The Queen Mary 2 made her maiden voyage on 12 January 2004 © Chantiers de l'Atlantique

The height of a 21 storey building and costing 800 million dollars, the Cunard Line Queen Mary 2 is the largest and most expensive liner ever built. She regularly carries over 4,000 people across the Atlantic. The logistics of project managing the build of this economically viable giant fell to Stephen Payne OBE. He told the story of his role as Chief Designer to the guests gathered at the Academy's New Year Reception and Address in January 2006.

TRUE LINER
THE CREATION OF THE QUEEN MARY 2

When the Queen Elizabeth 2 was launched in 1969, it was commonly believed that she would be the last of the great and grand ocean liners. The original Queen Elizabeth liner had been decommissioned in 1968, and the Queen Mary liner had been retired and moored permanently in Long Beach, California in 1967. The 1970s saw a general winding down of cruise activity. However, in the 1980s there was a huge resurgence in the popularity of cruising, and by the 1990s the QE2 had become an icon of luxury travel and was the last liner plying a very profitable transatlantic trade. It was time to consider the possibility of building the biggest and most expensive liner to date, the Queen Mary 2.

When I took over the task of designing the successor to the Queen Elizabeth 2, there were a number of economic factors that would influence what we would actually build. One of the first things that the Carnival Corporation, who took over Cunard in 1998, had to consider was whether the profitability of the QE2 warranted a like-for-like replacement.

It is absolutely fundamental to the story of the Queen Mary 2 to understand the difference between a liner and a cruise ship. The liner has a much deeper draught – the portion of the ship under the water – and a more pointed hull form, which we call the 'block co-efficient'. This is good for propulsion and for sea-keeping.

The liner must be inherently strong because she has to be driven hard through storms in order to maintain a schedule. For this reason it needs a higher speed potential. A cruise ship will normally run away, or divert. The liner needs higher endurance than a cruise ship because it has to transverse wide expanses of ocean, such as the Atlantic or the Pacific.

LINER VERSUS CRUISER

Before work on the proposed new design began in earnest a thorough review of the layout and operational capabilities of the Queen Elizabeth 2 was undertaken. When built back in 1969 the ship was the largest merchant ship able to transit the Panama Canal. Her volumetric size of 65,000 gross tonnes was achieved by building the top five decks from light aluminium alloy, thus enabling her to have one more deck than she could have accommodated, for stability reasons, had she been built completely of steel.

The maintenance cost of the QE2's superstructure over the years, and the desire to ensure that any successor would have a fatigue life of at least 40 years, precluded the use of aluminium in the new ship. Therefore, to have maintained the same footprint of the QE2, and the continuum of Panama transits, the ship would have needed to be one deck smaller than the QE2.

The economies of scale and the necessity to offset a 40% build premium (that is to say, a true liner would cost 40% more to build than a cruise ship of the same size) opposed this. It was therefore decided to preclude transits of the Panama Canal, especially as the QE2 only undertook one such passage per year as part of her annual world cruise. The size of the new ship could therefore be optimised according to the port facilities at New York and Southampton.

The whole raison d'etre of a liner is to offer and maintain a schedule. The QM2 had to be designed to cope with whatever the elements put in her path in order to meet her departure and arrival times.

MADE SHIPSHAPE

With the ship maximised to this effect and also gaining the maximum from economies of scale, it was still doubtful whether the Queen Mary 2 could generate sufficient income to warrant her construction. Drastic measures needed to be taken and the ship required remodelling in order to maximise her revenue potential. This manifested itself with the proliferation of premium fare balcony cabins supplanting standard window cabins. However, the placement of such cabins on an Atlantic liner in such numbers (80% of cabins) was not without complication as they had to be sufficiently protected from the elements.

The solution was to move the public spaces down towards the waterline, but leaving them sufficiently high that two decks afforded a comfortable margin above the waterline. The balcony cabins were then placed above them – a unique arrangement that neatly solved the problem. In the final analysis the ship emerged as the largest passenger ship ever built, with a volumetric capacity of 150,000 gross tonnes, a passenger capacity of 2,800, and a crew capacity of 1,300. Spectacular public rooms, and sumptuous cabins once consigned to a limited elite on the grand liners of the past, were provided as standard on the new ship for even the minimum fare passenger.

TESTING TIMETABLES

The whole raison d'etre of a liner is to offer and maintain a schedule. The QM2 had to be designed to cope with whatever the elements put in her path in order to meet her departure and arrival times. Before contract, analysis of several transatlantic season logs of the Queen Elizabeth 2 was undertaken. It was concluded that a maximum speed potential of 29 knots would be required to ensure no delays – ultimately the ship was contracted with a maximum speed of 29.35 knots.

Subsequently, comprehensive propulsion, manoeuvring and seakeeping tests were undertaken at the hydrodynamic laboratories of MARIN in the Netherlands. For the first time, using satellite weather data of the Atlantic over a five year period, MARIN developed a mathematical model of the QM2. This saw her continuously crossing the Atlantic, with the hydrodynamic and seakeeping data faithfully representing her progress according to the encountered weather. Although at times she was brought to a standstill because of the weather conditions, the modelling process showed that for the five year period in question the QM2 would never arrive late at her terminal port. In the event the ship achieved 29.65 knots on sea trials, providing a further operational margin. On the QM2's first true transatlantic crossing, in April 2004, she encountered two severe storm systems that threatened to impede her progress. Nevertheless, she arrived in New York on time.

PULLING POWER

The original main machinery configuration for the QM2 comprised six to eight medium-speed diesel engines, arranged in two engine rooms, to produce electricity in a power station configuration serving the hotel load (16MW) and propulsion load (86MW). In order to reduce the volume of the engine casing throughout the ship, and thus maximise the revenue potential for cabins and public spaces, one diesel engine room was deleted, along with its casing. This was replaced, unusually, by a gas turbine engine room, located at the base of the funnel, housing two 25MW gas turbines that did not impact on the internal arrangement of the lower decks. The total generation capacity is approximately 120MW, enough to supply a city the size of Southampton. For propulsion, a number of options were explored. The final choice was between conventional shafts or propulsion pods.

Left: *The mammoth Queen Mary 2 is the height of a 21 storey building.*

Top right: *The azimuthing pods are completely steerable, just like a conventional rudder, but whereas a rudder is limited to perhaps 40° each side of the neutral point, the pods can be revolved completely through 360°. With the pod/propeller slung at the base, each azimuthing pod can provide enormous directional thrust. The pods each weigh around 320 tonnes, equivalent to a fully laden 747 jumbo jet.*

Bottom right: *The bridge and observation deck being lifted on to the Queen Mary 2 during build.*

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The Queen Mary 2 in build in St Nazaire, France © Chantiers de l'Atlantique

The original models for the Queen Mary 2 had four pods and a rudder. Model-testing showed that the size of the rudder needed to influence and start steering the ship was so large, and introduced such a high drag, that we felt this could be better achieved by just using pods © Chantiers de l'Atlantique

The Queen Elizabeth 2 had been provided with two shafts completely encased in bossings, each with a 45MW propeller. Since the QE2 was built it has become generally accepted that arrangements with more limited bossings, in combination with supporting 'A' brackets, offer less drag. Although considerably larger than the QE2, it was estimated that the Queen Mary 2 would require approximately the same propulsive power to achieve her own contract speed of 29.35 knots. Propulsion pods, where the electric propulsion motor is encased within a watertight 'pod' enclosure mounted on a stay beneath the ship, offered some advantages over conventional propulsion. With forward-facing propellers an efficiency gain of at least 5% is not uncommon, coupled with improved noise and vibration characteristics and improved manoeuvrability.

ANOTHER FIRST

It was decided that the QM2 would have four pods: two forward non-azimuthing fixed pods of 21.5MW providing forward/aft propulsion only, and two aft fully-azimuthing pods of 21.5MW providing forward/aft propulsion and 360° manoeuvrability. Although Carnival Corporation had many years of experience of podded propulsion, these had been all twin pod installations. The QM2's quadruple installation was a first.

Another major advantage of the pods was that the distribution of power over four pods meant that the hydrodynamic loading on each propeller was much less than it would have been, with two screws leading to significantly lower levels of propeller induced noise and vibration within the aft ship. The quadruple pod installation also provides a level of redundancy if ever there is a problem with one of the pods. The ship can maintain nearly 27 knots with only three pods in service.

PUSHING THE BOAT OUT

After discussions with five shipyards, we eventually signed a building contract with Chantiers de l'Atlantique in November 2000. They built the *Normandie* in 1935, and the *France* in 1962. Our relationship with them was, and still is, a strong and productive one with ideas and changes made during construction that allowed the QM2 to be built on time and within budget. Queen Mary 2 is now in her third year of service. She heralded a new era of transatlantic travel and is feted across the globe. On a recent visit to Hamburg over 3 million people turned out to see the QM2 arrive. She is frequently booked to capacity, and her success has fully justified the decision to build her.

BIOGRAPHY – Stephen Payne OBE

Prior to the design and construction of the Queen Mary 2, Stephen Payne was involved with the design and construction of over 30 cruise ships for the Carnival Corporation. Stephen was originally a graduate of Southampton University, where he studied Ship Science.