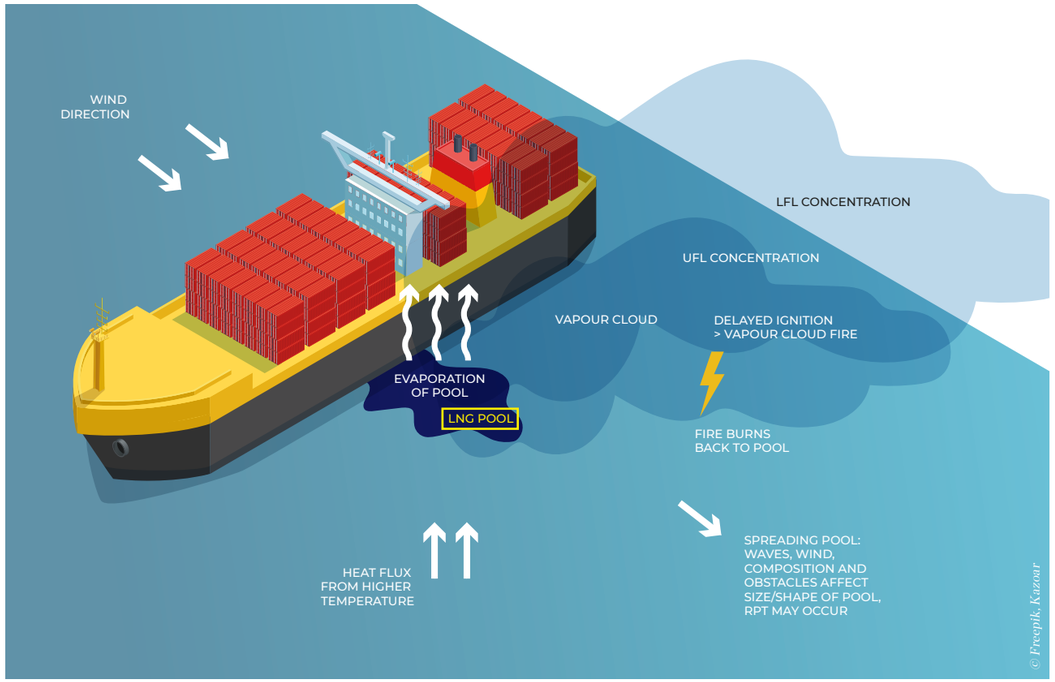
1 • Seakeeping analysis: calculates ship and tank motions. More specifically, this analysis accounts for coupling effects between liquid motions inside the LNG BV tank(s) and the ship's motions.

2 • Sloshing analysis: consists of predicting the maximum sloshing loads an LNG BV will encounter during its life cycle. In addition to sloshing model tests to be submitted by the designer, Bureau Veritas carries out its own CFD calculations for sloshing model test verification and to derive loads for the inner hull and pump-mast strength assessments. These CFD calculations are complementary to model tests. By recording all data at each step, in all cells, CFD calculations provide a total representation of the sloshing impacts on all tank walls.

3 • Applying sloshing loads to the CCS, the inner hull and the pump mast inside the tank, to undergo strength assessment against Bureau Veritas' Rules.

Mitigating Risks for STS Bunkering Operations

The risks inherent to LNG bunkering operations are now well known to all stakeholders involved. The major risk is LNG and gas release during the operation, for which immediate consequences include the potential for a fire, should the gas cloud encounter a source of ignition, and harmful effects on living creatures and metal structures if they come into contact with the cryogenic fluid. Delayed consequences occur if LNG spills into water, turning into a spreading pool and potentially catching fire if a source of ignition is met.



Though accidents can happen, none have been reported since since the earliest LNG projects began (in the 60s) because key industry players (e.g., regulators, operators, class) have worked together to ensure safety around LNG operations.

To support LNG bunkering operations and address the hazards associated with them, standards and guidelines address three main areas of focus:

- Risk Assessment, in particular the determination of Safety Distances, is the first phase of development of safe operations. This includes determining safety distances for different categories of personnel based on acceptable levels of risk, and whether a given location is safe in relation to surrounding activities.
- Operations are the second area of focus. This phase focuses on developing sound operational procedures to enable safe and continuous operations, as well as developing procedures for how to react appropriately if issues emerge.
- The third area of focus is SIMOPS. LNG bunkering should be as seamless as conventional fuel. It should lead to minimum disruptions to the commercial and usual shipboard operations of a ship calling at port. Hence the LNG BV shall be able to operate as part of SIMOPS of the ship being fueled.

In conjunction with the work done by international organizations and class societies, a great deal of effort has gone into the development of national and local standards to address these topics. Bureau Veritas works closely with all stakeholders involved to identify all potential risks associated with LNG bunkering, including the determination of safety zones, the drafting of operational procedures and the permitting and approval process with relevant authorities. Bureau Veritas does so through a suite of risk assessment tools including: HAZID and HAZOP workshops, Quantitative Risk Assessment and SIMOPS assessment.

Case Study

BUILDING THE LNG TRANSITION

CMA CGM JACQUES SAADE AND TOTAL *GAS AGILITY*

CMA CGM JACQUES SAADE *docked right after the start of sea trials. Her green constellation-infused livery underlines the environmental benefits of her natural gas propulsion.*

CMA CGM JACQUES SAADE

THE WORLD'S LARGEST LNG-POWERED CONTAINERSHIP AND THE FIRST WITH A MEMBRANE GAS CONTAINMENT SYSTEM

Bureau Veritas spoke to Xavier Leclercq, Managing Director CMA CGM, about the challenges of conceptualising, designing and building the world's largest LNG-powered containership, the *CMA CGM JACQUES SAADE*, and its associated LNG BV, the *Gas Agility*.

Xavier Leclercq
Managing Director CMA CGM

STEP ONE: A VISIONARY DECISION

The construction and delivery of the *CMA CGM JACQUES SAADE* and its sisterships is a world premiere, and an innovation breakthrough. The success of the project came first from the landmark decision of Rodolphe Saadé to embark the Group on a major program to build a new class of vessels. It is also the product of seven years of research and development efforts. Indeed, LNG applied to shipping existed, but had never been deployed on a container ship of this size. The technology therefore had to be adapted.

STEP TWO: FINDING A PROCUREMENT SOLUTION

The bunkering service played a key role by signing an agreement with Total that was unprecedented in the maritime world: a 10-year contract involving the construction of a barge of sufficient size to supply the 23,000 TEU. Indeed, at the time, the capacity of the largest LNG barges did not exceed 5,000 cubic meters, making the bunkering of our vessels very complicated, even viable.

This agreement is based on the visionary nature of the industrial strategy that CMA CGM has initiated and to which Total has contributed. It is a true testament to the two groups' commitment to making the LNG project a reality.

STEP THREE: DESIGNING THE TANK AND THE ENGINE

The tank and engine are key components of the vessel. The construction of these elements was very delicate because they were completely new for a vessel of this size. This stage required months of adjustments and testing. We were able to count on:

- The long experience of BV, GTT and WARTSILA, to master the fuel gas handling system and to deal with all the challenges encountered during the design and construction period.
- The strong support and experience of the CSSC shipyard in the construction of membrane tanks.
- And finally, WinGD's commitment to develop and build the most powerful DF engine was a major contributor to this success. WinGD and the CMA CGM Group spent a long time optimizing the development and design of the engine.

A HUMAN CHALLENGE...

Finally, beyond the technical aspects, the entire construction was above all a human challenge: it truly required several years of total cooperation and mobilized all the expertise and know-how of all the project partners.

...TO LINK ASIA AND EUROPE

The *CMA CGM JACQUES SAADE* and its sisterships are now ready to link Asia and Europe by considerably improving their environmental footprint and taking the shipping industry's energy transiton to the next level. ●

INNOVATING FOR THE FUTURE

On September 22, 2020, the world's first 23,000 TEU container vessel to be powered by LNG – the *CMA CGM JACQUES SAADE*, named in honor of the Group's founder – officially joined the fleet of CMA CGM Group, a world leader in shipping and logistics. A first-of-its-kind digital naming ceremony marked the event, with shipyard representatives in Shanghai and CMA CGM Group representatives in Marseille sharing this significant moment – at a safe distance.

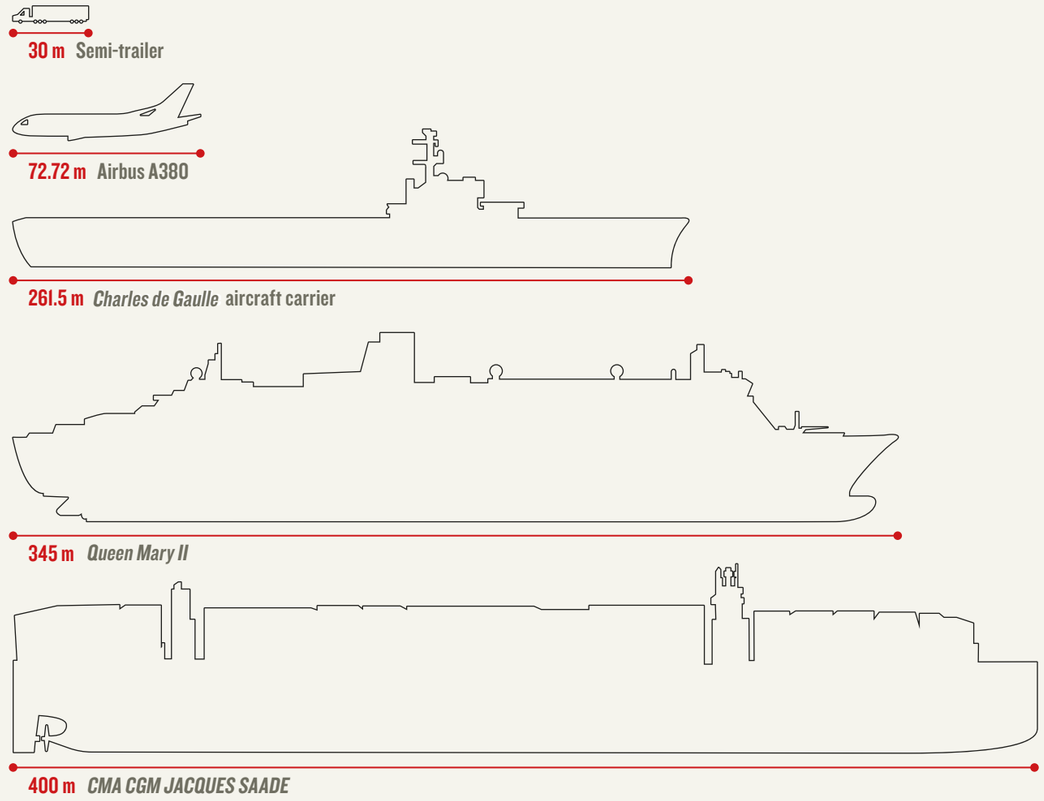
The *CMA CGM JACQUES SAADE* joins the French Asia Line, the Group's most emblematic line between Asia and Northern Europe.

Reflecting the company's ambitions to reach carbon neutrality by 2050, the *CMA CGM JACQUES SAADE*'s innovative design features are a significant step in that direction.

By 2022, CMA CGM Group's fleet will include 26 LNG-powered vessels: nine vessels of 23,000 TEU, eleven vessels of 15,000 TEU, and six vessels of 1,400 TEU.

Other innovative steps are also being taken by CMA CGM Group to move forward in this ambition. In 2019, the Group's containerships *CMA CGM White Shark* and *CMA CGM Alexander Von Humbold*t successfully tested the use of marine biofuel. The *CMA CGM White Shark* completed a round trip between Europe and North America fueled by biofuels made from cooking oil and logging industry residue. In addition to these successful trials, the CMA CGM Group is also exploring the potential of several technologies such as wind-assisted powering or hydrogen engine. The Group's experts are convinced that the solution to the challenges of energy transition will be a mix of technologies. ●

SOME PERSPECTIVE



CMA CGM JACQUES SAADE's Major Innovative Features

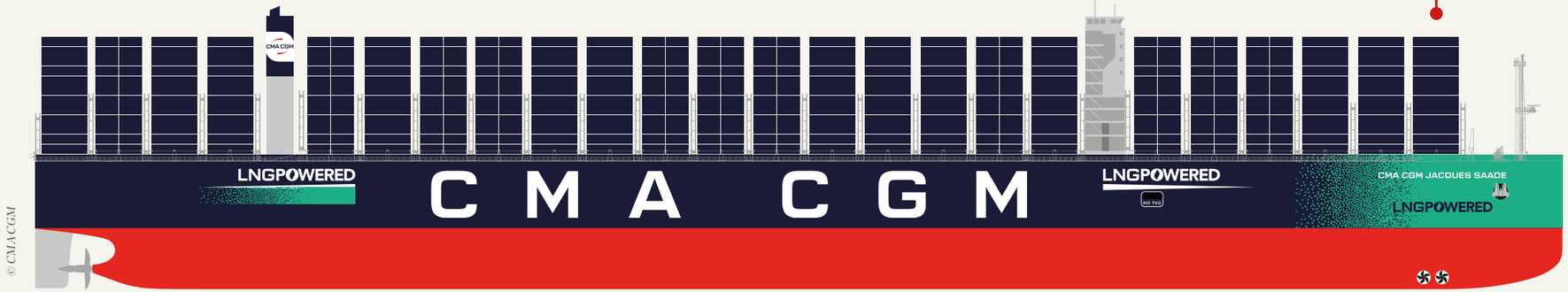
10 m
DIAMETER OF THE PROPELLER

A 100% Digitalized Platform

The vessel's cockpit brings together embedded technologies that drive the industry into the shipping 4.0 era:
- Ultra modern augmented reality screens for active shipping briefing and a perfect vision of navigation maps;
- A system that predicts the vessels exact location in the upcomig 3 minutes to facilitate the docking manoeuvers;
- The "smart-eye" is a set a cameras enabling a 360° visualization of the vessel.

Large Capacity

The *CMA CGM JACQUES SAADE* is the world's largest containership, capable of embarking 23,000 TEU. On October 12th, 2020, on its first call at the port of Singapore during its maiden voyage, she broke a new world record with 20,723 full containers loaded onboard.

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LNG Tank

Marking one of many firsts for this type of vessel, the *CMA CGM JACQUES SAADE* was built with an 18,600 m^3 stainless steel GTT Mark III containment tank. Tank insulation construction lasted approximately nine months and required high levels of technical expertise.
First, a thermal cocoon was manufactured to maintain the natural gas at –161°C, allowing it to remain in its liquid state and thereby occupy 600 times less space than in its gaseous states. Two layers of insulation and a second membrane further envelop the tank and are equipped with very high-tech sensors to ensure that LNG storage conditions remain optimal and meet all safety requirements. The capacity of the tank has been calculated to enable the ship to undertake a full round trip between Asia and Europe.

Optimized Design

The bulb of the vessel has been seamlessly integrated into the hull profile, while the bow is straight and tapered, improving hydrodynamics. At the back, the propeller is equipped with an innovative BECKER™ TWISTED FIN system, which optimizes water flow and significantly reduces energy consumption. These new design features greatly optimize the vessel's performance and contribute to a 4% reduction in CO_2 emissions.

23,000 TEU
VESSEL CAPACITY

63,840 kW
ENGINE POWER

CMD-WinGD
12X92 DF

18,600 m^3
TANK CAPACITY

"The bunkering service played a key role by signing an agreement with Total that was unprecedented in the maritime world: a 10-year contract involving the construction of a barge large enough to supply the 23,000 TEU."

Xavier Leclercq
Managing Director CMA CGM

The CMA CGM JACQUES SAADE has completed her first LNG bunkering with the LNG BV Gas Agility, chartered by Total, on 13th November, 2020 at the Port of Rotterdam in the Netherlands. The 23,000 TEU containership received around 17,300 m³ of LNG, making it the largest LNG bunkering operation to ever take place.

TOTAL'S *GAS AGILITY* NEXT GENERATION LNG BUNKERING VESSELS

Total has made natural gas a cornerstone of its strategy to meet the growing global demand for energy while helping to mitigate climate change.

Total's bunkering arm, Total Marine Fuels Global Solutions (TMFGS), is the charterer of two LNG BVs with 18,600 m³ storage capacity each. One, based in Rotterdam, will supply CMA CGM's 23,000 TEU ultra large containerships deployed on Asia-Europe routes. The second, to be based in Marseille, will serve CMA CGM's series of smaller 15,000 TEU LNG-powered ships. Both vessels will also be available to bunker other customers such as cruise ships, tankers, bulk carriers and ferries in the growing global fleet of LNG-fueled ships.

Bureau Veritas spoke to Fabiola Hernandez, HSEQ and Technical Director for Total, and Luc Descleves, the Total Project Manager on site in Shanghai, about working on the largest LNG BV vessels ever ordered.

—

TOTAL WORKED ON THE FIRST LNG BV PROJECT OF ITS KIND. WHAT MADE THIS PROJECT PARTICULARLY SPECIAL?

This was a project of many 'firsts' for all partners involved! It was the first LNG BV built by MOL, the first one chartered by Total, the first one built by the shipyard with a Mark III Flex technology from GTT. For Total, this first vessel is also a pioneer for one of our core values: to be the first company to build and charter a bunker vessel whose dimensions are closer to those of a small LNG carrier (18,600 m³) and that can safely deliver LNG as a marine fuel.

The way we organized ourselves to manage this project was also key. TMFGS could rely on its integrated model and in-house experts in shipping and LNG, on the expertise of a very experienced ship owner like MOL, as well as on a skilled shipyard which was very keen to show its capabilities in building membrane LNG carriers. In addition, to ensure close communication between the ship owner and the shipyard, two staff members from Total with complementary skills (one naval architect and one former LNG carrier seafarer) were mobilized to accompany the MOL's on site team, working hand-in-hand with them. We were also able to benefit from the fact that both the LNG BV and the client vessels were built in the same shipyard. Regular meetings were put in place to create fluid and efficient communication with our client, CMA CGM, to ensure compatibility with their LNG-powered container vessels.

Total worked so closely with many partners from the very early stages of a project, from concept the way through to delivery.

—

COULD YOU TELL US MORE ABOUT CMA CGM'S SPECIFIC REQUIREMENTS FOR THESE VESSELS - WHAT MADE THEM SO UNIQUE?

The underlying requirement was to ensure that bunkering operations for the world's largest LNG-fueled containership would be as efficient as possible. To this end, the project partners worked together to remove as many constraints from container operations as possible and allow for SIMOPS.

Another key requirement was the capacity of the first vessel. It was essential that the newly built LNG BV be capable of delivering the full LNG capacity of 23,000 TEU containerships in a single bunkering operation.

The project partners also decided to install a Mark III Flex membrane system from GTT instead of the usual Type C tanks installed in most LNG BVs built and ordered to date. This decision was driven by the need to optimize the tank volume/ship length ratio, as well as the BOG management. This enables LNG saturation pressure to remain as low as possible, and increases LNG BV flexibility, allowing bunkering for all type of vessels, regardless of their cargo containment system.

Finally, we wanted to ensure that these two innovative LNG BVs could be used to bunker other clients' vessels, and that there were no major constraints that would make LNG bunkering operations inefficient.

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WHAT WERE THE KEY CHALLENGES FOR THE DELIVERY OF SUCH AN INNOVATIVE PROJECT, AND WHAT WERE THE LESSONS LEARNED?

As we already said, LNG BVs of this size and capacity, with a membrane tank, are really a first on many levels. This means that all partners had limited experience and were continuously learning from each other as the project progressed.

At Total, for instance, we normally build on feedback from other projects to improve processes.

However, this time, we had no experience to build on. Similarly, it was the first time that the shipyard, Hudong-Zhonghua Shipbuilding had integrated a Mark III membrane system on a cargo design, even though they have significant and proven experience in building gas carriers.

We also had to work with a regulatory framework – guidelines, industry standards and rules for LNG bunkering – that is still in its relatively early stages. Because it was still evolving as the project was progressing, it required high levels of flexibility from all partners in order to ensure that the ships and their STS equipment were built according to the right standards.

We found that the best way to overcome these challenges was to work closely together with our partners and, for all of us, having staff members permanently based at the shipyard truly facilitated communication. This proved essential and highly beneficial, because the team could continuously monitor issues and challenges, tackling them as they came along on the first vessel and ensuring they were not repeated during the (parallel) construction of the second vessel.

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COULD YOU PLEASE TELL US MORE ABOUT HOW BUREAU VERITAS ASSISTED YOU IN THIS PROJECT?

Having Bureau Veritas members on site really made the difference in terms of assistance throughout the project to help us understand and adapt to the regulatory framework.

Bureau Veritas Solutions - Marine & Offshore (BVS) also organized and facilitated the risk assessments workshops (HAZID/HAZOP) and SIMOPS. This got all project partners and stakeholders together in the same room to discuss all possible risk scenarios and the mitigation measures in place. Participants also developed the scenario that defines the necessary safety distance for carrying out safe bunkering operations in parallel with the commercial operations of client vessels.

Most of Total's time-chartered LNG carriers are classed by Bureau Veritas upon our request. It greatly helped that CMA CGM had the same strong relationship with Bureau Veritas. Having a long-standing relationship based on trust and common experience facilitated dialogue, openness and learning, so that any challenges or issues could be resolved swiftly and cooperatively.

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HOW DO YOU SEE TOTAL'S ROLE EVOLVING IN THE LNG BUNKERING MARKET, AND MORE BROADLY IN LOW CARBON FUELS FOR SHIPPING?

LNG BVs fit very clearly into Total's new climate ambition. Beyond the LNG bunkering activity developed by TMFGS, in April 2020, the shipping arm of the Group signed a pioneering agreement to charter its first two LNG-powered Very Large Crude Carriers (VLCC). In June 2020, Total also joined the Getting to Zero Coalition. This coalition supports the maritime industry's decarbonization by collaborating with companies across the maritime, energy, infrastructure and finance sectors. Finally, in July 2020, Total, along with ten other international groups, created the Coalition for the Energy of the Future. This group "aims to accelerate the development of energy sources and technologies to address the challenges posed by sustainable mobility in the transport and logistics industry by reducing emissions, fighting global warming and protecting biodiversity".

All these steps demonstrate that Total is not just interested in developing the energy of the future. It is interested in doing so in partnership with other international groups which share the same goals and values. These goals are very ambitious, and it is only by working together with peers, partners and customers that we can make them happen. ●

Fabiola Hernandez, HSEQ and Technical Director for Total

Luc Descleves, Total Project Manager, on site in Shanghai

PARTNERING FOR A SUSTAINABLE FUTURE

CSSC HUDONG – BUILDING THE *CMA CGM JACQUES SAADE*

© OpenSource

Hudong-Zhonghua Shipbuilding (Group) Co., Ltd. is one of the major shipbuilding enterprises under the flag of China State Shipbuilding Corporation (CSSC). It has extensive expertise in engineering, construction and R&D for a wide range of ships. This includes over 3,000 vessels, such as LNG carriers, LPG carriers, medium- and large-sized container vessels, chemical tankers, Ro/Ro ships, oil tankers, bulk carriers, passenger ships, special purpose vessels, battle ships, auxiliary naval ships, for numerous shipping companies and navies all over the world.

CSSC Hudong was selected by CMA CGM Group to build the *CMA CGM JACQUES SAADE*, which is the first of a series of nine 23,000 TEU LNG-powered container ships.

— COULD YOU PROVIDE SOME INSIGHT INTO THE BENEFITS OF WORKING WITH BUREAU VERITAS, THE CLASSIFICATION LEADER IN THE LNG BUNKERING VESSEL SECTOR?

Working with Bureau Veritas has been very beneficial to us for this project. Their strong experience with LNG carriers and LNG bunkering ships has proven useful on many occasions. Building a ship prototype is always quite challenging and Bureau Veritas' support and assistance throughout the whole process was much appreciated while coping with unexpected difficulties.

— HOW HAVE BUREAU VERITAS' SITE PLAN APPROVAL TEAM AND RULES SUPPORTED THE DESIGN DEVELOPMENT?

We have received strong support from the local team in order to ensure swift approval of the drawings and anticipate possible issues. Project management on Bureau Veritas' side has also been very helpful in order to ensure smooth communication between the numerous parties involved in such a project (various Bureau Veritas approval offices, shipyard, owner, charterer, equipment makers, etc.). The development of such LNG bunkering solutions also requires a number of highly technical studies (risk assessment, gas dispersion, etc.) to which Bureau Veritas' expertise has also brought much value.

— PLEASE DESCRIBE HOW BUREAU VERITAS' SITE TEAMS HELPED DURING CONSTRUCTION, PARTICULARLY IN TERMS OF ENSURING THE QUALITY OF ALL SYSTEMS AND SHARING GAS CONTAINMENT EXPERTISE.

Our shipyard has strong expertise with NO96 membrane containment systems, but the application of Mark III was novel to us. The combination of our experience, together with Bureau Veritas' site team expertise on Mark III, was key to the success of this project. Close cooperation from early stages (*e.g.*, qualifications of welders & bonders) until the very last stages (*e.g.*, final tests) ensured the highest possible quality for these tanks.

This vessel has been the first Bureau Veritas classed vessel delivered from our shipyard in a while. It has been a success, and there are certainly many more to come: a second similar bunker vessel is already under construction, as well as the well-known dual-fuel container vessels. We hope for further, long-term, equally rewarding cooperation. ●

GTT – THE FIRST MEMBRANE TANK IN AN LNG BV

GTT is a world-wide reference technology and engineering company in containment systems for the shipping and storage of LNG in cryogenic conditions. The company shared with Bureau Veritas its experience working on the construction and fitting of the first membrane tank for an LNG BV.

In many aspects, this vessel is a first-of-its-kind, being the largest operating LNG BV in the world, the first membrane bunker vessel validated for worldwide navigation without any filling restrictions, the first application of Mark III Flex (one of GTT's proprietary technologies) with High Density polyurethane foam, and the first construction of Mark III vessel in China. The good cooperation and smooth exchanges between Bureau Veritas and GTT since the very beginning of the concept stage have been key to the ultimate success of this project.

Membrane CCS are installed directly onto the inner hull of the vessel, allowing a maximum utilization of available cargo space and offering the LNG BV unmatched thermal performance and compacity[1], combined with high maneuverability and low fuel consumption.

The challenge of wider tanks at partial fillings with higher liquid motions and sloshing loads were overcome by combining Bureau Veritas approved numerical methods and intensive liquid motion test campaigns in GTT's unique laboratory. This led to the optimized choices of pump tower sizing and CCS reinforcement.
The LNG BV was optimized from the earliest stage, leading to a low boil-off rate while ensuring all filling capability whatever the navigational area.

During this project, Hudong Zhonghua relied on Bureau Veritas and GTT to perform risk analyses for bunkering operations, resulting in safe and optimal methodology. In this respect, GTT engineers developed a tailor-made system for preventing rollover and an adapted Cargo Handling design for special operations onboard the LNG BV and also for the maintenance of LNG-fueled ships (*e.g.*, assistance during commissioning or decommissioning operations).
All these studies led to an excellent multi-purpose vessel, which can be used as both "a filling station" as well as a "garage" for clients.

Fitted with a membrane CCS, the *Gas Agility* will be operated at a low saturated pressure in the cargo tanks, giving the crucial advantage of delivering cold LNG[2], as requested by major LNG-fueled ship owners and charterers. Cold LNG enables faster bunkering operations, whatever the containment system of the receiving vessel. Moreover, membrane CCS have the intrinsic characteristic of maximizing delivered LNG volume, with the highest authorized loading limit and the lowest heel requirement, as there is no structural need to maintain empty tanks cold.

This vessel highlights a market shift towards larger bunker capacity, with no less than five LNG BV above 18,000 m³ currently in operation or under construction[3]. Benefiting from decades of expertise in LNG and thousands of cumulated years of membrane tank operations without loss of integrity, a membrane LNG BV can rely on GTT support at every phase of vessel life, from pre-design to operations.

GTT is proud to be part of this project, bringing the shipping industry towards a more sustainable future. ●


© Patrick Sagnes

GTT's laboratory where tests are carried out on small tank models (hexapods) to calculate sloshing.

(1) Compacity is a measure of compactness: the volume fraction that is filled within a medium.
(2) 'Cold LNG' means LNG at a low equilibrium temperature for a given pressure. The lower the LNG pressure, the lower its equilibrium temperature.
(3) As of September 2020.

MITSUI O.S.K. LINES (MOL)
BUILDING THE *GAS AGILITY*

MOL is a global shipping company working across a wide variety of fields. These include dry bulkers such as iron ore, coal, and woodchip carriers, crude oil tankers, LNG carriers, car carriers, and containerships.

Bureau Veritas spoke to Yoshihiko Sugimoto, Deputy General Manager, Technical Division, Technology Innovation Unit at MOL, about the challenges of building the first LNG BV of its size.

— COULD YOU PROVIDE SOME INSIGHT INTO THE CHALLENGES OF BUILDING THE FIRST LNG BV PROJECT OF THIS KIND?

This was indeed a project of many firsts. It had a new design, which included membrane tank technology being fitted for the first time onboard an LNG BV. The short construction period from contract to delivery was also a challenge, as we had to ensure that the *Gas Agility* would be ready at the same time as the *CMA CGM JACQUES SAADE*. This meant that for Hudong, and everyone else involved in this project, there was a steep learning curve.

We also had to learn how to properly and safely connect the LNG bunkering transfer system from the LNG BV to the LNG-fueled ship. This is something we had never done before, and it was important to get it right before the first real LNG bunkering operation, which is due to take place in November, and which needs to run as smoothly as possible.

© MOL

Teams at the shipyard test how to safely connect and disconnect the hose on the LNG BV.

— COULD YOU TELL US HOW YOU OVERCAME THESE CHALLENGES AND HOW INSTRUMENTAL BUREAU VERITAS WAS IN THE PROCESS?

Bureau Veritas' expertise in small-scale LNG carriers and bunkering vessels was key to helping us overcome these challenges. We invited Bureau Veritas' team to our weekly meetings so that they would be able to keep track of our progress and help us immediately if we ran into any problems.

The HAZID/HAZOP workshops performed by Bureau Veritas Solutions – Marine & Offshore were also extremely helpful. They allowed us, along with all our partners, to identify any potential risk to bunkering operations between the two vessels. They were also instrumental in helping us understand the order of operations for STS bunkering, including how to safely connect and disconnect the hoses.

Additionally, the fact that both ships were being built in the same shipyard was very convenient for two reasons.

Firstly, because construction of the Mark III membrane tank for the *CMA CGM JACQUES SAADE* began before construction of the *Gas Agility*, allowing us to benefit from experience and learn much faster than we otherwise would have. Secondly, it allowed us to carry out STS and interface connection demonstrations for bunkering operations between the two ships, teaching us how to best connect and disconnect the bunkering transfer system.

— GAS TRIALS TOOK PLACE IN MARCH, DURING THE PEAK OF THE COVID-19 HEALTH CRISIS IN CHINA. COULD YOU TELL US MORE ABOUT THE MEASURES YOU TOOK TO ENSURE THE SAFETY OF EVERYONE WORKING ON THE TRIALS?

Yes, this was a nightmare for us all. Back in March, the Covid-19 situation was critical in China; infections were at their peak. While representatives of the equipment manufacturers could remotely attend the sea trial, some degree of physical presence was also necessary. We could not afford to wait for the number of cases to go down before carrying out gas trials, so we had to put in place very strict safety measures.

Everybody was in full protective gear: we all wore caps, glasses and masks. We were also not allowed to eat in the shipyard's canteen. Instead, for each meal we had to first have our temperature taken by the doctor on site, who would give us our meal ticket if we had no temperature. We would then have to go to our cabins and eat alone.

These measures were very stressful for everyone, but they proved very efficient on all counts. No one got infected and we were able to carry out gas trials as planned.

— WITH SO MANY FIRSTS CAME MANY LESSONS. HOW WILL THIS BENEFIT OTHER PROJECTS?

A second LNG BV is currently under construction, so we will apply all the lessons learned from the *Gas Agility* to the construction stage.

For instance, on the first vessel, we had some issues related to the procedure and application method of wash primer to the cargo hold's steel panels. The mastic ropes that support the CCS insulation panels for the wash primer did not initially adhere correctly to the limited area. We will seek to make sure this does not happen with the second LNG BV.

We are also continuously in touch with the ship manager of the *Gas Agility* to get his feedback on operations. This enables us to make improvements to the second ship and address any potential issues.

Another LNG BV ordered by MOL is also currently under construction at SEMBCORP in Singapore. This new ship, to be chartered by Pavillion Energy, will also feature Mark III membrane tank technology, with a capacity of 12,000 m^3. We regularly attend meetings between all parties involved in the *Gas Agility* project to get feedback about their experience building LNG BVs with membrane tanks and apply any lessons learned to our own work. ●


© MOL

Project site team representatives inside the Gas Agility's Mark III Flex membrane tank during construction during construction in the Hudong Zhonghua shipyard.

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GTT
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Artistic Direction
KAZOAR AGENCY

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Cover photo credits

Bureau Veritas experts inspect the GTT Mark III tank during the construction of the CMA CGM JACQUES SAADE, *the first 23,000 TEU containership in the world to be powered by LNG*

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