Selecting the right cargo containment system

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Webinar Q&A summary

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There is a tendency to increase sloshing limits on LNG membrane above those stated in the cargo manual. There is also no extensive industry research and evidence for such operation. Would you kindly provide your feedback?

**CG** | Despite the fact up to 10% (or 2.75 m) and more than 70% have been traditional limits in membrane systems for LNGCs operated with no trade restriction, for FSRU and LNG bunkering ships as well as for gas fuel ships, these limits have been discussed. In LNG bunkering ships and gas fuel ships it should be possible to partial fill in navigation mode but this is a very specific case and the membrane is reinforced for the purpose. FSRUs in sheltered waters may be suitable and in some cases there may be no need to reinforce the membrane. For current standard LNG carriers (170-180,000 m³) on STS transfer to FSRUs there are also operational limits. Within such limits (wave height and other parameters) there is no sloshing issue in partial filling.

**CC** | In my experience, the ‘sloshing limits’ are based on extensive testing and solid experience over many years in operation. I was only involved in one case where damage occurred when a ship was operated right on the (ballast voyage) limit stated in the cargo manual. This unfortunately proved to be a design error, where tank length and height were mixed up (the tank geometry was unusual). The damage was fortunately quite minor, and lessons were learned by all parties. So I would not advocate operating at say 80% filling if Class permits 70% for a specific ship; however, the limit applies throughout the voyage, not just at the loading - so allow for normal BOR level reductions plus a 'reserve fuel' margin. Membrane systems are quite sensitive in respect of sloshing/filling limits - but it can affect 'Type C' tanks too. Less so the Type 'A' or Type 'B', in my experience.
What advantages are there for Type C over membrane for small LNGCs and the reason for their selection?

CG | We mentioned basically available yards (limited for membrane) and the possibility to build the tanks in parallel to the hull for integration later. In addition, reputed companies such as TGE, Wartsila, etc market these systems with numerous yards. Pressure build up may be an advantage as well for Type C as mentioned by Chris.

CC | Simplicity and availability. Owners have a wider choice of shipyard compared to integral membrane tank options. Operational flexibility due to the pressure build-up capability. The downside is volume occupation (can involve loss of cargo space). My personal belief is that Tank Types A or B offer many advantages, as do the 'brick' or 'lattice' membrane systems. After Kjetil's excellent presentation, more people should understand the alternatives better.

KS | Type C tanks are relatively simple and cost efficient for small sizes, and can be designed and built by a broad range of designers and yards. Furthermore, as tanks are pressure vessels they have an operational advantage where pressure is a concern. The main disadvantage of type C, is that they get very heavy (and costly) when scaling-up and cannot compete with prismatic tanks on volume utilisation.
Could the reduction of the speed on LNGCs be due to BOR being reduced over time?

**CG** | The ideal balance may be a ship speed in line with BOG consumption, in other words the speed for which there is no need to force vaporisation or reliquefy the BOG.

**CC** | Carlos is absolutely correct; the optimim speed is where the BoR matches the power demand. The data quoted was from Poten & Partners, and their presentation does discuss some of the reasons for the average results - which includes "waiting for discharge berth time", of course. Some ships trade on 'liner routes' at or near the design speed. But many do not, especially when trading on different routes. Ships can also be slowed for commercial reasons (eg traders expect the cargo price to rise). My reading of the market data is that 'slow steaming' is being used as a tool to balance supply and demand; traders are building in the inevitable cargo losses into their voyage calculations (except if the ship has 100% reliquefaction, of course).

**KS** | Yes, (declining) actual speed of the fleet in operation may to some degree be due to the fact that design BOR rates are being reduced. Having said that, I think this is also related to the market and energy efficiency. When charter rates are low, the speed of vessels also tend to be lower as the vessel is not in a rush to pick-up the next cargo. And finally, the most energy efficient speed in terms of fuel per tonne*mile is usually significantly lower than the design service speed.
Kjetil: How much reduced boil off rate is envisaged for your vessel?

KS | As mentioned above, BOR depends on the size of the tanks and insulation thickness. Size is relevant because BOR is subject to the relative surface area of a tank and volume inside, which is always more attractive for a larger tank. Thus, larger tanks will have lower BOR. Furthermore, the LNT A-BOX design has flexibility for variable thicknesses of the PU insulation panels, which also affects the BOR. To give an idea, the first LNT A-BOX vessel, the 45,000m³ LNG carrier Saga Dawn, has a design BOR of 0.15% per day with an insulation system thickness of 350 mm. Scaling this up to larger designs we are typically looking at BOR in the range of 0.10% per day for an 80,000 m³ LNT A-BOX vessel and 0.07% per day for an 174,000 m³ LNGC based on LNT A-BOX.
For Mr Chris Clucas. Boil off in loaded and boil off in ballast or partially loaded condition? Yard or GTT give only one value for BOR eg 0.09% but then many ask if it is the loaded capacity or loaded quantity?

CC | Here it is really necessary to read the system designers' BOG calculations formulae with great care before attempting to answer this question. The example I showed was from a publically available document by GTT. The assumption is that the voyage starts with all cargo tanks filled up to the maximum allowed limit (say 98.5%). That is the simple answer. If the tank is not completely full (but still within permissible 'sloshing limits'), the surface area of the cargo may be significantly larger but the wetted surface of the tank will be less; these factors tend to cancel each other out - but only up to a point. Also, with a larger surface area, the effect of rolling is to magnify BOR (due to an increase in wetted tank surface). If you look at the total heat flow into the cargo, it is remarkably low (ie the insulation is very efficient); but if you run a fuel-gas pump, the heat generated by this operation will increase the energy input to the LNG in that tank - so that tank must be excluded from the BOG quantification. So, in short, the BOR figure given by the Yard is applicable in certain specific conditions - so the "correction factors" and other assumptions need to be referenced in case this figure is used in any commercial document. It is also worth noting that Yards rarely give any data on ballast voyage BoR, because the conditions are so variable; again any figure used in commercial agreements should be stated with caution.
Question for Carlos: Is a Class survey of the containment system during the service period of an LNG vessel based on Maker or Class requirements?

Class survey for CCS follows class and statutory regulations (IGC and IGF Code) which may also rely on maker's test procedures for instance.
Question continuation: If a BOR is very low for membrane tanks, does it give more holding days in comparison to high BOR in type C despite the safety valve setting?

CG | It will depend on the tank volume but specific calculations to be provided by the membrane and type C designer would lead to a conclusion one or the other.

CC | It is always difficult to compare 'apples' with 'pears'. But as the LNG in both tanks has the same physical properties (ie enthalpy and latent heat), the answer will depend on the initial pressure, the relief valve setting and the insulation performance of both tanks. Type C tanks are being specified with highly advanced nano-technology advanced insulation that is extremely effective; they have an advantage over membrane systems in that the insulation does not have to be load-bearing. Other Type C tanks use vacuum insulation - also highly effective. And the 'lattice' or 'brick' design for membrane systems (ie with a 'strongback' support structure) means they can now operate at higher pressures (about 2 Bar(g)). So the range of options is increasing, and membrane system are no longer limited to about 25kPa(g) relief valve settings.

KS | As mentioned, holding time depend also on the design pressure/MARVS, but lowest possible heat ingress/BOR will always be an advantage.
What is the difference in volume uncertainty between different tank types and what are the different uncertainties?

CG | Just an example for gas fuel applications, if the cargo hold is 2,000 m³ with membrane we may get around 1,700 m³ but with a type C bilobe just 1300 m³.

CC | By 'volume uncertainty', I understand the question to be about the accuracy of tank gauging. Most tanks use proven float designs or radar systems - both of which have the track record needed for accurate gauging in a closed system such as an LNG cargo tank. If the accuracy is within say 10 mm in either case, then the possible volume difference depends on tank geometry and where in the tank is the liquid level being measured. The systems in use today have been in service for many years, and are recognised by Customs Authorities. Likewise the cargo tank calibration tables, which have to be provided by specialist companies because the LNG is usually bought and sold on the basis of volume plus energy content (the latter is a separate quantification). With LNG, there is no clingage, and no residue after the liquid has evaporated. So gauging accuracy is very high.
How is the trade off for a very low BOR made for a ship which will be using the BOG as fuel? Would it not be better to have a higher BOR eg 0.15% rather using vaporisation?

CG | Vapourisation of LNG required a very limited amount of energy as compared to reliquefaction. The problem of a high BOR is that in case of a problem related to the main BOG consumers there are few options on board (one is pressure build up if the tank is not atmospheric).

CC | There are several aspects to consider when answering this question. Whatever the BOR, the ship is likely to burn an alternative fuel as well as gas. And usually simultaneously. So if the speed required for the voyage intended requires more energy than provided by the 'natural BOG, then the operator has the option to burn the alternative (eg fuel oil) rather than force-vapourised LNG is the price of oil is more attractive than the revenue loss due to extra gas consumed. The lower the BOR, the more flexibility the ship provides in respect of trading. And as Carlos rightly points out, very little energy is consumed in vapourising the extra LNG needed if that option is chosen - and the equipment required will be installed anyway. Looking at it another way; the basic purpose of the ship is to safely deliver the maximum cargo volume possible for the hull - minimum-loss insulation has part in that equation.

KS | As already mentioned, lowest possible BOR is always an advantage of energy efficiency and operational flexibility. Even though some forced vaporisation may be needed at service speed, the energy required for this is very low. Whenever the vessel is slow steaming, at anchorage or idle the energy for reliquefaction or just to be burnt in CGU will be much more significant.
Question for LNG Marine - How does the BOR of A-box offer compared to a GTT membrane CCS and what are the other limitations, if any?

KS | As mentioned, above BOR is subject to size and thickness of insulation, but LNT A-BOX will typically give lower BOR than membranes if you compare vessels of same size and same thickness of insulation. This is due to the fact that the insulation system in the LNT A-BOX is not exposed to cargo loads, which means that the insulation materials (PU foam) can be optimised for the best possible thermal performance without being reinforced to increase compressive strength to cope with sloshing loads. Consequently, the fundamental design of the LNT A-BOX gives the possibility to offer market leading BOR. Not sure what kind of limitations or failure modes you have in mind, but please feel free to contact us directly and we will address your questions more in detail.
We have seen reliability issues with reliquefaction plant and ship managers have faced cargo claims due to its failure. It does not affect charterers as it is directly passed on to ship managers. Although steam turbine vessels were not fuel efficient, they

CG | Reliquefaction systems are now common on LNGCs since charterers want fully flexible ships in terms of fuel utilisation. Novel technology for reliquefaction has been used recently and past technologies had performance issues. Technology is evolving but it is true that reliquefaction systems’ performance and reliability has been questioned.

CC | Let us focus on the knub of this question - which I take as questioning the overall benefit of moving away from a simple, reliable but less-efficient technology to more complex arrangements that offer lower reliability. (As an aside, the question of who pays is something of a distraction - as this will depend on the agreement terms between owners and managers; the ultimate cost also depends on the loss-of-income sustained by the cargo owner and not just the repair cost of the plant). And of course we can turn the question around and look at it from the other direction - namely the increase in LNG demand is driven by society’s desire to reduce emissions, so how can we justify using higher-emission technology to propel the ships when significantly more efficient technology is available? As I mentioned in my presentation, the reality is that lesser numbers of ships now operate on liner trades at design speed (typically 19.5 knots) all their lives. And the transition to diesel propulsion was inevitable, not least due to the vanishing range of maritime steam propulsion equipment suppliers. (For further background, please see the inaugural edition of the LNG Journal (1996) - this was discussed in some depth). The low-consumption nature of diesel engines has pushed designers to reduce BOR dramatically - just as BOR was reduced from 0.25%/day to 0.15%/day during the 1990s when traders realised that increasing the cargo delivered gave better economic options than simply staying with previous insulation technology. It was simple to supplement the natural boil-off with fuel oil if that was economic in that generation of steam ships. Cargo reliquefaction was attempted a couple of times in that era, but the cost of generating the electricity for the plant outweighed the increased income for the extra cargo delivered. Who will spend 20$ to get an extra 10$ income?! But of course this was on the basis of steam propulsion. Remember, alternative propulsion was tried in the 1970’s - with one smaller experimental ship fitted with a gas-turbine, a sister ship with a gas-burning 2-stroke diesel and a different small LNGC fitted with a gas-burning 4-stroke main engine. All of these propulsion experiments failed for different commercial reasons. But diesel propulsion returned, and now is first choice - and this has made reliquefaction economically viable. We managed some of the first ships fitted with (Nitrogen expansion) LNG reliquefaction, and I was very disappointed with the early "teething troubles" - especially compared to my earlier experience of such systems in "peak shave" plants for British Gas. However, these have been upgraded and the designers have learned their lessons - probably because ship owners or managers made commercial claims on them! The more efficient MCR plants now entering service will surely also face some unexpected early issues, but I have worked with some of the designers for many years and have full confidence in them. In summary, the entire LNG industry is evolving towards a "reduced carbon footprint" era - and ships need to play their part in this march of progress.