



# THE NAVAL ARCHITECT

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### The Naval Architect 2018 reader survey

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Project Forward gains Eniram's data expertise



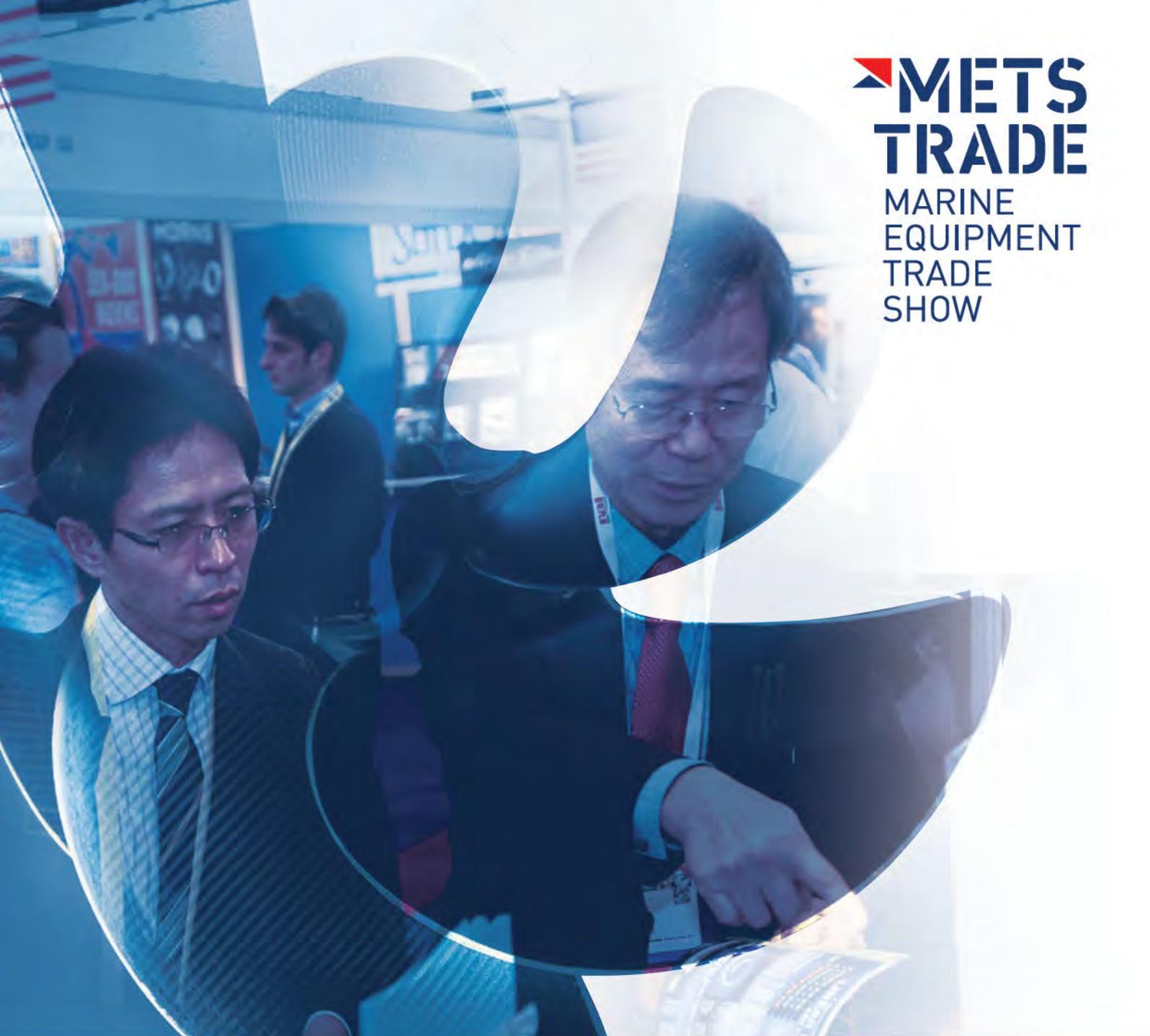
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Wärtsilä reaches LNGPac milestone



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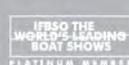
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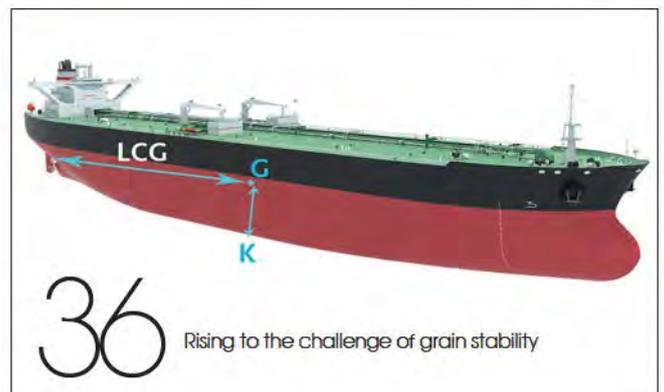
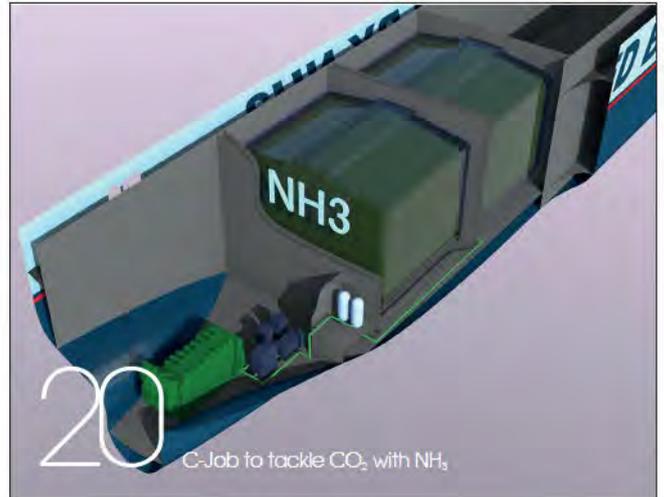
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# CALLING ALL TECHNICAL SUPPLIERS...

Image taken by Gabriel Zevri

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## The carbon factor

Decarbonisation in shipping is a case of ethics vs. economics

During our interview for this month's article on the potential of ammonia as a marine fuel (see p.20), Niels De Vries of C-Job Naval Architects raised in passing an interesting idea. He said: "Hopefully eventually Amazon will create a button on their website so that the client can choose whether they want clean transport and the willingness to pay more would enable that."

I didn't pursue whether he was referring to consumers for their retail services or Amazon's (relatively) nascent steps into logistics and freight forwarding, but in certain respects they amount to the same thing, namely: could we be entering an era with a two-tier system where more ethically driven, environmentally conscious ship operation co-exists with more economical, pragmatic options?

Certainly there is some evidence that the influence of the ethical consumer is on the rise, whether it's the growing popularity of organic foods at the supermarket or cruise and expedition ship passengers demanding greener vessels. However, there is a risk of taking the blinkered perspective that western European attitudes are shared by developing nations, or indeed those prosperous ones which have chosen to take a recalcitrant position on issues of climate change.

The 'carbon factor' and its full implications are very difficult to quantify; while increased environmental regulation is always counterintuitive to capitalism the knock-on effects to ordinary citizens are, on overall balance, beneficial to their health and wellbeing. Theoretically at least most countries are now locked into the Paris Agreement, and most would agree that these are necessary actions, but how many have

considered the sort of lifestyle changes this may require and how these adaptations will impact upon the cost of living?

As Trevor Brown, of consultancy group Ammonia Energy, observed while I was researching the aforementioned article: "We're moving into a world that's not going to look the same. There's going to be a transition from cheap energy to something we have to make work and there will be economic consequences."

For shipping, the much-publicised decision at MEPC 72 has to target a 40% reduction in 'carbon intensity' across shipping by 2030 and a 50% drop in overall CO<sub>2</sub> emissions by 2050 (by comparison with 2008 levels). Roadmaps and strategies now need to be planned and will require consultation across the industry, meaning a protracted period of digestion and discussion. IMO's 4th Greenhouse Gas Study is due for publication in 2020 and this will doubtless inform the Organization's promise to begin achieving GHG reductions in advance in the formal adoption of a revised GHG strategy in 2023.

After IMO's declaration there was some sobering analysis by Tristan Smith, of University College London's (UCL) Energy Institute. Figures previously prepared by UCL's Shipping Team suggest that to achieve the absolute reduction by 2050 means that by 2040 around 50% of shipping's fuel needs will need to be supplied by synthetic renewable fuels or biofuels. In real terms that would mean that by the 2030's most newbuilds will need to be zero carbon emissions.

Smith reflects that: "[The ships of the future] will look very different to today's ships. It's hard to predict exactly what the next 20 years will bring, but we could see a diverse shipping fleet powered by

hydrogen, ammonia, batteries, sustainable biofuels and sail."

He also notes the GHG decision represents a significant paradigm shift from efficiency improvements (as epitomised by IMO's Energy Efficiency Design Index) to decarbonisation. It's still hard to envisage how the jump will be achieved from the research projects and trial studies of today to the realisable, class-approved and cost-effective concept designs that will need to start securing orders from shipowners within 10-12 years.

Niels De Vries drew comparisons with the fringe status of LNG as a marine fuel a decade ago, but in terms of its energy yields its cost effectiveness and technological feasibility, and how these might further improve, could be predicted with some confidence. Moreover, it's not as if LNG-fuelled vessels now overwhelmingly dominate the orderbooks (although you might be forgiven for thinking so from the attention it receives); shipowners are still far more likely to opt for conventional fuel, even if they must now factor in a transition to low-sulphur fuel. In a report published in April 2018, DNV GL projected there would "probably" be 500 LNG-fuelled vessels (excluding LG carriers) in service by 2020.

The consternation concerning the 2020 sulphur cap, which has at least in part driven the uptake of the LNG, is another reminder of shipping's tendency to fudge and prevaricate. In theory, there's no running away from the GHG targets and for now you'll find few senior figures in the industry who will dare to publicly contradict that. Faced with a harsher economic reality however, history suggests that both shipping and consumer alike may decide that ethics come second to the exigencies of survival. *NA*

Ship management

## OSM to open 'benchmark' Maritime Operations Centre

Ship management company OSM are set to amalgamate their global sources from around the world in real time at a soon-to-be-completed 'Maritime Operations Centre' in Singapore.

Developed with local analytics company Azendian Solutions, the centre will 'transform decision-making, efficiency and performance,' OSM claim, 'while highlighting a new sustainable path forward for the industry.' It will act as the new headquarters of OSM's Operations and Technical Management division.

The foundation of the centre is a unique, tailor-made analytics solution that will allow OSM to monitor every financial and operational activity across their network. This enables 24/7 fleet support via data management, model optimisation, and descriptive analytics. A machine learning element will also be incorporated, to continually improve safety and efficiency.

A collection of applications will also allow remote devices to access these insights. According to CEO Geir Sekkesaeter, "this creates transparency throughout the organization and, through big data utilization, allows us to identify trends, predict issues and take actions that deliver safety, efficiency and cost benefits for all our stakeholders."

Once the Maritime Operations Centre is up and running, OSM hope to use its capabilities to develop and explore novel maritime solutions, including drones, blockchain, the Internet of Things and AI for predictive maintenance.

A 3D model of the Project Forward LNG bulk carrier design



LNG

## Eniram to join bulk carrier initiative Project Forward

Wärtsilä-owned company Eniram signed a Memorandum of Understanding (MoU) this month stating its intention to join Project Forward. Led by Arista

Shipping, the Joint Development Project (JDP) counts ABS, Deltamarin, GTT, Shell, and Wärtsilä as partners.

Project Forward started in 2013 with the goal of designing a commercially feasible but highly environmentally friendly dual-fuel LSFO/LNG bulk carrier that meets current and anticipated regulations including EEDI 2025, NOx Tier III and the 2020 sulphur cap. Following a five-year R&D period, the Forward Ships Corp. has been established, signing a preliminary deal in April with Yangzijiang Shipbuilding to build up to 20 bulk carriers to the Project Forward design.

Eniram's participation was sought by Project Forward due to the company's expertise in ship data modelling, which can highlight further possible efficiency improvements. These can be made either at the design stage using test data, or on a real-time operational basis via equipment monitoring.

According to, Arista Shipping's technical manager, Antonis Trakakis: "The aim of the project [with Eniram] is to arrive at a fully elaborated decision support tool, which will be extremely valuable in enabling us to predict, monitor, optimise, and also demonstrate the actual performance of the vessels."

IMO

## Regulations must remain IMO's focus, agrees future forum

Maritime industry leaders were unanimous in their belief that IMO's attention must remain firmly on legislature, not trade, at a forum held in London on 15 May. Entitled 'IMO 70: Our Heritage – Better Shipping for a Better Future', the event is one of a series being held to mark the adoption of the IMO Convention in 1948, and also a prelude to MSC 99, which took place from 16-25 May. The event was also live streamed, allowing online viewers to participate by sending in questions.

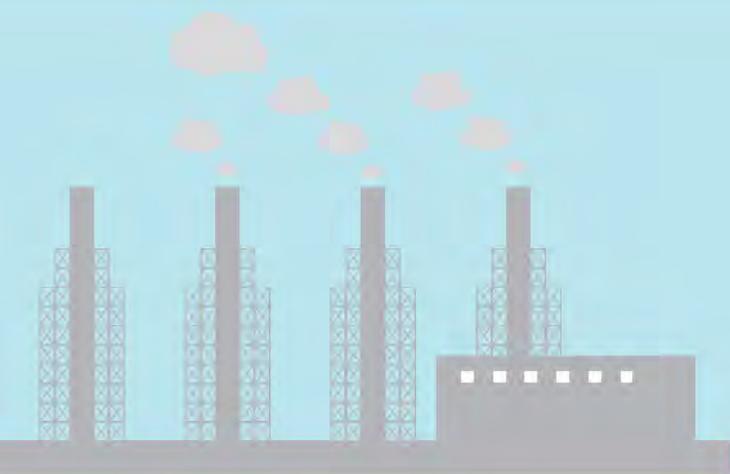
Following an introduction by IMO Secretary General Kitack Lim, two wide-ranging panel discussions took place. The first considered the challenges and opportunities facing IMO in the next 20 years, the second how the organisation can stimulate international trade, co-operate in sustainable developments, and raise its profile.

The first panel featured DNV GL's CEO Knut Ørbeck-Nilssen, Diane Gilpin of the Smart Green Shipping Alliance, Ghana's Minister for Transportation Kwaku Ofori Asiamah and the UNSG Special Envoy for the Ocean, Peter Thomson. Topics discussed by the panel included cybersecurity, autonomous vessels, the sustainable blue economy, and digitisation. IMO's structure was also considered, with debate over whether it is agile

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enough to respond to change. Drawing comparison with IACS, of which he is the current chair, Ørbeck-Nilssen pointed out that “politicians are always putting ambitious targets on the shipping industry... you have to balance that with finding pragmatic solutions that are possible to implement”

It was followed by a panel made up of Leo Ruijs of ECT Rotterdam, IMO Council Chair Xiaojie Zhang, and Alan McKinnon of Kuehne Logistics University and Heriot-Watt University. Questioned about trade, the panellists concurred that it is not IMO’s role to promote trade between nations, but to facilitate and regulate it. Asked what the ‘next revolution’ in shipping will be, the panellists felt that decarbonisation technologies would be prominent, as well as the possible entry of new players such as Amazon to the shipping market. Reflecting, Xiaojie Zhang suggested that “over the past 60 years, the IMO [has been] mainly reactive about regulations and technical standards.” However, he noted that the last few years have demonstrated a “more proactive and pragmatic” organisation.

Ro-ros

## Knud E. Hansen and Grimaldi develop new ro-ro design

Danish naval architecture firm Knud E. Hansen and logistics group Grimaldi have developed a newbuild ro-ro design called the ‘Grimaldi Green 5th Generation’ (GG5G). Following a contract with Nanjing Jinling Shipyard, a number of vessels will be built with the first delivered in 2020.

The 64,000gt ro-ro design is notable for its size, with a length of 238 metres, beam of 34 metres, and over 7,800 lane metres of rolling units, able to accommodate 500 trailers.

Also prominent is the inclusion of zero-emissions large lithium batteries to be used in port and at berth,

The ‘Grimaldi Green 5th Generation’ will be bigger than the Eurocargo class operated by Grimaldi



enabling the vessel to visit ports regulated under Emission Control Areas (ECAs). Recharging will take place as the vessel is at sea, via shaft generators adding the peak shaving system. 600m<sup>2</sup> of solar panelling will also aid with recharging.

To increase efficiency, an air lubrication system also features under the keel that will create bubble layers to reduce hydrodynamic resistance and therefore fuel consumption.

Emissions

## ICS stresses need for zero CO<sub>2</sub> fuels

Last month, the deputy secretary general of the International Chamber of Shipping, Simon Bennett, highlighted the need for a ‘global roll out’ of zero CO<sub>2</sub> fuels if the IMO’s 2050 goal is to be achieved.

Bennett made the remark at the International Transport Forum’s Summit of Transport Ministers, which is held annually in Leipzig. The event was attended by over 40 ministers and 1400 delegates.

Suggesting that the IMO target is “far more ambitious” than emissions reductions targets proposed by other industries such as aviation, as well as commitments made by global governments, Bennett claimed that it is nonetheless welcomed by the shipping industry.

However, Bennett pointed out that the target of a 50% reduction in CO<sub>2</sub> emissions by 2050 compared to 2008 levels, and an average efficiency improvement of 70% across the global fleet, cannot be achieved solely by what he termed the “interim solutions” of LNG or biofuels. LNG in particular has seen rapid uptake from shipowners as a supposedly greener alternative to conventional fuel oils. Whilst Bennett said it will “play an important part in the transition,” he declared that IMO’s targets “can only realistically be achieved with the development and global roll out of genuine zero CO<sub>2</sub> fuels.”

Possible zero CO<sub>2</sub> fuels that Bennett mentioned included methanol or ammonia fuelled hydrogen fuel cells, or renewably-powered batteries. He noted that such fuel cells are “radical and as yet unproven,” but urged cooperation across the industry to develop these solutions, as well as facilitation by governments of essential “pure research.”

Commenting on the role of IMO, which will next meet in October 2018 to consider CO<sub>2</sub> reduction, Bennett said: “At the moment we believe the IMO strategy can best be delivered with technical measures alone. We don’t think we need the smoke and mirrors of market based measures or the purchase of carbon offsets to compensate for emissions which the sector is quite capable of reducing itself in line with the targets now agreed by IMO.” **NA**

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## 2020 ripple effect causing concerns

Despite the focus on shipping's future at MSC 99, past decisions by the IMO at MEPC 72 threaten a tumultuous few years, writes Malcolm Latache

At the time of writing, the IMO at MSC 99 is considering two aspects of the future of shipping by establishing a task force to explore issues relating to autonomous ships and also debating the place of Iridium and other satellite service providers in relation to the updating of GMDSS.

The prospect of autonomous ships excites some and horrifies others but while there will be at least one sailing in Norwegian waters in around two years' time, the idea that they will be plying the deep oceans seems to attract very little support. Even so, it is right for the IMO to start considering how manned and unmanned ships might interact and how much the SOLAS regulations may need to be revised for ships that are sailing without a crew to react in emergencies.

It is now around 20 years since ships were obliged to rip out old radio equipment and modernise to the original GMDSS standards. In the intervening years things have changed and many believe that ending the Inmarsat monopoly – now it has become a public company – is long overdue. At MSC 99, the US has successfully advocated the right of Iridium to be recognised as an alternative despite apparent strong opposition from the likes of China, Germany and the UK which presented papers arguing that Iridium's recognition would be premature at this point. The recognition was simultaneous with another successful launch of five more Iridium satellites.

Whatever the outcomes of MSC 99 may be, it is the decisions of past MEPC meetings that are causing shipping the biggest headaches. Although anticipated for several years, coming to terms with meeting the 2020 deadline for reducing the sulphur level in fuels to 0.5% is proving difficult and looking to be heading for a chaotic rather than simple changeover. And, if the predictions of some analysts are to be believed, the ripples from the decision look to reach well beyond shipping.

The shipping industry's own confusion over the 2020 changes appears to have intensified as the deadline draws ever nearer. For several months preceding MEPC 72 in April, the shipping industry was campaigning for a total ban on the carriage of non-complaint fuels on any ship not fitted with a scrubber. With MSC 99 in full swing, the ICS issued a statement on 21 May reporting the conclusions of its AGM held in Hong Kong the week before.

Quoting ICS Chairman Esben Poulsen, the statement said: 'The shipping industry fully supports the IMO global sulphur cap and the positive environmental benefits it will bring and is ready to accept the significant increase in fuel costs that will result. But unless a number of serious issues are satisfactorily addressed by governments within the next few months, the smooth flow of maritime trade could be dangerously impeded. It is still far from certain that sufficient quantities of compliant fuels will be available in every port worldwide by 1 January 2020. And in the absence of global standards for many of the new blended fuels that oil refiners have promised, there are some potentially serious safety issues due to the use of incompatible bunkers.'

Just days before the ICS announcement, Reuters reported that 'New rules on ship emissions herald sea change for oil market'. According to the article, the energy and shipping industries are ill-prepared, with refiners likely to struggle to meet higher demand for cleaner fuel and few ships fitted with equipment to reduce sulphur emissions. 'This raises the risk of a chaotic shift when the new rules are implemented, alongside more volatility in the oil market', the report said.

Quoting Robert Herman, refining executive at Phillips 66, Reuters says the global refining industry needs to process an extra 2.5 million bpd of crude to make distillates for cleaner shipping fuels. However, another consultancy survey showed 40% of Middle Eastern and European refineries are not prepared. European plants, which tend to be less complex than those in other regions, produce more fuel oil and may face the biggest challenge.

Many energy analysts are now predicting that the extra crude needed, and the fact that heavy fuel oil may become unsellable, will force up the price of crude to levels approaching the heights reached in 2013. That could have a detrimental effect on the global economy and so reduce demand for shipping capacity at the same time as increasing bunker costs. Wood Mackenzie estimates that global shipping fuel costs are likely to rise by a quarter, or \$24 billion, in 2020. Others estimate extra costs for container shipping alone will be \$35 billion to \$40 billion. In addition, a surge in distillate demand by ships could push up prices of other products, such as jet fuel and diesel. *NA*



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## Energy storage systems

## Corvus Energy to supply Fjord1 ferries with ESS

Canadian manufacturer Corvus Energy has announced that it is to supply 2.9MWh lithium ion battery-based Orca Energy Storage Systems (ESS) for two new electric ferries being built for Fjord1 by Havyard. The news comes after an earlier contract in November to supply ESSs for three Fjord1 ferries, which will charge from shore stations with their own Corvus ESSs.

Whilst the newer vessels will operate between Magerholm and Sykkylven, and the preceding ferries between Hareid and Sulesund, all five are 111m, can accommodate 120 cars and are scheduled for a 2019 delivery.

The Corvus ESS will supply the power to the vessels' electric propulsion systems, developed by system integrator Norwegian Electric Systems. NES' sister company, Norwegian Control Systems, will also provide monitoring and automation solutions for the vessels, as reported in March's *The Naval Architect* ('Automation and integration drive Norwegian Control Systems' Fjord1 project').

NES' Stein Ruben Larsen stated: "Fjord1 continues to forge a very progressive path towards environmentally sustainable operations with these additional all-electric ferries. The proven reliability, safety and performance of the air-cooled Orca ESS was important in awarding this contract to Corvus Energy."

In recent months, Corvus Energy has been selected to supply a 1MWh Orca ESS to Stena Line vessel *Stena Jutlandica*. The ro-pax has been retrofitted with plug-in hybrid technology, enabling zero emissions whilst berthing and manoeuvring in port. Callenberg and Stena Teknik are working together to integrate the ESS, which may in future be upgraded as part of plans for full battery operation on the vessel's Gothenburg to Frederikshavn route, necessitating 50MWh of stored energy. [corvusenergy.com](http://corvusenergy.com)

## LNG

## Wärtsilä announces 100th LNGPac order

Last month Wärtsilä confirmed the 100th order to date of their LNGPac Fuel Gas Supply System, which is set to be installed on two newbuild shuttle tankers owned by AET Tankers. The 277m, 125,000 dwt vessels will also have Wärtsilä 34DF dual-fuel auxiliary engines and VOC recovery system.

Approaching its 10th anniversary, the LNGPac system is made up of a bunkering station, LNG tank, processing equipment, and a control and monitoring system. The multifaceted fuel handling system



A Wärtsilä LNGPac system ready for installation

was developed by the technology group following their recognition that 'more than just a dual-fuel engine and a stand-alone LNG system was needed' for LNG-fuelled vessels.

Over the years Wärtsilä has added further functionalities to the system, for instance employing the cold energy stored in LNG fuel to cool the HVAC system. For smaller vessels, a compact LNGPac was also developed featuring an integrated gas valve unit (GVU) and airlock. To continue to improve the system, Wärtsilä are in the process of developing monitoring capabilities such as energy content and gas quality measurement.

Tarbit's *Bit Viking* was the first vessel to install the LNGPac after it was converted to use LNG fuel in 2011. The upsurge in LNG popularity in recent years and wider availability of the fuel has led to the system being installed across the majority of vessel segments, including ferries, offshore vessels and dredgers.

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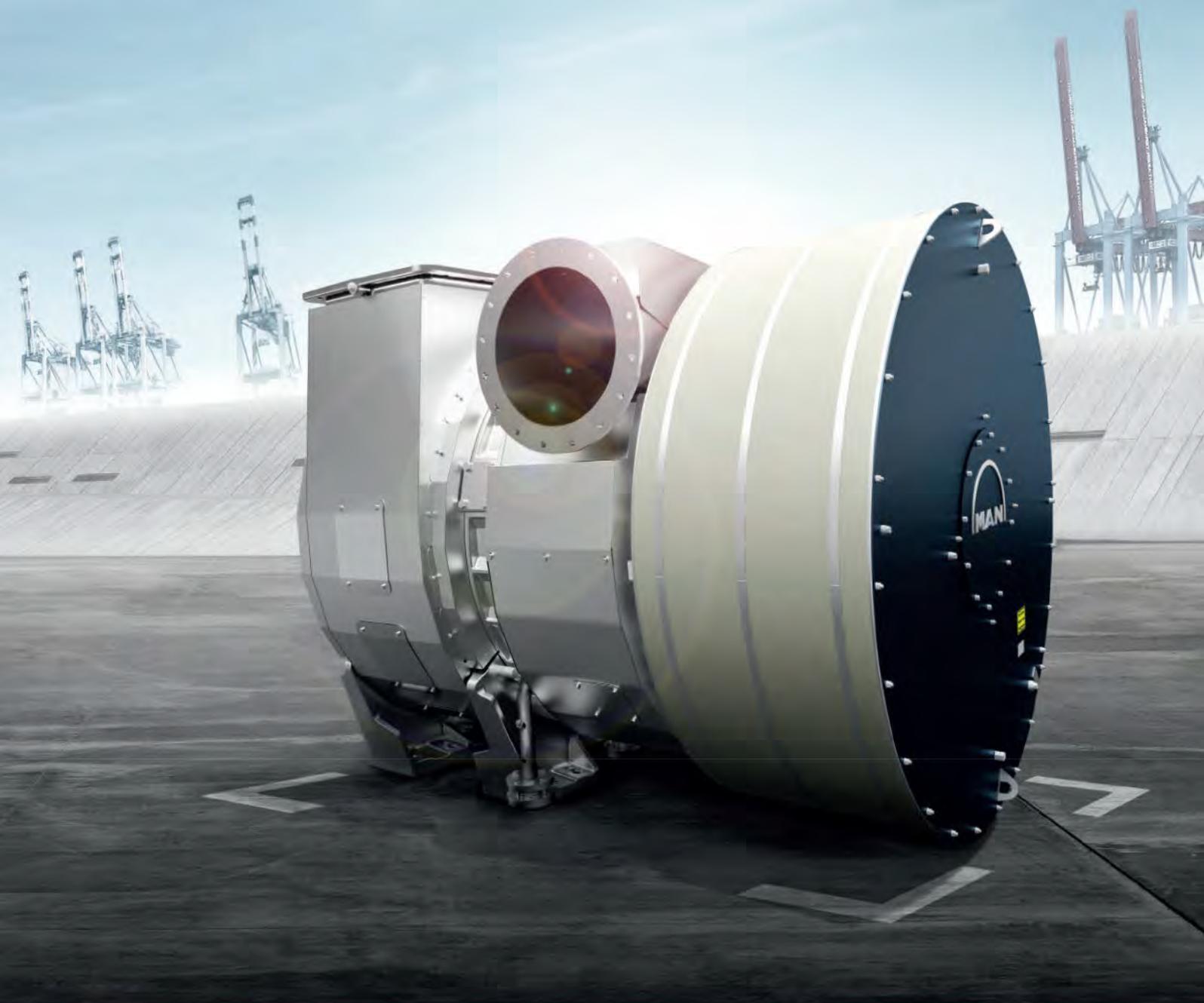
## MSC 99 approves Inmarsat's 'Fleet Safety' solution

The 99th session of the Maritime Safety Committee (MSC) has officially approved Fleet Safety, a new solution from Inmarsat heralded by President Ronald Spithout as "the most significant advance in maritime safety services since the introduction of GMDSS in 1999."

Fleet Safety, which supports GMDSS, conjoins maritime safety and broadband data services in Fleet One or FleetBroadband terminals for the first time. GMDSS-approved safety services that can now be accessed from either of the terminals include SafetyNET and an upgraded version SafetyNET II (released in November), Search and Rescue (SAR) communications, and systems for broadcasting and receiving Maritime Safety Information (MSI).

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To co-ordinate the new safety services, Inmarsat has released RescueNET, an online service intended for Maritime Rescue Coordination Centres capable of 'linking current and future Inmarsat Safety Services as well as increasing MRCC capabilities with enhanced real-time coordination during a search and rescue operation'.

Initially, Fleet Safety will be delivered via the Inmarsat-4 satellite constellation. However, from 2020 onwards, the service will also make use of the Inmarsat-6 satellites launching that year.

Inmarsat's Fleet Safety announcement comes after MSC 99 approved Iridium's request to provide GMDSS, given it passes performance tests. IMO's decision therefore ends the Inmarsat monopoly over GMDSS that has existed since the system's introduction in 1999.

Inmarsat's president Ronald Spithout extended his congratulations to the rival company.

[inmarsat.com](http://inmarsat.com)

#### Sulphur

## LR launches sulphur compliance tool

Lloyd's Register has released 'Sulphur 2020 – Options Evaluator', a free online tool that allows users to compare the various sulphur compliance strategies. The classification society developed the tool in response to the 2020 global sulphur cap, which requires the use of fuel with sulphur content of 0.5% or below in waters not already designed Emission Control Areas (ECAs).

Compliance strategies range from replacing fuel oil with MGO, switching to alternative fuels including LNG and methanol, or installing scrubbers, each with varying cost implications and emissions reductions potential depending on vessel type, size, and route. With the Options Evaluator, ship operators can gain an insight into the capital and operational expenditure of each option as well as its emissions performance for their vessels.

Despite providing a 'high-level indication' of viability, LR recommends that the tool only be used for an initial assessment; for 'a more bespoke, techno-economic analysis to support and validate the decision-making process', operators are required to contact the classification society directly.

The download link for LR's Options Evaluator can be found on their website.

[lr.org](http://lr.org)

#### Cylinder lubricants

## MFT's SEA-Mate upgraded with automation software

SEA-Mate, the cylinder lubricant blending-on-board system from Maersk Fluid Technology (MFT), has been upgraded with software that automates and optimises the oil blending process.

Developed for use with small to large-sized two-stroke engines, SEA-Mate blends system oil with high-BN cylinder oil (up to 100BN) to create a 'fit-for-purpose' cylinder lubricant. The system also continually refreshes the engine sump with fresh oil. SEA-Mate comes in three models – the B500Mk2, B1000 Mk2, and B3000 – of which the B1000 Mk2, designed for up to 600mm bore engines, currently has the option to be automated.

The new automation software analyses data outputs from the engine control system and external engine sensors to create a cylinder lubricant blend optimised for the engine type and operational parameters. This automated process was developed to enhance the existing benefits of SEA-Mate, which include a reduction in lube-oil consumption of up to 50%, cost savings on fuel due to lower friction, and mitigation of cold corrosion and hydraulic control system issues.

Maersk Fluid Technology claims over 200 installations of SEA-Mate at present. To demonstrate the benefits of the system, the company has developed a SEA-Mate value calculator, into which cylinder oil and vessel details can be entered to determine the potential fuel and cost savings the system could offer.

[maerskfluid.com](http://maerskfluid.com)



MFT's semi-automatic SEA-Mate system now benefits from automated blending

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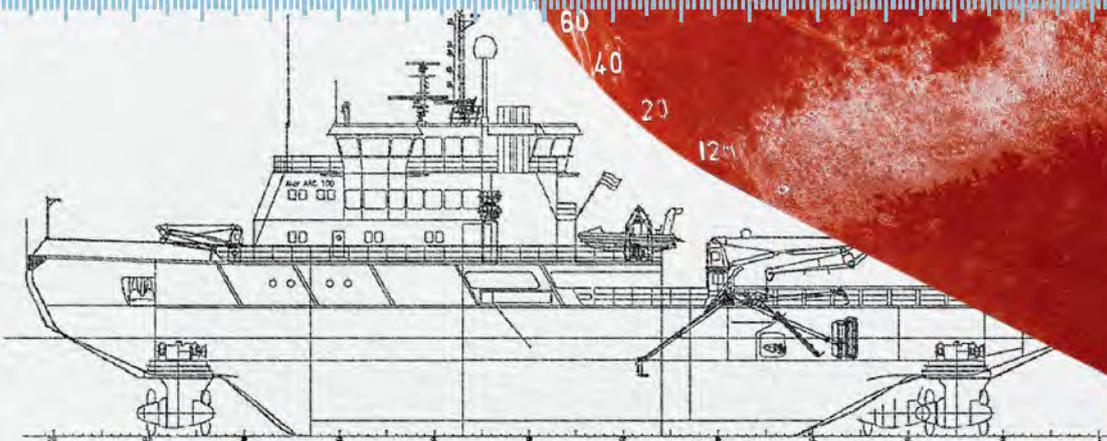


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# ITF report advises how shipping can meet, and exceed, the IMO's GHG target

Published just before the IMO agreed its initial GHG strategy, the ITF's ambitious 'Decarbonising Marine Transport' report offers clear recommendations on how it can be achieved

**B**etween the 9 and 13 April, MEPC 72 convened at the IMO with the goal of rectifying the shipping industry's lack of a universal decarbonisation strategy by setting an overall target for emissions reductions. This was partially driven by growing pressure to bring shipping in line with the Paris Agreement and its aim to limit the global temperature increase to 1.5°C above pre-industrial levels, significantly mitigating the risks of climate change.

IMO member states' desired targets for emissions reductions varied considerably as they headed into MEPC 72. The low-lying Pacific nations of Kiribati, Tuvalu, Marshall Islands and Solomon Islands proposed last September that the strategy should aim for full decarbonisation by 2035, suggesting that this is the only way shipping can meet the Paris Agreement's 1.5°C figure. These nations' target is by far the most demanding, reflecting the disproportionate threat they face from sea level rise.

Softening this target somewhat, a number of EU and larger Pacific nations had suggested an absolute reduction of 70% by 2050, but with efforts towards 100% (the EU itself has called for zero emissions by 2050). Downgrading this, Japan has previously called for 50% by 2060, whilst developing nations have only gone as far as suggesting decarbonisation post-2050 to allow them the chance for development already enjoyed by post-industrial nations.

After a week of protracted negotiations, the IMO reached a deal for shipping to cut its carbon emissions by a minimum of 50% by 2050, compared with 2008 emissions. Heralded as an 'historic' moment, the deal has been criticised by some as watered-



Now that IMO has agreed on a target, the real work to achieve it begins

down; others, however, have pointed out that this minimum target is likely to be exceeded as the technology required to meet it, and zero-carbon alternative fuels, will be exponentially less polluting than the status quo if they are taken up across the industry.

Having agreed a target, IMO member states need to develop a workable strategy. They would do well to heed the

International Transport Forum's (ITF) 'Decarbonising Marine Transport' report, released just before MEPC 72, which proposes the steps needed to almost entirely decarbonise shipping as early as 2035. Whilst this target goes far beyond what the IMO has agreed upon, the strategy laid out in the report is certain to be of use to IMO member states as a set of guiding principles, concentrating their

Table 1.

Types of measure	Main measures
Technological	Light materials, slender design, less friction, waste heat recovery
Operational	Lower speeds, ship size, ship-port interface
Alternative fuels/energy	Sustainable biofuels, hydrogen, ammonia, electric ships, wind assistance

Pathway	Operation measures	Technological measures	Carbon factor reduction due to alternative fuels	Electric ship penetration	Explanation
Maximum intervention	Maximum	Maximum	80%	10%	Drastic speed reduction; increase in ship size; zero-carbon fuels majority of fuel mix by 2035; few remaining emissions
Zero-carbon technology	Moderate	Maximum	80%	10%	Moderate speed reduction; maximum possible technology implementation; widespread use of zero-carbon fuels; few remaining emissions
Ultra-slow operation	Maximum	Maximum	50%	-	Drastic speed reduction; lesser uptake of zero-carbon fuels; higher remaining emissions
Low-carbon technology	Moderate	Maximum	75%	-	Moderate speed reduction; strong uptake of zero-carbon fuels (minus ammonia); less rapid emissions decline

Table 2.

efforts and encouraging them to aim as high as possible.

The report considers both the measures and the conditions needed to achieve decarbonisation. As for the former, it lays out four potential 'decarbonisation pathways' which combine these measures in various ways; for the latter, it makes three key recommendations surrounding policy and finance.

### Decarbonisation measures

The measures detailed in the report are split into technological measures, operational measures, and alternative fuels/energy, with a number of specific examples considered for each, as shown in Table 1 – taken from the report.

The four 'decarbonisation pathways' set out by the report place different emphases on each of these measures, besides technological measures, which are required to have maximum implementation across all four pathways. Electric ship penetration, or lack of, is also forecasted. Table 2, also taken from the report, shows the degree of application of these measures in each pathway; we have added a sixth column summarising their practical requirements.

### Policy and finance conditions

The report goes on to make the three core recommendations which advise on the

regulatory and financial conditions necessary to support the decarbonisation pathways. The first recommendation – 'Set a clear, ambitious emissions-reduction target to drive decarbonisation of maritime transport' – has already been completed (although whether it is 'ambitious' is debateable).

The second recommendation is 'Support the realisation of emissions-reduction targets with a comprehensive set of policy measures.' According to the report, these policy measures should cover technology, operations, and alternative energy as mentioned in the decarbonisation pathways, ultimately encouraging the development and purchase by shipowners of low-carbon vessels. Global policies encouraged include stricter energy efficiency targets, such as an updated EEDI, a standard for low-carbon fuel, and mandated speed limits. Nationally, it recommends that governments should research the development and commercial application of zero-carbon technologies, ports should update their facilities to include electric charging system and alternative bunkering, and shippers should assess their supply chain's carbon footprint.

The third recommendation – 'Provide smart financial incentives to advance the decarbonisation of maritime shipping' – recognises the issue of conventional fuels' competitiveness compared with

green fuels. To rectify this, the report suggests a global carbon-pricing scheme, forcing optimal recourse allocation and creating funds for green shipping research. Nationally, direct financial incentives could also be applied, such as electricity tax exemptions, and governments could aid banks to develop financial instruments based on green shipping. Ports might also be encouraged to offer reduced fees to environmentally-sound vessels.

Given that the ITF's report requires massive behavioural change across the industry, and considerable support from national and international regulatory institutions in the near future, the 2035 decarbonisation scenario is unlikely. However, by adopting one of the report's decarbonisation pathways – or creating its own – and supporting it with the necessary policy measures and financial incentives, shipping will be in an excellent position to meet its initial GHG target, and likely exceed it: something it must do if it wants to be seen as a responsible industry that meets its social and environmental obligations. *NA*

The report can be downloaded at: [www.itf-oecd.org/decarbonising-maritime-transport](http://www.itf-oecd.org/decarbonising-maritime-transport)

# C-Job explores ammonia's fuel potential

The Netherlands-based naval architects are putting their support behind research into NH<sub>3</sub>'s potential as a carbon-free solution



C-Job's concept illustration for an ammonia-fuelled vessel

The idea of using ammonia as a fuel source can hardly be said to be new. One of the first ammonia-powered cars was built in 1935, while during the Second World War buses in Belgium were run on a combination ammonia and coal gas. In the 1960's it fuelled the North America X-15 rocket-powered aircraft developed by NASA and in 1967 set the air speed record (4,520mph, or Mach 6.72) which still stands to this day.

But its potential as a marine fuel has been almost completely ignored, for the simple reason of economics. Historically, ammonia (NH<sub>3</sub>) production has been contingent on the availability of hydrogen, which is then combined with nitrogen sourced from the air, which on an industrialised scale is achieved using the Haber-Bosch process. Given this is itself energy intensive and yields a product with a lower heating value halve that of HFO in terms of mass and a third in volume, it's understandable why this was not considered a preferable option. Moreover, while ammonia combustion itself is carbon free, given that most hydrogen is derived from the cracking of natural gas (or to a lesser extent biomass), it does nothing to mitigate CO<sub>2</sub> emissions with conventional production of hydrogen.

But the drive for greener shipping, further galvanised by the commitment

announced at IMO's MEPC 72 that shipping will cut GHG emissions by at least 50% by 2050, means shipowners will soon have little alternative but to start exploring other options. There was encouragement also with the publication at the end of last year of a report by Lloyd's Register and University Maritime Advisory Services (UMAS), *Zero Emissions Vessels 2030*, which tested a variety of technology options and concluded that an ammonia-powered internal combustion engine came second only to biofuels in terms of relative profitability (still well behind HFO, naturally) across a range of operating scenarios.

It means, believe Netherlands C-Job Naval Architects, that as a sustainable fuel ammonia is very much back on the

radar. C-Job identified Hydrogen Based Renewables as the best solution and sees ammonia (NH<sub>3</sub>) as one of the high potentials in the role of renewable fuel for the maritime industry. In 2017, C-Job revealed it had started work on a project to explore ammonia's propulsion potential, both as a fuel for combustion engines and as a power source for fuel cells.

"At the moment we're at the preliminary concept design stage where we want to explore the possibilities regarding technical feasibility," explains Niels de Vries, a Naval Architect with C-Job. "We've identified several options but also want to understand the environmental benefits and create a breakeven point for when the moment comes when either client or the shipowner is either willing to pay more

The earliest ammonia-powered car in 1935



for clean transport or when CO<sub>2</sub> and other emissions are taxed.”

In January 2018, C-Job announced it was joining forces with Netherlands-based chemicals firm Proton Ventures and Enviu, a company which specialises in environmental startups, in a consortium that will explore the technical options and cost effectiveness of an ammonia tanker fuelled by its own cargo. The project is expected to last two years and involve a range of theoretical research, laboratory testing and evaluation of a pilot project. De Vries notes that while Enviu’s main interest is hydrogen, they see ammonia as having high potential as a ‘carrier’.

### Usage of surplus renewable energy

De Vries’ interest in ammonia’s potential began several years ago while attending a course at Delft University of Technology. Prof. F.M. Mulder, a specialist in renewable energy, suggested ammonia could be used as an electrochemical storage medium for periodic surplus energy generated by wind and solar power. While peak power production comes during the summer and could be stored to be used for the winter months, de Vries suggests that ammonia could also be ideal for chemically transporting renewable energy between different regions, for example between Australia (which has an abundance of empty space suitable for solar and wind power generation) and Japan.

Using renewable energy negotiates the previous drawback of the associated CO<sub>2</sub> production involved in creating ammonia. Rather, the surplus electricity is used for the electrolysis of water and nitrogen production and thereafter to convert it into ammonia.

In some respects it’s a throwback to the 1950’s and ‘60’s, when the first ammonia plants were built in the US and Norway alongside hydroelectric plants. But the idea of sustainable ammonia production is gaining traction around the world. Technology giant Siemens last year participated in the Green Ammonia demonstrator project in Oxford, which aimed to prove the feasibility of producing ammonia from wind power and then turning it back into energy again. Elsewhere, the Japanese government

is advancing its SIP ‘Energy Carriers’ program, which envisages ammonia as one of three methods for delivering hydrogen (the others being liquid hydrogen and organic hydrides). The US Department of Energy is similarly invested with its ARPA-E REFUEL project into the potential of utilising energy dense liquids.

That ammonia storage and transportation risks are already firmly understood from its use in the fertiliser industry alleviates some of the safety concerns. But while ammonia has a very different hazard profile, in terms

of its storage and management, from that of crude oil or natural gas, its risk level is approximately the same. Moreover, by comparison with pure hydrogen, whether in its compressed or liquid state, ammonia is not only less volatile but offers significantly higher volumetric energy density and can be stored in its liquid state at a far more cost-effective -34°C (see Table 1).

That said, the lower fuel density, around a third that of HFO, would pose certain design challenges for ammonia to become viable as a fuel for longer voyages. But



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	Volumetric energy density LHV (MJ/m <sup>3</sup> )	Pressure (bar)	Temperature (°C)
Compressed H <sub>2</sub>	6950	700	20
Liquid H <sub>2</sub>	8791	1	-253
Liquid NH <sub>3</sub>	12714	1 or 10	-34 or 20

Table 1. Liquid ammonia offers superior fuel density to hydrogen at a more cost-effective temperature

De Vries draws the comparison with where LNG was a decade ago, and indeed some of the technology developed for LNG containment could be adapted for ammonia. “LNG made the first step in requiring more space for fuel and ammonia adds to that. Liquid ammonia can be stored either at 1 bar -34°C in for example a membrane tank or under pressure in a cylindrical tank at 10 bar 20°C, which will take more space than a square box.”

Bunkering infrastructure would also represent a challenge to be overcome. He notes: “We have a several ports with ammonia available which could supply the first vessels powered by ammonia, preventing something of a chicken and egg story. Of course, it would have to be expanded to supply a substantial part of the commercial fleet. The significant advantage over other technologies (such as hydrogen) is that ammonia already has quite some infrastructure available as it is being used in vast quantities around the world for the fertiliser industry.”

Another challenge is that ammonia is less combustible than fossil fuels, meaning that the compression ratio for engines needs to be significantly higher and by

extension require efficiency improvements. It is also highly corrosive and, from a mechanical standpoint, will burn through any component using copper, zinc or an alloy thereof. However, De Vries says safe ammonia combustion is feasible as shown by the many prototypes and other examples in transportation in the past and also in today’s time by several research institutes like CSIRO in Australia. C-Job is working with a third party which has developed an improved combustion technology both suitable for conventional fuels and ammonia. This is currently being further explored with engine manufacturers. This could open up the intermediate option of ammonia being used as a dual-fuel and also pure ammonia combustion, particularly in the case of ammonia carriers.

### Ammonia fuel cells in the coming decade

One of the options being explored by the consortium is the viability of ammonia fuel cells. De Vries says: “Currently one of the most developed fuel cell technologies is the proton exchange membrane fuel cell (PEMFC). The PEMFC only runs on pure

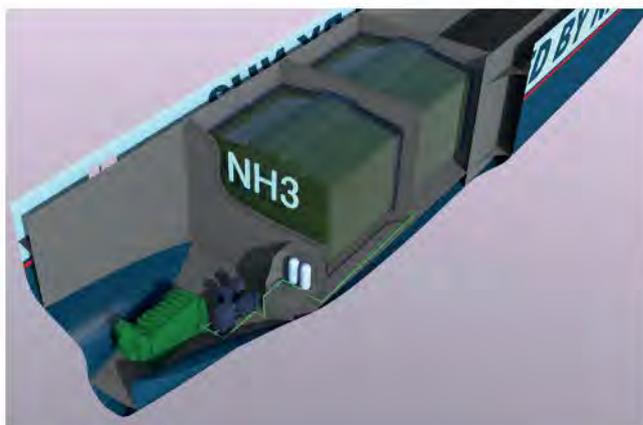
hydrogen, so the ammonia would need to be fully cracked to be utilised, which is costs about 22% and therefore not the most attractive way to use ammonia. But PEMFC has a high power density, offers decent efficiency and are quite affordable at around EUR 1,000 per kW. The solid oxygen fuel cell (SOFC) is somewhat behind the PEMFC in terms of power density and cost with around EUR10,000-15,000 per kW but is also going through a lot of development to become more competitive.

“SOFC has the main advantage that it is able to cope with varies kinds of fuels and in general has a higher efficiency than the PEMFC. The SOFC works at a higher temperature, which could be beneficial for other purposes [i.e. heat storage]. It cracks the ammonia inside the fuel cell, which is attractive in terms of efficiency. We foresee significant improvements in the coming decade within the fuel cell industry which will make fuel cells more attractive to compete with combustion engines. Using ammonia with either a PEMFC or SOFC does not produce NO<sub>x</sub> emissions which is a big advantage over a combustion engine. Conventional diesel electric vessels would be the first to use fuel cells for power generation considering that fuel cells provide electrical energy. For diesel direct vessels the fuel cell will have to overcome the losses in the electrical system to be compete with combustion engines.”

Initial discussions have now taken place with classification society Bureau Veritas who have offered their assistance with the risk analysis during the early design stages and re-evaluation when the final design concept is decided upon. De Vries is optimistic that this design stage of the project will be completed later this year.

Ultimately of course the harder challenge will be convincing shipowners, but there are encouraging signs of interest. “Companies acknowledge that exhaust gas treatment and LNG are just intermediate steps towards a sustainable future. Of course, they’re reluctant to make major investments in the application of renewable fuels at the moment. This is mainly because they can still cheaply burn HFO and operate in a highly competitive market, but over the next 10 years we will see more constructive arguments looking into the applications of what we are learning now. *NA*

The additional space and weight requirements for storage are perhaps ammonia’s biggest drawback



# Wind propulsion gathers momentum as installations prove successful

Wind propulsion solutions are becoming increasingly visible, viable and effective. *NA* speaks to the International Windship Association to gain an insight into the future of this promising alternative energy source

**W**ithin the last decade, wind propulsion technologies intended for maritime applications have undergone a period of development and testing that has culminated in a handful of installations on board commercial vessels. Whilst most innovations in shipping follow this path, such progress is unexpected in the case of wind propulsion given the long-standing (and somewhat ironic) tendency to see modern maritime wind propulsion technologies as futurist imaginings: interesting to engineers but with little practical or economic benefit.

Wind's change in fortune has been spurred primarily by the growing pressure on the shipping industry to reduce emissions, which has become a regulatory issue following the IMO's agreement of its initial GHG strategy, requiring a 50% reduction of CO2 emissions (compared to 2008 levels) by 2050. As interest in hybrid solutions to meet the emissions challenge has grown, wind has continued to gain legitimacy, particularly as a primary renewable that is free at the point of use, faces no bunkering issues, and does not need to be 'generated' as electricity, hydrogen, and biogas do.

## The shape of wind propulsion

The most visible symbol in recent years of wind's tentative return to commercial shipping is the towering Flettner rotors (also known as rotor sails) that have appeared on a number of newbuild vessels and as retrofits. The technology was first deployed in 1924 on German engineer Anton Flettner's schooner *Buckau*, but was never developed. However, Flettner rotors have been re-evaluated, aided by CAD design tools and advanced CFD software that allows for a high level of optimisation.

The rotors take the shape of a large cylinder, which is spun using an electric motor in order to capitalise on the Magnus effect, whereby the air passing



Viking Line's *Viking Grace* is fitted with an automated 24m Norsepower rotor sail (photo: Tuukka Ervasti)

faster around one side of the spinning rotor produces a force perpendicular to the direction of the airstream, resulting in propulsion. When installed as an auxiliary power source on vessels propelled primarily by fuel, the propulsive effect of the rotors helps to reduce fuel usage and therefore cost and emissions.

The first contemporary installation took place on Enercon's 2010-launched ro-ro vessel *E-Ship1*, which features four Flettner rotors and was constructed to transport wind turbine components. It took until 2014 and 2015 for Bore's ro-ro cargo vessel *M/V Estraden* to be retrofitted with the next rotors. This year has seen two vessels utilise rotors: Blue Planet Shipping's bulker *M/V Afros*, which features four, plus Viking Line's 2013-built cruise ferry *Viking Grace*, which was retrofitted with a rotor sail in April.

While Flettner performance is highly dependent on conditions and vessel type, Bore and rotor supplier Norsepower have quoted average fuel savings of just over 5% when *M/V Estraden's* rotors are in use, with

the potential to achieve 20% using multiple, larger rotors. At present, the rotors can deliver 2MW of engine-equivalent power.

A number of new projects are currently underway. Fehn Ship Management's 4250dwt general cargo ship *Fehn-Pollux* is in the process of installing two 'Eco-Flettner' developed as part of the 'Wind Hybrid Coaster' section of the 'MariTIM' project co-ordinated by MariGreen, a German-Dutch consortium promoting green shipping in the countries' border area. The rotors are optimised to operate across a range of wind speeds and will have the possibility of meeting 100% of propulsion demand if conditions allow. Maersk is also planning to install two 30m Norsepower rotors on a 109,000dwt tanker chartered by Shell, which are expected to save up to 10% in fuel and emissions.

Once these new projects are completed, MariGreen observes that 'Flettner vessels will be in operation in most of the major vessels segments from general cargo, ro-ro, bulker, tanker, and cruise/ferry', demonstrating the

widespread viability of the technology. Also notable is the pedigree of the companies, such as Maersk, Shell and Cargill, that are choosing to adopt this technology. Wind propulsion may be in its early stages, but with such big players involved and the considerable fuel savings it can deliver, it can no longer be dismissed outright.

## The IWSA

At least, that is the message of the International Windship Association, founded in 2015, which according to secretary Gavin Allwright is committed to “the overriding idea that wind is a credible propulsion solution.” The Association’s stated goal is to ‘facilitate and promote wind propulsion for commercial shipping worldwide and bring together all parties in the development of a wind-ship sector to shape industry and government attitudes and policies.’

*The Naval Architect* recently spoke with Allwright, unsurprisingly a keen advocate of wind propulsion, to gain a sense of the technology’s prospects and understand the role of the IWSA. As for the former, whilst Allwright noted that Flettner rotors are currently “the forerunner of the tech breaking into the market,” he advised they are just one solution out of roughly seven technology groups, comprising hard sails (also known as wingsails), soft sails (including DynaRigs), kites, turbines, hydrofoils and suction wings – a “toolbox of solutions.”

These technologies are at varying stages of development and have so far seen limited commercial application. Despite this, ambitious projects abound, such as SkySail’s towing-kite, installed on two Wessels Reederei vessels – *MV Michael A.* and *MV Theseus* – with another in production for a Cargill/Anbros Maritime Ship. Wing sail technology (propulsion-assisting aerofoil rigs similar in concept to aeroplane wings) has also seen much interest and competition, with a number of companies racing to develop solutions including London-based Windship Technology and their competitor Oceanfoil, whose wingsails achieved an average of 14% fuel and emissions savings on a 50,000dwt Panamax operating in the north Atlantic according to a report publishing by BMT (reported in January’s *Naval Architect*). Bound4Blue is another player, and is set to test its wingsail



The MarITIM Eco-Flettner awaits installation at SEC Ship services in Leer (photo: MARIKO)

on an ORPAGU fishing vessel following an agreement signed in April.

As of yet, there isn’t a clear precedent for which solutions work best for particular vessel segments. However, practical considerations of deck layout, visibility, and loading issues play a part in determining which technologies might be most viable in each case. For instance, on containerships where deck space must be preserved, kites offer an unobtrusive choice, whilst for vessels that undergo regular loading and unloading, rigs that can be retracted or moved will have the advantage. Some vessels with large superstructures such as ferries may pose challenges to the installation of large rigs or rotors.

## Convincing the industry

The maritime industry would be forgiven for being skeptical towards the idea that wind propulsion is the shining hope for emissions reduction, given the tiny percentage of vessels using the technology. Allwright is certainly not blinkered in this

regard, but is keen to add context: “If you look at LNG ten years ago, they had a handful of ships. Wind will be the same. Yes, it needs development. We need more ships out there using wind – we need demonstrator vessels doing sea trials with all of the technologies.”

Should the majority of wind propulsion technologies currently being developed reach the market, a study on market potentials and barriers to wind propulsion in maritime – carried out by CE Delft, the Tyndall Centre for Climate Change Research, Fraunhofer ISI and Chalmers University of Technology – suggests that they will see an uptake of between 3,700 and 10,700 installations (taking into account retrofits and newbuilds) by 2030. The number, the study suggests, will depend on the ability of the windship sector and governments to provide or facilitate:

- ‘(Trusted) information on the performance, operability, safety, durability, and economic implications of the wind propulsion technologies’
- ‘Access to capital for the development

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Modern navies are increasingly having to manage the trade-off between capability and cost. Versatility, flexibility, and affordability are key criteria which designers need to balance as warships become an exportable commodity, where market value may be just as important as the strategic value of any newly built vessel. Many nations are designing vessels with exportability in mind, this can mean that the Navy needs to accept some compromises to achieve this. On the other hand other nations are looking to build up their sovereign capability or to create jobs in country for national prosperity. In this scenario the nation must select a partner who can provide some degree of technology transfer and the key driver may not necessarily be the ships capability.

All of this is against the backdrop of rapidly advancing technologies including unmanned and autonomous systems, a changing threat environment and an insecure world; these factors require ever more adaptable ships that can fulfil a number of different roles and save money through life. Modularity may be one way to address this adaptability, however this approach has its compromises and there are other design considerations that must be in place to make a platform truly adaptable.

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of wind propulsion technologies, especially for building and testing of full scale demonstrators.’

- ‘Incentives to improve energy efficiency/reduce CO<sub>2</sub> emissions of ships.’

To make progress on these requirements, the IWSA is involved in the creation of a collection of regional hubs around the world, which will allow technology companies to engage with local industry clusters and court the support of regional and national institutions and government to secure funding. Already well established in Nantes, with dealings with over 40 companies, is Europe Atlantique de l’IWSA; although currently unofficial, clusters in the south Pacific and in northern Europe have also seen significant activity, and there are further plans to establish hubs in North America and Asia.

Once these hubs are up and running, the IWSA intends to act as a kind of umbrella organisation, sharing best practice and organising events. Allwright says that there is even discussion about developing a ‘Wind Code’, akin to the Polar Code, which will establish standards to smooth the adoption of the technology. Fortunately, wind technologies do not face the classification challenge currently looming over other innovations such as autonomous shipping; as Allwright notes, “almost every technology development we have on the books is class-certified,” avoiding the lengthy delays that can often slow the uptake of technological innovations.

Allwright agrees that the IMO’s recent GHG strategy has certainly given wind propulsion a boost. Wind has the advantage of being a primary renewable, which can have considerable impact as an auxiliary energy source when coupled with more common secondary renewables such as hydrogen or biogas:

“To reach the IMO target, everyone is looking at secondary renewables. If you look at 100% fleet switchover to secondary renewables, that’s a big nut to crack, a lot of fuel. If you put wind assist of primary wind into the mix, suddenly that nut becomes a much smaller one to crack. With wind-assist, you can get 10%-30% savings. Something like a Flettner rotor, you’re looking at 5-20%. A big rig, you may be looking at 15-30%. If



A SkySail towing kite in action aboard the Wessels Reederei vessel *MV Theseus*

you go with an optimised newbuild, you could be getting anywhere up to 50%. Even with retrofits, the middle number is 20%. That means you only have to find 80% secondary renewables, which becomes far more manageable.”

### A new market approach

As the above suggests, the driving force behind wind uptake will ultimately be the cost savings it delivers against expensive secondary renewables, as well as conventional fuels, which are expected to increase in price with the sulphur cap and possible future carbon pricing. As engine manufacturers achieve ever-smaller efficiency gains, the possibility of 10% savings are a huge incentive.

However, the problem faced by the IWSA until regulation kicks in, which struck concurrently with their founding in 2015 as bunker prices dropped, is the cheapness of fuel compared with renewables. Cheap fuel stretches the ROI of any wind technologies, putting off shipowners cautious of fledgling technology: “At current prices, all of the wind systems have an ROI of around 3-4 years. Shipping companies, from my experience, won’t go for anything above 3 years unless a political decision is made,” Allwright says.

One route that the IWSA is keen to explore to alleviate the pricing issue is leasing. As Allwright explains: “You go to

a customer and say you don’t have to pay a penny – we’ll come in and fit it, monitor it, maintain it. You can take it off anytime. The way you pay for it is we assess over a 3-month period what saving it is giving, and we split it in half. That changes the dynamic completely – there is no ROI anymore. And that’s always been a sticking point. If you completely switch that model around and say it’s all leased, of course it’ll cost a little down the road, but it’s maybe paid for completely by fuel savings.”

Whether such a scheme would prove popular is ultimately dependent on shipowners, but if so would represent a significant market shift, aligning shipping with the aviation industry, for instance, where 40 percent of all newbuild aeroplanes are delivered to leasing companies. For wind propulsion developers, leasing allows them to validate their technology at sea, but in a commercial context that may deliver a profit. For the shipowner, leasing removes the anxiety of taking a gamble on new equipment, but allows them to benefit from the possible efficiency gains, as well as demonstrate their commitment to greener shipping. Further ahead, Allwright even foresees – and hopes for – a switch from time charters to fuel charters, which would provide huge impetus behind wind propulsion as fuel usage becomes an even more carefully scrutinised cost factor.

Allwright is confident that, given a little encouragement, canny shipowners will come to recognise the benefits of wind as they begin the task of converting their fleets to alternative energy sources. As for the shape of this encouragement, Allwright admits that playing on shipowners’ commercial anxieties may prove most effective: “The message that we put out is that you’ve got a problem. If you don’t check [primary renewables] out, you’re going to be left behind. And there’s nothing people hate more in shipping than the feeling they are being left behind.”

Some opponents, however, seem put off by aesthetics alone: “Because [the technology] is so visible, many captains have said ‘I don’t like the look of it,’” Allwright says. “I should remind them that they don’t actually get to choose – if it’s safe and saving money, it’s your duty to your shareholders. But I usually answer that you can have it in any colour you like.” **NA**

# Swimsuits for ships: overcoming marine fouling through coatings innovation

In order to meet the operational and emissions improvements demanded by shipowners, the PPG-led eSHaRK project has developed a pioneering self-adhesive fouling release foil, writes project leader Peter Schoneveld

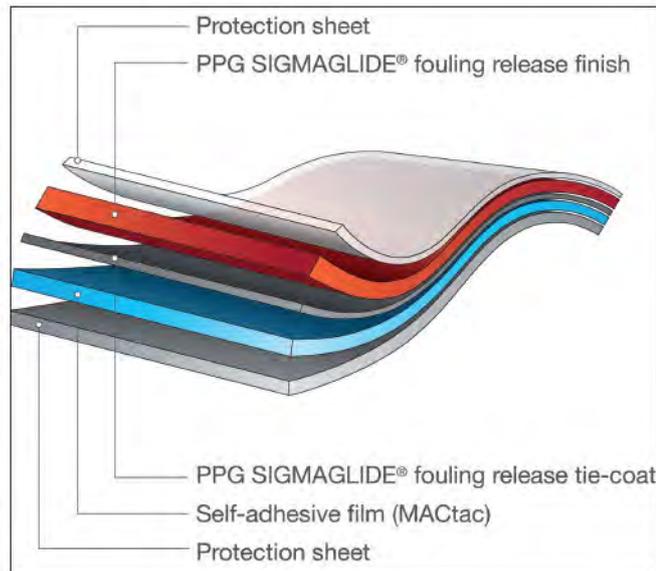
As a long-time supplier of coatings to the marine market, PPG has noted the trend of rising marine fuel costs, and works to produce advanced pure silicone fouling release systems in response. These systems have helped shipowners save money over the last decade, and will continue to do so as new regulations will see the industry move to low sulphur fuels whose costs could be far higher than current levels.

Further, with regulators enacting new rules covering greenhouse gas emissions from shipping, there is an environmental need for further efficiencies. As a result, shipowners are demanding marine coatings whose properties extend from improving operational performance to those that can reduce greenhouse gas emissions.

When the Eco-friendly Ship Hull film system (eSHaRK) project was first announced in 2016, its objective was ambitious but simple: bring to market a fouling protection technology which not only maintains current state-of-the-art protection standards but is superior to existing paint-based solutions in terms of eco-friendliness, ease of application, robustness and drag reduction effects.

The project took its inspiration in part from recent developments in hi-tech swimsuits which can enhance a swimmer's performance by reducing drag as they move through the water. In fact, the eSHaRK partners have described their ambition in creating a new fouling release solution as wanting to pull the ship as though it was wearing a high speed swimming suit.

Backed by European Union-funding, a consortium consisting of some of the world's leading marine experts and engineers is working to create an innovative new fouling protection system. eSHaRK consists of a self-adhesive and non-toxic fouling release foil, produced by applying a state-of-the-



The state of the art eSHaRK foil is made up of five layers, including MACtac's self-adhesive film

art PPG SigmaGlide 1290 fouling release coating onto a self-adhesive film.

Conventionally applied using a spray, PPG SigmaGlide 1290 is noted for its dynamic surface regeneration properties. These allow water to act as a catalyst to lower the surface energy of the coating back to its original state and thus restart its beneficial surface configuration properties. This regeneration preserves the coating's effectiveness over time, meaning that it will experience no loss in performance and stability throughout its lifetime.

Its low environmental impact also means that it can be applied to vessels trading in sensitive and strictly regulated environments. Under the eSHaRK project, a new method of applying the coating is set to offer further benefits.

Recent developments have seen the eSHaRK project team, comprising PPG, MACtac, Meyer Werft/ND Coatings, VertiDrive and Hamburg Ship Model Basin HSVA, develop and produce a prototype for the embossed fouling release foil, a concept proven by tests performed at

HSVA test institute. Progress has also been made towards production of an automated lamination system that will apply the foil to the underwater hull of a vessel.

A number of trial applications are underway in order to demonstrate the efficacy of the system. So far, the foil system has been able to offer clear advantages on newbuild projects in terms of minimised environmental impact and productivity improvements owing to a one-coat application operation.

On the smaller vessels that have been selected as testbeds, including pilot boats and other harbour craft, the foil is applied manually due to hull size and shape. For these vessels PPG has developed a highly sustainable combination of the very tough PPG SigmaShield 1200 anticorrosion coating to provide a basecoat with an extended lifespan. The foil is removed by hydrojetting and can be renewed after a prolonged period.

The industrial application process allows for an exact and optimally smooth silicon layer produced under controlled

application and curing conditions. These two elements are essential in boosting fouling release properties as the optimum surface characteristics of the silicone film are perfectly established.

The self-adhesive properties allow efficient application without release of solvents and do not result in silicone spread to the surrounding environment. Industrial application enables the foil to mould itself as closely as possible to the undulating surface of the vessel's hull – similar to hi-tech swimsuits and the human body – lowering drag resistance.

Though the eSHaRk project is far from complete, the early results suggest that it will maintain fouling protection standards and lead to fuel savings and reduction of GHG emissions greater than those of existing paint-based anti-fouling and fouling release technologies. The result will be an increased reduction in drag compared to the conventional spray-based



Whilst the foil can be applied manually on smaller vessels, work is underway to mechanise the application process for larger hulls

application of PPG SigmaGlide 1290 fouling release coating.

Some technical hurdles remain to be resolved, the most critical being mechanised application to hulls of large commercial

vessels. A patented, vertical laminating machine has been engineered; further mechanisation is now required to make the application process applicable for shipyard or dry dock conditions. *NA*



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# Changing the industry conversation on cyber security

Shipping lacks a risk model that accounts for its unique cyber security requirements. To rectify this, ABS proposes a quantitative model based on calculable factors, writes senior technical advisor Rick Scott

Cybersecurity has become a hot topic in the maritime industry, resulting in both positives and negatives. It is very positive that the subject is receiving the attention of industry leaders and specialists. However, that attention can be a distraction and even lead to confusion unless it yields clear and actionable ideas and tools focused on maritime requirements.

The trend towards increasing reliance on computerised control systems is evident – from cars to aircraft to air conditioning systems – and it represents a digitally-driven future. Whilst some users of this emerging technology may not fully appreciate the extents of this impact, most are becoming better prepared to control, maintain, and protect complex and highly integrated control systems.

The maritime industry is somewhat unique in its total dependence on and use of these computerised control systems. Unlike land-based industries, maritime applications of control systems are located on vessels that are afloat for extended periods of time.

This 'dislocation' from the suppliers and IT departments who create and maintain maritime control systems makes ship-to-shore connectivity increasingly critical. Since this connectivity is maintained over proprietary wireless communications links, those necessary links that are critical for vessel productivity, reliability, and safety open up digital maritime systems and assets to cybersecurity risks.

In 2016, ABS recognised cybersecurity as a key enabler for reliable vessel connectivity, and that controlling cyber risk is the heart of cybersecurity. The clear trend toward increased connectivity of complex maritime operating systems is relentlessly escalating the potential impact of cyber incidents and complicating the task of defending against them.



ABS senior technical advisor Rick Scott believes that maritime risk must be expressed in measurable terms

ABS also recognised that until cyber risk is well understood and approached in consistent engineering terms, cybersecurity implementations would arguably increase in cost, but be inconsistent in their effect. That recognition led to the creation of an ABS cybersecurity team that focused on clarifying maritime cybersecurity requirements and describing maritime risk in readily recognisable and measurable terms.

## A new model

In an increasingly complex maritime operating environment, traditional, IT-based prescriptive methods of assessing operational technology (OT) cyber risks haven't provided asset owners with clear direction about where their limited security resources are best applied. The primarily defensive methods available in 2016 were largely designed to identify, protect, detect and recover from cyber incidents based on a set of activities presented in NIST and related methodologies.

The methods were sound but needed tailoring for maritime use. Cyber risk recognition and response required a new model that gives asset owners a clear picture of the sources of maritime risk and tools to guide their risk mitigation actions. Risk needed to be observed and measured, specifically defining the individual risks inherent in marine operating systems so cybersecurity managers would have engineering "knobs to turn" to reduce them.

Historically, the most common model used to represent cyber risk is Risk = Threat x Vulnerability x Consequence. Cybersecurity practitioners frequently rely on this expression to understand that risk has three constituent factors, and it infers that risk can be reduced or eliminated by removing one of those factors. However, this expression is less a mathematical equation than a model for understanding the fundamental nature of cybersecurity risk. Its three core elements are difficult to capture using standard units of measure, which presents problems when trying to engineer a solution and/or calculate a resolution.

For today's maritime risk practitioner, the main challenge is to create a model that defines calculable risk for maritime operating systems that can be counted, measured, computed and compared against known-sufficient Cybersecurity Management Systems (CMS). This model would provide definition and depth to rigorously engineered cybersecurity management plans and system architectures.

With these gaps and needs in mind, ABS recently joined forces with the Hoboken-based research university Stevens Institute of Technology, to tailor the common risk model by redefining it as a true mathematical equation in terms that are countable, observable and easily understood. The result is a new model and that enables true risk-based cybersecurity approach driven by specific quantifiable risks that spotlight specific remediation requirements.

This enables engineered CMS designs built on identified solutions that are computationally engineered, highly detailed, and traceable to specific risks. One of the major findings of the research was that the nature of maritime cybersecurity risk is not well defined, understood, or managed. As a result, a risk-based approach, providing asset owners with understandable controls for responding to cyber risks, is essential to future cybersecurity programs.

While shifting industry cyber-risk practices away from the defensive approaches to a risk-based proactive method requires the industry to change the conversation, it most importantly requires a change in how risk practitioners think about maritime OT Risk. The research asserts that the basic 'Consequences, Vulnerabilities, and Threats' Risk factors can be authentically replaced with calculable factors in a risk equation for OT Risk, and represented as 'Functions, Connections, and Identities' (FCI), respectively.

## Functions, Connections and Identities

'Functions' in the context of the revised Risk Model are computerised control systems allowing the crew to manoeuvre a vessel or perform its mission, which can be anything from drilling oil, to carrying fluid, bundled cargo or even people. In this Maritime-specific FCI Risk Equation, Functions represent any consequential control system that a cyber incident could seek to corrupt, make fail, or illegitimately commandeer, such as steering, navigation, propulsion, or communications.

Similarly, 'Connections' in the new model represent the digital connections (e.g. digital message paths) and related



In March, ABS' Global Cybersecurity director, Paul Walters presented a certificate of cyber safety compliance to Samsung Heavy Industries for their Smart Ship Solution

access nodes that enable Function-to-Function communications, supplier remote access, and shipboard access by the crew. Implicitly, these Connections represent the digital environment that inherently makes all connected Functions vulnerable.

Lastly, 'Identities' are either humans or digital devices – typically mobile digital devices that can be readily associated with a human identity. In the context of the FCI model people and their surrogate digital devices can be associated with an agenda that makes them potentially threatening.

The agendas can range from cyber ignorance or laziness – "I'm not going to adhere to company rules and perform my duties in a secure way" – or can be malicious actions such as the hijacking of navigational systems to steal or destroy a vessel, disrupt normal operations for monetary gain or to advance a political agenda, or for self-aggrandisement.

An Identity can also be as simple as a USB memory device carried by a supplier representative, or a mobile phone or iPad. Recognition that people and their digital devices are the real threats, and that specific viruses and malware are merely threat modes, is a revolutionary concept in Risk assessment. By replacing 'Threats' with 'Identities,' the notion of threats can be observed, counted, and ultimately measured.

Converting the concepts underlying traditional cybersecurity terminology as described, Risk becomes both observable and countable, and supports creating a

mathematical Risk Equation, applicable to any assets by extending each countable risk element.

The calculable Risk data made available by observing and counting the Functions, Connections and Identities described can then be used to populate a worksheet that computes a Risk Index to demonstrate how specific FCI alterations or cybersecurity controls would change the relative asset Risk contributed by each Function, including integration network configuration; each Connection available for digitally communicating with each Function; and each Identity permitted to access each connection.

The FCI Risk Model quantifies the risk associated with OT architecture design decisions. It allows the user to consider whether the nodes (the access points) are adequately protected, whether or not networks to which Functions are connected are segmented to reduce risk associated with cascading Function failures, and whether or not the asset owner has sufficiently controlled the access of human and digital device Identities to connection nodes in the OT architecture.

The method described here is simplified, but the resulting Risk Index ultimately provides a quantitative view of the relative risk associated with the architectural design of the systems onboard the vessel, which until now has been missing in the maritime cyber-security space.

The FCI Risk Index allows the owner to examine the risk associated with an entire fleet to determine the relative risk associated with each vessel based on the way its OT system is constructed, the way people and their digital devices are allowed to access that system, and the way connections and their nodes are protected. This approach is practical as it gives owners concrete actions that can reduce cyber risk, and also helps owners decide where to deploy their often-limited cyber-defense resources.

There is an old adage in the management systems industry: you can't manage what you don't measure. As the maritime industry continues its journey toward automation, the ability to measure cyber risk will become foundational for operational reliability and safety, and a competitive advantage in the marketplace. *NA*

# Addressing the enforcement gap

The 2020 sulphur cap will not be effective unless backed up by regular inspections. Larry Rumbol, marine condition monitoring manager, Parker Kittiwake, believes onboard testing could be key

**W**ith all the discussion around what will happen come on 1 January 2020, one thing that is abundantly clear is the commitment to drive down harmful sulphur emissions from the shipping industry on a global basis. Whilst the 2020 sulphur cap will place a 0.5% limit on all vessels, the current 0.1% Emissions Control Areas (ECA) zones will remain in force affecting a small portion of the global merchant fleet, with further ECAs expected to emerge in the coming years. As shipowners evaluate which compliance solution they will adopt, significant questions remain around how the regulation be enforced and what the commercial impact will be, with many calling for a harmonised approach to enforcement that will ensure a level playing field.

A recent report from consultancy Wood Mackenzie states that one reason shipowners may not comply with the global sulphur cap is the lack of a robust enforcement mechanism from the IMO. Despite this, the IMO has reaffirmed its commitment to implement the regulation in 19 months. A key consideration for shipowners is the commercial impact of the global sulphur cap, and how they will safeguard their profitability. At its recent AGM, the Asian Shipowners' Association, whose members operate almost half of the global merchant fleet, stated that 'much work had to be done at IMO to determine exactly how the sulphur cap will be regulated and enforced so as to ensure a level playing field'. With the industry forging ahead towards 1st January 2020, the lack of clarity around compliance testing and enforcement of the regulation has raised significant questions.

Who is responsible for ensuring that the fuel on board the vessel is compliant? What impact will this have on insurance policies? Will there be formal processes in place to ensure both shipowners and port authorities can effectively test and prove compliance with the sulphur cap regulation? What other measures are being developed to promote consistent implementation?



Larry Rumbol

## Enforcement failings

The lack of enforcement mechanisms and the variance in fines handed out to shipowners serve as little incentive for compliance, leaving rule-abiding shipowners at a disadvantage given the additional investments and costs associated with meeting the sulphur cap regulation. At present, fines and penalties for non-compliance with sulphur regulations vary significantly. In the current European ECA, the highest fine in Denmark is US\$60,000, whereas a recently reported breach by a cruise vessel in France could result in a fine of up to US\$200,000 and a potential prison sentence for the master.

An additional consideration is the future fuels market, and the operational impact of fuel switching, blended fuels and compatibility. A recent comment from ICS Chairman Esben Poulsson said that 'in the absence of global standards for many of the new blended fuels that oil refiners have promised, there are some potentially serious safety issues due to the use of incompatible bunkers'. One certainty is that, regardless of which solution shipowners decide upon, the wider fuels market will be affected. With an increase in variety of fuels in the market, operators will encounter fuel compatibility and stability issues, including increased cat fines and differing parameters regarding viscosity, flash point, and pour points. Fuel quality has a direct impact on vessel

performance, efficiency and maintenance costs, adding further to the financial burden of compliance for shipowners. 95% of the new low sulphur fuels bunkered in Singapore for example will be blends.

## New guidelines

Much is being done to address inconsistencies in enforcement. The IMO's Pollution Prevention and Response (PPR) committee is working to develop guidelines that will cover shipowner's plans for implementation, verification and control issues, as well as fuel non-availability reporting. The PPR has also agreed to the proposed draft amendments to MARPOL Annex VI that will prohibit the carriage of non-compliant fuel oil. Furthermore, China had recently submitted its proposal to IMO's MEPC72, suggesting that the analysis of sulphur content in fuel oil should be made mandatory to avoid disputes, and that testing methods should be measured against ISO 8754 or ISO 14596 standards. China's proposal noted that the test range of ISO 8754 only varies from 0.03% to 5% and does not cover ships who receive and use fuel oil with sulphur content lower than 0.03%. To ensure a uniform approach to testing sulphur content in fuel, China has proposed adding ISO 14596 which covers fuels in the 0.001% to 2.5% sulphur range. More recently, the Paris MoU has agreed to issue a "Letter of Warning" from Port State Control (PSC) inspectors, beginning 1 January 2019, to encourage timely compliance.

While these measures are pushing the global shipping industry in the right direction, it is equally important to equip PSC and shipowners with easy access to the data they need to accurately check and prove compliance. It is worth noting that traditional methods for confirming compliance have relied on paperwork requirements such as the Bunker Delivery Note (BDN). However, this not only significantly increases the risk of non-compliance and subsequent penalties for shipowners, but also heightens the environmental impact of burning fuel with

a higher sulphur content. Furthermore, the delay incurred by laboratory testing creates the risk that the vessel may have left port with non-compliant fuel onboard, or may require non-compliant fuel to be de-bunkered and compliant fuel re-bunkered, incurring significant delays and additional costs.

### Spot-checks

Accurate portable sulphur testing provides the ability to conduct a spot-check analysis of the sulphur content in fuel onboard a vessel, allowing PSC to ascertain compliance almost instantly, and allowing shipowners the opportunity to avoid fines, plus the impact of having to de-bunker non-compliant fuel in order to take on compliant fuel again. This method also provides a vessel operator with the confidence that tank accumulations and contamination have not rendered them unwittingly non-compliant as has recently happened. Parker Kittiwake, for instance, has recently launched its portable XRF analyser, which provides an accurate indication

of sulphur content through the analysis of a small fuel sample in less than three minutes. With significant confusion over the stipulations in the way sulphur measurements are made – it is possible, for example, for fuel to pass ISO 4259 commercial tests but fail against MARPOL standards – it is clear that both shipowners and PSC require easy access to the data they need to accurately check and prove compliance

The XRF analyser is factory calibrated according to the ISO 8754 standard, and is capable of conducting field measurements that correlate strongly with laboratory measurements. Fuel can be sampled at any stage of the bunkering process, and these test results can be stored electronically, allowing operators to manage compliance audits more efficiently and to display the utmost in due diligence to PSC or other regulatory surveyors. In addition to sulphur testing, the XRF analyser can be used to measure a range of wear metals in lubricating oil, allowing operators to quickly

identify potential damage in cylinder liners, bearings, piston rings, gears, stern tubes and hydraulic systems.

Effective enforcement is at the heart of the sulphur cap, and onboard testing is the most efficient means of establishing compliance for both enforcers and fuel users. The industry is making significant progress towards effective enforcement, but more needs to be done. Shipowners and operators are fighting an uphill battle to not only ensure they can prove compliance, but also to minimise the impact of compliance on their operations. Robust implementation of the regulation is largely dependent on providing PSC inspectors with the right tools and access to reliable data to check and prove compliance quickly onsite. But this must be done in conjunction with providing support to shipowners in achieving compliance whilst mitigating the risk of additional cost, increased maintenance requirements, potential delays, and more importantly, a market skewed to favour those who duck the rules. *NA*

## RINA-QinetiQ Maritime Innovation Award

Innovation is key to success in all sectors of the maritime industry and such innovation will stem from the development of research carried out by engineers and scientists in universities and industry, pushing forward the boundaries of design, construction and operation of marine vessels and structures

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Nominations are now invited for the 2018 Maritime Innovation Award. Individuals may not nominate themselves, although employees may nominate their company or organisation.



**QinetiQ**

**Nominations** may be up to 750 words and should describe the research and its potential contribution to improving the design, construction and operation of maritime vessels and structures.

**Nominations** may be forwarded online at [www.rina.org.uk/maritimeinnovationaward](http://www.rina.org.uk/maritimeinnovationaward)

or by email to: [maritimeinnovationaward@rina.org.uk](mailto:maritimeinnovationaward@rina.org.uk)

**Nominations** should arrive at RINA Headquarters by 31st December 2018.

Queries about the award should be forwarded to the Chief Executive at [hq@rina.org.uk](mailto:hq@rina.org.uk)

# Tanker damage stability: a solution to the historical problems

Following March's article on historical problems associated with demonstrating a tanker's damage stability compliance, Keith Hutchinson and Andrew Scott discuss how consistent application of the regulations might be achieved

In the previous article [1] some of the long-standing technical problems associated with demonstrating a tanker's compliance with the damage stability regulations in MARPOL [2], the IBC Code [3], the BCH Code [4], the IGC Code [5], the GC Code [6] and the EGC Code [7] were outlined. On 22nd May 2014 MARPOL Annex 1 was amended by the addition of Chapter 4, Paragraph 28(6) and Chapter 1, Paragraph 3(6), which states that all oil tankers constructed on or after 1st January 2016 shall be fitted with a stability Loading Instrument capable of verifying compliance with not only intact but also damage stability requirements. Oil tankers constructed before 1st January 2016 shall be fitted with such a Loading Instrument at the first scheduled renewal survey of the ship on or after 1st January 2016 but not later than 1st January 2021, although this requirement may be waived if it can be shown that the existing system for verifying damage stability is satisfactory.

Similar amendments were made to ships constructed under the remaining Codes listed above except for the IGC Code where the amendments apply to ships constructed prior to 1st July 2016 with compliance required at the first renewal survey after this date and no later than 1st July 2021. In addition, the International Oil Pollution Prevention (IOPP) Certificate in MARPOL Appendix II (Form B) and the Certificates of Fitness in the remaining Codes were amended with statements to the effect that either the tanker has been fitted with an approved stability Loading Instrument in accordance with Regulation 28(6) (or equivalent in the remaining Codes) or that the fitting has been waived in accordance with Regulation 3(6) (or equivalent).



On board-loading instruments are preferred to manual methods for verifying damage stability compliance (photo: Khaled Abdelmoumen)

## The IMO guidelines on tanker damage stability computers

From the above amendments to MARPOL etc. it can be seen that it was concluded at IMO that the solution to the technical problems of demonstrating compliance with the damage stability regulations, as discussed in the previous article [1], is to employ suitable damage stability computers either on board as a Loading Instrument or at a shore station with suitable communication links. Recognising the need for a fuller explanation and more background information, IMO produced circular MSC.1/Circ.1461 'Guidelines for Verification of Damage Stability Requirements for Tankers' [8], which was approved at MSC 92 on 8 July 2013. The Guidelines are in two parts.

Part 1 defines how approval of damage stability calculations or stability Loading Instruments for new oil tankers, chemical tankers and gas carriers constructed on or after 14th June 2013 should be conducted. Although it directly applies to new approvals, Part 1 summarises all pre-existing guidance with which any previous damage stability approvals should have originally been made, hence it may also be used to assess the validity of an existing approval. Technically, an existing

stability approval which does not follow the Guidelines is deficient, as it does not follow the original Instruments against which it is approved e.g. MARPOL Annex 1. Part 1 also includes details of the qualifications of the personnel involved, the plans and data to be supplied, the calculation procedures and advice regarding the need to consider all relevant damage cases, including lesser cases of damage to both sides and bottom of the ship. It also describes the permissible limits within which damage stability calculations or a damage stability Loading Instrument must lie when checked for accuracy.

Part 2 is mainly intended for the guidance of third parties, such as ship operators, ship's officers and Port State Control Officers (PSCO). Section 6 describes the records required to be kept on board all tankers and gas carriers in order to demonstrate damage stability compliance for the approved methods of verification listed in Section 4. The processes and records described here are also applicable to existing ships and Section 6 should be considered mandatory once re-certification of existing tankers is completed under the revised Instruments. Part 2 provides guidance for operators and ship's officers to meet their obligations

under the ISM Code, and to related third parties such as PSCO and International Safety Management (ISM) auditors.

To ensure that tankers can have their damage stability reliably verified on board they must either be fitted with an approved stability Loading Instrument (the default position for new ships unless there are compelling reasons not to comply) or, for existing tankers, certified to continue to use a validated and approved existing method. All existing damage stability approvals in place at the time the guidelines came into force remain valid provided they meet the standards from Part 1 (as this repeats the required practice at the time of the original approval) and on condition that any guidance is being correctly followed.

The guidelines were developed by the IMO well before the applicable enforcement date for the changes to MARPOL and the other Codes, namely 1st January 2016. This was to allow time for operators to assess what changes, if any, were required to the stability verification methods used on their existing tankers and, if deemed necessary, to order new computer systems (on-board Loading Instruments) and have them approved in time to comply with the new regulations within the phase-in period.

Following the phase-in of changes to the applicable Instruments and re-certification, the default method of damage stability verification shall be carriage of a Type 3 stability Loading Instrument, which is discussed below, capable of verification by direct calculation. Other acceptable methods of verification, if retained from before re-certification, must be validated against the Guidelines and then authorised under a waiver on the IOPP Form B or Certificate of Fitness. These accepted methods include operating the tanker closely in accordance with, but not outside the range of, the loading conditions given in the approved Stability Information Book (Trim and Stability Book).

### Type 3 tanker damage stability computers

The International Association of Classification Societies (IACS) had previously introduced a Unified Requirement (UR) relating to stability computation under URL5, with the objective that any Loading Instrument fitted on a ship classed with an IACS member contracted after 1st July 2005,

which incorporates a stability element, should be approved for verification of all stability requirements that apply, including damage.

Under these requirements, a Loading Instrument utilising Type 3 software is capable of automatically calculating both intact and damage stability by direct application of pre-programmed damage cases for each loading condition. A clear warning of non-compliance shall be given on screen and in hard copy printout if any of the loading limitations are not complied with. 'Direct calculation' means that the stability Loading Instrument utilises a full 3-D model of the ship including the hull and all buoyant appendages, all damageable compartments / tanks / spaces downflooding points etc., and is programmed to analyse all the potential damage scenarios required by the relevant Code or Instrument.

### Conclusions

Although calculation of the damage stability of tankers is complex, recent advances in computer hardware and software have enabled comprehensive and robust assessments to be performed quickly and economically on board, which is considered preferable to placing reliance upon shore-based stations. The amended IMO Regulations promote the use of these improved computer systems (on-board Loading Instruments) in preference to using simplified manual and semi-manual methods for verifying compliance with damage stability regulations.

The United Kingdom's Maritime and Coastguard Agency's (MCA) preference is for the use of on-board stability Loading Instruments running Type 3 software on all tankers subject to the amended Regulations even though these still permit existing methods of verification to be retained on tankers constructed before 1st January 2016. New guidelines in the form of a Marine Guidance Notice (MGN) are currently being produced in consultation with stakeholders. It is hoped that this will be able to be outlined and discussed with readers of *The Naval Architect* in the near future once the MGN is published.

### Disclaimer

The views expressed in this article are those of the authors and do not necessarily represent those of the organisations

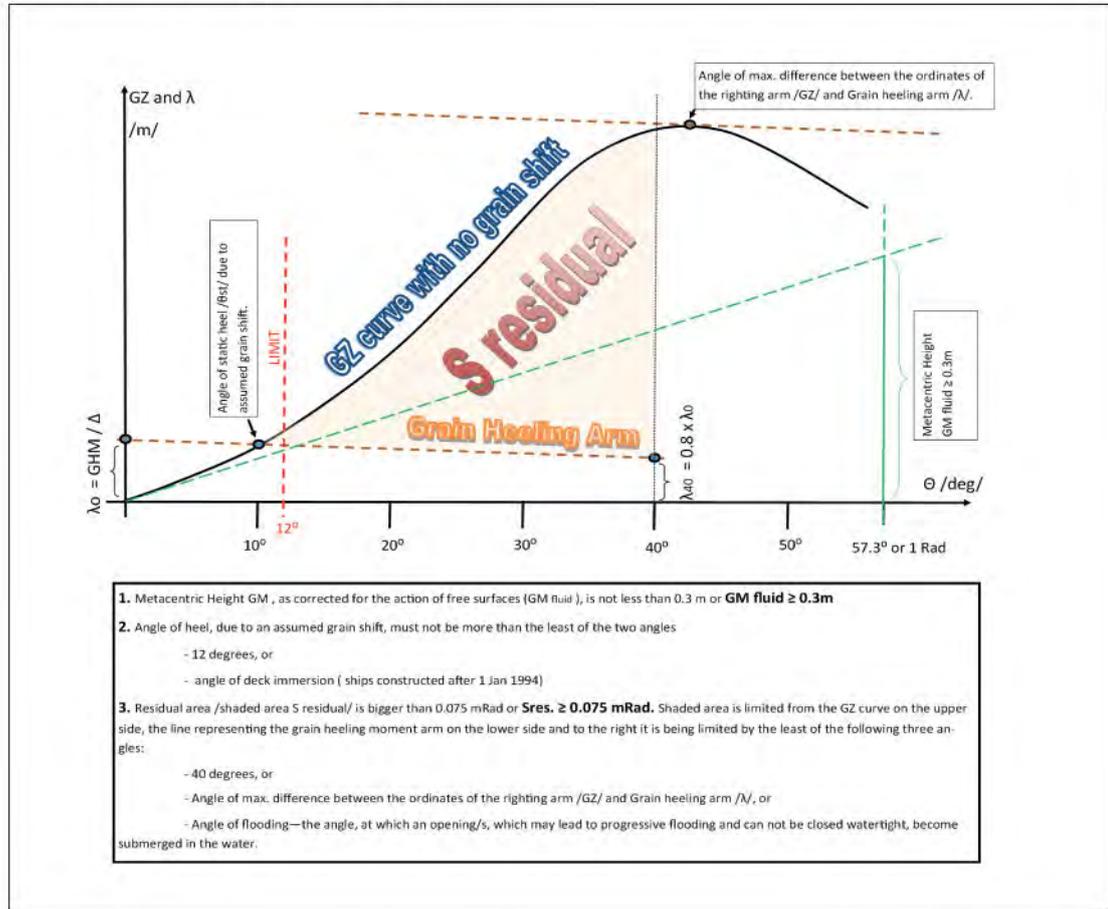
with which they are affiliated and the professional institutions of which they are members. *NA*

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# Grain stability: the missing link

Grain is a tricky cargo and liable to shift during transit. Capt. Petar Saydenov highlights a flaw in the stability requirements of the International Grain Code and puts forward a possible solution



Millions of tons of grain are transported by sea annually. Legislation governing the safe carriage of grain is therefore vital and regulated by strict criteria as stipulated in the International Code for the Safe Carriage of Grain in Bulk (International Grain Code – IGC), which was adopted by resolution MSC.23 (59) and became mandatory under SOLAS Ch. VI from 1 January 1994.

The specific stability requirements for ships which carry grain are set out in Section 7 (Stability Requirements) of the IGC. These are illustrated in Fig. 1, comprising the static stability diagram (Righting Moment Arm  $GZ$  /m/ as a function of the angle of heel  $\theta$ /deg/).

Many national bodies also refer to the Code and ask for a stringent way of demonstrating the ability of a vessel carrying grain to meet the stability requirements at all stages of the intended voyage. The National Cargo Bureau (NCB) of USA has a special form to be completed

prior to loading grain as a means of demonstrating that the vessel is IGC compliant (available at [natcargo.org/gscf.pdf](http://natcargo.org/gscf.pdf)). AMSA and Transport Canada have done likewise (fillable form AMSA 226 (12/12), Canadian Stability Form 82-0579 (0211-04)), while other maritime agencies



Figure 2. Centre of Gravity

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around the world simply make a direct reference to the IGC regulations.

All the forms should be properly filled in with the correct data, but very few Port State Control inspectors appreciate the numerous hurdles that chief officers and captains must negotiate in order to come to achieve those safe loading conditions. The process is tedious and includes many iterative steps through the relevant flowcharts (usually an integral part of The Grain Stability Manual (GSM), found on board of every bulk carrier). While Metacentric Height (GM) is comparatively easy to calculate, the second vital criteria – the angle of heel due to grain shift – is a vaguer concept both to understand and to cope with in the event that you find that your vessel does not meet it.

Preparing the cargo plan for a typical grain-carrying vessel, we locate the gravity point (G) above the keel point (K), where all the masses on board the vessel can be assumed to act (Fig. 2). This measurement (KG) is a function of the vertical distribution of cargoes (masses) on board and is considered to be the vessel's 'centre of mass'. All the displacement of the vessel can be thought of as acting downwards from this imaginary point G. When calculating the stability of the ship, we are more concerned about the vertical distance of this centre of gravity above the keel (KG), rather than the longitudinal stability and calculation of the trim of the vessel, which one would consider to be the Longitudinal Centre of Gravity (LCG).

The IGC provides for a specially designed table in every GSM, upon which we compare (for certain Displacement  $\Delta$  /mt/ and Center of Gravity KG /m/) the Maximum Allowable/Permissible Grain Heeling Moment ( $GHM_{max, permissible}$  /tm/) to the combined and corrected Grain Heeling Moment of all the lower holds of our vessel ( $\Sigma GHM_{all\ holds}$  /tm/) for partial load and untrimmed/trimmed ends. Many GSMs even state that all the stability criteria of the IGC has been taken into account when compiling such a table. Somehow, and quite inexplicably in the IGC, most of the GSMs simply and finally prescribe that when the vessel is carrying grain, the master has to ensure that the sum of the heeling moment due to grain shift is smaller than the value obtained from the limiting tables.

Figure 3a. Unstable IGC conditions

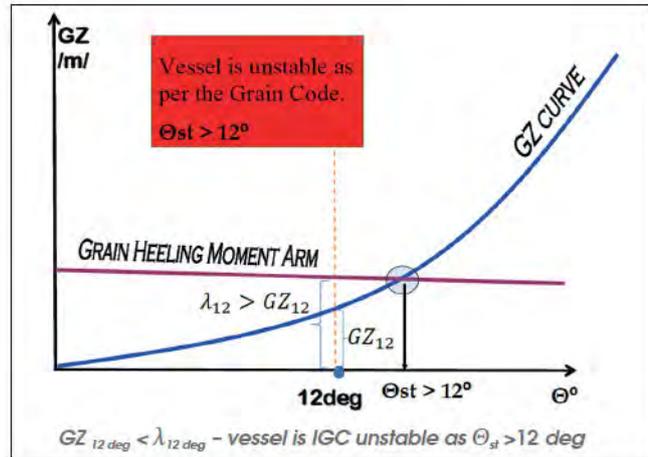


Figure 3b. Stable IGC conditions

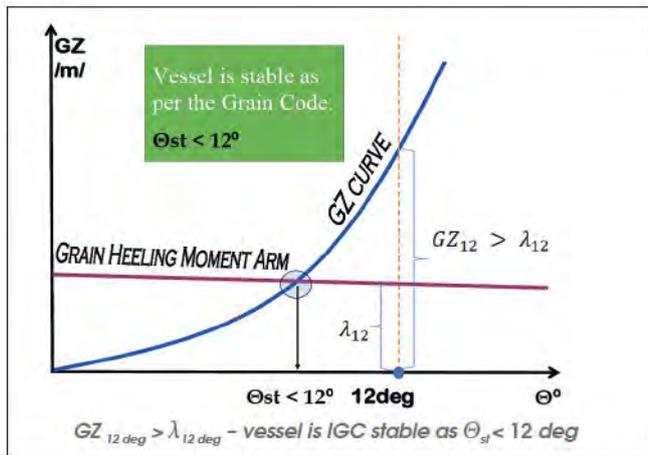
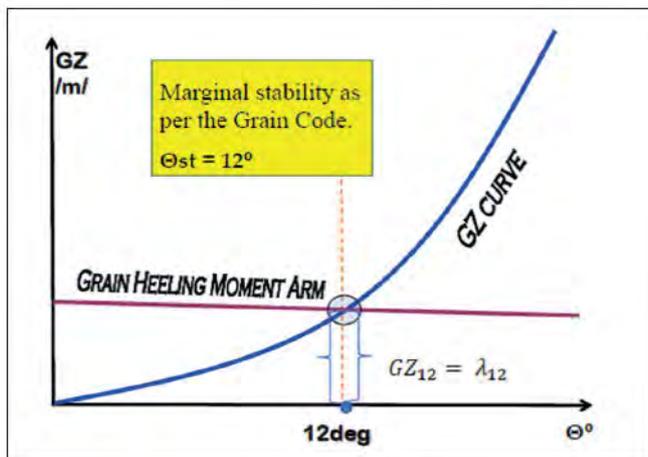


Figure 3c. Stable marginal IGC conditions



This might on face value sound easy, simple and convenient, but in practice it's not so straightforward, because what next if the vessel fails to meet these criteria? Lack of stability leads to taking a decision to ballast, but if we take a wild guess then we must repeat the whole checking process again and again until we find a satisfactory displacement and KG for which our unchanged (GHM does

not change with the increase of draught)  $\Sigma GHM_{all\ holds} < GHM_{max, permissible}$

Thus, the whole process lacks understanding of the actual physics of the requirements, shoots blindly at different conditions and simply guesses whether or not we will be 'stable' as per the IGC requirements. It's my humble opinion that the missing link is an explanation of how we come by the numbers in the Tables

for Maximum Allowable Grain Heeling Moments. So far nobody has proposed any formula to follow in pursuit of the IGC compliant vessel. The definition of such an equation would not only make the whole process more transparent, understandable and easy to follow, but bring us quickly and unambiguously to a quantitative and proven solution on how much ballast to take meeting IGC requirements; in other words, expanded programming options and solutions.

**Different stability scenarios**

Let's look more closely at that requirement and its logic: it has been determined that the vessel, at every stage of the voyage, should not heel to a static list of more than 12° following an assumed grain shift. Broadly speaking there are three possible scenarios. The first and least favourable of these (Fig 3a) is where our vessel would lack stability as per the Grain Code regulation – i.e. our vessel would heel to more than 12° on an assumed grain shift ( $\Theta_{st} > 12 \text{ deg}$ ).

In the second scenario (Fig 3b) our vessel heels to a list less than 12 deg on assumed grain shift i.e. ( $\Theta_{st} < 12 \text{ deg}$ ).

The third scenario, and most important from a scientific point of view, is where we have marginal stability i.e. our vessel heels

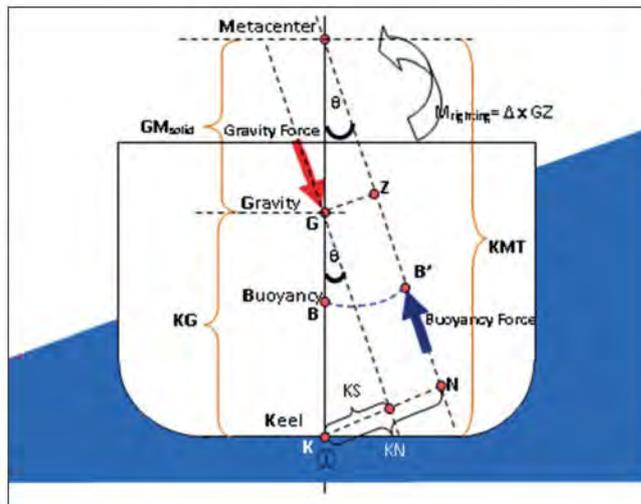


Figure 4.  $GZ_{12 \text{ deg}} = ?$

$$GZ = KN - KS$$

$$GZ = KN - KG_v \times \sin \theta$$

$$GZ_{12^\circ} = KN_{12^\circ} - KG_v \times \sin 12^\circ$$

to a list of exactly 12 deg on assumed grain shift i.e. ( $\Theta_{st} = 12 \text{ deg}$ ) (Fig 3c).

It turns out that if the line, representing the grain heeling moment arm  $\lambda$ , crosses the curve of the static stability (righting moment arm GZ) at 12 deg, then we have equation:

**Righting moment arm at 12 deg = Grain heeling moment arm at 12 deg**

or,  $GZ_{12} = \lambda_{12}$

Let us remind ourselves what is behind  $GZ_{12 \text{ deg}}$  (Fig.4) and  $\lambda_{12 \text{ deg}}$  (Fig. 5) and make them equal.

On Fig. 5, the point 'K' represents the keel of the ship. If at any angle of heel ( $\theta$ ), a line parallel to that of GZ were to be drawn from 'K', then the point of intersection of this line with the vertical line of action of buoyancy, is represented as 'N'. So, a computationally-derived plot of KN values for a range of displacements is obtained for different heel angles, and the resultant curves are collectively called KN Curves, Cross Curves of Stability, or Pantocarenes.

Naval science proves heeling arm decreases with heel on a cosine level. But IGC Reg. 7 stipulates for a linear approximation of the grain heeling arm, defined by the two points:

1.  $\lambda_0 = \frac{GHM}{\Delta} / m/$  ;
2.  $\lambda_{40} = 0.8 \times \frac{GHM}{\Delta} / r$

Therefore, the line  $\lambda_0 \lambda_{40}$  represents the grain heeling arm line. Following the similarity of the triangles  $\Delta ABC \sim \Delta AB_1 C_1$  (Fig. 5) we could define:

$$\lambda_{12} = 0.94 \times \frac{GHM}{\Delta} / m/ \quad (\text{eq. 1})$$

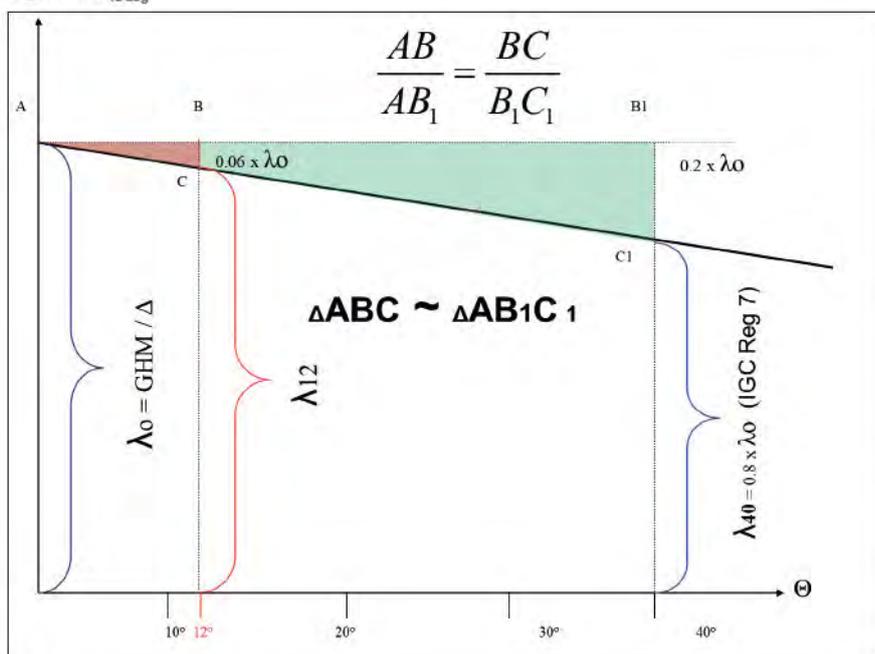
or  $GZ_{12} (\text{fig.4}) = \lambda_{12} (\text{fig.5})$

$$KN_{12 \text{ deg}} - KG_v \times \sin 12 \text{ deg} = \quad (\text{eq. 2})$$

$$= 0.94 \times \frac{GHM_{\text{max permissible}}}{\Delta}$$

If we input our displacement ( $\Delta$ ) (KG and KN) from the cross curves of stability we could define  $GHM_{\text{max permissible}}$ . In other words, we have found the equation upon which all the data, tabulated in the relevant Tables of Maximum Allowable Grain Heeling Moment, is being calculated. You can take this formula and try each and

Figure 5.  $\lambda_{12 \text{ deg}} = ?$



every ship Grain Loading Manual – that is how they calculate those ‘magic’ numbers, which you must comply with. The maximum deviation you could observe is less than 0.1 percent in the GHM, but we cannot be sure upon those tabulated figures until relevant Class authorities reveal the method they use in defining those limits.

By way of example let’s look at the bulk carrier *M/V Koznitza* (Displ. 27500 mts, KGv = 8.50 m, lifted GHM<sub>max,permissible</sub> = 5551.2 tm). Fig 6. shows the vessel’s stability booklet.

Most of the time, we have to compare our loading condition with displacement (Δ=27500) and certain cargo distribution, resulting in a particular vertical gravity centre at KG(8.50m). For such a combination we find *M/V Koznitza*’s GHM<sub>max,permissible</sub> in the specially designed table: this limiting value is 5551.2 tm. We have to compare this value to the combined grain heeling moment of the grain in all the holds of the vessel. The comparison is vital for the compliance of the vessel to the Grain Code requirements. But if we put the grain stability equation to work, we could easily find the GHM<sub>max,permissible</sub> without entering the above table, obtaining the KN value for 12 degrees from the vessel’s cross curves of stability or pantocarenes. In this particular case for *Koznitza*’s displacement (27,500) and the limiting angle of heel 12 degrees, we lift KN = 1.957m.

Following our grain stability equation:

$$\begin{aligned}
 KN_{12\ deg} - KG_v \times \sin 12\ deg &= \\
 &= 0.94 \times \frac{GHM_{Max.Permissible}}{\Delta} \\
 1.957 - 8.50 \times 0.20791169081 &= \\
 &= 0.94 \times \frac{GHM_{Max.Permissible}}{27500}
 \end{aligned}
 \tag{eq. 3}$$

$$\begin{aligned}
 \Rightarrow GHM_{max,permissible} &= 5551.2\ tm - \\
 \text{i.e. exact match of the tabulated value} & \\
 GHM_{max,permissible} &= 5551.2\ tm
 \end{aligned}$$

Therefore, all the table data in the relevant tables for maximum permissible grain heeling moments, as found in the ship’s grain loading manuals, is being calculated using the above equation.

Another surprising bonus is that if we play with the formula in a different manner, using actual GHM of the grain in the holds and trying to define KG at which this would happen, the formula takes another suit:

$$\begin{aligned}
 KN_{12\ deg} - KG_v \times \sin 12\ deg &= \frac{\sum GHM_{all\ holds}}{\Delta} \\
 &= 0.94 \times \frac{\sum GHM_{all\ holds}}{\Delta}
 \end{aligned}
 \tag{eq. 4}$$

Therefore, we would be able to calculate KG at which we could meet the IGC requirement for stability i.e. to define KG<sub>v, max,permissible</sub>.

Finding KG<sub>v, max,permissible</sub> answers two vital questions:

- Is my ship stable? (KG<sub>v</sub> must be ≤ KG<sub>v, max,permissible</sub>)
- If it is not stable, how much ballast must we take in order to meet the IGC requirements (KG<sub>v</sub> - KG<sub>v, max,permissible</sub>).

One would find it a bit tricky and vague how this difference would guide us on the ballast quantity to be taken, in order to meet IGC stability criteria. However, we can use a modification of the Varignon’s Theorem, which we use on a daily basis on ships. In fact, all the tables with weights and moments we calculate are representations of this theorem as we finally come to a combined displacement (sum of all weights) and weighted center of gravity (at which point all the weights on board could be assumed to act). Following the logic of this theorem, if we define our primary condition (unstable) and sum it with the change (due to ballasting), this must be equal to our desired final condition (stable, ballasted).

If we put this to work:

$$\text{Initial condition} + \text{Ballasting} = \text{Final (desired and stable) condition}$$

$$\begin{aligned}
 \Delta \times KG_v + Q_{ballast} \times Z_{ballast\ tanks} &= \\
 = (\Delta + Q_{ballast}) \times KG_{v, max,permissible} &
 \end{aligned}
 \tag{eq. 5}$$

Of course, here, KG<sub>v, max,permissible</sub> is defined for our initial displacement and not for the improved condition, but this is beneficial, because with the increase of displacement, GHM<sub>max,permissible</sub> will increase too, thus lowering the grain heeling moment arm λ. If we define Q<sub>ballast</sub> from the above equation, this would be the ballast quantity to be taken in order to meet the IGC stability requirements. Multiple iterations are

Displ, t	27500.0	28000.0	28500.0	29000.0	29500.0	30000.0	30500.0	31000.0	
KM, m	9.299	9.309	9.321	9.335					
KGv, m									
7.50	11633.7	11875.0	12147.7	12453.4	19500	0.844	1.694	2.037	2.557
7.60	11025.5	11255.7	11517.4	11812.0	20000	0.839	1.683	2.024	2.540
7.70	10417.2	10636.4	10887.0	11170.6	20500	0.834	1.674	2.012	2.526
7.80	9809.0	10017.1	10266.6	10529.1	21000	0.830	1.665	2.002	2.513
7.90	9200.7	9397.4	9635.6	9877.7	21500	0.826	1.658	1.993	2.501
8.00	8592.5	8778.2	9007.9	9241.6	22000	0.823	1.651	1.985	2.491
8.10	7984.2	8158.9	8377.5	8599.4	22500	0.820	1.646	1.979	2.482
8.20	7376.0	7539.9	7735.1	7963.4	23000	0.818	1.641	1.973	2.475
8.30	6767.7	6920.6	7104.8	7322.0	23500	0.816	1.637	1.968	2.468
8.40	6159.5	6301.2	6474.4	6680.5	24000	0.814	1.634	1.964	2.463
8.50	5551.2	5681.9	5844.0	6039.1	24500	0.812	1.631	1.961	2.459
8.60	4943.0	5062.6	5213.7	5397.7	25000	0.812	1.629	1.958	2.456
8.70	4334.7	4443.3	4583.3	4756.3	25500	0.812	1.628	1.957	2.453
8.80	3726.5	3824.0	3952.9	4114.8	26000	0.811	1.627	1.956	2.452
8.90	3118.2	3204.7	3322.6	3473.4	26500	0.811	1.627	1.955	2.450
9.00	---	2585.4	2692.2	2832.0	27000	0.812	1.627	1.956	2.452
9.10	---	---	---	---	27500	0.812	1.626	1.957	2.452
KGmax, m	8.999	9.009	9.021	9.035	28000	0.813	1.630	1.958	2.454
M <sub>gh</sub> , tm	2516.1	2778.1	2559.8	2607.5	28500	0.814	1.631	1.960	2.456
					29000	0.815	1.633	1.963	2.459

Figure 6. *M/V Koznitza* stability booklet

not needed; with just one pass through the flowchart, the entire loading plan is checked, improved and meets IGC criteria. The only thing left to do is to fill in the relevant applicable form (if any) or simply demonstrate that the vessel meets all the three criteria of Reg. 7 IGC, at all stages of the intended voyage.

Using the example of *Koznitza* again, let us assume that the GHM of the grain in the holds of the vessel has been calculated to reach 6,143 tm. Clearly this exceeds the 5,551.2 tm limit specified above and as such does not comply with the Grain Code. At this stage we must take a decision to improve the

stability by ballasting the vessel, but with how much ballast? We must guess and repeat the calculations after each and every ballasting we make.

However, we could make a major breakthrough by using newly defined grain stability formula, where:

$$KN_{12 \text{ deg}} - KG_{v \text{ max. permissible}} \times \sin 12 \text{ deg} = 0.94 \times \frac{\sum GHM_{\text{all holds}}}{\Delta}$$

$$1.957 - KG_{v \text{ max. permissible}} \times 0.20791169081 = 0.94 \times \frac{6143}{27500}$$

(eq. 6)

i.e.  $KG_{v \text{ max. permissible}} = 8.40\text{m}$

Comparing to our real distribution of cargo with present  $KG_v = 8.50\text{m}$ , we could say that our ship is not stable IGC-wise and we must lower the vertical centre of gravity by 10 cm ( $KG_{v \text{ max. permissible}} - KG_v = 8.40 - 8.50 = -0.1\text{m}$  - here the sign “minus” indicates for lowering the centre of gravity.)

This guides us on the ballast quantity to be taken in the following manner (keeping in mind that the ballast tanks are with an approximate centre of gravity [Zballast tanks] 1.4 meters above the keel):

$$\Delta \times KG_v + Q_{\text{ballast}} \times Z_{\text{ballast tanks}} = (\Delta + Q_{\text{ballast}}) \times KG_{v \text{ max. permissible}}$$

$$27500 \times 8.50 + Q_{\text{ballast}} \times 1.4 = (27500 + Q_{\text{ballast}}) \times 8.40$$

$$233750 + Q_{\text{ballast}} \times 1.4 = 231000 + Q_{\text{ballast}} \times 8.4$$

$$2750 = Q_{\text{ballast}} \times 7$$

$$Q_{\text{ballast}} = 392 \text{ mts}$$

This ballast quantity is considered enough for proving that our vessel is stable Grain Code-wise. This could be very easily checked:

Our new displacement is  $\Delta = 27500 + 392 = 27892$  mts; and our new KG is exactly 8.40m

$$\text{New } KG = \frac{\Delta \times KG_v + Q_{\text{ballast}} \times Z_{\text{ballast}}}{\Delta + Q_{\text{ballast}}} = \frac{27500 \times 8.5 + 392 \times 1.4}{27500 + 392} = 8.40\text{m}$$

i.e.  $\text{New } KG = KG_{v \text{ max. permissible}} = 8.40\text{m}$

(eq. 7)

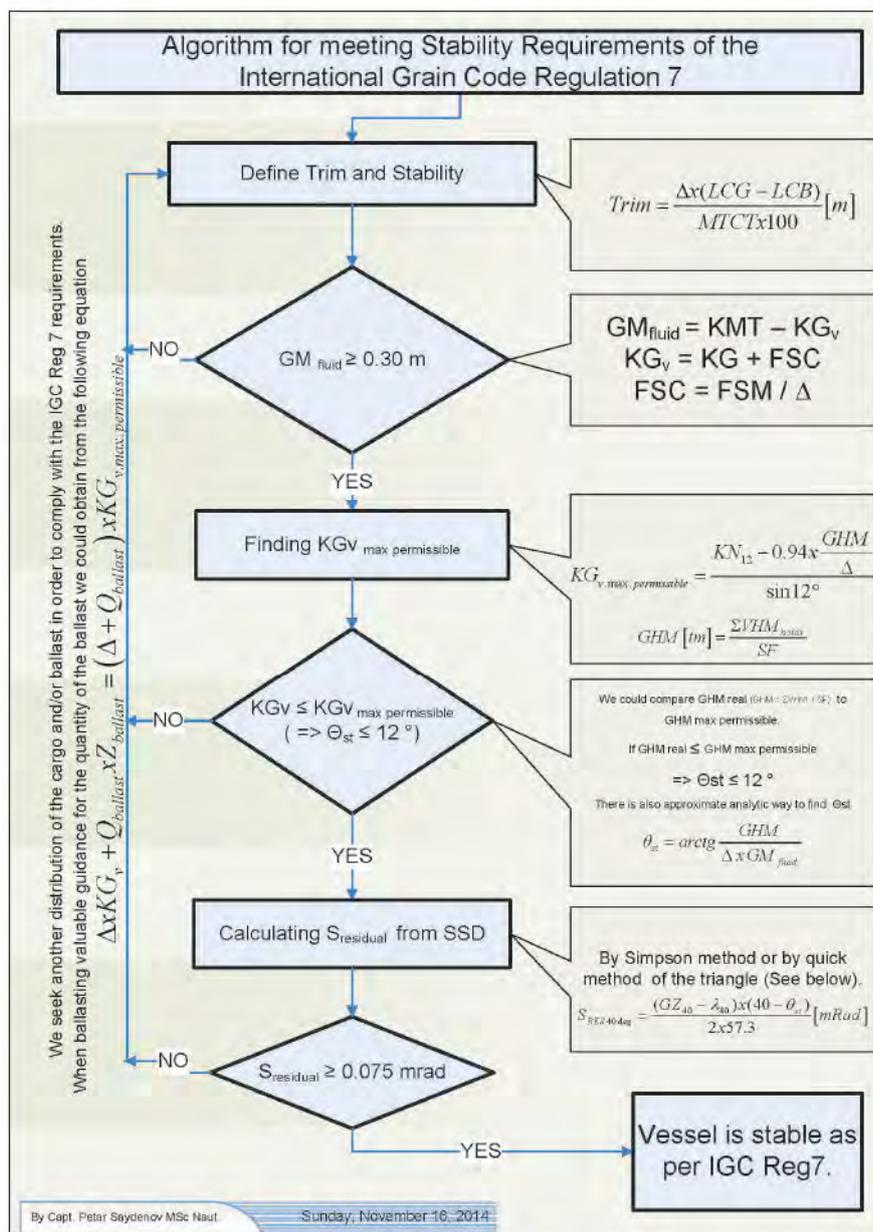
Our vessel is stable as per the Grain Code, because the maximum angle of heel due to an assumed grain shift would not be more than 12 degrees.

For those of you on the practical side, it would be much convenient to follow a separate, one-time-pass flowchart (Fig. 7) to meet the IGC Stability Requirements. Good luck! *NA*

### About the author

Capt. Saydenov would be grateful for your comments and feedback on his email address: saydenov@protonmail.com

Figure 7.



By Capt. Peter Saydenov MSc Naut. Sunday, November 16, 2014

# Not always afloat but (hopefully) safely aground on a flat earth

Current design precautions taken to prevent damage to vessels aground in tidal basins are not robust enough, writes Navalmartin's Val Martin

**W**e recently reminisced about the practical joke I played on a senior Master Mariner who is very well respected for his time at sea and his eloquent expertise in the court of arbitration in London. The man is an authority on everything that floats, navigates or steers.

To enlighten his life, I registered him formally as a supporting member of the Flat-Earth Society. Thereafter, Captain Flat-Earther would never again be allowed to brag about his skills with a sextant or his ability to find the optimum rhumb line to the watering hole.

Drawing on this truculent metaphor, I note again that it is at the boundary of the science (or commonly accepted knowledge) that lay the perils of our industry.

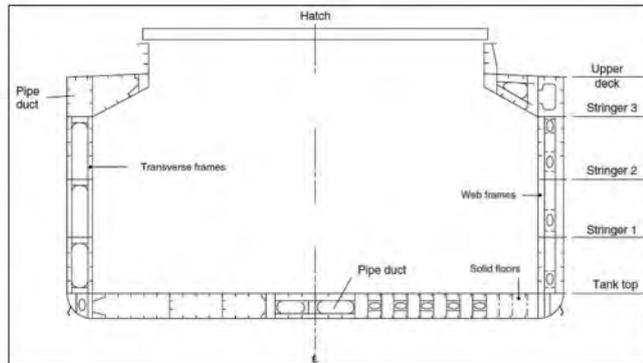
Specifically, the 'terra incognita' of naval architecture is the situation where the hull is in contact with the hard stuff: docking aground, on a slipway, or in slings.

The abnormal state of rest is one which is prone to anxiety; it is a time when the master surrenders his vessel to the shipyard, the crane operator, or merely allows the tide escape from under his keel (hopefully, not accidentally).

Separately from white yachts and behind the curtains of litigious circumstances, we have examined a number of vessels that had sustained damage at NAABSA berth: Not Always Afloat But Safely Aground. These are moorings where the tidal range has the visiting ship touching the bottom.

The 'Safely' here is governed by both the ship and the berth's propensity to meet one another, and unfortunate surprises occur when that is not the case. The presumption of guilt is with the berth as it is difficult to prove that the berth was free of obstruction.

As it turns out, from a design point of view, the class notation 'loading and unloading aground' is granted on some very coarse checks, and the precautions implemented by design to prepare a vessel for sitting on unknown sediments are surprisingly rudimentary, such as adding 20% on the



Common precautions such as adding 20% on steel plating thickness will not protect every vessel required to sit on sediment

steel plating thickness and a little bit extra for the inner structure. There is no check of the quantity of cargo carried, no check to reflect the loss of hydrostatic support away from the flat bottom, and no additional thin-plate-buckling critical stress check.

With general cargo ships that have a double bottom and whose longitudinal strength is governed by the stresses in the deck more than the stress in the bottom plating, much of the attention is devoted to the deck and hatch corners, with economy applied with regard to the intrinsically robust close-cell bottom and tank top

combination. As such, the bottom plating is not fundamentally very thick. Therefore, the risk of bottom damage in the drydock has been traditionally managed by the careful application of tins and blocks under the keel and selected longitudinal members. The master and the shipyard agree on the importance of the docking plan.

We have observed that some ships are better suited for NAABSA operations and this is not necessarily reflected in the certification. It is the remit of Class to assess the seaworthiness of a ship. As for their sediment-worthiness, it is, in my opinion, a grey area.

It is therefore valid to consider some kind of agreement between the port operator and the ship owner before the ship enters the tidal berth. This can protect all parties against an unpleasant surprise and accusations afterward.

In these modern times, the debate about the flatness of the earth is still raging and the flat-earthers have a valid point to make! **NA**

## About the author

Val Martin has worked variously as a naval architect, as part of a classification society's emergency response team, and as an offshore renewable energy advisor for the EU and UK. At Navalmartin, Val acts as an expert witness on design-related claims, and as an on-site salvage engineer.

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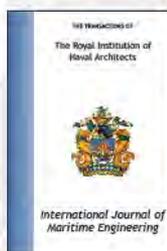
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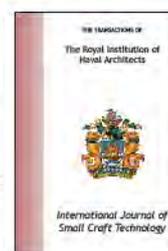
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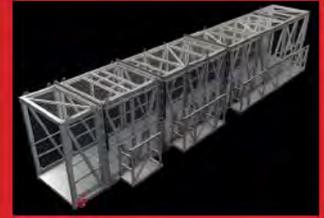
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