ACCIDENT REPORT

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of the fatality of a rescue boat crewman on board

Tombarra

at Berth 3, Royal Portbury Docks,

7 February 2011

Part B - The weight of the rescue boat

VERY SERIOUS MARINE CASUALTY

REPORT NO 19B/2012

July 2012

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2005 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 13(9) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2005, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

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GLOSSARY OF ABBREVIATIONS AND ACRONYMS

BRUFMA	-	British Rigid Urethane Foam Manufacturer's Association
BV	-	Bureau Veritas
DNV	-	Det Norske Veritas
EU	-	European Union
FRB	-	Fast Rescue Boat
GRP	-	Glass Reinforced Plastic
HP	-	Horsepower
ILAMA	-	International Life-saving Appliance Manufacturers' Assocation
IMO	-	International Maritime Organization
kg	-	kilogram
kt	-	knot
kW	-	kilowatt
LR	-	Lloyd's Register
LSA	-	Life Saving Appliance
MCA	-	Maritime and Coastguard Agency
MED	-	Marine Equipment Directive
MOD	-	Ministry of Defence
MSC	-	Maritime Safety Committee
MTD	-	Minton Treharne & Davies Ltd
NWH	-	Norsafe Watercraft Hellas S.A.
PMDI	-	Polymeric Methylene Diphenylene Disocyanate
PU	-	Polyurethane
rpm	-	revolutions per minute
SMS	-	Safety Management System
SOLAS	-	International Convention for the Safety of Life at Sea
SWL	-	Safe Working Load
USH	-	Umoe Schat-Harding
UTC	-	Universal Time, Co-ordinated
WLCCL	-	Wilhelmsen Lines Car Carriers Ltd

Times: All times used in this report are UTC

SYNOPSIS

At 1549 on 7 February 2011, the rescue boat on board the UK registered car carrier, *Tombarra*, plummeted approximately 29m from its davit into the water below, killing one of the rescue boat's four crew. The accident occurred when the rescue boat's fall wire parted as the boat was being recovered to its stowage during a monthly drill while *Tombarra* was alongside Royal Portbury Dock, Bristol.

The investigation of the failure of the fall wire is covered in **Part A** of this report. During the investigation, it was found that the rescue boat, a WHFRB 6.50, was significantly overweight. This did not contribute substantially to the failure of the fall wire on this occasion, but the boat's in-service weight growth is a cause for concern and warranted detailed examination of the circumstances.

The weight growth found on *Tombarra*'s rescue boat had been caused by the ingress and retention of water in the hull's internal stiffeners, which were hollow, and in segregated spaces containing buoyancy foam within the boat's hull. The water could not be drained from these spaces and the crew had no way of knowing the water was there. The foam used in the buoyancy chambers was of varying quality and contained voids in which water was able to collect. Inspection and testing of other WHFRB 6.50 rescue boats, along with reports of inspections of other rescue boat models, indicates that there is considerable scope for many rescue boats and lifeboats to be overweight due to water retention.

During this investigation, it was apparent that the problem of water ingress and retention in rescue boats and lifeboats using buoyancy foam is known by many of the interested parties within the shipping industry. There is general recognition that boats will not remain watertight and their weight will increase over time as the accumulated water cannot be drained. An increase in weight can not only adversely affect a rescue boat's ability to meet international requirements, but it can also compromise the safety of its launching and recovery equipment.

Recommendations have been made to the Maritime and Coastguard Agency aimed at ensuring rescue boats and lifeboats are designed so that water can be drained from all hull spaces and that the weights of rescue boats and lifeboats are periodically checked. A recommendation has also been made to the International Life-saving Appliance Manufacturers' Association aimed at ensuring the safety of boats already in service and improving future designs.

Tombarra

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *TOMBARRA* AND ACCIDENT

SHIP PARTICULARS

Vessel's name	*Tombarra*
Flag	UK
Classification society	Det Norske Veritas (DNV)
IMO number	9319753
Type	Vehicle carrier
Registered owner	Assetfinance December (R) Ltd.
Manager	Wilhelmsen Lines Car Carriers Ltd
Construction	Steel
Length overall	199.90m
Registered length	192.12m
Gross tonnage	61321
Built	2006
Authorised cargo	Vehicles

VOYAGE PARTICULARS

Port of departure	Koper, Slovenia
Port of arrival	Royal Portbury Docks, Bristol
Type of voyage	International
Manning	23

MARINE CASUALTY INFORMATION

Date and time	7 February 2011, 1549
Type of marine casualty or incident	Very Serious Marine Casualty
Location of incident	Royal Portbury Docks, Bristol
Place on board	Rescue boat

Injuries/fatalities	One fatality. Three crew suffered from hypothermia
Damage/environmental impact	Rescue boat fall wire failure, structural damage to the rescue boat
Ship operation	Cargo discharge alongside
Voyage segment	In port
External & internal environment	External air temperature: 7.6ºC Average wind speed: 13.9kts Water temperature 5ºC
Persons on board	23 (four on board the rescue boat)

1.2 INTRODUCTION

Following the failure of the rescue boat fall wire on board the car carrier *Tombarra*, the rescue boat, a WHFRB 6.50, fell approximately 29m to the water below. After the boat's crew had been recovered, the rescue boat was lifted ashore and weighed using a certificated load cell **(Figure 1)**. The boat weighed 1550kg, which was 570kg heavier than its weight of 980kg when manufactured. The drain plug in the boat's transom was opened and a strong flow of water drained out.

Figure 1: Rescue boat when weighed

Initial inspection indicated that the damage to the boat caused by its fall and subsequent recovery from the water was relatively minor, and included: the separation of the forward seam of the buoyant righting chamber and fracture of its upper surface **(Figure 2)**; a section of the glass reinforced plastic (GRP) surrounding the bow cleat had been torn away **(Figure 2)**; and several joint rivets at the gunwale port side joint of the righting chamber frame had failed **(Figure 3)**. A previous hull repair was also evident **(Figure 4)**.

Although the weight of the boat exceeded the Safe Working Load (SWL) of the davit, the weight of the boat did not contribute substantially to the failure of the fall wire **(**see **MAIB report 19A/2012 – Part A)**. However, the higher than expected weight of the rescue boat, and the results from inspections of the buoyancy spaces within the boat's hull, prompted Wilhelmsen Lines Car Carriers Ltd (WLCCL), *Tombarra*'s ship manager, to weigh other rescue boats in its fleet. It became quickly evident that other WHFRB 6.50 rescue boats were also overweight and that further investigation was warranted.

Figure 2: Damage to buoyant righting chamber and bow

Figure 3: Failure of rivets on port gunwale

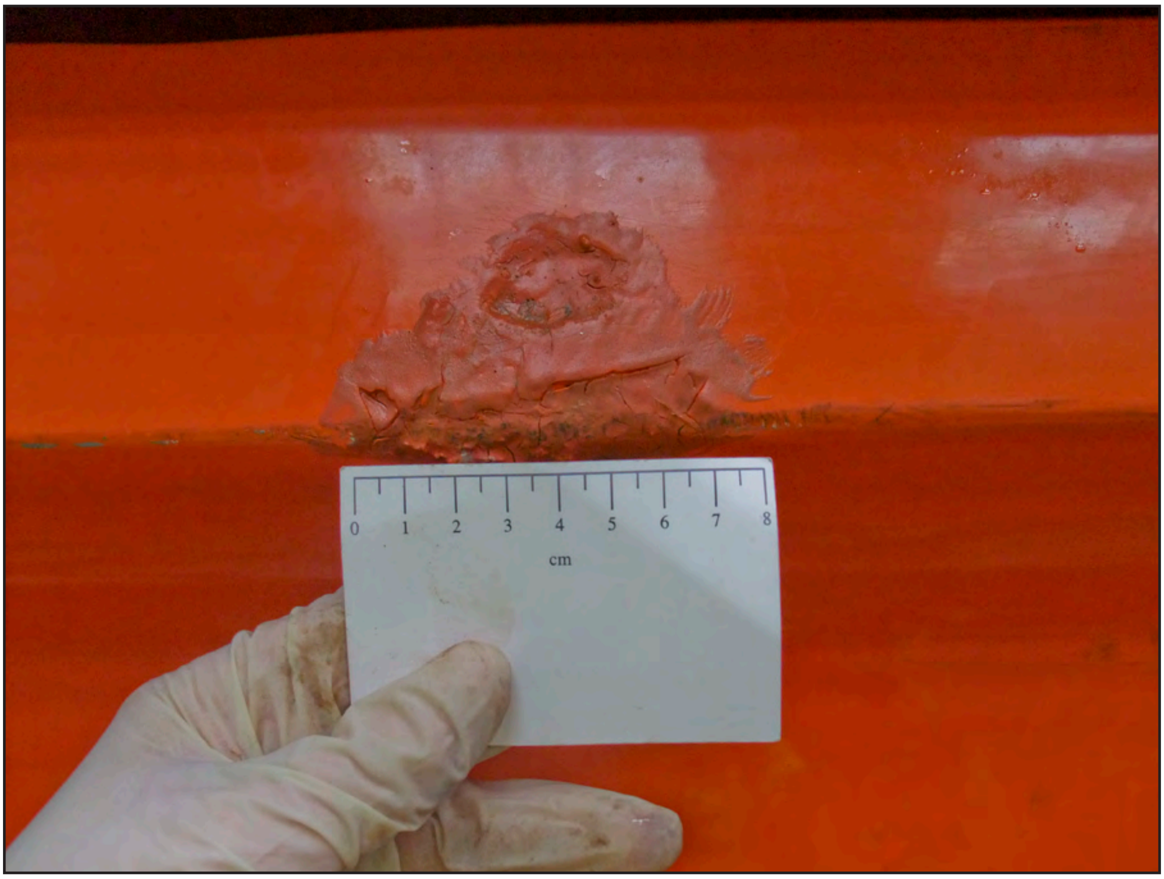

Figure 4: Hull damage repair

1.3 WHFRB 6.50

1.3.1 Construction

Tombarra's WHFRB 6.50 was manufactured by Watercraft Hellas S.A. Greece and was 6.35m in length (without engine) with a 2.2m beam. The boat was constructed from three separate GRP mouldings for the inner and outer hulls, and the stiffeners **(Figures 5, 6** and **7)**. The inner hull deck, located at the upper chine, enclosed the buoyancy spaces below, and the gunwale provided an additional enclosed buoyancy space.


Figure 5: Boat hull mould

Figure 6: Boat stiffener mould

Figure 7: Boat deck mould

The deck was constructed of balsa wood covered with GRP. The hollow GRP stiffeners comprised two longitudinal and five transverse sections, which divided the lower hull into 16 spaces or pockets **(Figure 8)**. There was a gap of approximately 60mm between the upper surfaces of the stiffeners and the inner hull deck.

Fifteen of the hull spaces were filled with low density rigid polyurethane (PU) closed cell foam which extended above the stiffeners to the underside of the deck. The remaining hull space was sited on the centreline aft and was left empty to allow access to the engine's mounting bolts. This space could be drained through a screwed plug in the transom **(Figure 9)**. The 15 foam-filled spaces were not inter-connected at the lower level, for example by limber holes in the stiffeners, for drainage. Two 'elephant trunks' were fitted on the transom to drain water from the deck **(Figure 9)**.

A steering console was fitted with in-line seating for the driver and a crewman. Behind the console seating was a fixed storage box and a single point lifting frame. The lifting frame was attached to the boat by four bolts passing through a conduit between the deck and hull. Aft of the lifting frame, transverse seating was provided for a further three persons. Behind the aft seating was the engine space, and above the engine on GRP supports on the port and starboard gunwales was a fixed buoyancy righting chamber. A conduit for the engine control cables ran underneath the deck on the starboard side of the centreline.

All of the deck fittings and deck penetrations were sealed with a flexible adhesive maritime sealant to prevent water ingress into the buoyancy spaces below the deck. Foam injection holes on the deck were sealed with plugs.

1.3.2 Evaluation and testing

The evaluation and testing of the WHFRB 6.50 prototype was undertaken by Bureau Veritas (BV) on 19 October 2000. Designed as a fast rescue boat (FRB), the test procedure and acceptance criteria were in compliance with the applicable International Convention for the Safety of Life at Sea (SOLAS) Type Approval[1] requirements. The boat's weight data detailed in the evaluation and test report included:

Unloaded boat:	935kg
Loose equipment:	26.5kg
Fuel:	38.5kg
Persons:	450kg

The boat's calculated loaded weight when fully equipped with six persons on board was 1450kg.

[1] "Type approved" means that equipment has been certified to meet certain minimum regulatory, technical and safety requirements of a State. Type approval enables the product to display a mark, eg CE (Conformité Europeenne) within the European Union. Type approval generally requires: a technical evaluation, including prototype tests to establish that a design complies with specific codes or specifications; the witnessing of a product's manufacture (type test); and an assessment of a manufacturer's ability to consistently manufacture a product in accordance with approved specifications.

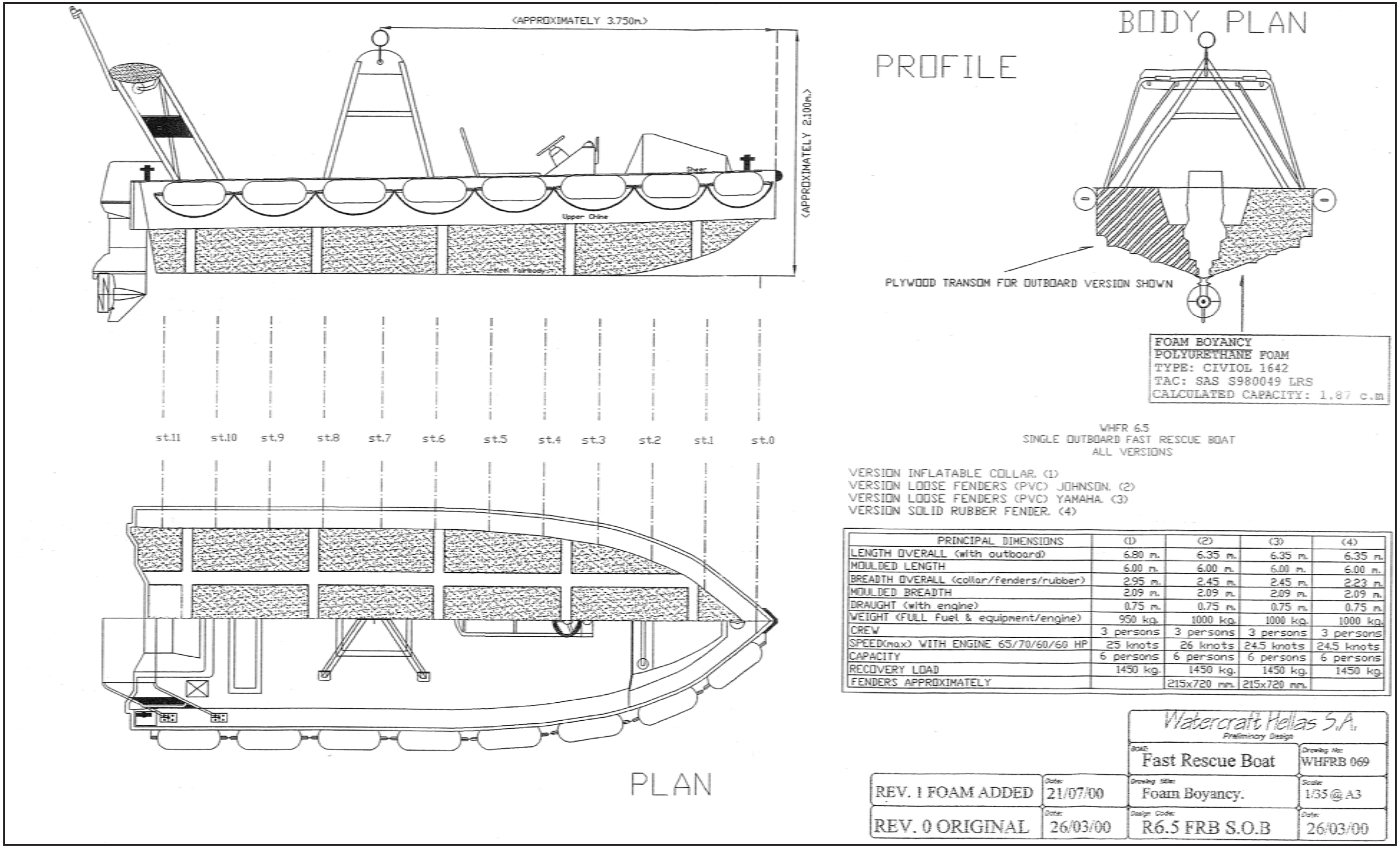

Figure 8: Body plan

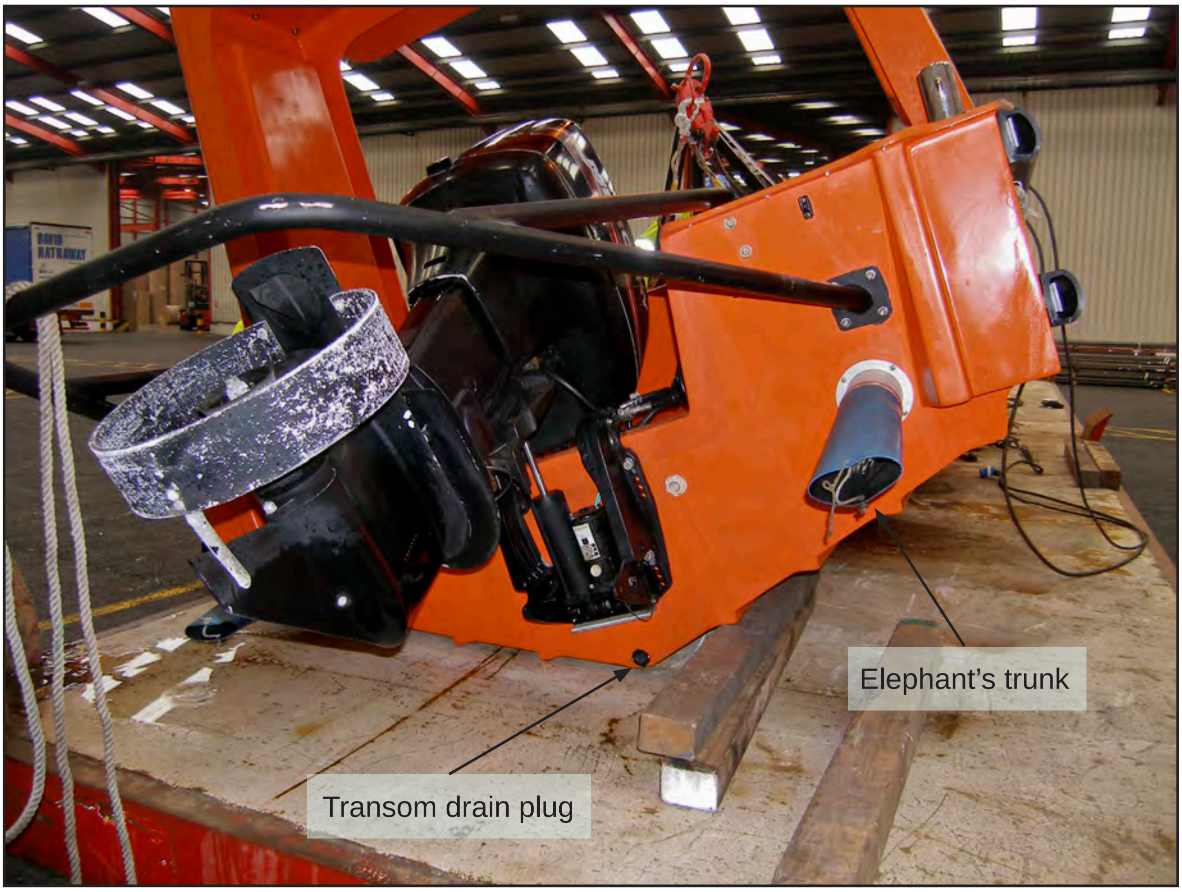

Figure 9: Deck and transom drains

The boat's weight included a 44.1kW Yamaha 60F two-stroke outboard engine weighing 107.5kg which, at full speed, propelled the boat at a speed of 22.05kts.

An overload test, with the boat loaded to four times the weight of equipment and full complement of persons (1900kg), was conducted by suspending the boat from its hook for 5 minutes. No structural damage was observed.

Tombarra's rescue boat (hull 124) was completed on 1 June 2006 and conformed with the provisions of the European Union Directive 96/98 CE on Marine Equipment (MED)[2]. The boat was fitted with a 67kW (90 HP) Mercury outboard two-stroke petrol engine (weighing 130kg), and weighed 980kg including the engine and standard equipment. It was purchased by Umoe Schat-Harding (USH) and was delivered to the Mitsubishi Heavy Industries shipyard in Nagasaki. The rescue boat was one of six WHFRB 6.50 supplied to the Torrens class vessels operated by WLCCL.

[2] The EU Directive 96/98/EC on marine equipment, as amended, came into force on 1 January 1999 and became mandatory for all equipment from 1 January 2001. The Directive, commonly referred to as the Marine Equipment Directive (MED), applies to all ships with safety certification issued by or on behalf of European Union (EU) member States. Notified bodies are responsible for assessing that marine equipment conforms with the provisions of the MED. Different conformity assessment modules may apply; module B = type-examination and module D = production quality assurance.

1.4 RESCUE BOAT INSPECTIONS

On 23 March 2011, MAIB inspectors and representatives from the boat manufacturer, Norsafe Watercraft Hellas S.A. (NWH), examined *Tombarra*'s rescue boat to determine the source of the additional weight. The boat was re-weighed and was found to weigh 1450kg.

Sections of the deck were cut open in three locations (forward, midships and aft). The mid position, aft of the lifting frame, was found to contain voids, free water, and what appeared to be degraded or poorly made PU foam in the lower part of the foam buoyancy space **(Figures 10** and **11)**. The gap between the stiffener and the underside of the deck was clearly visible **(Figure 11)**. The buoyancy spaces opened forward and aft were in a similar condition, but not to the same degree. Fifteen holes were drilled into the hull's hollow stiffeners and water drained from 14 of them **(Figure 12)**. NWH's inspection report **(Annex A)** identified several possible routes, other than the damaged areas, through which water could have entered the hull. These included:

> *The starboard side of the hull was found repaired in a bad manner and osmosis had appeared. This could also be a possible area of water penetration in all compartments.*
>
> *The inspection hatches of the crew seating bench were destroyed.*
>
> *The screws around the helmsman's console could also allow water to penetrate under the deck. Silicone was found on top of the manufacturer's sikaflex used to protect water penetration.*
>
> *Foaming application holes on the deck floor were found to be needing service. Water can penetrate through these holes if remains for a long time on the deck.*
>
> *Water can also penetrate from the lifting frame both from the deck or from the hull.* [sic]

On 6 April 2011, MAIB Inspectors and a representative from Bayer plc (Bayer)[3], the supplier of the buoyancy foam used in the rescue boat, removed foam samples from the hull. Sections of the foam appeared to have contracted to leave voids, and the foam's characteristics changed markedly midway through its depth. The lower section of the foam was dark and brittle, while the upper section was light in colour and seemed to be more dense **(Figures 13, 14** and **15)**.

A further inspection of *Tombarra*'s rescue boat was conducted by Longitude Engineering in October 2011 to check the side shell gel coat for potential lateral impact damage, and to check the condition of the internal stiffeners using a boroscope. The inspection report **(Annex B)** included:

- No conclusive damage was found to the primary stiffeners
- No evidence of lateral impact damage was found.

[3] Bayer supplied the raw materials which were mixed by Watercraft Hellas to make the PU foam. In this report the use of the term "foam supplier" refers to the supplier of the constituent parts that are mixed to produce PU foam.

Figure 10: Free water in buoyancy space

Figure 11: Degraded foam and void

Figure 12: Water draining from drilled hole

Figure 13: Void within foam

Figure 14: Demarcation line through foam

Figure 15: Foam demarcation - forward opening

1.5 FOAM ANALYSIS

Bayer's analysis of the foam from *Tombarra*'s rescue boat indicated that the lower layer of the foam, which was darker and more brittle than the upper layer, had been poorly mixed and also possibly contained a higher proportion of Polymeric Methylene Diphenylene Isocyanate (PMDI) than recommended[4]. As a result, the darker foam had a high proportion of open cells, that had allowed water to penetrate the foam. However, the characteristics of the darker foam were considered to result from processing errors rather than from the foam coming into contact with water. In support of its conclusion, Bayer produced two foam samples for reference **(Figures 16** and **17)**. Both samples were made using the correct ratio of constituents, but were mixed at different speeds. One sample, which was considered by the manufacturer to be representative of the quality expected, was mixed at a speed of 2500rpm, and the other at 150rpm. The appearance and feel of the sample mixed at the lower speed was similar to the samples removed from the lower hull of the rescue boat, while the samples mixed at the higher speed were similar to the foam found in the upper section of the boat.

Foam and water samples from the rescue boat, and the reference samples provided by Bayer, were further analysed by Minton Treharne & Davies Ltd (MTD), Cardiff, for buoyancy, density, porosity and flammability. The analysis identified that:

- The water from the boat's hull was primarily sea water.
- The darker foam sample from the lower section of *Tombarra's* boat, and the Bayer reference sample mixed at 150rpm, with a spatula, were able to support the least weight.
- The darker foam sample from the boat had a density of 90kg/m³, whereas the reference sample mixed at 2500rpm had a density of 47kg/m³.

Figure 16: Bayer foam reference samples

[4] Rigid PU foam is commonly produced from two main liquid constituents, a polyol and a polyisocyanate (or isocyanate known as Methylene Diphenylene Isocyanate). The correct chemical name for MDI is now diphenylmethane – 4,4' - diisocyanate

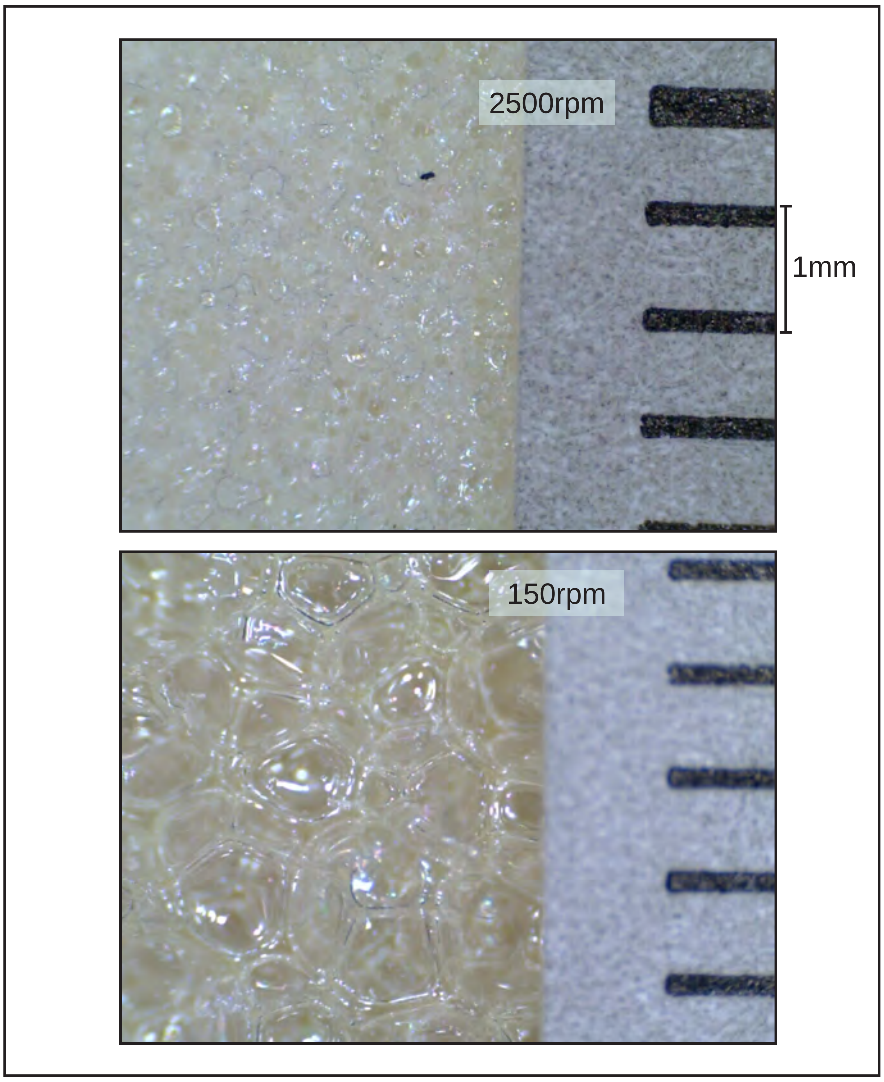

Figure 17: Bayer foam reference samples (x200 magnification)

The analysis report concluded:

> *The effectiveness of the mixing technique is significant and would have a direct effect on the pore size, density and buoyancy of the cured foam. The samples submitted exhibited regions of significantly reduced buoyancy/increased density, compared to the Good Bayer reference, resulting from improper mixing of the foam prior to application.* [sic]

1.6 CHECKS ON OTHER TORRENS CLASS VESSELS

Tombarra was one of 10 Torrens class vessels managed and operated by WLCCL. Following the weighing of *Tombarra*'s rescue boat, WLCCL requested that NWH inspect and weigh the rescue boats on board *Tombarra*'s sister vessels.

All six of the WHFRB 6.50 rescue boats on board the Torrens class vessels were found to be overweight **(Table 1)**, and two exceeded the Safe Working Load (SWL) of their davits (1500kg).

Vessel	Rescue boat hull Number	Year built	Before draining (kg)	After draining (kg)	% overweight (nominal 1000kg)
Torrens	110	2004	1495	1400	49.5
Toledo	113	2004	1190	1160	19
Toronto	115	2004	1490	1300	49
Topeka	123	2006	2100	1560	110
Tombarra	124	2006	1550	1450	55
Tortugas	128	2006	1440	Unknown	44

Table 1: Weights of WHFRB 6.5 on board other Torrens class vessels

NWH assessed that the weight growth was primarily due to water ingress of the hulls' internal spaces. NWH service engineers drained as much of the water from the boats as possible by drilling holes in to the bottom of the hulls. The holes were then plugged. The boats were also inspected for potential routes for water ingress. Varying levels of damage, and modifications to the decks and hulls, were found. Reports of the inspections of the rescue boats carried on board *Torrens* (hull 110) and *Topeka* (hull 123) are at **Annexes C** and **D** respectively.

Topeka's rescue boat was subsequently transported to the NWH factory in Greece, where the boat's manufacturer identified that water had penetrated almost all of the boat's buoyancy spaces through cracks and GRP damage on the deck and hull. When the water and foam were removed from the hull, the boat weighed 1078kg. The inspection report is at **Annex E**.

1.7 WHFRB 6.50 HULL NUMBER 5

1.7.1 Weight

In March 2011, Stena Line weighed a WHFRB 6.50 rescue boat (hull 5) carried on board a ro-ro ferry it was purchasing. The boat, which was constructed and fitted to the vessel in 2000, weighed 1800kg, and its lifting ring was elongated **(Figure 18)**. Following weighing, 550kg of water was drained from the boat via the transom drain plug.

1.7.2 Testing

Due to the possibility that the boat had sustained internal damage, Stena Line removed the WHFRB 6.50 (hull 5) from service. The boat was then inspected and tested by Longitude Engineering on behalf of the MAIB to determine whether the boat met the type approval and MED requirements.

Figure 18: Stretched lifting ring

The tests undertaken and measured against the applicable SOLAS requirements **(Paragraph 1.12.1)** identified that:

- The boat's freeboard was compromised due to the open control cable transom conduit route which allowed the boat to flood. Although the boat passed the freeboard test with the conduit blocked, the freeboard was half of its original measurement and the engine was very low in the water, which potentially compromised its reliability.

- The boat's self-draining capability was inadequate when it was swamped.

- The boat achieved a maximum speed of only 7.5kts, compared to its design speed of 20kts.

The boat passed the towing, bollard pull and righting tests, and met the speed requirements for a rescue boat.

On completion of the performance tests, destructive examination of the boat identified that its primary structure was damaged to the extent that there was a risk that it would fail when hoisted or lowered on a fall wire. It also identified that the boat's deck leaked and significant amounts of water were able to accumulate in the hollow stiffeners. In addition, the water retained in the boat's stiffeners and foam edge voids could not be drained.

The report's executive summary **(Annex B)** included:

> *The vessel was removed from its ship in the condition in which it was tested and as such the MAIB trials have been highly representative of an overweight in-service craft. It was considered that the assessed craft in this condition was not suitable for safe use as a Fast Rescue Boat.*

1.7.3 Foam condition

Foam samples from WHFRB 6.50 hull 5 were sent to Bayer for inspection. The company's report included:

1. *The "orange" foam (which definitely cannot be from us) has very coarse cell-structure/open cells (probably due to bad mixing). Not surprisingly, this may suck up water.* [sic]

2. *The "white" foam seems to be normal: acceptable cell-structure/compressive strength/dimensional stability.* [sic]

1.8 WATERCRAFT HELLAS S.A.

1.8.1 General

Watercraft Hellas S.A, based in Thebes, Greece, was founded in 1974 in co-operation with Watercraft Ltd, UK. The company was acquired by Norsafe AS, Norway in 2006 and was re-named Norsafe Watercraft Hellas S.A. in 2009.

Watercraft Hellas S.A. produced 141 WHFRB 6.50 rescue boats between 2000 and 2008. Of these, 26 were delivered to USH and the majority of the rest were delivered to Greek vessel operators. The WHFRB 6.50 was withdrawn from production in 2008 as it was a direct competitor of a rescue boat manufactured by Norsafe A.S., the parent company.

1.8.2 Quality assurance

In July 1999, BV performed the initial audit of Watercraft Hellas S.A. as part of the process of approving that the manufacturer's quality system complied with Module D (Production Quality Assurance) of the MED. Watercraft Hellas S.A's quality system was approved by BV on 26 February 2003. BV also approved the EC Type Examination Certification (MED - Module B) for the WHFRB 6.50 and its variants on 24 October 2005. The certifying authority for Watercraft Hellas S.A's conformity with Module D of the MED changed from BV to BG-Prüfzert in March 2007.

Between 2003 and 2006, BV surveyors visited Watercraft Hellas S.A. 31 times to inspect the manufactured products. The audits carried out concerned the production quality system and included checking the buoyancy foam documentation against the boats' approved technical data. The weights of the completed boats were also inspected.

1.9 BUOYANCY FOAM

1.9.1 Types used

Hull numbers 1 to 121 of the WHFRB 6.50 rescue boats were filled with Civiol 1642 (also known as Tecfoam) PU foam supplied by Tectrade Getinge AB, Sweden. Civiol 1642 was type approved by Det Norske Veritas (DNV) on 15 October 1999 for use as buoyancy foam in rescue boats. The mixing ratio for the two main constituents of Civiol 1642 specified on its technical data sheet **(Annex F)** was 120g isocyanate to 100g polyol by weight. The foam's density when hand-mixed was 41kg/m³ ± 2.0.

In WHFRB 6.50 hulls from 122 onwards, the foam used was Tecphen CX-42-D-200/W (Tecphen) manufactured by Tectrade A/S, Denmark, a subsidiary of Bayer plc. Tecphen CX-42-D-200/W, and its later trade name of Baymer CX-42-D-200/W (Baymer), had a mix ratio of 140g isocyanate to 100g polyol by weight, and 126:100 by volume **(Annex G)**. Its density when hand-mixed was 44kg/m³ ± 1.5, and was 42kg/m³ ± 1.5 when machine-mixed.

The Tecphen technical data sheet used by Watercraft Hellas S.A. stated that the foam had:

> *'a very fine cell structure, good mechanical properties and the best possible adhesion on all usual construction materials', and 'a low pressure foaming with good flow ability.'*

The technical data sheet also stated the reaction profiles and reaction times for the different stages of the foaming process for both hand and machine-mixing methods**.** Information on the duration of mixing times, the mixing speed, the maximum volume that should be mixed by hand, sampling, testing, and how the mixture should be introduced into a cavity to prevent air entrapment, was not provided**.**

The Tecphen/Baymer foam was type approved by Lloyd's Register (LR) on 10 November 2005. The type-approval certificate, which was valid until 9 November 2010, stated that the Baymer foam was a water-blown, two- component, PU foam system for use in-situ or moulded blocks as buoyancy material in LSA.

A subsequent LR type approval certificate for Baymer foam, issued on 6 January 2011, described the foam as for use as buoyancy material suitable for use in survival craft but not in personal flotation devices. The certificate also required random samples to be taken during production, and tested for loss of buoyancy in accordance with Maritime Safety Committee (MSC) Circular MSC.81(70) **(Paragraph 1.12.1)**.

1.9.2 Production

In the WHFRB 6.50 hulls in which Civiol 1642 was used, the boats' 15 buoyancy spaces were filled in two stages. First, the isocyanate and polyol were measured in separate buckets with overflow orifices to ensure the correct quantities of liquid were used **(Figures 19** and **20)**. The liquids in the two buckets was poured into a third bucket and hand-mixed for a short period using an electric drill and paint mixing tool **(Figures 21** and **22)**. The mixture was then poured into the boat hull buoyancy spaces in two layers, each of between 10cm and 20cm in depth. The foam expanded rapidly to nearly fill the spaces **(Figures 23** and **24)**. Once the deck was

Figure 19: Foam hand-mixing plant

Figure 20: Measuring foam liquid constituents

Figure 21: Foam mixing bucket and tool

Figure 22: Foam mixing

Figure 23: Pouring foam mix into mould

Figure 24: Foam expanding in mould

attached to the hull, a foam injection machine was used to pump foam through holes drilled in the deck into the remaining void spaces below. The holes also allowed air to vent as the foam expanded.

In the later WHFRB 6.50 hulls in which Tecphen was used, the foam injection machine could no longer produce the correct foam mix due to the different mix ratio required. Consequently, Norsafe informed Watercraft Hellas S.A. that only the hand-mixing method should be used during the foam production process. The foam mixing procedure developed by Watercraft Hellas S.A. was to mix the isocyanate and polyol constituents for 15 seconds at a speed of between 500 and 600rpm. Foam samples were taken during the production process, but the quality of the foam samples was not frequently tested.

All WHFRB 6.50 rescue boats were weighed before and after the addition of foam, and an inspection checklist was maintained during the production process.

1.9.3 Problems

In April 2009, NWH was concerned that the Baymer foam being used in its boats was shrinking when exposed to elevated temperatures. Bayer investigated, and its resulting test and quality control reports included:

> *All countersamples from the last 4 deliveries to Watercraft Hellas are within acceptable limits regarding reaction profile and temperature resistance.*
>
> *Based on the amount of isocyanate and polyol delivered to Watercraft Hellas, there is a risk that too little isocyanate has been used to produce the foam, which might show shrinkage after a while and especially when exposed to elevated temperatures.*
>
> *We strongly recommend, that Watercraft Hellas check the mixing equipment/ procedure to ensure, that the correct ISO/POL ratio is used.*
>
> *The present mixing (15 sec/5-600 RPM) is insufficient since the cell size/quality are very course and irregular. Using longer and faster stirring improves cell size/ quality significantly.*
>
> *The densities are relatively lower compared to small handmix samples. Using longer and faster stirring reduces the core density due to a more efficient mixing.*
>
> *Cold conditions/raw materials will have a high impact on the possibilities to make an acceptable mixing of isocyanate/polyol by handmixing, since the viscosity is much lower and hence makes it more difficult to blend. This could explain, why Watercraft Hellas has observed problems with adhesion, shrinkage etc.* [sic]

1.10 RESCUE BOAT SERVICE AND MAINTENANCE

1.10.1 Service

The servicing of the lifeboats and rescue boats on board the Torrens class vessels has been conducted by Schat-Harding UK since the vessels' build. Servicing and inspection was carried out by qualified service technicians on a yearly and 5-yearly basis, and the work instruction covering rescue boats included checks on the hull and deck for signs of damage, general deterioration and leakage.

The service history for *Tombarra*'s rescue boat and fully enclosed free-fall lifeboat shows that Schat-Harding UK service personnel attended the vessel each year between 2007 and 2010. The service reports included:

> *The hull canopy both internally and externally found in very good conditions.* [sic]
>
> *Carried out inspection and service to rescue boat WHFRB6.50 in accordance with Schat-Harding approved checklist AR10.002.*
>
> *- all found to be satisfactory at the time of inspection.*

Service reports on other Torrens class vessels, included:

- *Toledo*: 25 December 2007

  B1. Checked the hull of boat. Found some GRP damaged. Need to repaired ASAP. [sic]

- *Toscana*: 11 May 2010

  Noted at the request of ship crew inspect small GRP damage/gel coat stress damage. Advised this is very common to freefall system due to flexing of boat when launching. Request ship staff to keep a visual check to area and to inform Schat Harding if this damage area increases in size. [sic]

1.10.2 Onboard maintenance

Tombarra's Safety Management System (SMS), Section 7 'Maintenance of lifeboats and rescue boats' stated:

> *Any damage to lifeboat hulls or mechanisms that render the boat to be less than seaworthy shall be brought to the attention of the managers and the classification society and repairs done to the satisfaction of class.*

Weekly checks included:

> *Check the boat inside and outside in order to ensure readiness for use, plugs out but ready for use.*

Monthly checks included:

> *Check for any damage to the hull exterior.*
>
> *Take corrective action to remedy any deficiencies found in the above.*

Quarterly checks included:

> *Check the plugs for leakage.*

The onboard LSA maintenance records completed by the crew indicate that boat drills were conducted monthly.

1.11 LIFE SAVING APPLIANCES (LSA) CODE

The LSA Code requirements for lifeboats that are also applicable to rescue boats include:

- 4.4.4 Lifeboat buoyancy

  All lifeboats shall have inherent buoyancy or shall be fitted with inherently buoyant material which shall not be adversely affected by seawater, oil or oil products, sufficient to float the lifeboat with all its equipment on board when flooded and open to the sea.

- 4.4.7 Lifeboat Fittings

- 4.4.7.1 *All lifeboats except free-fall lifeboats shall be provided with at least one drain valve fitted near the lowest point in the hull, which shall automatically open to drain water from the hull when the lifeboat is not waterborne and shall automatically close to prevent entry of water when the lifeboat is waterborne. Each drain valve shall be provided with a cap or plug to close the valve, which shall be attached to the lifeboat by a lanyard, a chain or other suitable means. Drain valves shall be readily accessible from inside the lifeboat and their position shall be clearly indicated.*

1.12 INTERNATIONAL PERFORMANCE STANDARDS

1.12.1 Rescue boats

SOLAS test requirements for (fast) rescue boats are laid down within the LSA Code, MSC.81(70) and MSC/Circular 809. The tests include:

- Freeboard – with the rescue boat suitably loaded, the test is considered successful if the measured freeboard, on the low side, is not less than 1.5% of the rescue boat's length or 100mm, whichever is greater.

- Towed – fully equipped, the rescue boat should not exhibit unsafe or unstable characteristics, or suffer any damage while being towed at not less than 5kts in calm water using the boat's painter.

- Bollard pull – with the rescue boat and its approved load, the test should demonstrate that a minimum 25 person liferaft, fully loaded, can be towed at a speed of at least 2kts in calm water.

- Speed and manoeuvring – with the rescue boat and its approved load, the test should demonstrate satisfactory operation of the engine during manoeuvring and be capable of 6kts with three crew for a period of 4 hours (20kts for a fast recue boat).

- Self-bailing – the rescue boat should be capable of automatically self-bailing or be capable of rapidly clearing water.

- Righting – both with and without the engine, the test should demonstrate that the rescue boat is capable of being righted by not more than two persons.

1.12.2 Foam buoyancy

Foam buoyancy test specifications are detailed in MSC.81(70) part 6.2.2 – 6.2.7. which require moulded and cut foam blocks to be subjected to temperature cycling and immersion in various liquids, including water, and various fuels and oils commonly used on board ships. The water immersion test is conducted over a period of 7 days under a head of water of 1.25m. Foam's reduction in buoyancy over this period should not exceed 5%.

1.13 EVIDENCE OF OTHER OVERWEIGHT BOATS

1.13.1 Rigid raiding craft

In May 2011, the UK Ministry of Defence (MOD) advised MAIB that it had withdrawn from service 32 Mark III rigid raider craft built between 1995 and 2000. This action was taken following investigation into the crafts' increase in weight over several years. In some cases, boats were found to be 500kg - or 25% overweight. Subsequent trials and calculations raised significant safety concerns regarding the boats' performance and their launch and recovery arrangements.

During the investigation, a number of rigid raider craft were cut open to enable an examination of the condition of the foam-filled buoyancy compartments to be carried out. Void spaces were found within the foam that had filled with water. The voids were considered to have occurred due to contraction of the foam as a result of immersion in water over an extended period of time.

The investigation report included:

> *The increase in weight is likely to be due to ingress of water into the foam filled hull. With age, polyurethane foam is known to degrade and it may be absorbing water as a result[5].*

1.13.2 Umoe Schat-Harding MOB17 FRB

On 5 June 2011, a fast rescue boat on board a ro-ro passenger ferry fell about 15m to the water when its fall wire parted during a monthly drill. Fortunately, it was usual practice to first test the davit system by lowering and raising the boat without any crew embarked.

The MOB 17 FRB was manufactured by USH and was supplied to the ship in 1997. The boat had a history of water ingress in its foam buoyancy spaces. In 2006, the extent of the water ingress resulted in unapproved repairs being carried out that included the fitting of an inspection hatch to the deck and two drain plugs to the forward part of the hull **(Figure 25)**.

After the accident, one plug and the inspection hatch were opened and a considerable amount of water flowed out from the plug, while the foam below the hatch was found to be saturated and easily compressed **(Figure 26)**.

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[5] MAIB comment: The degradation of PU foam is usually attributable to mechanical and thermal stresses and/or incorrect processing


Figure 25: Hull drain plug


Figure 26: Inspection hatch and saturated foam

The boat weighed 1050kg, an increase of over 300kg from when it was new. The boat was overhauled by Schat-Harding UK which found that water appeared to have remained in the lower part of the hull, possibly for some considerable time, causing a black discolouration at the foam/hull interface **(Figure 27)**. The foam had also delaminated from the hull.

Figure 27: Inner hull discolouration

1.13.3 Norsafe Midget MkII

In August 2011, an international vessel operator found 10 Norsafe Midget MkII rescue boats on its vessels to be overweight by at least 12%. Three of the boats were about 60% overweight, and these were replaced and sent for overhaul.

1.13.4 Fassmer FRC 6.1 ID

In December 2011, the MAIB was informed of two 10 year old fast rescue boats on board passenger vessels, which were about 300kg (approximately 17%) overweight due to water ingress into the foam buoyancy spaces. The buoyancy foam was found to be saturated, and the boats were later repaired.

1.13.5 Pleasure craft

Dory

On 16 September 1999, a 4.19m dory with one teacher and nine school children on board capsized on Fountain Lake, Portsmouth, UK. One of the children drowned.

The MAIB investigation[6] found that the boat adopted an unusually large angle of heel when boarded. The void below the deck was found to contain open cell foam that had become saturated and was breaking up. 56.8 litres of frothy water containing bits of foam were removed. The water appeared to have been there for some time. A further 20 litres were drained by drilling two small drain holes in the hull aft.

The Report Analysis (Section 2.4.1 – Long term accumulation in the void space) stated:

> *One of the discoveries made during the post-accident inspection was that this foam crumbled easily. This is symptomatic of long term degradation.*
>
> *It is known that at least one of the regular users of the dory hadn't noticed anything untoward when using it during the 1999 sailing season. Had the foam become saturated, it suggests it might have done so over such a long time that nobody noticed it. If this was in fact the case, only someone with an intimate knowledge of this particular craft might have noticed that she was floating more deeply than designed…*
>
> *In the opinion of the MAIB, the balance of probability is that the foam inside the void was at least partially, and probably totally, saturated prior to being used on 16 September, and had been like that for a long time. There might have been free water in the void if one of the stern holes had been exposed, and not noticed.*

As a result of this and similar accidents involving dories (another seven between 1989 and 1999) resulting in seven fatalities, MAIB published a safety bulletin in November 1999[7]. The aim of the bulletin was to inform the boat-building, fishing and recreational industries of the potential dangers of water being trapped in a dory's void space below its deck.

<u>Change in design</u>

In August 2011, the MAIB contacted a UK-based leisure boat manufacturer that was aware of water being retained within the foam-filled buoyancy spaces of its boats. The company's customers had reported a number of problems which resulted from the additional weight of the water. These problems included: an increased axle loading on a boat's trailer that, in turn, affected trailer-braking capability, and stability at speed; and in the water, the heavier boats had difficulty getting on the plane and did not manoeuvre as easily as expected.

To make PU foam for its boats, the boat manufacturer used an electric drill and stirrer to mix measured quantities of the two constituent parts. The quality of foam produced was found to vary. The manufacturer considered that this was primarily due to the weather conditions, which were found to affect the length of time the mix needed to be stirred. However, on some occasions, the manufacturer was unable to determine the cause of its poor quality foam.

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[6] Report on the investigation of the capsize of a school boat on Fountain Lake, Portsmouth with the loss of one life on 16 September 1999. Report No. 6/2001

[7] MAIB Safety Bulletin 4/1999

The manufacturer recognised that poor quality foam had the potential to develop void spaces and to delaminate from the inner surfaces of the boat's hull. In addition, the manufacturer realised that it was unlikely that its boats would remain watertight throughout their lifetime. Consequently, it re-designed the buoyancy spaces of its boats to allow pre-moulded foam blocks to be fitted where possible, and to add drainage channels from the foam spaces into the inner-keel, which was kept empty. These measures were aimed at ensuring that any water that did enter the hull space could be drained out. **(Figure 28)**.

Figure 28: Buoyancy space drainage

SECTION 2 - ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.2 WEIGHT GROWTH

It is clear that the weight of *Tombarra*'s rescue boat had increased significantly due to the ingress and retention of water within its internal stiffeners and buoyancy spaces. Although some of the water would have entered the boat's hull through the damage sustained as a result of its fall and inversion **(Figures 2** and **3)**, the condition of the buoyancy foam **(Figures 10** and **11)** shows that water had probably been present in *Tombarra*'s rescue boat for a considerable time. Furthermore, the condition of the foam and the water found in other WHFRB 6.50 craft, and other rescue boats and craft using rigid PU foam **(Paragraphs 1.6, 1.7** and **1.13** and **Annexes A,B,C,D** and **E)** also demonstrates that the increase in the weight of *Tombarra*'s rescue boat due to water retention was not an isolated case.

2.3 WATERTIGHT INTEGRITY

Progressive water ingress into the hull space of *Tombarra*'s and other WHFRB 6.50 rescue boats had almost certainly occurred over a number of years through a variety of penetrations, such as; unsealed cable holes, unsealed penetrations associated with the lifting frame, inadequate repairs, other through deck fittings not being made watertight, and holes due to wear and tear in the deck **(Annexes A, C** and **D)**. However, although Schat-Harding UK carried out yearly and 5-yearly inspections and servicing of the WHFRB rescue boats and lifeboats on the Torrens class, only damage to the GRP and gel coat to a freefall lifeboat and a rescue boat were identified.

The WHFRB 6.50 was designed and constructed with the intention that the hull would remain watertight. However, this expectation was unrealistic. As a minimum, vessel crews are required to carry out rescue boat drills monthly. Although these drills are invariably conducted in harbour areas, where conditions are relatively sheltered, there is still potential for the boats to become damaged during their launch and recovery, particularly when operated from high-sided vessels such as car carriers and passenger vessels. Furthermore, given that deck fittings will experience a degree of wear and tear during a rescue boat's time in service, it is inevitable that through deck fixings will eventually loosen. Diligent servicing and maintenance will undoubtedly help to prevent water ingress but, as many hull penetrations through which water can flow are microscopic, it is unlikely to be stopped entirely. Furthermore, the breakdown of a boat's gel coat, which might not be readily apparent, can lead to water entering the hull through capillary action. In pleasure craft this has been found to add significant weight to a vessel's hull.

2.4 WATER RETENTION

The WHFRB 6.50 rescue boat was typical of many rescue boats currently available. Although their designs differ to some extent, the majority comprise a rigid hull, frequently made from a GRP moulding, with voids inside the hull either filled with buoyant foam or left empty.

The WHFRB 6.50's internal structure was subdivided into 16 spaces by hollow stiffeners **(Figure 8)**, but 15 of the spaces were filled with PU foam and had no means of drainage. Consequently, once water penetrated the hollow stiffeners and into voids within the foam, not only would its presence not have been readily apparent, the water could also only be removed by drilling into the hull **(Figure 12)** or by removing the deck **(Annex E)**. The boats' 'elephant's trunks' only drained water from the deck, and the transom drain plug only drained water from the aft space that provided access to the bolts on the engine mounting **(Figure 9)**. Without a detailed knowledge of the rescue boat's construction, ships' crews would not have known the limited value of the transom drain plug, which in many smaller GRP craft, such as dinghies, is used to drain the entire hull.

If the watertight integrity of a rescue boat or lifeboat cannot be guaranteed, it is essential that all of the spaces within a hull can be easily drained. Although the international requirement for the fitting of a '*drain valve fitted near the lowest point in the hull'* **(Paragraph 1.11)**, applies to both rescue boats and lifeboats, it is based on traditional lifeboat design and does not take into account the need to remove water from foam-filled buoyancy spaces.

It is evident that some operators and boat manufacturers have tackled the problem by the retrospective fitting of drain plugs **(Figure 25)**. However, such action must be considered as a short-term fix rather than a long-term solution. This is endorsed in the report of the fast rescue boat trials and analysis conducted by Longitude Engineering **(Annex B)**, which states:

> *With regard to improving the safety of new or existing craft it is proposed that the issues highlighted in this report can only be avoided by carrying out a specific formal safety assessment of any design that recognises that the following will inevitably occur:*
>
> - *Water will be on the deck for long periods of time*
> - *Water will leak through the deck*
> - *Buoyant foam cannot be guaranteed to fill the hull void or remain so throughout the life of the boat.*

The action taken by the pleasure vessel manufacturer in **Paragraph 1.13.5** demonstrates that drainage can be provided in foam-filled spaces **(Figure 28)**.

2.5 USE OF BUOYANCY FOAM

Expanding rigid PU foam is primarily used in the building, automotive and domestic appliance industries due to its superior thermal insulating properties, range of densities, adhesion to a range of materials, and its ability to fill complex cavities. In the marine industry, which uses less than 1% of the PU foam produced worldwide, the foam is used extensively to provide buoyancy, particularly in smaller craft and lifesaving devices. In the case of rescue boats and lifeboats, the foam enables the craft to retain sufficient stability following material damage to the hull. However, it is evident from the inspections of the WHFRB 6.50 **(Paragraphs 1.4, 1.5, 1.6** and **1.7)** and other small craft filled with rigid PU foam **(Paragraph 1.13)**, that the quality of the foam used to fill the buoyancy spaces was not always as intended.

The type of foam used in *Tombarra*'s rescue boat, which when tested met the required international performance standards **(Paragraph 1.12.2)** and was approved by LR, contained voids in which water had accumulated. In addition, some areas of the foam had a relatively open cell structure and had absorbed water and had become discoloured and degraded.

The darker foam samples taken from *Tombarra'*s rescue boat had a density of 90kg/m³, over twice the 44kg/m³ specified on the foam's technical data sheet **(Annex G)**. However, this was probably due to the effect of residual water, and would have resulted in only a 5% reduction in buoyancy. As such, the foam complied with the test requirements regarding buoyancy.

It is possible that the degradation of the foam was exacerbated by thermal and mechanical stresses when the rescue boat was in service. As *Tombarra* traded between the Baltic and the Middle East, the rescue boat would have been exposed to a temperature variation of approximately -10°C and 50°C that could have accelerated the degradation process. It is also possible that the degradation process was exacerbated by the entrained water being forced under pressure between the foam and the hull due to the flexing of the hull when the rescue boat was underway during drills.

It is clear from the problems experienced by Watercraft Hellas S.A. with its foam production in 2009, the findings of the resulting investigation carried out by Bayer **(Paragraph 1.9.3)**, and the analyses of the foam from *Tombarra*'s rescue boat **(Paragraph 1.5)**, that the poor quality of the foam found in *Tombarra*'s rescue boat and other WHFRB 6.50s was caused by one or a combination of several factors. These included the mixing of polyol and isocyanate liquids in incorrect proportions, the speed at which the foam was mixed, the ambient temperature, and the method of application. Given that poor quality foam was found in WHFRB 6.50 hull 5, which used Tecfoam, and in the later WHFRB 6.50 carried by the *Torrens* class, which used Tecphen, the change in foam type was not contributory.

When PU foam is manufactured on an industrial scale, the foam is mixed in machines where the polyol and isocyanate liquids are brought together in metered proportions (in the region of ± 2% accuracy) and the mixing temperature is controlled at between 20ºC and 25ºC. In the marine industry, boat manufacturing is frequently carried out on a small-scale, with boats often being built to order. Consequently, the use of mixing and foam injection machines is often precluded by both consideration of cost and low production volume.

Given the consequent reliance of many rescue boat and lifeboat boat manufacturers on hand-mixing and manual application methods, it is essential that foam suppliers provide adequate guidance regarding low volume foam production, and that boat manufacturers strictly follow the guidance provided. In this case, the information provided on the technical data sheets **(Annexes F** and **G)** lacked detail, which is not unreasonable due to the variety of potential applications. Although Bayer offers training, in this case the local training and quality control regime were not sufficiently rigorous.

2.6 IMPACT ON SAFETY

2.6.1 Rescue boats

To gain type approval and MED certification, the WHFB 6.50 prototype was tested against, and met, the applicable SOLAS requirements **(Paragraph 1.12.1)** for a fast rescue boat. However, it is not surprising that any increase in a rescue boat's weight adversely affects several aspects of its safe operation.

First, the tests carried out by Longitude Engineering, using the WHFRB hull 5 **(Paragraph 1.7** and **Annex B)**, which was 80% overweight, highlighted that the additional weight reduced the boat's freeboard to the extent that the reliability of the engine was compromised and the boat's self-draining capability was inadequate when the boat was swamped. Importantly, the tests also showed that the maximum speed of the overweight boat was only 7.5kts, which was significantly less than the 20kts required of a fast rescue boat. Hull 5 clearly no longer met the performance standards required of a fast rescue boat, or a rescue boat, and its overall suitability for use as a rescue boat was questionable.

Second, any increase in the weight of a rescue boat also has a significant impact on the safety of its launching and recovery system. On board *Tombarra*, the SWL of the rescue boat davit was 1500kg. Therefore, notwithstanding the possibility of some water entering the boat's hull during its inversion in the dock, the weight of the boat (1550kg when first weighed after recovery), along with its four crew (approximately 300kg), easily exceeded the SWL of the davit. WHFRB hull 5 weighed 1800kg and the adverse effect of the additional 800kg on the boat's launching and recovery equipment is shown in **Figure 18**.

Third, SOLAS requires that *at least once every five years rescue boats and lifeboats shall be turned out and lowered when loaded with weights to simulate 1.1 times the total mass of the lifeboat or rescue boat when loaded with its full complement of persons and equipment or with an equivalent load*. The dangers of undertaking a dynamic load test of this type, using a rescue boat that significantly exceeds its certified weight, are obvious.

Finally, hoisting and lowering a rescue boat that is significantly overweight can damage the boat's internal structure. In the case of WHFRB 6.50 hull 5, Longitude Engineering identified that the boat's primary structure, which had already been damaged by a side impact, would possibly fail when hoisted or lowered on a fall wire. The additional weight of the boat undoubtedly increased the risk of this happening.

The degree to which a rescue boat's performance is adversely affected by weight growth will depend on the amount a boat is overweight and the characteristics of the boat in question. Consequently, once a boat is found to be overweight, any assessment of its continued suitability as a rescue boat, and the need for any repairs to be conducted, must be made in consultation with the boat's manufacturer. Where the weight of a boat, including crew and equipment, results in the SWL of its davit being exceeded the boat's continued use on board a vessel is unsafe.

2.6.2 Other boats

Lifeboats constructed with internal spaces that cannot be drained have the same potential to become overweight through water retention as rescue boats. Lifeboat design is regulated by the same requirements, and lifeboats are just as likely to develop conduits through which water can ingress into the hull. In the case of free-fall lifeboats, the potential for any additional weight to impact on safety is even more significant. As free-fall lifeboats are stowed bow-down, any water that accumulates in the hull will gravitate towards the bow. Consequently, when the lifeboat is launched, the additional weight of the water at the bow has the potential to adversely influence the angle at which the lifeboat enters the water. In such circumstances, the safety of the lifeboats' occupants could be jeopardised.

Pleasure craft that are overweight due to water ingress and retention may suffer reduced stability, performance and manoeuvrability. Such vessels being transported by road may exceed the axle weight limits of their trailers, placing the towing vehicles' drivers and other road users at risk.

2.7 MONITORING OF WEIGHT

It is extremely difficult for ships' crews and boat service agents to know if a rescue boat or a lifeboat has water in its internal spaces that cannot be drained. The retained water, either within the foam, in hollow stiffeners, or another internal space cannot be seen, and its impact on a boat's performance is likely to occur gradually over time.

The simplest method of checking to see if a boat has water in its internal spaces, is to weigh it. This would be relatively inexpensive, but there is currently no requirement for a rescue boat to be weighed once in service.

Furthermore, although rescue and lifeboat weights are based on prototype models, the weights of individual boats can be up to 10% heavier. In the case of the WHFRB 6.50, *Tombarra*'s rescue boat was almost 5% heavier than its prototype. To ensure that a rescue boat or a lifeboat stays within the SWL of its davit, there is a need for manufacturers to provide the actual weight of the boat supplied, rather than its prototype.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT WHICH HAVE RESULTED IN RECOMMENDATIONS

Not applicable

3.2 OTHER ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. The water found in other WHFRB 6.50 rescue boats, and other rescue boats and craft using rigid PU foam made by several manufacturers shows that the increase in the weight of *Tombarra*'s rescue boat due to water retention was not an isolated case. [2.2]

2. The weight of *Tombarra*'s rescue boat had increased significantly due to the ingress and retention of water within its internal stiffeners and buoyancy spaces. [2.2]

3. The expectation that the WHFRB 6.50 rescue boat hull would remain watertight was unrealistic. [2.3]

4. Once water penetrated into the hollow stiffeners and into voids the water could only be removed by drilling into the hull or by removing the deck. [2.4]

5. Although the international requirement for the fitting of a '*drain valve fitted near the lowest point in the hull'* applies to rescue boats and lifeboats, it is based on traditional lifeboat design and does not take into account the need to remove water from foam-filled buoyancy spaces. [2.4]

6. It is evident from the inspections of the WHFRB 6.50 and other boats filled with rigid PU foam, that the properties of the foam, as applied, are not always as intended. [2.5]

7. The poor quality of the foam found in *Tombarra*'s rescue boat and other WHFRB 6.50s was caused by one or a combination of several factors, including; the mixing of polyol and isocyanate liquids in incorrect proportions, the speed and ambient temperature at which the foam was mixed, and the method of application. [2.5]

8. Given the reliance of many rescue boat and lifeboat manufacturers on hand-mixing and manual application methods, it is essential that foam suppliers provide adequate guidance regarding foam production, and that boat manufacturers strictly follow the guidance provided. [2.5]

9. Any increase in a rescue boat's weight will impact on its safe operation to some degree. Additional weight might affect performance, it might compromise the SWL of its launch and recovery system, and it might also lead to damage of the boat's internal structure. [2.6.1]

10. Lifeboats constructed with internal spaces that cannot be drained have the same potential to become overweight through water retention as rescue boats. [2.6.2].

11. The potential adverse effects of any additional weight through water ingress on safety is even more significant in the case of freefall lifeboats [2.6.2]

12. Once an overweight rescue boat has been identified, the boat's manufacturer should advise on its continued suitability as a rescue boat, and on any corrective action required. [2.6.1]

13. To ensure that a rescue boat or a lifeboat stays within the SWL of its davit, there is a need for manufacturers to provide the actual weight of the boat supplied, rather than its prototype. [2.7]

14. The simplest method of checking to see if a boat has water in its internal spaces, is to weigh it, but there is currently no requirement for a rescue boat to be weighed once in service. [2.7]

3.3 SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION WHICH HAVE NOT RESULTED IN RECOMMENDATIONS BUT HAVE BEEN ADDRESSED

None

SECTION 4 - ACTION TAKEN

4.1 MARINE ACCIDENT INVESTIGATION BRANCH

The MAIB issued a Safety Bulletin (1/2011) in April 2011 **(Annex H)**. To summarize, the bulletin identified that water had entered the majority of the foam-filled buoyancy compartments and, in addition, void spaces within the foam enabled water to be retained. The safety issues identified were:

- The SWL of the davit and fall could be exceeded.
- The rescue boat's performance and manoeuvrability could be adversely affected in relation to:
  - *The ability to self-right (or be righted) after capsize*
  - *The ability to tow survival craft, and*
- *Safety of the 5-yearly dynamic test where the boat is included in the test weight could be compromised.*

The bulletin recommended:

Owners of ships using rescue boats or fast rescue craft built with integral polyurethane foam-filled compartments should:

- *In the case of Watercraft WHFRB6.50, follow the advice issued by the manufacturer, or urgently contact the manufacturer if a product awareness notice has not been received.*
- *Be alert to the possibility of boats being heavier than designed and arrange for the boats to be weighed, or boat manufacturers contacted for advice, where doubt exists.*
- *Inspect boats' hulls and exposed decks for possible holes, cracks, or fittings through which water could penetrate.*
- *Ensure that drain plugs fitted to the hull are regularly opened.*
- *Monitor boat performance for unusual characteristics that could be attributed to an increase* in weight, eg that it does not feel 'heavy' or 'sluggish' when manoeuvring.

4.2 MARITIME AND COASTGUARD AGENCY

The MCA has drafted guidance advising operators of UK registered vessels to weigh rescue boats annually.

4.3 NORSAFE WATERCRAFT HELLAS

NWH has:

- Issued a Product Awareness Notice to its customers **(Annex I)**.
- Contacted the owners of vessels supplied with WHFRB 6.50 boats to locate and determine if the boats are overweight.
- Purchased a foam-making machine to help ensure that the foam used in its boats is of a consistently high quality.
- Included an annual weight test in its maintenance and servicing schedules for rescue boats.

4.4 BRITISH RIGID URETHANE FOAM MANUFACTURERS' ASSOCATION (BRUFMA)

BRUFMA has:

Undertaken to circulate to its members the findings of this report and request them to advise customers using PU buoyancy foam to ensure that recommended processing methods are followed and that appropriate levels of quality control are in place.

SECTION 5 - RECOMMENDATIONS

The **Maritime and Coastguard Agency** is recommended to:

2012/134 Submit to the IMO proposals to amend the LSA Code designed to:

- Ensure any water entering foam-filled buoyancy chambers within the enclosed hulls of rescue boats and lifeboats can be easily removed.
- Require the actual weight of the rescue boat or lifeboat supplied to the vessel, rather than its prototype, to be provided in its certification.

2012/135 Submit to the IMO proposals to amend MSC.1/Circ.1206/Rev.1 designed to require the annual weighing of rescue boats and lifeboats which use buoyancy foam within internal spaces, as soon as practicable.

The **International Life-saving Appliance Manufacturers' Association** is recommended to:

2012/136 Promulgate guidance to its members, on the potential that an increase in the weight of a rescue boat or lifeboat could adversely affect its structure and performance, and could result in over-loading the host vessel's davits. Such guidance should emphasise that:

- It is best practice to weigh rescue boats and lifeboats to check for weight growth during annual servicing;
- Where a rescue boat or lifeboat is found to be overweight then corrective action must be taken;
- Drainage of water from foam-filled buoyancy spaces is extremely difficult unless specifically provided for in the design of the rescue boat or lifeboat;
- The internal quality control standards required by SOLAS and the MED, and strict adherence to foam suppliers' instructions, are essential to ensure that buoyancy foam is produced to the required level of quality.

Marine Accident Investigation Branch
July 2012

Safety recommendations shall in no case create a presumption of blame or liability

Marine Accident Report