Royal Institution of Naval Architects

1860 - 2010

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FOREWORD

By
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Chief Executive Officer

"to promote and facilitate the exchange of technical and scientific information…thereby to improve the design of ships"

I have often wondered how the founding fathers of the Institution would view the changes which have occurred to the Institution since 1860. Would John Scott Russell, Edward Reed, Nathaniel Barnaby and the others who formed the Institution of Naval Architects recognise the Institution they founded, and would they approve of the changes?

When the Institution was founded, its mission statement – if the founding fathers would have recognised the term – was "to promote and facilitate the exchange and discussion of scientific and technical developments….. and thereby to improve the design of ships". In 1860, that was achieved mainly through the publication of papers in the Institution's Transactions. That mission statement remains equally valid today, when it is achieved through the Institution's publications and conferences. Since 1860, the Institution has published over 6000 papers, either in the Transactions or conference proceedings. These papers are in themselves a history of ship design and construction, and have exerted considerable influence on their development. For example, few papers can have had such a significant impact on ship design than William Froude's paper "The Rolling of Ships", published in 1861.

The Institution was formed in London, at a time when Britain was at the epi-centre of world shipbuilding. Today, reflecting the global shift in maritime activity, the Institution is a truly international organisation, with members in over 90 countries. This internationalism is reflected in both the membership and the activities of the Institution, with the majority of members from outside the UK – a number that continues to grow every year as the Institution extends its international profile. The first conference was held in London, in 1860. In 2010, the Institution organised conferences in the UK, Italy, Belgium, Greece, India, Singapore, Korea, China and Australia. In 2010, the Institution's journals were distributed in over 100 countries and even printed in the Chinese language – I am sure that would come as a surprise to the founding fathers!

For many members, the opportunity to meet with other maritime professionals at local Branch meetings represents one of the greatest benefits of membership. Over the past 150 years, the number of branches, some joint with other organisations, has increased, with 22 Branches now in 16 countries.

In 1860, there were no student members. Today, the Institution has links through the membership of staff and students with over 60 universities worldwide. I am sure the founding fathers would applaud the Institution's priority of engaging with those about to enter or newly entered into the maritime industry. Recognising achievement is an important part in that engagement, and today the Institution presents Student Naval Architect Awards in 39 universities, many sponsored by local companies.

In 1860, the Institution sought to influence such issues as ship design, maritime safety and the protection of the maritime environment from its base in the UK – although the environment was not perhaps such a priority in 1860 as it is in 2010. Its aim of "improving ship design" was perhaps made easier by the UK's dominant position in shipbuilding. Today, the Institution still seeks to influence such issues, but on a global scale. It does this through its international membership, through its agreements of co-operation with many national professional societies and through its close links with its Corporate Partner members in industry. The Institution contributes its collective expertise in such forums as the International Maritime Organisation, of which it is a Non Governmental Organisation member, the International Standards Organisation and the Confederation of European Maritime Technology Societies.

The history of the Institution over the last 150 years is reflected in the development of the design and construction of marine vessels and structures, and indeed the maritime industry as a whole. In this Commemorative Book, members give their personal views on that development, to which I believe the Institution can rightly and proudly claim to have made a significant contribution, both collectively as an international organisation and individually through the work of its members. Would John Scott Russell, Edward Reed, Nathaniel Barnaby and the others who formed the Institution of Naval Architects in 1860 be proud of their legacy in 2010? I believe they would.

The Society for the Improvement of Naval Architecture

By
Eur Ing David K Brown MEng CEng FRINA RCNC

The late David K Brown tells the story of the foundation in 1791 of The Society for the Improvement of Naval Architecture, the ancestor of the Royal Institution of Naval Architects.

Towards the end of the 18th century, a bookseller named Sewell, who often visited naval ports, became convinced of the superiority of French warship design and believed that this superiority was due to their more scientific approach to naval architecture. He took two positive actions himself to remedy the problems as he perceived them; firstly, he made available the covers of a journal, *The European Magazine*, which he published, for articles on naval architecture and, secondly, on 14 April, 1791, he called a meeting at the "Crown and Anchor" inn in the Strand, London, of those interested in the "Improvement of Naval Architecture". The Society subsequently formed did not have a very long life but it was most influential. The Royal Institution of Naval Architects (RINA), The Royal Corps of Naval Constructors (RCNC) and most British schools of naval architecture trace their ancestry back to the Society.

French Influence

How did this all come about? In 1681, Jean Baptiste Colbert, Minister of Marine to Louis X1V, summoned many of the leading scientists of France to a conference in Paris where the problems of warship design were outlined to them, and their help invited in finding solutions. The Academy of Science encouraged these studies by offering prizes for the best papers submitted on naval architecture.

By the end of the 17th century papers had been published on the theory of sails, manoeuvring and other techniques. In 1697 Paul Hoste, Professor of Mathematics at the Royal Seminary at Toulon, wrote that "unless the fundamentals of naval construction were fully understood, design would continue to be a process of trial and error".

During the 18th century many books were published in France and elsewhere on naval architecture. The most famous is Bouguer's *Traite du Navire* (1746) but there were other important works from Euler, Don Juan and Chapman. The state of naval architecture at the end of the century was summarised in Chapman's works. Many of these books and papers were translated and published in England, usually quite quickly.

The only British contribution to theory, but a most valuable one, was that by George Attwood on the stability of ships at large angles of heel, presented in two papers to the Royal Society in 1796 and 1798, though it would be some 75 years before Barnes reduced his work to usable form.

Sewell and others believed that British designers were ignorant and reactionary in ignoring this work but this common verdict needs re-examination French studies on metacentric stability were valid and useful but their hydrodynamics were totally fallacious- about as relevant as the "phlogiston" theory of combustion.

There was no significant French contribution to structural design which had to wait for the British work of Snodgrass and Seppings. Captured French ships in Royal Navy (RN) services required far more refit work than British built vessels. Even the "evidence" for the superiority of French designs is dubious, to say the least, and is probably based on unrealiable accounts by both naval officers and naval architects endeavouring to enhance the reputation of their profession or themselves.

The Society

Be this as it may, the belief that British ships were inferior was generally held and a distinguished body assembled at the Crown and Anchor inn in 1791. By June, the Duke of Clarence, himself a naval officer and later King William IV, had agreed to become president of the Society, and the membership included the Earl of Stanhope (a naval innovator of note), Lord Mulgrave (First Lord), Sir Joseph Banks (president of the Royal Society), Admiral Sir Charles Middleton (a former Comptroller, later Lord Barham), Sir Charles Knowles (a hydrodynamicist) and others. Captain Sir John Warren, distinguished both for his intellect and his fighting record, was a vice president. By the next year some 270 people had paid their subscription of two guineas.

The principal object of the Society was stated to be "the improvement of naval architecture in all its branches". The Society intended to offer awards of up to £100 for work on the theory of floating bodies and their resistance to motion, to obtain plans of various ships and calculate their capacity, position of the centre of gravity, tonnage and other parameters. The Society also intended to carry out its own experimental work. Johns noted that the rules of the Society were very similar to those of this Institution and asked some of the founder members if they had been copied but they said this was not so.

The collected papers of the Society were published by Sewell in 1800 and it can be seen how well they lived up to their aim of studying all branches of the subject. The first paper was by an anonymous naval officer (possibly Warren) entitled *Remarks on Forms and Proportion*. As well as general comparisons of British and foreign ships, by no means all critical, it discussed problems of stability and described how de Romme had measured the metacentric height of the *Scipio* in 1779 by running out the guns on one side only and then moving the crew across to the low side. Finding the stability inadequate, de Romme had the ship girdled, adding a foot each side to the beam.

This unknown author then describes how he carried out three similar inclining experiments, moving 14 guns, each weighing 3 tons, through 3ft and measuring the heel. From this he was able to deduce the metacentric height.

Ship	**Displacement (tons)**	**Metacentric Height (Ft)**
Formidable	3150	3.42
Barfleur	3360	3.77
Bombay Castle	2700	4.47

He found that the *Bombay Castle* was stiff enough, perhaps even a little too much, whilst the other two needed more ballast to improve their stability. The full theory of the inclining experiment was given by Chapman, the Swedish naval architect, in the same volume.

A lengthy paper by Gabriel Snodgrass surveyor to the East India Co, who was later brought into the Admiralty as a director of shiprepair, gives his views on the strength of wooden ships, whilst Attwood's classic work was republished. There was a paper on the use of iron beam knees and a note on the trials of *Kent Ambi-Navigator*, the Earl of Stanhope's unsuccessful attempt at a steam-powered warship. More practical articles covered the curing of beef, stowage of drinking water and lifesaving, whilst Clerk's well known book on tactics was reviewed.

Beaufoy's work

The most famous work of the Society was the series of model tests on the stability and resistance of various forms carried out by Colonel Beaufoy, a member of council. Between 1793 and 1798 he completed some 1700 successful runs in Greenland Dock, London. The models were up to 42ft long, pulled by a falling weight through a run of 160ft. The results were published in 1800 and, in more detail, in 1834.

It is clear from a recent analysis by Dr Tom Wright that Beaufoy's work was accurate and that he was close to a solution of the problem of estimating resistance of full size ships, finally solved by William Froude, some 70 years later. In particular, he appreciated the importance of friction, neglected by most previous workers, using a breakdown proposed by the Earl of Stanhope:

The end of the Society and its legacy

The Society seems to have ceased to function from around 1799 but it had a lasting effect on the progress of warship design in Great Britain. In particular, Lord Barham had come to believe in the need for a better educated class of naval constructors within the Admiralty service. He had probably noticed that few, if any, Admiralty naval architects belonged to the Society.

The School of Naval Architecture

As a result of the general belief in the inferiority of British design, Lord Barham, on becoming First Lord, set up a commission 'to enquire into and revise the civil affairs of the Admiralty'. This commission produced a voluminous series of reports between 1803 and 1808 in which it expressed its concern over the low standard of education of Dockyard officers and its fears that this standard might fall even further.

As a result a School of Naval Architecture was set up in 1811 at Portsmouth, initially in the Naval Academy and later in a new building across the square. The school produced many outstanding graduates who were to dominate warship design and contribute to merchant shipbuilding in the middle of the century. Opposition by vested interests led to the decay of the school and it was closed by the reactionary First Lord, Sir James Graham, in 1832.

Before this, in 1827, Morgan, Creuze and Chatfield issued the first volume of *Papers on Naval Architecture*. For four years they edited volumes dealing with all aspects of naval architecture and ships construction and with tactics, weapons and other subjects. Translation of foreign papers and reviews of books were also included. These papers may be seen as an early form of learned society transactions.

It is, however, interesting to note that Morgan dismissed members of Sewell's Society as "amateurs". Though he admitted that a few of the papers were valuable, he dismissed others as "totally devoid of scientific knowledge" and wrongly saw Beaufoy's work as inferior to that of the Royal Academy of Paris. Though there is an element of truth in his comments, similar criticism could be levelled at his own *Papers on Naval Architecture*. There was undoubtedly considerable ill feeling between the Society and the Admiralty Constructors; this was strange, since the Admiralty School largely owed its existence to the Society.

A second School was opened in 1848 and, like the first, produced some brilliant men before it was closed by the same Sir James Graham when he returned to office. The intellectual stimulus of The Great Exhibition and the exciting developments in ships such as *Warrior*, Froude's early work on rolling and other aspects led to the formation of the Institution of Naval Architects in 1860 and to the Admiralty's Royal School of Naval Architecture and Marine Engineering at South Kensington in 1864. In 1872 a new journal, *Naval Science*, began publication but though it contained a great deal of fascinating material it ceased after four years.

It seems clear that Sewell's Society was the seed, nurtured by Lord Barham's School and the later Schools from which the Institution can claim descent.

David K Brown was a Vice President of the Institution for many years, and following his retirement from the Royal Corps of Naval Constructors in 1988 was the author of 11 historical books.

A Tribute to Early Naval Architects

By
Richard White MRINA

Maritime migrations involving some sort of navigable craft have been taking place for several tens of thousands of years. For only about the last 5000 years of this period do we know of images, surviving artefacts or documents. But the oldest material that exists shows sophisticated and complex vessels which had clearly had a long development period behind them.

The First Naval Architects

The popular view of the dawn of navigation is of enterprising cave dwellers straddling a floating log and paddling happily away. Given the propensity of logs to roll over, presumably someone then, wetter but wiser, decided to find the answers to a number of questions. How to make the craft stable enough to carry the required load of people and goods? How to make it go with the minimum of effort in the desired direction? Whoever took up the challenge was the first naval architect, and many thousands of years later we are still working on the same questions. For most of the time it has been a matter of building, evaluating and improving at a million different locations worldwide. During the past few hundred years the process has become steadily more scientific and analytical as mathematical tools have been developed to unravel the hydrodynamic and structural problems. To put the timescale into perspective using an analogy: if the distance from a person's nose to the outstretched finger tip represents the time that marine craft have been in use, scientific naval architecture corresponds to about a fingernail length, while a moment's work with nail clippers would remove all evidence of computer aided design.

Natural materials, which were all that were available until comparatively recently, impose their own discipline on the designer and builder. Anyone responsible for creating a vessel needed a very deep and specialised range of knowledge and skills within the local tradition, but this knowledge might not transfer easily to a new material or technology. Cautious progress and conservatism have generally ruled, periodically punctuated by the introduction of radically new materials that have changed the whole face of ship design.

Ships were the most complex structures built by humans until the space age. The risk to life and property has always been high in shipping, so new techniques tend to take over cautiously from old as experience builds up. For instance, early iron ships took many of their structural features from wood construction, and only gradually did designs developed from the outset to exploit the properties of iron gain acceptance. Acting in favour of progress in naval architecture is the fact that ships have a fairly short gestation period, varying from months to a few years. An individual designer or master shipwright could therefore amass personal experience of many vessels in the course of a career, hopefully advancing the state of the art with each.

Practically any material that can be used to build a vessel has been, somewhere at some time. From inflated animal skins to hollowed logs. From the radially split planks and iron rivets of the Viking era to the split bamboo in filled natural resin composite of Vietnam. From birchbark to mild steel. With each grew a tradition of how best to exploit the useful properties and avoid the weaknesses, and each method imposed a particular discipline on the naval architect. But to a considerable extent the designer has been able to decide hull shape in its general form before starting to build, while refining the detail shape during the build process. For instance an early naval architect could refine the bow or stern shape of a log canoe within wide limits. Natural competitiveness among users would then determine which variants were the best able to meet local requirements. This is the mechanism for progress in design. Most vessels operate in a competitive environment and the winners are those that give their owners the most satisfaction, whether financially or otherwise. This gives the spur to evolution. However, the speed of evolution has traditionally been a balance between the advantage of trying something new set against the risk of these departures not working out and leading to an uncompetitive or insufficiently seaworthy vessel.

For most of its history, naval architecture has been part of the '*shipwrightis art and mysterie*'. A master shipwright would build up a comprehensive knowledge of shipbuilding in a particular tradition, such as scantlings, fastenings, and rig proportions. He would also be able to craft a vessel to meet the customer's demands in terms of cargo capacity, speed and weatherliness. But to go beyond accepted proportions was to enter dangerous territory, since displacement was hard to predict, as was stability.

The recent reconstruction of a Greek trireme of about 2400 years ago showed how advanced ship design was then. Analysis with the benefit of modern methods indicated a very tight design envelope. For ramming attacks, speed and manoeuvrability were vital, yet oarsmen have poor power-to-weight and power-to-space ratios, limited endurance and a high requirement for water supply. Packing enough 'power plant' into a vessel within the length limits of structural strength of the wooden hull, and combining this with a sufficiently stable and low-resistance hullform, was a major achievement. Yet it was done, and the ability to transmit the knowledge was good enough to enable fleets of hundreds of these advanced warships to be built quickly. The same difficulties of power density re-occurred more than 2000 years later when steam engines were first applied to marine propulsion.

Throughout history, naval architects have had the choice of power, sail or a combination of the two. For most of the period power meant paddlers or rowers. Unfortunately, the factors that made a good vessel for this type of propulsion were diametrically opposed to those making an effective sailing ship. Slim lines for ease of propulsion against beam to stand up to a press of sail. Low freeboard and flat sheer to enable oarsmen to row effectively versus high freeboard for range of stability.

Trireme *Olympias*.

Many Ways

Until the last two centuries, naval architecture had overwhelmingly to do with wooden vessels, which can be built by many different methods. In the Mediterranean, shell construction and planks linked by mortise and tenon ruled. In the north at least three main methods evolved – clinker shell construction; heavily built flat-bottomed vessels and extensive use of long iron nails, and the later skeleton framed carvel planked tradition. The first and last of these in particular governed how abstract design methods would emerge. Shell building lends itself to changes in shape as construction progresses, using a mould or two to control the mid section and doing the rest by eye or from a recipe for plank bevels. Skeleton building lent itself to larger vessels, and the need to predetermine the shape of at least some of the frames at an early stage opened for a more scientific approach. One way was to carve half models, which could then be discussed by the interested parties and modified until the shape was approved, then cut up to discover in miniature the shape of frames at intervals along the vessel. China went its own way. A characteristic from an early period was the use of structural bulkheads, typically about 12, with planking secured to these by ingenious hooked nailing plates, and iron nails locking the planks against movement relative to each other. Quite how large a ship this construction tolerated is hotly debated, but there is some evidence that it was bigger than western techniques allowed on the grounds of longitudinal strength.

By the 15th century there was a growing interest in why ships behaved as they did. In parallel there was a desire to write down recipes for the scantlings and rigging that would lead to a dependable vessel, and to reproduce hull lines on paper. Matthew Baker's treatise was an example of this. Scaling from drawings involved taking off measurements, the start of the digitising process in ship design.

As a heavy armament of guns became general in naval warfare, limitations in naval architectural knowledge became all too visible. We have two splendid ship survivals, both retrieved from the sea bed – *Mary Rose* and *Vasa*. *Mary Rose* seems to have been a good ship spoilt by greed for armament at a 'mid-life refit'. *Vasa* had insufficient stability from the outset. The inability to pre-calculate displacement or stability continued to lead to bad vessels. It was not a matter of shipwrights' ignorance, but lack of knowledge at all levels, as a case in the early 1600s shows. The vessel '*stooped so much that she laid the upper edge of the ports of her lower tier in the water*'. The master shipwright had made a good job of construction, but '*she only wants two or three foot of breadth, which he sayeth is non of his fault, for the dimensions were delivered to him, and he gave her twenty inches more than he had order for*'.

From Art To Science

Scientific methods became more established in course of the 17th century, and attempts were made to understanding the physics of a ship moving through the water. In England, active royal interest in yachts and warships and in bodies such as the Royal Society gave naval architecture respectability. Sir William Petty was an example. Although primarily an economist, he became fascinated by catamarans, or 'double bottoms' as they were known, carrying out towing trials with hullforms and building a succession of ever larger vessels. His test tank work showed Petty that the stern was as important as the bow shape in minimising resistance, and he was ahead of his time in his power predictions.

'*If you accelerate the progression of the said body to a double swiftness then you must quadruple the potentia. If you would have the swiftness trebled add nine times the first potentia*.'

At least as far back as Leonardo da Vinci, people have been towing ship models in the hope of finding forms of least resistance. Some of the experimenters reached commendable levels of accuracy in getting repeatable data. But this data had a poor correlation with full size. Partly it was because sailing vessels in real life proceed at an angle of heel and make leeway, mainly because until Froude the scaling factor for speed for equivalent wavemaking was not understood.

Although there were some forward thinkers, shipbuilding continued to be a craft. The towering figure at the end of the 18th century and beginning of the 19th was Frederick af Chapman, Swedish born of English parents, who devoted his life to improvements to ships and their equipment, rising to be head of the Swedish corps of naval constructors. Chapman combined a sound knowledge of construction methods and scantlings with mathematical ability. Early in his career he studied under Professor Simpson, and became an enthusiastic promoter of Simpson's rule for calculating displacement volumes. He also understood the significance of metacentres in ship stability and ability to stand up to sail, and tried to establish methods for finding the position of a ship's centre of gravity. Incidentally, he designed buttons for the uniform of the Swedish constructor corps bearing a motif of a mathematical integral for calculating metacentre, changed to an anchor by his successors. His papers, and book *Architectura Navalis Mercatoria*, achieved international recognition, and formed the basis for teaching naval architecture. But the nature of ship resistance evaded even him. He tow tested small ship models and got repeatable results, but the world had to wait many years before Froude made the distinction between the frictional and the wavemaking components of resistance. Chapman himself considered that scientific ship design owed a great debt to Bouguer and Euler. Scornful of the rather 'suck it and see' design methods still practiced by the traditional master shipwrights, he noted the fallacy of expecting that building a bigger version of a known good vessel would produce an equally good larger ship. Also, trying to eradicate faults from one design might induce even bigger failings in a different direction in the new one, because of an underlying lack of understanding.

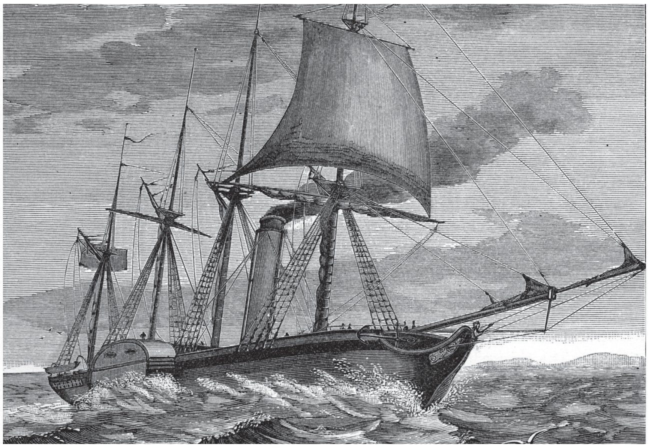
In Britain, the move towards a more scientific approach to ship design was taking place, with the foundation in 1791 of the Society for Improvement of Naval Architecture as one example of this. It put up prizes for specific improvements, including the better determination of the laws of resistance of fluids particularly when applied to curved surfaces; better methods of calculating tonnage; the best way to design full-bodied ships that would be more weatherly under sail. Also for other aspects of design from firefighting to prevention of sinking and the proportioning of masts and yards.

Yet design does not live in an ideal world. Artificial constraints have produced many dubious vessels. Tonnage rules, for example, usually start off reflecting good practice, but by the time commercial pressures have encouraged designers to seek to exploit every loophole and competitive advantage, the resulting ships may be far from optimum in terms of seaworthiness.

The coming of iron and steam power

The coming of iron for ship construction, and steam power, changed the face of naval architecture. The former constraints on length disappeared. Mechanical propulsion allowed vessels to proceed in a straight line and upright, so powering calculations became feasible. Paddle wheels and screw propellers imposed their own demands on hull form. The traditional shipwright slowly gave way to the scientific naval architect, who in turn had to dance to the tune of the marine engineer and the rhythm of the classification societies.

The three vessels associated with I K Brunel and his various collaborators serve to lead us into the modern era of naval architecture. *Great Western* combined the best in side lever paddle engines with a wooden hull at the limits of traditional timber construction, in a ship that was both successful and long-lived. While early side wheel paddle steamers had their paddles well forward and clung to the 'cod's head and mackerel tail' form of the traditional sailing ship, experience showed that another approach was needed. The hull lines of *Great Western* are essentially those of a clipper ship, years before that type fully emerged. *Great Britain*, whose design changed from paddle to the newly developed screw at the design stage, seems to have been given its antiquated hull mid section because of the available building dock and the requirement to get this wide beam ship through the



Great Western

Bristol lock. The iron hull, however, was of a sound design structurally, showing great confidence in handling this material. Ewan Corlett's analysis in connection with saving the ship for long-term preservation showed that Brunel's powering predictions were quite accurate, and his propeller design efficient.

Great Eastern, the last of the trio, is also associated with Scott Russell, a naval architect who developed the wave line approach to hull lines with some success, who more importantly introduced many of the techniques for longitudinal framing of metal ships, and who not least was a founder and enthusiastic member of the Institution of Naval Architects, now RINA. *Great Eastern* was not a commercial success; too large for the imagination and resources of its owners, but it was a technical tour de force. The largest vessel in the world for many years, it used a complete double-hull built from a strictly standardised and limited range of thicknesses of iron plate, angle irons and rivets. Behind its size was Brunel's recognition that a vessel's carrying capacity grew faster with size than the power needed to propel it at a given speed, a proposition that was deeply doubted in some quarters.

The Future?

It would be gratifying to be able to chart continuous progress to the present day, but it seems that old lessons have to be relearnt again and again. Although naval architects now have the knowledge and the tools to predict both intact and damage stability, structural strength, there are still disasters from time to time. Some are due to the way the vessel is operated, or lack of margins for bad maintenance, or mismatch between the way the designer thought the vessel would be used and the actual operation later in life. Water on ferry vehicle decks; container vessels rolling over because the actual centre of gravity of the cargo is not known, bulk carriers sinking, risky adventures in ice, to cite but a few examples.

Looking back over the millennia, clearly great progress has been made in the last century. But even so, it is questionable if today's naval architects would do much better than their predecessors if transported back in time and given the same list of requirements and the same constraints. Ship design has always demanded competence.

Richard White is a naval architect and journalist.

A Brief Sketch of William Froude's Life and Contribution

By
D. K. Brown FRINA and R. Eatock Taylor FRINA

The Proverbs tell us that there are some things too wonderful to know, one of which is the way of a ship in the midst of the sea. This sketch concerns a man who contributed much to the understanding of this mystery. It aims to explore briefly the way in which Froude worked, rather than present just a biography. The unusually full documentation of Froude's way of working enables us to understand a little of the way his brain operated.

The Early Years

William Froude was born in 1810 and was brought up in an intellectual home, Dartington Parsonage. He was an undergraduate at Oriel College, Oxford, where he seems to have had a number of fringe interests, including chemistry experiments: a contemporary noted that you could always pick out his room in College because of the sulphuric acid stains down the wall outside his window. It seems that he ran a model railway in his room. He also worked on modifying a small yacht for sailing at sea, and it is likely that his skill with tools developed at this time. He graduated with a 1st in maths and a 3rd in classics, and in 1833 he went to work on the South Eastern railway under H. R. Palmer, a distinguished railway engineer of the period. Palmer had in 1824 carried out experiments on canal barges and Froude may have picked up some ideas on model testing from him.

William Froude

In 1837 Froude became an assistant to Isambard Kingdom Brunel on the Bristol – Exeter railway line. He devised a new system of brickwork for skew bridges, and also developed the widely used idea of using cant of the track for gentle entry to a curve. Remarkably, in 1846 he retired (aged 36). Of his several activities around this time, his work as a judge of agricultural machinery at the Bath and West Show was highly significant in relation to his future achievements, as here his passion for measurement came to the fore. He made dynamometers to measure mechanical efficiency and this was combined with a very strong hatred for poor design. One machine was condemned as "unprincipled in not matching thickness to stress", which he described as professional immorality.

In 1850 Froude carried out tests in Lake Bassenthwaite with a 3ft clockwork model, helped by Thomas Spedding. This laid the foundations for his later work on hull-propeller interaction. Together with his work on the Torquay water main this led him to think about the friction of water on solid surfaces. He made the important discovery that, contrary to his earlier belief, friction in water varies with speed at a rate less than the square.

Ship Rolling

In 1856 Brunel was deeply involved with the *Great Eastern* and hired Froude to work on both the launching arrangements and on the roll of the ship, working with William Bell. This project was the first occasion on which the vertical centre of gravity and the weight of the ship had been calculated a priori. Subsequently Barnaby, a senior naval architect and later Director of Naval Construction, said that this calculation was virtually impossible, as it was so lengthy and tedious. Froude responded that Bell and he had done it for the *Great Eastern* and if one can do it for the world's biggest ship one can do it for any other.

Between 1863 and 1867 Froude and his friends designed and built a large house at Chelston Cross on the outskirts of Torquay. But not only was the new house a splendid home, it was also a major research facility. The basement was the heavy workshop, and there was a small model tank for rolling work. In a paper he read in 1861 to the INA, he described his first experiments with a 4 inch diameter float carrying a tiny pendulum. He discovered that in waves the apparent vertical indicated by the pendulum was at right angles to the wave surface, and not a true vertical. He went on to show that reducing the stability of the tiny float reduced rolling. These two vital discoveries due to observation were worked up into an elegant mathematical theory, with the help of Bell.

The main conclusions were:

- All ships with the same natural period of roll will move in the same way in an identical seaway.
- The worst roll occurs when the natural period of the ship equals that at which the waves are encountered.
- Ships with the longest period, that is having least stability, will roll the least.

The Admiralty's Chief Constructor, Sir Edward Reed, was supportive of Froude's findings on ship roll. But Froude was well aware of the difficulties in using his work, and over the next decade read several more papers mainly directed to empirical solutions. These brought a nice tribute from Scott Russell: "each time we come together, something which was almost impossible last time has been done; [that] we live, in short, in a time when the impossibilities of yesterday become the achievements of today". Froude and Scott Russell were not friends but they generally were polite, at least in public (but see below).

Froude on the scientific method

Following tests in 1871 on two models of the new battleship *Devastation* at different scales, Froude noted that resistance to rolling varied as angular velocity rather than velocity squared. Later tests involved forced rolling of the *Devastation* by 400 men running across the deck. Froude realised that rolling resistance involved something other than just friction. He said: "On travelling again and again over the whole question, the idea suddenly suggested itself that the waves created by the oscillation had been left out of account." He remembered as a boy standing up in a small boat and rocking it to make waves. This short passage illustrates Froude's frequently used aphorism: "It is our sacred duty to doubt each and every proposition put to us – including our own." In a letter of June 1853 he had written: "Science progresses only by following clues: it is only when, in such a pursuit, our stock of acknowledged principles fails to account for some unmistakably residuary phenomenon, that experimentalists venture cautiously to think that they have really got hold of what may turn out to be a new and unacknowledged principle".

Propulsion

In the mid 19th century the estimation of the power needed to drive a ship was seen as very important, and discussion was frequent and often heated. Between 1838 and 1870 the British Association (BA) set up eight committees to consider this problem and the linked topic of the "optimum" form. Leading scientists and engineers contributed to the work. All were agreed that model testing was misleading and should not be considered.

HMS *Devastation*, used for Froude's rolling trials © National Maritime Museum, Greenwich.

In the early 1860s Froude had begun to think of the design of a new yacht. His first model (which later became known as the *Raven*) had fine ends, influenced by Scott-Russell's waveline theory. A little later he tried another form with very bluff ends, the *Swan*. The initial results seem to have surprised him – *Raven* was superior at low speeds, *Swan* at higher speeds. In other words an single ideal form as suggested by Newton and followed by mathematicians in France was an illusion. Froude's results also demolished the BA attempt to find a single ideal form by full-scale trials. This seems so obvious now that its contemporary significance is forgotten.

He then built additional models of *Swan* and *Raven* of 3ft and 12ft length c.f. the original 6ft. He showed that these scaled as he had suggested in 1863: if the speeds are in the ratio of the square root of length then resistance per ton of displacement is the same. Froude established that much of the resistance of a ship is due to wavemaking, and he showed that this could be reduced by controlling the interference between the bow and stern wave systems.

The Torquay Tank

In 1869 the BA Existing Knowledge Committee reported on ship powering, and suggested multiple testing of full size ships. Froude submitted a lengthy dissenting annex. In it, he concluded that:

"I contend that unless the reliability of small-scale experiments is emphatically disproved, it is useless to spend vast sums of money upon full-size trials, which, after all, may be misdirected, unless the ground is thoroughly cleared beforehand by an exhaustive investigation on small scale."

A paper to the INA in 1870 by Merrifield attacked the whole idea of model tests and all the speakers in the discussion of that paper were hostile to model testing. Scott Russell, who chaired the meeting, noted:

"Therefore you will have on the small scale a series of beautiful, interesting little experiments, which I am sure will afford Mr Froude

infinite pleasure in making them, as they did to me, and will afford you infinite pleasure in the hearing of them; but which are quite remote from any practical results upon the large scale."

Froude, however, was supported by Sir Edward Reed, who asked Froude to submit a proposal to build a tank in which model testing of naval ships could be carried out.

The tank was duly built in Torquay and completed in June 1871. It was full of novel features of which the most innovative was the use of wax models which could be made in a day on a special cutting machine, and easily altered or melted down after a run. The carriage rails were specially planed at the Great Western Railway works in Swindon. Many calibration runs were carried out, mostly on models of the sloop *Greyhound*, and over the next year the resulting full-scale trials data were compared with model tests in the new tank and Froude's Law validated. This study was very different from the British Association plans to which Froude had objected. He proposed a single trial to validate the model testing method. The BA wanted a series of ship trials, in a vain hunt for the single ideal.

Friction was still a problem and a number of tests were carried out on planks up to 50ft in length, in which resistance per unit length was not changing. This led to the brilliant approximation by Froude that the frictional resistance of a ship was the same as that of a plank of the same length and wetted area moving at the same speed. He also looked at the effect of roughness.

Froude's Legacy

The Great Man approach to history has few supporters today, but it is interesting to speculate on what might have happened without William Froude's contribution to hydrodynamics. The leading scientists on the BA committee were seeking a single ideal form and were opposed to model tests of resistance. The 1870 INA meeting had been even more bitterly opposed to them. Abroad, Reech's work had been taught in France since the 1840s, but with no sign of application. Only Tiedeman in Holland was attempting to follow the correct principles, though he had very little official support. It was William Froude who made the pioneering contributions, which were taken forward by his son Edmund over the next 40 years.

The tank at Torquay was small, and in 1887 Edmund Froude built a new tank at Haslar (christened, as were many later tanks, with a flask of water from Torquay). All the vast Royal Navy fleet of WW I and most of that of WW II were tested there. The Froude approach to ship model testing was adopted widely around the world, and many tanks and tunnels were built. The facilities for Spezia and St Petersburg were designed and supervised by Edmund Froude. The great US pioneer David Taylor learnt his trade at Haslar. William Froude changed a small but important part of the world and his Law of Comparison based on Froude Number remains valid today.

This article by Professor R Eatock Taylor is a condensed version of a lecture given in Oxford University by David Brown in October 2007 (his last public presentation before his death in April 2008). The full lecture is published in the Institution's International Journal of Maritime Engineering.

On the rolling of ships

By W. Froude, ESq., Assoc. I.N.A.

(Read at the Second Session of the Institution of Naval Architects, March 1, 1861, the Rev. Canon MOSELEY, M.A., F.R.S., Vice-President I.N.A., in the Chair.)

I FEEL some diffidence in bringing before the experienced members of this society what assumes to be a tolerably complete theoretical elucidation of a difficult and intricate subject, which has hitherto been treated as if unapproachable by the methods of regular investigation.

I may, however, perhaps, bespeak some attention to it, by mentioning that it is the result of an inquiry undertaken at the request of the late Mr. Brunel, with whom I frequently discussed its fundamental principles, while he was engaged on the design and the construction of the *Great Eastern*, receiving, as no one could fail to receive who discussed such principles with him, the greatest assistance from his broad and masculine perception of their real bearings and of their mutual relations.

The most observable feature in the actual movements of a ship when rolling, and that which had always appeared to me to be specially characteristic of the dynamical laws to which it world be necessary to refer them, is the gradual accumulation of angle during several successive rolls; the cumulative action thus growing up into a maximum, and then dying out by very similar gradations, until the ship becomes for a moment steady, when a nearly similar series of excursions commences and is reproduced: while in reference to the momentary pause, or cessation of motion, it has seemed to me clear that it occurs, not because the waves themselves cease, or cease to act, but because the last oscillation has died out at a moment when the ship and the waves have come to occupy, relatively, a position of momentary equilibrium.

The best information, however, which I have been able to collect from the report of others, and from my own observation, confirms me in the belief that the very large angles of rolling which are occasionally reached are never due to single wave impulses, but are invariably the cumulative results of the operation of successive waves. And I believe, too, that the law of accumulation does, in fact, accord very closely with that which is arrived at in the following investigation.

The investigation, then, of the laws of rolling motion in ships when thus regarded, assumes the form of the inquiry, "What is the cumulative result of the continuous action of "a series on consecutive waves operating on a given ship?"

The Barnaby Dynasty
1829 - 1968

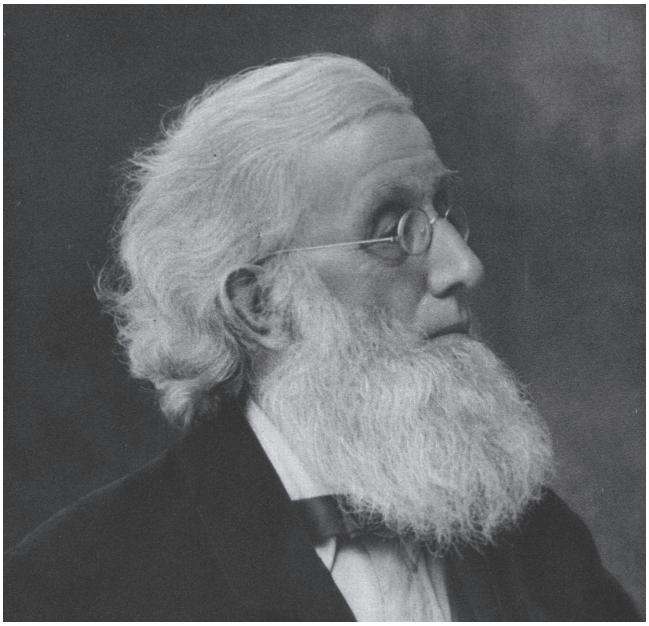
By
Fred Walker FRINA

Three generations of the Barnaby family served the profession of naval architecture on a continuous basis from the middle of the 19th century up until the 1960s. At one time, the grandfather, his son, and grandson were all members of the INA, a unique record that may remain unchallenged for years to come. The remarkable and conspicuous service of these three men is well worthy of record.

It is not uncommon for successive generations of a family to serve one industry, one dockyard or one employer, and in earlier years it was quite usual to meet families where many members shared the same trade or calling: Such traditions are less frequent within professional organisations like the Engineering Institutions.

The Royal Institution of Naval Architects is proud of the fact that for 108 years of its 150-year history, three generations of one family – all naval architects of great distinction – served the Institution continuously. For a period of close on 30 years, the family involvement was unique with a grandfather, a son and a grandson enrolled as members of the INA. As far as can be ascertained, this situation has never been repeated, and well may remain unchallenged for years to come.

Nathaniel Barnaby



It is uncertain where the Barnaby family hailed from, but it is likely to have been in the London area as Nathaniel served for some time at the Royal Naval Dockyard, Woolwich. His son Sydney also had his basic training on the Thames, serving an apprenticeship at the remarkable engineering firm of John Penn of Greenwich, before being lured to the shipyards of the south coast. The grandson, Kenneth, was brought up in Hampshire and served an apprenticeship with Thornycroft of Southampton, a company to which he devoted many years of his life. Their stories are worth recalling:

Nathaniel Barnaby 1829 -1915

Nathaniel Barnaby lived from1829 to 1915, serving the Admiralty for almost his entire career. After working at Woolwich Dockyard as a draughtsman, he joined the staff of Sir Edward Reed, and at an early age was singled out for promotion. He was associated with our Institution from the very beginning. In 1872, and while in his early 40s, Nathaniel was appointed Chief Constructor of the Navy, a position he held until 1885, and by which time it had been re-designated Director of Naval Construction (DNC) making him the first man to hold this distinguished post. During his 13 years at the helm, the Royal Navy took delivery of some interesting ships, whilst experimenting with steel, armour plating and different forms of bracketless construction, a forerunner of longitudinal framing. There was a mild flirtation with composite construction and several sloops (some later re-designated as corvettes) were built, one of which H.M.S. *Gannet* (Sheerness Dockyard 1878) has just been restored and is afloat at the Chatham Historic Dockyard, Kent. During his tenure of office, a race developed between arms manufacturers and armour plate suppliers, forcing the size of ships upwards and creating complexities with regard to weight and displacement. At a meeting in the Institution of Naval Architects, Barnaby made the classic remark " … we cannot allow foreign seamen to have guns afloat more powerful than our own, however, we might allow them to defend themselves with thicker armour". The turret battleship *Colossus* launched at Portsmouth in 1882 was arguably the Royal Navy's first steel capital ship. Nathaniel Barnaby presented a remarkable number of papers to the Institution of Naval Architects, something like 12 in the 29 years between 1863 and 1892. It is interesting to note that in his paper on Armour in 1879, his appellation is 'N Barnaby' while in the following year for the paper on The Nelson Class it had changed to 'Sir Nathaniel Barnaby'.

Sydney W Barnaby c1860 - 1925

Sydney W Barnaby grew up in an atmosphere permeated by shipbuilding and there is little wonder that he chose to serve an apprenticeship with the remarkable engineering and shipbuilding company John Penn of Greenwich. On completion of his apprenticeship, he studied engineering at Victoria University, Manchester (now part of UMIST), before joining the Pacific Steam Navigation Company and serving as a junior engineer for several voyages. Coming ashore he was recruited to the staff of John I Thornycroft & Co; here good fortune came his way in that he gained the trust of the remarkable John Thornycroft, who asked him to assist in propeller experiments at his private ship model testing facility at Bembridge, Isle of Wight. In 1885, Sydney Barnaby published one of the world's first texts on propellers, based on a series of lectures given at the Royal Naval College, Greenwich. He became an established public figure being honoured with the biennial James Watt Lecture in Greenock (1906) as well as a series of lectures at the Massachusetts Institute of Technology. In 1910, he presented a paper on Torpedo Boat Destroyers to the INA. In time, Sydney was transferred from Chiswick to Southampton and appointed naval architect, and later Technical Director at Thornycroft with the remit to contribute to the strategic thinking of the company in the early 20th century when small, fast naval ships were becoming fashionable. During the World War I, the losses of British and allied merchant ships through torpedo and mining led to his appointment as Chairman of the INA committee into the effects of mines and torpedoes. This committee made recommendations which were adopted before hostilities ceased. In 1924 and after close on 45 years service, Sydney Barnaby handed over his post as naval architect of the company to his son Kenneth. He died one year later.

Kenneth C Barnaby c1887 - 1968

Kenneth C Barnaby started his apprenticeship with John I Thornycroft in 1904 and simultaneously studied engineering at the Central Technical College, South Kensington, gaining a BSc before going to work with Augustin-Normand at Le Havre, then John Brown of Clydebank and finally Costiera of Rio de Janeiro. In 1924, he was appointed naval architect of Thornycroft in succession to his father, and commenced over 30 years service in this position. During World War II, he was responsible for the design of specialised destroyers as well as for ocean floating 'sea-dromes' to combat the U-boat threat. Sadly these were never built. Despite an impediment in speech, Kenneth Barnaby gave four papers to the INA but is remembered in the profession for the remarkable number of books and published works of which pride of place must go the 1960 Centenary History of the then newly renamed Royal Institution of Naval Architects. Here the family connections enabled him to write lucidly and clearly on every published paper as well as imparting interesting background information on the 'affairs' of the profession, in a light manner and with many flashes of good humour. He retired in 1966, accepted the post of honorary naval architect to his former employers, but sadly died within two years.

The founding of the Royal Institution of Naval Architects

On 16 January 1860, at a meeting at the Crown & Anchor Inn in London, the following persons formed themselves into a Society to be known as *"The Institution of Naval Architects"* having for its objects *"the improvement of ships and all that specially appertains to them, and the arrangement of periodical meetings for the purpose of discussing practical and scientific subjects bearing upon the design and construction of ships and their means of propulsion, and all that relates thereto":*

Sir John Aplington, GCB, DCL, of London;
The Rev'd Joseph Woolley, MA LLD FRAS, of Portsmouth;
John Scott Russell, Esquire, FRS, of Millwall;
John Penn, Esquire, of Greenwich;
Henry Chatfield, Esquire, of Deptford;
John Grantham, Esquire, of London;
Oliver Lang, Esquire, of Chatham;
James Martin, Esquire, of London;
Alexander Moore, Esquire, of Chatham;
Joseph Horatio Ritchie, Esquire, of London;
William Braham Robinson, Esquire, of Sheerness;
Philip Thornton, Esquire, of Woolwich;
George Turner, Esquire, of Woolwich;
John White, Esquire, of West Cowes;
John McGregor, Esquire, of London;
F. Kynaston Barnes, Esquire, of Portsmouth;
James Chessell Crossland, Esquire, of Portsmouth;
Edward James Reed, Esquire, of Portsmouth;
Sir Nathaniel Barnaby KCB, of London

On the 16 December 1910, by order of His Majesty King George V, the Institution of Naval Architects was granted its Royal Charter.

On the 27 January 1960, by order of Her Majesty Queen Elizabeth II, the Institution was authorised to use the name "The Royal Institution of Naval Architects".

Ship Design 1860 - 2010
From Art to Science

By
By Professor David Andrews FREng FRINA

The standard textbook on naval architecture, Rawson and Tupper's "Basic Ship Theory" states: "The raison d'etre for the naval architect is the design of ships." Yet not one of the papers in the first volume of the Institution's Transactions is on ship design, either in general or describing the design intent behind a specific new ship. Rather, papers concerned themselves with what could be called the application of science (and mathematics) to the practice of naval architecture as an engineering discipline. Over the past 150 years the practice of ship design has both changed out of all recognition and yet seems to have retained the essential element of "art."

Introduction

The development of the "art and science of ship design" is chronicled in the papers published in the Transactions. Yet it is notable that not one of the papers in the first volume 1860 Transactions is on ship design, either in general or describing the design intent behind a specific new ship. Rather, the papers concerned themselves with what could be called the application of science (and mathematics) to the practice of naval architecture as an engineering discipline. Was indeed therefore, ship design just a science and not an art?

The Nature of Ship Design

To consider the development of ship design practice over the last 150 years it is appropriate to start by summarising the particular nature of our form of engineering design. To do so one must start with the product being produced and, in this regard, ships are highly diverse. A useful division is to categorise ship types in terms of their complexity and thus, in terms of the design issues, in regard to their usage. There are other ways of categorising ships, such as differing hull configurations (e.g. monohulls/multihulls, advanced/high-speed hull forms, displacement/aero-lift/hydrodynamic lift/hybrid) or different propulsion types which, from a technical point of view, might seem more significant. However, the usage stance is considered to be more fundamental. Thus vessels, which are part of a wider transportation system, such as bulk carriers and container ships, are in this respect distinct from service vessels, be they offshore support ships, cruise ships or naval vessels, as the latter go to sea to do things, which are often unplanned and in response to unpredicted events. This often makes the design process for these vessels more complex, at least in the initial design phase.

If the nature of ships is considered further, there are many issues which most complex (ocean going) vessels have to address. They have to operate in a demanding physical environment, which varies across the extremes of cold and heat, as well as occasional violent and still unpredictable sea and wind states. Ships remain the largest manmade mobile environments. Most ship have very high endurance and even today, with reduced crews, are highly self sufficient; operating, potentially, for months away from land and support facilities. Ships are assembled using a large number of diverse technologies, from domestic systems of water, sewage and HVAC to, nowadays, the most advanced electronics. These subsystems all have to be designed into the whole system constituting the ship. Furthermore many of the subsystems are interdependent, so their efficient integration into a totality is a clear challenge. Given the complexity of the end product that the designer sets out to achieve, it is worth emphasising that the design of a complex service vessel is also challenging because of the nature of the process used to design it. Firstly, in common with most ships that have been designed, the process is in response to a specific customer's need and thus is "bespoke", like a tailor-made suit, rather than "off the peg", while the latter description can be applied to most other vehicles. In fact from both a design view and considerations of manufacturing, a complex ship is more like a large civil engineering product, such as a bridge or modern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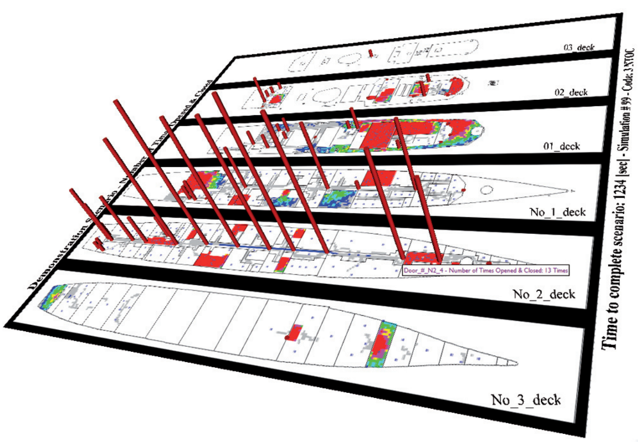
art gallery, than smaller forms of vehicles, including the most sophisticated aircraft.

This neatly brings me to the next aspect in the nature of such ship design, that of the requirement the design is trying to meet. For a complex multirole vessel, intended to operate for many years often in ways not initial perceived, this identification of the requirement is thus not just the start point of the design process but also the most difficult part of that process. Given the consequences of getting this wrong, it is also that part of the process which has the greatest impact on the end product. This challenge to "work out what is really wanted" and what can be sensibly afforded, has been typified in the architectural and urban planning professions as the "wicked problem" i.e. working out the right requirement is more difficult than the subsequent part of the process of designing the product. It can also explain why the front end of the naval ship design process, in particular, is so often highly protracted.

The next issue in this design process consideration is that the ship designer has many performance issues that need to be addressed. Clearly a lot of these will be associated with the perceived primary role of a given new vessel. However, there remain general ship performance design issues, summarised by terms such as "S5". Of these Speed (really Resistance and



A trimaran design developed by the UCL DRC, using the Design Building Block approach, to meet the requirements of the US Navy Littoral Combat Ship, showing the interactive graphical and hierarchical views of the ship design, in addition to the integrated performance analysis tools.

Propulsion issues), Stability, Strength and Seakeeping have been traditional disciplines for the naval architect and the final item of "Style" was coined (by David Brown and myself) to cover a wider range of stylistic issues, including margin policy, adaptability, survivability and a host of standards.

Art v Science

The view that ship design is both an art and a science can be seen to be consistent with the wider practice of engineering design. However, it is often the case that the term "art" is used, in our case, to denote the craft origins of, first, boatbuilding and, then, shipbuilding, in the sense of the practical art of an artisan, rather than the "more creative" approach of an artist.

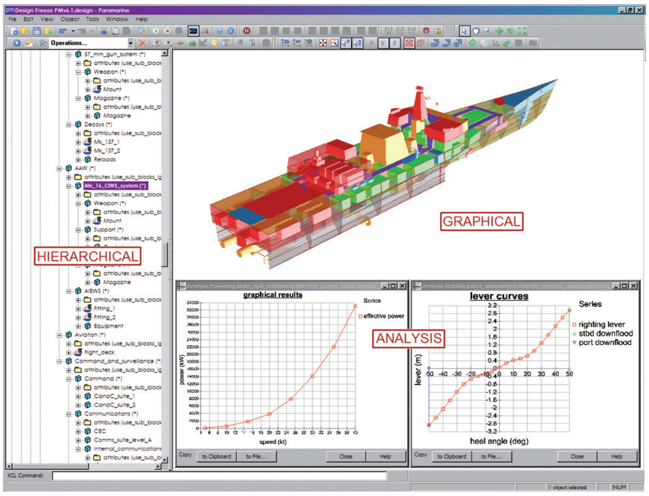
It is often believed that only the arts are "creative" with the sciences and engineering being limited by scientific rationality. Yet many scientists and, especially, mathematicians see elegant solutions as manifestations of a creative aesthetic and, indeed, engineering designers typify "a good design" as one that "looks right". So the issue in engineering is far from straight forward, with the extreme of cruise liners or mega yachts, where the aesthetics can appear to dominate the engineering design, just as it can for prestige buildings.

The issue of art and science in ship design is therefore far from obvious and it is possible to consider, both the scientific aspects, or strictly the application of the engineering sciences to ship design, and what is meant by "art" in ship design. As far as the latter is concerned it can be thought of having two meanings; aesthetics in ship design, just referred to and being a direct manifestation of the "visual form in ship design", and, perhaps more fundamentally, design synthesis, denoting the "art" of creating a new ship design.

Naval architects are seen as *the* profession most directly concerned with the design of ships. As such they may be considered to be the maritime equivalent of architects of the built environment, but there are significant differences from building architecture. This is due to naval architecture becoming one of the engineering professions, to which the early Transactions bear eloquent witness. Thus naval architects provide the equivalent of the built environment's civil/structural engineering capability, while remaining the ship design equivalent to the architect in providing the integrating design input. However, since the founding of the naval architectural profession in the 19th century it has focused its education and research on the application of the disciplines of engineering science rather than on the core skill of ship design, which was, traditionally, left to be "learnt on the job".

So to conclude with the question posed by this article's title, namely how much ship design owes to art and how much to science, it would appear that in 2010, it is more a science than the art it seems to have been in 1860. Despite our greater knowledge, I would want to assert that the "art and science" dichotomy, when applied to ship design, is really misleading. There remains a practitioner's "art" in the application of our increasingly scientific approach to ship design, at the analytical level, and there always has been more "science" in the "art" of ship design than, still, is often believed. This "science" or rational approach, even in incorporating the "pure art" of ship aesthetics into a given ship design and, more so, in our growing computer-aided capability in design synthesis, is becoming more apparent as we learn more about the human being's creative capabilities.

Thus it seems that what has been traditionally considered by most engineers to be subjective, both in (ship) aesthetics



A VRML visualisation of a representative maritime EXODUS simulation of personnel movement in a frigate during an operational scenario.

and in the "art" of design synthesis of such complex systems, is amenable to a rational "scientific" approach. Despite this, art, in the artisan sense, does remain present in the nature of design practice in the many large and small decisions the engineering designer makes, despite increasing pressure to automate much of ship design. However, the essential bespoke nature of ship design already means it is possible to use the power of the digital computer to allow the designer to have more freedom to explore design options and provide better solutions for an ever more demanding marine world. Furthermore, another facet of the art, that associated with the creative element, can now be provided as part of initial ship synthesis design by exploiting the advances in computer graphics, so science and art can, and should, be integrated together in preliminary ship design.

The Future

With the intent to foster creativity in the design synthesis of future ships, there already are developments underway, such as those to incorporate ever more sophisticated simulation tools into graphically driven preliminary ship design. This can mean that ship design can become more creative and exploratory, through a comprehensive marriage of art and science. However, in the future this will require naval architects to acquire a more creative and broader knowledge base of skills than just the traditional engineering disciplines we have relied upon. So we can be sure that the future practice of ship design will be just as demanding and exciting in its unpredictability as the last momentous 150 years.

In the150 years since the Institution was formed, the practice of ship design has both changed out of all recognition and yet, thankfully, it seems to have retained the essential element of "art".

David Andrews is a past Professor of Naval Architecture and currentlys Chair in Engineering Design at University College London.

The publications of the Royal Institution of Naval Architects

For 150 years, the Institution has "promoted and facilitated the exchanges of technical information and discussion of technical and scientific information" though its international publications.

The first papers were published as the Transactions of the Institution of Naval Architects in 1860. From 2003 onwards, the Transactions were published in two parts – Part A as the *International Journal of Maritime Engineering,* and Part B as the *International Journal of Small Craft Technology*.

The Naval Architect journal, reporting on developments in vessels generally over 100m was first published in 1971. It also served as the Institution's newsletter, giving details of elections, obituaries etc. Since 2001, *The Naval Architect* has also been published in the Chinese language.

Developments in vessels under 100m are reported in the *Ship & Boat International* journal, first published by the Institution in 1989.

The first issue of the *Shiprepair & Conversion Technology* journal was published in 1987.

Warship Technology was first published in 1989, reporting on global developments of the warship platform. This was followed by the journal *Offshore Marine Technology,* first published in 2004, reporting on developments in those aspects of the offshore sector of interest to those involved in the design and construction of marine structures.

News of people and events have been reported since 1995 in the Institution's newsletter *RINA Affairs,* and since 2008 in its e-newsletter *RINA News.*

Profiles of the 50 most significant completions during the year have been published in *Significant Ships* since 1990 and in *Significant Small Ships* since 1998.

From 2000, the Institution's journals have been published in both printed and electronic formats. In 2008, the journals were also published online. In 2010, the Institution's journals are distributed in over 100 countries.

The Application of Scientific Theory to Ship Design

By
Larrie D. Ferreiro MRINA

Naval architecture was founded in the 18th century as a central element of the Scientific Revolution. Even then, scientific theory was being systematically applied to ship design. Four conditions were present that allowed this process to flourish: first, a clear problem to be solved; second, institutions to collect, analyze and disseminate scientific discoveries to shipbuilders; third, a canon of design standards and practices based on scientific theory; and fourth, a continuous, government-supported infrastructure for applied research. The upheavals in Europe at the turn of the 19th century upended that process. It would take another century for those conditions to be restored and for science to fully resume its central role in ship design.

Introduction: Applying scientific theory to ship design

Naval architecture was founded in the 18th century by the same scientists (Bouguer, Euler and Bernoulli, to name a few) who were working on the problems of hydraulics, astronomy and mechanics that ushered in the Scientific Revolution. Moreover, their scientific theories on stability, resistance and maneuvering were being systematically applied to ship design by the navies of Spain, Denmark and Sweden and most prominently, France. Four conditions were present that allowed this process to flourish: first, a clear problem to be solved (in this case, achieving a common set of warship designs to reduce costs and improve fleet performance); second, institutions to collect, analyze and disseminate scientific discoveries to shipbuilders (Navy-run schools of naval architecture); third, a canon of design standards and practices based on scientific theory (naval ordinances); and fourth, a continuous, government-supported infrastructure for applied research (the various Royal Academies of Science). After 1790, however, the French Revolution and subsequent Napoleonic Wars laid waste to many of the European navies and effectively shut down the scientific academies that had sponsored research into ship design. At just this time the Society for the Improvement of Naval Architecture was established in London, which promised to take up the mantle of research; but it folded in 1802, leaving the science of naval architecture adrift. It would take another century for all four conditions to be achieved one by one, until scientific theory could, again, systematically be applied to ship design.

The Quest for Accuracy

The first of these conditions materialised quickly: solving the practical problems of using the new technologies of iron and steam. By the mid-1800s, these technologies had already revolutionised the transportation industry – i.e. railroads and shipping – but for businesses to stay competitive, engineers had to continuously improve speed and efficiency; and this meant both more rigorous science and more accurate measurements of performance. At the center of these developments stood Isambard Kingdom Brunel, a civil engineer trained in both theoretical and practical mechanics. He used both applied science (e.g. structural theory) and increasingly accurate measurements (e.g. of coal consumption) to pave the expansion of his engineering empire, from bridges to railroads to steamships. Along the way he brought into his circle several key individuals who revolutionised the application of scientific theory to ship design, culminating in his magnificent but ultimately flawed *Great Eastern* (1859). John Scott Russell, the mathematically minded naval architect who designed the ship, had developed the "wave-line" theory of hull shaping which he applied to the vessel in order to minimise its resistance. William Fairbairn, the civil engineer whose work greatly influenced Brunel, envisioned ships as a floating box beam girder and developed the "balance-on-a-wave" concept for structural loading to improve structural efficiency. And most important was William Froude, who was one of Brunel's railroad engineers when he tasked him to examine the rolling motions of *Great Eastern*. Froude spent the next ten years developing the theory of, and accurately measuring, the stability and motions of ships.

These advancements in scientific naval architecture occurred primarily in the commercial sector; by contrast, the navies of Britain and Europe were primarily interested in developing theories for ship manoeuvering, in response to the resurgent interest in ramming as a naval tactic. Neither the commercial nor the naval sectors evinced much interest in the scientific analysis of resistance and propulsion, until William Froude began tackling the question of predicting ship resistance using small-scale models in 1869. He convinced the British Admiralty to sponsor the construction of a highly instrumented model towing tank in Torquay, where he developed his famous concept of separately calculating frictional and wave-making resistance; this tank subsequently became the mould from which all future model basins would be built.

Isambard Kingdom Brunel

The professionalisation of naval architecture

The second condition for systematically applying scientific theory to ship design was the creation of institutions that would link shipbuilders with scientific discoveries. These institutions – schools and professional bodies – were rapidly becoming the hallmarks of the Industrial Age, as shipbuilders were transitioning from being "mere craftsmen" to professional, scientifically trained engineers. In Britain, a series of such institutions came and went for almost half a century: first, the aforementioned Society for the Improvement of Naval Architecture; then two Schools of Naval Architecture opened briefly in Portsmouth in 1811 and 1848. For a time, the Institution of Civil Engineers served as the primary conduit for disseminating the occasional study of ship theory, such as the performance of the newfangled screw propeller.

It was no coincidence that John Scott Russell founded (in 1860) the first permanent institution devoted to the science of ship design, the Institution of Naval Architects (INA, now RINA). Shipbuilders were "anxious" to know more of developments in the Navy, as well recent advancements in ship theory, such as those made by that Scott Russell, Fairbairn and Froude made in connection with *Great Eastern*. The very first session was introduced by the paper "On the Present State of the Mathematical Theory of Naval Architecture". INA's meetings quickly filled with reports of new research from across Europe. In 1864, the need for scientifically educated shipbuilders who could effectively use this growing body of knowledge led to the opening of the Royal School of Naval Architecture and Marine Engineering (in what is now the Henry Cole wing of the Victoria and Albert Museum), later becoming part of the Royal Navy College in Greenwich. Detailed textbooks explained the scientific principles of stability and resistance, as well as the practical means of calculating metacentric height and estimating resistance. This drive for professionalisation was furthered in 1883 when the Royal Corps of Naval Constructors was founded, based on the French Corps of Maritime Engineers that had been in existence since 1765. The British models for professional societies and schools of naval architecture were soon copied by the United States, Japan, Russia, Germany and other nations, which also created bodies such as the Society of Naval Architects and Marine Engineers (SNAME) in 1893, and sent its first naval architects to the Royal Navy College before opening their own schools (e.g., the MIT and University of Michigan's programs established in 1899).

During the 20th century, the professionalisation of naval architecture extended around the globe, as naval architects increasingly came from engineering universities teaching scientific and technical theory, rather than from the more hands-on shipyard apprenticeships. Professional societies also increased their outreach worldwide as a primary source for collecting and disseminating new discoveries and findings.

Developing standards and practices

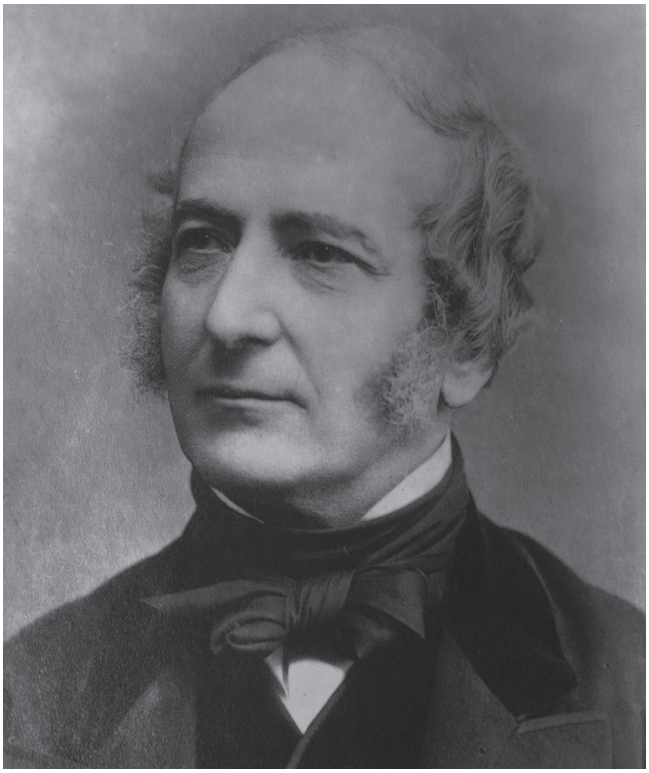
But the professionalisation of naval architects to be able to employ scientific theory was only part of the process of incorporating science into ship design. As the third condition of systematisation, that theory had to be codified and incorporated into a set of design standards and practices that could be used by shipbuilders. Governments, insurance agents and shipping companies were increasingly concerned about the performance and safety of ships, and demanded greater oversight for their vessels. Classification societies such as Lloyd's Register, Bureau Veritas and the American Bureau of Shipping were established as independent agents to develop and ensure compliance with design and construction Rules. Governments also set rules for safety, for example the "Plimsoll Mark" established in 1876, and the Safety of Life at Sea (later International Maritime Organization) conventions beginning in 1914. At first based on traditional "best practice", over the years these Rules became increasingly based on scientific theory and empirical data; for example, structural Rules were influenced by the scientific examination of cracking carried out in the 1940s by the US Ship Structural Committee.

Navies generally kept their own standards and practices for design, given the very specialised military requirements for ships, and often required more rigorous use of scientific theory; for example, after the foundering of HMS *Captain* in 1869, navies began requiring extensive stability calculations be performed, whereas merchant shipbuilders generally employed rules of thumb. This separation of naval and commercial design practices continued until the beginning of 21st century, when a combination of financial and political factors led many navies to bring in commercial classification societies to maintain their shipbuilding standards and criteria.

Laboratory Life

The fourth and final condition for systematically applying scientific theory to ship design was the development of government infrastructure that would continuously support research into naval architecture. Through most of the 1800s, research into naval architecture was generally carried out by private individuals with narrow interests (e.g. John Scott Russell's investigations in wave theory) or by shipbuilders in response to very specific problems (like Froude's research into *Great Eastern's* rolling). But even the biggest shipbuilders had to focus on the bottom line, and that precluded large investments in scientific research that might not pay off for decades. Only governments – usually navies – could, over the long term, develop and maintain the laboratory infrastructure needed to carry out fundamental research: towing tanks, maneuvering basins, structural laboratories, and most importantly, the cadre of highly educated and carefully trained scientists and engineers. This process of government support took root with the British navy's sponsorship of Froude's work at Torquay, which was followed by a navy facility at Haslar in 1886. Within a few years, comparable facilities were opening in France, Germany, Japan, Russia and the USA, with many more following later at both naval and university sites. These large-scale laboratories became the primary source for our understanding of powering and resistance, the behaviour of ships in waves, manoeuverability, structural behaviour, vibrations, etc.

So by the turn of the 20th century, the four conditions outlined at the beginning of this article had been realised. An integrated system of scientific naval architecture fairly exploded around the world, with more research accomplished and applied during the first 20 years than in the entire two centuries prior. Fundamental investigations were carried out by government-sponsored laboratories, both within navies and at universities, the latter of which turned out high-caliber naval architects, scientists and engineers. The results of these investigations were reported and assimilated via a global web of professional societies, towing tank conferences and texts. Classification societies and navies were at the forefront of turning these theoretical developments into tangible rules and standards for designing and building ships. This system, dominated during the early part of the 20th century by European laboratories, shifted its locus to the United States after World War II, as it had largely escaped the massive disruptions to science and industry. But at the dawn of the 21st century, Asian nations such as China, Korea and Malaysia are rapidly increasing their research and development capabilities, and the locus of research is once again shifting west.



John Scott Russell – founding member of the Institution of Naval Architects.

Epilogue: From metacentre to metasystem

The 21st century also brings with it a shift in the paradigm of science and engineering. The 19th and 20th centuries were considered to be the Industrial Age, when large-scale research was largely carried out using physical models. The 21st century is often referred to as the Information Age; for naval architecture, the advent of wide-scale computing and global connectivity has dramatically reshaped the research landscape. Not only are more virtual experiments being carried out by multinational teams at widely separated locations, but the various disciplines within naval architecture (structures, resistance, seakeeping, etc.) are rapidly becoming more integrated as computer power and connectivity increases exponentially. Perhaps more significantly, ships themselves are increasingly seen as part of a metasystem; for example, a destroyer may be just one "node" in an interconnected system-of-systems comprised of unmanned aircraft, satellites and submersibles; and a cargo ship is merely one link in a global transportation system that moves containers via trains, trucks and barges.

Some Significant Changes in Ship Design and Construction 1860 - 2010

By
Dr Ian Buxton FRINA

The development of ship design and construction is essentially an evolutionary process. However, over the past 150 years, there have been a number of changes or events which in retrospect, may be seen to have had a significant and far reaching impact on the work of the naval architect. In no particular order of date or importance, and very much the author's personal view, they are:

Bulk manufacture of cheap mild steel replacing wrought iron from about 1880 – previously steel was only available in small quantities of inconsistent quality at high price. Allowed stronger boilers with higher steam pressures as well as lighter stronger hulls.

The steam turbine from 1894 (Parsons), which in only a dozen years allowed much higher powers and speeds in both warships and passenger vessels.

The seagoing diesel engine from about 1910, offering much lower fuel consumption (hence greater payload) and smaller engine room crews.

Electric light from 1880s, which did away with dangerous guttering oil lamps in machinery spaces and permitted more spacious accommodation with less need for natural light for passengers and crew.

Anti-fouling coatings for iron (and later steel) hulls from 1860s, which reduced added resistance and speed loss, and permitted longer periods between drydockings.

Model testing and associated resistance calculations from 1870s (W Froude) giving greater confidence in predictions of power and speed, as well as exploration of alternative hull forms.

International agreements like Load Line Conventions which not only made for safer ships but also 'level playing fields' internationally.

Welding – initially by gas then electric arc from about 1910. Although used at first for repairs and awkward structures, paved the way in the 1930s for lighter, larger, smoother, oiltight hulls, leading on to large prefabricated hull modules.

Standardisation of container dimensions in 1965, allowing full intermodal transport and rapid replacement of break-bulk cargo vessels by ever larger container ships.

Steel hatch covers from 1930s, resulting in more efficient cargo access and safer ships.

Progressive development of specialised vessels from 1880s to partly replace general purpose vessels: tankers, refrigerated ships, ore carriers, roll-on/roll-off ships, chemical tankers, bulk carriers, container ships, liquefied gas carriers.

Computer aided design from 1960s initially for more complex calculations, but eventually providing effective integration of design and production.

Fibre reinforced plastics from 1960s offering cheaper leisure craft for mass markets, as well as special properties, e.g. anti-magnetic.

Light alloys and multi-hulls from 1970s, permitting high-speed commercial craft.

The establishment of professional institutions, classification societies and widespread use of the English language in technical literature from the 1860s, permitting worldwide dissemination of knowledge and standards.

Carriage of liquids in bulk from 1880s, superseding awkward, expensive, leaky containers like barrels and cases, paving the way for ever larger tankers, including specialised types.

A Brief Discussion of the Development of Mathematical Models in Ship Motion Theory

By

D.A. Hudson, W.G. Price, P. Temarel and S.R. Turnock

The initial science of naval architecture relied heavily on experimentation due to the lack of suitable mathematical models. Hindsight shows that these depended on theoretical advances in other fields of science and engineering such as applied mechanics and structures, oceanography, wave theory and fluid dynamics, probability and random process theories, etc. Even when mathematical models were available simplifications to the theory were necessary to allow derivation of practical solutions.

Introduction

One hundred and fifty years ago, when the Institution of Naval Architects was founded, the science of naval architecture was limited because of the imperfect state of the associated mathematical theory. Uncertainties existed in many facets of naval architecture which we now take for granted or have a fuller understanding of the underlying scientific principles. For example, the calculation of the volume of a body, application of Simpson's rule, fundamentals of hydrodynamic theory, locus of centre of buoyancy, metacentric height and period of roll oscillation, static and dynamic stability, etc. Erroneous theories founded on more or less unsound laws were used by the profession. There existed no reliable experimental data to corroborate or repudiate the mathematical theories because of the lack of a scaling law between model experiments and the behaviour of a full-scale ship. Such deficiencies caused ships to be designed which were unseaworthy and, tragically, resulted in the loss of life. The establishment of the Institution provided a forum to discuss the design and behaviour of ships at sea and to archive scientific developments which would lay the foundation of the science of naval architecture.

Froude era

In the latter half of the 19th century, sail was giving way to steam and there was great concern about the speed, power and coal consumption of steamships. Ships were being built dangerously long and narrow to save fuel and some were lost at sea. Although model tests were performed, the absence of a scientifically proven scaling law between model and ship meant that the models were usually towed too fast giving unreliable predictions. William Froude advocated performing resistance experiments on models and through his innovative, scientifically-based studies, the scientific foundation of naval architecture was established. Froude produced rules for the towing speed between model and full scale vessel (which also reflected their geometric scaling) and for the prediction of full scale power. These methods gave substantially correct results.

Froude towing tank at Torquay.

In 1871, life changed considerably for Froude, when towing trials on HMS Greyhound confirmed his predictions for model experiments and discredited other full-scale trials, such that Froude's principles of model testing were rapidly accepted by the naval architecture profession. Froude's scaling or similarity law provided a great boost to the development of naval architecture through the worldwide expansion of towing tank facilities. These created reliable and scientifically derived experimental data on which the findings of developed mathematical models could be compared. However, it must be remembered that measurements from model experiments only provide approximate descriptions to full scale behaviour because of the impossibility to achieve simultaneously similarity of wave (Froude number) and viscosity (Reynolds number) effects. Reynolds' scientific findings were introduced into the scientific literature approximately 30 years after Froude's initial studies.

Wave-ship interaction

The initial science of naval architecture relied heavily on experimentation due to the lack of suitable mathematical models. Hindsight shows that these depended on theoretical advances in other fields of science and engineering such as applied mechanics and structures, oceanography, wave theory and fluid dynamics, probability and random process theories, etc. Even when mathematical models were available simplifications to the theory were necessary to allow derivation of practical solutions.

One of the earliest assumptions introduced to describe the behaviour of a ship travelling in waves was that the vessel was rigid. In the 19th and first part of the 20th century this was acceptable because of the over design and type of ship structure, limited powering capacity, relatively small cargoes carried and the ship's modest size. Thus for a ship moving through waves parasitic motions are excited, and based on the theory of applied mechanics, mathematical models were developed to describe the equations of motion of the rigid ship. The model, involving six degrees of freedom of motion (i.e. heave, pitch, roll, etc) introduced the concept of coupled equations requiring information on the structural properties of mass, principal and cross moment of inertias as well as descriptions of wave loadings. The latter were of an elementary nature and calculations of structural properties were very labour intensive with dubious accuracy. Unfortunately imperfections in the knowledge base caused a lack of interest in such science-based mathematical models and the topic of a ship's motion lay relatively dormant until the latter half of the 20th century. In practice, the naval architect focussed on the behaviour of the vessel to a specific motion (e.g. heave, roll, etc) in isolation of the other coupled motions. Concepts were postulated, e.g. the Froude-Kriloff hypothesis, which were utilised in future developments, and linear theory of ship motion developed on the assumptions of small wave disturbances and ship parasitic motions.

Two-dimensional hydrodynamics

Central to the development of the ship motion mathematical models was the study of the inertia of water surrounding a vibrating rigid ship. It was assumed that the water flow around a circular cylinder floating half immersed in the calm water surface is identical with that around a deeply immersed cylinder. Adopting potential flow theory and utilising conformal transformations, it was demonstrated that the added mass of an infinitely long ship-shaped section oscillating at very high frequency in a fluid of infinite depth could be derived from that of a submerged cylinder of unit radius. Ship shaped sections satisfying the transformation are known as Lewis forms and, for different values of beam-draught ratio and sectional area coefficient of a ship section, added mass values could be tabulated. This provided the incentive for the development of strip theory in which the continuous ship hull is discretised by a number of sections (i.e. 20 or more) each treated independently of one another. The summation of the added mass of each ship section produces the total added mass of the ship.

A modern towing tank.

The Lewis transformation approach ignores the effects of the presence of a free surface and assumes an infinite frequency of oscillation. However, for a ship in waves, the frequency of oscillation is much decreased and experimental evidence shows that inertia fluid actions are frequency dependent as is the added mass. This was confirmed theoretically allowing determination of the frequency dependent hydrodynamic properties (e.g. added mass and fluid damping) of ship-shaped sections.

Spectral analysis

A ship operates at the interface between atmosphere and sea and because of the unsteady interaction between these fluids, an ever changing sea surface is observed which is random in nature and, in time, not definable in an analytical manner. This obstacle proved a major stumbling block to the assessment of ship motions and although wave theory included analytical descriptions of wave surfaces e.g. trochoidal wave, etc because of their forms they were difficult to utilise in predictions of ship motions.

In the 1940-50 era, theoretical advances in the fields of communications and oceanography surmounted this obstacle, through their desire to extract information from time dependent signals. Random process theory was developed allowing an irregular signal such as a continuous waveheight record at a point and varying with time to be analysed and statistical data extracted. It was also demonstrated that an irregular sea surface could be represented by the sum of a large number of regular sinusoidal waves, each being a solution of the linearised hydrodynamic equations describing water waves. These advances provided the impetus to assess the behaviour of a rigid ship travelling in an irregular seaway through analysis of wave disturbance and ship response random processes with the introduction of a statistical language (i.e. mean square value, spectrum etc.), incorporating the role of uncertainty through probabilistic measures, into the profession. The analysis also showed that there remained an essential role for deterministic mathematical models describing the motions of a ship excited by regular sinusoidal waves and the need for experimental model test data to corroborate the theoretical predictions based on a linear mathematical theory.

The development of two-dimensional (i.e. strip theory) and three-dimensional (i.e. treating the ship as a single rigid body) mathematical models allowed description of ship-wave interaction characteristics in terms of receptances or response amplitude operators, which convey information on motion resonances and ship-wave matching. Their combination with a sea spectrum (Pierson-Moskowitz, JONSWAP, etc) produces a ship response spectrum embodying the statistical data describing an irregular ship motion response.

Three-dimensional hydrodynamics

The linear, three-dimensional models overcame the inherent weaknesses of the simpler strip theory models. Namely, the idealisation of the continuous hull form into a series of two-dimensional sections, failure to represent the actual hull shape and omission of fluid-structure interactions between sections. Boundary element methods provided a better representation of the three dimensional hull through a patchwork of panels distributed over the mean wetted hull surface with a suitable source function (i.e. Rankine, etc) satisfying the linearised free surface wave condition placed on each panel. Mathematical models, based on Green theory, initially adopted a zero speed oscillating source function with forward speed treated as a correction to the zero speed solution. Significant computing effort and power were required to derive information describing the six degrees of freedom responses and wave loads experienced by a ship travelling in a seaway. By utilising translating, pulsating sources the mathematical models were able to account for steady state and oscillatory behaviour of the vessel as well as incorporating forward speed. Although the mathematical models were developed in a rigorous theoretical manner, they remain an approximation to reality because of the assumptions of hull rigidity, disturbances are small and only the calm water wetted hull surface area contributes to the calculations of hydrodynamic pressure, responses, wave loadings, etc. The latter depend on available computer power and developed numerical schemes of study which transfer solution derivation onto studies of the employed numerical methods, numerical analysis (i.e. stability, convergence, accuracy, etc) and inherent model characteristics (i.e. irregular frequency, etc) rather than the physical modelling of the problem.

Hydroelasticity

The mathematical models developed apply to rigid ships, irrespective of size. However as ships evolved through significant changes of construction, available power, specialist cargoes transported and their very large increase in size (i.e. tankers, bulk carriers, etc), the assumption of a rigid ship became untenable. For example, a ship hull, at rest in calm water, is acted upon by gravity and buoyancy forces with the result that it deflects, adopting a particular attitude and distortion. These deflections depend on the loading of the ship which, when the ship travels in waves become time dependent fluctuations.

The rigid hull assumption was addressed by adopting fundamental concepts of sound and vibration theory with the development of hydroelasticity theory modelling the hull as a flexible structure experiencing deflections. The fluid surrounding the hull was treated as an external fluid loading exciting the flexible hull and, in the absence of fluid, the ship examined as a dry beamlike, flexible, non-uniform structure. This allowed determination of unique fundamental structural dynamic properties (i.e. principal mode shapes, natural frequencies, etc) by investigating the free vibration of the undamped free-free structure. The introduction of a suitable beam theory (e.g. Euler, Timoshenko, etc) or finite element model to describe the structure and development of a wet analysis, dependent on the adopted hydrodynamic theory (i.e. strip theory, source distribution, etc), resulted in generalised, coupled equations of motion to describe a flexible ship hull travelling in an irregular seaway. This unified mathematical model incorporates both rigid body motions and distortions since a deflection is a summed weighted (i.e. principal modes) combination of both. The model treats ship strength and ship dynamics on the same fundamental basis providing a framework to assess, at any position in the hull, the behaviour of a vessel to wave induced responses causing stresses, fatigue, etc. Furthermore, in accordance with the theory of applied mechanics, internal loadings of bending moment, shear force, stress etc at all positions in the hull and frequencies are determined only from the distortions of the hull structure.

In recent years, attention has focussed on the detailed idealisation of a hull structure by utilising finite elements. This has perhaps limited the position of the naval architect as a highly skilled theoretical innovator since focus of much theoretical innovation has transferred to the embodiment of knowledge into the description of finite element type. Nevertheless, a realistic detailed idealisation of a ship structure by finite elements requires great modelling expertise of the naval architect, significant computing power and a clear understanding of how the ship structure is expected to behave. The introduction of finite element analyses into naval architecture has provided the practical means of analysing the fluid-structure interaction behaviour of complex mono-and multi- hull structures of all shapes, sizes and materials, (steel, composites, etc) travelling in an irregular seaway based on an unified, linear hydroelastic mathematical model.

Future developments

With increasing computer power, the future ultimate goal of naval architecture research is the replacement of linear mathematical models by physically consistent, rigorously developed mathematical models based on Navier-Stokes equations to simulate, in real time, the operational behaviour of a ship travelling in an irregular seaway. Although practical use of Reynolds Average Navier-Stokes (RANS) models are becoming ever more accessible with increasing speed and capability of computers they require a high level of user expertise. Their everyday use as a design optimisation tool still remains someway off. However, in due course their adoption, for example, to predict the fluid flow and manoeuvring behaviour of a deeply submerged travelling submarine or, the self propelled efficiency of a ship design in calm water will be a regular part of the role of a naval architect. The complexity of these types of problems increases very significantly when the vessel is in the vicinity of an irregular free surface. It therefore follows that the prediction of all ship motion and wave loading responses associated with a flexible ship structure travelling in an irregular seaway is limited to grand challenge exercises using the largest computers.

Model experimental data and mathematical model predictions both provide approximate solutions to fluid-structure interaction problems. The approximation in experiments arises because of accuracy of measurement, signal processing analysis, the difficulty in satisfying the disparate corresponding requirements of wave and viscous effects at model and full scale, etc whereas the mathematical model depends on initial theoretical assumptions and the developed numerical scheme of study which influence solution. Both approaches are of equal importance in the accumulation of knowledge through observation of physical interaction mechanisms, data, etc which the mathematical model should replicate together with defining the behaviour characteristics of the solution within the experimental range and its trends beyond, without contradicting the initial assumptions.

Concluding remarks

Since its formation in 1860, the Institution has been at the forefront of developments in naval architecture. It has provided a learned society for the dissemination of information through its roles in education, discussion forums and professional publications. Changes continue to occur in the profession and the importance of these roles increases as ship types evolve to support world trade. With approximately 95% of commodities and manufactured goods transported by sea, shipping underpins worldwide economic growth and the shipping industry has been very successful in carrying goods from manufacturing centres to markets at low cost and thus contribute to the economics of the respective countries through employment by manufacturer to booms in sales at markets. The synthesis of the applied engineering problems resulting from real ship design and the advances in mathematical theory, modelling and understanding have been fundamental to the ability to design larger, more structurally complex and ever more efficient ships of a multiplicity of form and function. For such progress to continue requires the Royal Institution to raise standards in the profession and naval architecture education to focus on the fundamentals of science, engineering and operational management so that there is a full appreciation of the growing spheres of influence in which the naval architect interacts.

Professor W.G. Price was President of the Royal Institution of Naval Architects from 2004 to 2006.

Dr D.A. Hudson, Professor P. Temarel and Dr S.R. Turnock are members of the School of Engineering Sciences at the University of Southampton

The First Transactions Paper

Over 5000 technical and scientific papers have been published in the Institution's Transactions, recording the development of ship and offshore design and construction. The first paper published by the Institution of Naval Architects in its Transaction of 1860 was "On The Present State of The Mathematical Theory of Naval Architecture" by The Rev. Joseph Woolley, a founding member of the Institution. The paper was read at the first meeting of the opening Session of the Institution, on Thursday, 1 March, 1860.

In 1860, and for some years afterwards, it was not the practice to preface a paper with a summary, but the paper opened with the following paragraphs:

"On The Present State of the Mathematical Theory of Naval Architecture"

"The subject of the present Paper is one of very considerable magnitude, and I can here pretend to do nothing more than give a very imperfect sketch of it ; indeed, I shall confine myself entirely to that branch of it which treats of the construction and behaviour of ships. I can only wish, for the sake of the science of naval architecture, that the subject were more extensive than it is. It must, unfortunately, be conceded that the mathematical theory of that science is in a very imperfect state, and that some of the most important and interesting problems have hitherto eluded the grasp of the geometer and physicist.

One of the chief benefits to be looked for from the Institution of Naval Architects, which we are inaugurating to-day, is a more systematic inquiry into the laws of nature on which the motions of a vessel at sea depend than has hitherto been attempted, an inquiry that shall furnish to the mathematician satisfactory data on which he may found his calculations. The great and hitherto insurmountable difficulty has been the discovery of these laws.

I think it right, however, to assert at the outset, that the practice of naval architecture owes more to mathematical investigation than might be inferred from the very limited number of problems directly affecting the form of ships which scientific inquiry has furnished. Even erroneous theories – theories, I mean, founded on laws known to be more or less unsound have done, and continue to do, good service; and general reasoning on mechanical principles as applied to ships, although incapable of being put into the accurate language of analysis, has been, and may still be, the means of preserving the scientific builder from errors of a grave kind, and of guiding him to the construction of vessels with a fair share of the good qualities he wishes to impart to her…….."

The Development of Hydrodynamics: 1860 – 2010

By
Professor A F Molland FRINA and Professor P A Wilson FRINA

In the early 1860s, little was really understood about ship resistance and many of the ideas on powering at that time were erroneous. Propeller design was very much a question of trial and error. The power installed in ships was often wrong and it was clear that there was a need for a method of estimating the power to be installed in order to attain a certain speed. However, over the following 150 years, significant development was made in estimating ship propulsive power.

The Early Years

In 1870, William Froude initiated an investigation into ship resistance using models. He noted that the wave configurations around geometrically similar forms were similar if compared at corresponding speeds, that is speeds proportional to the square root of the model length. He propounded that the total resistance could be divided into residuary, mainly wavemaking, resistance and skin friction resistance. He derived estimates of frictional resistance from a series of measurements on planks of different lengths and with different surface finishes. Specific residuary resistance, or resistance per ton displacement, would remain constant at corresponding speeds between model and ship. His proposal was initially not well received, but gained favour after full-scale tests had been carried out. HMS *Greyhound* (100 ft) was towed by a larger vessel and the results showed a substantial level of agreement with the model predictions. Model tests had been vindicated and the way opened for the realistic prediction of ship power. In his 1877 paper, Froude gave a detailed explanation of wavemaking resistance which lent further support to his methodology.

In the 1860s, propeller design was hampered by a lack of understanding of negative, or apparent, slip, naval architects being not fully aware of the effect of wake. Early propeller theories were developed to enhance the propeller design process, including the momentum theory of Rankine in 1865, the blade element theory of Froude in 1878 and the actuator disc theory of Froude in1889. In 1910, Luke published the first of three important papers on wake, allowing more realistic estimates of wake to be made for propeller design purposes.

Cavitation was not known as such at this time, although several investigators, including Reynolds, were attempting to describe its presence in various ways. Barnaby, in 1897, goes some way to describing cavitation, including the experience of Parsons with *Turbinia*. During this period, propeller blade area was based simply on thrust loading, without a basic understanding of cavitation.

By the 1890s the full potential of model resistance tests had been realised. Routine testing was being carried out for specific ships and tests also being carried out on series of models. A notable early contribution to this is the work of Taylor, closely followed by Baker. It is a tribute to Taylor that the results of his work, including the re-analysis by Gertler, are still in common use today.

The Middle Era

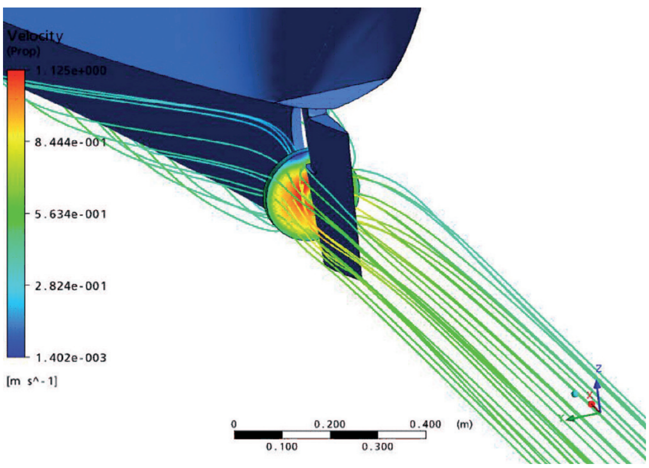
The next era saw a steady stream of model resistance tests, including the study of the effects of changes in hull parameters, the effects of shallow water and to challenge the suitability and correctness of the Froude friction values. There was an increasing interest in the performance of ships in rough water and the need to assess this performance. Several investigations were carried out to determine the influence of waves on motions and added resistance, both at model scale and from full-scale ship measurements. Following the earlier work of Michell and Havelock, Wigley presented his first of several papers on the mathematical calculation of ship resistance together with supporting experimental results.

The 1920s saw much interest in improving propeller efficiency and, in 1928, vortex theory applied to propellers was introduced by Perring. This was basically a combination of momentum and blade element theories, generally following the approach for airscrews used by Lanchester, although there were shortcomings due to the wide blade of the marine screw.

In 1927, Telfer introduced a fundamentally new method of extrapolating model resistance values to full-scale ship values which does not entail breaking down the resistance into its components. Experiments are carried out on a family of models, which Telfer termed 'Geosims', and the slope of the extrapolator determined experimentally in the region of the model values. The method has a sound scientific basis and is valuable as a research tool, but is found not to be cost effective for routine commercial testing. Several other families of Geosims have been tested since the early work of Telfer.

The 1930s saw the publication of work on cavitation by Lerbs and Kempf, based on results from their new cavitation tunnel, which greatly improved the understanding of cavitation. In 1937, Gawn published a series of tests on wide bladed propellers and, in 1938, Troost published the first results for a series of propellers that were to become the Wageningen B–Series. The mid-1940s saw the description of the Kort nozzle (ducted propeller), together with a description of supercavitating propellers by Posdunine.

The presence of transitional and laminar flow on hull models had long been suspected, even from the days of the anomalies in the Froude data. In 1937, Lackenby re-analysed the Froude data. He plotted the data to a base of Reynolds number and showed clearly that mixed transitional and laminar flow did exist. Allan and Conn carried out tests in the late 1940s that also clearly proved the presence of laminar flow and the need for turbulence stimulation on models. From about that time, turbulence stimulation has been applied to all models.



Velocity distribution showing the effect of the ship hull, propeller and rudder.

The Modern Era

In the 1950s there was a renewed interest in friction lines. As well as the Froude values, other proposals over the years had included those of Tideman (using Froude data), Gebers, Prandtl, Schlichting, von Karman and Schoenherr. All were aware by now that the extrapolation process depended on the level and slope of the friction line, and that the Froude values were not explicitly defined in terms of Reynolds number. Also, the increasing size and speed of ships was leading to significant errors in power prediction, particularly when using the Froude friction coefficients. The predominant friction lines in use at the time were those of Froude and Schoenherr, whose line had been adopted by the ATTC in 1947. After much experimentation at the National Physical Laboratory, Hughes proposed a new formulation, and a modified form of his equation was adopted by the International Towing Tank Conference (ITTC) in 1957. This, together with a form factor to estimate the total viscous resistance, is the basic format of resistance extrapolation still in use. This era also saw the start of formal model-ship correlation, where correlation factors or coefficients were introduced to take account of the differences in the model and full-scale predictions that might arise due to such aspects as scale effects and levels of hull surface roughness.

The 1950s and 1960s saw the development of resistance tests for standard series models, including those for merchant ship forms, semi-displacement and planing forms. The basic results provide a comparator with other model tests and allow parametric variation of hull parameters for optimisation studies to be carried out and the refinement of the particulars of models to be used in future tests. The 1950s also saw the publication of the Gawn series of propellers, over-riding the earlier 1937 tests, and the Gawn/Burrill series, which included investigations into cavitation. These series, together with the extensive Wageningen series and other series such as those developed in Japan and elsewhere, have provided extremely useful tools for propeller design and continue to do so to the present time. Other propeller developments included the measurement of stresses in propellers using strain gauges and the effects of propeller surface roughness.

During the 1960s, much effort was also directed at measuring the individual components of resistance in order to provide a better understanding of the physical nature of the flow and the relative magnitude of the resistance components. This entailed measurements of the viscous resistance and wave resistance, which can be seen as energy dissipation, together with friction resistance and pressure resistance which comprise the forces acting on the hull. Such measurements allowed the division between components to be assessed better, including the distribution and magnitude of the skin friction and viscous resistance for the improved estimation of form factors.

The mid-1960s to mid-1970s saw a significant evolution of ship types, including container ships, chemical and gas carriers, RO-RO and car carriers, together with a general increase in size and speed. These developments called for a number of specific hydrodynamic investigations. The 1970s also saw increased attention to theoretical work, in particular the means of predicting wave resistance. Early CFD techniques were being developed in earnest.

Since the 1960s there have been many developments in propulsor types. These include various enhancements to the basic marine propeller such as tip fins, varying degrees of sweep, changes in section design to suit specific purposes and the addition of ducts. Contra-rotating propellers have been re-visited, cycloidal propellers have found new applications, waterjets have been introduced and podded units developed. Propulsion enhancing devices have been proposed and introduced including propeller boss cap fins, upstream pre-swirl fins or ducts, twisted rudders and fins on rudders. It can of course be noted that these devices are generally at their most efficient in particular specific applications.

The Computational Era

From the start of the 1980s, the potential of CFD was fully realised. This included the modelling of the flow around the hull and the derivation of viscous resistance and free surface waves. This generated the need for high-quality benchmark data for the physical components of resistance necessary for the validation of the CFD. Much of the earlier data of the 1970s was re-visited and new benchmark data developed, particularly for viscous and wave drag. Much of the gathering of such data has been coordinated by the International Towing Tank Conference.

Propeller theories had continued to be developed in order to improve the propeller design process. Starting from the work of Rankine, Froude and Perring, these included blade element-momentum theories, such as Burrill in 1944, Lerbs in 1952 using a development of the lifting line, and lifting surface methods where vorticity is distributed over the blade. Vortex lattice methods, boundary element, or panel, methods and their application to propellers began in the 1980s. The 1990s saw the application of CFD and RANS solvers applied to propeller design together with CFD modelling of the combined hull and propeller.

Other numerical methods of a fundamental nature developing through this period include SPH (Smooth Particle Hydrodynamics). This is a numerical technique for the approximate integration of the governing partial differential equations of continuum mechanics. It is a mesh-less Lagrangian method that uses a pseudo-particle interpolation method to compute smooth field variables. Each SPH particle has a mass, Lagrangian position, velocity and internal energy. The SPH approach was initially developed for the simulation of astrophysics problems, with the critical development being a method for the calculation of derivatives without a computational mesh. Libersky and Petschek extended SPH to work with the full stress tensor, developing a 2D formulation.

More recently, SPH simulations have been further compared with published experimental results, an example being Scott Russell's wave generator, with the SPH method in agreement with the experimental results. In these simulations he used an artificial equation of state to produce a quasi-incompressible fluid. SPH has also been used for wave mechanics with exact enforcement of incompressibility. This uses an implicit pressure update that allows a larger time step but requires more computational work per time step. Recently, SPH methods have been successfully applied to 2D simulations of green water overtopping and wave overtopping using rigid representations of the impacted structure.

The Future

As to the future, as long as there continues to be changes in the economic and environmental operating conditions of ships, there will be a continuing need for hydrodynamic investigation. These changes might include movements in oil prices, an emphasis on reducing CO_2 and other emissions, environmental requirements such as the reduction of wave wash, the general drift to higher speeds, high-speed commercial craft, large container ships and high-speed cargo carriers.

All these topics tend to lead to the need to examine the hydrodynamics of the situation and to minimise ship propulsive power. This might include further investigations of hull shape, hull coatings, more efficient propulsors including energy recovery devices and hull-propeller interaction. Operational aspects will continue to be examined, such as optimum trim and ballast scenarios, developing a better knowledge of seakeeping and speed loss in waves, leading to enhancements in weather routing and minimising the average propulsive power. Many of these investigations will be enhanced and extended by the further development and use of CFD, together with the continuing support of physical experimentation, which is where it all began in a formal way 150 years ago.

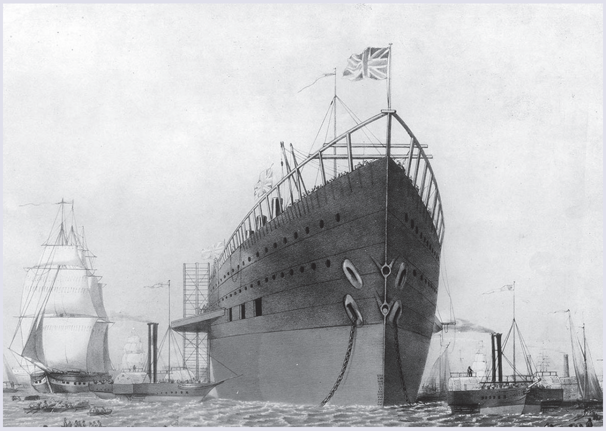
Professor Tony Molland has over 50 years' experience of ship resistance and propulsion through research, teaching at the University of Southampton, and membership of ITTC committees.

Professor Wilson has taught and researched for nearly 40 years in the field of hydrodynamics at the University of Southampton and the current editor of the International Journal of Maritime Engineering.

Events of 1860

Maiden voyage of the *Great Eastern*

On 17 June 1860, the *Great Eastern* began her 11-day maiden voyage from Southampton to New York. She carried 35 paying passengers, eight company "dead heads" (passengers who didn't pay) and 418 crew.



The *Great Eastern*

The *Great Eastern* was built by Messrs Scott Russell & Co. of Millwall, London, the keel being laid down on 1 May, 1854. She was finally launched - after many technical difficulties - on 31 January, 1858. She was 211 m (692 ft) long, 25 m (83 ft) wide, with a draft of 6.1 m (20 ft) unloaded and 9.1 m (30 ft) fully laden, and displaced 32,000 tons fully loaded. She was at first named the SS *Leviathan*, but her high building and launching costs ruined the Eastern Steam Navigation Company and so she lay unfinished for a year before being sold to the Great Eastern Ship Company and finally renamed SS *Great Eastern*.

History of Computing in Naval Architecture

by
Philip Christensen FRINA

Few technological changes have had as much effect on naval architecture as the introduction of digital computers and their application to the design, analysis and production of ships. From its earliest beginnings in the early 1960's, computer aided design has now become the standard means by which vessels are designed. The scope of application has broadened from basic lines definition and fairing in the earliest applications through to complete, detailed definition of all aspects of vessels as well as analysis tools for damage stability, motions and resistance prediction, stress analysis and maneuvering.

The genesis of computer aided design in general was at MIT in 1963 where Evan Sutherland created the SketchPad system. His use of a light pen and interactive graphics to solve engineering problems laid the foundations for all computer aided design systems to follow. Another key development which was an important part of the framework on which naval architecture software systems would be based, was work by Pierre Bezier on numerical curves and surfaces. An engineer at Renault in France, his work was focused on modeling of surfaces for automobile body design. His work implementing Bezier curves and surfaces was later extended into B-Spline and then NURB surfaces. These curves and surfaces are now the most frequently used means of describing the three dimensional shape of ship hulls.

Early Systems

The marine industry has always been international in nature and the development of software systems for naval architecture is no exception. A first phase of development commenced in the early 1960's when a series of naval architecture programs were developed for deployment firstly on mainframe and time-share minicomputers, and then later in the 1970's on engineering workstations. In Scandanavia, developments at the Wartsila shipyard in Finland and at the Kockums yard in Sweden were important early steps in the creation of naval architecture and production systems respectively. In the US, an early paper on computer aided ship design by DT Ross at MIT was an important milestone in the developments supported by the US Navy's Navsea department. Around the same time, BSRA in the UK supported the development of programs for stability and strength calculations.

A later phase of development commenced in the early 1980's when the first personal computer software systems began to appear. In contrast to the large scale developments of the 1960's sponsored by yards or government agencies, these new developments were by a disparate group of individuals but again, in a range of international locations. Surprisingly, almost all of these systems are still in use today. In the US these systems included Bill Plice with GHS, George Hazen with FastShip and John Letcher with Multisurf. In Australia Andrew Mason created Macsurf (later Maxsurf) and in Canada Grahame Shannon created Autoship. Based on these systems, in a period of 10 years, almost all design offices switched from paper to digital models of their hull designs.

Hull Definitions

Software applications for the definition of hull geometry have evolved using two methods of hull definition. The first, used mostly in the definition of large ship hulls, uses a series of master curves to define key curves on the hullform. These typically include bow profile, stern profile, midship section, flat of side, flat of bottom and sheer line. Within this curve framework, a series of surface patches are then created to define all locations on the hull. These surface patches can then be sectioned for hydrostatic and other calculations and can also be used to define sub-meshes which are used for shell plate development. The second method of definition, used more commonly on medium and smaller sized vessels, uses a series of joined NURB surfaces to define the complete hull surface. This patchwork of surfaces can then be sectioned and subdivided for analysis and construction. While the first method uses an approach that is broadly similar to the way in which traditional manual definition of hull lines are defined, the second effectively reverses the process. That is, instead of defining a series of orthogonal 2D curves and then constructing a 3D hull surface from them, the 3D surface is defined directly and the 2D sections, waterlines and buttock lines are derived from it.

Stability and Strength

All software systems now provide means both of automating fairing as well as displaying numerical measures of fairness. Although the term "fairness" is used in naval architecture as an aesthetic measure of smoothness, in software systems it is generally measured as a rate of change of curvature along key curves on the hull surfaces.

The calculation of intact and damage stability characteristics of vessels has been an area of application of naval architecture software from its earliest days. Simple implementations of Simpsons rule for numerical integration have now been superceded by the use of trapezoidal numerical integration of a series of hull sections to evaluate the properties of the immersed volume of a vessel. In recent years, a number of systems have also used an approach based on integrating the surface area mesh of a hull model to achieve the same results. The development of the probabilistic approach to damage stability has made computer based analysis of stability criteria a mandatory approach because of the large number of combinations of damage stability that are required to be considered.

The earliest implementations of structural analysis focused on the application of beam theory to the hull girder and calculations of basic hull deflections, moments and shears. As a step forward from this, the application of the finite element method to the stiffened plate structures found in ships has been very successful. In most naval architect offices, commercial general purpose finite element systems are used. However for earlier stage design, the work of Owen Hughes and others has created a series of tools which are optimized for ship structural design. The approach used allows for a global model to be prepared which smears the stiffness of stiffeners across plates to simplify the global analysis model in the early stages. As analysis and design progresses, a more detailed local model can be created and analysed to check local structural performance.

Resistance prediction and propeller selection are areas which have also benefitted from computer applications. Many regression methods of resistance prediction have been implemented over the years. These methods use data fitting to tank test data to predict performance of similar vessels. A number of computational fluid dynamics (CFD) methods have also been implemented specifically for application to ship flow problems. Generally these have been potential flow panel methods which cover the hull with a mesh of panels and then predict pressure distribution over this surface. The America's Cup campaigns of the 1980's were a fertile ground for the development of these techniques. Following the development of the winged keel on the winning Australia II design in 1983, a range of syndicates developed systems which linked the 3D hull, keel and wing model to CFD applications. The applications were tailored to account for the free surface which is so important to vessel design.

3D Modelling and Production

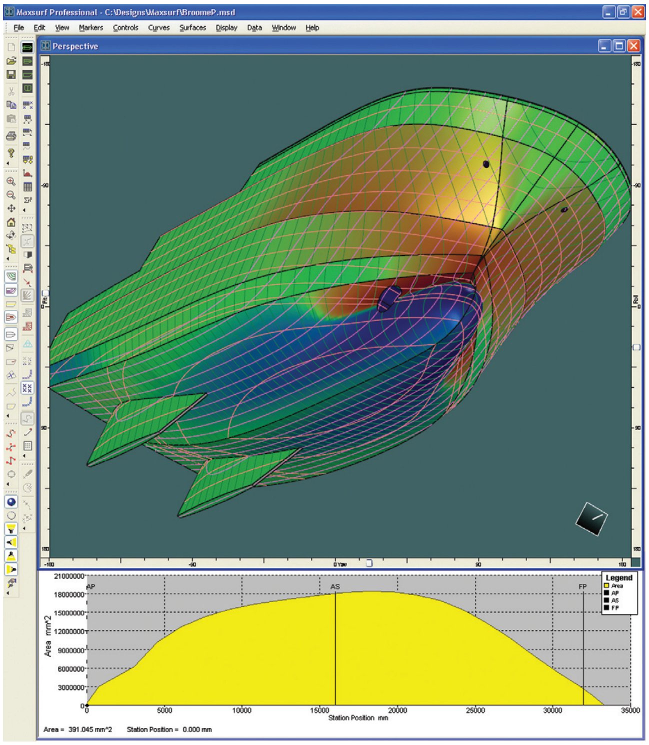
The design of the internal systems found in a vessel, as well as its detailed structure, has always been a key area of application for 3D CAD systems. The complexity of this design and production problem means that the systems in use such as Aveva Marine (formerly Tribon), ShipConstructor and Foran have evolved over a number of decades in all cases. They have each started from a structural application with particular emphasis on the doubly curved plates and stiffeners found in a ship hull. The unique geometry of this structure is what initially set these systems apart from conventional mechanical CAD applications. Later, application modules were added to address equipment layout, piping and HVAC design and electrical applications. While these systems have typically been used by draftsmen under the supervision of naval architects, we are now starting to see offices in which naval architects use the system directly to create computer models in the earliest stages of the project.

One interesting effect in the application of software systems to naval architecture is that it has had, and continues to have, an effect on the workflow and responsibilities in shipbuilding projects. For example, whereas traditionally a naval architecture design office would have delivered a set of lines and associated calculations for a project, many now use 3D CAD software from the earliest stages and deliver a full 3D product model and the generated production drawings and reports. For a naval architecture office which is integrated within a shipyard, this can deliver significant improvements in productivity, as well as improving communication between design and production teams. For independent design offices, this approach requires a new set of skills within the design team. In addition it means that the naval architecture team takes on responsibilities which were once the preserve of the production team. Obtaining a corresponding increase in design fees associated with the increased workload and liability associated with preparing and delivering detailed production information can be problematic. This situation is only going to get worse as software systems increase in scope and integration between design and production capabilities.

The evolution from paper tape and punch card batch processing of stability calculations, through to the modern 3D, interactive modeling of entire ships, has empowered naval architects more than any other technology in naval architecture history. We are very fortunate as a profession to have the power of these tools take away the previous drudgery of repetitive calculations and replace it with a tool set that encourages naval architects to explore design alternatives and adapt to changing requirements.

Philip Christensen is the Managing Director of Formation Design Systems

A typical naval architecture software application



Developments over the last 150 years, which have, and will continue to challenge the profession of naval architecture

By
G H Fuller CEng FRINA FIMarEST RCNC

To meet the future, the Naval Architect must be a polymath, meeting internationally acceptable standards of education and training. Thus a heuristic approach is essential, covering all elements of arrangement, form, structure, hull systems and propulsion. Globally, new Universities and Colleges will appear, challenging the older ones. However, the role of RINA as a professional institution will continue to be vital in covering standards, the formation and continuing development of Naval Architects and the dissemination of information. The future for the profession of Naval Architecture and shipbuilding will be bright as the world will continue to need global trade for food, energy and raw materials and tourism.

1860 – 1900

The Great Exhibition of 1851, led by the Prince Consort, endorsed the need for more professional engineers. Civil construction and the railways were exploiting iron and steam but except for some notable examples, the ships still relied on wood and sail. However, by the 1860's, the expansion of Empire required a large merchant fleet protected, as the Flag followed Trade, by a new generation of warships. Greater speed and range required the application of hydrodynamics and thermodynamics, leading to better hull forms, propellers, and more efficient propulsion engines. Refrigeration enabled fresh food for long voyages to be no longer dependent on farm animals on deck and perishable cargoes to be transported.

There was concern with losses at sea in two areas. It was realised that the losses of ships and cargoes, costs which were met by marine insurance, were linked to poorly designed and maintained hulls and machinery. 'Classification Societies' were formed to underwrite the concept of the insurable risk. Secondly, the huge loss of life led to reformers bringing their concerns to Parliament. New laws were passed covering freeboard, overloading and lifesaving.

Education and Training

The period was dominated by 'practical men', the product of industry-based apprentice schemes with higher training based on the 'premium' apprentice and night schools. Although science and mathematics were taught in UK Universities, engineering had to wait the end of the century. However, the growing sophistication of warships coupled with some major disasters, endorsed the need for properly trained Naval Architects. Thus schools of naval architecture were founded firstly at South Kensington and then at the Royal Naval College Greenwich. In 1873, these 'new' naval architects were grouped into the Royal Corps of Naval Constructors, a civil service group involved in the design, construction and support of Royal Navy (RN) ships. Dissemination of information was improved by the founding of professional Institutions – that for Naval Architects in 1860.

In Europe, the professional engineer was the 'ingenious' person although occasionally naval architects produced designs, which were more ingenious than practical. The USA was also different, at West Point founded in 1802 and at Annapolis founded in 1845 all had to study engineering. The best students from West Point joined the Corps of Engineers, still today responsible for major waterways. Then came the great engineering schools such as MIT. The US Navy (USN) design Bureaux and Shipyards were staffed by Officers with advanced Naval Architectural and engineering degrees trained at MIT, although some naval architects including Rear Admiral David Taylor USN were trained at RNC Greenwich.

1900 –1950

The start of the period saw new challenges, including:
- The growth of the North Atlantic passenger trade for the rich

and poor required larger and faster ships plus the need for better ships on the Empire and South American routes.

- The steam turbine developed by Parsons.
- The development of the large Diesel engine led by Germany.
- Not only did the Diesel need oil fuel but oil-fired steam boilers had huge advantages over coal for warships.
- The big gun Battleship, the torpedo and the practical submarine transformed navies.

Merchant shipyards were either flat-out meeting the demand for ships before, during and immediately after both world wars or facing closure. There was little incentive to invest in new facilities and few passenger liners built mostly as 'make work' projects.

The design of warships between the wars was more challenging, meeting Treaty limitations, building and modernising battleships and exploiting air power at sea. Larger surface warships were equipped with one or two aircraft and the concept of a ship to carry aircraft as the main armament emerged. The design of aircraft able to cope with the ship interface and the marine environment was difficult. The USN having retained its own naval air force coped well. But with the RN air arm subsumed into the RAF at the end of World War I, maritime air was well down the priority list.

During WWII, production was paramount for merchant ships and escorts including aircraft carriers plus submarines. There was a new requirement to transport large armies by sea to heavily defended enemy coasts, needing innovative ships of all types and sizes and mobile harbours.

Education and Training

The period saw little change to the well-established systems of apprentice training in shipyards and dockyards with 'degree' courses offered by provincial colleges and Naval Colleges to the brightest apprentices. The small numbers produced were adequate for WWI but in the naval area, naval architects as both designers and dockyard managers were in short supply prior to WWII due to inter-war cuts. New recruitment sources had to be found.

1950 – 2010

For the commercial naval architect, there were new challenges, including:

- Passenger liners, superseded by aircraft, evolved into massive cruise ships to meet a worldwide tourist market.
- Global trade in bulk foodstuffs, minerals and oil led to ships many times the size common in 1950's.
- The carriage of general cargo moved from the modest sized, break bulk, tramp ships to the massive container ships.
- Vehicular cargoes required large Ro-Ro ferries and car carriers.
- High-speed ferries exploited novel hull forms, lightweight materials and propulsion plants.
- Rigs and ships to meet the needs of the offshore oil & gas industry had to be designed, built, maintained and disposed.
- The exploration of the seabed required unmanned vehicles able to go to depths, which were difficult by manned craft and impossible by divers.
- Losses of tankers causing widespread oil pollution and losses of ferries and passenger ships with large loss of life resulted in a deep review of overall safety. International and national organisations were set up. More recently there have been demands to reduce air and wastewater pollution.
- Merchant shipbuilding moved to cheaper locations.

For the warship naval architect, the 1950's saw the start of the Cold War, with naval requirements dominated by the deployment of nuclear weapons in surface ships and submarines. In addition there were material advances:

- Stronger steels overcame limitations in the diving depth of submarines and aluminium and glass-reinforced plastics reduced superstructure weight.
- Nuclear power enabled the true submarine to be realised and surface warships to have unlimited endurance.
- Air independent power plants gave submersibles higher speeds and better underwater endurance.
- The marinisation of aircraft gas turbines freed designers from the high maintenance steam plant.
- High performance and VSTOL aircraft and helicopters became available.
- Electronics led to guided and ballistic missiles and better radar, sonar, and communications.
- Behaviour of explosive blast and shock waves had to be understood as did the transmission of noise underwater.

From the 1970s, the computer revolutionised design, production and maintenance. Many design variants can be created but time can be wasted in evaluation and designs even after being built can be rejected. For warships this has led to building legacy designs and modernising older ships to avoid loss of numbers.

Education and Training

Five events may be seen to have dramatically changed education and training in the UK and the role of the Royal Institution of Naval Architects:

- The expansion of University-based education led to the closure of government-funded Colleges such as RNC Greenwich.
- The regulation of professional engineers changed from stand-alone Institutions to a quasi-federal structure under an Engineering Council setting industry-wide standards.
- The rapid expansion of CAD/CAM and new technologies required new subjects to be covered plus the need for Continuing Professional Development.
- Cuts in shipyard workforces led to reductions or closures of apprentice schemes.
- Knowledge dissemination by Institutions moved from the topic-based learned papers to the subject-based conferences.

2010 – onward

Merchant vessels will continue to be needed for ocean and coastal transport of bulk materials and manufactured goods, the tourist trade and the exploration and exploitation of the very deep ocean for oil and gas. Energy from wind, tides currents and waves will be developed. Stricter anti-pollution measures will be imposed. The need for new ships and rigs will be high as older ships cease to be energy efficient and cannot meet pollution standards.

Navies will face new threats such as piracy and terrorism as well as the projection of power and aid to failing states. In addition over-flight and over land restrictions will make seaborne transport of armies essential.

A major problem will be the archiving and recovery of computer-generated information over the long life of the marine product. Paper records some centuries old can still be accessed and are virtually indestructible. Computer-based records depend on the hardware and software extant at the time. The systems have unproven lives may be ten or so years. Already tapes and old discs are difficult to read and 'modern' discs go mouldy. In addition face-to-face communication, minuted meetings, written reports and letters are being replaced by conference calls and non-archived Emails adding to retrieval problems.

Future Education and Training

The place of the marine industry must be understood to design education and training systems. Engineered products can be divided into two groups, those to be mass produced in large numbers and those in small numbers to bespoke designs. The former require in-depth design, prototyping, specialised production facilities and international support networks. The latter, applicable to the built and marine environments, require independent designers to interpret the customers requirements and to prepare documents for competitive production and to oversee production and maintenance. The product must work first time.

Marine products will continue to range from the very small to the very large and with lives of 40 plus years followed by environmentally friendly disposal and be able to be mobile in the aggressive air-water interface or the pressure of undersea operation.

To meet the future, the naval architect must be a polymath, meeting internationally acceptable standards of education and training. Thus a heuristic approach is essential, covering all elements of arrangement, form, structure, hull systems and propulsion. Globally, new Universities and Colleges will appear, challenging the older ones. However, a network of professional Institutions will continue to be essential covering standards, the formation and continuing development of naval architects and the dissemination of information.

The future for the profession of naval architecture and shipbuilding will be bright as the world will continue to need global trade for food, energy and raw materials and tourism.

Geoff Fuller is a past Vice President of the Institution and member of the Professional Affairs Committee.

The Royal School of Naval Architecture 1864-1873

Throughout its 150 years' history the Institution of Naval Architects, and later as the Royal Institution of Naval Architects, has been closely involved with the education and training of naval architects. Today, the Institution continues that involvement through its Student membership, its accreditation of academic and training courses, and its many awards and prizes which encourage and recognise the achievement of academic and professional excellence.

In the quadrangle of the Victoria and Albert Museum, South Kensington, there is a plaque commemorating the Centenary of the Royal School of Naval Architecture. The plaque was unveiled by the Institution's President, Viscount Simon, on 4 November 1964.

The Royal School of Naval Architecture was the third government school, and was the first to accept private students from the shipbuilding industry. The two earlier schools had been confined to apprentices in the Royal Dockyards.

The first government school was established in Portsmouth Dockyard in 1811, and was termed, "The Central School of Mathematics and Naval Construction" but closed in 1832. The second school was also established in Portsmouth Dockyard in 1848, and was closed some five years later. During this short period, some 20 Students were trained, including Sir Edward Reed, one of the founding members of the Institution.

In 1863, at the fourth annual meeting of the Institution of Naval Architects, John Scott Russell, builder of the *Great Eastern*, made an impassioned plea for a new British School. The Council agreed and a sub-committee was formed to "draw out a scheme with a view to the formation of a School of Naval Architecture." It proposed a three-year course with alternating periods of six months at the School and six (Summer) months at either naval dockyards or in private shipyards. The School was established in 1804 at South Kensington under the control and management of the Science and Art Department. This was considered by the INA to be much preferable than having the School under the control of the Admiralty, under whom the first two schools had been short-lived, and who considered that " the school should have been situated at a seaport, preferably Portsmouth, that the instruction would be too theoretical and not sufficiently practical and that future naval architects would learn more by being sent to sea"!

The School closed in 1873 and students transferred to the Royal Naval College, Greenwich. However, in its short life, the school trained many fine naval architects, including Sir William White, and amply justified the initiative and persistence of the INA.

Enabling Technology and the Naval Architect 1860 - 2010

By
Ian Buxton FRINA

Enabling technology permits the naval architect to do more with less, increasing capability, decreasing cost and improving productivity, with the resulting benefits being widely distributed in a worldwide economy. For example a bulk carrier's energy consumption per ton-mile today is less than 3% of what it was a century and half ago – more efficient machinery, larger hulls with lower resistance per ton and improved propulsive efficiency, and with higher speed and shorter port times.

The First Half Century

The 1860s were still a period of transition, from sail to steam and wood to iron. The thermal efficiency of most steam reciprocating engine was low at about 8% (2.5 lb coal/hp-h), which limited endurance as well as increasing fuel cost. Of the steamship types, the greatest number were colliers, ferries and tugs, although the liner companies like Cunard and P&O were expanding their fleets of long-distance passenger-cargo vessels.

On the theoretical side, Scott Russell had expounded his wave-line principle for hull forms, William Rankine had established the basics of ship strength, while William Froude was working out his theories on ship resistance and rolling.

The 1860s saw the first underwater telegraph cables laid, which greatly improved commercial communications and operating efficiency, as shipowners, agents and masters could be advised of available cargoes. Equally important was the opening of the Suez Canal in 1869, which gave a boost to long-distance trade to the eastern hemisphere, and putting another nail in the coffin of sailing ships. In the late 1860s, the compound steam engine was widely adopted with higher steam pressures. Specific fuel consumption was reduced, which translated into more cargo with the same power, or less power with the same cargo, as well as reduced fuel cost and fewer bunkering calls.

The compound engine gave way to the triple expansion engine in bigger ships from about 1880. With higher pressures of about 150 lb/sq in (10 bar), SFCs were reduced to about 1.5 lb coal/hp-h (13% efficiency). Such higher pressures required very thick iron plates in large boilers, so boilers began to be built in steel from that same date, requiring plates about 20% thinner. Siemens-Martin open hearth steel of consistent quality became available from about 1878. With steel production rapidly expanding and prices falling, the transition from iron hulls took only ten years. Its greater strength reduced steelweights by around 15%, while the larger plate size (up to 8ft wide in place of 4ft) reduced riveted joint length and construction cost.

The 1880s also saw the birth of two specialist ship types – the tanker and the refrigerated ship. Previously oil had been carried in wooden barrels or metal cases, prone to leakage and slow to load and discharge. The 3200-ton deadweight GLUCKAUF built on Tyneside in 1886 was the first successful bulk oil carrier, stowing cargo within the hull itself, with longitudinal and transverse bulkheads, and with machinery aft, and its own pumping and piping system, a concept that endures to this day, although the ships are one hundred times larger and double the speed. The first steam propelled fully refrigerated ships based on CO_2 arrived in the early 1880s, permitting the export of cheap frozen meat from countries like New Zealand, to feed the increasing urban populations of Europe. By the turn of the century, the steam trawler and ore carrier had been added, the latter especially on the Great Lakes.

Although the basic concepts of buoyancy and initial stability were well known in 1860, the calculation of large angle stability was onerous, yet capsizes of ships such as the ironclad *Captain* in 1870 had shown the need. Fortunately Amsler came up with his mechanical integrator in 1878, a concept later extended to the integraph, which allowed bending moments and shear forces to be calculated for demanding vessels like large passenger vessels or warships.

Froude's towing tank first at Torquay (in 1872) and then at Haslar, based on his law of comparison between model and ship, provided the means to explore a great variety of hull forms as well as predict power with greater confidence.

By this time, the major Classification Societies had become well established, Lloyd's Register starting in 1760 (100 years before RINA), Bureau Veritas in 1828 and Norske Veritas in 1864. As well as approving scantlings, these societies also assigned freeboards. Other late 19th century technical developments which enabled larger and faster ships to be built included forced draft for boilers and electrical generators permitting better lighting.

Into The 20th Century

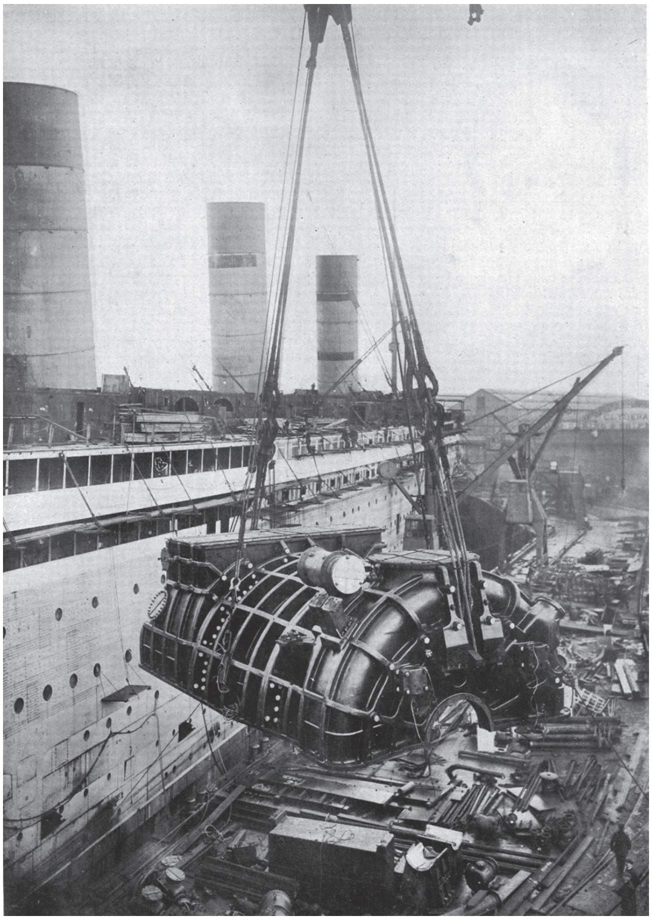
The most significant enabling technology at the start of the 20th century was the introduction of the steam turbine. The turbine offered almost unlimited power compared with the steam reciprocator. Following Parsons' experiments with *Turbinia* in 1894-97, Royal Navy applications progressed rapidly from destroyers to cruisers, and then to the battleship *Dreadnought* ordered in 1905. In parallel, merchant ships moved from the 3000-shp ferry *King Edward* in 1901 to the momentous decision by Cunard in 1904 to order 70,000-shp turbines for their 25-knot transatlantic liners *Mauretania* and *Lusitania*, a massive jump in capability that no engineer would risk today.

The early steam turbines were coal fired, so boiler capacity and firing rate were limitations on sustained power. New designs of watertube boiler were developed offering greater steam raising capacity, and by the early 1900s, successful designs of oil burner had been developed. From about 1914 all the major vessels of the Royal Navy used oil fuel. Although more expensive than coal either on a weight or calorific value basis, the weight of fuel was less, it could be stowed in awkward compartments like double bottoms and it greatly reduced the number of stokers.

The same decade (1900) saw the application of the oil engine to marine propulsion, initially only in small vessels. Its greatly increased thermal efficiency (32%) offered a lesser fuel load. After Burmeister & Wain had developed the directly reversible diesel, the way was clear to use them in deep sea ships, resulting in the Danish *Selandia* of 1912. Between the wars, different shipowners took different views on the diesel's potential problems of lower reliability, more expensive distillate fuel, greater maintenance and repair bills and more skilled operators.

There was little evolution of ship types between the two world wars, not so much due to lack of technology but due to economic stagnation with little growth in world trade. Apart from transatlantic liners reaching 80,000 grt and 30kts (*Queen Mary*, *Normandie*), cargo ships and tankers remained around the 8000 grt mark, whose speeds had barely increased either, with around 11kts. Particularly in passenger carrying ships, innovations were introduced such as partial air conditioning, fin stabilisers, gyro compasses, echo sounders; in tugs nozzle propellers and in a few smaller ships the first controllable-pitch propellers.

Welding came of age in the 1930s. Introduced in the 1900s using gas, the shielded electric arc was developed in time for WWI, where it proved useful in awkward repairs. But welding was regarded as expensive, unproven and less reliable than riveting, especially for main hull structures, so it tended to be used where there were clear advantages such as oiltight bulkheads in tankers. It took the high production demands of WWII to bring about the widespread use of welding. The huge emergency shipyards in the USA were laid out for all-welded prefabricated construction, with large welding bays, heavier cranage and ample storage space for units – and needing less skilled labour. But there were still problems to be solved with brittle fracture, requiring the development of notch tough steels in the late 1940s, and the need to integrate design and construction more closely, both in terms of detail design to remove stress concentrations and in block assembly methods. But welding brought significant performance advantages in terms of lower structural weight and in smoother hulls; by 1960 the transition was complete.



One of *Aquitania's* low-pressure turbine casings being lifted on board at John Brown's shipyard by their 150-ton crane, probably late in 1913. The steam turbine enabled much higher powers and speeds to be obtained in passenger ships and warships, compared with steam reciprocators

Post World War II

The last half of the 20th century saw the fastest ever evolution in ship development, with sizes increasing tenfold, and more new ship types and the container revolutionising general cargo transport, while on the naval side, the nuclear-propelled submarine changed warfare for ever. Postwar recovery saw a booming world economy, with oil replacing coal as the primary energy source. Tankers increased dramatically from

15,000 dwt to the first 50,000 dwt in 1956 to the 200,000 dwt *Idemitsu Maru* in 1962, culminating in the 550,000 dwt giants of 1976 like Shell's *Batillus*. Nearly all such vessels were built in building docks, some spanned by gantry cranes of up to 1000 tonnes capacity. An enabling technology was computer aided design, initially used to mechanise tedious naval architectural hand calculations from the late 1950s, but soon applied to structural analysis where finite element methods allowed ever larger tankers to be designed with greater confidence. In due course CAD was linked with computer aided production with full product models associated with numerically controlled machine tools.

The fourfold increase in oil prices in 1974 not only halted the growth of tankers but encouraged the search for offshore oil. While jack-ups were adequate in shallower waters, drilling in deeper waters required semi-submersibles. Motion analysis programs were essential, and coupled with dynamic positioning using thrusters, increased operability in all manner of offshore vessels.

The bulk carrier concept of a single-deck vessel with hoppered holds was not new, as it had been used in short sea colliers for decades. But it was not applied to deep sea ships until the late 1950s, although iron ore carriers with their small central cargo holds dated from the 1920s. Size grew steadily from the initial 20,000 dwt to over 100,000 dwt by 1968. The late 1950s and 1960s saw a great increase in specialist ship types, as demand for large volumes of cargoes like export motor cars justified a tailor-made design rather than a general purpose ship.

Liquefied Petroleum Gas (LPG) carriers were another 1950s development, where cargoes like propane could be liquefied either by cooling to about -48°C, or in smaller tanks by pressure alone. A more demanding technology was required for Liquefied Natural Gas (LNG) which liquefies at -1631°C, so requiring heavily insulated tanks separate from the main hull structure. The first purpose built LNG ship was *Methane Progress* of 27,400 m^3 in 1964 with aluminium alloy tanks. LNG carriers have now broken the 200,000 m^3 barrier.

The impetus for specialist ships comes when volume of a particular trade expands to a level sufficient to support a dedicated fleet. The increased efficiency and improved quality of cargo outturn can outweigh the lack of flexibility for alternative cargoes. It was the inefficiencies of the multi-deck general cargo ship that spurred the development of the container ship to reduce port time from a week or more to a day or so. Standardisation of container dimensions by ISO in 1965 paved the way for its widespread adoption. The now ubiquitous 20ft and 40ft boxes allowed mechanised handling and stowage processes and equipment to be developed. Such was the increase in productivity from larger faster container ships that one vessel replaced five or six break-bulk vessels, so all the main trade routes had been containerised by the mid-1970s. Since then the 3000 TEU (20ft equivalent unit) ship has grown to 14,000 TEU, although speeds have remained in the mid-20s knots. The short sea roll-on/roll-off vessel offered big reductions in port time where trailers could be used, as well as providing a drive-on/drive off facility for cars and trucks.

It was in the 1950s that the use of turbocharging in 2-stroke diesels and cheap heavy fuel oil enabled the slow speed direct drive engine to challenge the steam turbine in bigger ships. That remains the prime mover of choice today, although the emphasis is now on reducing emissions which require higher quality fuel. Geared medium-speed diesels had been developed between the wars, and postwar were favoured in smaller vessels and in low headroom ships like ferries.

Post WWII deep sea passenger vessels continued to be built in significant numbers. But long distance passenger sea transport had been overtaken by air transport by the late 1950s, so by the late 1960s all the large liners had been scrapped or converted to cruising. But as that door closed, another opened, the purpose built cruise ship. Ever larger and more luxurious floating leisure centres developed into today's 150,000 gt plus monsters carrying 4000 plus passengers. Transport of passengers is today focussed on short sea ferries, including vehicle transport. From the 1960s, high-speed craft began to challenge conventional ferries on short routes, with speeds of 35-50kts. With their inherently low lift/drag ratio, light alloys were needed to keep hull weight down and gas turbines often used to provide the high power, while waterjets were developed to ever higher powers. While fibre-reinforced plastic has been used in some high-speed craft, a much larger market has been in mass produced leisure craft.

Gas turbines have been the prime mover of choice for most high-speed warships from the late 1960s, derived from aircraft jet engines. High power-weight ratio and reduced manning have for military vessels outweighed the disadvantage of high fuel cost. Electric propulsion technology with high power density motors has increased the number of ships with full electric propulsion, especially those with a wide range of power demands, whether naval, commercial or offshore. Azimuthing thrusters have become the propulsor of choice for tugs, giving greater manoeuvrability as well as a smaller crew.

But perhaps the most pervasive recent influence has been the ever increasing technical regulatory demands and standards. Coordinated by IMO, the intent is to achieve international agreement before implementation by individual flag states. But the marine industries have for historical reasons had more fragmented regulatory regimes than land based industries, so adoption of readily applicable best practice takes time. So perhaps what the marine industries need in the next decades is to focus enabling technologies on getting the best out of well established concepts like steel hulls and internal combustion engines by improving reliability, operational efficiency and mitigating the safety and environmental impacts of ships, but without jeopardising the technical and economic gains of the last 150 years. The professional institutions have a continuing role in discussing and disseminating the best ways forward, largely using the English language, now universally adopted in the maritime industries.

On the Coating of Ships 1860 - 2010

By
M Raouf Kattan BSc (Hons) MSc PhD CEng FRINA

Coating technology has developed over time with new solutions emerging as a result of changes in materials, ship design, production requirements, operator expectations, regulations and environmental concerns. Today's technically sophisticated ships, are being coated with technically sophisticated coatings, but using application technology that has changed little since the inception of the Istitution of Naval Architects in 1860.

To 1860

By 1860, the main challenge for coatings was to prevent fouling growth on the ships. Hull roughness was already well understood (At the Battle of Trafalgar in 1805, Admiral Collingwood was able to engage the enemy sooner than the rest of the British fleet because his vessel had fitted new copper sheathing that was both smoother than the old one and foul free).

The wooden ships of that time had little need for corrosion prevention (worms were a bigger concern). The anti-fouling solutions had narrowed to two options, one was sheathing either by copper or zinc and the other by the application of some form of composition/ Graving - *a white mixture of Tallow, Sope and Brimstone, or Traine-oile, Rosin and Brimstone Boiled together, is the best to preserve her calking and make her glib and slippery to passé the water* – A Sea Grammar with the plaine exposition of Smiths Accidence for young seamen enlarged. J Smith Governor of Virginia and Admiral of England – 1627.

The use of compositions could arguably be traced back to Noah who was presented with the following owners specification for the Ark – "Make yourself an Ark of cypress wood, make rooms in the ark and cover it inside and out with pitch." Only having completed the paint specification did God go on to describe the principal dimensions of the vessel and its' General Arrangement (it would seem the first ship owner appreciated the importance of coatings).

The fact that there were problems with surface preparation appears to have been noted early - "*Before I begin on this subject, I shall give a few necessary cautions which ought to be minded in fitting and preparing the parts that are designed to be painted, otherwise your paint, (Which undeniably is a very good Preservative, if rightly apply'd) will be of little use or service*…..Sutherland: Of painting ship-work 1717". Sutherland was looking at paint as a preservative not as an anti-fouling and thus meeting concerns for asset protection.

Thus two distinct needs for coatings emerged by the 1700's, fouling prevention (and therefore vessel performance) and asset preservation. The science was not far behind. By 1625 William Beale had filed a patent for an anti-fouling composition. While in 1842 Sir Humphrey Davy was employed by the Admiralty to study the problems of corrosion on iron ships.

From 1860

It was not until the 1890's that other required features of coatings started to emerge, house colours becoming important as the nascent oil majors started to develop their fleets (Navies had carried house colours before). As refining capacity grew and, in parallel, food exports developed into a grain trade, cargo compatibility became important. Although no specific dates can be ascertained by the author, for the first coated chemical tanker (the vessels emerged in the early 1960's) or the first grain or freshwater compliant coatings (early 1970's).

During that time many developments have taken place (curious readers are directed to "On the Corrosion and Fouling of Iron Ships: 110 years on" by Dr A Milne - NECIES Junior Section, 11 March 1982; and "Speed-power performance in service. Can the effects of the bottom condition be assessed?" by Dr R L Townsin - 70th Andrew Laing lecture 2002, to show the influence of the INA in the dissemination of those) but the physics and chemistry have not changed and neither has the biology of fouling and so one must ask why are we still experiencing problems that require international regulation?

The science of corrosion came of age in the 1903 (see "Electrolytic theory of corrosion of iron" by Whitney, J. J - Am. Chem. Soc. P 397. 1903).

By the 1950's the Society for Protective Coatings (SSPC) started to produce many landmark publications to provide guidance to engineers on the preservation of steel structures.

By the 1960's vessel performance was established as a science/ engineering discipline with considerable work being undertaken at Newcastle University under the aegis of the Ship Performance Group, headed by Dr R L Townsin FRINA.

From the 1960's developments took place in surface preparation and application technologies, following the pickling of plates and the introduction of airless spray application in the early 1950's the first automated shop primer line was installed in the 1960's helping to improve productivity by better engineering. The coating solution envelope narrowed to the use of Self Polishing Co-polymer coatings based on Tri Butyl Tin (TBT) for anti-fouling (this improved vessel performance by an estimated 30%), epoxy-based coatings as anti-corrosives, polyurethanes for cosmetic finishes and phenolics for chemical tanks.

It is fair to say that the shipping industry arrived at a stable solution envelope with various coating product offerings differentiating themselves based on paint supplier expertise and knowledge, rather than differences in chemistry.

Five major factors emerged by the late 1980's and early 90's that upset the status quo and set the scene for the present day:

- Increased production rates at shipyards
- Health and Safety concerns
- Increased vessel size and complexity
- Environmental concerns
- Increased concerns over vessel safety

As shipyard productivity improved led by the Swedes and the Japanese, the need to integrate the coating into the production process became evident. By the 1980's the Japanese yards had already identified the importance of integrating the coating process into the ship build strategy (See "Integrated Hull Construction Outfitting and Planning (IHOP), L.Chirillo, US Department of Transportation Maritime Administration in cooperation with Todd pacific Shipyards Corporation. 1983"). However, it was not until the early 1990's that the coating process was identified as a production bottleneck (See "Painting and Ship Production – Interference or Integration" by Kattan, R. Townsin, R. Baldwin, L; RINA Conference on Corrosion 1994).

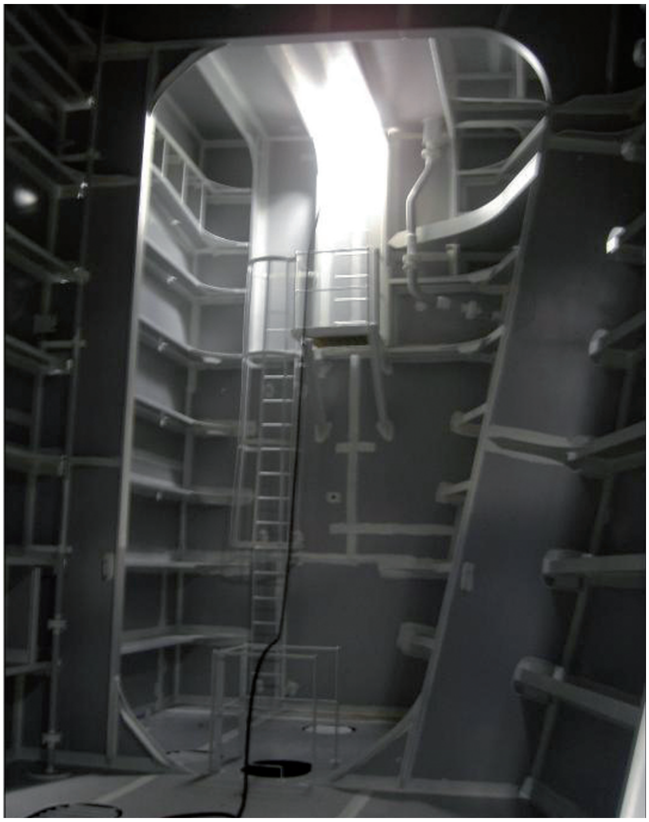
This posed a challenge to the industry as meeting the needs of the ship owner was no longer enough. The coatings also had to match the needs of the production process, in terms of drying time and over-coating intervals in particular and of course the number of coats in the scheme (to control man-hours), all these affected quality, cost and delivery at the shipyard. This became increasingly important as shipbuilding output was concentrating in fewer high-volume producing yards largely in the Far East. The increasing tempo of production placed pressure on the coating process, often resulting in a compromise on quality. In turn coating suppliers started to develop products to meet these new demands.

At the same time Health and Safety concerns were raised about the established anti corrosive products of the 60's and 70's resulting in the need for new developments in coating technology throughout the 80's and early 90's (explosions, worker exposure, skin sensitization).

These changes together with increased vessel size, structural complexity, extensive use of high-tensile steels and increased areas to coat (the introduction of the double hull increased ballast tank areas by 400%), subjected coatings to new challenges in operation and in production that resulted in new failure mechanisms being seen in the field.

Added to these changes the emergence of environmental regulations, also forced product development most notably through the ban of the TBT based anti-fouling products, resulting in the emergence of TBT-free and foul release coatings of various types, all of which have required time to move from development to widespread use and are not without new problems of their own.

Recently concerns over vessel safety have resulted in new IMO regulations that place greater onus on the yards and owners to manage coating activities to provide better anti-corrosion protection under the watchful eye of Classification Societies, while recent rises in the price of oil and emission concerns, have re-invigorated the drive to improve vessel performance and hence anti-fouling developments.



Ballast tank – showing complexity of structure that has to be coated

Market demand has moved away from the well established technologies and the coating industry has to develop products that meet these changes, the pace of which seems to be ever increasing.

2010 and beyond

Looking to the future, the key challenges arising are:

- Improved through-life maintenance
- Improved repair cycles (increased dry-docking intervals)
- Considerable reduction in the man-hours associated with new build coating work, including measurement and management of data
- Coating friendly vessel design
- Invasive species migration (ballast water treatment and underwater hull cleaning)
- Environmental and Health & Safety reporting

Over the next 150 years Naval Architects must rise to these challenges by developing a much better understanding of the needs of the coating systems requirements that protect the vessel and enable it to operate effectively. If the challenges are not met, then costs of asset preservation and vessel performance could prove to be prohibitive as the regulatory framework tightens.

Raouf Kattan is the Managing Director of Safinah Ltd.

The Development of FRP as a Ship and Boatbuilding Material

By
Robert Curry FRINA

The last 50 years have seen the development and introduction of new hull structural materials. One such development which has had a profound impact on the design and construction of smaller vessels has been fibre-reinforced plastic (FRP), more commonly referred to as composites.

In the Beginning: 1940 – 1960

It is generally accepted that the first FRP vessels were single-skin E glass-reinforced plastic (GRP) hulls, a series of which were built in the late 1940s as navy personnel craft. GRP was chosen because its strength to weight ratio was superior to either steel or aluminium. It also offered very good resistance to the harmful effects of the marine environment, low thermal conductivity, good fracture toughness at low temperatures and was considered relatively easy to repair. These attributes remain and, although there are disadvantages in the use of GRP and FRP, these generally only emerge as craft size increases above around 70m.

Even in the late 1940s, plastic had been used commercially for many years but without the use of fibre reinforcement. Plastics are made from synthetic resins that are produced from natural resources such as coal, oil, limestone, salt and water. Plastics are formed by curing resins from the liquid state to the solid state. Catalysts, hardeners, and accelerators are used to promote the curing process while additives are used to develop special characteristics such as fire retardant properties. Fillers are used to increase the volume of the resin and reduce costs.

For those first GRP vessels, the resins used for hull construction were unsaturated isophthalic polyester resins. To attain the necessary cured condition strength and stiffness, the liquid polyester resin was applied to plies of E glass chopped strand mat (CSM) and woven roving (WR). For a structurally efficient cured laminate it was essential that the void spaces between the fibres were, as far as possible, completely filled with the liquid resin or, in industry terminology, fully wet–out.

In the late 1940s and early 1950s FRP construction was carried out in a very practical way: so many plies of a given weight/meter squared of E glass CSM and WR for a specific craft length and frame spacing. Structural design theory did not then exist.

As with early steel shipbuilding, theory followed practice. The structural theories for the use of FRP were developed from general structural engineering theory, adapted to suit the different engineering concepts of FRP and the mechanical and chemical properties of the resin, fibres and core materials. Later, very valuable input was introduced from the advanced composite structural engineering theories of the aerospace industry.

The Engineering Concepts of FRP

Fibre reinforced plastic consists of plies of very high strength and stiffness fibres such as E glass and later for superior mechanical properties, carbon and aramid fibres. These are fully saturated in the liquid resin matrix, initially orthophthalic and isophthalic polyester resins and later for superior mechanical properties, vinylester and epoxy resins. Catalysts, accelerators and hardeners are used to promote curing. Additives are used to provide special properties and very limited, carefully selected fillers may be added to provide bulk. The cured laminate has suitable mechanical and physical properties for a hull structural; material. The advantages of the material provide a long, low lifecycle cost for the craft when properly maintained.

The elements of the laminate are complimentary to each other. Tensile and flexural strength and stiffness, and shear strength, are provided by the fibres. The cured resin matrix protects the fibres from physical damage while the strong adhesive bond of the resin to the fibres provides the laminate with the necessary strength and stiffness under compressive loads and the means of transmitting shear forces between the fibres.

Mechanical properties of the cured laminate depend on the mechanical and physical properties of the reinforcing fibres and the mechanical and physical properties of the cured resin matrix. Mechanical properties also depend on the strength of the bonds between the fibres and the cured resin and the percentage of fibre content of the laminate. Attainment of good adhesive bonds between the fibres and resin and a very low presence of void spaces in the cured laminate, requires the application of a quality assurance system throughout the building process.

FRP has a higher strength to weight ratio than either steel or aluminium, an extremely valuable property for a hull construction material. However, the modulus of elasticity is very low compared to steel and aluminium. This means much more elastic deformation under load with possibly undesirably large deflections and possibly a potential for harmful effects on the natural frequencies of the structure. This requires careful consideration to in extending the use of FRP to hulls of more than about 70 m in length.

1960 – 1980

Until the early 1960s FRP laminates were generally single-skin E glass fibre, CSM or WR, reinforced polyester. It was used extensively for smaller, high production, recreational craft where many hulls could be laminated and cured in a short time using the same female mould.

In 1960, the *Marine Design Manual for Fibreglass Reinforced Plastics*, authored by Gibbs and Cox, became the first major publication that addressed engineering theory for the construction of fibre reinforced plastic hulls. This Design Manual gave design criteria for both E glass reinforced single skin and sandwich laminates; design examples; design details; identified potential problem areas and enumerated mechanical properties based on test results of many different E glass fibre reinforced plastic laminates. The book was the foundation for establishing the technology of GRP as a boat building material and provided the means of extending the use of GRP to much larger vessels.

The Gibbs & Cox manual gave designers guidance for minimizing the disadvantage of low modulus of elasticity for local structure through the use of sandwich laminates, which are formed by two thin single-skin laminates enclosing a very light core material such as PVC foam. As the foam core weight is negligible, the sandwich laminate has vastly greater strength and stiffness for a lesser weight than a single-skin laminate. However, the greater number of potential failure modes of a sandwich laminate do require increased care in the design and a higher level of quality assurance during the building process. Also, the sandwich laminate has a much lesser resistance to impact damage than a single-skin laminate. Designers must take into account the drawbacks of the lighter weight hull structure, of otherwise comparable strength, against sea loads.

During the 1970s, responding to industry need, classification societies developed and published Rules for FRP hulls. In doing this, classification societies also developed standards for the building process and quality system, an important step in verifying that the constructed hull attained the required design strength. At this time, FRP was used primarily for most recreational craft, up to about 20m in length, for nearly all lifeboats, for many fishing vessels and for relatively large minesweepers.

Ocean Racing Yachts

By the late 1970s the design of sandwich laminates was well established and designers were looking at advanced performance FRP materials used in the aerospace industry, such as epoxy resins and carbon and aramid fibres, which had improved mechanical and physical properties compared to polyester resin and E glass fibres. These new techniques introduced a revolution in the design of ocean racing yachts.

Lighter, higher performance hulls which, for the same displacement, allowed greater ballast in the keels, offered improved racing speeds. Designers of ocean racing yachts for category 0, 1 and 2 ocean races regulated by the Offshore Racing Council (ORC) turned to epoxy resin reinforced by carbon, aramid and glass fibres to achieve this. The hulls were entirely of sandwich laminates, except in way of the keel structure, the mast and other critical locations where the concentrated loads were supported by thick single-skin laminates. While the use of advanced FRP laminates resulted in lighter hulls for the same strength, those same advanced composites also demanded more sophisticated design and higher construction quality assurance to realise their full potential.

Inevitably there was a learning period. Not all of the potential failure mode mechanisms for advanced composite hulls had been identified for inclusion in the design criteria available at that time. As a result, there were some prominent hull structural failures of these high performance yachts during severe weather.

This led the ORC to decide that a structural standard was urgently needed for offshore, ocean racing yachts constructed of advanced FRP materials, as well as conventional FRP. The ORC contacted ABS and proposed that ABS, together with the International Technical Committee (ITC) of the ORC, develop this structural standard for offshore racing yachts. Two members of ABS and three members of the ITC developed the standard based on input from many prominent racing yacht designers.

The resulting ABS *Guide for Building and Classing Offshore Racing Yachts* also included extensive requirements for the building process and quality system, recognizing this as an important component of the design strength being attained in the completed hull. Following publication in 1981, the ORC required all yachts racing in Category 0, 1 and 2 races to comply

HMS *Wilton* was the first warship in the world to be constructed from glass reinforced plastic

with these standards. ABS carried out plan review to verify compliance.

1980 – 2000

The introduction of criteria for advanced composites in the Guide proved to be a major step in the development of FRP as a hull construction material. From 1981 until at least 1995, valuable experience was gained from the service of advanced composite racing yachts exposed to long periods of severe weather. By this time classification societies such as ABS, BV, DNV, GL, LR and RINA had developed Rules for FRP Yachts, High Speed Craft, and later High Speed Naval Craft.

Due to its light weight and resistance to corrosion, FRP was also being considered for the superstructures and deckhouses for large steel or aluminium ships as well as for masts, propeller shafts and structural outfit items.

During this time, a number of manufacturers of advanced composite materials emerged, with an initial emphasis on the manufacture of epoxy resin systems and the use of carbon and aramid fibres. Since then they have continued to develop the manufacturing capabilities and today provide excellent technical services, including design services. At the same time, some design houses specialising in the design of composite hull structures, started to provide design services. There is no doubt that these companies have extended the design knowledge of the use of advanced composites.

Today

Today, most recreational craft up to about 35m in length are constructed of FRP, the largest being 90m in length. In addition, many high-speed craft such as high-speed passenger ferries, high-speed military craft, and RNLI lifeboats have adopted FRP construction where the material's equivalent strength for lighter weight and low maintenance needs are recognised as valuable performance and cost saving assets. Highly notable are the 72m Swedish navy sandwich FRP "Visby" class corvettes.

Visby Corvette - the hull material is of a sandwich construction comprising a PVC are enclosed in carbon fibre reinforced vinyl skins

The offshore industry uses FRP for risers and other applications chosen for their mechanical properties and ready repair properties. FRP contributes to the renewable energy industry with carbon-fibre reinforced laminates being used for the blades of wind turbines.

RNLI Tamar class lifeboat - FRP construction

The Future

Presently there is research into the use of FRP for superstructures and deckhouses on large steel or aluminium ships. This and other uses of FRP beyond its present limits are now under consideration and await further advances in technology or innovation to remove some of the remaining barriers.

There are, of course, both advantages and disadvantages in the use of FRP as a hull construction mat. In many cases, the disadvantages will be overcome by developments in FRP technology, or can be minimized by careful design. However, the negative perception of FRP as a hull construction material, still held by many, results in a reluctance to accept the advantages of FRP and to focus on its disadvantages. Greater awareness of the current capabilities of FRP technology and further advances in FRP technology are needed if such misconceptions are to be overcome and FRP construction is to be extended to large ships.

Bob Curry has been involved with FRP Structures throughout his long career with ABS, particularly with the rule development of the hull structural requirements for high speed craft , motor yachts and sailing yachts. He tutors on hull structures at Lloyd's Maritime Academy, is the UK member for the ISO WG Large Yacht Safety and has written many papers on FRP structures.

Passenger Ship Survivability Regulations 1960 - 2010

By
Dr Tom Allan BSc DSc. CEng FRINA

It is appropriate that the first real damage stability requirements for passenger ships were agreed at IMCO (now the International Maritime Organization (IMO)) in 1960, on RINA's 100th anniversary. Much water has gone under the proverbial bridge since then and much has happened to damage stability requirements as they apply to passenger ships during the past 50 years.

By coincidence during the Institution's 100th anniversary in 1960 the International Maritime Consultative Organisation (IMCO), the UN specialised agency solely concerned with maritime safety and pollution prevention, held what was primarily the first major international diplomatic conference on the Safety of Life at Sea (SOLAS). The resulting SOLAS convention was the forerunner to all the current international safety legislation that applies to the maritime industry today.

With regard to passenger ships - Regulation II - 7(f) of the International Conference on the Safety of Life at Sea (SOLAS) 1960 stated:

The final conditions of the ship after damage and, in the case of unsymmetrical flooding, after equalisation measures have been taken shall be as follows:-

(i) in the case of symmetrical flooding there shall be a positive residual metacentric height of at least 2 inches (0.05M) as calculated by the constant displacement method;

(ii) in the case of unsymmetrical flooding the total heel shall not exceed seven degrees, except that, in special cases, the Administration may allow additional heel due to the unsymmetrical moment, but in no case shall the final heel exceed fifteen degrees; and

(iii) in no case shall the margin line be submerged in the final stage of flooding. If it is considered that the margin line may become submerged during an intermediate stage of flooding, the Administration may require such investigations and arrangements as it considers necessary for the safety of the ship.

It is also appropriate that the first real damage stability requirements for passenger ships were agreed at IMCO (now the IMO) in 1960 on RINA's 100th anniversary. Much water has gone under the proverbial bridge since then and much has happened to damage stability requirements as they apply to passenger ships during the past 50 years.

It is difficult to believe that ships such as the *Queen Elizabeth 2* (1969) were built to these standards and for the *QE2* to survive with much aplomb for the next 40 years. In essence these new regulations would not be acceptable today as anything like a sufficient survivability standard. But of course the *QE2* was a well maintained ship; well manned and well operated throughout her life; which some may say is just as important as any safety / survivability standard.

It was not until the late 19th century and more so post-*Titanic* that final agreement on a sub-division requirement was initially reached in about 1929. It is also interesting to note, from periodicals at the time, that in the view of some naval architects "there appeared to be no need for damage stability requirements as passenger ships of those days had relatively narrow beams and deep draughts which it was surmised provided sufficient residual damage stability!"

However, design criteria did change over the following years as many of the ships of the day capsized before sinking. It was the 1948 Convention that first introduced the above requirements which stood, almost without alteration, until the 1974 Convention on SOLAS.

One quote from the 1960 Conference is probably worth repeating: "*The Conference has considered carefully the question of watertight subdivision of passenger ships in the light of the results achieved since the international Convention on the safety of life at Sea 1948, came into force and has agreed on certain additional requirements calculated to secure greater safety. It recognises however, that the questions of watertight subdivision and stability deserve further study which the limited time available to the present Conference did not permit, and accordingly recommends that the Organization should at the earliest practical date initiate further studies of watertight subdivision on the basis of proposals which*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any participating Government may submit, including proposals submitted to the Conference. The objective should be to review the existing criteria of subdivision, stability and damage and to consider the relative merits of these criteria in comparison with other possible criteria from the point of view of safety and practicability."

In the paper to the RINA Transactions on the 1960 SOLAS Conference by R J Shepherd (then Chief Ship Surveyor, Ministry of Transport) concern was raised to, what to-day would appear to be very minimal standards? A comment by Mr R Turner stated that: "*the amount of initial stability required in order to satisfy the damaged stability conditions is more than adequate to deal with the most unlikely coincidence of unfortunate circumstances tending to heel the intact ship. Watertight subdivision and the associated damaged stability therefore become the most important subjects to be considered in the I.M.C.O. rules*." However, he later goes on to say "*We are particularly anxious regarding the volume of detailed calculation required to cover the large number of cases to be considered in connection with damaged stability.*"

The later point is significant in that when a few years later the Ministry of Transport carried out damaged stability calculations on the new *QE2*, while a large number of initial calculations were made, only one full hand calculation was carried out on the one identified and most probable damage case. It was not until the early 1980's that the *QE2* was re-defined to be placed on a computer at which stage some 30 damages were then carried out. In comparison the world's largest passenger ship built today the *Oasis of the Seas* had some 9500 damage cases carried out in conjunction with compliance with the new probabilistic damage calculations.

In SOLAS '60 the new Subdivision and Stability regulations contained all the requirements for Floodable lengths; Permeability; Permissible Lengths; margin line; special Rules concerning subdivision and Stability of ships in a Damaged Condition. For those of a "younger age" reading this I would recommend looking through the archives for what I mean by floodable and permissible lengths – the computation of which was – to say the least – interesting!

By the time we get to SOLAS '74 the same regulations re-appear almost in their entirety. However, from 1984 (SOLAS '84) amendments were agreed on a regular basis through to 2010 when the final set of amendments introducing the probabilistic approach to passenger ship survivability came into force.

Apart from the change over from the deterministic approach to the current introduction of the probabilistic approach, two main incidents resulted in the first real changes in the survivability requirements. The first was the capsize of the *Herald of Free Enterprise* in March 1987 and the second the loss of the *Estonia* in September 1994.

For the *Herald*, the prime reason for the capsize was that she went to sea with her bow doors open and trimmed by the head until sufficient water entered her hull to make her unstable. While various preventive measure were immediately put into place to prevent a similar incident taking place the UK administration also looked at the stability standards applying to ships at that time. Most ships post 1980 operating in the UK were required to have a higher standard of residual stability than that required by SOLAS 1974. The UK '80 standards were higher in that not only do they require that the margin line is not submerged during any stage of flooding but also required a specific residual GZ and range.

In looking at the stability of ro-ro passenger ferries it must be recognised that in 1980 the positive margin of stability in the damaged condition was never very great. There are many different ways that slender margins could be reduced to nothing whether through uncertainty about the draughts, the weight of cargo carried or its distribution, or because of growth in the lightship weight or indeed the trim of the ship. It was therefore decided that each passenger ship should be inclined and its current lightship established on a regular five-year basis. Furthermore UK ships, if not already complying with the 1980 UK residual stability requirements, had to be so modified to comply or a short and finite term was put on their lives.

Post *Estonia* the IMO took instant action in referring the whole issue of ro-ro ferry and passenger ship safety to a panel of experts. The "survivability" group in the panel, in particular, looked at three new proposed regulations – these were to apply new standards in both the intact and damaged conditions as follows:

- Regulation 8-1 – stability in the damaged condition;
- Regulation 8-2 – stability in the intact condition; and
- Regulation 8-3 – one compartment ships.

Regulations 8-1 and 8-2 both addressed the problem of water on the car decks. But just as important, the new regulation 8-3 now prevents the construction of one compartment passenger ships from carrying large numbers of passengers. The limit is now restricted to 400 passengers.

It was accepted that from a naval architectural point of view that revised GZ criteria would be the best way forward, however, it was also accepted that it would not be possible to devise and validate criteria in the time made available to them. It was at this stage that the Panel agreed, as a first step, to accept one of the conclusions of the UK research post *Herald* which stated that – "Ro-Ro passenger vessels constructed to meet the standards of SOLAS '90 were capable of avoiding capsize after an assumed extent of damage in moderate sea states with a significant wave height up to 1.5 metres." This research was the first to actually consider water movement on board ships in the damaged condition.

Having accepted wave heights of 1.5m as a minimum, in association with a residual freeboard of 0.3m the question became - in what sea state should ferries be expected to survive? After considerable debate this was taken as 4.0m as based on available statistics that 99% of all collisions occur in sea states up to 4.0m significant wave height. It was also importantly felt that this was a sea state that could be recognised as a significant standard for survival.

However, in the end those areas of the Panel's proposals relating specifically to survivability proved to be the most contentious. At the 1995 SOLAS diplomatic conference the majority of countries rejected the Panel's proposal for worldwide survivability standard of SOLAS '90 plus 50 cms of water on deck. In the end SOLAS '90 was accepted as the world wide standard for all existing passenger ships while Northern European countries separately agreed to apply the higher standard in their areas of operation. The other important issue established at this stage was the opportunity for ferry operators to alternatively use model tank testing to show the survivability aspects of a particular ferry in an agreed sea-state.

I believe this last point has allowed the knowledge of naval architecture to move forward at a faster pace that would have originally been envisaged. The use of model testing of passenger ships, in the damaged condition, and in a significant seaway, has permitted naval architects a better understanding of the characteristics of the movement of water within the ship and the resulting reaction of the ship in a seaway. In particular it permitted the investigation of the actual movement of water upwards and the consequential flooding of spaces that would not have been expected to flood from the use of calculations alone. This is a tool which all designers of passenger ships must, in my opinion, make more use of in future designs.

The Future

As of 1 January 2009 all passenger ships constructed on or after 1 January 2009 shall be built to the new probabilistic methodology. So now, gone are the days of the floodable and permissible lengths and "positive" residual survivability. Now all passenger ships will have to be designed to meet a required probabilistic index. This index will, I am sure, also be under as much scrutiny in the years to come as "positive" survivability in "still-water conditions" did over the past 20 years. I do not believe we have seen the end to the improvements as I consider the current index will be seen by many as needing improvement and refinement as more experience is gained in designing ships using the new methodology.

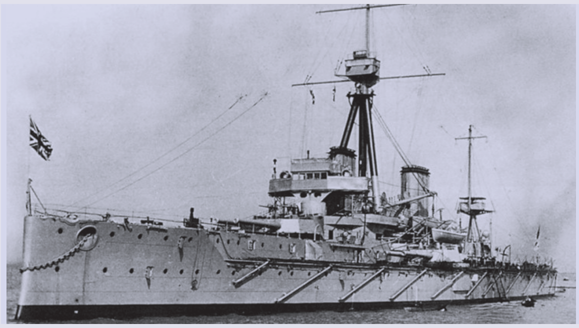
Does the new methodology result in a better and safer design? – I trust that it does, in that it gives the naval architect more flexibility in the design and allows him/her to improve suspect areas with a freedom that was not available with the old deterministic approach. Will an index of 0.80 to 0.85 be acceptable in the future? I doubt it. I have already seen that with a great deal of thought and judicious re-arrangement of watertight / weather-tight features the index can be improved to the higher regions of 0.95 to 0.98. This will surely be the aim in the future. We will never have the illusive "unsinkable" ship but I do believe that with the right attitude and co-operation between all involved that these higher figures can be achieved

So from the passenger ship of the 1960's the *QE2* :– 70,327 GT; 293.52 m in length with a passenger ship capacity of 1900 with one fully hand calculated damage condition to the passenger ship of today *Oasis of the Seas* – 225282 GT, 360m in length and a passenger capacity of up to 6250 with over 9000 damage cases analysed by probabilistic calculations; the enhancement in naval architecture over the last 50 years will, I am sure, be further exceeded when my successor writes about the advancement of survivability requirements at RINA's 200th anniversary in 2060? We have lost the "permissible length, "Floodable length", "the margin line"; "positive residual stability" and of course the "B/5" line what will we lose in the next 50 years?

Tom Allan is a former Director of the UK Maritime & Coastguard Agency and former Chairman of the IMO Maritime Safety Committee.

Sir Phillip Watts KCB LLD DSc FRS, 1846 - 1926

Members visiting Headquarters will have often passed the two busts which stand in the foyer. However, only the more observant will have noticed that one is a memorial to Sir Phillip Watts, the distinguished naval architect, presented by and subscribed to by members of the five societies with which Sir Phillip was associated – the Worshipful Company of Shipwrights, the Royal Society, the Smeatonian Society of Engineers, the Institution of Civil Engineers and the Institution of Naval Architects. And even fewer members will be aware that the bust was received on behalf of the Institution of Naval Architects in 1928 by the Right Hon. Winston Spencer Churchill, CH, MP, then Chancellor of the Exchequer and previously First Lord of the Admiralty, and an Honorary Fellow of the Institution.



HMS *Dreadnaught* 1906

A graduate of the Royal School of Naval Architecture, his first appointment was with the Admiralty and involved making various calculations in connection with the design of new ships. In this capacity, he used his scientific knowledge by calculating the proper sizes of various parts of a ship's structure, and did much to assist in breaking down the tradition of long standing, of determining the scantlings of many parts by custom or precedent. He was later to be appointed to assist William Froude in his investigations into the laws relating to the resistance and propulsion of ships.

He retired from the Admiralty in 1912 after 10 years as Director of Naval Construction, during which time HMS *Dreadnought* was designed and built, and it is perhaps in connection that this vessel more than any other that Sir Phillip laid claim to be one of the world's greatest naval designers.

Sir Phillip Watts became a member of the Institution in 1873, was elected Member of Council in 1885, Vice – President in 1901 and was made an Hon. Vice-President in 1916.

150 Years of Self Regulation in the Maritime Industry

by
Alan Gavin BSc, CEng, FRINA, FIMarEST

In the second half of the 18th Century, a large proportion of the world's merchant shipping was operating out of London. Insurers would meet with shipowners to insure ships and cargoes being transported by sea. The insurers realised that there was no information on the condition of the ships for which they were providing insurance cover and they were becoming deeply concerned over the increasing losses or ships and cargoes. They formed the 'Society for the Registry of Shipping', which eventually became known as Lloyd's Register.

Origins

Self regulation in the maritime industry was born out of the introduction of classification as a concept in 1760 in London, England. In the second half of the 18th century, a large proportion of the world's merchant shipping was operating out of London. Underwriters would meet with shipowners to insure ships and cargoes being transported by sea. There was no information on the condition of the ships for which they were providing insurance cover and they were becoming deeply concerned over the increasing losses of ships and cargoes. They formed the 'Society for the Registry of Shipping', which eventually became known as Lloyd's Register, to provide this information and better inform the insurer. The classification society employed surveyors with technical knowledge gained through many years practical experience at sea to assess the condition of the ships. The *Register Book* listed details of the ships classed.

In 1834, Lloyd's Register issued the first comprehensive Rules for the Classification of Ships and regulations covering the governance of its organisation and the conduct of it surveyors. These simple rules were expanded to include examination of steam engines and tables listing different types of wood used in ship construction. The first iron-built ship to be classed was Sirius in 1837, even though iron construction was known from the 18th century. In 1844, the Rules included a section entitled '*Ships Built of Iron*'. These rules could be said to be the start of a period of 150 years of self regulation. In 1855, Lloyd's Register published its first '*Rules for Iron Ships*' setting minimum requirements for ship scantlings . At this time, the Register Book listed 11,027 ships of which 9020 were classed. As knowledge increased, the Rules became more complex. Rules for different construction methods such as composite, wood and iron were introduced. The first steel ship classed with Lloyd's Register was the screw steamer Annie and built in 1864. Rules for new ship types, such as tankers, turret deck vessels and Rules for refrigerating machinery, were introduced in the latter half of the 19th century.

From 1764, the first classification system was developed and ships given a class notation after inspection. Lloyd's Regsiter assigned the letters A, E, I, O, U to denote the condition of the hull and G, M and B (good, middling and bad) for the condition of equipment (sails, ropes, rudder, etc). The equipment notation G, M, or B was later replaced by 1, 2 and 3. The highest class was therefore AG and the lowest UB. In 1768, the highest class AG was replaced by a1, this became A1 in 1775 and led to the notation 'A1 at Lloyds' entering the English language and being synonymous with the highest quality. The class of the ship was published in the *Register Book*. This is the origin of the term 'class' or 'classification', the origin of the class notation 'A1' for ships, and the origin of classification societies being termed 'registers of shipping'.

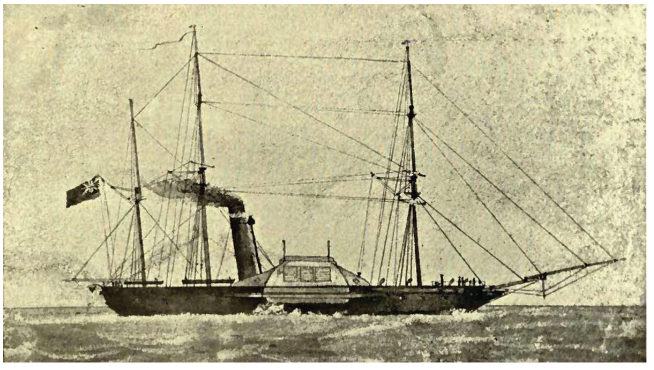


Illustration for LR Rules for Composite Ship 1866

Classification and Statutory Regulations

In the mid 19thcentury, the first statutory regulations were issued. The first was the British Merchant Shipping Act of 1854 following the grounding and loss of the ship HMS *Birkenhead*. This was followed by the Merchant Shipping Act of 1876, made famous by Samuel Plimsoll, which established minimum levels of freeboard for merchant ships. Lloyd's Register took the initiative over load lines in 1835, instituting what became known as 'Lloyd's Rule'. In 1874, Lloyd's Register's Rules specified a compulsory load line for awning deck ships newly built to class, marked on the hull with a device consisting of a diamond with a bar at each end and LR on either side of the bar. In 1875, load lines were retrospectively assigned to all ships of this type. By the end of the 19th century, most shipping nations had introduced legal requirements addressing safety at sea.

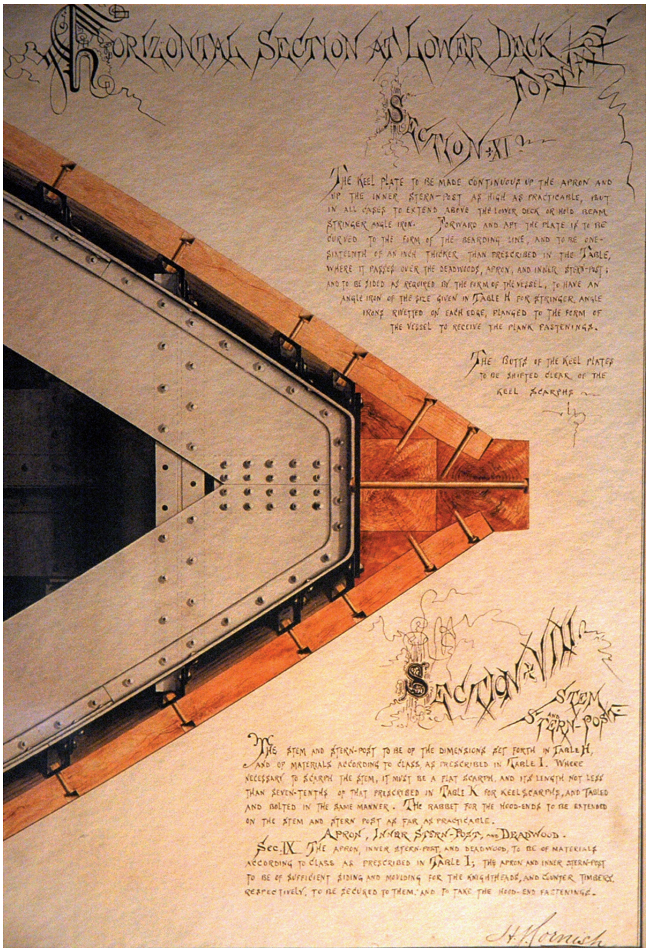


Illustration for LR Rules for Composite Ship 1866

This process continued until well after the Second World War, leading to ships being subjected to a combination of international classification rules and different statutory requirements depending on their country of registration (the country flag the ship flies and later called the ship's flag Administration or flag State). The statutory standards and requirements varied considerably from country to country and were sometimes contradictory.

It was generally accepted that this situation was unacceptable for global shipping and this led, in 1948, to establishing the Inter-Governmental Maritime Consultative Organization (IMCO). This became the International Maritime Organization (IMO), in 1982, an agency of the United Nations. One of the most important tasks assigned to IMO was the development of international standards which would replace the multitude of national legislation that existed. IMO concentrated on standards for safety, floatability and pollution, and accepted that the rules for the ships structure, and its machinery, would be provided by the classification societies.

The first classification society was Lloyd's Register of Shipping (LR) which was founded in 1760 in London. This was followed by Bureau Veritas (BV) in 1828; Registro Italiano Navale (RINA) in 1861; American Bureau of Shipping (ABS) in 1862; Det Norske Veritas (DNV) in 1864; Germanischer Lloyd (GL) in 1867; Nippon Kaiji Kyokai (NK) in 1899; Russian Maritime Register of Shipping (RS) in 1913; China Classification Society (CCS) in 1949; and Korean Register of Shipping in 1960.

A considerable number of other classification societies were formed in the 20th century; notably – Hellenic Register of Shipping (founded Piraeus 1919); Polski Rejestr Statkow (founded Warsaw 1936); RINAVE Portueguesa (Portugal); Croatian Register of Shipping (founded Split 1949); and Indian Register of Shipping (founded Mumbai 1975). ACS Unified Requirements Z10.1, Z10.2, on the Enhanced Survey Programme for tankers and bulk carriers adopted by IMO in 1995 as IMO Resolution A.744(18). This has been continuously updated by IACS/IMO. This allows for more comprehensive and wider coverage of inspecti

International Association of Classification Societies

Most classification societies developed rules and procedures separately from each other although some were initially based on those of established class societies . This changed with the formation of the International Association of Classification Societies (IACS). IACS had its origins in the International Load Line Convention of 1930. The Convention recommended that classification societies secure "*as much uniformity as possible in the application of the standards of strength upon which freeboard is based …*".

The Italian classification society, RINA, hosted the first conference of major classification societies in 1939. The conference was attended by ABS, BV, DNV, GL, RINA and NK, who agreed on further cooperation between societies.

The second major class society conference was held in 1955. This led to the creation of Working Parties to address specific topics and, in 1968, to the formation of IACS by the seven leading classification societies – ABS, BV, DNV, GL, LR, NK and RINA. The value of their combined and unique level of technical knowledge and experience was recognised and, in 1969, IACS was granted consultative status at IMCO. It remains the only non-governmental organisation with Observer status at IMO which is able to develop and apply technical rules. In 2009, IACS had ten member classification societies – ABS, BV, CCS, DNV, GL, KR, LR, NK, RINA, and RS. The number of members is expected to increase in 2010 after the review of IACS' organisation by the European Competition Commission.

IACS develops Unified Requirements (URs) through joint working groups of its members drawing on their experience and expertise. These are published and adopted by each of its members. The URs have specific suffixes – A for mooring, E for electrical, F for fire protection, G for gas tankers, I for polar class, K for propellers, L for load line, M for machinery, N for navigation, P for pipes and pressure vessels, S for strength of ships, W for materials and welding, and Z for surveys. The most notable recent harmonised rules are the Common Structural Rules (CSR) for Oil Tankers and the Common Structural Rules for Bulk Carriers.

The major classification societies, through IACS, have been responsible for major enhancements to maritime safety over the last twenty years; of particular note are the following:

- Ions on oil tankers and bulk carriers. IACS identified the significant safety and environmental risks from these ships as they age and maintenance reduces. The introduction of these standards has significantly reduced the number of losses, ships and lives, and pollution from these ships.
- IACS Bulk carrier safety initiatives covering new bulk carriers and retrofitting existing bulk carriers were adopted by IMO as Strength Standards and referenced in SOLAS chapter XII. In the 80s and early 90s, there was a considerable rise in the number of bulk carriers damaged and lost, with corresponding increase in the loss of seaman's lives. IACS initiatives provided for major increases in strength standards for new ship and retrofitting structure to strengthen existing ships.
- IACS Formal Safety Assessment study for IMO on the safety of bulk carriers. IMO continued to review and investigate the causes of bulk carrier losses in the 90s and 2000s. IACS carried out an in-depth formal safety assessment which formed the background to new IMO legislation.
- Development of bulk carrier safety requirements resulting from the reopened formal enquiry into the loss of the *Derbyshire*. The UK's formal enquiry completed in 2000 recommended that IACS develop specific requirements for sea loading on deck and an increase in hatch cover strength. IACS introduced these rules in 2002 and they were applied globally to all new construction.
- Development of the formula for the determination of the loads on the hatch covers of bulk carriers for incorporation into IMO Load Line Convention.
- Post *Estonia* requirements for the bow/side doors for new ships and with retrospective application to existing ships. The ro/ro passenger ferry Estonia capsized and sank in bad weather in the Baltic in 1994 after failure of the bow door and the flooding of the car deck. It was identified that there were not sufficient residual measures in place should there be a failure of the bow door. IACS set a working group to study all aspects of bow doors on ro/ro passenger ships and introduced new criteria for new ships and retrofitting strength requirements for existing ships. Within a two year period, all IACS classed ships had been modified.
- Common Structural Rules for bulk carriers and tankers. Requested by Industry Associations, the IMO and the European Commission. From 1st April 2006, all IACS members applied the same rules for all new build oil tankers and bulk carriers.
- Formulating with IMO States the Goal based framework for classification rules. IACS developed the draft rule making process for IMO that provides the overarching goals, functional requirements and verification processes for rule making. Initially to be applied to class strength rules, these standards will eventually provide the process for all IMO regulation development.
- TOCA, Transfer of Class Agreement, (required through Agreements with flags, EU Directive 94/57/EC, and incorporated into IMO Circular MSC-MEPC.5/Circ.2),
- TCMS, transfer of certification of management systems,
- TOSCA (transfer of ISPS Code certification),
- Early Warning Scheme,
- Transparency of class status information. IACS members provide online class data to the international database EQUASIS which also serves the SIRENAC database used by Port State inspectors.
- Development of the supporting procedures for the implementation of IMO ISM Code and the training material for auditors,
- Development of the supporting procedures for the implementation of IMO ISPS Code and the training material for auditors,
- At the request of IMO – development of unified new construction survey requirements,
- Production of a number of Guidance for Industry on various safety aspects:
- Safe Loading and Unloading of bulk carriers,
- SARQS (ship construction and repair quality standards),
- General Cargo Ships – Guidelines for surveys, assessment and repair of hull structures.
- Post *ERIKA* measures – IACS requirements introduced into IMO resolutions A.744(18),
- Development for IMO of requirements applicable to the design and construction of shipboard fittings and supporting structure (to support SOLAS regulation II-1/3-8),
- At the request of IMO and in collaboration of selected Governments – development of unified requirements for ships operating in ice covered waters (Polar class requirements), which provides the basis for the IMO Guidelines for ships operating in Arctic ice covered waters (MSC Circ 1056) (the IACS Unified Requirements are directly referenced in the Circular),
- Study into safety of general cargo ships – UR Z7.1 on hull surveys for general cargo ships (IMO currently reviewing for inclusion in SOLAS),
- Development of IMO Condition Assessment Scheme requirements for the safe phase out of single hull tankers,
- Continuous development of interpretations of IMO Conventions, submission to IMO for adoption (IACS is the only organisation that has its own item on the work programmes of IMO Sub-Committees),
- Development for IMO of Technical Provisions for means of access for tankers and bulk carriers, unified interpretations and guidelines,
- Development of Formal Safety Assessment training courses - which are now offered world wide at request - to support the use of FSA as a tool in the IMO regulatory development process, and
- Development and application (on behalf of the Governments) of procedures directed at raising the quality of fleet of poorly performing flags. Port State Control inspection result in detentions of ships in port where the ship does not comply with international regulations. The annual reports of the Port State Control authorities issue lists of ships detained and the countries (flags) where the ship is registered. A Black List of Flags is provided by the authorities and IACS developed procedures to raise the quality of these flags.

Classification is a statutory requirement under SOLAS (Safety of Life at Sea) but has remained separate for 150 years. With the adoption by IMO of their new Goal-based standards for rule-making, the maritime industry is entering a new phase where classification rules will be reviewed and accepted by IMO. Initially the Goal-based standards will be applied to rules for oil tankers and bulk carriers and, eventually, expanded to cover all classification and statutory rule-making.

Today, ships are classed by a large number of classification societies to different standards. The main standards are formulated by the IMO, IACS, and the classification societies in IACS, and applied to the majority of ships trading internationally. There are still a significant number of ships for which the standards are not known, as over 50000 are not classed by IACS members.

The IMO, the European Union and the majority of National Governments are dedicated to raising standards for ships at sea. They rely on the technical expertise of classification societies to formulate harmonised classification rules and to provide the specialist knowledge, and background data from ships in service, to develop the international statutory regulations. Classification rules and statutory regulations form the integral standards for today's ships. The relationship between these standards is of paramount importance to providing safe, robust and long-serving ships.

The Future

Many have asked the question whether it is safe for an industry to be self-regulated. Objectors point to the air industry and its international regulations and contend that a similar policy be adopted for marine. However, the air industry only has a few major manufacturers and few designs in comparison with the multiple shipbuilders and ship designs. Air manufacturers are responsible for their own designs and licence specific companies to maintain and repair their aircraft. This is a completely different situation than the maritime industry. Maritime self regulation has arguably resulted in the safest worldwide transportation system; statistically safer than road, train or air travel. However, that does not mean that there is still not more to do.

The European Commission require classification societies under their jurisdiction to have rules and procedures for increasing safety and preventing accidents and pollution. These rules must be implemented in such a way that the classification society remains in a position to derive from its own direct knowledge and judgment a reliable and objective declaration on the safety of the ships concerned by means of class certificates on the basis of which statutory certificates can be issued, and that they provide worldwide coverage by its exclusive surveyors. I would wish that this was the case worldwide.

The main Port State Control regions (Paris MOU, Tokyo MOU and USCG) list over 70 'classification societies' that issue classification certificates on ships that they inspect. 10 of these are members of the International Association of Classification Societies and meet the European Commission's criteria. At best, a further 10 have rules and procedures with various degree of capability to develop and maintain their own rules. This would suggest that around 50 classification societies do not meet the Commission criteria. Whilst I am not in agreement with all the Articles within the European Commission requirements for classification societies, I consider that the basic criteria should be applicable worldwide to classification societies.

In 2010, the Royal Institute of Naval Architects celebrates its 150th anniversary and Lloyd's Register its 250th anniversary, I would urge the main maritime nations to address the issue of low standard classification societies by reviewing, auditing and approving those classification societies under their control, and for the underwriters, who instigated self regulation, to cease insuring ships 'classed' by organisations that do not meet basic criteria for classification societies. In this way, the industry can ensure that the 250 years of self regulation, that has provided a high level of maritime safety, can continue and improve for the future.

Alan Gavin retired from Lloyd's Register in 2009 after 35 years with LR and 10 years as LR's Marine Director.

Events of 1860

Launch of HMS *Warrior*

HMS *Warrior*, Britain's first iron-hulled, armoured battleship, designed and built as Britain's answer to the French *La Gloire*, was launched on 29 December by the Thames Iron Works & Shipbuilding Company, based at Blackwall, London.

HMS *Warrior* in drydock

HMS *Warrior* was the first 'modern' iron & steam warship with armour and a mixed battery of trainable big guns. Although not a good seakeeper and not long in operational service, it was the precursor of the cruiser type warship.

Reflections of a Shipbuilder

By
Sir John Parker DSc (Eng) FRINA FREng
President of the Royal Institution of Naval Architects 1996-1999

"My shipbuilding career started over 50 years ago as a sponsored student apprentice at Harland and Wolff's famous Belfast Queens Island Shipyard, studying Naval Architecture. In an interview I gave about 20 years ago, I was asked if I had any regrets about the career I ventured out on, I said then: "I have never doubted the wisdom or the great privilege to have studied naval architecture and engineering and for the years of my student apprenticeship in Queen's Island, that great university of life, where I experienced not just the design and construction of great ships but where I first learned about human engineering and the management and challenges of leading teams of people". Today the response would be no different."

Engineering Sciences

The application of the engineering sciences has been the life blood of all of the companies I've served and that applied engineering has enabled me to be involved in the design and construction of great maritime structures – merchant ships, naval ships and offshore structures, each presenting different challenges.

Unlike most other branches of engineering, the dynamics of the sea and its corrosive powers single out naval architecture as a particularly demanding application of engineering. In the early 1960's when I was engaged in my naval architecture studies the ship designer was heavily reliant on empirical formulae and on executing masses of long hand calculations that determined the ships structural strength, the horsepower of its engines, the stability and capacity of the vessel etc. Such calculations were undertaken by the slide rule or the 'Fuller' barrel – an 83ft slide rule! – and later by the mechanical calculating machine.

Since then the profession, with the aid of modern computing techniques, including mathematical modelling of sea states and 3D finite element structural analysis, has taken us a long way towards a more exact science not just in ship design but in all branches of engineering.

One of my favourite ships of all time was the 45,000 grt passenger ship SS *Canberra* for P&O.

As a student naval architect, I had a modest technical role, in charge of the Deck Covering Plan for the complete vessel. This plan specified the materials laid on the decks for every space, from the many varieties of terrazzo tiles in galleys and pantries to the highest grade of Axminster carpets and associated underlay in the first class lounges and cabins. The role took me regularly on board to check progress against the plan. It gave me a superb opportunity to view almost every aspect of a passenger ship fitting out prior to her delivery in May 1961.

It's a tribute to *Canberra's* designers that her distinctive shape and character kept her looking a very modern cruise ship until her retirement in 1997 – after an amazing 36 years at sea – including distinguished service as a troopship in the Falklands Campaign.

My work brought me into contact with some great characters in shipbuilding. Humour and playing tricks on each other was a normal part of the working day. At that time Harland and Wolff (H&W) had a thriving Ship Repair Division, it was carrying out major conversion work on a passenger ship, the *Rina del Mar*. One evening, unexpected severe gale force winds blew up and the ship broke her moorings and drifted into the middle of the Belfast Lough. She was in complete darkness as the shore power was disconnected. There were some 600 men on board and a few were trapped in the main lift which had locked when the power went off. Whilst awaiting the arrival of the rescue tugs, some of the workforce climbed the stairway that spiralled around the liftshaft, and on their way up collected the fire buckets, filled with water located at each stairway landing.

On reaching the top they poured them down the liftshaft on to their trapped mates singing in *Titanic* style 'nearer my God to thee.' So even in a crisis you have to recognise the remarkable humour and resilience that come forth from a workforce!

A decade ago the largest cruise ship was the 101,000 grt - *Carnival Destiny* which can carry a maximum of 3400 passengers. Today the largest cruise liner, as distinct from cruise ship, in service is Cunard's *Queen Mary II*. Her grt is 150,000 and she can carry 2620 passengers.

As a pure cruise ship she has been overtaken by Royal Caribbean Cruise lines *Freedom of the Seas* which entered service in 2006. At 160,000 tons grt, she can carry 3634 passengers.

However, she has been eclipsed by the delivery of an even bigger sister *Oasis of the Seas* at 222,000 tons capable of carrying over 5400 guests.

Interestingly over 20 years ago, at H&W we developed a conceptual design based on the ideas of the US Shipowner Ravi Tikkoo for a 3150 passenger vessel of 160,000 grt. All passengers were located in outside cabins and all had private balconies above the main desk. This was achieved by a zigzag type superstructure. Many cruise operators then held the view that such a concept and size of cruise ship would never be in demand! However, the 20-year interval has demonstrated that this unique design concept represented a correct interpretation of where the cruise market was heading.

One of my greatest industrial regrets was that despite all our market research in the mid-1980's at H&W, pointing to this new and significant growth market for cruise ships, I could not persuade the UK Government to support entry to what we can now look back on as a 20-year bonanza. It gives me no satisfaction to have predicted then that these new ships would be built in Italy, France and Germany.

Modern cruise ship designs have created vessels that are 'destinations in themselves' with innovations such as private balconies and atriums, a variety of restaurants; lounges and theatres etc. These developments demonstrate how new markets can be created by sensing out opportunities, pursuing innovation and skilfully managing the high investment risks – given that a 3000 passenger ship will cost about US$800 million.

LNG Carriers

The transportation of liquefied natural gases (LNG) by sea is of itself a fascinating story of technical evolution in which the UK has played a leading part. As a young naval architect, I worked on the design of the *Methane Progress* being built at Harland and Wolff as the World's first commercial LNG vessel.

In parallel with some early experimental shipments in the USA, British Gas negotiated a long-term contract to ship Algerian LNG to Canvey Island. Based on this contract, the design for two new 26,450 m(3) LNG vessels was developed with Vickers, Harland and Wolff and US design consultants J J Henry.

These first two major commercial LNG carriers were jointly constructed by Vickers Shipbuilding in Barrow (*Methane Princess*) and Harland and Wolff, (*Methane Progress*). *Methane Progress* was delivered first in May 1964 and I sailed with her on my first of many sea trials. What a thrill it is to take a ship on sea trials in which you have had a hand in its design or construction.

Methane Progress

Since these first two commercial LNG tankers there has been an exponential rise in the capacity of the worlds LNG fleet. By 2010 more than 360 LNG tankers will be in service. The maximum size of vessel now under construction is a 265,000m^3 – almost 10 times the capacity size of *Methane Progress*.

Offshore Energy

The 30-year development from fixed platforms on the shallow North Sea continental shelf at under 200m to floating production technology in hostile waters West of Shetland at about 400-500m deep is a fascinating story.

My first encounter was as a young naval architect when H&W took the order from BP for the first semi-submersible rig to be built in Europe for the North Sea and delivered in 1966.

The triangular shaped rig was constructed straddling three slipways, before the era of the building dock and well before computer aided structural design programmes were available. As a member of small technical team assembled to figure out in detail how it was to be safely launched, I experienced one of the most challenging technical roles that I could ever have wished for.

To avoid the rig 'tipping' during launch, which would have been a catastrophe, a temporary barge was built in the middle slipway to provide greater buoyancy and uplift as the rig entered the water. The calculated loads on the barge were enormous and we estimated that we had little margin, particularly if the tide was not as high as predicted on launch day, which would have reduced the buoyancy uplift on the rig structure. The tide on the day was indeed somewhat lower than predicted, due to wind direction, but the courageous decision was made to 'let her go in', despite the inevitable risks. As the rig launched on a reduced and falling tide, loads on the barge were significantly higher than predicted and the temporary barge started to visibly

Sea Quest. The launch challenge

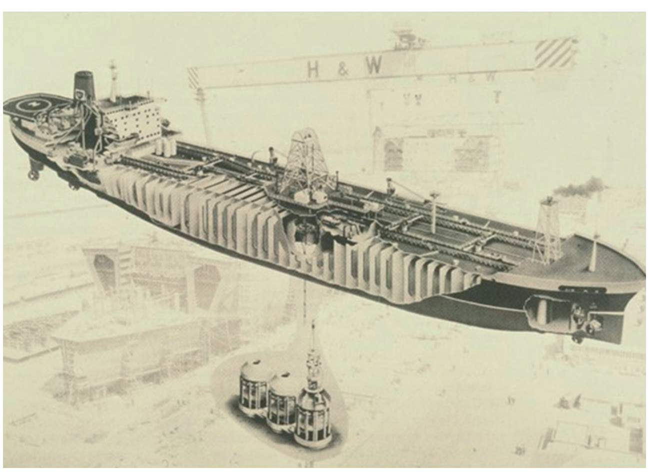
buckle, as did my knees. I was sure a promising career in naval architecture was about to 'go out of the door'. However, the rig was safely launched!

Another unique first in the world was BP SWOPS. In 1984, some 18 years after Sea Quest's delivery, and during my time as Chairman and CEO of H&W, we won the order from BP for the design and build of a prototype dynamically positioned floating production system, code named at the time SWOPS (Single Well Oil Production System). Her role was to recover oil from the marginal oil fields of the North Sea, process it, store it and transport it to a discharge port. The Gaellic name later chosen by BP, "Seillean", translates to the "Honey Bee" – going around collecting pollen from various flowers'!

The vessel was to be dynamically positioned over the well using seven azimuth thrusters controlled by a computer system linked to satellite navigation and to transducers located at the well head. She had no anchors!

This technology had not been applied before to a 76,000 tonnes displacement vessel attached to a rigid 600ft riser connected to the well head on the seabed. She was also expected to stay within a small radius of surface movement in Force 7/8 conditions. SWOPS was regarded as the worlds most sophisticated ship and a truly pioneering vessel.

Single Well Oil Production System (SWOPS)



Many challenges were inevitably encountered in developing and constructing such a pioneering design. However, at the outset of the contract the formation of a joint project management team drawn from the shipyard and BP staff assisted in resolving quickly many of the crucial engineering and commercial decisions which had to be taken day by day. The management of the sheer mass of electrical, electronic controls and computer interfaces proved a major task, as was the continuing role of interpreting and satisfying the myriad of statutory safety requirements arising from both ship and offshore safety authorities. Seillean was handed over to BP in 1989 after fully meeting her design and performance criteria during her sea and extended well head trials.

Naval

In 1986 H&W won the design and build contract for *Fort Victoria* a first of class sophisticated replenishment ship to service the Royal Navy Frigate fleet, on a one-stop basis. She was also fitted with missile systems and full helicopter servicing facilities. She was an absolutely unique vessel with a design, development, build and commission cycle of over six years.

The Kawasaki Experience

After the privatisation of H&W in 1989 which I led, after bringing in the Norwegian Shipowner Fred Olsen, we agreed that in order to change our productivity drive, we would negotiate a tie up with KHI of Japan. We sent groups of the workforce to Japan to work for about 1 month each on the shop floor and building docks to gain first hand experience of Japanese production methods. Japanese supervisors and managers also came to Belfast to assist introduce new techniques. The overall impact was that over a 2-3 year period, we reduced the man-hours to build a 140,000 ton tanker by some 45%.

Summary

My reflections on my career as a shipbuilder ends where they started, with my appreciation of the great people I have worked with and still work with and learn from. My favourite Chinese proverb: 'when the best leaders work is done the people said we did it ourselves". Without such people, my shipbuilding journey would not have been the enriching one that it has been.

Sir John Parker's shipbuilding appointments have included Chairman and Chief Executive, Harland & Wolff Holdings Plc; Board Member for Shipbuilding and Deputy Chief Executive, British Shipbuilders Corporation; Managing Director, Austin & Pickersgill (Shipbuilders & Engineers).

Reflections of a Shipbuilder

By
Dr Peter J Usher CBE DSc RCNC FRINA FREng
President of the Royal Institution of Naval Architects 1993 - 1996

"I was 15, when my headmaster Mr Letchford, at Maidstone Technical School, suggested I go into Chatham Dockyard. He knew and admired the Royal Dockyard School system that enabled apprentices to reach a degree level of education if they kept in the upper half of their year for four years. It was 1942, the war was at its height, planes were frequently overhead, and higher education was not an option, so I was pleased to take his advice. By this route I became a naval architect and member of the Royal Corps of Naval Constructors."

Royal Corps of Naval Constructors

I didn't know that at the very moment of my conversation with Mr Letchford, the Minister of Labour and National Service, Ernest Bevin, was berating the shipbuilding industry for its poor labour relations and low productivity, and that I would witness in my lifetime, the near extinction of shipbuilding in Britain. I would also see the number of ships in the Royal Navy (RN) dramatically reduced, and the Royal Corps of Naval Constructors made redundant. There is much to reflect upon.

I spent most of my time in the Corps dealing with submarines, including four years on the staff of FOS/M, where I shared an office for a while with John Fieldhouse (later to become Chief of the Naval Staff) and I enjoyed a variety of other jobs, including overseeing the surface warshipbuiding work of John Brown on Clydebank and Yarrow at Scotstoun. The Fairfield Experiment, aimed at doing away with demarcation and restrictive practices, was launched on the Clyde in 1966, but failed owing to inter company and inter union rivalry. This gave impetus to those who believed that nationalisation of the whole of British shipbuilding was the only answer. We were in fact nationalised in 1977, but it did little to improve productivity, and was also a failure in my view.

Vosper Thornycroft Ltd.

It was in 1966 that Vosper in Portsmouth had taken over JI Thornycroft in Southampton to form Vosper Thornycroft Ltd. They were the only shipbuilder in the UK with a dedicated sales team, and had just won a contract with the Shah of Iran for four fast destroyers of 1300 tons. Their technical genius Peter du Cane was about to retire and they were looking for a new head of design. I felt that my future in the Corps was probably steady but unexciting, so I decided to chance my arm, and I became the Technical Director of the new company that same year. John Rix was the Managing Director and driving force. We did the detailed design of the Iranian destroyers with the help of some staff from Vickers Barrow and had the enormous joy of meeting the promised speed of 40kts on the Arran measured mile three years later - a remarkably short time by today's standards. These were impressive little ships; the first with a surface to surface missile system and twin Olympus gas turbines for propulsion.

It was the beginning of eight years of fantastic achievements by Vosper Thornycroft, with our turnover growing by at least 20% per annum. In association with Yarrow we won an MoD contract to design and build a "Leander replacement" (the first occasion for many years of the Royal Corps not designing an RN ship, owing it was said, to the load of the nuclear submarine programme) and we then designed and built four 4000 ton frigates for the Brazilian Government. These ships carried a very impressive weapons outfit and are still in service. We also took orders from a number of Middle and Far East countries; we built the first minehunter made of glass reinforced plastic and designed and built a range of fast strike craft, as well as a new hovercraft.

However, the labour costs on our first Brazilian ship *Niteroi* were over-running in February 1975 as she approached her launch, and with three more of these vessels to go, John Rix decided that I should leave my comfortable chair in design to take over our Woolston shipyard. So began my career as a shipbuilder proper, and I have always been grateful for those years when I could best be described as a naval architect. In any production job, it helps to really know the product.

My most important role was to explain to the shop stewards that to get customers, we needed an attractive price. Materials were pretty well defined, and our overheads clearly weren't excessive, so it was labour costs that we had to play with. They had not been dragged down that unwelcome furrow, face to face with the boss, before. We were making profits, so why couldn't they have more pay? After a while it was, "Well, we see what you're saying Mr Usher but the lads won't." So we held meetings with everyone in the work force at Woolston to get our message across. Some years later Bill Richardson, Chairman of Vickers joined us, and was amazed that in 1975, senior managers and I were speaking directly to the men. Elsewhere in the industry, shop stewards would have prevented it. Our monthly meetings were initially in groups of no more than 30 and for about half an hour. It was time consuming, but in my opinion it developed a lasting trust. Our shop stewards of that time were prepared to see reason.

The call from the trades unions, and from some shipbuilders in the North, for nationalisation of the shipbuilding and ship repair industries grew through the early '70s, and union attitudes in our yards became more aggressive. David Brown, our chairman, fought hard to prevent Vosper Thornycroft being taken over by the state because our record of investment in production facilities was good, but he failed, despite taking the case to Strasbourg.

British Shipbuilders

Vesting Day was 1 July 1977. John Rix resigned in January 1978 and after a while I was appointed Managing Director. It was decided later that warships would be built by just three companies, Vickers, Yarrow and ourselves, but with Swan Hunter kept in reserve. When I left the Corps in 1966 there had been not three but 13 warshipbuilders.

Throughout the eight years of being nationalised we felt very much the unwanted, in the remote and affluent South. We had opposed nationalisation; we were profitable when few others were; we felt that MoD work which we would previously have won was being put in the North, and we had no friends at court. However, I recall one small incident of value. British Shipbuilders had arranged for a team to visit Bath Iron Works in Maine in the States, to see their production methods. I went on that trip and was inspired, so we made an even greater effort both to improve productivity and to measure it. In April 1981 our Technical Director Tony Dorey and I wrote a RINA paper "A Family of Warships" setting out how this might be done. In it we show for example that we built the fourth of our Brazilian ships for 83% of the labour we spent on the first. We had also won MoD minehunter contracts by demonstrating the labour savings in multi-ship orders.

I now look back with some sympathy on the efforts which BS made to improve shipbuilding productivity. They tried to demonstrate what was happening in Japan for example, but the yards saw themselves as the competitors they had always been, and I recall the antagonism to my suggestion at a warship group meeting that we should exchange measurements of our productivity, in terms of kilograms of ships weight on the berth per man hour of direct labour.

The enthusiasm in the unions for being nationalised began to wear off as wages were held down. Our boilermakers refused to launch HMS *Southampton* in October 1978 seeking more pay, so we delayed the ceremony to allow negotiations to proceed. We then had the embarrassment in January 1979 of naming the ship and leaving her on the blocks, as the centralised wage negotiations had made no progress. At the sponsor's lunch in the Guildhall, my shipyard manager Gordon Dodd suggested to me very quietly that we launch the ship ourselves on the next of our double tides. What a challenge! Why not? At midnight we mustered enough physically fit staff to set her up and my only concern as she went down the ways was whether word could have leaked out, and the tug crews would refuse to pick her up. The new Itchen Bridge had only recently been built and I visualised *Southampton* being carried on to it a few hundred yards up stream. But all was well. There was no untoward reaction from our workpeople, and there just may have been some wry admiration!

Type 42 Destroyer – HMS *Southampton*

By the end of 1982 Margaret Thatcher was in power and she said the shipbuilding industry was to be privatised, starting with the warship builders. I wrote immediately to BS saying that it was my intention to lead a management buy- out of VT. Graham Day BS chairman declared that "We must put the best gloss on the apple". This meant there would be a cull of elderly managers, and as I was nearly 58, I guess I only escaped because of that letter.

Post Nationalisation

I invited all of the remaining directors to take part in the buy-out. We had lost Len Peacock our personnel director and James Pardoe who ran Portchester, in the apple polishing, and I would have preferred a wider employee involvement, but our venture capitalists, County Bank, advised against that. The biggest stroke of luck in the whole episode was that Roy Withers was just retiring from Davy Corporation. He and I got on well, and he became our chairman – a wonderful man. At a somewhat tense meeting the night before the bids were due we decided to bid £18.5 million for the company believing that there were others who saw opportunities in our 54 acres of prime Hampshire waterfront. In doing so each of us was committed to approximately the value of our houses. To our delight we won, and the company was ours on 1st November 1985. We enjoyed five wonderful years of growth with Roy Withers before I took over the chair for another five. We floated the company on the London Stock Exchange in 1988, and our share price improved five fold by the time of my retirement in 1995.

Now, 14 years later, how things have changed! The shipbuilding interests of VT plc have been sold off to BAE Systems, who have also absorbed the other warship builders, and are now a monopoly supplier of ships and submarines for the Royal Navy. The latest ocean liner, the *QM2*, was built in France, because there was no British yard capable of building it, indeed the merchant shipbuilding industry of Britain has virtually disappeared.

Vosper Thornycroft shipyard at Woolston, circa 1985

Looking Back

Consequently my reflections as a shipbuilder are of amazement that a significant industry could dwindle so rapidly. It is understandable that the City should react against industries in thrall to undisciplined trade unionists (such as Arthur Scargill in the '70s), but thankfully that era has gone. It has however been followed by a widely held belief today that manufacturing is of little or no importance to our economy, and I do not share that view. I believe that we should address shipbuilding productivity by using highly automated manufacture, despite the considerable set-up costs, and we should encourage academics in our universities to become involved in design for improved productivity.

The world is two thirds covered in water and I believe it will forever be impossible to carry heavy cargoes by air economically. Ships are therefore here to stay. Shipbuilding provides interesting skilled employment which will be in demand. Perhaps the current economic down turn will renew its attraction.

Reflections may console the elderly, but they only have value if the young use them to good effect. I believe the country needs to be a manufacturer, and for real interest, a shipbuilder.

Peter Usher was the first Technical Director and later Managing Director of Vosper Thornycroft Ltd.

Vosper Thornycroft 1860 - 2010

John I Thornycroft & Co Ltd

In 1860, John I. Thornycroft & Company Ltd. was building his first ship at Chiswick on the River Thames in London. Thornycroft was a pioneer in the production of high-speed vessels, specialising in the development of fast steam powered torpedo boats and destroyers achieving speeds that were previously considered unobtainable by many leading architects. The Thornycroft yard built HMS *Lightning*, the world's first torpedo ship. Launched in 1876, it was the first ship to be armed with self-propelled torpedoes.

The shipyard at Chiswick closed in 1904 when the company relocated to the River Itchen at Woolston in Hampshire. The first ship built by Thornycrofts for the Royal Navy (RN) at the Woolston Yard was the Tribal-class destroyer HMS *Tartar*. In the period up to the start of the Great War, Thornycroft's built 37 destroyers for the RN alone.

Vosper & Co

Herbert Edward Vosper set up his Company, Vosper & Co when he was only 21 in 1871 at Camber, a small commercial dock in Portsmouth. The main work of the Company during the early years was largely in the refitting and repair of coastal vessels. The company began producing their own range of steam reciprocating engines which were fitted into all types of craft, including yachts, tugs, tenders and launches, for the Admiralty and for export.

By the turn of the century, Vosper & Co was prospering as a general-purpose builder of small craft, boilers and marine engines, for which they had made a name for themselves as a producer of reliable designs. By the early 1930s, the company began to concentrate on high-speed naval craft, yachts and power boats, for which they would become renowned. In 1936, as Vosper Limited, they opened a second yard in the Portsmouth area. They built Sir Malcolm Campbell's water speed record breaking *Bluebird K4*, reaching 141.74 mph in 1939.

Vosper became famous as the builder of small (60 to 70 ft) un-stepped planning hull-form naval Motor Torpedo Boats and Motor Gun Boats for the Royal Navy in World War II.

Vosper Thornycroft

John I. Thornycroft & Company joined forces in 1966 with Vosper & Co. to form one organisation, although the formal merger to create Vosper Thornycroft (VT) took place in June 1970.

In 2008 when VT placed its shipbuilding business into a Joint Venture with BAE Systems to form BVT Surface Fleet. In 2010, VT sold its shipbuilding interests to BAE Systems, thus bringing to an end 150 years of shipbuilding.

Reflections of a Shipowner

By
Marshall Meek CBE RDI BSc DSc FREng FRINA FIMarEST FRSA
President of the Royal Institution of Naval Architects 1990 - 1993

"Two features were predominant in the shipping industry of the l960s and early 70s. Firstly, ship speed was always important as a selling point. If we built ships of 17 knots, Ben Line competitors moved to18 knots. If we built for 19 knots the Japanese claimed 20 knots. Good sport for us designers but somewhat crazy – until it all ended with the oil price shocks of the 1970s when speeds, of necessity, dropped dramatically. The other persistent problem was the time ships spent loading and unloading in port. Some companies' ships spent only half the year at sea, such was the deplorable performance of port labour."

Introduction

Having embarked on the maritime scene almost 70 years ago with entry through the drawing office of a shipyard, it soon became apparent to me that the people who mattered most in the ship business were the shipowners – those distant, lofty, fearsome and of course, wealthy individuals on whose decisions, preferences and prejudices our livelihoods depended.

It was natural that those of us who had a vague sense of ambition or even some fancied ability, should aspire to cross the gulf from builder to owner. Although I was also to meander through further spells in shipbuilding, in the research world and elsewhere, my best years were with shipowners. I still consider they were somehow different. So I determined that my reflections as a shipbuilder should concentrate on the people in the shipowning companies that I have had the privilege of meeting or working with. I have, of course, a strong bias towards the Blue Funnel Line of Liverpool whom I served directly for 25 years, and also more indirectly when in shipbuilding.

Caledonia Shipyard

As a drawing office apprentice at the Caledon Shipyard during World War II, and as a junior in the design office, there was naturally rather little personal contact with the exalted shipowner individuals who visited the shipyard, but some remain very clearly in my mind. Edmund Watts of Watts Watts Shipping was one who showed much interest in the design of his ships. He believed his officers should be made to face the elements, get a feel for the weather and not be cooped up comfortably in the wheelhouse. There was to be no interior access to the bridge, but all must cross open deck to reach the wheelhouse – and so 'get their eyes open'. This is rather a contrast to the bridge of the *Queen Mary 2* on which I have crossed twice from the USA recently. Her wheelhouse extends the whole width of the ship and is totally enclosed in the modern style of these large ships. Sadly, Edmund Watts while visiting the shipyard for the launch of his *Wanstead* in 1949, made the mistake of going shooting in the country on a day out with Po Thomson, the foreman riveter and a recognised countryman. He appeared at the launch with his neck heavily bandaged having taken a barrel-full of lead shot indvertently released by Po. No hard feelings were apparent.

One particularly welcome visitor was Fred Ritchie when we were building *Rajah Brooke* for the Sarawak Steamship Company. He was a nice, quiet but determined Dundonian who had been taken prisoner by the Japanese. During the years he was incarcerated he had schemed out a design of this ship which was quite unusual in its loading and unloading arrangements because of the nature of the ports of that area. It became much admired in the region and was highly successful.

Blue Funnel/Alfred Holt

But by far the most important shipowners as far as Caledon Shipbuilders were concerned were the Blue Funnel people. Alfred Holt, the alternative name for the company, were major shareholders and built a large part of their post war fleet there. In the 1940s and 50s it was a case of rebuilding fast to replace wartime losses. There were always Blue Funnel ships on the berths or fitting out, and they received preferential treatment – even in wartime. I recall Willie Bingham, chief draughtsman, complaining they were built to a 'disgustingly high standard' for wartime. I never met the exalted bosses of Blue Funnel (known as Managers) at that time, but certainly got to know them well a little later when I joined the renowned Liverpool company.

The two principal figures who tormented the shipyard people were William Dickie, technical manager, and Harry Flett, the naval architect, whose job I was one day to take over. The pair always operated together, one playing up to the other, bullying and terrorising shipyard people. I remember Flett bawling at George Houlden, Managing Director of the Vickers Walker shipyard (Caledon often shared orders with Vickers) 'Get your chinstrap sorted' when the poor man, who was deaf, was into a tangle with his rather complicated hearing-aid wires. As I was to discover when I joined the naval architect's department in Liverpool, Flett's common greeting when someone timidly knocked at his door was 'D'you want to see me?' when the obvious unspoken answer must have been 'preferably not'. Caledon kept on building Blue Funnel ships into the 1960s when the ships became too big for the berths.

Alfred Holt, the originator of the Line, has had much written about him. Basically a civil engineer, he had worked in railway engineering, and dabbled in cotton broking to appease his father, before he embarked on ship owning with his first real ship *Dumbarton Youth*. She it was that flaunted the first blue funnel, because when bought she had among her stores muskets, Bibles and an excess of blue paint. It was his nephew Lawrence Holt that I knew a little in his retirement when I joined as a junior naval architect in1954. There must have been some propensity amongst the family for getting close to nature. In Clement Jones' biography of Alfred he says 'Alfred was a real boy. Amongst his earliest memories was that of creeping into the dog's kennel which stood in the stable yard.' Lawrence used to call in to the naval architects department occasionally after I joined the company. I was his 'Dundee boy.' Amongst sundry sound advices to keep my eyes on the horizon and to keep the flag at the top of the mast, he confided that as a boy, at the Scottish family house in Abernethy, he had once been found asleep in the pen with his arms round the pig. Nevertheless these were men who got to grips with the practicalities of shipowning – how ships were designed and constructed, how they performed at sea, how the officers and crew performed, and not just concerned with the commercial and financial aspects of the business. There was instilled a respect for the dangers of the sea as well as an urge to run efficient vessels; for economic success but coupled with a deep respect for the well being of the people. They were businessmen with both christian and commercial principles, and a whole range of interests and responsibilities outwith their shipping activities. From these early ship purchases there grew a Blue Funnel fleet which, at its peak when I was naval architect and director of Ocean Fleets in the 1960s, had 120 ships. The traditional routes were mainly to the Far East but latterly spread worldwide.

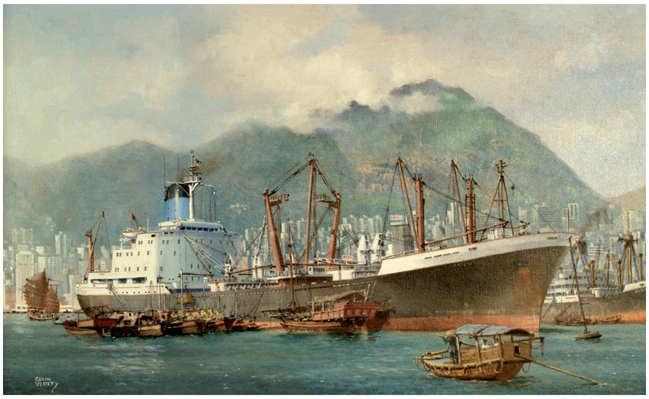
An early decision of Alfred Holt was not to insure his ships on the market but to keep insurance in-house. He believed he and his naval architect of the day, Henry Bell Wortley, could design and operate their ships without having to pay insurance premiums, and so they saved much cost. This was still the position when I joined in 1953 and lasted till we built the then novel container ships in the 1960s when joint ownership with other companies caused a reappraisal. Not only did Alfred Holt attach little importance to the classification societies, where Lloyd's Register boasted its so-called A1 class, but he considered Plimsoll's introduction of the Load Line legislation an impertinence. Holts themselves would decide all that was needed to ensure the ships were sufficiently strong and properly maintained and operated. Legislation could only mean accepting lower standards. Over the years this led to a sort of quiet and probably justified arrogance, but in later times such as when I joined, it had induced an over-cautious and unenterprising attitude.

On becoming naval architect to the Company on the death of Harry Flett in 1961, it was my privilege to try and move the Company out of complacency and into some forward and more competitive thinking. Sir John Nicholson was chairman for the greater part of my time and he was a man born to command. There was much train travel between Liverpool and London. Sir John was to be observed processing through the first-class carriages, submitting any Blue Funnel staff whom he discovered to acute questions about their business – as well as offering kindly paternal advice where considered necessary. He brought his own eggs for cooking for breakfast on the morning train.

All our managers/directors were from Oxbridge, naturally, and each successive wave of juniors was brought in through the Oxbridge milk-round. But Sir John and his successor Sir Lindsay Alexander, and indeed those who followed, always had great respect for the company's naval architect. When I was appointed on Flett's death Sir John said: "The Naval Architect of our Company need never doubt the support of the Management" and so it proved. I was able and indeed encouraged to build a very able team of naval architects which grew over the years as we took on more work and were involved in more complicated ships than the traditional cargo liners that were the mainstay of the fleet.

Two features were predominant in the l960s and early 70s. Firstly, ship speed was always important as a selling point. If we built ships of 17 knots, Ben Line competitors moved to18 knots. If we built for 19 knots the Japanese claimed 20 knots. Good sport

MV *Priam*



for us designers but somewhat crazy – until it all ended with the oil price shocks of the 1970s when speeds, of necessity, dropped dramatically. The other persistent problem was the time ships spent loading and unloading in port. Some companies' ships spent only half the year at sea, such was the deplorable performance of port labour. The last of the great cargo liners we designed was the *Priam* class of 20 knots, crammed with expensive cargo gear, and with hull structure schemed at great cost to reduce time to load and unload. Having suffered appalling delays in delivery from British shipyards they were never able to fulfil their potential. They were overtaken by the advent of the container ship in the late 1960s. And I and my team had the immense satisfaction and honour of designing this new type of ship.

Overseas Container Lines (OCL)

The formation of Overseas Container Lines (OCL) was a landmark. Led by Blue Funnel's Sir John Nicholson and P&O's Sir Donald Anderson, four of UK's major shipping lines realised the need to work together if they were to face up to the great cost of container ships and all that went with them in the way of port facilities and infra structure. Against the background of pride and individualism existing in these great companies we can appreciate what a significant move this was. So we in Blue Funnel found ourselves working with P&O, British & Commonwealth (Sir Nicholas Cayzer) and Furness Withy (Sir Errington Neville) in the mid 1960s in a consortium which was determined to lead the world in the new venture of containerisation. My own naval architects team, with other Blue Funnel technical staffs, were entrusted with design responsibility. It was a glorious period for me (all written up in the RINA Transactions and in the *History of OCL* and elsewhere.) Within five years container ships were to be found in every major port. In the end, however and disappointingly soon, OCL could not be held together.

The last major figure involved was Lord Sterling of Plaistow, who as Sir Jeffrey Sterling was heading up P&O when it finally acquired the Blue Funnel interest in OCL. He had become the last powerful figure in UK shipping with seeming access to Government and Prime Minister Thatcher. I marvelled that he visited the Fairfield shipyard when P&O were planning their North Sea ferries to operate out of Hull. He sought words with the Boiler Makers shop steward in an endeavour to ensure cooperation in the building. On being asked by Sir Jeffrey whether his men would cooperate and be flexible in their working practices, the reply came 'Mr Sterling, we are so flexible now we can hardly stand up.' Surprisingly the shipyard got the order. In the end UK shipowners could no more hold their pre-eminence on the world stage than the rather despised shipbuilders with whom so many of us naval architects had been familiar. But that is another story.

Looking Back

My own happy experience in shipowning is unlikely to be repeated. Design is now mainly the responsibility of the shipyard but I am certain that reputable forward thinking shipping companies should have qualified naval architects on the staff to guide, control and advise on the design and building of the ships. I found the closeness to the masters and officers, to the freight departments, to the catering and medical people, and all those engaged in actual operations so interesting and beneficial.

My own impression gleaned over these past six or more decades is that shipowners were a different genre, with their own culture, background and outlook compared not only with shipbuilders with whom my generation was closely involved, but with other spheres of maritime activity, such as the research realms or academia. The senior figures were so often men of calibre, intelligence and diligence. But I do feel that in Blue Funnel the heirarchy was too well defined. There was a gap between the top management and the rest of us, and something was lost along the way. It was becoming too late in the day to change it.

Looking Forward

But what is most encouraging to me now is that new things are continually happening in our profession. The pages of *The Naval Architect* journal show how old fashioned and out of touch my generation is becoming, but at least I can read and wonder and admire – and wish all success to those naval architects who have the privilege of interfacing directly with the people who make the purchases. They used to be called shipowners.

Marshal Meek is a former Chief Naval Architect and Director of Alfred Holt & Co (later Ocean Fleets Ltd).

Events of 1860

The Scottish Shipbuilders Association

From its early days, the Institution of Naval Architects has had a long association with shipbuilding in Scotland, with many of its members also being members of the Scottish Shipbuilding Association, later to become the Institution of Engineers and Shipbuilders in Scotland.

The Scottish Shipbuilders Association was established in September 1860 to perfect, as far as possible, the art and science of shipbuilding. It also gave early proof of its value when one of the members read a paper on river steamers and put forward proposals for the fitting of deck saloons. The Association followed this with an approach to the Board of Trade - then the statutory authority - and got its agreement that deckhouses used as shelter would not be measured and added to the tonnage of the hull. From then onwards the misery of pleasure sailing on wet days was gone.

In 1864, the Association joined with the Institution of Engineers in Scotland, formed earlier in 1857, to become the Institution of Engineers and Shipbuilders in Scotland.

The Submarine 1860 - 2010

By
Dr D W Chalmers OBE RCNC FRINA

At the time of the Institution's centenary in 1960 very little had been reported concerning submarines in the transactions, the notable exception being papers by Sims in 1947 reviewing British submarine designs and in 1948 by Starks reviewing German wartime designs. It is not until the 1980s with the start of the RINA triennial series of symposiums on Naval Submarines that there is much open publication, despite the rapid advances in technology that followed the introduction of nuclear propulsion in the 1950s.

The US Civil War, Garrett and Holland

Although there were many more or less eccentric and bizarre attempts at building submersible vessels through from the 16th to the 19th centuries, it could be said that the US Civil War precipitated the evolution of the modern submarine. The most notable of these was the Confederate *Hunley* which was the first submarine to sink a surface vessel, the *Housatonic*, although *Hunley* was sunk in the process.

This experience led to the work of the pioneers, Garrett and Holland. Treating Garrett first as his trail comes to a sad end; in 1878 he lodged a patent for a "submarine boat for placing torpedoes, etc." The Rev. George Garrett was trained as a scientist; he was fascinated by submarines and as a young man had invented an underwater breathing apparatus using a chemical absorber. In 1879 he built a large submarine named *Resurgam* with the intention of demonstrating its capabilities to the Royal Navy. It was powered by steam, using the fireless principle with an accumulator charged to 150 psi. Curiously, although he had perfected a system of water ballasting, *Resurgam* had no ballast tanks but was slightly buoyant, being held submerged by forward propulsion. The vessel completed trials and in December 1879 Garrett with a crew of two commenced has voyage to Portsmouth. Three days later he reached Rhyl and berthed to undertake some modifications.

In February 1880 he sailed again with the boat under tow and unfortunately *Resurgam* was lost due to swamping. It has since been located but remains on the seabed as a historical relic. At the same time, Garrett had worked with a Swedish company, Nordenfelt, to design submarines, a number of which were built for foreign navies. Nordenfelt did however figure in one of the first (if not the first) mention of submarines at a meeting of the INA in 1888 in the discussion of a paper by Hovgaard, entitled "Proposed Designs for Surface Boats and Diving Boats" where Hovgaard recommended electric underwater powering and Nordenfelt disagreed. Also in the period to 1900 designers in many countries in Europe were pursuing the submersible vessel concept, some such as those from Waddington in the UK and Peral in Spain being very advanced and others bizarre, all well described in historic literature.

John P Holland is a very different character. He was a school teacher, amateur inventor and ardent Irish Nationalist who emigrated to the USA in 1873 at the age of 32. He conceived that a submarine boat could be used to create havoc in the British Navy in the interest of Irish Nationalism. After experimenting with a smaller boat, he was funded by the Fenian Brotherhood to build a vessel which became known as the *Feniam Ram*. It was 31ft long 6ft beam and displaced 19 tons; propelled by a petrol engine and crewed by three men, it was controlled by vertical and horizontal planes and ballasted with water to be flooded and blown with compressed air. It was armed with a pneumatic gun. In other words it had most of the characteristics of a modern submarine. The boat carried out successful trials but was lost in a New Jersey river while escaping

Holland 1 - Underway

investigation. The *RAM* was later salvaged and went on display in a park in Paterson, New Jersey.

For a while Holland was disillusioned but some years later he entered a US Government sponsored competition for a submarine design and won. This led to the formation of the Holland Torpedo Boat Company and a boat called *Holland*, a 75 ton vessel and the first to be propelled underwater by batteries. Later Holland was backed financially by the battery makers and the Electric Boat Company came into being. The US Navy then contracted for seven Holland boats while at the same time other foreign powers were eying each others growing submarine fleets. Holland's greatest achievement was the *Octopus*, a 270 ton boat completed in 1906 capable of 11 knots surfaced and nearly 10 submerged and able to dive to 200 ft. He died in 1914 having become disillusioned and transferred his interests to flying machines.

At the same time as Holland, a much less well known designer in the USA, Simon Lake, was following a similar path. He was the first to suggest a non-military role, and his earlier ones were fitted with diver lock-out for survey and salvage as well as having wheels for stability on the sea bottom. The primary difference between his and Holland's boats was that the Lake boats submerged level by flooding tanks while the Holland boats were always slightly buoyant and submerged by driving down on the planes.

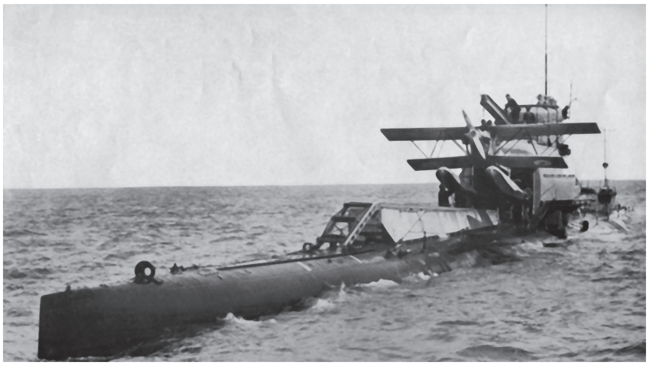
World War I

By the start of the 20th century most navies had seen the potential of submarines and were taking forward projects as national developments rather than speculative ones, in particular France, the USA and Russia had numbers of submarines built to both Holland and Lake designs as well as indigenous ones. The two countries least interested were Great Britain and Germany, probably because they had the largest surface fleets and had the most to lose from submarine warfare.

In Britain there was the problem that as the navy had officially ignored submarines to that time there was no available design and no expertise. However, Vickers at Barrow had experience in building Nordenfelt boats and they were contracted to build five to a Holland design under licence to the Holland Company in the USA. These were quickly followed by Navy/Vickers designs of larger boats so that by the start of the war in 1914 Britain had 77 active boats, some of the later ones being fitted with diesel engines, although there was still no agreed tactical role. The German position at the start of the war was more fragmented, again partly due to having no readily available designs. They had 29 operational submarines from a variety of different builders.

WWI saw rapid increases in size and capability of boats as well as greater reliability and acceptance of diesel engines. At the end of the war German development inevitably ceased but in Britain the idea of the Fleet Submarine evolved based on the Swordfish design of 1916 and leading to the K and M classes built between 1916 and 1919. These were large (submerged displacement 2600 tons) steam/diesel/electric boats intended to be part of the battle fleet and with a surface speed of 24 knots. The K's were fitted with 3 and 4 inch guns as well as eight 18 inch torpedo tubes while the M's had a single 12 inch gun instead of the 4 inch. M2 was later converted to carry an aircraft instead of the gun. The vessels were unsuccessful and strategically ahead of their time, they were very difficult to control and many of them were run down by surface vessels in bad visibility.

British M-class submarine



Development of Technologies

Up to WWI the technology of submarines, be it hydrodynamics, stability or structures, had been had been pragmatic. However, with the rapid development of submarine operations there was much incentive to improve underwater performance and there are the beginnings of papers presented to the Institution in this period; Hovgaard presented a paper on submarine motions in 1901 and Lake presented a paper on submarine safety in 1907. However, it was not until after the war that papers to the Institution became more frequent although even then they tended to be speculative and recommend research and model testing rather than presenting solutions.

The principle design questions had by this time been answered:

- Underwater navigation by the periscope (introduced in 1902 by Lake in the USA) and the gyro compass (introduced in 1889 by Krebs in France).
- Air-independent propulsion by the use of rechargeable batteries and electric motors introduced in a number of countries between 1880 and 1900.
- The Snorkel or snort system for running petrol or diesel engines submerged introduced in a crude version by Garrett in *Resurgam* but later refined by the Dutch.
- Steel cylindrical ring stiffened hull structure to withstand sea pressure, although still predicated on "boiler formula" type calculations and riveted.
- A much better pragmatic understanding of ballasting and vertical and pitch stability and control.
- Life support systems using chemical means to generate oxygen and absorb carbon dioxide (understood in various forms from the middle of the 19th century).
- Armament using the self-propelled torpedo developed by Whitehead in Austria in 1868.

Submarine development during WWII paralleled that of WWI except that boats were bigger and more generally capable, but the war spurred much more experimental work on structures and hull forms, although this was inevitably not reported until some time after the war. This period was also notable for the introduction by all combatant navies of midget submarines for attacking surface fleets in harbour avoiding submarine defences. Important papers of this period are on structural theory by Kendrick and Ross and presented to the Institution in 1965 when Kendrick in particular developed the instability theory of ring stiffened cylinders to allow for small imperfections in circularity, still used in principle today.

The Nuclear World

Development of submarines slowed except for work on improved hull forms until the introduction in 1959 of the *USS Nautilus*, the world's first nuclear-propelled submarine. With nuclear propulsion making available almost unlimited power everything in the submarine could change; endurance, speed and size led to increases in diving depth and in almost all other technologies. The history of submarines since that time is well documented, but it has also spurred developments into more capable vessels, for example:

- Improved high-strength weldable steels have enabled much greater diving depths;
- The need to navigate under ice has led to inertial navigation systems;
- Improved sonar had led to the need for greater stealth which has led in turn to quieter machinery and stealth coatings;
- Improvements in electronics has led to huge advances in submarine systems and control as well as allowing the use of non-penetrating masts;
- The need for higher speed and better control has led to advances in propulsor technology and new control surfaces arrangements and control algorithms.
- Life support systems using the almost unlimited power of the nuclear reactor to replace purely chemical processes.

Nuclear submarine: HMS *Astute*

The Future

The submarine is still seen by all advanced navies as an essential element for defence against surface vessels as well as enemy submarines, but few nations can afford the cost of nuclear technology, requiring as it does not only the vessel and power plant itself but highly sophisticated on-shore support facilities. The author would therefore expect to see steady advances in fuel cell and equivalent power technology as well as improved batteries systems, in order to take advantage of the other advances that are made by the nuclear navies. The resulting vessels will be relatively small but very stealthy; diving at least as deep as nuclear powered vessels but inevitably with less endurance, having highly capable electronic surveillance and control systems, and with sufficient weaponry to pose a significant threat.

RINA Headquarters 1928 - 1938

With the reconstruction of Adelphi Terrace after the 1914-1918 war, the Institution moved its Headquarters in 1928 to the south corner of Adam Street nearby, where it remained until 1938.

Institution offices at 2 Adam Street from 1920 to 1938

The Development of High Speed Vessels 1860 - 2010

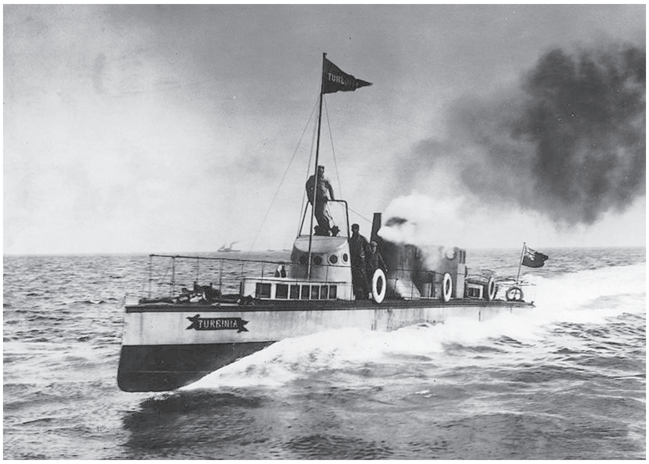
By
Dr Nigel Gee RDI DEng CEng FREng FRINA
President of the Royal Institution of Naval Architects 2004-2007

On the 17 June 1860, the largest and fastest ocean-going steamship the world had ever seen, Brunel's Great Eastern, set sail from Southampton on her first voyage to America, reaching New York some ten days later. Her top speed of 14 knots was slower than the sailing clippers which often averaged 16 knots and were reputed to be capable of over 20 knots.

1860 – *Turbinia*

In the year of the formation of the Royal Institution of Naval Architects steam power was in its infancy and commercial traffic on the world's oceans was dominated by sailing vessels. Nevertheless, the achievement of Brunel, *Great Eastern's* naval architect, was enormous; his 'Great Ship' was six times larger than any previous vessel and it would be another 40 years before a bigger vessel would be constructed. Brunel foresaw that the future of marine transport lay with powered vessels that could keep a timetable without having to rely on the vagaries of the wind. As a good engineer he also understood that a longer vessel required less horsepower per ton to achieve a given speed and could therefore operate more economically than shorter rivals. He thus laid the foundations of high-speed vessel development and for the following decades passengers and premium cargoes would fill the longest and slenderest ships before the rest. The speeds of powered vessels steadily increased throughout the second half of the 19th century until the development of the steam turbine by Charles Parsons allowed his *Turbinia* to achieve 34.5 knots in 1897, setting the stage for the application of steam turbines in the fastest ships and boats of the first half of the 20th century.

Turbinia at speed



Hydrofoils and Hovercraft

As the new century dawned, a number of far-sighted naval architects realised that ships' velocities would always be governed by the waves they made and limited by 'hull speed,' which was about 30kts for the largest vessels afloat, unless the hull could somehow be lifted partially or fully from the water surface. Enrico Forlanini, the Italian airship designer built the first successful hydrofoil, his 'Hydro-aeroplane' which achieved 38 knots in 1905 and a little later in 1916 Dagobert Muller von Thomanhul produced the first successful air-cushion vehicle which reached a speed of over 40 knots and thus these two pioneers led the way for high speed vessel development which would become a major world-wide industry.

Between the two world wars, by far the most promising development was the hydrofoil design and the work of Baron von Schertel in Germany. Von Schertel had a small prototype running in 1939 but it was the outbreak of hostilities that led to the rapid development of a 17 ton vessel capable of a then amazing speed of 47.5 knots. By 1953 he had produced the first of a very long line of passenger hydrofoils, the PT10. This craft carried 32 passengers at speeds up to 38 knots on Lake Maggiore, cutting voyage times between Switzerland and Italy by a factor of three. This enormous technical breakthrough might have gone unnoticed were it not for the attentions of a tourist from Sicily, Carlo Rodriquez, head of the Rodriquez shipyard in Messina. He immediately recognised the potential of this design for operations in the Mediterranean and in particular between Naples and Sicily. He became von Schertel's first and most successful licensee, building a total of more than 250 hydrofoils from the first PT20 carrying 75 in 1956 up to the present day Foilmasters carrying up to 350 passengers. Throughout this period, a parallel development in Russia, using the shallow immersion foil system designed by Alekseev, led to the building of hundreds of hydrofoil boats for use on rivers and sheltered waters.

Foilmaster *Ettore M*

At the time of the centenary celebrations of the Royal Institution of Naval Architects in 1960, Hydrofoils completely dominated the field of high-speed vessels. However, a British engineer, Christopher Cockerell, was thinking along very different lines and had already persuaded the government to fund the building of a prototype fully amphibious hovercraft. At the time of the launch of the prototype SRN1 in Cowes Isle of Wight in 1959 there was huge enthusiasm in the press and in industry for the potential of Hovercraft to represent the next generation of fast passenger and military craft. Very rapid developments led to the first cross channel passenger service by the SRN4 hovercraft *Princess Margaret* in 1968. All the more remarkable was that this lightweight craft, capable of speeds in excess of 60 knots, carried up to 30 cars as well as 254 passengers – it was to be another 22 years before fast catamarans were able to operate as vehicle carrying vessels. The SRN4 and the smaller SRN5/6 passenger hovercraft stimulated the demand for fast commercial ferry services but were expensive to purchase and operate. Their amphibious capabilities were of limited use on most ferry routes where special 'Hoverports' had to be constructed in lieu of existing dock infrastructure.

Princess *Margaret*

The Catamaran

Meanwhile in Norway, a country geographically dependant on waterborne transport, a new and simpler type of fast ferry was under development. Norwegian engineer and businessman Taralf Westermoen, had started Westermoen Hydrofoil in 1961 to build hydrofoils under licence. Searching for a more economic alternative they adopted the established catamaran hullform and produced the design for the first aluminium high-speed catamaran, the *Westamaran 140*. This craft and its successors were to revolutionise fast ferry design over the next three decades. The evolution of weldable marine aluminium alloys and high power-to-weight ratio diesel engines suddenly made it possible to achieve with a relatively simple catamaran what had hitherto only been achievable using foil or air systems for lift. Catamarans now dominate the world of fast ferries with the majority of the 1350 fast ferries operating in the world using this hullform. Catamarans which exceed the size and speed of any previous hydrofoil or hovercraft have now been built and catamarans are built in every developed country with a seaboard, most notably in Australia, Norway and the USA.

An accident in Hobart Tasmania, damaging the Tasman Bridge, led Australian naval architect Phil Hercus and fisherman/boatbuilder Bob Clifford to get together and build the first Southern Hemisphere passenger catamaran, as a means of crossing the harbour while the bridge was re-built. The success of this operation led to the formation of Incat Designs and Incat Tasmania. Incat quickly increased the size of their designs to cope with the demand for this type of transport and by 1990 had produced the design for the world's first car carrying fast catamaran. Ten years later there were 100 high-speed car ferries operating and by 2008 the total stood at 150. The largest of these vessels are over 120m long and can carry heavy loaded trucks and must surely qualify to be recognised as fast ships rather than boats.

On the other side of Australia, near Perth, a catamaran building industry was emerging from the remains of a fast fishing boat building economy. In recent years one company, Austal has become the world's largest builder of high speed vessels, producing passenger and car carriers similar in size and speed to the Incats. Austal Chief Naval Architect, Tony Armstrong, saw the potential to adapt another known hullform, the Trimaran, for application as a fast car ferry. *The Benchijgua Express*, launched in 2005, is the longest multihull ferry in the world at 127m, and capable of 40 knots.

Military Vessels

High-speed military vessel design has followed in the wake of commercial ferry development. Throughout the Cold War in the USA hydrofoil designs were favoured and existing surface piercing commercial designs were developed into fully submerged foil systems giving enhanced seakeeping characteristics. The USSR meanwhile designed some of the world's largest air cushion vehicles. Most navies have now all but abandoned large hydrofoils and hovercraft in favour of simpler monohull and catamaran hullforms. A notable exception is the LCAC amphibious hovercraft landing craft. The USA has built 91 of these large hovercraft capable of travelling at 40 knots and carrying a fully loaded battle tank. Today, as we celebrate 150 years of the Royal Institution of Naval Architects, high-speed vessel design has matured to the point where very large and fast prototype Littoral Combat Ships using monohull, catamaran, and trimaran technologies are all undergoing trials in the USA.

Benchijugua Express

The Future

150 years ago cars existed as a number of steam prototypes, aircraft were only dreamed about, and ships were the only viable means of mass transport. The steam engine had freed marine transport from the variability of the winds that previously drove them and gave naval architects the opportunity to concentrate on designing hullforms for speed and efficiency. This has been achieved firstly through classical naval architecture utilising ships with high length/displacement ratios and later through innovation with the invention of hydrofoils and hovercraft and the the adaption of multihulls using modern materials and powerplants. A personal view from this author, is that we shall see further innovative developments in the naval architecture of fast vessels over the next 50 years. Sponson-assisted monohulls, be they trimaran or pentamaran, will undoubtedly see wider application for larger fast vessels. With rapidly rising fuel prices and increasing awareness of the effects of emissions on the environment there will certainly be a search for lower drag, lower power designs. Current catamaran and trimaran designs have successfully minimised wave-making drag but viscous drag remains a seemingly irreducible hurdle to further power reductions. It may be that further hybridisation of current successful hullforms with emerging technologies for viscous drag reduction will lead to the naval architect's Holy Grail; - the fast vessel with both low viscous and wavemaking drag.

240m 40kt Pentamarin RoRo - a concept by BMT Nigel Gee Ltd.

Nigel Gee retired from BMT Nigel Gee Ltd, the international design company specialising in high speed vessels, which he founded in 1986.

RINA Headquarters 1938 -

In 1938, the Institution moved to its present headquarters at 10 Upper Belgrave Street.
The wood paneled Denny Library on the first floor was furbished by Margaret Lady Denny in 1939, in memory of her husband, Sir Archibald Denny (an Honorary Vice-President of the Institution).
In 1955, the premises were extended to include a Lecture Hall, the building of which was greatly facilitated by the generosity of the late Viscount Weir of Eastwood (an Honorary Vice-President of the Institution) after which the hall is named.

10 Upper Belgrave Street, circa 1930

The Development of the Passenger Ship

By
Stephen M. Payne OBE RDI FRINA FREng,
President of the Royal Institution of Naval Architects 2007-2010

From the 1830's until the 1970's, most major developments in the design of passenger ships arose from the design of transatlantic liners. This was not surprising considering that the transatlantic route was considered the most profitable due to the volume of traffic and that the Atlantic Ocean was deemed the most demanding due to frequent violent storms coupled with the prevalence of fog and ice.

Great Western

The first ship that can lay claim to being a transatlantic liner was Isambard Kingdom Brunel's wooden paddle steamer *Great Western* 1838. This was the first steamship built for transatlantic service following Brunel's suggestion at a board meeting of the Great Western Railway that they should extend the railway which ran from London to Bristol with a scheduled service to New York. Although Brunel was not a naval architect he was an exceptional engineer and grasped the fact that the ship would need to be large enough to carry sufficient coal for continuous steaming. Confounding his critics he reasoned that the bigger the ship became, proportionately the lower the power that would be needed to propel her at a given speed. He also realised that the ship would need to be exceptionally strong to withstand the adverse conditions frequently encountered on the Atlantic. At 1340 grt *Great Western* was the largest steam ship in the world when completed and had accommodation for 128 passengers, 20 servants and 70 crew. She was powered by a two-cylinder side lever steam engine of 750 ihp and averaged 8.66 knots on her maiden transatlantic crossing.

Great Britain

The success of *Great Western* and the emergence in 1840 of competition from the government subsidised Cunard Line led Brunel to suggest that a second much larger ship should be built as a consort. Brunel chose to build *Great Britain* 1844 of iron and initially conceived her as a paddle steamer. However, advances in screw propulsion led him to reconsider her propulsion and although already under construction she was completed as a screw steamer, her machinery having been turned through 90 degrees and a geared up chain drive incorporated to rotate the screw. At 3270 grt *Great Britain* was the largest ship in the world and introduced many novel features including the provision of bilge keels and watertight bulkheads. The ship was particularly well appointed for the period with an ornately decorated saloon and covered promenading space complimenting her first class passenger cabins. The demise of her owners, the Great Western Steamship Company, through an unfortunate grounding incident with the ship in September 1846 did not end her career and she was subsequently successfully used on the run to Australia as a steamship and sailing ship. That she survives to this day in Bristol at the dock where she was originally built is testament to Brunel's design and vision in using iron for her construction. Recent model tests on her propeller design show that it is only a few percentage points less efficient than a modern counterpart.

Great Eastern

Brunel's third and last great ship was originally conceived to sail to Australia and back without refuelling. *Leviathan*, latterly renamed *Great Eastern* in 1859, was an immense iron steamship propelled by paddle wheels, screw propeller and sail. Built at John Scot Russell's yard at Millwall in London she stuck fast mid-way through her sideways launching into the Thames and the delays and subsequent cost over runs bankrupted her owners. She was finally completed for the transatlantic trade but was too far ahead of her time and failed to attract sufficient clientele. As with his earlier ships Brunel introduced many concepts that are still in use to this day such as a double bottom and a steering engine to turn the rudder, the size of which was deemed too big to turn with muscle power alone. Converted into a cable layer, *Great Eastern* went on to lay the first transatlantic telegraph cables as well as several others linking parts of the British Empire. At 18,915 grt the ship remained the largest ship built well past her scrapping in 1888 and it wasn't until 1901 that her displacement was exceeded by another ship. As originally outfitted as a passenger liner for 4000 passengers *Great Eastern* offered the height of luxury in exceptionally well appointed accommodations. Apart from her success as a cable layer the ship was a commercial failure and it is open to conjecture as to whether she would have faired better on the run to Australia for which she was originally conceived. John Scott Russell her builder was instrumental in forming the Institute of Naval Architects which with the addition of Royal Charter is now The Royal Institution of Naval Architects.

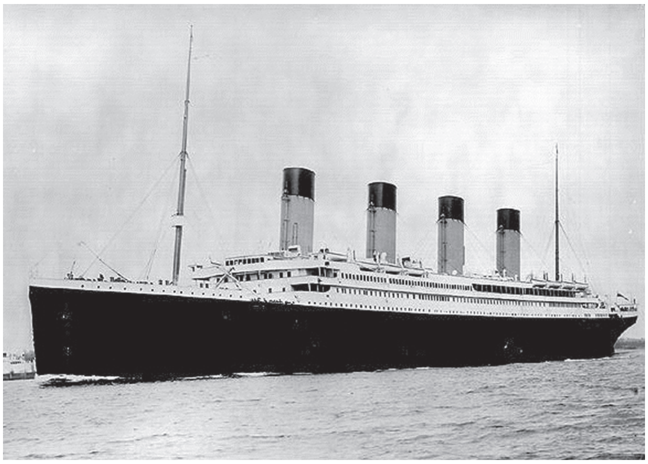
White Star Line

The Oceanic Steam Navigation Company was founded in 1869 by Thomas Ismay. Better known as the White Star Line the Company's ships set new standards for design and comfort. Powered by compound steam engines the ships of the Adriatic and Britannic classes were considerably more fuel efficient than earlier ships. The concept of a midships superstructure with an associated boat deck was introduced for the first time. First class passenger accommodation which had hitherto been placed aft was now placed amidships where ship motions were much less, thus contributing greatly to passenger comfort. All first class cabins were enhanced with hot running water and were placed at the side of the ship affording natural daylight through portholes. Even steerage passengers were well accommodated, dormitories having given way to simple four berth cabins. Successive White Star ships followed the same philosophy but after *Teutonic* 1889 and *Majestic* 1890 the Line abandoned the concept of ultra high speed as too costly to aspire to without government subsidy, deciding to concentrate more on the provision of comfort and luxury instead.

Cunard

Developments continued apace. Steam reciprocating machinery reached its zenith in a series of German liners culminating with the *Kronprinzessin Cecile* 19,360 grt 1907. The next significant advance was the introduction of Cunard's *Lusitania* and *Mauretania* 1907. At 31,000 grt these ships significantly larger than anything previously seen. They introduced quadruple screw propulsion with the machinery based upon the then new steam turbine. Developing 70,000 shp the two ships could maintain a 25 knot transatlantic service speed. Fuel consumption was some 900 tons of coal per 24 hours, all of which had to be fed into the 25 boilers by an army of stokers and trimmers. The two ships provided three classes of accommodation for 2165 passengers ranging from en-suite Regal Suites in First Class to dormitories in Third Class. The biggest problem with the ships appears to have been extremely high vibrations which severely affected the stern areas where Second Class was located. Before entering service the Second Class public rooms on board *Lusitania* had to be substantially rebuilt with structural reinforcements which detracted greatly from the ambiance of the spaces so treated. Despite the modifications vibration was still a major problem; the design of the propellers was the root cause of the vibration. Propeller design was still very much in its infancy compared to modern practice and although several designs were tried only partial improvements were achieved. Whereas *Lusitania* was lost during World War I *Mauretania* survived and had a very successful career not being scrapped until 1935. The cost of building and operating these ships was so high that they required both a building and operating subsidy, something the British Government readily agreed to for purposes of national prestige and national security. Cunard's great British rival, the White Star Line, countered with a trio of ships that were designed to be self supporting without the need of such subsidies. Being designed for a more modest service speed with a corresponding reduced fuel consumption these ships were 50% bigger than their Cunard counterparts thus benefitting from economy of scale. Accommodation on an even greater lavish scale was incorporated into the ships with a swimming pool, squash racquet court and Turkish Baths augmenting all the other facilities. The three ships of the Olympic class 1911 have become legendary mostly by virtue of the loss of the second ship which was named *Titanic*.

The loss of *Titanic* in April 1912 whilst on her maiden voyage with over 1500 fatalities led to a number of important changes in ship design. The international maritime community worked together to set new standards for ship subdivision and construction and the provision of adequate lifesaving appliances. This resulted in 1929 in the first SOLAS (Safety Of Life At Sea) regulations. These regulations have been updated from time to time and now constitute an extremely wide ranging set of regulations covering all aspects of all type of ship design and operation.



RMS *Titanic*

Normandie and *Queen Mary*

In 1935 the French Line introduced the 29 knot 80,000 grt turbo-electric *Normandie*. With a view to maximising the French content of their new national flagship and with the perceived weakness of French reduction gearing, the French Line chose to adopt electric transmission to effect an efficient speed reduction from the high-speed turbines to the relatively slow turning propellers. This was by far the largest marine installation of its type to date. The ship was largely a technological triumph and was considered as revolutionary as her rival, Cunard Line's *Queen Mary* 1936, was considered evolutionary. It is largely perceived that *Normandie* set new standards for passenger accommodation that have never since been met let alone surpassed. The First Class public spaces and cabins were heroic in scale and exquisite in execution. Superlatives abounded as they should because the ship represented an enormous capital expenditure almost twice that of her similar sized rival, *Queen Mary*. *Normandie,* however, suffered from two major flaws. Firstly the scourge of vibration aft which initially made her uncomfortable at high speed until new propellers were designed and fitted and secondly, the scale of First Class was so extensive that Second and Third Class were much restricted, being provided with fewer public spaces and facilities than her British rival. In consequence *Normandie* failed completely commercially whereas *Queen Mary* was heralded as a success. In fact *Queen Mary* was the only great "ship of state" of the 1930's that operated profitably without the need of any subsidy. *Queen Mary* was joined by a half sister in 1940, *Queen Elizabeth*, and the pair operated very successfully until the mid 1960's post WWII. *Normandie* was sadly a war loss having caught fire and sank at her New York berth whilst being outfitted as a troopship. *Queen Elizabeth* met a similar fate in Hong Kong in 1972 but *Queen Mary* survives in Long Beach California as a museum ship.

RMS *Queen Elizabeth*

The 1950s and 1960s

The last great transatlantic liners of were largely refinements of what had gone before. The 50,000 grt *United States* 1952 was the fastest liner of all time, achieving a top speed on sea trials of 38.3 knots. *France* 1962 66,000 grt was also fast but her interiors were something of a disappointment when compared to *Normandie*. The Italians built a number of new transatlantic liners but the legacy of the loss of their *Andrea Doria* in 1956 led to subsequent designs being so designed that their use as cruise ships was problematic. The Dutch 38,000 grt *Rotterdam* 1959 was probably the most successful ship of the period. Holland America Line had judged that off season cruising would soon become the norm and they designed their final "ship of state" in such a way that she could be economically operated as a cruise ship. This beautiful ship is now a museum in her namesake port still embellished with much of her original interiors.

Following the withdrawal of *Queen Mary* and *Queen Elizabeth* Cunard introduced what was thought would be the last true liner, *Queen Elizabeth 2* 1969. Originally a steamship, she was re-engined with a modern diesel electric plant after nearly two decades of service and was in commission for nearly 40 years. Like *Rotterdam* she was designed for the dual purpose role of crossing and cruising and eminently fulfilled both roles until her withdrawal. She is now on a new phase of her career as a floating hotel.

SS *Rotterdam*

All other transoceanic routes steadily developed with bigger and bigger ships until the late 1950s and early 1960s when the last ships primarily designed for liner voyages were introduced. Three of the largest such ships were Orient Line's 42,000 grt *Oriana*, P&O Line's 45,000 grt *Canberra* and Union-Castle Line's 37,000 grt *Windsor Castle*. The first two ships successfully switched to long distance cruising in the early 1970s once the demand for their line voyages out to the East was supplanted by the aeroplane. *Windsor Castle* was less adaptable to cruising due to her commodious cargo holds which took up almost half of her internal volume. Following withdrawal in 1977 she served for a short time as an accommodation ship before languishing in lay-up and ultimate scrapping, still in her two class cargo-liner configuration.

Cruising

Cruising was initially considered the poor man's relation in passenger shipping as it was not considered that such operations could turn a profit. Historically brand new ships were sent on cruises as part of a shakedown exercise where on board staff could find their way around the ship and prepare her for full liner service. Cruises could be timed to allow the ship to slot into the liner schedule when needed. The Great Depression of the early 1930s saw many prestigious liners pressed into cruise service between line voyages, none more celebrated than the transatlantic liners that were sent on Prohibition busting so called "booze" cruises out of New York crammed full of thirsty Americans. A few liners were converted into full time cruise ships with the addition of swimming pools and other holiday inspired amenities but these were few and far between. With the advancement of air travel at the expense of passenger ship operations almost complete by the late 1960s many considered that once the passenger ships then in commission were withdrawn that would be the end of passenger shipping period. Indeed, Cunard Line announced at the introduction of their *Cunard Princess* in 1976 that she would be the last passenger ship ever commissioned. For several years it certainly looked as though this would be the case but several new enterprising companies began marketing cruises to the mass market rather than the luxury market where most cruises had been traditionally aimed. As these companies thrived and larger and larger cruise ships were built eventually rivalling in size the great transatlantic liners. In 1996 Carnival Cruise Lines introduced the 101,000grt *Carnival Destiny*, the first passenger ship to exceed the tonnage of the previous largest liner, Cunard's 83,000 grt transatlantic liner *Queen Elizabeth* 1940, and the first passenger ship over 100,000 grt.

Queen Mary 2 and the future

The only passenger ship built as a true liner since the construction of *Queen Elizabeth 2* of 1969 is her successor *Queen Mary 2* which entered service in January 2004. At 150,000 grt she exhibits all the qualities of a true ocean liner combining the form, strength and power to maintain a demanding Atlantic schedule. Whereas only First Class passengers on the old Queens were provided with grand public spaces *Queen Mary 2* is truly egalitarian in offering all her passengers access to a wide range of voluminous public spaces with amenities and facilities to match. The largest passenger ship in the world when built she soon lost that accolade to a number of cruise ships and the bench-mark has since been set even higher with the introduction of Royal Caribbean International's 220,000 grt *Oasis of the Seas* late 2009. It remains to be seen if the cruising public prefer to cruise on such giant ships where the ship itself becomes much of the destination rather than the ports of call, or whether the preference is for somewhat smaller ships that have easier access to a more varied number of ports. Whatever the case, it appears Cunard's prophesy of the mid-1970s that passenger shipping would wither and die within a generation of ships was totally wrong.

Stephen Payne is Vice President and Chief Naval Architect, Carnival Corporate Shipbuilding.

Queen Mary 2

Presidents of the Royal Institution of Naval Architects 1860 - 2010

1860-1880	The Right Hon Lord Hampton GCB DCL
1880-1893	The Right Hon The Earl of Ravensworth
1893-1896	The Right Hon Earl Brassey GCB DCL
1896-1901	The Most Hon The Marquis of Linlithgow PC Kf GCMG GCVO
1901-1908	The Right Hon The Earl of Glasgow GCMG LL D
1908-1911	The Right Hon The Earl Cawdor
1911-1916	Rear-Admiral The Most Hon The Marquis of Bristol MVO
1916-1921	The Right Hon The Earl of Durham KG GCVO
1921-1928	His Grace The Duke of Northumberland KG CBE MVO LL D
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1933-1941	The Right Hon Viscount Stonehaven GCMG DSO LL D
1941-1948	Admiral of the Fleet The Right Hon Lord Chatfield GCB OM KCMG CVO DCL LL D
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1961-1971	The Right Hon Viscount Simon CMG
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1981-1984	Admiral Sir Anthony Griffin GCB
1984-1987	Professor J B Caldwell OBE PhD DSc FREng
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1993-1996	Dr P J Usher CBE FREng RCNC
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1999-2002	D Goodrich RCNC MBA,
2002–2004	Professor W G Price FREng FRS
2004 – 2007	Dr N Gee DEng FREng
2007 – 2010	S M. Payne OBE RDI FREng
2010 -	P French FRSA

The Amphibious Hovercraft

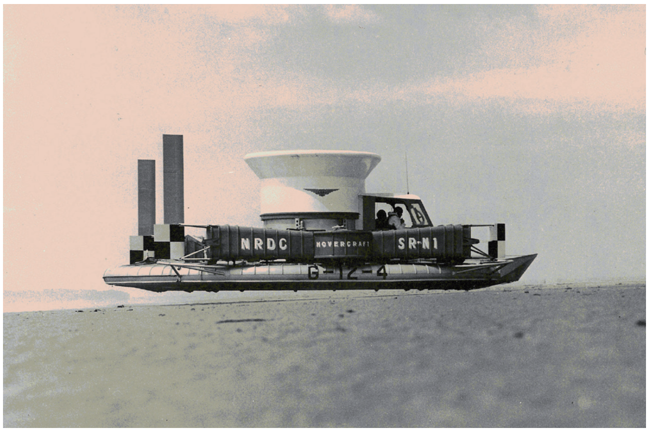
By
Brian J. Russell B Sc (Hons) MRINA

Although a relatively modern concept, the hovercraft has had a major impact on maritime transport, through its high-speed capability and flexibility of operations. Other characteristics have led to benefits in other roles and areas of activity.

SRN1

The SRN 1 was based on a multi chambered buoyancy tank. Construction material throughout was thin rivetted aircraft aluminium sheet and stiffeners. A single four-bladed fan, mounted in the large central vollute was driven by an Alvis Leonides engine. A portion of the fan output was used to control the craft via external ducts and vanes.

The craft was unveiled to the media on 11 June 1959 and undertook the first crossing from Calais to Dover by a hovercraft, on 25 July. Although an experimental design, the SRN 1 demonstrated the viability of the hovercraft principle developed by Sir Christopher Cockerell, and which led to many worldwide applications.



The Saunders Roe SRN 1 Hovercraft.

Ferries

Designs were developed to meet passenger and vehicle ferry needs. The most noticeable being the SRN 4 services of Seaspeed, Hoverlloyd and Hoverspeed on the short cross-Channel routes and the Hovertravel operation across the Solent. These services either required an amphibious capability, or capitalised on the high workload capability. Seaspeed operated out of Dover to Calais and Boulogne, and Hoverspeed from Ramsgate, across the Goodwin Sands to both French ports. The two companies amalgamated to form Hoverspeed and all operations were from the Dover hoverport. The two SRN 4 Mk 3 hovercraft, *Princess Anne* and *Princes Margaret* were taken out of service in 2001.

Hovertravel are still operating, after nearly 45 years on the cross Solent route between Southsea and Ryde, on the Isle of Wight. Initially the SRN 6, which could carry 38 passengers, was used, but the noise generated by the open propeller resulted in new craft being required. The AP 1-88 was developed, using diesel engine, ducted propellers and welded aluminium construction. The newest craft is the BHT 130, which can carry up to 130 passengers and has completed a very successful trial as an alternative means of crossing the Firth of Forth.

UK Military Applications

The military potential of this new vehicle was soon recognised, with activity initially in the UK, USA and Russia. The UK set up a dedicated trials unit that carried out role evaluations, demonstrations and overseas visits. The Royal Naval BH 7 went to the Baltic for cold weather trials, travelling under its own power, operating from un-prepared sites some 1500 nautical miles from its home base. During these trials, it was observed for the first time that a hovercraft could operate as an ice-breaker.

Mine countermeasures proved to be a natural role for hovercraft, initially towing sweeps and sonars. The supporting air cushion between the hard structure and the water surface meant that acoustic, magnetic and pressure signatures were at a minimum. The air cushion also helped to absorb some of the energy of any explosion adjacent to the craft. The ability to transit to a suspected mined area at high speed was another significant advantage. The final configuration of the BH 7 was as a mine hunter.

Military interest in the UK involves the Royal Marines and the amphibious assault and logistic support roles. The RM has four Griffon 2000 hovercraft which can be operated independently, or form the LPDs or amphibious ships. They were used in the first Gulf War, particularly for the rescue of injured personnel, from an up river location, when a conventional landing craft was hit by a missile. They were also used to transport engineers to clear a suspected mined beach landing area of mines and tank traps.

There has been an increasing interest in moving high-value amphibious ships to over the radar horizon, to reduce vulnerabilty to enemy fire, when approaching protected shores. However, if conventional landing craft are used, their vulnerability is increased, as exposure time can be doubled. To this end, a PACSCAT (Partially Air Cushion Supported CATamaran) demonstrator is about to be launched. This craft will have the same load carrying capability as a Mk 10 landing craft, but at twice the speed.

The military hovercraft Griffin

Other Military Activity

In the USA, interest was fueled by the tour of the BH 7 on the East coast, from New York to Charleston. The major programme is the Landing Craft Air Cushion (LCAC), which saw over 100 craft built, with around three-quarters currently operational. LCACs were used in Somalia, the first Gulf War and for humanitarian relief during flooding in Bangladesh. A number of craft are undergoing a mid-life extension, leading to improved performance and increased payload capability.

Russia has a wide range of hovercraft, many mirroring western designs, the main interest being amphibious assault and logistic support. The capabilities range from an 18-personnel platoon to three tanks. The craft are fitted with guns, cannons and missiles and a plethora of communication, navigation and counter measures equipment indicate that they are very capable craft. Three *Zubr* hovercraft are in service with the Greek Navy and it is understood that the Chinese Navy may be acquiring up to six of these craft.

Humanitarian Operations

Transport in marginal environments has seen the employment of hovercraft. In the third world, rapid flowing rivers provide natural highways for small hovercraft, used to take patients to hospitals, or medical staff and equipment to remote centres of population. Dedicated hovercraft are based in Irian Jaya, Papua New Guinea and on the upper reaches of the Amazon. In Zambia and Madagascar, River Rover hovercraft of the organisation HoverAid are used to provide transport for relief personnel and stores, particularly during the monsoon season when severe flooding occurs.

Para-Military Activities

Many coastal areas are made up of shallow waters, tidal areas, sandbars and mudflats and are the natural home of amphibious hovercraft. In some countries transport on the land adjacent to the coast is difficult, or non-existant. Also, in some locations, smuggling and terrorist activity involves high-speed boats. However, these boats have to use relatively deep water, but the hovercraft can steer a straight course over all terrain. Patrol hovercraft are used in Scandinavia, the Middle East and the Indian sub-continent for border patrol and counter-insurgency roles.

Search & Rescue

Small hovercraft are increasingly being used for search and rescue tasks on mudflats and during floods. The RNLI have seven dedicated craft, some based at lifeboat stations around the coast of the UK, including Southend-on-Sea, Essex; Hunstanton, Norfolk; Poole, Dorset; Weston-super-Mare and Morecombe Bay, Lancashire.

Fire and Rescue Services have recently procured small hovercraft for use in flooded areas. The advantages are that with an undulating surface, there is no need to disembark, or change vehicles when the surface is flooded and then dry. Also, the hovercraft rides on the surface, so under water obstructions are not an embarrassment.

In conclusion, the amphibious hovercraft has not only had an impact on marine transport, but has brought significant benefits in a number of other roles and will continue to do so in the future.

Brian Russell is a Council member of The Hovercraft Society.

Events of 1860

Schooner *Aline* launched

In 1860, Camper & Nicholson launched the 216 ton schooner *Aline* for Charles Thellusson. Designed by Ben Nicholson, she was an instant success winning the Queen's Cup on her first outing. She was also the first schooner to be rigged without steeply raking masts which had become fashionable after the effect of the visit of the *America* in 1851.

She became the most famous Victorian yacht and was bought by the Prince of Wales in 1888 when she was still competitive and she no doubt encouraged him to build HMY *Britannia* in 1893.

Changes in Yacht Design 1860 - 2010

By
David M. Cannell FRINA

The word "yacht" is derived from "yaght", believed to have its derivation from "yaghen", a Dutch word meaning to hunt or pursue, or an alternative meaning to tow a vessel.

The Early Yachts

The earliest recorded yachts were fighting vessels of the 17th century when the Dutch fleet was at its preeminence, defeating combined English and French fleets in 1673. These yachts generally had a length of nearly 70ft and were heavily timber planked and rigged with a combination of square and fore and aft sails. The largest Dutch yachts were over 100ft long but there were a number of private yachts of little more than 20ft.

In Britain, yachting developed as a sport in the 18th century, with the first yacht club formed in Cork, Ireland, in 1720. Vessels at this time, generally rigged fore and aft, were slow and cumbersome by today's standard. During the 18th and into the 19th century, very large prizes were introduced for yacht racing and yacht clubs were formed throughout the UK and at major ports worldwide, where the sport of yachting became popular.

1800 - 1900

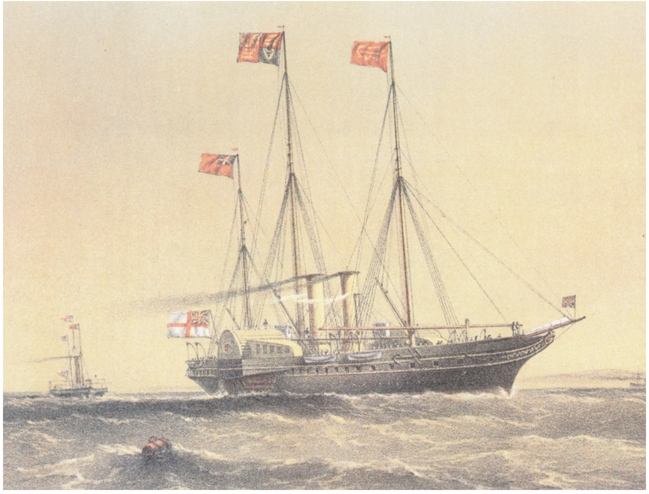
During the 19th century, large royal yachts were built, enabling visiting royalty to remain, as it were, on home territory when attending a foreign country. In 1843, the new British Royal Yacht *Victoria and Albert* was built. The *Victoria and Albert* was a paddle steamer with a length of 200ft and beam of 59ft. The problems experienced by a vessel this size when visiting many ports in Europe were overcome by building a smaller steam screw driven yacht, the *Fairy*, having only a 21ft beam. "Shadow" or supporting vessels have recently introduced with the modern large yachts.

The more recent trend towards larger motor yachts, now called Superyachts or Megayachts, reflects the trend seen during the 19th century when a new British Royal Yacht, the *Victoria and Albert* was built in 1855 with over twice the tonnage of the predecessor and 360ft in length, capable of achieving just under 15 knots.

Steam-powered motor yachts with some sail assistance in the late 19th century were of very efficient hull forms, being long and lean. During this period, it was not unknown for these larger motor yachts to undertake international voyages with some steaming round the world over several years.

The popularity of smaller boat sailing in the 19th century led to the introduction of town racing regattas, where yachts or boats ranging from 20 to 80ft would be allotted a primitive handicap number. The repeated success of some vessels led to dissatisfaction with the handicap system, resulting in the birth of the raters in the 1890's, where similarly constructed and rigged vessels raced against one another, as half raters, ¾ raters and the like. This approach was replicated in the latter half of the 20th century with the half ton, ¾ ton and 1 ton designs.

Yachting in America was centred around the East Coast, with the larger sailing yachts often schooner rigged and with long, lean hull forms. The schooner *America* was typical of the type, winning the famous America's Cup in 1851.



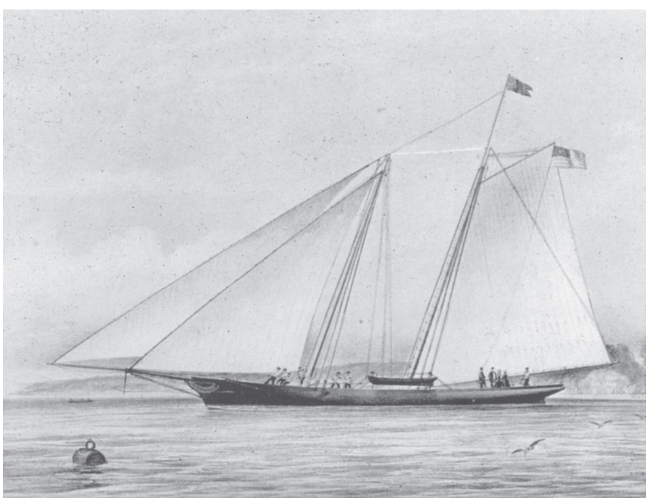
Victoria and Albert II

1900 – 2010

Yacht design in the early part of the 20th century evolved through trial and error. Very large sums were spent by keen racing sailing yacht protagonists in developing faster vessels, often resulting in an unsuccessful vessel being built and scrapped within a few years. In order to control the diversity of racing yachts in a particular event, the Class yachts developed, including 12, 15, 19 and 23 metre Classes, with America developing the J and M Class racers. As the first holder of the America's Cup, the USA stipulated the type of vessel the challenger should race to win the cup, resulting in the very fine J Class yachts being built during the 1920s and 1930s. A number of these yachts have been almost totally rebuilt and re-rigged using modern materials, to enable them to race today. Originally, these vessels did not have the niceties of the modern winches and required up to 19 men hauling on a sheet to tighten home a headsail in heavy wind. The latest America's Cup vessels are trimarans built to the most advanced technology in hull and rig design, but perhaps lacking the grace and potential future use as their J Class predecessors.

During the early 20th century, offshore races evolved, including the Bermuda race in 1906 and Fastnet race in 1925. USA designs often won the trophies, particularly during 1950s, with the advent of more sophisticated tank testing. This was utilised with great success by the yacht designers Sparkman and Stephens. In the 19th century, American yachts such as the *America* were very successful due to the use of cotton in the manufacture of sails, rather than the heavier flax canvas. Sail development today has been one of the major factors in the increase in sailing yacht performance with combinations of plastics, mylar, kevlar and carbon fibre, allowing the very high precision cut and developed sail shapes, resulting in high speeds and ability to sail close to the wind.

Monohull forms have developed from the long keel fine ended sailing fishing boats and pilot boats of the 18th and 19th centuries to the more extreme canoe bodied deep fin keel hull forms with a ballast keel bulb, developed in the mid 20th century for model yacht racing, again demonstrating the benefit model design and tank testing to the development of hull forms. But probably, the most exciting development in sailing vessel design has been the introduction of multi hulls – catamarans and trimarans of very light weight, largely achieved by the use of carbon fibre and epoxy resin construction with large rigs of highly controllable material. These vessels have reached speeds which were unimaginable at the turn of the 20th century. In excess of 40 knots is often attained, and the current round the world record at just over 50 days, with an average speed of 22 knots, is held by *Orange II*.



America

In sailing yacht racing, the introduction of a racing Rule to which the vessel should be built has always resulted in extreme hull forms to "bend or cheat" the Rule. In 1887 the Thames Rule was introduced giving a rating based on the formula LxBxB/2÷ 94. Thus breadth, being a squared term, has a very significant effect on the rating. In this case, half breadth was intended to represent the depth of the hull, breadth being easier to measure than depth. Vessels became narrower and deeper, resulting in the extreme 5 tonne *Oona*, drawing eight feet but only having 5.5ft beam.

Today, racing Rules are far more sophisticated and try to control extremes. However, this has encouraged "one design" yacht racing, enabling yachtsmen to race on supposedly equal terms as far as the vessel is concerned. However, "one design" racing, adds little to progress in naval architecture, or the development of structures.

The development of speed in motor vessels reached a peak with steam powered propellerdriven torpedo boats and destroyers, achieving 30 knots in the late 1890s. Parsons Engineering Company developed the fast steam turbine launch *Turbinia* to show the advantage of this form of propulsion, the vessel powering at speed between the massive warships at the Spithead naval review in front of Queen Victoria to publicise turbine propulsion.

Petrol and diesel engines were developed in the 1890s and gave the advantage of the fuel being carried in tanks, rather than coal holds, where the boiler fire required continual manual stoking. Hull development progressed quickly during the early 1900s with the stepped bottom being shown to dramatically reduce wetted surfaces for high-speed planning vessels. John I Thornicroft & Co. developed a vessel capable of 55 knots, a remarkable achievement in view of the poor power to weight ratio of the engines compared with the modern internal combustion engine.

Smaller high-speed motor yachts were built during the 1920's with Hubert Scott Payne developing the ancestor of the more modern 30 knot motor yacht. Other high-speed motor yacht builders, in particular Isotta Fraschini, Hall Scott, Packard and Sterling, used lightweight petrol engines, while the high speed lightweight diesel was developed in Germany. In 1912, *Maple Leaf IV*, built by S E Saunders with a 40ft waterline length, achieved 50 knots with two petrol engines of 800 horsepower. This compares well with modern motor yachts of that size where speeds in the larger power boat classes reach 100 knots.

Probably, the two greatest changes in the development of motor yachts since 1860 have been in construction materials and screw propulsion. Fast vessels, both power and sail, were largely built of laminated timber when bone glues became sufficiently strong with closely framed and stringered hull shells. Today, the most sophisticated vessels are built of carbon fibre and epoxy resin, usually in sandwich construction, using very thin skins of laminate separated with a plastic foam core. This results in a structure many times stronger and stiffer than the best timber construction of the early 20th century.

Problems were experienced with traditional propeller screw propulsion with speeds exceeding 35 knots, where cavitation became increasingly damaging to the propeller blades. This did not matter much for relatively short races but for high-speed commuter vessels becoming popular in the USA, alternatives were sought. The development of the fully cavitating surface propeller and water jet propulsion largely overcomes these problems, resulting in relatively unsophisticated pleasure motor yachts often achieving over 50 knots. Higher speed vessels using water jet propulsion, however, suffer from intermittent or lack of thrust in fairly moderate sea conditions as the designs rely on the bottom intake scoops to the water jets being in contact with the sea at all times.

The development of high speed in motor propulsion has also resulted in hydrofoil and hovercraft, but these have not become popular as pleasure vessels or motor yachts, possibly due to the noise associated with hovercraft and the greater vulnerability of the hydrofoil in the increasingly polluted seaways.

Today

Today, the fastest large motor yachts have been built using multiple gas turbine propulsion and of sizes even larger than the royal yachts of the 19th century, with the largest yachts built today approaching 150m length with high-speed diesel propulsion. The naval architecture design of the hulls to these vessels has not developed to any extent over the last 50 years and indeed in some respects these large yachts are less efficient and sea kindly than vessels built in the early 1900s. There have, however, been recent "throwbacks" in design, including bow shapes very similar to warships of the 1890s, incorporating vertical stems or even stems raking aft, and some designs increasing length to beam ratio to reduce hull resistance.

It is interesting to observe that fast sail boat design has adopted features from a century ago. The gaff rig, with a spar holding the top of the mainsail, developed into the Marconi rig where the separate top mast was effectively stepped on top of the main mast, eliminating the necessity for the gaff, resulting in the Bermudian rig. Clearly, the top of the narrow triangular sail is very inefficient and more recently Bermudian mainsails have incorporated very long and stiff top battens, resulting in a sail not too dissimilar from some of the gaff rigs in years gone by. The hull form of the fast racing yachts are now vertical or plum stemmed with often a large retractable bow sprit on which to set a flying jib or spinnaker – common in sailing vessels a century ago.

Major developments not dreamed of in 1860 are the advent of the modern electronic navigation aids and engine control, radio communication and weather prediction, undreamed of in 1860, have enabled yachting enthusiasts to proceed to sea without the experience of seafarers of the previous century.

The Future

Undoubtedly, the next 150 years are likely to see many fascinating developments in yacht design, although they are unlikely to surpass the major changes during the previous 150 years. The necessity to reduce fossil fuel consumption, particularly in response to concerns of climate change, will certainly result in restrictions on the use of very high diesel consumption seen in today's large fast motor yachts. However, this change will hopefully concentrate minds on hull efficiency, bringing the naval architect back to the fore. Unfortunately, over the past 30 years, naval architecture has taken a considerable "back seat" in the development of large motor yachts with the advent of the "yacht stylist". Shapes and appearances have become far more important to many owners than development of seakeeping and hull efficiency.

In sailing yacht design, ease of rig handling, incorporating sail cloths developed from plastic sheet, perhaps produced from hot moulds to the require shape, will further improve the performance of production cruising yachts. Higher speeds under sail are likely to come from foil supported hulls, further reducing wetted surface area, allowing the possibility of the world sailing speed record breaking the 100 knots barrier.

David Cannell is the Principal of David M. Cannell & Associates, Naval Architects, Surveyors & Consultants and has been involved in designing and surveying "small craft" up to 100m throughout his career.

America's Cup 2010 challenger and winner *USA* (right) with *Alinghi* (left) (Photo by Gilles Martin Raget)

The Royal Institution of Naval Architects and Lloyd's Register

Given their common roots in the UK maritime industry, it is not surprising that throughout the 150 years in which the histories of both organisations have overlapped, many members of the Institution have held important positions within Lloyd's Register. Such connections can be traced back to 1860, when the joint Chief Surveyors, Joseph Horatio Ritchie and James Martin were two of the 18 founding members of the Institution.

Joseph Horatio Richie (Member 1860-1872) was born in Port Glasgow. Apprenticed to John & Charles Wood, builders of the Comet, on completion of his indentures he was sent to St John, New Brunswick by Pollock, Gilmour & Co to build three ships for their timber trade. He then joined Charles Wood in Quebec to build and deliver the timber raft *Baron of Renfrew*. A brief partnership with John Wood followed before he established himself as a shipbuilder on the Thames at Rotherhithe. When this failed he applied for, and was given, a post as a Lloyd's Register surveyor.

Richie was appointed joint Principal Surveyor with **James Martin (Member 1860-1880)**, and together they were entrusted with the drafting of the new rules for iron ships. They visited many of the shipyards experienced in iron building, and from their observations were able, at a Conference of Senior Surveyors held at Glasgow in February 1854, to present Lloyd's Register's first *Rules for Iron Ships*.

Many of LR's notable surveyors were members, including **Charles H Jordan (Member 1861 – 1930)**, who recorded that "the Institution from its commencement has exercised a most beneficial effect on naval architecture, and its influence in all matters relating thereto has been of world-wide importance." Charles Jordan worked at one time in John Scott Russell's shipyard and was present not only when the *Great Eastern* was launched but was also on board her for her maiden voyage.

Other surveyors included **Bernard Waymouth (Member 1872-1890)** who did much research into composite construction and designed *Thermopylae, Leander and Macquerie*; **Harry Cornish (Member 1876-1927)**, who assisted Waymouth with formulating and preparing the *Rules for the Construction of Composite Ships*; **Benjamin Martell (Member 1873-1902)** who trained as a naval architect at the Royal Dockyard, Portsmouth and whose work on freeboard tables did much to assist Samuel Plimsoll with his campaign against "coffin ships".

Known as 'The Father of Lloyd's Register', **Thomas Chapman (Member 1865-1885)** was to remain Chairman of Lloyd's Register for 46 years. He was a Vice President of Institution of Naval Architects.

Sir Westcott Stile Abell (Member 1909-1961), was a lecturer at Royal Naval College, Greenwich before being appointed Chief Surveyor. He was an Hon Vice President of the Institution of Naval Architects.

Sir Archibald Denny (Member 1986-1936) served for a time at Liverpool office of Lloyd's Register before becoming a partner in his father's firm. He was an Hon. Vice President, of The Institution of Naval Architects.

And many more


Best wishes.
We send our very best wishes to The Royal Institution of Naval Architects on the occasion of their 150th anniversary. We are committed to being at the forefront of technological innovation in our industry and by sharing this knowledge, together we help make the world a safer place.
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Composite Clippers

By
Peter Roberts MRINA

The Clipper Age brought the development of a highly skilled set of sailors and craftsmen, and great notoriety for both the ships and crews that sailed them. Clippers were designed for speed and this resonated with the 19th century's fascination for speed. Today they still represent some of the fastest ocean-going sailing vessels in the world.

Clippers were instrumental in opening new trade routes. The Great Clipper Races, relating to the transport of Australian wool and Chinese tea to the London markets, are an enduring memory of the importance of the clippers.

Wrought iron hulled vessels were first being built in the 1820s. By the time of the launch of the *City of Adelaide* in 1864, wrought iron was a mature technology for ship hulls. However, the speed of wrought iron hulls was significantly impacted by marine growth, particularly during long voyages through the tropics. Whereas wooden hulled ships could be sheathed with copper to inhibit marine growth, iron hulled ships could not because of bimetallic corrosion.

Innovation then led to the development of ships designed with wooden planking over wrought iron frames – composite construction. The wooden planking allowed the application of copper sheathing essential for fast ocean crossings while the iron frame made the ship lighter and took up less interior space than wooden framing.

Composite ships obtained formal recognition and endorsement from Lloyd's Register in 1867 when Lloyd's issued their rules for composite construction. Prior to this, all composite ships were labelled "experimental". The *City of Adelaide* was built in the years prior to Lloyd's publishing their rules for composite ship construction and thus is an important example of the development of composite ships. The *Cutty Sark* built in 1869 is an important example of the construction of composite clippers following the publishing of Lloyd's Rules.

The opening of the Suez Canal in 1857 and ongoing improvements in steam ship technologies ultimately led to the brief reign of composite clippers as the fastest mode of transport between Europe and Asia. In maritime history, the composite clippers were to become the final stage in the evolution of fast commercial sailing ships and thus represent the pinnacle of sailing ship technology.

The only two remaining examples of this important era of composite clipper design are the *City of Adelaide* and the *Cutty Sark*. The *City of Adelaide* is also rather unique in that she was designed as a passenger ship – and is important in the history of migration to the Australian colonies. In May 2007, the *Cutty Sark* was nearly lost to the world when a horrific fire engulfed the ship. Composite Clippers are an endangered species on the verge of extinction. That the *City of Adelaide* and the *Cutty Sark* have survived to this day is a testament to the designers and builders of composite clippers.

Peter Roberts is Naval Architect and Director of Clipper Ship 'City of Adelaide' Ltd. an organisation working with Scottish authorities to return the clipper ship 'City of Adelaide' to South Australia for its 175th Jubilee and then subsequent preservation. Peter is also the descendant of a 17-year-old Cornish miner, Joseph Nancarrow, who migrated to South Australia in 1873 on board the 'City of Adelaide' with an extended family of 12 to work in the young colony's copper mines at Moonta.

Clipper ship *City of Adelaide*

The Institution in Australia

By
John Jeremy FRINA

From its founding as the Institute of Naval Architects, Australia in 1952, the Australian Division of the Royal Institution of Naval Architects has played an active and important role in the community of naval architects in Australia.

Introduction

Members of the Institution made a major contribution to the development of Australia's maritime industry during the 20th century, particularly during the two World Wars. Their numbers were small — the shipbuilding industry waxed and waned with the wars and barely survived the Depression. Most were trained in Britain and came to Australia to fill positions in Australian dockyards and shipping companies. Some young Australians like apprentice ship's plater Cecil Boden, who started work at the Commonwealth Naval Dockyard in Sydney in 1916, moved into the profession through the dockyard drawing office. Boden studied engineering at Sydney University before sailing to Scotland to study naval architecture at Glasgow University where he graduated in 1927. He returned to Australia in 1933.

The Association of Naval Architects

With the rapid growth of the industry during the war, the need to train naval architects locally prompted the establishment of a diploma course in naval architecture at the Sydney Technical College. Some of the graduates and students were keen to have an association to promote their interests and to provide an opportunity to read and discuss their theses. At meeting of students and graduates on 15 May 1947 in Sue's Café, not far from Wynyard railway station in Sydney, the Association of Naval Architects, Sydney Technical College, was formed with Cecil Boden as President.

With the increasing number of qualified naval architects working in the Australian industry, which had expanded considerably during World War II, and the transfer of the diploma course from the Sydney Technical College to the University of New South Wales, on 22 October 1951 the Association's committee decided to draft a modified constitution to enable naval architects not associated with the Sydney Technical College to be admitted to membership. The draft was considered on 30 January 1952 and Institution of Naval Architects, Australia was inaugurated at a dinner on 4 June 1952 attended by 32 members and guests.

The Institution of Naval Architects, Australia

The constitution of the Institution of Naval Architects, Australia was based on that of the Institution of Naval Architects, London, mainly in the hope that some affiliation or cooperation with the UK Institution would become possible, and the council of the Institution in London was informed of the Australian developments.

The Australian Branch of the Institution of Naval Architects

Responding to the news from Australia the Secretary of the INA expressed the concern of the London Council that there could be confusion between the two bodies because of their similar aims and objects. A Council member, S. F. Dorey, visited Australia in February 1953 and at a meeting in Sydney he told the Australians that the London Council was prepared to favourably consider the formation of an Australian Branch of the INA. The membership of INA at the time was less than 4000 worldwide, and although a junior joint branch of the INA and the Institute of Marine Engineers had been formed in the Southampton/Portsmouth area it was limited to junior members of both institutions and was not comparable to the kind of body needed in Australia.

At the time, it was thought that the membership of the Australian Institution was unlikely to exceed 100 and that an Australian Branch of INA would benefit from the professional standing of INA and have a status similar to that of Australian Branches of other overseas professional institutions. Negotiations on the constitution of an Australian Branch of INA moved quickly and proposals for amalgamation were considered by the London Council on 5 November 1953. After some further negotiations final Branch rules were agreed in February 1954. The rules enabled the proposed Australian Branch to act freely in matters of local administration with the INA London prevailing in matters of overall policy.

The first branch of the Institution of Naval Architects was formed in July 1954 with Cecil Boden as President. By the time of its 25th anniversary in 1979 the membership of the Australian Branch of the Royal Institution of Naval Architects had grown to some 360 throughout Australia. In recognition of the Branch's achievements over the previous quarter century the RINA London Council approved the elevation of the Branch to become the first international Division of the Institution.

The Australian Division Council - 9 November 1979

The Australian Division of the Royal Institution of Naval Architects

The change was celebrated at Jubilee Symposium and dinner in Sydney on 6 November 1979 attended by the President of the RINA, Derek Kimber OBE. The ninth President of the Australian Branch, John Jeremy, became the first President of the Australian Division of RINA.

Over the following 30 years the membership of the Australian Division has continued to grow to 640 by late 2009. The constitution of the Division was modernised in the 1990s to better represent the wide distribution of members throughout Australia and the Division now has active Sections in New South Wales, The Australian Capital Territory, Victoria, Tasmania, Queensland and Western Australia with a South Australia/Northern Territory Section the most recent, formed in 2008. Continuing a practice started in 1973 in association with the Institute of Marine Engineers and the University of New South Wales, the Division organises major conferences in association with the Institute of Marine Engineering, Science and Technology and the Institution of Engineers, Australia. The conferences are now held every two years as the Pacific series of International Maritime Conferences. The Australian Division of the Royal Institution of Naval Architects is an active and important part of the community of naval architects in Australia.

The ninth President of the Australian Branch, John Jeremy became the first President of the Australian Division of the Royal Institution of Naval Architects.

The Denny Library

Sir Archibald Denny, to whom the Denny Library is dedicated, was one of a long line of successful shipbuilders whom it may well be said put Dumbarton on the map of the shipbuilding world.

Sir Archibald Denny (1860 – 1936)

Archibald Denny was born in the year in which the Institution of Naval Architects was founded. He was the son of Peter Denny, who, with his brothers, William and Alexander had founded the Dunbarton shipbuilding company in 1844.

After serving an apprenticeship in the family shipyard, he entered the Royal Naval College, Greenwich, where he completed his studies. A short spell of work on Lloyd's Register at Liverpool gave him some insight into classification work, before he left to become a partner in the Denny firm.

At that time, Denny specialised in high-speed steamers, and Archibald Denny played a large part in their successful development from paddles to screw propulsion, and from reciprocating engines to turbines and diesel-electric motors. Many fine ships, marking milestones in ship development, were launched from the Denny yard during Sir Archibald's time. They included vessels such as the Princess Henrietta, a 300ft paddle steamer built in 1880 which achieved a great advance in speed over contemporary channel steamers, largely as a result of the improvements in hullform which were effected from the results of tank experiments. Denny had built an experiment Tank for testing ship models while that method was still in its infancy.

Sir Archibald Denny became a member of the Naval Architects in 1886 and was elected an Honorary Vice-President in 1923. The wood paneled Denny Library on the second floor of RINA Headquarters was furnished by Lady Margaret Denny, in 1939, in memory of Sir Archibald, who had been an Honorary Vice-President of the Institution.

The Denny Library 2010

The Naval Architect – a View from the Deck Department

By
Michael Grey AssocRINA

"The naval architect, despite his lofty and sometimes gruff demeanour, is one of the most obliging of souls, giving his clients, who might also be his employers, exactly what they want. And this has always been the case, although there are still dispiriting theological arguments over whether Noah, rather than God, was the first naval architect, rather than a mere shipbuilder."

But arks aside, and forgetting rather futile disputes about whether hydrodynamics began with Froude, or some unknown who deduced that if you sharpened the end of a dugout canoe, it would go faster, naval architecture might be thought of as an undeniable benefit to mankind, and even seamen should, along with shipwrights, celebrate this institution's significant anniversary. They that go down to the sea in ships, might, in the heat of some frightful storm cast doubts about the designer of their craft, which might be behaving rather like a submarine, with the motion of a washing machine, but when it is calm again, (and supposing they have survived the experience) they will acknowledge the intellect of ship designers.

Naval architects for their part, might politely point out that if sailors stow all the cargo on the top deck, it might just affect the stability of a ship, but they do this not out of a sense of superiority, but a desire to impart knowledge. When naval architects get together and point out that they design ships, shipbuilders construct them, and sailors wreck them, it is a sort of professional joke, which should offend nobody. Similarly, naval architects do know that engineers are not 3ft high, possessed of inordinate bodily strength and are fitted with six arms. It is a mere figure of speech, and this cheerful badinage between the various maritime professions is surely an expression of relaxed respect.

But to get back to my original thesis, which suggested that naval architects will always deliver exactly what people want, I offer the thought that they are able to do this, because they are masters of compromise, and skilled, above all, in reconciling conflicting sets of unreasonable demands. This is their real professional expertise. The shipowner requires his ship to be burdensome, capable of carrying enormous quantities of cargo at high speed, with a miserly fuel consumption, but at a modest draught. He would also rather like the design to incorporate a registered tonnage such that almost no port or canal dues are ever paid, with the ship capable of being operated by an extraordinarily small and undemanding crew of sailors, who don't eat very much.

Faced with such impossibly contradictory criteria, lesser folk would have despaired; naval architects shrug and mentally lay a fresh sheet of paper on their drawing boards. In fact they merely select some amazing software, program in the shipowner's laughable needs, at which point the computer crashes. So they sigh, and go to the drawing board, where, after many hours of work which would have fried the brains of mere mortals, a suitable design is devised.

These days the word "compromise" assumes negative aspects; of principles set aside and of dubious concessions or scandalous behaviour, rather than the settlement of differences by the mutual concession which drives the creative naval architect. And they have always done it. Let us, in our imagination, propel ourselves back 1200 years or so, to some beach in what is now Scandinavia, where some sweating shipwright is fashioning long strakes out of felled timbers. Enter a Jarl, idly swinging a double-edged axe. This is the local chief and he explains in a tone unused to counter argument, that he requires a new ship for the coming season. It will be for oceanic navigation, to Ultima Thule and beyond, and thus capable of withstanding the worst weather Thor can throw at them. He wants it to be a fast sailer, but also light enough to manoeuvre under oars. He wants it to be capable of carrying a heavily armed crew with their war goods, and sufficient additional room for a paying cargo of loot, captives, furs and strong drink. He also spells out the essential need for this large, burdensome ship to be capable of running up rivers and creeks where there might be just a couple of feet of water. Late delivery, he intimates, swinging his axe meaningfully, cannot be tolerated.

And if you are fortunate enough to see them near Oslo, or at Roskilde in Denmark, you can see with your own eyes the product of this compromise, designed by skilled shipwrights who knew the meaning of the word and could ably balance these very different needs, all those years ago. You can delight in the sweetness of line and form, the beauty of a seaworthy hull and the utility of simplicity that continues to inspire us down the centuries.

Mind you, in this balancing of needs that has been carried down through the years, the requirement for habitable accommodation for the crew often gets sidelined in the fulfilment of the other more essential criteria. Just as on that Viking ship, which delighted its owner and enabled him to make many profitable voyages, the poor old sailors had to hunker down under the thwarts, or on the voyage home, to shelter behind the slaves. Over the centuries, a sort of rule of naval architecture, as immutable as that of Froude's Number, has been that "whatever the purpose of the ship, the crew will fit in where it can".

And if you look closely at the plans of ships as they have emerged from shipyards over the centuries, you will indeed find the crew "just fitting in". On sailing warships, they slept around their guns. On the wonderfully lined clippers, they hot-bunked in a small triangular space in the bows, where there really wasn't any room for tea chests or wool to be stowed. In the great Atlantic passenger liners, the stewards and stokers and sailors were sort of sandwiched in to cofferdams and steering flats and lower forepeaks where you couldn't expect even emigrants to live. I am old enough to have sailed in ships built in the 1920s and 30s, where the sailors had to live in the forecastle, where they had to put up with condensation and being battened down in heavy weather, with the attendant violent accelerations and decelerations. The two forward cabins even had hawse pipes passing through them, so the occupants had to evacuate before you dropped the anchors, lest they become psychologically damaged by the terrifying noise, which was like the end of the world about six inches from your head.

There was a period, in the last days of the pre-container cargo liners, when naval architects loosened up a bit and gave us good accommodation, and wide decks to play deck-golf on, even recreation rooms and gyms. But this was a sort of aberration and very soon, with the consuming need to fill up a ship with cargo and an engine, and every square inch on deck with containers piled seven high, the poor old crew was consigned to a sort of tower block, perched abaft the stern frame and above the mooring deck. Some unfortunates would find themselves, like their iron-fisted forebears, right forward, where they were able to serve as a useful breakwater and protect the deck cargo from the onrushing seas. They fitted in where they could, thus satisfying tradition.

Tower blocks were once hugely admired by architects of the brutalist persuasion as entirely appropriate for the grim barracks of the poor, but have, thank goodness, been largely discredited for the manifold social ills they have vested upon their wretched inhabitants. Might not these same social considerations apply to seafarers, as they spiral around in their vibrating steel towers in a following sea? There is nowhere to walk, nowhere to sit in the sun, the only exercise available being running on the spot atop the monkey island, and going up and down the stairs.

Perhaps naval architects have been too influenced by shipowners like the well-known liner Lord, who, in his declining years, used to sit in his stately home in the Isle of Wight and closely examine the port side of his homebound ships through an enormous telescope to detect cosmetic deficiencies, telephoning to London to sack the Mate if the ship did not come up to his expected standards. Once approached by the company naval architect to approve the plans for a new Commonwealth liner, he is supposed to have seized his pencil and divided up an "officers' recreation room" into small cabins for all the officers. "They don't need recreation" he is supposed to have confided to the naval architect – "they are supposed to be out on deck or down below – working". There would be, he said, more room for cargo as a result of his amendment.

If naval architects went to sea occasionally, just to experience the wonders of the deep, might ship design profit from such a strategy? And this is not meant as a criticism of the profession, but a suggestion for improvement, to make very well educated individuals more rounded. Nothing but good would surely come from such experience as the young naval architect discovered not just the nuances of ship behaviour in a seaway, but the way in which the operations of the ship were organised and the curious ways in which sailors worked. I happen to know two practising naval architects with Foreign-Going Masters' certificates and their perspective is appropriately wide, but even six months' sea experience would be brilliant. After all, the Royal Navy and its celebrated Royal Corps of Naval Constructors insisted on this sea experience, to their mutual benefit.

But there are always reasons for not doing something. The academic approach is not exactly supportive, hinting darkly at all those things which the student naval architects will not learn from their crowded syllabus, if they are to go roistering around the seaports with sailors. And it is a sad fact that so meanly are modern ships fitted out that there is scarcely a spare bunk to be found for a cadet, let alone a visiting naval architect. Is the naval architect a passenger, a supernumerary, or a crew member? Who insures him or her, and who will pay for all the food he or she will eat? People really do think like this, no matter how deplorable it might seem, and one could imagine some wretched naval architect swinging around in his hammock in a steering flat or store-room, subsisting on sandwiches which are gradually becoming more inedible as the voyage progresses. Sometimes you probably wish you could seize the shipping industry by the scruff of its scrawny neck, and give it a good kicking! Which is, when you think of it, precisely why you need journalists!

But for all its faults, you cannot deny that we have an industry that thrives on innovation, and that naval architects tend to be the people who make it all happen. It is also a fact that their powers of creativity seem to be enhanced when the rest of us are despairing in the depths of the economic depressions, which come around rather too often in our cyclical industry of derived demand. There is probably no mystery to this, the limited imagination of shipowners being dulled by the surfeit of high freight rates; their greed precluding any thoughts about innovative designs, at least while the good times last.

But when the rates slump, and the bankers are hammering at the door, the fearful shipowner is apt to embrace innovation, and the questing naval architect is welcomed with open arms as he produces his design for an LNG-powered sheep carrier (why has nobody thought of this before?) or a bottom-discharging capesize. And if anyone doubts this, just look at the explosion of amazing innovation that emerged during the last great downturn, in the 1970s and 80s. The bays of the Peloponnese and the Norwegian fjords might be roofed over with laid up tonnage, but amazing designs continued to be produced to answer all the owners' questions, and many others which they would never have thought of asking.

There was just nothing which an owner could request, which naval architects seemingly could not deliver.

"I need a tanker ten times the size of the biggest yet built."
"I require a ro-ro with a stern ramp that can take four lanes of traffic – and which can be deployed on either quarter, or astern."
"I urgently want a ferry that can load and discharge 50 trucks, 300 cars and 1000 passengers in 15 minutes".
"I have a pressing requirement for a coal carrier that can run on --- coal!"
"I need a 45 knot ferry that can carry people, trucks and cars"

The list of satisfied demands is endless. Ships that can fit through the canal with 6000 containers. Ships that can hover like a bee over a wellhead 3 miles down on the bottom of the sea. Ships that can plant wind turbines like Geordies plant leeks. The designers rise to the challenge. True, they don't always work. Unlike car manufacturers who can spend years designing new models, and happily crashing them with dummy drivers, and the aircraft makers who can expend millions on torturing prototypes to death, naval architects have no such luxury, in that what they design gets built, and ultimately delivered.

I have somewhere the famous series of photographs of the launch of an Italian liner, which begins with the happy launch party waving their top hats as the ship begins its slide down the ways, and ends with the ship lying on its side. I guess it is a sort of warning against hubris which might tempt the practitioners of naval architecture. And in modern times there has been the occasional beautiful swan which turned out to be an ugly duckling, or even a turkey; ships that would not make their design speed, no matter how severe the threats against the Chief Engineer, or ships which would vibrate so much that the crew demanded thick foam-rubber shoes. I remember too well a nice new ship I sailed in where the elegant table in the Master's dayroom vibrated so much that if he put a drink on it, it was instantly thrown onto the deck. Eventually seamanship, in the shape of a polished wooden joist provided by the chippy, triumphed. It was appreciated as a sort of conversation piece, when the shore side officials called.

But you cannot keep a naval architect down for long, even if you pull out the plug on the computer, and chop up the drawing board. Just as you had to have respect for a person who would look at an oak tree and see a ship of the line, even sailors are forced to concede that the modern naval architect remains the intellectual edge of the maritime industry. He delivers what we want, no matter how unreasonable, or improbable. But remember, if a naval architect designs that methane powered livestock carrier, he saw it here first.

Michael Grey is a Master Mariner turned journalist, who, over a 20- year period, was a columnist, leader writer and editor of Lloyd's List.

The Weir Lecture Hall

When the Institute of Naval Architects moved into 10 Upper Belgrave Street in 1938, the property included a small house at the back in Wilton Mews. This house was demolished by a bomb in 1940.

In 1947 it was decided to rebuild the present Headquarters, and in 1950 plans were approved by Council to build a lecture hall on the bombed site, together with other improvements to the Headquarters.

Early in 1953, the Institution received an unexpected and magnificent donation of £10,000 from Viscount Weir of Eastwood, an Honorary Vice-President of the Institution. This sum was devoted specifically to the construction of the lecture hall, to be named the "Weir Lecture Hall" after the generous donor.

The Weir Lecture Hall

Building work finally started in 1954, and the Weir Lecture Hall was formally opened by Viscount Runciman of Doxford, President of the Institution, in April 1955.

A number of well-known shipbuilding firms and organisations contributed equipment and embellishments to the Lecture Hall, and their names are engraved on the plaster panel in the foyer. Amongst them is the British Corporation Register of Shipping and Aircraft (the President's Chair), Messrs Yarrow and Company (the mural hanging behind the President's chair), Lloyd's Register of Shipping (the carved stone panels flanking the mural, representing the theory and practice of shipbuilding), the Royal Corps of Naval Constructors (the speakers lectern) and Messrs John Brown & Co Ltd (a carved walnut panel showing the Grant of Arms to the Institution).

A link with the Institution's Headquarters for over 50 years is to be found on the exterior wall of the lecture hall in Wilton Mews. There, "suspended" from the roof line is one of the original Adam's decorative stone features from the façade of the Adelphi Building.

RINA Motto

SALUM ET CARINAE PIGNORA VITAE

“To the open sea and keel of a ship we pledge our lives”

Quote on Presidents Board in RINA enterance hall

“Kepe then the sea that is the wall of England
And than is England kept by Goddes Hande”

The original quote was from a very early English political poem, “*The Libelle of Englyshe Polycye*”, written. in 1436-37. In which the anonymous author was convinced that command of the sea was the key to England’s greatness.

“This vnitie is to God pleasance:
And peace after the werres variance.
The ende of battaile is peace sikerly,
And power causeth peace finally.
Kept than the sea about in speciall,
Which of England is the towne wall.
As though England were likened to a citie,
And the wall enuiron were the see
Kepe then the sea that is the wall of England:
And than is England kept by Goddes hande;
That as for any thing that is without,
England were at ease withouten doubt,
And thus should euery lond one with another
Entercommon as brother with his brother
And liue togither werrelesse in vnitie,
Without rancour in very charitie,
In rest and peace, to Christes great pleasance,
Without strife, debate and variance.
Which peace men should enserche with businesse,
And knit it saddely holding in holinesse”.