Finding the right balance
The evolution of marine LNG has been defined by creativity, particularly when it comes to containment and propulsion. The relationship between the two is significant. How do you find the right balance between retaining cargo and consuming boil-off? How do you most efficiently allow for flexibility in charter markets so that, for example, a ship can change routes and terminals to adapt to a new operating pattern?

In the early days, when ships were contracted for long periods (typically 20-25 years), they were tailor-made for specific routes: ship speed, voyage duration and quantity of landed cargo were pre-determined. But today, more speculative orders covered by relatively short-term charter contracts are seeing a demand for greater built-in flexibility related to size, propulsion systems and cargo management.

At Bureau Veritas, this demand for flexibility is where our experts focus a lot of their time, helping clients find the right solutions and addressing the related safety, regulatory and risk aspects.

The emergence of membrane systems as the dominant technology

After the early prototype containment technologies, two dominant families rapidly emerged the French membrane-type containment systems developed by Gaz Transport and by Technip and the self-supporting type ‘B’ containment systems developed by the Norwegian company Moss Maritime and the Japanese IHI Group. Today, the merger of the two French companies – GTT – dominates LNG containment, with variants of the NO96 and Mark III membrane systems installed in most ships being built and entering operation.

Evolution to 2-stroke slow speed propulsion

The evolution from steam turbine ships, to dual fuel diesel electric (DFDE) ships and, now, 2-stroke dual fuel powered ships has been relatively quick and has delivered significant advances in efficiency. But the search for optimal systems continues and the key issue remains the relationship between propulsion and containment. For example, do you need a re-liquefaction plant? Or can you manage without one? The market continues to expand and demand for cleaner fuels is increasing. There are some big orders for LNG carriers in prospect, and small-scale LNG is taking off. So, there are some big decisions to be made.

BV will always be there to help stakeholders make the best safety and commercial decisions based on the best technical insight, as the exciting LNG sector continues to evolve.
The BV teams involved in the Yamal LNG project have dedicated their expertise to every stage – from the initial discussions, through plan approval and construction to, now, the ships’ operational lives.

BV had been involved with a wide variety of Arctic projects for well over two decades, but this project presented the BV and RS teams with fresh challenges. Each ship was to be equipped with technologically advanced azimuth propulsion (3 units of 15MW each), high winterization levels and a hull reinforced to Polar Class 3 level (equivalent to ARC7 of the Russian Maritime Register of Shipping, RS). The ships’ size (at 299m in length and 50m beam) for a cubic cargo capacity of 172,000 cu. m required that they be fully autonomous in ice.

So, providing assurance that the project risks could be effectively addressed was vital. The podded propulsion, structure, containment, winterization aspects and issues related to vibration all had to be addressed, and their interdependencies had to be recognized and understood. BV had an excellent working relationship with the Russian Register, whose ice expertise, combined with BV’s structures and gas leadership, were vital. Testing at Aker Arctic’s ice towing tank was a key area of activity.

The project has been a massive undertaking, and there has been excellent feedback on the classification aspects from both the yard and the owners, and on the close and effective cooperation between RS and BV.

“The BV teams involved in the Yamal LNG project have dedicated their expertise to every stage – from the initial discussions, through plan approval and construction to, now, the ships’ operational lives.

BV had been involved with a wide variety of Arctic projects for well over two decades, but this project presented the BV and RS teams with fresh challenges. Each ship was to be equipped with technologically advanced azimuth propulsion (3 units of 15MW each), high winterization levels and a hull reinforced to Polar Class 3 level (equivalent to ARC7 of the Russian Maritime Register of Shipping, RS). The ships’ size (at 299m in length and 50m beam) for a cubic cargo capacity of 172,000 cu. m required that they be fully autonomous in ice.

So, providing assurance that the project risks could be effectively addressed was vital. The podded propulsion, structure, containment, winterization aspects and issues related to vibration all had to be addressed, and their interdependencies had to be recognized and understood. BV had an excellent working relationship with the Russian Register, whose ice expertise, combined with BV’s structures and gas leadership, were vital. Testing at Aker Arctic’s ice towing tank was a key area of activity.

The project has been a massive undertaking, and there has been excellent feedback on the classification aspects from both the yard and the owners, and on the close and effective cooperation between RS and BV.

“During the course of the history making Yamal ARC7 LNGC project, there were tremendous challenges and obstacles when developing & building the World’s 1st ARC7 LNG carrier. However, upon her completion she has successfully proven herself to be an outstanding shipping solution in the Arctic and Northern Sea Route all the year round.

Over a number of decades, BV has been one of DSME’s most reliable and trustful partners and we could not imagine our great achievements on the Yamal LNGC project without BV’s dedication and professional expertise.

We strongly believe that BV and DSME will build upon such fruitful collaboration on other valuable projects and deepen our win-win partnership for many years to come:”

Dae Seong JUNG, Executive Vice President, Head of Production Business Unit, DSME

“The BV teams involved in the Yamal LNG project have dedicated their expertise to every stage – from the initial discussions, through plan approval and construction to, now, the ships’ operational lives.

BV had been involved with a wide variety of Arctic projects for well over two decades, but this project presented the BV and RS teams with fresh challenges. Each ship was to be equipped with technologically advanced azimuth propulsion (3 units of 15MW each), high winterization levels and a hull reinforced to Polar Class 3 level (equivalent to ARC7 of the Russian Maritime Register of Shipping, RS). The ships’ size (at 299m in length and 50m beam) for a cubic cargo capacity of 172,000 cu. m required that they be fully autonomous in ice.

So, providing assurance that the project risks could be effectively addressed was vital. The podded propulsion, structure, containment, winterization aspects and issues related to vibration all had to be addressed, and their interdependencies had to be recognized and understood. BV had an excellent working relationship with the Russian Register, whose ice expertise, combined with BV’s structures and gas leadership, were vital. Testing at Aker Arctic’s ice towing tank was a key area of activity.

The project has been a massive undertaking, and there has been excellent feedback on the classification aspects from both the yard and the owners, and on the close and effective cooperation between RS and BV.

“During the course of the history making Yamal ARC7 LNGC project, there were tremendous challenges and obstacles when developing & building the World’s 1st ARC7 LNG carrier. However, upon her completion she has successfully proven herself to be an outstanding shipping solution in the Arctic and Northern Sea Route all the year round.

Over a number of decades, BV has been one of DSME’s most reliable and trustful partners and we could not imagine our great achievements on the Yamal LNGC project without BV’s dedication and professional expertise.

We strongly believe that BV and DSME will build upon such fruitful collaboration on other valuable projects and deepen our win-win partnership for many years to come:”

Dae Seong JUNG, Executive Vice President, Head of Production Business Unit, DSME

“The BV teams involved in the Yamal LNG project have dedicated their expertise to every stage – from the initial discussions, through plan approval and construction to, now, the ships’ operational lives.

BV had been involved with a wide variety of Arctic projects for well over two decades, but this project presented the BV and RS teams with fresh challenges. Each ship was to be equipped with technologically advanced azimuth propulsion (3 units of 15MW each), high winterization levels and a hull reinforced to Polar Class 3 level (equivalent to ARC7 of the Russian Maritime Register of Shipping, RS). The ships’ size (at 299m in length and 50m beam) for a cubic cargo capacity of 172,000 cu. m required that they be fully autonomous in ice.

So, providing assurance that the project risks could be effectively addressed was vital. The podded propulsion, structure, containment, winterization aspects and issues related to vibration all had to be addressed, and their interdependencies had to be recognized and understood. BV had an excellent working relationship with the Russian Register, whose ice expertise, combined with BV’s structures and gas leadership, were vital. Testing at Aker Arctic’s ice towing tank was a key area of activity.

The project has been a massive undertaking, and there has been excellent feedback on the classification aspects from both the yard and the owners, and on the close and effective cooperation between RS and BV.

“During the course of the history making Yamal ARC7 LNGC project, there were tremendous challenges and obstacles when developing & building the World’s 1st ARC7 LNG carrier. However, upon her completion she has successfully proven herself to be an outstanding shipping solution in the Arctic and Northern Sea Route all the year round.

Over a number of decades, BV has been one of DSME’s most reliable and trustful partners and we could not imagine our great achievements on the Yamal LNGC project without BV’s dedication and professional expertise.

We strongly believe that BV and DSME will build upon such fruitful collaboration on other valuable projects and deepen our win-win partnership for many years to come:”

Dae Seong JUNG, Executive Vice President, Head of Production Business Unit, DSME
BV works with RS to benefit Arctic LNG transportation

Classification societies BV and RS can look back on a long cooperation in the classification of the cutting edge Yamal gas carrier fleet. RS with its ice class expertise and hands-on experience in membrane LNG containment systems designed for ice-going ships and BV with the long experience in all types of containment systems and LNG carrier innovation have been closely in partnership for the Yamal LNG newbuilding program.

The series of 15 state-of-the-art Arc 7 Yamal LNG carriers, along with two Arc 7 condensate tankers, under construction at DSME has been a primary focus area for the joint efforts of BV and RS dual class.

A further joint project is an LNG bunker vessel under construction at Keppel Nantong shipyard. The BV-RS dual class arrangements feature a practical combination of strong expertise and specific knowledge to consolidate added value for high-technology projects for the benefit of all involved.

Sovcomflot: a shipowner’s perspective on a good partnership

In 2017, Sovcomflot took delivery of Christophe de Margerie, the first icebreaking LNG carrier ever built. Working on this pioneering vessel proved to be an excellent example of cooperation set by Sovcomflot, the ship-owner, together with DSME, the shipyard, and the class societies BV and RS.

From the moment of her delivery two years ago to today, the vessel has performed exceptionally, even when operating in challenging ice conditions. In 2018, SCF placed orders for three conventional 170,000-cbm LNG carriers at DSME with BV as class. Officers working onboard Sovcomflot’s LNG carriers undergo mandatory extensive in-house training at a corporate training centre in St. Petersburg. This centre is equipped with a state-of-the-art LNG operations simulator certified by BV.

A distinguished paint job: the LNG carrier Christophe de Margerie, the first of the Yamal ARC7 ships to be delivered, named after the former CEO of TOTAL who was known for his big mustache.

BV LNG and ice class expertise combine again in the classification of Ponant’s innovative icebreaking LNG-hybrid polar expedition cruise ship, Le Commandant Charcot, due for delivery in 2021.

A more recent star project in the world of LNG-fuelled ships is the Ponant icebreaker – the world’s first LNG-powered, hybrid-electric passenger vessel to navigate through polar waters (see picture below). The ship’s innovative design – Polar Class 2 surpasses Polar Code regulations for environmental protection and provides unparalleled ice-breaking ability. Projects like the Arctic LNG-2 will soon be sanctioned and will need additional LNG carrier capacity. BV is ready, and has the expertise, to support the project stakeholders to meet the safety and pollution prevention requirements.

A distinguished paint job: the LNG carrier Christophe de Margerie, the first of the Yamal ARC7 ships to be delivered, named after the former CEO of TOTAL who was known for his big mustache.
THE KEY CHALLENGE TODAY - LNG CARRIERS AS A GLOBAL SYSTEM
MATCHING CONTAINMENT AND PROPULSION
WITH SUPPORTING EQUIPMENT

Technical developments have helped the LNG carrier industry to evolve very rapidly in recent years. Cryogenic cargo containment system evolution, new engines and re-liquefaction systems have been at the core of recent developments to respond to charterers’ and shipowners’ needs.

The main operational challenge is the right combination of these systems on board. The operating profile of the modern LNG carrier has changed – flexibility is now key, with ships calling at different loading and offloading terminals and requiring high fuel and energy efficiency. Having the right equipment on board is vital for all stakeholders.

Containment systems
Containment systems commonly used for large LNG carriers, such as GTT Membrane and Moss type B systems, have evolved significantly. The boil-off rate guaranteed by the developers of the systems has been reduced by half, from values typically in the range of 0.15% of the tank volume per day in laden condition, to values as low as 0.07%.

New technologies such as dual fuel and gas-only engines, were developed in the early 2000s and implemented for the first time on LNG carriers when the first ship with dual fuel diesel electric propulsion, GDF Suez Global Energy, was delivered early in 2016, and the first Winterthur Gas & Diesel X-DF engines on the SK AUDACER eighteen months later. These new dual fuel engines also allow different fuels to be used, offering additional flexibility in terms of fuel cost-optimization.

Re-liquefaction technology
Re-liquefaction equipment has been widely used in LPG and LEG carriers, but the technology is more complex when charters and owners want to be able to re-liquefy LNG boil-off gas. This demand for fuel flexibility has driven leading companies such as Wartsila, Cryostar, Air Liquide and Babcock to develop a second wave of re-liquefaction systems, which are being installed in most of the new LNG carrier projects today.

The question of boil-off
The ideal LNG carrier is designed not to waste gas – this means the total system is designed to avoid producing either too much boil-off or too little.

If the boil-off rate is higher than required by the ship then there are two options: either re-liquefy with a re-liquefaction plant or burn the excess in a gas combustion unit (GCU).

If the boil-off rate is too low then either boil-off must be forced to produce fuel for the ship or fuel oil must be used as an alternative.

Traditionally this balance relies on a known speed and distance for the laden leg. Today, with shorter charters becoming the norm – or even spot chartering – a factor there is demand for ships that can operate efficiently with different operating criteria.

The table compares the boil-off rates and fuel consumption of the three main ship architectures in use today. The 2-stroke, low consumption and low boil-off ships being delivered today, are significantly more competitive than previous generation LNG carrier tonnage.

<table>
<thead>
<tr>
<th>Propulsion</th>
<th>Typical size '000K</th>
<th>Cargo-Containment System (CCS)</th>
<th>Boil-off rate (BOR)</th>
<th>Approximate daily fuel consumption (tons) at a design speed of 19.5 knots</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam*</td>
<td>130-140</td>
<td>0.15%</td>
<td>150-160</td>
<td></td>
</tr>
<tr>
<td>DFDE</td>
<td>155-175</td>
<td>0.1%-0.125%</td>
<td>120-130</td>
<td></td>
</tr>
<tr>
<td>DF 2-stroke*</td>
<td>170-180</td>
<td>0.05%-0.085%</td>
<td>90-100</td>
<td></td>
</tr>
</tbody>
</table>

*Modern steam turbine LNG carriers are larger (170-180K) and have a reduced BOR (0.1%) with DFDE propulsion systems. Their fuel consumption is in the range of 120 tons/day.

**The notable exceptions are the fuel oil powered Q-Flex and Q-Max ships developed for Qatar Gas.

Cargoes focus – GTT systems: constant development
BV is closely involved with containment system developers, assessing their different designs. Assessment is based on the IMO IGC Code and class regulations, which cover the safety aspects to be considered for approval of the technologies.

Table 1 – The three main ship architectures trading today, clearly demonstrating the evolution of ship design and the demands of the market

Table 2 – All the modern GTT containment systems approved by Bureau Veritas since 1995

FA = Final assessment. A ship is classified and the system installed on board.

FA = Final assessment. A ship is classified and the system installed on board.

BV = Approval in principle subject to a final assessment later stage.

Today, the clear preference of most owners ordering new LNG carriers is for Gas Transport and Technicap (OTT) systems (see Table 2). GTT has been developing improved systems to align with the market demands for improved insulation and improved resistance to sloshing pressure.
The GTT NO96 system has evolved significantly in recent years, since it was introduced for the first time in Chantiers de l'Atlantique newbuilds in 1994 and then in Hanjin Heavy Industry-built LNG carriers in 1995. The same process has been put in place by GTT for the Mark III series installed for the first time on large LNG carriers at Samsung Heavy Industries in 2000 and in three small-scale LNG carriers built in the nineties. The figure 1 illustrates the reduction in BOR achieved by the latest Mark III Flex – and NO96 Flex systems, from 0.15% to 0.07%.

DEFINING THE GLOBAL ARCHITECTURE

Modelling LNG carrier design with advanced computer tools, and by studying different ship architectures and different configurations of containment systems, engines and other equipment, for one or several trade patterns, is now the recommended pathway to developing competitive LNG carrier solutions.

A computerized detailed LNG carrier model will help to select the best equipment to be installed on board by comparing different options. Different values can be compared to determine the most efficient global architecture. These may include key performance indicators such as:

- FROG: Forced boil-off gas mass;
- NBOG: Natural boil-off gas mass;
- GCU: Boil-off gas burned in the gas combustion unit;
- Total gas consumption from all consumers (gas boilers, main engines and generator sets);
- Pilot fuel consumption in dual fuel engines.

Modern 2-stroke DF design

174,000 cu. m³ design

Standard operating speed

19.5 knots

BOR range

0.085% to 0.105%

= 2.8 – 3.5 tons/hour

Requires approximately

10-25 tons of forced vaporisation

Figure 1 – The BORs achieved by GTT containment systems

Mark III Mark III NO96 NO96 NO96 NO96 NO96 NO96

0.15% 0.13% 0.11% 0.07%

Figure 2 – The typical fuel consumption curve of a modern LNG carrier with 2-stroke engines (BOR 0.085%)

Modern LNG Carrier Technology - Technology Report #05 - Autumn 2019
DEFINING THE GLOBAL ARCHITECTURE system. The low BOR of the system is achieved by increasing the thickness of the insulation from 270 mm (Mark III) to 480 mm. However, the interbarrier space situated between the two barriers is the same thickness as in the Mark III and Mark III Flex systems, so the temperature on the secondary barrier is lower than in the previous systems. The system is industrialized and presently being installed on at least one ship under construction at SHI, to be delivered in 2019.

LNG is a corrugated, thin stainless steel 1.2mm sheet, welded to support plates prefabricated in the insulation panels. The secondary barrier, which needs to be able to contain an LNG leak for a minimum of 15 days is the so-called triplex membrane, made of aluminium foil and two glass fibre covers used in two forms, rigid triplex secondary barrier prefabricated with the insulation panels and flexible secondary panels bonded to the panels at the yard during the erection of the membrane.

The Mark III Flex + system is the latest evolution of the Mark III series developed by GTT. Today, HHI, HSHI and SHI are proposing this system for their standard 174,000 m³ LNG carriers. The system comprises standard prefabricated panels made with reinforced polyurethane foam and plywood, and two different barriers, as required by the IGC Code. The primary barrier in contact with the LNG is a corrugated, thin stainless steel 1.2mm sheet, welded to support plates prefabricated in the insulation panels. The secondary barrier, which needs to be able to contain an LNG leak for a minimum of 15 days is the so-called triplex membrane, made of aluminium foil and two glass fibre covers used in two forms, rigid triplex secondary barrier prefabricated with the insulation panels and flexible secondary panels bonded to the panels at the yard during the erection of the membrane.

The tables 3.1 and 3.2 describe two typical modern LNG carrier designs along with their components.

### Table 3.1 – 174,000 m³ LNG carrier design with Mark III Flex containment system and X-DF

<table>
<thead>
<tr>
<th>BOR</th>
<th>0.085% V/day</th>
<th>Propulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>WIN G&amp;D - 2 x 5X72DF</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nominal rating each: 12,500 kW @ 69 RPM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific gas consumption: 144.3 g/kWh (100% power, gas mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific diesel fuel consumption: 182.2 g/kWh (100% power, diesel mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific energy consumption: 7.249 kJ/kWh (100% power, gas mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific energy consumption: 7.780 kJ/kWh (100% power, diesel mode)</td>
</tr>
</tbody>
</table>

| Genets | 2 x HYUNDAI HMSEN 8E33DF (2,880 kW @ 720 rpm) |
|        | 2 x HYUNDAI HMSEN 6FD31DF (2,880 kW @ 720 rpm) |
|        | Specific energy consumption: 7.207 kJ/kWh (100% power, gas mode) |
|        | Specific energy consumption: 7.814 kJ/kWh (100% power, diesel mode) |

| Re-liquefaction | Mixed Refrigerant 2.5 t/h |
| Fuel Gas | 2 x 6-stage Cryostat compressors (2 x 860 kW) |
| Fuel pumps | 4 x 30 kW | Vaporizers |

### Table 3.2 – 174,000 m³ LNG carrier design with NO96LO3+ containment system and MEGI

<table>
<thead>
<tr>
<th>BOR</th>
<th>0.1% V/day</th>
<th>Propulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>MAN 8L32A-C10.5-4 CI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nominal rating each: 12,590 kW @ 69 RPM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific gas consumption: 136.3 g/kWh (100% power, gas mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific diesel fuel consumption: 168 µ/kWh (100% power, diesel mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific energy consumption: 6.917 kJ/kWh (100% power, gas mode)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Specific energy consumption: 7.174 kJ/kWh (100% power, diesel mode)</td>
</tr>
</tbody>
</table>

| Genets | 2 x 2 x WARTSILA 8L34DF (3,840 kW @ 720 rpm) |
|        | 2 x WARTSILA 6L34DF (2,880 kW @ 720 rpm) |
|        | Specific energy consumption: 7.440 kJ/kWh (100% power, gas mode) |
|        | Specific energy consumption: 7.530 kJ/kWh (100% power, diesel mode) |

| Re-liquefaction | Mixed Refrigerant 3.5 t/h |
| Fuel Gas | 2 x Burckhardt Labyrinth compressors (2 x 480 kW) |
| Fuel pumps | 4 x 30 kW | High pressure fuel pumps (2 x 180 kW) | Vaporizers |

A REVIEW OF CARGO CONTAINMENT SYSTEMS TODAY

Mark III Flex +

The Mark III Flex + system is the latest evolution of the Mark III series developed by GTT. Today, HHI, HSHI and SHI are proposing this system for their standard 174,000 m³ LNG carriers. The system comprises standard prefabricated panels made with reinforced polyurethane foam and plywood, and two different barriers, as required by the IGC Code. The primary barrier in contact with the LNG is a corrugated, thin stainless steel 1.2mm sheet, welded to support plates prefabricated in the insulation panels. The low BOR of the system is achieved by increasing the thickness of the insulation from 270 mm (Mark III) to 480 mm. However, the interbarrier space situated between the two barriers is the same thickness as in the Mark III and Mark III Flex systems, so the temperature on the secondary barrier is lower than in the previous systems. The system is industrialized and presently being installed on at least one ship under construction at SHI, to be delivered in 2019.
leads to a higher BOR. Having a reinforced insulation system is achieved by increasing the plywood sheet (0.7 mm thickness low thermal expansion steel alloy with 36% nickel content). To achieve the very low BOR, the total thickness of this new containment system is the same as for the NO96 LO3 and LO5 (530 mm) but the complete insulation system is made with reinforced polyurethane foam.

**Withstanding sloshing**

One area of development being worked on by GTT is the reinforcement of membrane containment systems. These types of applications such as FSRUs, FSUs and, more recently, LNG-FPSOs, as they are suitable for partial filling levels, ship to ship transfer offshore, etc, when addressing high sloshing pressures. BV has been extensively involved in sloshing studies for FSRUs, LNG bunkering ships and LNG fuelled ships with different containment systems, but mainly GTT membrane containment systems. Those types of application require a full range of fill levels making sloshing a more critical factor than in diesel vessels.

**Type B systems (Moss and prismatic)**

Most Moss type ships have traditionally been equipped with steam turbine technology, and only a few of them are equipped with the more recently available DFDE systems. Therefore (taking into account the link between BOR and propulsion system efficiency) insulation performance of Moss type ships has been less important than in modern ships equipped with membrane systems and 2-stroke engines. Since consumption of a steam turbine system is approximately 50% more than that of 2-stroke engines, a BOR in the range of 0.12% may be satisfactory for a Moss-/steam turbine LNG carrier. However, for modern Moss ship designs equipped with DFDE engines (a small number are in service) or 2-stroke engines (under development), additional insulation thickness will be required.

Moss type containment systems have been extensively used in applications such as LNG carrier conversions to FSRUs, FSUs and, recently, LNG-FPSOs, as they are suitable for partial filling levels, ship to ship transfer offshore, etc, when addressing high sloshing pressures.

**Type C systems**

Type C containment systems are commonly used in small-scale LNG carriers. They are made of single shell steel alloys with external insulation, and are independent of the ship structure. Elongation of type C tanks during thermal cycles is important, so the tanks are supported on the bottom of the cargo hold by a fixed support and a sliding support. Because type C tanks are smaller than standard 40,000 m³ membrane tanks, the BOR increases significantly. Values of around 0.3% are commonly used for small carriers, and 0.2% for larger vessels (20,000 m³ and above). Despite the fact that more vapours will be generated than in a large tank, for the reasons already mentioned, the advantage of type C tanks is that pressure build up is an option for boil-off management. The loading conditions at the terminal have to take into consideration the fact that at the end of the trade, tank pressure may be in the range of 4-5 bar, taking into account the heat ingress (generation of vapour).

Therefore, the loading limit in a type C tank is usually reduced, as opposed to atmospheric systems (membrane or type B), which are set at a maximum of 0.7 bar. Many other systems (see table 4) have been proposed and assessed by BV – all with different challenges to overcome. A high manganese system, recently the subject of an EMO circular, is also among the systems in the process of being assessed. Many of the new non-GTT systems assessed in recent years have been designed for small-scale applications and gas fuelled ships, but have never been considered for standard LNG carriers, except for the Moss, Type C (cylindrical, bi-lobe or tri-lobe), IHU/SPI and KC-1 systems.

---

**Table 4 - Level of assessment achieved for systems other than GTT membrane designs**

<table>
<thead>
<tr>
<th>Other CCS Type Level</th>
<th>Type</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSS</td>
<td>B</td>
<td>BV Class Ships (FA)</td>
</tr>
<tr>
<td>CYLINDRIC/BI LOBE/TRI LOBE</td>
<td>C</td>
<td>BV Class Ships (FA)</td>
</tr>
<tr>
<td>IHU / SPI</td>
<td>B</td>
<td>BV Class FSRU (FA)</td>
</tr>
<tr>
<td>KOGAS / KC-1</td>
<td>MEMBRANE</td>
<td>DA</td>
</tr>
<tr>
<td>SHI / SCA</td>
<td>MEMBRANE</td>
<td>DA</td>
</tr>
<tr>
<td>DSME / ACT-IB</td>
<td>B</td>
<td>AiP January 2012</td>
</tr>
<tr>
<td>NORDIC YARDS / ADIT</td>
<td>B</td>
<td>AiP December 2011</td>
</tr>
<tr>
<td>LNTA / BOXTM</td>
<td>A</td>
<td>AiP May 2014</td>
</tr>
<tr>
<td>Lattice Technology / LPV</td>
<td>A</td>
<td>AiP April 2016</td>
</tr>
<tr>
<td>Braeumar / FSP</td>
<td>B</td>
<td>AiP May 2016</td>
</tr>
<tr>
<td>Altair Engineering / CPT</td>
<td>B</td>
<td>AiP/DA in progress</td>
</tr>
<tr>
<td>AnStyer / Bilobe High Mn</td>
<td>C</td>
<td>AiP in progress</td>
</tr>
<tr>
<td>DSME Solidus</td>
<td>MEMBRANE</td>
<td>AiP in progress</td>
</tr>
</tbody>
</table>

AiP = Approval in principle subject to a DA in a later stage.
FA = Final assessment. A ship is classified and the system installed on board.
FA / design assessment. The system is fully approved but not yet installed on board of a classified ship.
AiP = Approval in principle subject to a DA in a later stage.

---

14
For BV, gas has been a focus from the very beginning of its transportation by sea, and we have never stopped investing in the sector. We can look back with some pride on an industry where safety has always come first – the sector’s safety track record speaks for itself. BV has achieved many classification firsts in the seaborne carriage and marine storage of LNG. In the beginning, this was, of course, partly based on the early leadership of France in LNG ship construction and design of LNG containment systems. But as leadership in commercial LNG ship construction has shifted across the globe – from Europe, to the United States, and now to Asia – BV has remained at the fore.

Proud to be at the forefront of classification in an evolving market

BV classed the first Korean-built membrane LNG carrier in 1995, the Hanjin Pyeong Taek, and the first Korean-built LNG carrier for an overseas country in 2002, the Excalibur. The first dual fuel diesel electric LNG carrier, Global Energy, was built in 2006 in France – and was BV classed. And, most recently, in a project marked by innovation, BV has jointly classed with the Russian Register the 15 icebreaking ARC 7 ships contracted to load LNG in the Russian Arctic at Yamal.

First class rules for floating gas terminals

BV recently updated and clarified its rules to provide the first set of dedicated FSRU and FSU rules. These allow for different technical and regulatory options, reflecting the main issues and questions to be addressed in floating gas terminals: conversion or newbuild; near shore or offshore location; ship or barge; storage only.

BV classed the first LNG FSRU in 2005, Excelsior, the first FLNG in 2013, Tango FLNG (Ex-Caribbean FLNG), and, in 2017, the largest FSRU ever built – the 263,000 m³ MOL FSRU Challenger. Today, the floating terminal sector market looks set to grow further including supporting the availability of small scale LNG for use as a cleaner fuel for conventional ships.

We are ready as demand for floating gas terminals grows.