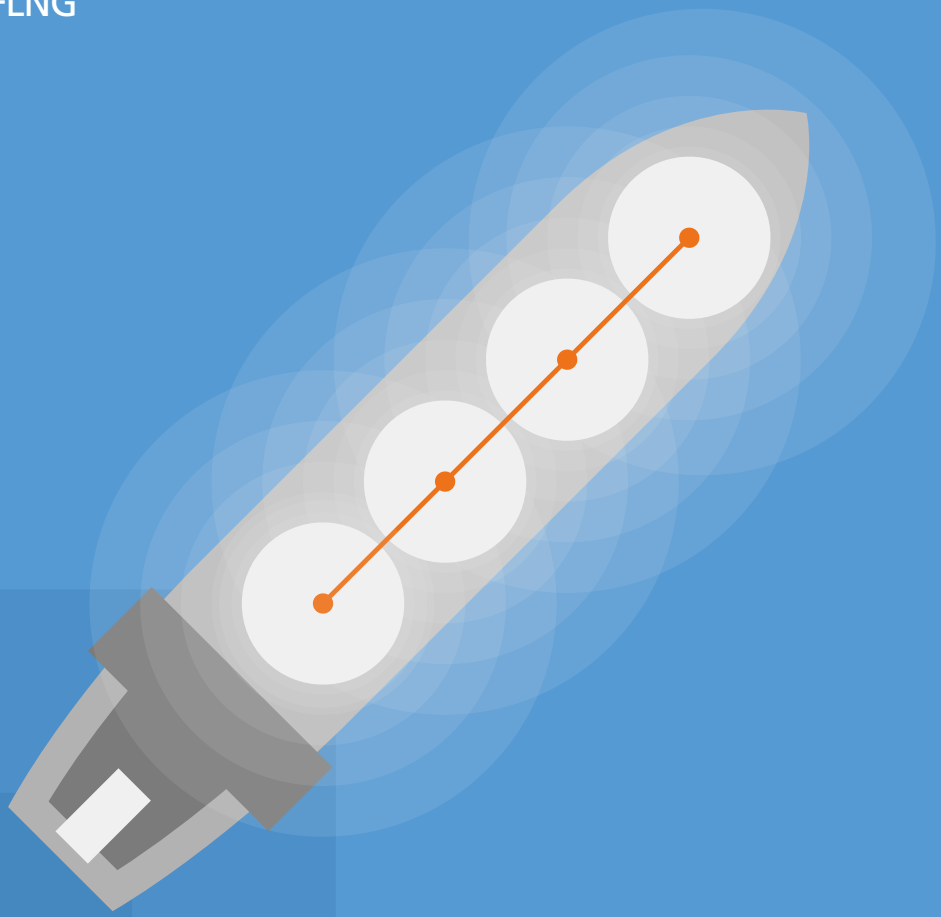
A Lloyd's Register Report March 2014

Gas technology

Inside:

The technology behind Arctic LNG
Gas containment – always evolving
The world's largest FLNG



Lloyd's Register Marine

Working together for a safer world

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Breaking news

UECC orders two dual-fuel liquefied natural gas (LNG) pure car and truck carriers (PCTC) with 1A super Finnish/Swedish ice class

United European Car Carriers (UECC), jointly owned by Nippon Yusen Kabushiki Kaisha (NYK) and Wallenius Lines, has signed a contract to construct two LR classed dual-fuel LNG PCTCs.

The contract has been signed with Kawasaki Heavy Industries (KHI) and the vessels will be constructed at the NACKS shipyard in Nantong, China, which is a joint venture between KHI and China Ocean Shipping (Group) Company. Deliveries of both the vessels will be in the second half of 2016.

The vessels will be 181 metres long with a 30 metre beam. Both the vessels will have 1A super Finnish/Swedish ice class, facilitating year round trading in the Baltic area. Approximately 3,800 standard sized cars spread over 10 decks will be able to be transported. A significant part of the cargo capacity can also be used to transport high and heavy cargo and any other cargo loaded on to mafi trailers. The deck configuration is optimised for both present and predicted future cargo mixes.

The vessels are capable of operating with LNG fuel or heavy fuel oil and marine gas oil, providing greater flexibility and efficiency. They are the first PCTCs of their kind to be fitted with an LNG fuel propulsion system, and can complete a 14-day round voyage in the Baltic using solely LNG fuel, including main engine and auxiliary power generation. ■

Computer-generated image of the new UECC PCTCs.

Strong demand for marine LNG

In this issue of Lloyd's Register's Gas Technology Report we look at LNG containment systems, Arctic LNG and how a marine engine maker is expanding across the gas value chain.

Demand for gas continues to grow. The LNG carrier order book is at a record high and more orders are likely to be placed soon. Since the last Gas Technology Report was issued in November, the picture we painted of growing demand for gas fuelled ships in North America has become more detailed, and a number of other significant developments elsewhere in the world reflect the way the industry may be going. Nakilat's announcement that it will convert at least one Q-Max LNG carrier to run on gas (long-rumoured) and Brittany Ferries' news that it was ordering a new flagship cross channel ferry were yet further trend indicators.

No owners have ordered large deep sea tankers, bulk carriers or container ships with gas as fuel propulsion – yet. Container ships may be the first, with talk from at least one operator of being gas ready. But as we finalise the report, confirmation has emerged that a small bulker, an innovative Finnish ice breaker and a car carrier design will be built with gas propulsion – all to Lloyd's Register (LR) class.

Additionally, the weekly shipping newspaper TradeWinds has been covering both the LNG and LPG sectors with keenly expanding interest, as well as looking regularly at LNG-fuelled shipping – particularly engine technology. The coverage of machinery in a commercially focused newspaper reflects how the choice of fuels and engines has become a more uncertain issue and a board-level investment decision.

Our latest research into the future of marine fuels, using our Global Marine Trends 2030 scenarios, is covered in this report and it has some interesting findings on future LNG fuel take-up.

One thing that unites both those interested in LNG carrier technology and LNG-fuelled shipping is gas containment. The design path that led to evolutions in Moss type gas carriage tanks is covered in this report. The new Brittany Ferries flagship will not use 'Type C' tanks to store gas bunkers. And Wärtsilä speculates, in passing, in our wide ranging coverage of the expansion of their activities, that deep sea ships might need to consider systems more like those used in LNG carriers if they are to use LNG as fuel.

In 1978 Lloyd's Register's Alan Gavin wrote the seminal paper on LNG containment systems, in his Lloyd's Register Technical Association paper, Design and Construction Aspects of Containment Systems for the Carriage of Liquefied Gases in Ships. Still worth a read today, you can find it at www.lr.org/AlanGavinPaper

We're continuing his work today as the safe carriage of gas and use of gas as fuel continues to develop and we seek to help the world understand how to manage the risks. ■

Lloyd's Register's latest research into the future of marine fuels, using our Global Marine Trends 2030 scenarios, has some interesting findings on future LNG fuel take-up. In the most optimistic of three scenarios, LNG-fuelled (non-LNG carrier) deep sea shipping will have grown from zero today to about 11% of the global fleet in 2030.
For more information go to www.lr.org/gmft2030

Growth of the LNG Carrier Fleet 1980 – 2014

A tale of trade, terminals and technologies by Jim MacDonald, Principal Specialist, Lloyd's Register Marine.

By the end of 1979, after a surge of newbuilding in the second half of the 1970s, the world fleet was 52 ships – 17 Moss, 16 Gaz Transport, 12 Technigaz, and 7 others. There were a limited number of trade routes, with ships working on long-term charter to deliver LNG from the exporting to importing countries. These trade routes were Brunei, Abu Dhabi and Alaska to Japan; Libya to Italy and Spain; and Algeria to France, Belgium and USA.

After a stagnant period in the 1980s without much expansion and some ships going into lay-up, the number of exporting regions has grown to include Angola, Australia, Dominican Republic, Egypt, Equatorial Guinea, India, Indonesia, Kuwait, Malaysia, Nigeria, Norway, Oman, Peru, Qatar, Russia (Sakhalin), Trinidad, and Yemen. New importing countries include Argentina, Brazil, Canada, Chile, China, Dominican Republic, Greece, Korea, Mexico, Puerto Rico, Singapore, Taiwan, Turkey, and the UK.

Some of the importing countries require particular mention. Korea has become the second biggest importer of LNG after Japan; China has become a major importer of LNG in recent years and is expected to increase imports greatly in the coming years; and the UK is no longer self-sufficient in natural gas from the North Sea and has become an importer of LNG. The USA was for a time an importer of LNG, but has become an exporter again after their development of large shale gas deposits.

Gas innovator: "BP's *British Emerald*, constructed at HHI and delivered in 2007 was the first of a kind," comments Leo Karistios – Lloyd's Register's Global Gas Technology Market Manager. "*British Emerald* is the first membrane type LNG tanker adopting dual-fuel diesel-electric (DFDE) propulsion, which has become the orthodox propulsion choice."

In recent years there has also been re-export of LNG from the USA and Belgium, and this has been developing into a spot market which is gradually taking an increasing share of world LNG trade.

Among the exporting countries, the biggest development was Qatargas's decision to greatly expand its LNG exports, seeing opportunities to sell in Europe and the USA. They employed ExxonMobil from 2001 to optimise membrane ship design for the trade. The capacity of LNG ships had gradually risen from around 135k in 1979 to around 140k in 2000, with the size limited in order to have the flexibility to trade to most LNG terminals, but following ExxonMobil's advice, the new Qatargas ships were ordered first as Q-Flex size (210k to 216k), then as Q-Max size (260k to 266k), enabling them to trade only to specially built and adapted terminals. A total of 31 Q-Flex and 14 Q-Max ships were delivered between 2007 and 2010 – the first ships in each series and the largest share of all 'Q' ships were built to Lloyd's Register class.

As the available depth of water at the Ras Laffan Terminal in Qatar was only around 12.3 metres, the loaded draft of these ships could only be made around one metre greater, so the additional capacity was mostly provided by making the ships longer (five cargo tanks instead of four), and broader. As sloshing pressures increase with tank breadth, it was recognised from the outset that evaluation was an important task, and this prompted advances in sloshing pressure assessment.

The Q-Flex and Q-Max ships are notable not only for their large size but also for several other innovations. Instead of the boil-off being used to power the ships via boilers and steam turbine propulsion, these ships used conventional slow-speed diesel engines, and reliquefaction equipment was fitted to deal with the boil-off.

However, in-service experience with the reliquefaction plant and the increased price of fuel oil has seen the initiation of plans to re-engine them.

Another significant development in 2005 was the Excelerate project centred around the *Excelsior* regasification vessel sited in the Gulf of Mexico, designed to receive LNG by ship-to-ship transfer (STS), re-gasify it and deliver to shore via a pipeline. This has proved the model for other similar offshore receiving terminals, several of which are being planned and built at the time of writing.

Offshore LNG production terminals were also mooted from around this time, and the first major project of this kind, the LR classed Shell *Prelude* FLNG, a massive vessel of 488 metres in length with the liquefaction capability to produce approximately 22k LNG per day (as well as condensate and LPG), is under construction at the time of writing.

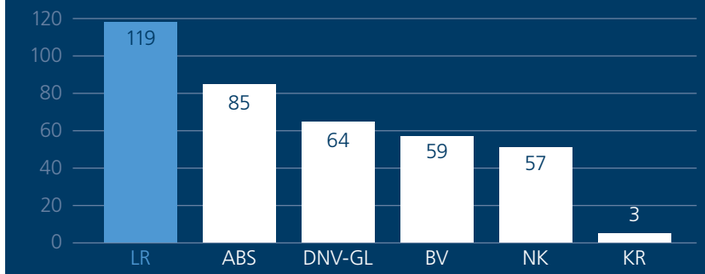
At the other extreme, since the 1990s there has been a gradually increasing number of small LNG ships of around 10k to 30k built for coastal trade. As reported in our Wärtsilä story (page 20) and given the developments described in our LNG bunkering map (page 16) this trend is likely to continue.

LNG carrier entering drydock at Sembawang shipyard, Singapore.

More recently, of course, there has been a boom in orders by independent owners for membrane type 'standard' ships with cargo capacity around 170,000 cbm. At the same time there is a mini-resurgence of interest in Moss type ships, for example the Petronas 4+4 order placed at the end of 2013. But the big news as we enter 2014 is the award of 16 Arctic-capable LNG carrier contracts to serve the Yamal LNG projects – these ships will be built using membrane systems.

As of December 2013, the LNG existing fleet comprised 387 ships and the orderbook stood at 114 ships. (Source: IHS Fairplay.) ■

Latest figures for existing LNG carriers – by classification society/number of ships



Figures from IHS Fairplay (December 2013)

Brittany Ferries' new LNG-powered ferry, to be built at STX Saint-Nazaire.

Membrane bunker storage system chosen for new Brittany Ferries vessel

GTT membrane technology has been selected by STX France to fit out PEGASIS (Power Efficient GAS Innovative Ship), the new environmental ferry propelled with LNG, ordered by Brittany Ferries.

This innovative vessel will use the GTT Mark III insulation system and will be built in Saint-Nazaire, in France. It should be delivered by the end of 2016.

In addition, GTT has also been selected to design the tanks of three other Brittany Ferries ships to be converted to LNG propulsion.

GTT says that membrane technology developed by GTT for LNG propulsion offers shipowners many advantages of optimisation of space and cost.

Philippe Berterottière, Chairman and CEO of GTT, declared: "This order marks the entrance of GTT into the new field of LNG bunkering, and demonstrates once again our clear expertise in the LNG industry. GTT is perfectly positioned to accompany its shipowner customers during the industry-wide evolution towards more environmental ships."

Safe gas containment for the growing gas fleet … and for LNG-as-fuel tanks

Which containment systems should a shipowner choose for safe and efficient LNG transportation?

In 1978 Lloyd's Register's Alan Gavin wrote the seminal technical overview of options. Fundamentally, the industry is still using the technology he described. But the industry has taken two principal alternative paths: either the independent type 'B' spherical Moss-Rosenberg tanks concept or membrane tanks – as designed by GTT.

In recent years membrane ships have comprised the vast majority of gas ship orders, with GTT systems being used in all the Q-Flex and Q-Max ships delivered. However, the Japanese market has preferred Moss tanks. And recently it was confirmed that Petronas has ordered 4 +4 Moss ships using the IHS design referred to in depth overleaf.

An understanding of gas containment systems, their properties and shipyard production issues is hard won and, given the scale of investment and the importance of performance requirements, both shipyards and operators have tended to concentrate on one or the other of these main options – membrane or Moss.

But in early March 2014 it was confirmed that, on the back of a long term charter from Tokyo Gas, a consortium of Japanese owners had chosen the SPB tanks, a prismatic independent type tank, not used in 25 years, in an order for two 165,000 cbm ships from JMU. With orders for membrane ships healthy, Moss orders growing and now SPB in the frame, it seems the industry is going for a healthy mix of containment sytems.

The development of different containment technologies has to be good as the wider marine industry looks at gas as a fuel for all ship types: sharing the experience of LNG containment systems is important. To date, LNG as fuel applications in non-gas carriers have used type 'C' pressure vessels for bunker storage – as images of the *Viking Grace* show clearly with the two Wärtsilä gas tanks mounted aft. But a demand for larger scale storage beneath deck and maximising cubic capacity means that the industry will consider alternative independent or prismatic type tanks. There is a whole range of technology solutions appearing in the market. Each solution may show its benefits only in dedicated service and route. LNG fuel tank concepts for short-sea-shipping on regular routes may differ greatly from those good for long haul on irregular routes. The rich but low-weighing and extremely cold liquefied gas fuel and the unavoidable insulation systems and inspection space around some tank concepts can altogether lead to huge sacrificing of ship's effective cargo space. On the other hand, some tank concepts cannot take pressure build-up of boil-off gas which leads to more complicated gas handling systems and alternative ways of burning or wasting the excess gas in a safe way. ■

The Lloyd's Register classed *Grand Aniva*, an example of a Moss type gas ship.

The Lloyd's Register classed *Mozah*, the first ever Q-max LNG carrier, an example of a membrane type gas ship.

IHS – integrated hull structure

In our April 2013 Gas Technology Report we looked at *Sayaendo*, a new generation Moss type LNG carrier which features the integrated hull structure (IHS) design concept. Here we look at the design path that led to *Sayaendo*, as well as to a recently contracted Petronas LNG carrier which also uses IHS.

What distinguishes the MHI-designed *Sayaendo* (which in Japanese means peas in a pod) and the HHI-designed Petronas carrier is the evolution of the Moss-Rosenberg type spherical tank cover design.

Because, although these ships might not look to the uninitiated like Moss ships, underneath they accommodate more or less conventional Moss spheres. The *Sayaendo* and HHI designs use what is known as an Integrated Hull Structure (IHS). Instead of covering each tank with a separate protective cover, the IHS concept, used under a licence from Aker Arctic of Finland by MHI and HHI, provides longitudinal hull strength as well as protecting the tanks. This enables reduced steel weight and greater tank size to be accommodated within the same hull envelope.

The origins of the Moss spherical tank concept lie in Moss, a town in southern Norway that gave its name to the distinctive spherical LNG containment systems and the company that designed them further – Moss Maritime. The IHS concept was developed as a by-product in a shipyard in Turku, Finland, in search of the most suitable tank cover shape for their forthcoming LNG carrier design.

Between January 1996 and May 1997 the Kvaerner Masa Yard (KMY), as it was then known, in Turku built a series of four 135,000 cbm LNG carriers for ADNOC, the Abu Dhabi National Oil Company. These four gas carriers were notable for a number of innovations. And it was the design work on these ships that shaped the path to IHS. The ADNOC LNG carriers built in Turku were the first ships of such a size to be designed with only four larger, rather than five smaller, cargo tanks. Going for four large tanks presents obvious efficiencies both in shipbuilding production and operations. At the time of construction the tanks were the largest ever built. But larger tanks also require a wider beam ship with implications for hull form, installed power and speed. Therefore the ships were designed with a longer hull than would have been necessary just to accommodate the four spheres. As a result, the delivered ships have installed power on the same level as that for a less wide five-tank competing design. Many later Moss designs with the same or higher cargo volume have adopted the four-tank concept.

Sayaendo – a design using the integrated hull structure concept with Moss spherical LNG containment tanks under a stretched tank cover.

Mauri Lindholm is Aker Arctic's Principal Naval Architect – for more than 33 years he has been working with the same people in the same shipyard but under a host of different names, reflecting the ever-evolving journey of Finnish shipyard ownership. In the 1990s the Turku shipyard was owned by KMY. What has not changed is the focus on design excellence and efficient shipbuilding production.

He recalls some of the principal challenges they addressed when trying to design the best gas ships: "At KMY we concentrated very heavily on developing efficient designs but also on efficient production techniques and processes, especially on those for the tank fabrication. The most advanced and most efficient of mid 90s aluminium tank production technologies included extensively automated welding, hot forming, machining and inspections processes followed by a number of methods worldwide patented.

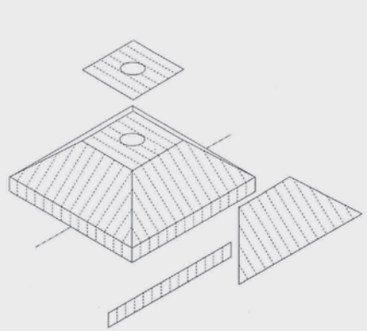
"An area of concentrated work explored the best way to cover the gas spheres. This focus started in the early 1990s as KMY tried to work out the best way to design and build Moss tanks. When the contract for the ADNOC ships was signed in 1993, we were already advanced in our thinking on various issues. For example, as well

The IHS concept provides longitudinal hull strength as well as protecting the tanks. This enables reduced steel weight and greater tank size to be accommodated within the same hull envelope.

Gas containment

The proposed tank cover construction methods

The design and production teams were looking for an effective design solution that could be built as simply as possible, cost-effectively and by reducing the materials used – a number of options were considered.



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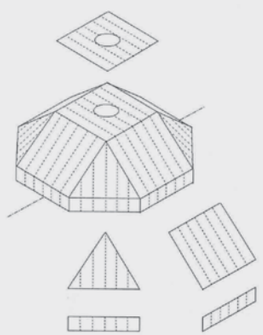

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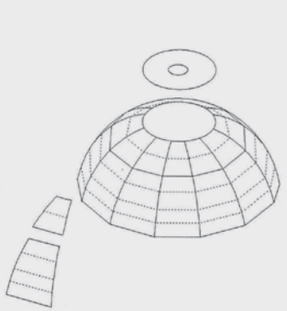

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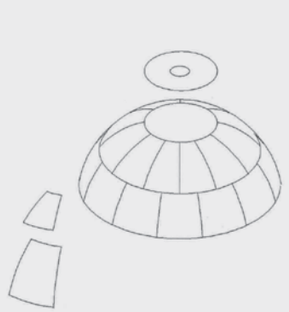

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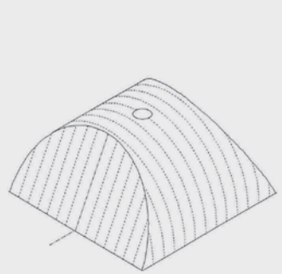
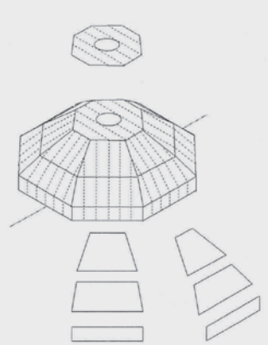


Alternative E



Alternative F

as the tank covering, what is the best way to support the Moss spheres in the hull of a ship? With the spheres exposed to huge thermal stresses when cold, aluminium becomes even stronger but it shrinks, drastically – it is vital that any of the normal deflections to the hull when operating in seaway are not transferred to the tanks.

"We looked at various options and started to co-operate with our Norwegian friends at Moss Maritime. We quickly decided on four tanks, rather than five." Next was looking at how to support the tanks, and the orthodoxy of upright skirt structure with the equatorial rings was challenged, inspired by the Moss maritime people, looking at alternatively designed skirts and even at hanging the spheres. In the end KMY stuck with the conventional way of supporting the spherical tanks but their investigations and free thinking sparked innovation elsewhere.

The difference between 'a large' and 'a larger' sphere is mainly in the amount of aluminium material. Each and every tank holds two large and precious cryogenic pumps, a smaller spray pump at the bottom and a huge number of various sized piping, pipe penetrations, valves, instrumentation and other outfitting at its dome on top of the tank. Four sets of everything instead of five leads to remarkable savings, both for the builder and the operator.

Designing the tank covers efficiently became an interesting challenge – the design and production teams were looking for an effective design solution that could also be built as simply as possible, cost-effectively and by reducing the materials used. A number of options were considered.

Lindholm says, "The solution we chose was a geometric shape, imitating a hemispherical cover but consisting of eight exactly similar sections. No force was needed to bend and construct the sections; the relatively thin skin plate was laid on a jig that gave the desired form for the plate. Stiffeners and heavier web frames were placed and welded on the curved plating. The eight sections were assembled to a complete cover and lifted on the cargo hold to cover it immediately after having lifted the main tank sections inside the cargo hold.

"After the ADNOC ships were designed, when focusing on larger Moss ship designs and tanks, the tank production people in Turku invented so-called tank stretching, another improvement to the Moss ship concepts. By adding a cylindrical insert to a spherical tank the cargo volume could be increased. It costs only some additional tank material whereas the steel hull remains practically unchanged by its main dimensions. Of course the tank covers need to be raised accordingly. The increased weight due to additional cargo and tank material in the middle of the ship is well carried by a typical Moss ship hull form which is slender at both ends." The cargo capacity of a medium-sized Moss ship can be extended easily by 5,000 to 10,000 cbm depending on the height of the cylindrical insert. By now three other builders in South Korea and Japan have adopted and are licensed to use the Vertically Stretched Tank (VST) concept. 7 such ships have been built and 10 are on order.

Lindholm concludes, "Lloyd's Register's contribution and role was essential for the development of both the IHS and the vertically stretched tank concept (VST). LR's feasibility calculations and 'approval in principle' were necessary to confirm us, the inventors at KMY, and also the forthcoming Moss ship builders and their clients, to go for these inventions and make them come true!" ■

ADNOC ships: The solution chosen was a geometric shape, imitating a hemispherical cover but consisting of eight exactly similar sections.

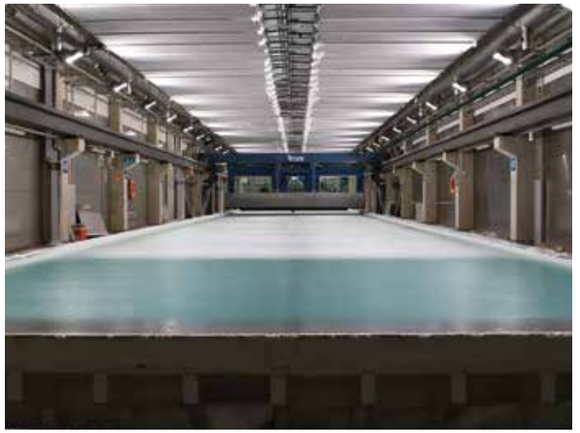
Mikko Niini, Special Advisor for Aker Arctic, and previously the company's Managing Director. Photo credit: Johannes Romppanen

Arctic LNG designs supported by today's Aker Arctic ice capability

Today Aker Arctic Technology Inc. and its facility at the new Vuosaari port just outside Helsinki is the current home of the design technology capabilities that originated in Finnish shipyards. While no longer building ships they have developed clear leadership in ice model testing and Arctic ship design based on 40 years of experience.

Ice model testing started in Helsinki in 1969 when Exxon developed the 'Manhattan' project to evaluate the potential for Arctic tanker operations through the North West Passage to exploit the North Slope oilfield. The large tanker *Manhattan* was modified with an ice bow and hull and tested in full scale.

After research, Arctic tanker operations were then considered to be too difficult and the oil companies built the Trans-Alaska pipeline across Alaska instead – to Valdez. But the ice testing foundations had been laid and Wärtsilä continued the ice testing in the facility that was originally intended for one-off case testing only. Later in 1983 a new purpose-built facility was opened elsewhere in Helsinki. Through various evolutions of ownership and now in its third ice model testing facility, what is now Aker Arctic was created in 2004, when the ice technology capability was separated from the shipyards and the turbulent changes in ownership that have characterised the last 30-40 years of Finnish shipbuilding.



The Aker Arctic towing tank at Vuosaari. Photo credit: Johannes Romppanen

At the sharp end of understanding ice and cold. Photo credit: Johannes Romppanen

Arctic LNG

Model testing at Aker Arctic Technology Inc.'s state-of-the-art facility.
Photo credit: Johannes Romppanen

Through those 40 years of ice model testing and design work Aker Arctic's expertise was honed across a wide variety of ice and cold-related projects. Today the ice model basin sees testing of all sorts of initiatives to develop designs that can efficiently and safely navigate and break their way through ice. Aker Arctic helps to develop new concepts for new operations and validates their performance. Now the potential for LNG exploitation in the Arctic is a reality. Mikko Niini, Special Advisor, Aker Arctic, and previously Managing Director, says, "the possibilities of LNG in the Arctic have been around for a while".

But feasibility studies by oil majors really started in earnest in 2006 when the oil majors started looking at the Shtokman gas field and there were potential Canadian gas opportunities as well. Niini says: "We saw for example, that the IHS tank cover concept in a Moss ship could be useful for Arctic operations and so we agreed that key staff and patents would be transferred to us from our shipyard shareholders in 2006." A continuous tank cover or IHS encapsulates the steel hull around the spherical tanks and provides proper strength, rigid structure and a lighter hull with ordinary material thickness – in comparison to conventional Moss ships. Also that one larger tank cover entity with its smooth form provides lower wind drag and is less sensitive to icing. In a conventional Moss ship the exposed cargo pipe rack or 'flying passage' on top of the tanks is supported by complicated truss structures – exposed to ice accumulation. In the IHS concept the piping is laid on top of the continuous cover that forms a plain deck to support the pipe rack and other outfitting there.

But rather than Shtokman it is on the Yamal peninsula in North-eastern Russia where progress has really been made with Arctic LNG. Yamal LNG, a partnership between Novatek, Total and CNPC, was formed to develop the field from Sabetta, on the estuary of the Ob River, ice-bound for nine months of the year. The Yamal LNG project is now one of the largest industrial undertakings in the Arctic. It will eventually involve the drilling of more than 200 wells, the construction of three LNG trains, each with a capacity of 5.5 million tons per year, and a vast gas exporting terminal.

The project enables production and marketing of the Russian Arctic's vast natural gas reserves and will create a major new maritime route for transporting LNG to Europe and Asia.

> "The possibilities of LNG in the Arctic have been around for a while."
>
> Mikko Niini
> Special Advisor, Aker Arctic

Breaking the ice

Come winter, come summer, an LNG tanker will come to load its cargo at the Yamal LNG terminal every 38 hours. This steady traffic will make the Sabetta seaport one of the busiest in the Far North. Year-round navigation will be possible thanks to the "double-acting" ship operating concept, the high ice class of the ships and an effective ice-management system.

The design of the seaport and its jetties draws on extensive studies of local sedimentology and ice behavior, conducted with the help of the Arctic and Antarctic Research Institute (AARI) of Saint Petersburg – the undisputed scientific expert in this field. The protective systems deployed are based on existing technologies that have passed muster in similar conditions at the Russian port of Dudinka. Two huge anti-ice barriers will protect the Sabetta seaport and its tanker traffic from accumulations of ice during ice jams, and from drifting blocks of fast ice during ice break-up.

A number of various sized icebreakers will be mobilised for ice management to keep the port access channel free and clear and ensure year-round navigable conditions all the way to the LNG terminal. Models of currents and ice conditions in the Gulf of Ob will be used to optimise these fairways. In addition, Total's 'extreme cold' experts are currently reviewing technologies for limiting brash ice that have already been tested in the United States and Finland. (Brash ice is an accumulation of floating ice made up of fragments and debris left in the wake of icebreaking vessels.)

LR classed LNG-powered icebreaker for Finland

A new icebreaker will be built by Arctech Helsinki Shipyard Inc. and delivered to the Finnish Transport Agency by the beginning of 2016. The icebreaker's concept design was done by Aker Arctic Technology Inc. and ILS, and model tests and simulations were carried out at Aker Arctic's testing facilities.

The new icebreaker will feature the industry's most advanced technology – it has been designed for operations in the most demanding icebreaking conditions in the Baltic Sea. The icebreaker will be able to perform oil spill response operations and emergency towing under demanding conditions at open sea both in winter and summer, and will operate all year round to ensure safe seaborne transport in the Baltic Sea. The icebreaker will be powered by both diesel and LNG – which reduces both emissions and fuel costs. It will be the first LNG-powered icebreaker and its planned state of the art innovations promote Finnish Arctic expertise worldwide.

It is notable that, at 21 megawatts, the installed power of the new icebreaker will be equivalent to that of a large tanker, giving some idea of the power required in ice – although with a far more flexible and responsive performance than would be necessary for a big tanker.

Technical specifications

Length	110 m
Breadth maximum	4 m
Draught	8 m
Deadweight	about 3,000 t
Installed power	21 MW
Propulsion power	19 MW
Speed	16 kn
Speed at 1.2 m ice	6 knots
Crew	16 + 8
Range	30 days
Nationality	Finland
Classification	Lloyd´s Register

The new LNG-powered icebreaker.
Photo credit: Liikennevirasto/Flickr under Creative Commons Licence http://bit.ly/1cfOzXY

16 Arctic LNG carriers

In December 2013 Yamal LNG announced an investment of US$27 billion to exploit, produce, process and transport the gas in a project that includes Arctic class LNG carriers. A slot reservation agreement has now been signed with DSME in Korea for 16 170,000 m^3 Arc 7 ice class LNG carriers based on Aker Arctic's 'Double-Acting' technology using azimuthing propulsion pods that, when in ice breaking mode, propel the ship stern first. The containment systems chosen will be the membrane type systems, rather than IHS. The first vessel is due to be delivered in 2016. The first firm shipbuilding contract between the yard and a shipowner was signed in February.

By now, Aker Arctic have been carrying out detailed model testing in their ice testing facility for a longer time and comprehensive final testing continues.

The operators at Yamal believe that deploying this portfolio of proven solutions beyond the Arctic Circle opens the way to a new and important shipping route for LNG. ■

Built for ice and cold – new gas carrier for Sovcomflot

In February Russia's largest shipping company, Sovcomflot, took delivery of its latest LNG carrier – the *Velikiy Novgorod.* The 170,200 cbm ship was constructed at South Korea's STX Offshore & Shipbuilding and is classed by Lloyd's Register. The membrane ship is equipped with a diesel-electric, dual-fuel propulsion system consisting of 2 × MAN 8L51/60DF and 2 × MAN 9L51/60DF engines.

The propulsion facility provides the LNG carrier with a highly efficient, low-emission propulsion system, especially when running in gas mode. It also features a high degree of redundancy, while the MAN 51/60 DF engines provide multiple fuelling options.

The ship is named after one of Russia's oldest cities. Velikiy Novgorod has a glorious history going back to the establishment of the Russian state and the start of merchant shipping between Russia and Europe. ■

The ceremony at the shipyard was attended by: Deputy Chairman of the Management Committee, Gazprom, Alexander Medvedev; Deputy CEO of Gazprom Export Elena Burmistrova, who is the Sponsor Lady of the vessel; SCF President and CEO Sergey Frank; and Novgorod city administration representatives; as well as representatives of international financing organisations, including Tom Boardley and Iain Wilson of Lloyds Register. Image: Sovcomflot.

LNG bunkering map

LNG bunkering map

LNG bunkering is spreading around the world and our expertise is supporting its development.

Amsterdam
The Netherlands port opened an LNG bunkering zone in December 2013. It enables LNG to be transferred from road tankers to coastal and small ocean-going vessels.

Stavanger
LNG-fuelled ferries will be able to bunker fuel at a liquefaction plant next to the port later this year as demand for LNG grows in the Nordic region ahead of the new ECA rules in 2015.

Antwerp
The port is developing procedures and technical specifications for LNG bunkering. It is working with Exmar on a dedicated LNG bunkering vessel to use in the port.

Tornio Gulf of Bothnia, Finland
LNG terminal to start construction. (See article on page 20.)

Gulf of Finland
Plans underway to build large scale LNG terminal with bunkering capability.

Zeebrugge
A rapid rise in recent activity at the 25-year-old LNG import terminal has led to the building of a new jetty for LNG coastal and bunker tankers later this year. The LR classed dual-fuel tanker *Argonon* uses the facility to bunker LNG.

Gothenburg
The Swedish port is building 500m³ capacity storage tanks for short and deep sea bunkering and inland distribution by rail.

Vancouver
An expansion project will double the size of the existing LNG storage facility on Tilbury Island near Vancouver. Its liquefaction capacity will be increased more than tenfold. A second peakshaving LNG storage plant on Vancouver Island is also due to be expanded.

Rotterdam:
Bomin Linde LNG is studying the potential of building an LNG bunkering facility at Europe's number one port.

Fourchon
The Louisiana-based port is the first US port to build an LNG bunkering station in the USA. The facility which is due to start operating this year will include three 340m³ storage tanks.

Hamburg
Germany's first LNG bunkering terminal is due to be operational in 2015. The Bomin Linde LNG-led facility will be built on a modular basis. Together with the German port of Bremerhaven, Hamburg will be a strategic hub serving the North and South Baltic Sea ports.

Tenerife
The port is building a regasification plant at the new port of Granadillam on the south of the island. It is involved with several other projects for the supply of LNG – notably from barges and satellite stations.

Singapore
The world's leading bunker port, it supplied 42.7 million tonnes of fuel oil for ships in 2012. In October 2013 LR completed an LNG bunkering report for Singapore's Maritime and Port Authority (MPA) and the port is looking at several major LNG bunkering options.

A prelude to great things

Lloyd's Register Energy's (LRE) Overarching Project Manager, Daryl Attwood, saw the Shell *Prelude* FLNG substructure launch in November 2013. A proud moment well worth getting up for at 5am, Daryl shares his insight into this remarkable project, which is advancing energy and marine innovation.

Prelude's substructure being floated out of dry-dock.

***Prelude*, Shell's floating liquefied natural gas (FLNG) facility, at nearly 500 metres in length, will be the world's largest floating facility. It will be installed off the northwest coast of Australia in the Browse basin, and will not be dry-docked for the first 25 years of its expected 50-year operational life.**

"At dawn on a beautiful morning in late November 2013, *Prelude* achieved the major milestone of its substructure being launched at Samsung Heavy Industries' (SHI) yard in Geoje, South Korea. Staff, family and friends of all major *Prelude* stakeholders were delighted and proud at the sight of the result of their hard work leaving the dry-dock and floating across the bay to its new home, where topsides installation and commissioning will continue," described Attwood, who was joined by many other Lloyd's Register personnel from around the world for the launch.

LRE is delivering classification, certification, and validation services to *Prelude*. The substructure and turret have been designed and will be constructed in accordance with LRE's Floating Offshore Installation at a Fixed Location (FOIFL) Rules. The topsides will be certified according to an agreed set of industry codes and standards, and the combination of this compliance will lead to the entire vessel being taken into LR classification. In addition to this, LRE will confirm compliance of the entire vessel with Shell's design and engineering practices (DEPs) and a set of performance standards (PS) defined by Shell within their safety case document.

> "Family and friends were delighted and proud at the sight of the result of their hard work leaving the dry-dock."
>
> Daryl Attwood
> Lloyd's Register Energy

A truly global project

Design appraisal for *Prelude* was conducted at the locations most convenient for the project – topsides in the UK, close to the engineering contractor, Technip, in Paris; the turret also in the UK, close to engineering contractor Single Buoy Moorings (SBM), in Monaco; and substructure in Busan, South Korea, close to the engineering and construction contractor Samsung Heavy Industries in Geoje. Design appraisal of individual equipment packages was undertaken either at the office holding the direct equipment package certification contract with the local fabricator, or the next closest office capable of doing the work, which in most cases was in the same country as the packages' fabrication.

The equipment packages which arrive at site in Geoje on a daily basis were subjected to LR design appraisal and survey at offices around the world, including those in several European countries (The Netherlands, Germany, Spain, France, Italy, Norway, and the UK), Japan, Korea, the United States, and others. A country-based LRE *Prelude* project manager was assigned in each country where significant *Prelude* equipment package work took place, ensuring that all surveyors and design appraisal specialists in the country were familiar with the various applicable classification, certification, DEP, and PS requirements.

Our people

A multinational surveying team comprising some 30 technical experts has been assembled at LR's office in Geoje to survey the substructure and topsides construction and perform follow-up work on several hundred equipment packages. Several nationalities are represented in the team; the majority of the substructure surveyors being Korean and project management and topsides surveyors calling the UK, Ireland, and Canada home.

Also, a dedicated LR team was set up at Drydocks World Dubai to survey the fabrication of the turret against LR classification requirements, Shell DEPs, and PS. The Dubai-based lead surveyor visited SHI in Geoje upon delivery of the first turret module and is expected to visit again upon delivery of subsequent modules.

"It is a privilege to work with so many of our own dedicated teams from around the world and with the many stakeholders involved in this project. It really has been and is an exciting time," said Attwood.

Innovative solutions

There is a saying "prepare for the world not as it is today, but for the world as it's going to be". The FLNGs of tomorrow are being designed to extract new gas reserves which have been discovered in some of the world's deepest waters, answering society's demand for the provision of more 'carbon-lite' energy sources.

"*Prelude* is a world-first innovation in this area and its influence is being felt throughout LR. Two major initiatives have been extensively used on the project – an enhanced formal project management structure and formal database management of the procurement chain. These two initiatives, which have been very well received are being employed on other major projects with effective results. In addition, the LR technical capabilities resident in South Korea have improved as a direct result of the work achieved on *Prelude*. This puts LR's energy and marine businesses in a favourable position for knowledge retention and experience on future projects – integral to their safe, sustainable and economic operation. This growing capability can only be expected to continue as the project moves into the next phases," concluded Attwood. ■

Wärtsilä
Maximising energy value

Marine engine maker going well beyond machinery to support the entire gas value chain.

Finnish based, multinational Wärtsilä has been a leading actor in the development of gas-as-fuel energy for the shipping industry.

Well known for their medium-speed dual-fuel engines, Wärtsilä has supplied a significant share of the gas engines sold to the marine market, including to benchmark projects such as *Viking Grace*. In addition they have been providing the gas tank and piping arrangements to many gas-as-fuel projects, as well as the propellers, silencers, power electric and thruster machinery in some cases.

And in November last year Wärtsilä showed the world their new slow speed gas engines, the RT-flex50DF, Wärtsilä X62 and X72, to provide the market with an engine offer suitable for deep sea tankers, bulkers and container ships. Right away, Sweden-based Terntank Rederi A/S ordered two of the Wärtsilä RT-flex50DF engines for Terntank's new 15,000 dwt product carriers.

Tomas Aminoff, Director, Technology Strategy: "We want to add value to the gas supply chain AND help reduce the wasted energy and harmful emissions from oil and gas production and shipping."

Breaking into new markets – turnkey gas terminal capability supported by acquisition

But even more recently Wärtsilä announced the signing of a turnkey contract to engineer, supply, and construct a new LNG receiving terminal to be built in Tornio, northern Finland. The contract, valued at approximately EUR 100 million, is with Manga LNG Oy, a joint venture between the Finnish companies Outokumpu Group, Ruukki Metals Oy, Gasum Oy and EPV Energy Ltd. Winning such a significant contract was only possible following Wärtsilä's acquisition of Hamworthy Marine in January 2012. Hamworthy, based in Poole, Dorset, on the southern UK coast, significantly expanded Wärtsilä's capabilities beyond engines and tanks to encompass a full range of marine gas handling systems, including LNG reliquefaction, regasification, VOC recovery, LPG and ethylene cargo handling, as well as deepening its capability in LNG fuel systems.

Tomas Aminoff, Director, Technology Strategy, Wärtsilä, talks about a company that is increasing its capabilities and reach to address issues and challenges right across the gas supply chain, from well to business consumer. He explains: "Engine technology, of course will play a big role in our future, but we now have the capability to support upstream gas production, midstream and gas terminal operations – these are the areas where we are going to focus increasingly. We now have a specialised Oil & Gas focus division – providing onshore and marine services. We have some real diamonds in our capability portfolio now – we have to keep polishing them."

Tornio – LNG bunkering capability

LNG terminals are going to be vital for gas supply chains – there has been a lot of talk about infrastructure and here is a real project. Tornio, at the northern extremity of the Gulf of Bothnia, will be able to take 20,000 cbm ships to provide LNG reception, storage and bunkering facilities. Ships serving the terminal will need to be either 1A

"Well known for its medium-speed dual-fuel engines, Wärtsilä has supplied a significant share of the gas engines sold to the marine market, including to benchmark projects such as *Viking Grace*. In addition they have been providing the gas tank and piping arrangements to many gas-as-fuel projects as well as the propellers, silencers, power electric and thruster machinery in some cases."

Looking across the gas supply chain – LNG terminals are going to be vital.

Viking Grace, looking aft.

Building gas engines and gas systems

or Super 1A to the Finnish/Swedish ice class rules to cope with winter conditions supported by ice breakers. It is likely that a substantial number of ships will need to be built to supply the terminal.

"This is a large and extremely important project, and we see the selection of Wärtsilä Power Plants to engineer, supply, and construct the new LNG receiving terminal as an acknowledgement of our expertise and experience in engineering, procurement and construction (EPC) project execution, in LNG handling systems, and in the use of LNG as fuels. The terminal will enable this clean and competitively priced fuel to be available for industrial consumers in the Bay of Bothnia region, and will further enhance the growing acceptance of LNG as a marine fuel," says Vesa Riihimäki, President, Wärtsilä Power Plants.

Wärtsilä is extending its LNG value chain strategy to cover LNG terminal solutions:
Wärtsilä is recognised for its market-leading gas engine technology, as well as for its broad offering in gas handling systems. With the Tornio Manga LNG receiving terminal, Wärtsilä is for the first time combining its strong Power Plants EPC capability with its industry-leading LNG gas handling technology to provide a turnkey LNG terminal solution.

While Tornio is a mid-scale import terminal, able to supply local industrial energy, plans for a large scale LNG terminal in the Gulf of Finland to support regional demand, are also being made. The location could be on either side of the Gulf, in either Finland or Estonia.

In terms of gas development, there is quite a lot going on in the Baltic, with substantial governmental, commercial and societal support for LNG, but Aminoff says that it's important to focus elsewhere as well. The Brittany Ferries order for a new flagship to cross the English Channel is yet more evidence of the spread of LNG-fuelled shipping in Europe and will rival the scale of the *Viking Grace*. Inland waterways could adopt LNG now on a large scale. And even more significantly the explosion in interest in gas in North America is the real story now (as covered in the previous Gas Technology Report): the availability of cheap gas is driving operators of short point-to-point ships, like ferries and certain container players, as well as OSV companies, to go for LNG.

But expanding LNG into international blue sea shipping will be another matter, states Aminoff. "There are many deep sea shipping companies, looking seriously at LNG as fuel. But as well as availability of bunkering (being looked at by big ports such as Singapore and Antwerp) deep sea ships may need different containment systems to the 'Type C' tanks standard to date." (Aminoff thinks we'll be looking at the sort of tanks more commonly used in LNG carriers).

When asked what the big issue to be addressed is, Aminoff immediately talks LNG pricing. "If you want to highlight any kind of bottleneck, it's price, not availability. If you look at the price of any kind of energy, the costs of production are not necessarily linked to the cost to the consumer of that energy. What the industry needs is an LNG price that makes gas attractive as a bunker fuel." But how can shipping get gas at a good price?

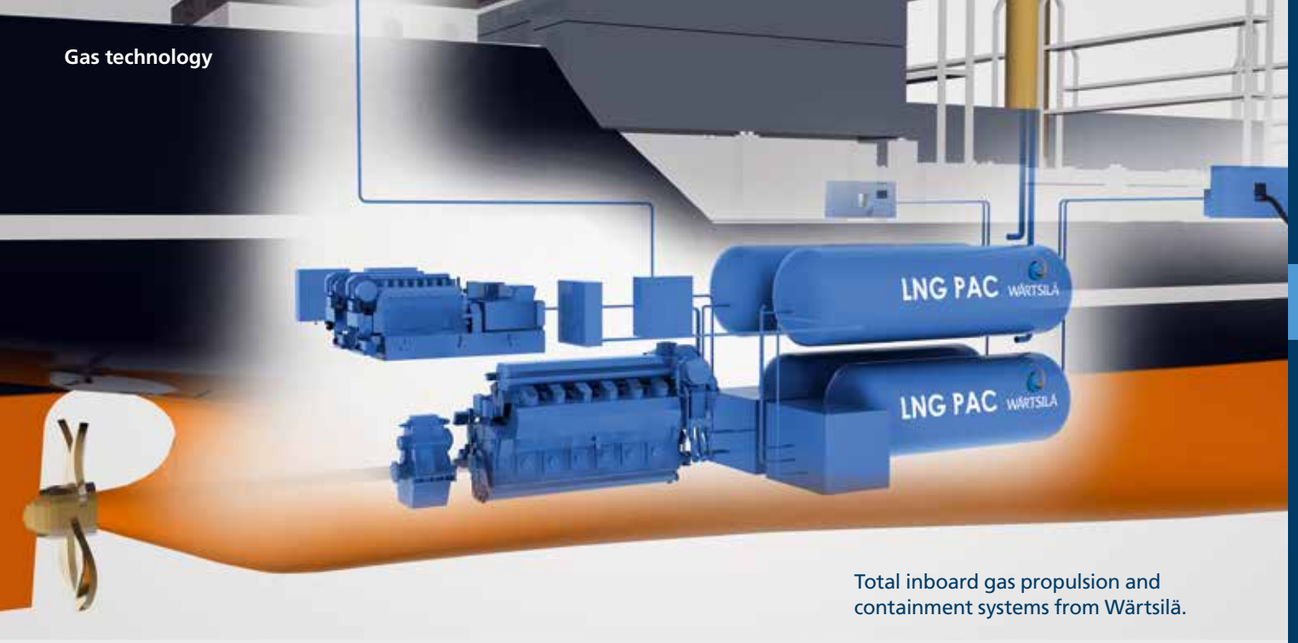
Aminoff: "It's about finding a price level that works for both sellers and buyers of LNG. The production costs are not the same as the market value but shipowners' ideas of what they want to pay for gas may be very different from the gas suppliers' or traders' views on pricing. The development of big scale terminals in places like the Gulf of Finland will help but we don't yet have the 'bottom up' pricing model that exists in North America." ■

The silence of the gas engines

Tomas Aminoff relates that the *Viking Grace*, whose engines and gas tanks were supplied by Wärtsilä, is so quiet that some passengers are reported to have complained about the noise of the air conditioning on board. While the air conditioning units are the standard, latest design, the lack of noise and structural vibration even when manoeuvring is new for the industry. And another indicator of the silence of the gas engines is that in the duty free shop the usual clinking of all the bottles, again due to the vibration of the engines, is absent to give experienced ferry passengers an eerily quiet shopping experience.

Bunkering as usual for LNG Viking

The Viking Grace has now bunkered so many times in Stockholm, around 250 times, that it really is business as usual and most of the practices involved are not unfamiliar to bunkering procedures on many cruise ships. Aminoff says, "It's the most boring operation – and so it should be!"



Total inboard gas propulsion and containment systems from Wärtsilä.

Keeping a lid on emissions

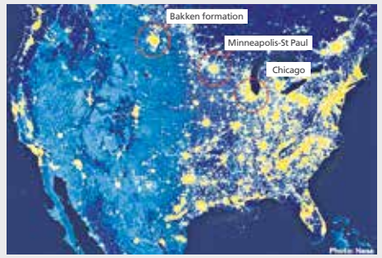
Upstream efficiency – reducing flare-off and reducing greenhouse gas emissions

One of the big challenges with oil and gas production is flaring – for a combination of production reasons, flaring has been difficult to manage. Both regulators and business are becoming increasingly focused on reducing flaring – to reduce pollution and to eliminate energy waste. Tomas Aminoff explains that flare off from oil and gas production is around 20-25% of the total greenhouse gas (GHG) emissions from the oil & gas sector's total of 5-6% of total global GHG emissions. To put it into context, the emissions from flaring might be the equivalent of one third to 50% of the total GHG emissions from the global shipping industry, estimated at 2.3% of global emissions.

Wärtsilä has developed a Flare Gas Recovery system that enables production operation without a flare. The recovered gas is used in the FPSO´s process train and can later on be used for different purposes, as a source of energy or for hydrocarbon blanketing.

Midstream emissions

Norway, in its submission to MEPC 65, estimated that volatile organic compound (VOC) emissions from global shipping and production offloading were the equivalent of 12-15 million tonnes of CO_2. And that's not just harmful emissions being lost to atmosphere but valuable cargo. Reducing VOCs from tanker operations is important – as with flare off. Wärtsilä's gas reformer technology in combination with Wärtsilä VOC recovery is looking to further improve both the shipping and offshore sectors' management of VOCs. Aminoff: "In every part of the energy chain you have VOCs – particularly in the North Sea with FSO to shuttle tanker operations. We can help companies manage these emissions". ■



The Bakken oil field from space, lighting up the night sky like a big city.

Reducing greenhouse gas emissions: a flare gas recovery system.

Lloyd's Register at the Centres of Technical Excellence, Gastech 2014

CoTE Theatre B, KINTEX 1, Korea

Seminar agenda

Tuesday 25 March – LNG Fuel Technology

Time	Presentation	Presenter
10:30 - 10:35	Introductory Remarks	Leonidas Karistios, Lloyd's Register
10:35 - 11:00	LNG and Gas as Fuel Update	Luis Benito, Lloyd's Register
11:10 - 11:35	Safety of LNG Bunkering at Port Through Risk Assessment	Kidong Kim, KOGAS
11:45 - 12:10	LNG Bunkering – Standards and Operational Procedures	Thanos Koliopulos, Lloyd's Register
12:20 - 12:45	LNG as Transport Fuel – Transforming Vision into Reality	Jane Carland, Shell
12:45 - 13:45	Lunch Break	
13:45 - 14:10	Global Marine Fuel Trends 2030	Dimitris Argyros, Lloyd's Register
14:20 - 14:45	LNG Pac-ISO and GVU-ED – Two Further Steps in the Transition Towards Gas	Sören Karlsson, Wärtsilä
14:55 - 15:20	Alternatives for LNG Tank for Commercial Vessels – Some Innovative Designs	Arthur Barret, GTT
15:30 - 15:55	LNG as Fuel Regional Highlight – North America Projects	Luis Benito, Lloyd's Register
15:55 - 16:00	Closing Remarks	Leonidas Karistios, Lloyd's Register
16:00 - 17:00	Networking Reception	

Wednesday 26 March – LNG & Gas Carrier Ship Technology

Time	Presentation	Presenter
10:30 - 10:35	Introductory Remarks	Luis Benito, Lloyd's Register
10:35 - 11:00	Novel Design Appraisal and Survey Aspects of FLNG Classification	Daryl Attwood, Lloyd's Register
11:10 - 11:35	Advances in GTT Membrane Type Tank Design for Large & Small Scale LNG Carriers	David Colson, GTT
11:45 - 12:10	Alternative Support Material for Small LNG Ships	Kai Ehrich, Fraunhofer AGP Rostock
12:20 - 12:45	Innovative Ship Design & Construction Amidst a New Regulatory Landscape	Parker Larson, General Dynamics NASSCO/DSME
12:45 - 13:45	Lunch Break	
13:45 - 14:10	Contracting, Designing and Operating Efficient TFTE LNG Carriers	Andreas Spertos, Richard Gilmore and Stavros Hatzigrigoris, Maran Gas Maritime Inc.
14:20 - 14:45	Aboveground Type Modular LNG Storage Tank	Dae-Soon Kim, HHI
14:55 - 15:20	The 2 Stroke Dual Fuel ME-GI Engine – A Robust Gas Combustion Solution	René Sejer Laursen, MAN Diesel & Turbo
15:30 - 15:55	FSRU Technology and Operations – Critical Issues	Thanos Koliopulos, Lloyd's Register
15:55 - 16:00	Closing Remarks	Luis Benito, Lloyd's Register
16:00 - 17:00	Networking Reception	

Over 50 years of global gas leadership

In 2014, shipping celebrates over 50 years of commercial LNG carrier operations. Whether you are talking gas carriers, LNG as a marine fuel, or LNG bunkering, our expertise and leadership in gas operations can help you make the best decisions based on the best, independent, technical insight.

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