Floating gas terminals – FSRUs and FSUs

Increasingly important in LNG Supply Chains

TECHNICAL AND REGULATORY OPTIONS FOR FSRUs AND FSUs

— Conversion or newbuild?
— Near shore or offshore location?
— Preference for a fixed location?
— FSRU/FSU - a ship or a regasification/storage barge?
— Storage only?

A technology report from Bureau Veritas Marine & Offshore

In November 2017 Bureau Veritas published NR645, the first rules document fully dedicated to Floating Storage and Regasification Units (FSRUs).

New notations under Bureau Veritas *Rules for the Classification of Floating Storage Regasification Units and Floating Storage Units* (NR 645 – July 2018) address the specific requirements of Floating storage units (FSUs):

- The notation ***FSU-LNG*** provides the specific classification requirements including structure and safety aspects for floating units dedicated to store LNG that are neither designed nor built to transport LNG;
- The notation ***Liquefied Gas Carrier – FSU*** provides specific classification requirements including structure and safety aspects for floating units dedicated to store LNG that are also designed and built to transport LNG;
- New Guidelines, (NI655 – July 2018) ***LNG Carrier Conversion to FSRU or FSU*** address the requirements for conversion of existing LNG carriers to either floating LNG gas storage units fitted with a regasification plant (FSRUs) or floating LNG gas storage units (FSUs).

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INTRODUCTION

Floating gas terminal solutions enable demand for gas imports to be met relatively rapidly by seaborne LNG shipments. Furthermore, the potential mobility of a floating unit provides operators with the flexibility to seek and serve alternative markets on redeployment. As availability of gas expands, and demand rises for cleaner energy, interest has grown in the potential for FSRUs and FSUs as rapid and flexible options to provide solutions for LNG reception, storage and regasification requirements.

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Deployment of a *Floating Storage and Regasification Unit* (FSRU) or *Floating Storage Unit* (FSU) is a relatively fast, relatively low cost path in the development of LNG import capability. The construction of onshore LNG reception terminal infrastructure including gas storage tanks and regasification capacity is a lengthier and more expensive solution with, possibly, more arduous regulatory and planning requirements taking into consideration land availability and societal impact.

WHAT ARE FSRUs AND FSUs?

— FSRUs and FSUs are a type of vessel, which may not even resemble a ship – they could be a barge; perhaps flagged, or maybe not; whose engine may be disabled - or never even existed; which could be permanently moored for a very long period of time without dry-docking, off port limits, in an exposed environment, but nevertheless possibly in the close vicinity of a densely populated shores; processing large quantities of a hydrocarbon gas product from cargo tanks before being pushed outboard for export ashore; with a crew whose professional experience after several years may be closer to that of refinery employees than professional seafarers.

There are issues and questions that arise of relevance to the operators, bankers, regulators, the insurers and customers as well as local populations:

- What construction standards should be used?
- What operational conditions and associated risks should be considered?
- What conventions and regulations should be applied - for the vessel, for the crew, for the environment?
- Which authorities actually control the complete story - the flag state, or port state?
- What influence will local regulatory requirements and governance have for the operations?

All the above will be, or can be, addressed in different ways, dependent on the customer needs – the compromise or balance sought as a consequence of asking the following questions related to operational requirements.

— Operators considering the floating terminal approach to meet LNG import infrastructure requirements have a number of options:

- Conversion or newbuild?
- Near shore or offshore location?
- Preference for a fixed location?
- FSRU/FSU – a ship or a regasification / storage barge?
- Storage only?

Commercial options need to be enabled and supported by the best technical insight and, vitally, in compliance with appropriate regulatory regimes and standards.

CONVERSION OR NEWBUILD?

— A key decision to be made when developing an FSRU/FSU project is choice of either a newbuilding or conversion of an existing LNG Carrier (LNGC). Conversion projects are likely to be quicker to enter operation than newbuilds. To date five of the 27 FSRUs in service are conversions. With recent increases in efficiency of LNGCs (lower fuel consumption / lower oil off), and a growing fleet of gas carriers in a developing spot market, opportunities to convert previous generation gas carriers into use as FSRUs or FSUs have been identified. Fuel consumption and boil off rates will be less of an issue if the FSRU is not trading as a ship and regasification operations are prompt. Conversion to FSU is a simpler than to FSRU. Taking an FSU, with regasification on a separate barge or terminal, may be the fastest and most cost-effective route.

The fundamental issue is whether to follow a 'marine' approach to addressing risk, akin to the risks addressed through classification ship rules and SOLAS. Or to adopt a risk approach that is more similar to that of the offshore industry. So, at one extreme, an LNG carrier with some or little modification could be used as a floating reception and storage terminal. At the other end of the spectrum, a FSRU or FSU newbuilding may have no propulsion capability, a site-specific hydrodynamic hull form: effectively a floating barge envisioned, and intended, to be moved only very seldom and designed to be moored in sheltered waters.

NEAR SHORE OR OFFSHORE LOCATION?

— Intended location is important for the design and regulatory as well as operational requirements. Trading LNG carriers sail either in a fully laden condition – from the export to the import gas terminal – or almost empty with a slight 'heel' of LNG to keep tanks cool, when they return to load. LNG carriers do not generally sail with cargo tanks partially filled. Loading and discharging are performed in sheltered gas terminals where the ship stands stationary - and so does the liquefied gas in the tanks throughout the cargo operation - without disturbing the free surface during partial filling phases.

The FSRU regasification LNG carrier will normally be expected to operate with tanks at all ranges of fill level. Ship motions cause 'sloshing' of the cargo inside the tanks which may be only rarely full and often partly filled at all levels from almost empty to almost full. The sloshing of the cargo may generate huge impact loads on tank bulkheads, containment system boundaries, and pump towers - which all must be designed and reinforced accordingly.

The further away the mooring is from the shore, the more exposed the ship is to significant sea states and wave conditions. In the calm, protected, environment of a port, transferring liquefied gas by flexible hoses from one ship to another is certainly not a picnic party. But it is no more complicated than discharging to an onshore LNG terminal. The crew of an LNG carrier is well trained for the operation and fully aware of the potential dangers, not only for the people on deck, but also the risks of leaking liquefied gas which, at -160C, which may cause severe damage to the steel deck structure.

PREFERENCE FOR A FIXED LOCATION?

— LNG transfer between two side-by-side ships, some way offshore and subject to erratic motions induced by wave and wind in quasi-open seas, is a very different matter. To mitigate risk, dedicated offshore jetties can be constructed to permanently accommodate a regasification LNG carrier on one side and a feeder LNG carrier on the other side. With each ship, connected to fixed points and the manifolds of the jetty the problem of relative movements between the two floating bodies is suppressed – at least as far as cryogenic liquid transfer is concerned. Linkage ashore to a ground pipeline network can be ensured, in shallow water, by a relatively short subsea flow line.

Class (design and in-service requirements) and Statutory Rules, as developed for navigating vessels, could be too conservative in very mild weather areas and in adequate in others. Class Rules for offshore units usually allow design optimization against actual site and operational conditions. Seen from the perspective of the shipowner it might be an opportunity to save unnecessary steel weight or to gain cargo capacity, - in addition to other possible operational gains. Seen from the conventional shipyard's point of view, the standard designs are challenged.

Terminal siting and mooring are specific areas of expertise that require expert support and modelling combining analysis of location weather and sea conditions, marine traffic and geophysical conditions.

FSRU/FSU – A SHIP OR A REGASIFICATION / STORAGE BARGE?

— The first FSRUs entered service in 2005 with a submerged turret loading (STL) concept in open seas (US Gulf of Mexico) in 2005 with a newbuilding project developed jointly by Exmar and Excelerate Energy. The same partners then developed a jetty moored FSRU concept, also a newbuilding, before Golar introduced the first of their conversions in 2008.

What became clear was that from technical and regulatory perspective, FSRUs may operate - depending on the operator's requirements and risk profile - across a spectrum between a traditional maritime classification and regulatory regimes and the different requirements of the offshore oil and gas sector.

FSRU owners and operators challenged the class and regulatory regimes for their assets, in particular, requirements for periodical dry-docking. But they also looked to stop main engine maintenance or, for newbuilds - as opposed to conversions - to develop specifications for non-propelled, barge-shaped units, that would not be required to conform to 'ship' rules and requirements.

For shipyards involved in both ship and offshore businesses, the word 'offshore' is immediately associated with large oil-major-company projects and likely translated into a plethora of specification requirements leading to significant ramp up in costs that were difficult to evaluate initially and then difficult to control.

Flexibility

Even seasonal repositioning of FSRU capability /capacity is possible – such as in Brazil related to seasonal fluctuation of demand for energy and production of electricity from hydro energy, an FSRU is shifted from the north to the south of the country and *vice versa*. Likewise, Egypt may re-commence LNG exports while importing gas through two FSRUs in the Red Sea reflecting the lack of infrastructure connecting different regions of the same country. While, elsewhere, we have seen reversal of gas flows as an importer (USA) begins exporting gas. FSRUs are a flexible solution to cope with future demand.

STORAGE ONLY

— The FSU is probably the fastest route to terminal infrastructure and addresses the likelihood that one of the lengthier aspects of onshore terminal development is the construction of tank capacity. Conversion to FSU may be the most attractive conversion option as it is a relatively straightforward option for use of an existing LNG carrier.

FSUs – most suitable for conversion projects?

Over 20 LNG carriers are presently in laid-up condition. Most of them may be candidates for a conversion to either FSRU or FSU.
The complexity of the regas facility on board and the necessary changes related to machinery makes conversion into FSU easier with the installation of the regas plant onshore, close to the floating terminal, to minimize the cost of a cryogenic pipeline from the FSU.
Half of the laid-up units are of the MOSS type and so the cargo containment system is of independent type providing additional flexibility in terms of conversion when flexible storage capacity is desired by simply either removing (or adding) operational MOSS spheres.

Armada LNG Mediterrana, originally an LNGC built in 1985 with MOSS tanks – converted into an FSU ready for operation in Malta in 2016.

RULES, NOTATIONS, GUIDELINES AND SERVICES

With one leg in Marine and one leg in Offshore, most FSRU/FSU projects raise technical, regulatory, operational and environmental issues and questions - from all stakeholders. These may now be addressed through Bureau Veritas Rules, Notations, Guidelines and Services.

RULES

- **NR467** - Rules for the Classification of Steel Ships
- **NR445** - Rules for the Classification of Offshore Units
- **NR 542** - Classification of floating gas units
- **NR 645** - Rules for the Classification of Floating Storage Regasification Units and Floating Storage Units

GUIDANCES

- **NI 554** - Design Sloshing Loads for LNG Membrane Tanks
- **NI 564** - Strength Assessment of LNG Membrane Tanks under Sloshing Loads
- **NI 567** - Risk Based Verification of Floating Offshore Units
- **NI 623** - Condition Assessment Programme for LNG Carriers (LNG CAP) - Annex to NI 465
- **NI 655** - LNG Carrier Conversion to FSRU or FSU

Bureau Veritas offers advanced technical services across a wide range of disciplines. Two significant areas of expertise are particularly relevant to floating storage terminals addressing significant areas of risk: mooring and sloshing.

Mooring expertise to address requirements of floating terminals

— For 30 years Bureau Veritas has been developing and evolving an ever more advanced understanding of mooring systems supported by Ariane, the advanced mooring analysis tool developed by BV. Deep and shallow water mooring sites, larger units, long life spans, reduced inspection budgets and improved mooring technology place ever increasing demands on the design of mooring systems for marine and offshore units.

Ariane

Ariane is an advanced mooring analysis software tool, recently released in version 8. Keeping and improving all Ariane7 capabilities, Ariane8 provides new features, enabling the analysis of more complex mooring systems, with greater accuracy, applicable to floating terminal applications - such as side-by-side or jetty mooring arrangements.
Calculation of the 6 degrees of freedom motions of floating bodies and use of coupled calculations between low and wave frequencies is now possible.

Gas tank sloshing – advanced analysis

— The gas tanks in floating terminal applications need to be safely operational at any fill level. Bureau Veritas has developed methods and tools to analyze the risks and consequences rising from tank sloshing allowing an understanding of the required engineering responses for strengthened containment systems if required.

Bureau Veritas has a three step sloshing assessment and calculation process:

1. Seakeeping analysis – to calculate ship motions and, consequently, tank motions
2. Using the calculated tank motions, sloshing model tests and computational fluid dynamic (CFD) calculations are carried out in order to determine sloshing loads
3. Sloshing loads are applied to the entire containment system

Dynamic probes

Classical CFD studies only consider predefined hot spot zones as since storage of all the data for all time steps requires too much computational memory space. To circumvent this issue a specialized in-house processing tool – 'Dynamic Probes' - is used. This dedicated BV tool provides a complete understanding of all sloshing events over the tanks' boundaries during the simulation allowing all sloshing impacts to be detected.

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TECHNOLOGY REPORT

LNG SUPPLY CHAINS

Transportation

Today's LNG megaprojects require new solutions to transport gas from production sites to customers around the world. Bureau Veritas is classing innovative carriers for recent projects. Three of a total of 15 icebreaker carriers serving Yamal LNG were delivered in 2017. For Ichthys LNG the challenge is one of scale: at 182,000 m^3, the vessel's Moss-type cargo tank capacity is the largest of any LNG carrier worldwide.

Storage and regasification

Floating import terminals are providing importers with flexibility, enabling them to take in new volumes faster and more cheaply than by adding land-based infrastructure. In 2017, two BV-classed FSRUs were delivered: Exmar's 25,000 m^3 FSRU, and the MOL FSRU Challenger, the largest FSRU to date at 263,000 m^3.

Bureau Veritas is playing a key role at each stage of the LNG value chain, ensuring the viability and safety of projects, and helping bring together offshore operators, port authorities, ship owners and terminal operators to address challenges.

+47%
Increase in global LNG demand since 2000

Source : International Energy Agency. 2017

28%
of LNG-fueled ships in operation are BV-classed

80%
of LNG bunkering vessels in operation, under construction or on order are BV-classed

150 ships
use LNG as fuel, more than 120 are in construction or on order worldwide

Production

Operators are increasingly looking to floating LNG production solutions to commercialize previously stranded resources. Bureau Veritas supported Shell on quality assurance and control for the construction of Prelude, the world's largest FLNG, and subsidiary Matthews Daniel is the project's nominated sole Loss Adjuster.

LNG fueled ships

The benefits of LNG as a fuel in terms of environmental compliance and competitive advantage recently boosted the number of new orders for vessels with high-capacity LNG tanks and large DF propulsion systems. While such vessels were initially used only for short sea shipping, a tipping point was reached in 2017, when the proportion of new orders for LNG-fueled ships within the total vessel-order market reached 11%. This major change is symbolized by the CMA CGM order: nine 22,000-teu container carriers each able to carry 18,600 m^3 of LNG as fuel, and an innovative 20,000 m^3 bunker vessel owned and operated by MOL and chartered by TOTAL.

LNG Bunkering

Ship-to-ship bunkering is crucial for a global adoption of LNG as a fuel. Bureau Veritas classed the first ever LNG bunker vessel, Zeebrugge Gas4Sea, along with the Coralius Sirius, the second LNG bunker vessel to enter service. In Japan, Singapore and Canada, Bureau Veritas is a key partner in several new projects, sharing its know-how, technologies and safety methodologies for LNG bunkering in safe commercial operations.

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