Recent Regulatory Changes and their Impact on the Design of Large Yachts

Alex Meredith Hardy, *Naval Architect, BMT Nigel Gee Ltd*
Sylvain Julien, *Naval Architect, BMT Nigel Gee Ltd*
James Roy, *Yacht Design Director, BMT Nigel Gee Ltd*

ABSTRACT

The Large Commercial Yacht Code (LY2) has in the last decade become the de facto standard for the design and construction of large yachts. However the code is limited to a passenger number of 12 and a gross tonnage of 3000 GRT, implying a maximum length of approximately 85m LOA. In recent years, the number of large motor yachts outside of these boundaries has been steadily increasing making them subject to full SOLAS passenger ship regulations in addition to other pertinent conventions. This SOLAS based regulatory frame work has recently been subject to a period of significant change with the entry into force of a number of new regulations and conventions. It was recognised that gaining quantified insight into the impact of these on large yacht design would be of value to the industry, allowing refinement of design methods and procedures.

This paper investigates several new or recently updated regulations and conventions all of which will have varying degrees of impact on large yacht design practices and arrangements. These include SOLAS harmonised probabilistic stability, MARPOL fuel tank protection, MARPOL exhaust emissions, the Maritime Labour Convention and the Ballast Water Convention.

Each topic has been assessed in order to extract and summarise the relevant areas with regard to large yachts. Where possible the paper quantifies the effect the new regulations will have on yachts offering naval architects and designers insight as to how current design practices will need to change to ensure compliance.

1. INTRODUCTION & BACKGROUND

The large yacht market (>30m in length) has seen rapid growth in the last ten years. On average this has been 13% per annum year on year and over 300% overall. Not only has the number of yachts designed and built increased significantly so too has their size.

The majority of these large yachts are restricted to carrying 12 passengers and are less than 3000 GRT in order that they can be regulated under the Large Yacht Code (LY2). This code was developed in the early 1990's by yacht industry policy makers and was based on SOLAS Cargo Ship, Load Line Regulations and others. These standards incorporated sufficient equivalencies to allow the freedom and flexibility in design that yachts need in order to satisfy an owner's desire for individuality.

In recent years the size of yachts in the upper segment of the industry (as large as 160m in length) has become such that they are now outside of this regulatory framework and are subject to full SOLAS passenger ship regulations as well as other pertinent regulations. A limited number of yachts have been successfully designed and built to these regulations and there are now moves being made by the industry policy makers to develop specific regulations for these vessels based on equivalences to SOLAS, as had been done for the smaller yachts with the LY2 code.

However the SOLAS based regulatory framework is currently undergoing a period of change. Forthcoming ratification and entry into force of recent and future regulations will have a significant impact on the layout of SOLAS certified passenger ships and therefore the yachts in the upper segment of the industry. For several regulations no equivalency will be sought by the policy makers, specifically the introduction of probabilistic damaged stability for passenger ships, the Ballast Water Management Convention, MARPOL Regulation 12A (protection of fuel tanks), MARPOL Exhaust Emissions Compliance and the soon to be ratified Maritime Labour Convention 2006.

BMT Nigel Gee has undertaken a research project to investigate the implications of these future regulations on the layout of large yachts and how current design practices will need to change in the future to deal with the regulatory changes. Although the paper is focussed on yachts of 3000 GRT plus, some of the regulations discussed will also apply to smaller yachts, particularly the Maritime Labour Convention.

2. THE MARITIME LABOUR CONVENTION

The Maritime Labour Convention (MLC) 2006 has been created to form a single coherent instrument embodying as far as possible existing up-to-date maritime labour conventions, recommendations, and principles. The convention is governed by the International Labour Organisation (ILO) and will enter into force after ratification by at least 30 Members with a total share in the world gross tonnage of ships of at least 33%. It is predicted to reach the required ratification level by mid

2011 and will apply to yachts ordinarily engaged in commercial activities (charter yachts). It is believed that the ILO also mean to include yachts owned by businesses or companies. This differs from the interpretation of 'commercial' by some Flags and may not be enforced by those administrations.

This convention covers many topics with regard to seafarer working conditions. However the main concern with regard to design is the minimum size requirements for crew cabins. This is currently an area of contention between the ILO and the yachting industry and if enforced as written, will have major implications on the design of yachts less than 65m. This will impact on yachts constructed after the date that the convention comes into force for the member state concerned. MLC Standard A3.1.20 allows member states to exempt vessels less than 200 GRT from the accommodation area requirements. The MCA have indicated that they intend to apply accommodation requirements on this size of vessel through other codes such as the Small Commercial Vessel Code [1].

To assess the impact that implementation of the MLC would have on 200 GRT+ yachts, BMT Nigel Gee carried out a crew accommodation study. This applied the MLC requirements to crew cabins, officer cabins and messes of 15 large yachts between 40m -100m LOA regulated under both LY2 and full SOLAS as passenger ships. The results are shown in Figure 2.1.

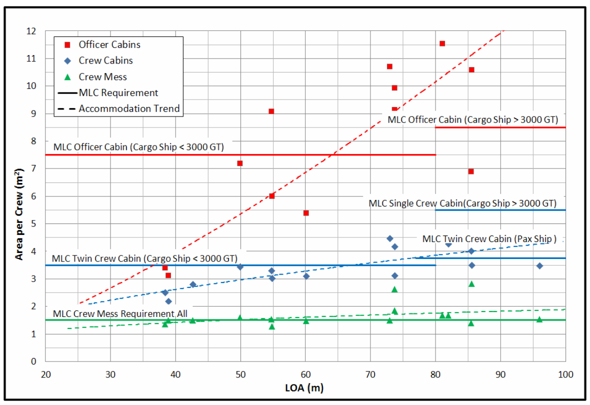

Figure 2.1 – Accommodation Study Results

Looking at LY2 yachts (less than 3000 GRT) it was found that yachts below 65m (approx 1150 GRT) were not meeting the crew cabin requirements. At the lower end of the scale (35m) crew cabins were approximately 65% of the area required. For yachts built to SOLAS cargo ship rules larger than 3000 GRT the MLC requires all crew to be in single cabins. This is not current industry practice and would have serious implications for future yachts of this type, effectively doubling the number of crew cabins. For full SOLAS passenger ship yachts the crew cabin threshold was 77m (approx 1800 GRT). When investigating the officer cabin area requirements it was found that the MLC threshold was 62m (typically 1000 GRT). A significant problem in smaller vessels was that only the captain had an officer cabin. LY2 states that there should be between three and five officers on a yacht. MLC requires all these to have officer sized cabins. On a separate study of two 40m yachts, the combined effect of the officer and crew requirements reduced the number of guest cabins from four to two. This has a large impact on cabin arrangements and crew/guest balance of a yacht resulting in significant loss of function of the vessel. The MLC requirement for crew messes is $1.5m^2$ per person. It was found that yachts over 45m generally already comply. In smaller vessels some increase in mess size may be required.

It is clear from this study that the MLC will have a significant impact on the commercial viability of yachts less than 65m (approx 1150 GRT). The yachting industry is currently involved in coordinated dialogue with the ILO through representatives such as the PYA, SYBAss, ICOMIA and MYBA as well as the UK MCA. The ILO is aware of the problem. The hope is that yachts will be recognised by the ILO as a special case and equivalent accommodation standards with reduced area requirements can be drawn up and agreed upon. This would consider that yacht crew generally have en-suite bathrooms and long periods in port compared to other seafarers. There is no guarantee from the ILO at this stage that a special case will be made for yachts. Although the current advice is that future designs should meet the requirements of the MLC as written, it should be borne in mind that the equivalent standard for yachts under development may come into effect. What is fairly certain is that with either route seafarer cabins will be larger than current standards. Discussions are ongoing, so watch this space.

3. PROBABILISTIC STABILITY

The probabilistic stability method has been under development since the early 1960s. It was first adopted in 1990 as the damaged stability method for dry cargo ships. From 1995, considerable efforts were made to provide a harmonised probabilistic stability standard applicable to all ships. In 2005 MSC 194(80) was adopted to form what is commonly referred to as SOLAS 2009. This stability standard entered into force on 1st January 2009, and is applicable to all passenger ships as well as cargo ships over 80m built from that date. The aim of the new probabilistic standard is to provide an equivalent level of safety to SOLAS 90 [2].

3.1 ATTAINED AND REQUIRED INDEX

Unlike deterministic stability, the probabilistic method uses a risk based approach assessing the probability of damage and the severity of the consequences. The calculation assesses this across all compartmentation on the vessel. The final result is expressed by the Attained Index value 'A', the maximum value of which is 1.00. This can be thought of as a percentage of total safety.

Practically, no vessel is 100% safe so it is necessary to define some level of acceptable safety. This is defined by the Required Subdivision Index 'R'. The method that defines 'R' is a function of the size of the vessel, number of persons on board and configuration of the lifesaving equipment. Table 3.1 compares the typical complement of a yacht compared to a passenger ship. It can be seen that the complement of a yacht does not increase significantly with length compared to a passenger ship. Figure 3.1 shows how 'R' varies with length considering these typical values.

Length [m]	50	100	150
Yacht - Total Complement	54	81	96
Passenger Ship - Total Complement	200	525	1425

Table 3.1 – Comparison of Typical Complements

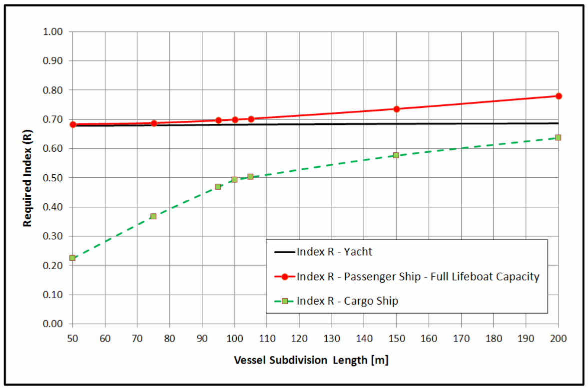

Figure 3.1 – Comparison of Required Index R

It can be seen that 'R' remains relatively constant as the yacht length increases. Whilst the subject of equivalency to SOLAS 90 is outside of the scope of this paper, it can be seen that the gap in safety between a typical passenger vessel and a yacht increases with vessel length. This is a significant difference to the SOLAS 90 standard where the level of safety is the same whatever the number of people onboard. Additionally, with the probabilistic method, catastrophic damage cases with a low probability of occurrence can exist whilst not reducing 'A' sufficiently to cause the vessel to fail. There is currently debate within the wider industry as to whether the probabilistic method is equivalent to the previous deterministic standards. As a result, probabilistic stability standards still include deterministic requirements for passenger ships to guarantee minimum stability characteristics following minor damage. This adds further to an already complex set of regulations.

3.2 AIM OF THE WORK

The primary aim of the research carried out by BMT Nigel Gee was to see how the naval architect can assess large yacht designs, with confidence, at a preliminary design stage. Unlike deterministic methods, the probabilistic calculations are unintuitive. It is hard to get a feel for how changes during the preliminary design process will influence the Attained Index. As a result, in the early design stages it is difficult to be confident that the final design will pass. As a result, the aim of the work carried out was to ascertain what the major influences on the Attained Index are, and what level of subdivision must be defined in order to have confidence that a vessel will pass.

3.3 SIGNIFICANT INFLUENCES ON 'A'

Three draughts are defined for the calculations, Deepest Subdivision, Partial Subdivision, and Light Service draught. The deadweight distribution in each case is undefined and totally reliant on the judgement of the naval architect. It is important at the preliminary design stage that a practical VCG is used for each case to get a realistic Attained Index.

The margin line concept is not applied in probabilistic stability. The survivability of the craft in any single flooding scenario is considered to be zero if any part of a horizontal evacuation route on the bulkhead deck is submerged. It is important that preliminary positions of evacuation routes are defined as they can have a significant effect on 'A', especially in yachts with stepped bulkhead decks.

The subdivision arrangement, and the level of detail represented, has a major influence on the final result. As would be expected, representing all major transverse subdivisions is the most efficient way to increase the Attained Index. Longitudinal subdivision can result in large reductions in Attained Index due to asymmetric flooding. Horizontal subdivision can both improve and reduce the result depending on its location compared to the waterline. In order to better understand how sensitive the Attained Index was to the level of subdivision modelled, a study on a 95m and 85m yacht was undertaken. Starting with the as built fully defined subdivision arrangement, subdivision definition was progressively removed in a methodical manner and the Attained Index assessed at each stage. Table 3.2 describes the levels of subdivision assessed.

Table 3.2 – Levels of Subdivision Investigated

Stability Model	Compartmentation Description
As built	As built, highest level of complexity.
Option 0	Removal of small double bottom, central tanks. Main longitudinal subdivisions maintained.
Option 1	As option 0 but with cross connection of all wing spaces to eliminate any asymmetric flooding effects.
Option 2	Removal of all longitudinal subdivision and transverse tank ends in the double bottom (excluding main WT bulkheads). No subdivision below the tender bay deck.
Option 3	Removal of double bottom and tender bay floor. Only main transverse bulkheads represented.
Option 4	As option 3 with every other main transverse bulkhead between the forward engine room bulkhead and the forepeak bulkhead removed.
Option 5	Only aft peak, forepeak and engine room bulkheads defined.
Option 6	Only aft peak, forepeak and forward engine room bulkhead defined.

Figure 3.2 shows the Attained Index achieved at each stage of subdivision as a percentage of the 'as built' vessel.

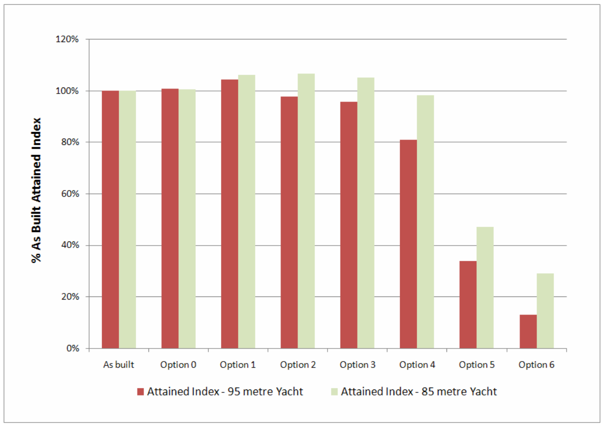

Figure 3.2 – Results of Subdivision Study

The most significant conclusion was that there is a danger of calculating an overly optimistic result unless all asymmetric flooding is considered. For a preliminary design where longitudinal subdivision is not defined a margin must be used (10% for typical levels of asymmetric flooding). It was found that removing small central bottom tanks does not significantly alter 'A'. These do not need to be considered at a preliminary design stage. To obtain a sufficiently valid Attained Index the following should be modelled; collision, aft peak and intermediate main transverse bulkheads, tender bay deck and any subdivision resulting in asymmetric flooding.

3.4 PRELIMINARY DESIGN METHODOLOGY

From this body of work, a methodology was developed to allow the naval architect to use the probabilistic method effectively for yachts at the preliminary design stage and have confidence in the Attained Index before all levels of subdivision are defined. This is based on the assumption that below the main deck, the majority of large yachts follow a generic layout, illustrated approximately as shown in Figure 3.3.

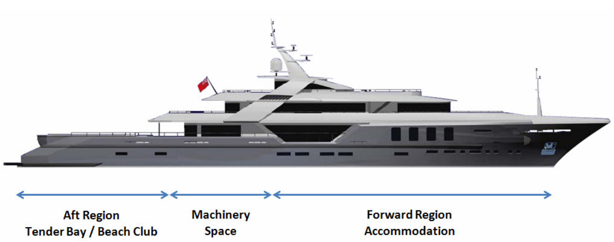

Figure 3.3 – A Generic Yacht Arrangement

A brief summary of the methodology is discussed.

- Step 1 - Even in the earliest design stages with a preliminary general arrangement the following subdivision should be defined; collision bulkhead, aft peak bulkhead, extents of tender bay, vertical location of tender bay deck, extents of engine room, and bulkhead deck geometry. Define the position of evacuation routes on the bulkhead deck.
- Step 2 – Define the loading conditions for the required draughts ensuring calculated VCGs are realistic.
- Step 3 – Optimise the main transverse subdivision in the forward region and check the position of engine room and tender bay bulkheads are suitable. This can be done by inspecting the contribution to the attained index for each compartment. If the tender bay is not overly large then the Attained Index may now meet the required index. However, as no asymmetric flooding has been considered it cannot yet be concluded that the vessel will pass.
- Step 4 – Add double bottom.
- Step 5 – Optimise subdivision in the aft region. This step applies when tender bays or beach clubs are overly large. Additional subdivision below the tender deck can allow a limited increase in the size of tender bays. On completion of this step the aim should be to have an attained index with sufficient margin over the required index (at least 10%) as longitudinal subdivision has yet to be considered.
- Step 6 – Introduce longitudinal subdivision. This will primarily be dictated by the tank arrangement. Void wing spaces should be cross connected to minimise asymmetric flooding. The Attained Index at this stage should be a good representation of the final Attained Index.

Ultimately, whether the exact methodology above is adopted or not, it is critical for the naval architect to understand the influence of the various principal levels of subdivision within a design. It is only through intimate understanding of the calculation and intermediate results that contribute to the Attained Index, that the subdivision can be optimised.

4. MARPOL REGULATION 12A

The MARPOL Convention covers pollution of the marine environment by ships. MARPOL Annex I covers the prevention of pollution by oil. Regulation 12A is an amendment which entered into force in August 2007. The purpose of the regulation is to minimise the quantity of oil lost from a vessel following damage from grounding or collision. This is achieved by enforcing a certain level of oil fuel tank protection. The new regulation applies to all ships with a fuel oil capacity of greater than 600m^3 delivered on or after 1st August 2010. The regulation provides two methods through which suitable oil fuel tank protection can be achieved.

4.1. PROTECTED FUEL TANKS

This method achieves adequate protection by positioning fuel tanks a required distance (typically 0.76m – 1.1m for large yachts) from the hull shell of the vessel effectively creating a double skin.

There are several issues associated with protected fuel tanks that are likely to discourage naval architects from pursuing the protected fuel tank route. The current yacht practice of using double bottom fuel storage is beneficial because it makes use of awkward, otherwise unusable void spaces. The protected tank method effectively creates more void space. Figure 4-1 shows a possible protected fuel tank arrangement. In order to accommodate an equivalent capacity of fuel the tank top height has to be increased significantly. In the example shown an additional 75% of volume was required compared to a pre regulation arrangement. This significantly impacts internal accommodation volume and the deck arrangement of the vessel. Wing tanks and tanks near the bow and stern, where there is high curvature, become very ineffective. The structural design and production of such a protected fuel tank arrangement would be significantly more challenging than current bottom arrangements, especially in areas of hull curvature. The additional tank boundary and supporting structure will increase structural weight. The increase in the double bottom height also shifts the decks above increasing lightship VCG impacting on stability and aesthetic profile. Deadweight VCG is also increased.

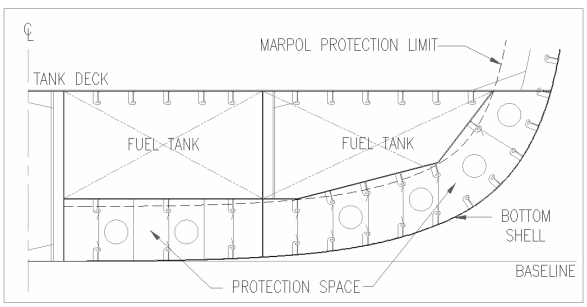

Figure 4-1: A Protected Tank Arrangement

4.2 ACCIDENTAL OIL FUEL OUTFLOW

The second method of compliance is a performance based method involving a probabilistic analysis of the fuel tank arrangement focussing on the likelihood of damage to each tank, and the subsequent quantity of oil that would be lost. A certain score must be achieved to demonstrate the required level of protection.

The main advantage of the outflow performance standard is that fuel tanks can remain in contact with the hull shell in line with current yacht design and production practices for double bottoms. However, the arrangement of tanks is severely restricted in order to pass the outflow standard and needs to be considered from the outset of the design process. The calculation effectively achieves protection by driving the designer to position tanks in areas where probability of damage is low, and where outflow resulting from damage will be minimal. From the authors experience it has been found generally that to achieve a suitable outflow score tanks need to be positioned in the bottom away from the shell sides. Tanks may also need to be deeper than is current normal practice, in some cases extending up to the deck above the inner bottom.

The main two factors that influence the impact on vessel design is the overall fuel capacity and longitudinal tank distribution (fuel LCG). As the requirements for either become more extreme, flexibility in the arrangement is quickly lost. Where this is the case, tank top heights will generally increase impacting internal accommodation volume and the deck arrangement of the vessel.

Other points to note are that impact on vessel lightship and deadweight VCG is less significant than with protected fuel tanks. The outflow result can also be improved by subdividing or making fuel tanks smaller. This will drive up the number of tanks resulting in a more complex, heavier fuel transfer, bunkering and supply systems.

4.3. COMPARISON STUDY

A study was carried out that looked at these two methods and investigated the requirements and the impact of each method when applied to large yacht design. The impact was assessed and quantified for two concept designs by looking at the effect on various design parameters. These where the number of bunker tanks (an indication of complexity), fuel LCG (ability to control design trim and LCB), fuel VCG (impact on deadweight VCG) and the lower deck height (to indicate impact on deck arrangement and lightship VCG). The lower deck is the deck above the tank deck.

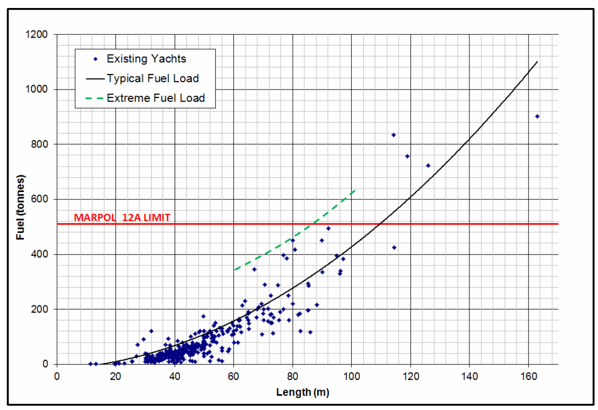

Figure 4-2: Regulation Threshold Length

An initial assessment of existing yachts was made to identify what size yacht the 600m^3 fuel threshold is reached. This showed that 110m was the typical size, and in extreme cases as small as 85m. See Figure 4-2. These two sizes of yacht where used as the subject of the quantitative study, each with a design fuel load of 600 m^3. The results for the parameters investigated are shown in Table 4-1. From the results of the study it can be seen that in general the number of bunker tanks, the fuel VCG and the lower deck height are less for the oil outflow method. It can be seen that for the typical threshold yacht (110m) the impact on these three parameters is minimal. However, there was a significant restriction on fuel LCG. It was found that a suitable fuel LCG of 43.5%LWL could be achieved, but any further forward and an increase in tank top height would be required. A pre-12A arrangement could achieve a fuel LCG 6% further forward with no need to increase tank top height. The ability to adjust fuel LCG is useful during the design process to achieve suitable trim and LCB. The loss of flexibility needs to be considered from the outset of a design. It can be seen that the protected tanks method can achieve more flexibility in fuel LCG (about 2%), but the designer has to balance the benefit of this with the increased impact on build complexity, stability and internal arrangement. A further point to note is that the required bottom clearance for protected tanks is calculated from beam. Therefore as vessels get larger the protected fuel tanks method will impact more on the internal volume and arrangement of the ship.

85m Motor Yacht	Pre-Reg. 12A Unrestricted Tanks	Reg. 12A Protected Tanks	Reg. 12A Oil Outflow
No. of Bunker Tanks	12	13	10
Fuel LCG (%LWL)	43.5	43.5	41.9
Fuel VCG/Reduction GM (m)	1.81	2.22 / 0.08	1.95 / 0.03
Lower Deck Height (m)	4.70	5.10	5.10

110m Motor Yacht	Pre-Reg. 12A Unrestricted Tanks	Reg. 12A Protected Tanks	Reg. 12A Oil Outflow
No. of Bunker Tanks	10	12	10
Fuel LCG (%LWL)	49.4	45.3	43.5
Fuel VCG/Reduction GM (m)	1.48	2.55 / 0.09	1.49 / 0.00
Lower Deck Height (m)	4.70	5.20	4.70

Table 4-1: Study Results

The results considered in this paper are for two specific vessels. They have been presented to illustrate some of the issues that must be considered, but it should be noted that every yacht is different with their own design priorities. What can be said with certainty is that Regulation 12A is a dominant factor that must be considered at an early stage.

5. BALLAST WATER CONVENTION

The International Convention for the Control and Management of Ships' Ballast Water and Sediments (BWM) has been developed to control the transfer of harmful and invasive aquatic organisms and pathogens through ships' ballast water and sediments. This has become a significant problem due to the expanded trade and traffic volume over the last few decades. The effects in many areas of the world have been devastating. Data shows that the rate of bio-invasions is continuing to increase at an alarming rate. Effects such as invasive fouling and extinction of local fish stocks have been reported. The convention was adopted by the IMO in Feb 2004 but has not yet entered into force. The BWM will enter into force 12 months after it has been ratified by not less than thirty States, constituting not less than thirty five per cent of the gross tonnage of the world's merchant shipping fleet.

All yachts with seawater ballast will have to comply with Regulation D-2 of the convention by 2016. Some flags may implement the Regulation on new yachts (constructed in or after 2009) before that date. Regulation D-2 is the Ballast Water Performance Standard which states the required water quality that must be achieved for any ballast water that is being discharged. An acceptable water quality is defined by achieving maximum numbers of various micro-organisms per volume of water. To meet this standard, ballast water will need to be treated.

A review into the types and availability of systems suitable for yachts was undertaken. In general treatment units available use a two stage process which first filters the water and then sterilises it. The methods of sterilisation vary between manufacturers, examples being UV light, electrolysis, additives, and oxidation. With the aid of a technology review carried out by Lloyds' Register [3] it was found that the availability of suitably sized units for yachts was seriously restricted at this time. Most systems have been developed for large commercial vessels. From the research carried out, only one approved system was found that offered a low enough capacity to be suitable on a yacht. An assessment was carried out to ascertain the impact of installing such a system by looking at the size, weight and required power demand. For a 90m yacht the system would need a footprint area of approximately 3m^2, weigh 1.5t (wet) and use 15 kW of power. Apart from the additional space requirements in what are usually already very tight machinery spaces, it was concluded that the impact of installing the system on a large yacht would be relatively small.

As a result of the review it was concluded that there is a lack of availability of suitably sized, approved systems for a yacht application. Considering the current status, the most sensible course of action at this stage would be to reserve space in current yacht designs for a ballast water treatment unit but not install it. Once the convention is ratified, it is likely there will be more choice of products for large yachts thus allowing the most suitable system to be installed.

6. MARPOL EXHAUST EMISSIONS

Regulations governing the prevention of air pollution from ships are dealt with in Annex VI of MARPOL. The main pollutants relevant to yachts are those emitted from engine exhausts such as nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM). These cause harm to the environment as well as human health.

IMO Resolution MEPC 176 (58) contains amendments to Annex VI which will see higher emission standards coming into force. These are the addition of tier II and tier III nitrogen oxide limits, more onerous sulphur content limits on fuel oil and the establishment of Emission Control Areas (ECA).

An ECA is an IMO approved geographical area where there is a need or requirement to reduce the level of emissions from ships. More stringent emission limits for NOx, SOx or both will be applied in these areas. An ECA is a progression from the Sulphur ECA (SECA) which was used in previously enforced regulations. SECAs are already established for the Baltic Sea and the North Sea including the English Channel. These areas are subject to SOx requirements only and will only become subject to NOx requirements if re-designated by the IMO. A new ECA (subject to NOx and SOx) has however been recently adopted. This will come into effect in 2011 and covers all areas within 200 miles of the US and Canadian coastline. It is possible that other areas such as the Mediterranean could also become ECAs. As yachts spend the majority of their time near to the coast it is likely that the more stringent regulations required in the ECAs will have a significant effect on yachts.

Regulation 14 of Annex VI deals specifically with the sulphur content of fuel oil used onboard ships. The maximum limits allowed are to be reduced over time. Globally the intention is to reduce the fuel sulphur limit to 0.5% by 2020. In ECAs and SECAs the intention is to reduce the sulphur limit to 0.1% by 2015. The sulphur requirements will not have any significant impact on yachts as it is generally the case that large yacht engines are high speed diesel types which use marine gas oil (MGO). MGO is a high quality diesel grade which has low sulphur content. As a result of preceding EU and US sulphur regulations on automotive fuels, MGO with a sulphur content below the MARPOL 0.1% limit is becoming more widely available. Use of this fuel will negate the need for 'add on' sulphur treatment systems for yacht exhausts.

Regulation 13 of Annex VI is concerned with NOx emissions from marine diesels with a power output greater than 130kW. The regulation limits the weight of NO_2 that can be emitted per kW hour of engine operation. The gram/kWhr limits specified are a function of engine RPM. There are three different limits (tiers) which will be introduced with varying time frames. Figure 6-1 shows the requirements for the three NOx tiers. Table 6-1 shows how the three NOx tiers will be implemented, and to which engines they will apply. It can be seen that the tier III requirements only apply to vessels built after the 1st Jan 2016 whilst operating inside an ECA.

In light of the new regulation, engine manufacturers have been carrying out development programs in order to optimise the combustion process and improve engine emissions sufficiently to meet the tier I and tier II NOx requirements. Some suppliers to the yacht market are already offering tier II compliant engine models. As a result, tier II compliance can be achieved simply through appropriate engine selection. However, at present, tier III requirements are beyond the capabilities of 'on engine' technology. There are several 'add on' technologies being developed that may in the future offer a viable treatment method for reducing NOx emissions to meet tier III requirements. These include exhaust gas recirculation and water emulsification technologies. However, currently there is only one that is technically proven to reduce NOx sufficiently to tier III requirements. This is Selective Catalytic Reduction (SCR).

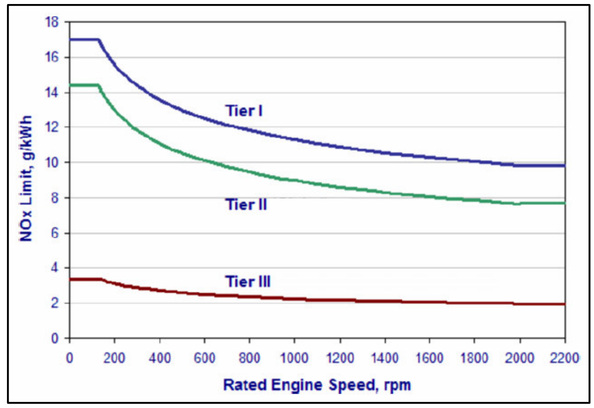

Figure 6-1: Tier I, II & III NOx Emission Limits

Engine Installation	Outside ECA	Inside ECA
Engine installed on a ship constructed before 1st Jan 1990	-	-
Engine installed on a ship constructed Jan 1990 - Jan 2000 which is smaller than 5000 kW or 90 litres per cylinder	-	-
Engine installed on a ship constructed Jan 1990 - Jan 2000 which is larger than 5000 kW and 90 litres per cylinder	Tier I	Tier I
Engine installed on a ship constructed 1st Jan 2000 - 1st Jan 2011	Tier I	Tier I
Engine installed on a ship constructed after 1st Jan 2011	Tier II	Tier II
Engine installed on a ship constructed after 1st Jan 2016	Tier II	Tier III

Table 6-1: Implementation of NOx Emission Limits

SCR is a treatment technology where urea or ammonia is sprayed into the hot exhaust gas before flowing through a catalyst. This causes a reaction which causes the NOx gases and the reactant to breakdown into harmless nitrogen and water. The reaction is relatively sensitive to temperature but can achieve good results; it is claimed up to 98% reduction in some cases. This technology is currently in service, and has been shown to be effective on ships and some yachts. The SCR system can be combined with a soot and particle filter which reduces soiling and odour on deck. At present this type of system seems the most appropriate for future yacht applications. The number of manufacturers able to supply the yacht industry is currently very low.

A SCR system proposal was developed with a manufacturer for a 100m concept yacht with 4 x 2900kW propulsion engines in order to assess the impact of installing such a system. The reactor/filter unit, fitted in each exhaust line, is the central system component. The units are positioned in a similar fashion to a silencer. Each unit is of significant size (2m x 1.7m x 1.9m) and weighs 1.5 tonnes. This could increase engine room or casings sizes impacting on accommodation space. The unit does provide some noise attenuation (15 – 25 dB) but not enough to meet high yacht standards. Silencers are still required which will add to the arrangement complexity. The urea reactant for the system has to be stored in a tank onboard. The urea is injected via a supply pump and dosing unit. These items and the associated additional piping will add to engine room space requirements and weight. Urea consumption rates are reported to be between 3% - 7% of fuel consumption by volume. It should be noted that the de-NOx process only needs to be running when a vessel is inside an ECA. Generators will also require exhaust treatment when running in an ECA. A 100m yacht with a fuel capacity of 500 tonnes spending a large proportion of time in an ECA would require a urea capacity of 32 tonnes. This is a significant increase in the deadweight of a yacht. A look at current urea prices shows that it is available for GBP 0.28 /litre. This is fairly inexpensive and will not increase running costs of a yacht significantly.

In conclusion, the installation of an SCR system on a large yacht will have a significant impact in two main areas; space and weight. The size of the units and its ancillary equipment will compound the problem of tight engine room arrangements already found on yachts. It is likely that accommodation space will be lost to compensate. An approximate design displacement increase for such a system on a 100m yacht will be in the order of 45 tonnes (well over 1% of displacement for a 100m).

It should be remembered that the implementation date for tier III is still 5 years off. This will allow further development of current products which may see the impact on large yachts reduce. It should be noted that the automotive industry is well advanced in SCR development indicating that the potential emergence of new technologies is less likely. A close eye should also be kept on the NOx tier III review in 2012-13 which will verify the final implementation schedule for the tier III requirements after considering the available technology.

7. SAFE RETURN TO PORT

Safe Return to Port (SRtP) is a set of amendments incorporated into SOLAS that entered into force in July 2010. They were developed following concerns over the ability to safely evacuate passengers (including elderly and injured) to lifeboats and rescue craft on ships with high passenger densities. The SRtP amendments aim to improve survivability of passenger ships so that, in the event of a casualty, people can stay safely on board as the ship proceeds to port. SRtP applies to all passenger ships that have a length (deepest subdivision load line) greater than 120m, or three or more Main Vertical Zones (MVZs). For a yacht the transition between two and three MVZs will generally occur in vessels with a waterline length no greater the 104m.

Considering that large yachts have low passenger densities and generally operate near to shore, the SRtP requirements seem overly onerous. It has been indicated by industry policy makers that SRtP will not be applied to passenger ships carrying 36 passengers or less.

8. CONCLUSIONS & THE FUTURE

All of the regulations considered in this paper will have some impact on the design of large yachts. Perhaps the most conspicuous is the MLC, the unknown future outcome of negotiations and the potential impact it could have on yachts between 200 – 1150 GT. The new emissions and ballast regulations demonstrate how increasing environmental responsibility is leading to more and more equipment being squeezed onto vessels, inevitably adding weight and altering the balance of accommodation space and machinery space on yachts. The increased protection of fuel tanks will result in more loss of accommodation space and reduced flexibility of design. In an effort to improve safety, the new SOLAS probabilistic stability also adds complexity to the design process. The challenge facing yacht design teams has certainly increased.

It should be noted that each of the six regulations studied have been considered in isolation. In reality MARPOL Regulation 12A will have some influence over probabilistic stability performance and vice versa. Also the combined effect of the BWM Convention and the MARPOL emissions requirements will have a compounding influence on engine room size. The aim of this paper has been to demonstrate the likely impact of these new regulations. It is not until industry responds and subsequent future designs emerge that the true impact will be known.

The large yacht industry is currently in the consultation process for the Passenger Yacht Code (PYC). This is being developed by members of the Red Ensign Group and in a similar vein to LY2, will provide a code for yachts carrying between 13 – 36 passengers on international voyages. It is hoped the code will take into account that some aspects of the SOLAS and Load Line regulatory framework are impractical in the context of yachts of this type considering their operating profiles and layouts compared to commercial passenger ships. This would allow designers to have more freedom in certain areas than is currently the case and remove previous ambiguities from interpretation for yachts. However, looking at a draft version published, it is not believed that any of the regulations discussed in this paper will be subject to any equivalences or concessions in the code except for SRtP. The code is due to be presented to the IMO in November 2010.

9. REFERENCES

[1] ‘Application of the MLC 2006 – United Kingdom Policy’, MCA, http://www.mcga.gov.uk/c4mca/...2006/mcga.ds-ssh-mlc-definitions

[2] A. Papanikolaou & E. Eliopoulou, ‘Impact of New Damage Stability Regulations on Ship Design’ Proc. 2nd Int. Maritime Conference on Design for Safety, Sakai-Osaka, October 2004.

[3] ‘Ballast Water Treatment Technology – Current Status’, Lloyds’ Register, February 2010.

10. AUTHORS’ BIOGRAPHIES

Alex Meredith Hardy is a Naval Architect at BMT Nigel Gee. He has worked on a wide range of projects including commercial and military vessels. More recently he has focussed on large yachts as an active member of the design team for several yacht projects.

Sylvain Julien is a Naval Architect at BMT Nigel Gee. He is involved in a wide range of naval architectural duties from the concept design stages through to the detail design stages, including hull lines development, stability calculations, performance predictions, and model testing.

James Roy is the Yacht Design Director at BMT Nigel Gee Ltd. He is responsible for development of the companies’ yacht design activities and managing conceptual and preliminary design work as well as consultancy services.