Estonia re-visited

Naval architect Anders Björkman* reconsiders some technical aspects of the disaster.

A NEW research project into the exceptionally controversial disaster that befell the passenger/vehicle ferry *Estonia*, on September 28, 1994, is being carried out for VINNOVA, the Swedish government agency for innovation systems, in its capacity as government agency responsible for the national Sea Safety Programme. A consortium headed by SSPA Sweden AB (the model test tank, in Göteborg) has been contracted to do this work, which aims to present the most likely foundering scenario of *Estonia*.

Partners include Ship Stability Research Centre/Safety at Sea (at the Universities of Glasgow and Strathclyde), MARIN (from The Netherlands), and Chalmers University of Technology (Göteborg). The results will be used for improving maritime safety for passenger ships of today and in future.

Some new hypotheses were published in October 2006 by Chalmers University and in September 2006 by Safety at Sea, which make highly interesting reading. These consider various possibilities, including open watertight doors (associated with possibly faulty colour-lamp controls on the bridge), flooding through lift shafts, flooding through various ventilation ducts, and a consideration that accumulated water would not necessarily have flowed out from the car deck. Although this complex disaster took place 12 years ago, the chilling events of that night still make captivating reading for technically minded readers. The two reports can be read at the following websites:

www.safety-at-sea.co.uk/mvestonia/downloads/WP2%201%20Final%20Report% (Chalmers University report)

www.safety-at- sea.co.uk/mvestonia/downloads/VIES01-RE-001-AJ-e.pdf (Safety at Sea report)

In view of these developments in the still-running saga of the *Estonia* disaster, readers may be interested in the accompanying viewpoint by naval architect Anders Björkman. This is followed by a copy of a letter to VINNOVA, submitted to us for publication by Maciej Pawlowski (a member of the STAB standing committee) regarding the little-publicised capsizing in January 1993 during a Baltic Sea storm, of the Polish train ferry *Jan Heweliusz*.

Readers should be aware that Mr Björkman has made various previous submissions concerning *Estonia* to authorities and to this journal, and that his brother, Mr Per Björkman, is a lawyer involved in new representations to the governments of Sweden, Finland, and Estonia, to re-examine the disaster.

The Naval Architect also hopes that a summary of some research work on *Estonia* by the SNAME Forensics Panel, from the USA, can be published in a future issue.

YOUR article in the September 2006 edition (page 47) of *The Naval Architect* concerning the new research project being conducted by HSVA, in Hamburg (funded by the Swedish government agency VINNOVA) suggests that '*the required damage stability* (of existing safety regulations for passenger ships) *does not guarantee the survival of a ship*' (no regulation can guarantee this), according to the HSVA model test tank. It would be interesting to see any evidence to this effect and why IMO does not react.

The suggested reason seems to be, according to HSVA, that passenger ships are alleged to capsize (!) after collision (!) in severe weather (!). As far as I am concerned, no passenger ship has ever collided in severe weather (in significant wave heights of 5m-6m) and later capsized. The probability for collision in severe weather is very small and, regardless, a passenger vessel (with its two-compartment flooding standard) should survive the damage, according to existing safety regulations. It should float safely upright on its hull within a certain range (20 deg) of positive stability GZ.

To capsize such a vessel, one would need an additional force x lever = moment to exceed that inherent stability after damage. From where would that come: external, severe waves, or from water loaded somewhere inside the ship above the waterline, or a combination of the two?

HSVA suggests that external sea water accumulates on a passenger ship main deck (still above the waterline after collision), due to rolling, and causes the vessel to capsize, ie, to turn upside down and to float upside down, ie, not to sink. Is there any evidence for this? Has it ever happened?

What does the space above the main deck of a passenger ship look like, whether it is a superstructure or a deckhouse? There are normally no watertight divisions above the main deck. There might be some fire-resistant bulkheads on a pure passenger ship, but they are not watertight. There may be an open vehicle deck on a ro-pax ferry, with or without moveable transverse partitions, to prevent the spread of any inflow in a large volume - but not to prevent inflow.

Regardless, if water flows in due to rolling, it also flows out due to rolling, and there is, in my experience, no evidence that water should accumulate and cause capsize. There is no registered accident in history to this effect. Of course, conventional freight ro-ro ships without passengers will sink rapidly after collision/flooding (a probable very recent example is *Finnbirch*, due to flooding of the hull) since they are not subject to any damage stability criteria (only one-compartment flooding standard). Many people mix up these two types of ships.

The news is, however, that HSVA has been awarded funding by Swedish VINNOVA to explain the 1994 sinking of *Estonia*, a ro-pax ferry. Officially**, *Estonia* neither collided nor capsized but sank with a 100% intact hull, and this has very little to do with the above research by HSVA .

The official cause of the *Estonia* accident, still very much under debate, is faulty locking devices on the main-deck bow doors (visor and ramp opening due to wave loads), thus permitting ingress of water into the superstructure 2.5m above waterline. It was and is officially suggested that water caused *Estonia* to list to a certain angle, but not to capsize, and later to sink with increasing angle of list ... but, I repeat, not capsize. The actual sinking has never been described and now, 12 years after the accident, HSVA is expected to explain it, based on official information.

It is recommended that anyone participating in the discussion agrees to the following definitions based on the ILLC:

Hull – watertight and subdivided parts of vessel on which it floats and which provides buoyancy and stability, ie, on *Estonia*, all compartments below deck 2

Reserve buoyancy – volume between assigned waterline and freeboard deck

Superstructure – weathertight compartments on freeboard deck (deck 2 on *Estonia*), which provide buoyancy and which contribute to stability when submerged during rolling, pitching or listing, ie, the compartments below open weather deck 4 and above freeboard deck 2. It should be mentioned that the superstructure of *Estonia* – the complete car deck - was gas-tight and fire-insulated, protecting the stairwells and engine casing. No water on the car deck could, eg, flow down into the engineroom or other spaces below (readers are invited to read the Chalmers University report in this connection – Ed)

Weathertight – all openings in a superstructure above the waterline which can be closed to prevent water ingress due to rolling, pitching, and green water

Freeboard deck – in the case of *Estonia*, deck 2. It should be pointed out that the freeboard of *Estonia* was based on SOLAS two-compartment damage criteria for passenger ships, ie, that the ferry would float in stable condition with two watertight hull compartments flooded, ie, with sufficient (reduced) reserve buoyancy in those cases to survive. Thus the freeboard was much larger than that assigned to a cargo vessel.

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** 'Final Report on the Capsizing on 28 September 1994 in the Baltic Sea of the Ro-ro Passenger Vessel MV *Estonia*'. Published by The Joint Accident Investigation Commission of Estonia, Finland, and Sweden. 1997. ISBN 951 53 1611 1.

Deckhouse – non-weathertight compartments on the weather deck above the superstructure which do not provide any buoyancy and do not contribute to any stability, ie, all compartments above deck 4 on *Estonia*
Capsize is sudden loss of stability (GZ<0) causing a vessel to turn upside down, unless it is stopped by an outside support, eg, the sea floor or a quay. *Estonia* never capsized.

It should be agreed that any water on a car deck flows out by gravity through drains and 'other openings' since the car deck is several metres above the waterline. If the 'other opening' is, eg, the bow ramp, any water that entered due to forward speed will flow out through the same opening when the speed is stopped; the water trims the vessel on the bow when pitching on the bow and flows out.

Evidently, the first step by HSVA is to:

- establish and confirm the amount of water that will enter the superstructure 2.5m above the waterline and accumulate at the side to cause the list; and to
- establish what happens with this water, when the vessel stops.

According to official information, the mean water ingress (Fig 12.16 in the official report) into the superstructure with an open bow ramp was 320tonne/min at 15knots (initial speed), 140tonne/minute at 10knots, and 80tonne/min at 5knots with head seas of 150deg. *Estonia*, however, slowed down after one minute very quickly, reached 9knots after two minutes, and changed course 160deg away from the waves after a few minutes, and then stopped. HSVA has to establish what happened then.

One would expect that the water ingress first becomes zero and then negative, ie, that water already accumulated inside the superstructure flows out again through the same opening through which it entered. Thus, the heeling moment due to water inside the superstructure would become zero, and the vessel would return to its upright position after a few minutes.

It is evidently very easy to verify what happens with free water inside a superstructure of a vessel of *Estonia's* type, with an open bow ramp away from the waves in severe weather at zero speed using a model. This water always trims and heels the vessel, so that the water flows to the lowest point of the main deck. Model tests verify this.

When the vessel/model pitches on the bow, all water flows to the bow and trims the vessel more on the bow, and since the bow is open, all water flows out. Evidently, one cannot load water on a deck with a large opening at one end and expect it to remain there. All water flows out, when the speed is zero.

Estonia had very good intact stability with an intact hull. She could load a lot of water on her car deck without capsize (as reported in the Chalmers University report – Ed). Any water temporarily loaded on the car deck 2.5m above the waterline would just heel the vessel until capsize, which would require 2000tonnes. However, since the ferry stopped very quickly, this water would flow out again and there would be no capsize.

This is what, I believe, would have happened to *Estonia*, and it is very good news that 12 years later HSVA now will actually establish this simple fact. However, according to official data, no water flowed out when the vessel had stopped. On the contrary, more water flowed up and in, and the angle of list increased. That more water flowed in at zero speed is very strange and cannot be explained by laws of physics. It should flow out.

According to the official investigation, there was, after eight minutes of increasing water ingress, at least 2000tonnes of water at one side of the superstructure, and the angle of list was 38deg - but there was no trim! In this condition - the vessel had stopped four minutes earlier with the bow in a lee - any person would expect *Estonia* at least to capsize and float upside down, since both GZ and range of positive stability were zero. No ship can remain upright in such condition.

But that did not happen either. The ferry did not sink until 30minutes later one mile further east while drifting sideways at >2.2knots when the hull suddenly disappeared - no capsize. According to the official investigation, the lower deckhouse, decks 4 and 5, started to flood after eight minutes after it was submerged under water; however, very strangely, decks 6 and 7 of the upper deckhouse were 100% watertight and dry. The ferry apparently floated on the upper deck house, decks 6 and 7, which prevented capsize. It is suggested that deck 6 and the windows above deck 6 were 100% watertight. Then, mysteriously, all watertight compartments in the hull - deck 0 and 1 - filled with water.

These facts lead to the apparent conclusion that the official investigation used totally false assumptions when calculating *Estonia's* alleged stability in 1994. This was evidently pointed out to responsible persons in 1996; it was suggested that there was no water at all in the superstructure but that the ship sank due to leakage below the waterline (open watertight doors or defective bilge pumps). It will be most interesting to see what results are revealed by the HSVA study.

Learning from the often-forgotten *Jan Heweliusz* disaster

READERS may be interested in the following letter, which was sent to Mr John Graffman, programme manager, the Swedish research organisation VINNOVA, by Prof Maciej Pawlowski, concerning the ro-ro ferry *Estonia*, which is currently the subject of a new study at the HSVA model test tank in Hamburg, Germany. Professor Pawlowski is employed at the School of Ocean Engineering & Ship Technology, the Technical University of Gdansk, Poland, and is a member of the international STAB standing committee. He sent a copy of his letter to *The Naval Architect* for consideration.

Dear Mr Graffman,
It was nice to meet you recently at the STAB Conference in Rio de Janeiro. I listened with great interest to your presentation on the revival of an investigation into the sinking sequence and loss of *Estonia*, with the budget of €840,000. You indicated that the justification for the re-investigation was due to great pressure from the public, the large loss of life, and the need for a better understanding of the causes of capsizing. You illustrated the importance of the problem by a slide showing a number of ro-ro passenger ferries, which had capsized within the last 20 years or so.

I welcome your initiative, endorsed by the Swedish Government, but I have some reservations. Firstly, you did not make mention of a Polish ro-ro train ferry, *Jan Heweliusz*, which capsized and sank in January 1993, 18 months before *Estonia*, with a loss of 55 lives. Secondly, you did not produce any new evidence, which could shed light on the fate of *Estonia*. Without new evidence, it is unlikely that the investigation will be anything more than a series of speculations.

It is now well known that the main hazard for ro-ro vessels comes from water on deck, even a relatively small amount of water can capsize a ship. The question is then - what was the reason for water on the deck? In view of the lack of new evidence we can only speculate.

It is worth recalling three accidents: *European Gateway* in 1982, *Herald of Free Enterprise* in 1987, and *Estonia* in 1994. All of them triggered off substantial R&D investigations. In the aftermath of *Estonia*, a large multinational project was started, known initially as the Nordic Project, but later named the North-West R&D Project.

As a result, in 1995 the Static Equivalent Method was developed at Strathclyde University, which was the first ever rational method capable of predicting the critical sea state in which a damaged ship could survive. Were we dissatisfied with the former Nordic Project that we now resume the investigation? Contrary to the three disasters mentioned earlier, the *Jan Heweliusz* tragedy did not attract any research, either in Poland or abroad. This tragedy therefore merits as much investigation as *Estonia*.

Like the latter ship, *Jan Heweliusz* was operating between Sweden and a port across the Baltic Sea, and the wreck lies in international waters.

The flag was non-Swedish, but among the 55 victims were a number of Swedes. Should they not receive the same attention from your government as those who were lost on *Estonia*? I do not understand the Swedish Government's attitude to this. Another investigation is being launched for *Estonia* and yet no investigation into the capsizing of

Jan Heweliusz. Why is this? I believe lessons can be learned from the *Jan Heweliusz* disaster.

It is intriguing that both ferries sank within around 20 minutes. This indicates the importance of the initial stages of flooding being overlooked in all previous research, which focused on survival after the completion of flooding.

From this perspective, watertight decks seem to be very detrimental for ship safety. For this reason, decks that can be accidentally flooded should be made transparent for floodwater, to avoid a repeat of the *Estonia* tragedy (the first such ships have been already built in Poland by the Szczecin yard Nowa). Besides, bilge pumps should be equipped with probes for detecting floodwater.

I think it would be beneficial for our profession if the Swedish authorities launched a similar investigation into the sinking sequence and loss of *Jan Heweliusz*. I appeal to you, as the Swedish Government seems to show a different attitude from the Polish authorities, which turns its back on research. We should not miss an opportunity to learn from the *Jan Heweliusz* tragedy, unless there are constraints imposed by some politics, which should not be mentioned here. In view of the catastrophic hurricane that foundered the *Jan Heweliusz*, some claim that her sinking was an Act of God, whereas I claim it was an Act of Human Fault and Ignorance. ⚓

BOOK REVIEWS

The Way of the Ship in the Midst of the Sea
The Life and Work of William Froude

By David K Brown. Published by Periscope Publishing Ltd, 33 Barwis Terrace, Penzance, Cornwall TR18 2AW, UK. 2006. 265 pp. Hard back. ISBN 1-904381-40-5. £60.00.

The author, David Brown, will be well known to many members of RINA as both an eminent naval architect and a naval historian. Like so many of us, David first became aware of the work of William Froude - known by naval architects all over the world - while he was at university. He became much more deeply involved later in his career whilst serving what was then still the UK Admiralty Experiment Works.

As with David's other books, this one is very well researched. Many references are cited, and the author gives us his views on their reliability and the background against which they were made. Quite a lot of extracts are quoted in the main text; his gives the reader very good insight to the way Froude developed his various theories. This was often against the prevailing views of respected engineers of the day.

Froude founded the art and science of ship model testing. It is a testimony to the value of his work that there are today more than 150 ship-model test tanks throughout the world, based on and still using his 19th century ideas. It may be said of Froude that his '...great breadth of understanding was his greatest strength in technical advance, many individual aspects of his work were already known; his genius lay in putting everything together and applying the result to the solution of important problems.'

This new book will, however, have a wider appeal than just to naval architects. It describes Froude's early work with I K Brunel (the iconic Victorian engineer) on England's railways, and his correspondence with a number of great engineers of the day. Froude was a friend of John (later Cardinal) Newman and they exchanged views on religious matters, on which they chose to differ. Their views on the similarities, and differences, between 'certainty' based on scientific reasoning on the one hand, and on religious experience on the other, make interesting reading.

William was born in 1810 in Devon, where his father was the Archdeacon of Totnes. He entered Oriel College, Oxford, in 1828 and in 1832 achieved a First Class in Mathematics and a Third in Classics. In 1833 he began working as a railway engineer and in 1836 joined I K Brunel and developed a new approach to the design of masonry bridges. He also worked on the curvature of track, needed to minimise the jolt due to sideways forces on trains entering a bend, and gained the respect of Brunel, who placed great trust in his work. It is interesting that later Brunel's son, Henry, did much work for Froude.

Froude gave up full-time professional work in 1846 for family reasons, and it was about 10 years later that he began work on ship-related problems, having been consulted by Brunel on the launching and also the rolling of *Great Eastern*. It is impossible to do justice to all the engineering matters in which Froude took an interest - an improved seal for the South Devon Atmospheric Railway; the boundary layer concept; a boring machine for a Channel tunnel; gas turbines; a pipe scraper; and even flying machines (he realised that existing power plants were too heavy for powered flight).

Froude's greatest achievement was to break the total resistance of a ship into two components, each scaling differently from model to full scale. The book covers the *Swan* and *Raven* experiments, with Froude using a range of models to study the affect of form on resistance and the two wave systems produced at the bow and stern.

The more scientific aspects of Froude's work are dealt with in annexes to the main text. Many great minds of the day became involved in resistance and propulsion, and the fact that they made limited progress before Froude shows the latter's genius. He realised that he was making a number of simplifying assumptions and discussed these.

He also appreciated the importance of interaction between hull and propellers, and again broke the problem into a number of different elements, allowing a practical approach to the prediction of the power needed to drive a ship at the desired speed. The fact that his approach is still the basis of modern methods indicates the soundness of his ideas.

Often these ran counter to the perceived wisdom of the day. David Brown's comments on present-day opinions/knowledge on the various topics reinforce this. Not least, the testing tank Froude created at Torquay, and the equipment he designed to tow models and measure forces, became a template for most modern tanks.

Froude's success followed from his method of working. He thought about a problem, and applied the best theory to solving it approximately. He then set up tests to observe and measure what happened. Careful and critical analyses of the observations led to an improved idea of the physics of the problem. A revised theory was then tested - by full-scale trials where possible.

After William's death in 1879 in Simon's Town, South Africa, his work was applied and developed by his son Robert Edmund (Eddy), who had helped his father in earlier work. For completeness, the book devotes a chapter to Edmund's work, including the circular notation, the move to Haslar, and the need to use a 'standard' model – the Iris model.

Three years before his death Froude was awarded the Royal Society's Royal Medal and, in the same year he was presented with an Honorary Degree of LLD by Glasgow University. He was a truly great engineer and craftsman, to whom naval architects are much indebted. He was a kind man and treated everyone with kindness, whether a lord or a workman. There is much in his character and way of working, that modern engineers would do well to emulate. David Brown is to be thanked for giving us such a clear insight into the man and his work.

Eric Tupper

BONDSHIP Project Guidelines

Edited by Jan R Weitzenböck and Dag McGeorge. Published by Det Norske Veritas, Veritasveien 1, N-1322 Høvik, Norway. 216 pages. Hardback. ISBN: 82 515 0305 1. Available from the BONDSHIP website: http://www.dnv.com/research/BONDSHIP_guidelines/index.asp at a cost of NKr399.00 (Europe) or NKr449.00 (rest of world).

Adhesives are being increasingly used in mainstream shipbuilding; therefore this new book (first published in 2005) will be of great interest to those shipbuilders and designers likely to use such technology. The BONDSHIP project (yet another R&D programme part-financed by taxpayers of the European Community) ran for three years, April 2000 to June 2003, and involved, in typical EC fashion, 13 partners from seven nations. Some of them are household names in the marine industry, eg, Fincantieri, Vosper Thornycroft (VT), CETENA, the University of Southampton, and Meyer Werft.

The aim was to summarise all the steps necessary to design, build, and inspect all types of shipboard bonded joints. There are two parts to the book: the code, and recommended practices. The editors believe – probably correctly – that 'most' designers, builders, and owners are not yet aware of the possibilities – and limitations – of adhesive joints.

The book is mainly aimed – naturally – at high-speed craft and passenger ships, where the benefits will perhaps be most obvious, and at joining lightweight and dissimilar materials and structures. It is recommended that adhesives are first applied in less critical areas of a ship and as service experience