ACCIDENT REPORT

MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

Report on the investigation of the steering control failure and subsequent contact on board the high-speed catamaran

Moon Clipper

on the River Thames, London

resulting in injuries to several passengers and crew

5 October 2011

LESS SERIOUS MARINE CASUALTY   REPORT NO 21/2012   August 2012

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 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 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

All MAIB publications can be found on our website: www.maib.gov.uk

For all enquiries:

Marine Accident Investigation Branch
Mountbatten House
Grosvenor Square
Southampton
United Kingdom
SO15 2JU

Email: maib@dft.gsi.gov.uk
Telephone: +44 (0) 23 8039 5500
Fax: +44 (0) 23 8023 2459

CONTENTS

FIGURES

ANNEXES

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

AIMTEK	-	AIMTEK Pty Ltd
AIS	-	Automatic identification system
BML	-	Boat masters' licence
CCTV	-	Closed-circuit television
CFR	-	Coffee franchise retailer
CPP	-	Controllable pitch propeller
CRE	-	Collins River Enterprises Ltd
CSA	-	Customer services assistant
DOC	-	Document of Compliance
EU	-	European Union
FMEA	-	Failure mode and effects analysis
HSC	-	High-speed craft
HSC Code	-	The International Code of Safety for High-Speed Craft
ISM Code	-	The International Management Code for the Safe Operation of Ships and for Pollution Prevention
knots	-	Nautical miles an hour
Kobelt	-	Kobelt Manufacturing Ltd
kW	-	kilowatt
LR	-	Lloyd's Register
LRS	-	London River Services Ltd
LSA	-	Life saving appliances
m	-	metre
MCA	-	Maritime and Coastguard Agency
MMS	-	Maintenance Management System
NQEA	-	NQEA Australia Pty Ltd
PLA	-	Port of London Authority
rpm	-	Revolutions per minute
SMC	-	Safety Management Certificate
SMM	-	Safety management manual
SMS	-	Safety management system

SOLAS	-	The International Convention for the Safety of Life at Sea (SOLAS) 1974
STCW Code	-	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended in 1995 and 1997 (STCW Convention)
t	-	tonne
UTC	-	Universal time, co-ordinated
VHF	-	Very high frequency
VTS	-	Vessel Traffic Services

TIMES: All times in this report are UTC+1 unless otherwise stated

Image courtesy of Dai Taylor Photography/Thames Clippers

Moon Clipper

SYNOPSIS

At about 1850 on 5 October 2011, the high-speed catamaran *Moon Clipper* hit Tower Millennium Pier at a speed of 8.5 knots. The impact caused fourteen passengers and two crew to suffer whiplash and/or minor injuries. The stem of the vessel's port hull was fractured above and below the waterline, resulting in flooding of the port forepeak tank. Slight damage was also caused to a section of the pier's handrails and rubber fender.

At 1849, *Moon Clipper* had departed London Bridge City Pier with 53 passengers on board and headed for Tower Millennium Pier on the opposite side of the river. Approaching the pier, the vessel suffered a steering control failure and veered to port. During the master's attempts to regain control the starboard main engine stalled and, 5 seconds later, the stem of *Moon Clipper*'s port hull made heavy contact with the pier, causing her passengers and crew to be thrown forward. Following the accident, the master regained manoeuvring control, alerted London Vessel Traffic Services and brought the vessel alongside. The uninjured passengers disembarked and eight of the injured passengers were later taken by ambulance to hospital.

Earlier in the day, it was noticed that *Moon Clipper*'s steering control joystick was sticking hard over rather than centering when released. The defect could not be immediately rectified but the vessel remained in service on the understanding that the helm wheel would be used to steer the vessel. *Moon Clipper* veered to port because the master had reverted to using the joystick, which subsequently stuck hard over to port during the approach to the pier. The joystick had not been designed for continual operation, and its centring spring had failed.

The vessel was running behind schedule and, in an attempt to make up time, the master crossed the river and approached the pier at 12 knots. The speed of approach accentuated the effect of the steering control failure, and distractions on the bridge adversely affected the master's reactions. The starboard main engine stalled because the master pulled the propulsion control lever to the full astern position too quickly.

Crew resources were overloaded during the emergency response, no information broadcasts were made, the passengers were not mustered, and a headcount was not taken prior to the passengers being allowed to disperse.

Thames Clippers has taken actions to improve crew competence and reduce the level of distractions on the bridge. It also intends to make improvements to the ergonomic layout of the bridge by changing the position of the vessel's propulsion and steering controls. Kobelt Manufacturing Ltd has changed the design of the centring spring fitted to its non-follow up joysticks to provide a longer in service life.

Recommendations have been made to Thames Clippers and the Maritime and Coastguard Agency aimed at improving the reliability of *Moon Clipper*'s steering and propulsion control systems and ensuring the vessel's crews are sufficiently resourced to deal with all reasonably foreseeable emergency scenarios.

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *MOON CLIPPER* AND ACCIDENT

SHIP PARTICULARS

Vessel's name	*Moon Clipper*
Flag	United Kingdom
Classification society	Not applicable
IMO number	9245586
Type	Category A passenger craft – high-speed catamaran
Registered owner	Collins River Enterprises Ltd
Manager(s)	Collins River Enterprises Ltd
Construction	Aluminium
Length overall	31.10m
Registered length	30.35m
Gross tonnage	98
Minimum safe manning	3
Maximum number of passengers	138

VOYAGE PARTICULARS

Port of departure	London Bridge City Pier
Port of arrival	Tower Millennium Pier
Type of voyage	River commuter service
Cargo information	Not applicable
Manning	3

MARINE CASUALTY INFORMATION

Date and time	5 October 2011 at about 1850
Type of marine casualty or incident	Less Serious Marine Casualty
Location of incident	River Thames, London
Place on board	Navigating bridge (operating compartment)
Injuries/fatalities	14 passengers and 2 crew reported impact related injuries (lacerations, bruising, sprains and whiplash)
Damage/environmental impact	Port hull stem holed above and below the waterline/nil environmental impact
Ship operation	Inland waters passenger service
Voyage segment	Arrival
External & internal environment	Twilight, good visibility, wind SW force 4, sheltered waters, flood tide, tidal stream 2 knots
Persons on board	57 (53 passengers, 3 crew and 1 refreshments retailer)

1.2 NARRATIVE

At 0700 on 5 October 2011, Thames Clippers' high-speed catamaran, *Moon Clipper,* entered service on the company's fast craft passenger commuter route **(Figure 1)** on the River Thames, London. At about 1035, she was taken out of service and returned to her operating base at Trinity Buoy Wharf to be refuelled and to facilitate a crew change. The new master and mate received verbal handovers on the quay before boarding the vessel. Once on board, they carried out a set of routine pre-departure checks and read the company's daily briefing sheets. At about 1105, the master manoeuvred *Moon Clipper* off the berth and navigated across the river to North Greenwich Pier, where he picked up his customer services assistant (CSA) and the vessel's coffee franchise retailer (CFR).

Moon Clipper departed North Greenwich Pier at 1115, and headed upriver on the westbound leg of the commuter circuit. Shortly after entering service, the master noticed that the bridge console's steering control joystick **(Figure 2)** had become loose and was sometimes sticking over to port or to starboard when released, instead of springing back to its normal central position. The master reported the fault to his fleet controller and requested the attendance of an engineer on his return to North Greenwich Pier at the end of the run.

At about 1255, *Moon Clipper* berthed at North Greenwich Pier where one of the company's duty service engineers was waiting. The engineer boarded the vessel and made his way to the bridge. The master explained the defect to him and demonstrated the problem by moving the joystick to port and to starboard several times **(Figure 3)**. The engineer told the master that he did not have a spare joystick with him, but said there might be one in the store ashore. The master decided to keep his vessel in service and use the wheel to control the ship's rudders. The engineer pointed out that the joystick was still working and could be used as a back-up. The master explained that the vessel would be temporarily out of service for a crew break at about 1700, and the engineer said that he would return then if they had a spare joystick in the engineers' store. At 1315, the master manoeuvred *Moon Clipper* off the berth and began his second trip of the day.

Moon Clipper's second and third commuter trip went according to schedule and, as planned, she was taken out of service for a 45 minute crew break at 1653. However, the service engineer did not return to the vessel because he had earlier established that there were no spare joysticks in the store.

At 1740, *Moon Clipper* departed North Greenwich Pier and headed westbound for the crew's final trip of the day. The master was now alternating between using the wheel and the joystick which was occasionally sticking hard over to port and starboard **(Figure 4)**. When *Moon Clipper* departed London Eye Pier and headed back downriver on the eastbound leg of the route, she was running on time according to the company's timetable.

At about 1843, as *Moon Clipper* approached London Bridge City Pier, the master saw that his intended berth was occupied by another Thames Clippers catamaran, *Star Clipper*, and he had to stand off. Concerned about delays, the master spoke to both his fleet controller and the master on board *Star Clipper* on VHF radio, and then attempted to hasten *Star Clipper*'s departure by sounding his horn. *Star Clipper*

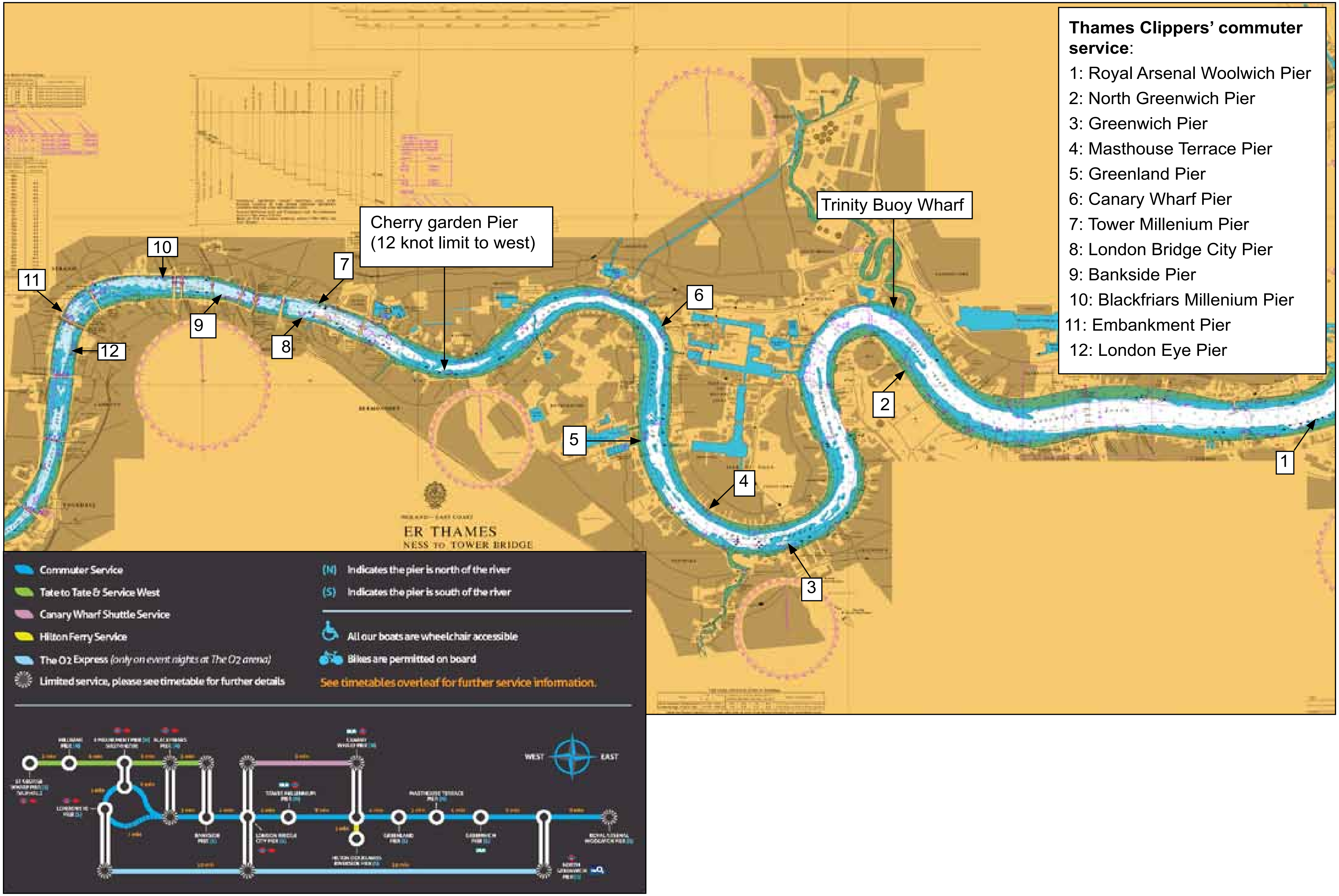


Figure 1: Thames Clippers' commuter service route

Figure 2: Steering control system joystick

Figure 3: Service engineer investigating the reported steering joystick fault (CCTV time local + 3 minutes)

Figure 4: Examples of the steering joystick sticking prior to the accident
(CCTV time local + 3 minutes)

left the berth at 1845 to make room on the pier for *Moon Clipper*. Once secured alongside, 5 passengers disembarked and 15 boarded, resulting in a total of 53 passengers on board.

At 1849, the mate released the mooring rope and the master manoeuvred *Moon Clipper* off the berth. *Moon Clipper* was running about 3 minutes behind schedule, and once clear of the pier, the master increased speed quickly to 12 knots and navigated his way between the historic warship, *HMS Belfast*, and the Belfast ebb buoy **(Figure 5)**.

As the mate passed through the passenger cabin on his way to the port forward mooring deck, he opened the door to the bridge and shouted the passenger figures up to the master **(Figure 6)**. The master set a course for the lower (east) end of Tower Millennium Pier, entered the passenger figures into the River Thames automatic identification system (AIS) **(Figure 7)** and then wrote them in the company's passenger log **(Annex A)**.

About 1 minute after departing London Bridge City Pier, the master used the joystick and then the wheel to close on Tower Millennium Pier. With about 100m to run, the vessel began to make a moderately fast unintentional swing to port. When the master realised what was happening, he attempted to arrest the vessel's swing by first moving the joystick to starboard and then putting the starboard propeller astern. With *Moon Clipper* approaching the pier at about 10 knots and the helm responding slowly, the master pulled the vessel's starboard propulsion control lever to full astern. Almost immediately, the starboard main engine stalled and, 5 seconds later, the stem of *Moon Clipper*'s port hull made heavy contact with the pier **(Figure 8)**.

Moon Clipper struck the pier at 8.5 knots, at an angle of about 60º, and then rebounded astern. The force of the impact caused everybody on board to be thrown violently forward **(Figure 9)**. Most of the passengers seated in the cabin hit the back of the seats in front of them. Those passengers seated on the open deck aft and in the front row of seats in the cabin, including a passenger seated in a wheelchair, were thrown on to the deck. At least 14 passengers and the CFR were injured. The vessel drifted momentarily with the port gearbox in neutral while the master attempted unsuccessfully to restart the starboard engine. However, he soon regained control and manoeuvred alongside using the port engine and wheel steering.

The mate lifted the passenger back into his wheelchair and saw that he was bleeding heavily from a head wound. The CSA picked herself up off the deck and asked those passengers around her at the front of the cabin if they were okay. The mate instructed the CSA to fetch the first-aid kit from the bridge. The CSA collected the first-aid kit, briefed the master and then returned to the cabin. She gave the first-aid kit to the mate and immediately returned to the bridge to tell the master that an ambulance was needed. At 1852, the master informed London Vessel Traffic Services (VTS) by VHF radio that *Moon Clipper* had collided with Tower Millennium Pier and that he required an ambulance for a male passenger who had been thrown from his wheelchair. The VTS officer informed the emergency services, and a River Thames lifeboat was tasked to attend the scene.

When the master had finished manoeuvring the vessel onto the pier, the mate went forward to secure the mooring line, leaving the CSA to look after the passengers. Once *Moon Clipper* was secured alongside, the master read through the bridge emergency collision procedure checklist **(Annex B)** and then instructed the mate

Reproduced from Admiralty Chart BA 3319-0 by permission of the Controller of HMSO and the UK Hydrographic Office

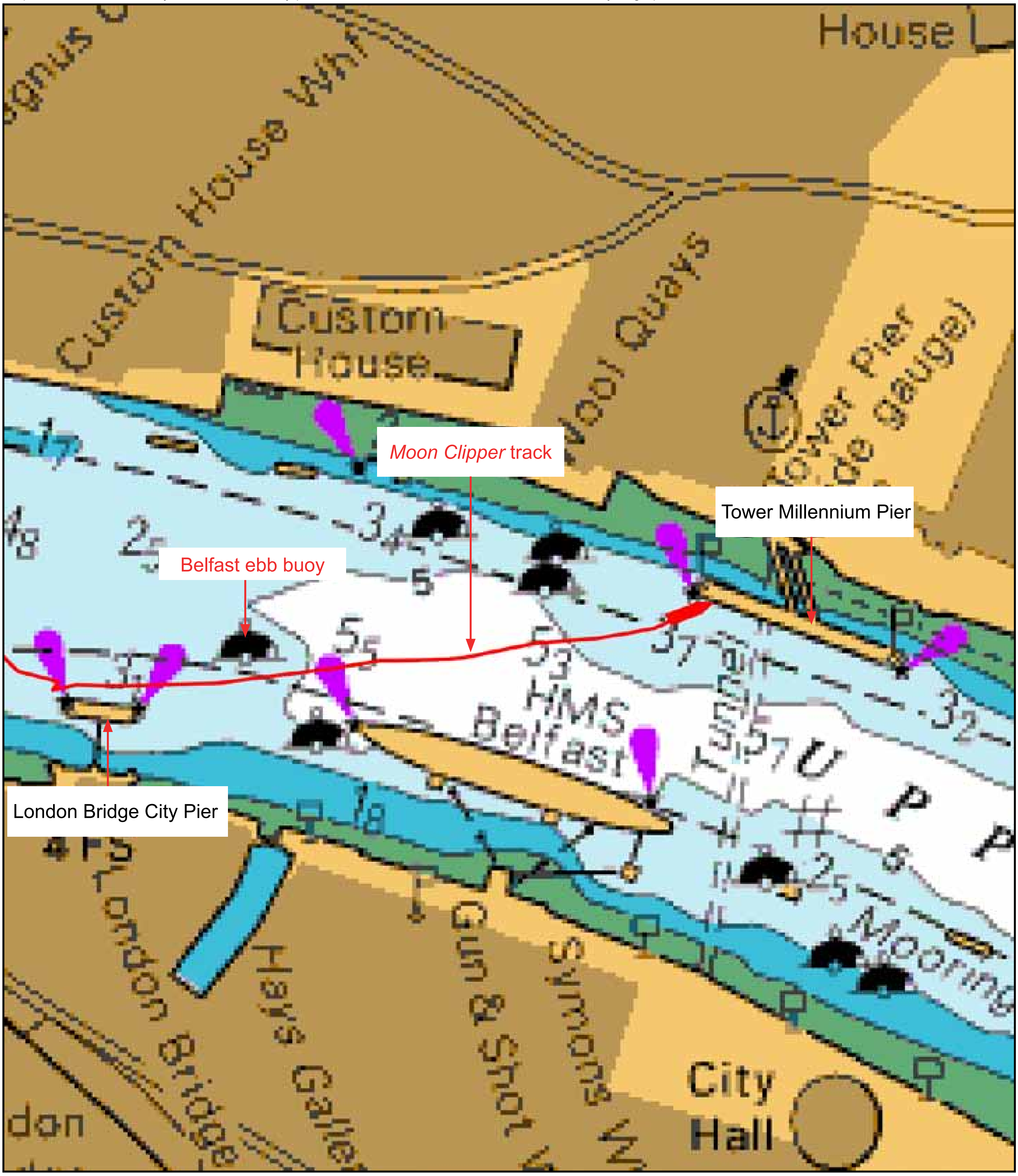


Figure 5: *Moon Clipper*'s passage between London Bridge City Pier and Tower Millennium Pier

Figure 6: Mate shouting passenger figures to the master
(CCTV time local + 3 minutes)

Figure 7: Example of passenger figures being recorded by the master on the bridge
(CCTV time local + 3 minutes)

Figure 8: *Moon Clipper*'s impact with Tower Millennium Pier
(CCTV time local + 3 minutes)

Figure 9: Passengers and crew thrown forward on impact
(CCTV time local + 3 minutes)

to check for damage. The mate inspected the bow of the port hull and checked the port forward void tanks for water ingress. He found the tanks to be dry, and reported back to the master.

Several passengers had been injured on the open deck at the stern of the vessel, and one angry male passenger made his way forward to confront the mate and demand to know what was going on. The mate pacified the passenger while the CSA went to the bridge to tell the master that a second ambulance was needed. The master informed VTS of the requirement and then instructed the CSA to disembark the uninjured passengers.

At about 1900, the emergency services started to arrive at Tower Millenium Pier and began to attend to, and assess the condition of the injured passengers. The majority of the uninjured passengers had disembarked *Moon Clipper* and were waiting on the pier for the next commuter service vessel.

By about 1920, the police, the ambulance service, the London fire service, the lifeboat crew and the deputy harbourmaster were all on scene. The police breathalysed the master and mate and confirmed that they were not under the influence of alcohol at the time of the accident. The master then moved *Moon Clipper* along the pier to allow the next scheduled Thames Clippers vessel alongside. Most of the passengers waiting on the pier boarded that vessel and continued on their journeys. At 1930, the police closed the pier to the public and eight of the passengers were taken by ambulance to hospital for treatment.

A short time later, two Thames Clippers service engineers arrived on board and began to assess the condition of the vessel. At about 2100, following approval from the duty harbourmaster, *Moon Clipper* left the pier and returned at slow speed to its moorings at Trinity Buoy Wharf. At 2130, following a structural inspection, the police allowed the pier to be reopened.

1.3 ENVIRONMENTAL CONDITIONS

The accident occurred at twilight on the sheltered waters of the River Thames. It was 2 hours before high water and the tidal stream was flooding at about 2 knots. The visibility was good and the wind was south-westerly force 4 to 6.

1.4 CREW

1.4.1 Manning levels

Moon Clipper's crew of three comprised a master, a mate and a CSA. This was in accordance with the minimum safe manning level set by the UK Government's Maritime and Coastguard Agency (MCA) for the vessel. In addition to the crew, a CFR was on board at the time of the accident.

The master was a 27 year old British male. He had been employed by Thames Clippers for 7 years and held a tier one, level two, Boat Masters' Licence (BML) with both fast craft and passenger endorsements.

The mate was a 49 year old British male. He had been employed by Thames Clippers for 3 years and also held a tier one, level two, BML.

The CSA was a 32 year old Polish female who had worked for Thames Clippers for almost 5 years.

The CFR was a 26 year old Saudi Arabian male who had worked on board Thames Clippers' vessels for just over a year.

1.4.2 Roles and responsibilities

In addition to having overall command of his vessel, the master's main role on board was to navigate and manoeuvre the vessel. In an emergency situation, the master was required to conduct his command and control responsibilities from the bridge. Specific tasks included the remote launching of the vessel's 65-man liferafts **(Figure 10)** if required. In the event of the passengers and crew being required to evacuate to liferafts on the river, the master was designated to take charge of a 14-man flotation device that was located on the roof of the cabin behind the bridge.

In addition to assisting the master on the bridge while underway, the mate was responsible for making fast and letting go the mooring ropes; manning the gangway as passengers embarked and disembarked; and recording the passenger numbers. The mate's initial role in an emergency was to investigate and report to the master. His tasks included passenger control and the distribution of adult lifejackets. In the event of an evacuation on the river, he was designated to take charge of the starboard 65-man liferaft.

The CSA's main role on board was to check and collect passenger tickets and deal with general customer-related issues. Although the CSA was nominated to assist the mate as directed, her emergency responsibilities included passenger control, the delivery of first-aid medical assistance and taking charge of the port 65-man liferaft.

CFRs were not always carried on board *Moon Clipper* and were not included on the vessel's muster list. When carried, they were classed as supernumerary crew members and were expected to provide assistance to the crew, as directed, during emergency situations.

1.4.3 Crew training and drills

The training package developed by Thames Clippers for its crew members consisted of generic training that met the standards set out in the STCW Code[1] followed by vessel specific training.

The generic training packages for Thames Clippers' masters and mates were provided by external suppliers. These included:

- Crisis management and human behaviour training
- Personal sea survival techniques
- Fire fighting
- First-aid.

[1] STCW Code - The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended in 1995 and 1997 (STCW Convention).

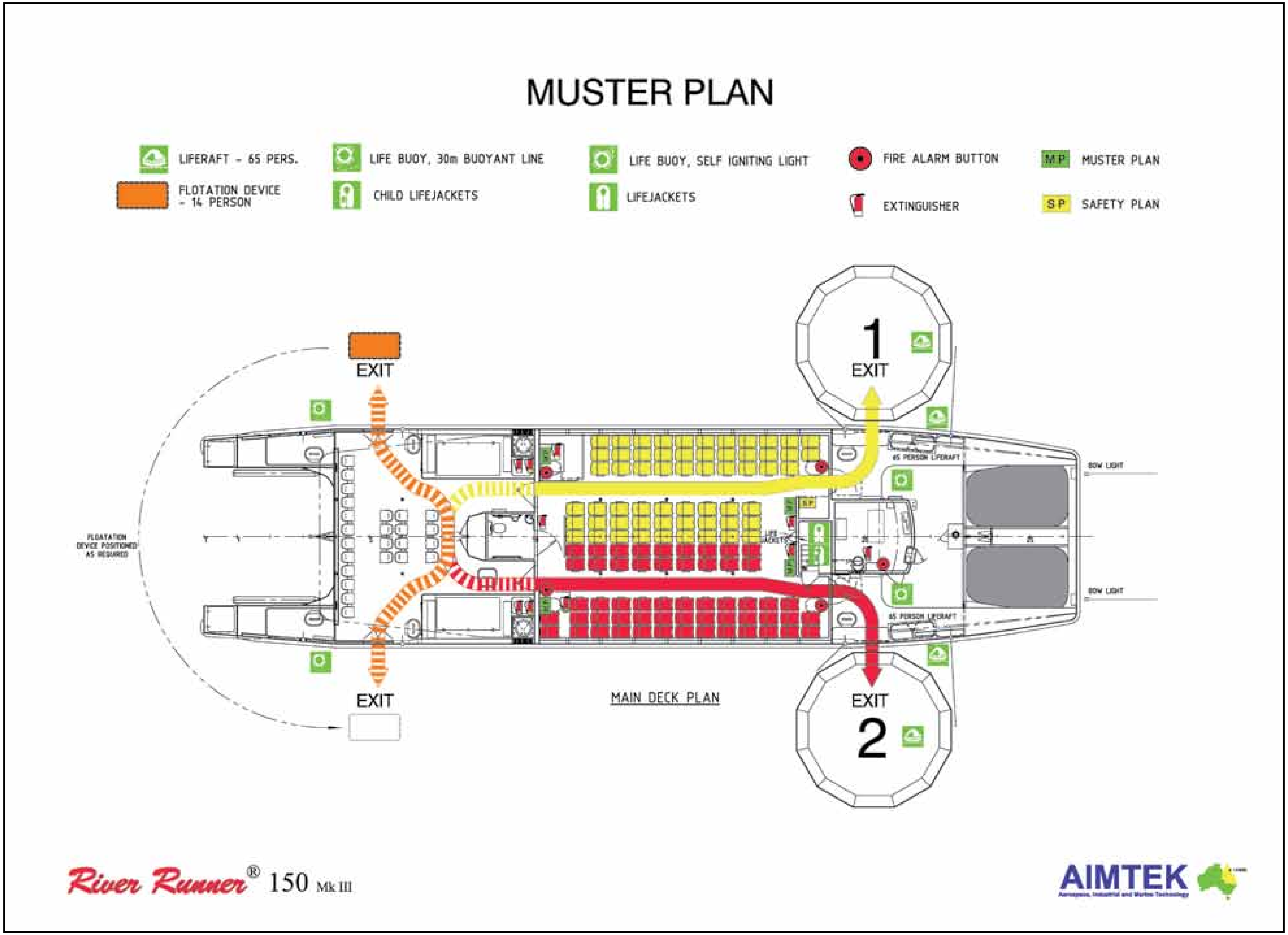


Figure 10: *Moon Clipper's* muster plan

Additionally, Thames Clippers' masters were required to complete a certificated craft specific type rating training programme that had been approved and was endorsed by the MCA. These type rating certificates had to be revalidated every 2 years, and the masters were assessed annually by the vessel's appointed senior master. As part of this process, they were expected to demonstrate knowledge and understanding of the information and instructions contained in the vessel's operating manuals.

The CSAs attended externally provided *elementary first-aid, emergency first-aid at work,* and *crisis management and human behaviour* training courses. Their *personal sea survival techniques* and *fire-fighting* training courses were delivered internally by the company's safety manager and senior masters. The CFRs were given craft awareness training by the vessel's senior master.

In addition to the external and internal training courses provided by the company, its crews carried out regular emergency training exercises, which included vessel evacuation drills. Each crew member maintained their own training drill record sheet, which had to be signed off by the masters. The crews' drill sheets were collected at the end of each month by the safety manager and were recorded and filed centrally.

As part of their crisis management and human behaviour training, the Thames Clippers crew members were taught to make the most of the resources on board by identifying and tasking willing and capable passengers. Following the accident, *Moon Clipper*'s crew did not formally nominate or ask any passengers to assist them.

1.5 THAMES CLIPPERS

1.5.1 The company and its fleet

Moon Clipper was owned and operated by Collins River Enterprises Ltd (CRE). CRE was founded in 1999 and owned 13 catamarans that it operated on several passenger routes under the brand name 'Thames Clippers'. Its vessels' passenger-carrying capacities ranged between 62 and 222. In addition to the company's scheduled services, the Thames Clippers vessels were available for private charter, and were regularly used for corporate events and parties.

The Thames Clippers fleet consisted of four conventional catamarans, seven River Runner 200 class high-speed craft (HSC) and two smaller River Runner 150 class HSC. The River Runner craft were designed and built in Australia by NQEA Australia Pty Ltd (NQEA) who later became AIMTEK Pty Ltd (AIMTEK).

1.5.2 *Moon Clipper*

Moon Clipper was a River Runner 150 Mk3 low wash high-speed catamaran. She had a maximum speed of 26 knots and, as a category A[2] passenger craft, was certificated to carry up to 138 passengers. Along with her sister vessel *Sun Clipper*, she was built by NQEA in 2001. Seven earlier versions of the River Runner 150 craft were built; five to operate in the Netherlands and two in Australia.

[2] Category A craft - is any high-speed passenger craft operating on a route where it has been demonstrated to the satisfaction of the flag and port States that there is a high probability that in the event of an evacuation at any point of the route all passengers and crew can be rescued safely within the least of: the time to prevent persons in survival craft from exposure causing hypothermia in the worst intended conditions, the time appropriate with respect to environmental conditions and geographical features of the route, or 4 hours; and carrying not more than 450 passengers.

Moon Clipper and *Sun Clipper* were originally named *Down Runner* and *Antrim Runner,* and were leased to the Loughlink business consortium based in Belfast, Northern Ireland. Loughlink intended to operate the vessels on a peak-hour commuter service between Belfast Lough, Carrick Fergus and Bangor. They had been built to Lloyd's Register's (LR) *Special Service Craft Rules* and complied with the requirements set by the MCA. Both vessels were originally certificated to operate up to 20 miles from a place of refuge[3].

Although the two vessels were delivered to Belfast in 2001, they never entered service with Loughlink and were later leased to an oil company in Nigeria. Due to regional conflicts the two craft did not enter service in Nigeria, and in 2006 they were transported to London. Following extensive refits overseen by AIMTEK, the vessels were renamed *Moon Clipper* and *Sun Clipper* and put into service on the River Thames by CRE.

1.5.3 Thames Clippers' commuter passenger service

Thames Clippers' commuter service operated 7 days a week between 0600 and midnight, providing a scheduled eastbound and westbound service between the Royal Arsenal at Woolwich and the London Eye at Waterloo **(Figure 1)**. The commuter craft picked up and dropped off passengers every 20 minutes at 11 of the River Thames's major piers. It took 1 hour and 10 minutes for each vessel to complete one full circuit. Thames Clippers calculated that its vessels called at the commuter service piers over 400,000 times in 2011.

The HSC were permitted to operate at full speed on the east section of the river between Woolwich and Cherry Garden Pier **(Figure 1)**. To the west of Cherry Garden Pier the craft were required to comply with the Port of London Authority's (PLA) maximum speed limit of 12 knots.

The timetable allowed 4 minutes between departing London Bridge City Pier and departing Tower Millennium Pier. On the westbound leg of the crew's final run on the day of the accident, *Moon Clipper* took 2 minutes and 30 seconds to complete the transit between the two piers. On the eastbound return leg, the vessel took 1 minute and 10 seconds to complete the same transit.

1.6 TOWER MILLENNIUM PIER

Tower Millennium Pier was situated on the north side of the River approximately 250m west of Tower Bridge. It was owned and managed by London River Services Ltd (LRS). The floating pier was 125m long, constructed from steel and held in position by three piles that had been driven into the river bed. Access to the pier from the river bank at Tower Hill was provided via two pedestrian access brows **(Figure 11)**. The pier was fitted with its own dedicated closed-circuit television (CCTV) cameras.

Contained within the pier's steel structure, below the waterline, was a network of LRS offices. The pier was manned between 0600 and 1800 by an LRS pier manager, and its offices were used by LRS staff. The pier was also manned periodically by employees of those passenger vessel operators that used it, such as Thames Clippers. In the evenings the pier remained open but was not manned.

---

[3] Place of refuge - is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

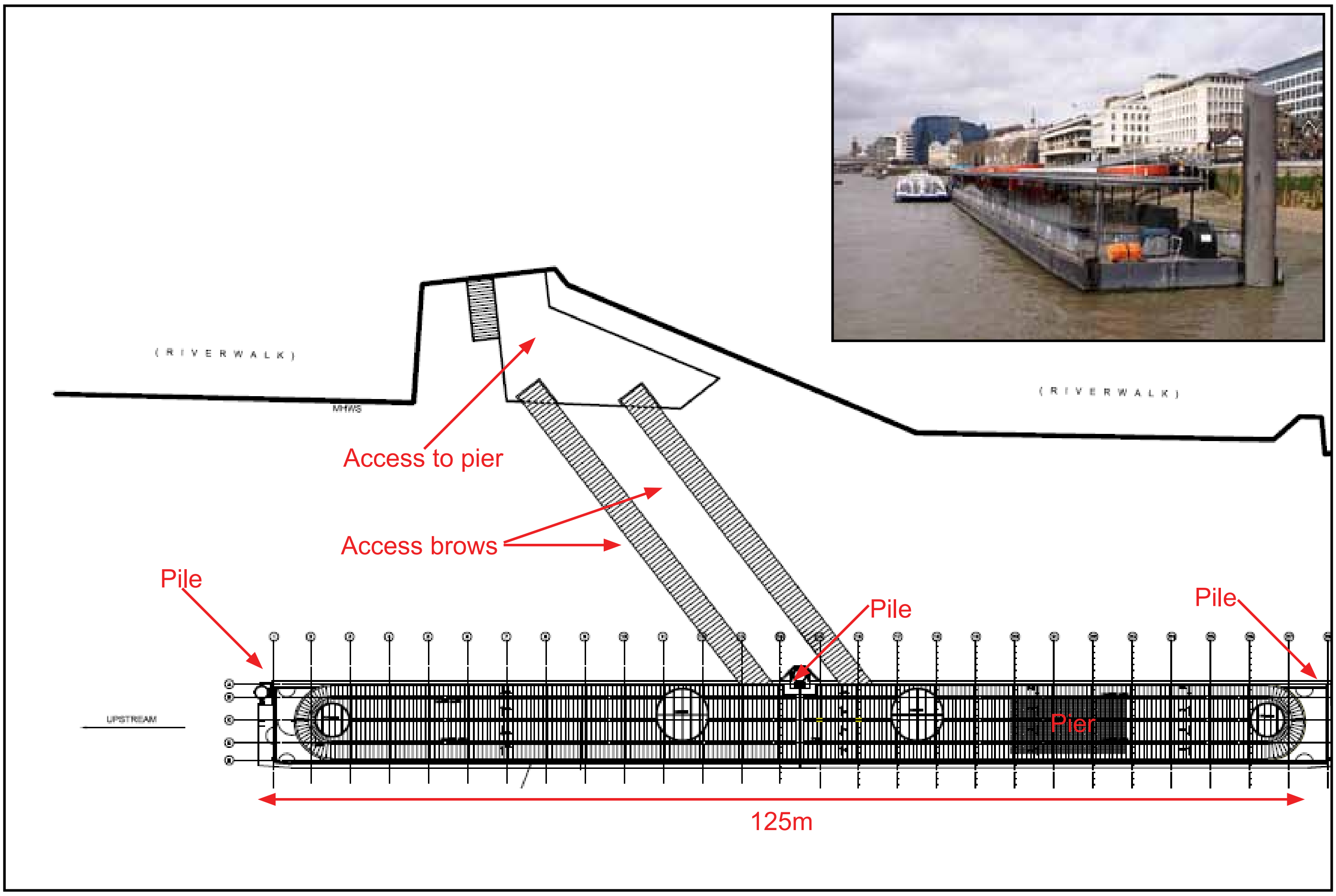


Figure 11: Tower Millennium Pier

1.7 DAMAGE CAUSED TO *MOON CLIPPER* AND TOWER MILLENNIUM PIER

Moon Clipper's contact with Tower Millennium Pier caused damage to both the craft and the pier's pontoon **(Figure 12)**. The damage to the high-speed catamaran was limited to the stem of her port hull. The force of the impact caused the aluminium stem to crease and tear above and below the waterline **(Figure 12)**. The tear just below the waterline was about 10cm long, and the second tear approximately 1m above the waterline was about 20cm long. The water ingress was limited to the port forepeak tank and had little effect on the craft's stability.

The stem of *Moon Clipper*'s port hull damaged a section of the pier structure's solid rubber fender. The tip of *Moon Clipper*'s port bow also struck a section of handrails and an access gate, causing minor damage to both. The pier was not holed.

1.8 INJURIES SUFFERED

A total of 14 passengers and 2 crew members reported suffering injuries as a result of the impact. The majority of the injuries suffered were limited to minor cuts and bruises to the face and head, but several passengers reported suffering spinal whiplash-related injuries. Eight passengers were taken by ambulance to hospital for treatment, one of whom had a suspected fractured jaw.

Figure 12: Damage caused by the contact

The CSA and CFR were thrown to the deck on impact. The CSA picked herself up and continued with her emergency response duties, but the CFR was unable to assist the crew due to the extent of his whiplash injury. On completion of her duties, the CSA made her own way to hospital to be checked over by a doctor.

1.9 BRIDGE LAYOUT AND CONTROLS

Moon Clipper's bridge was ergonomically designed to allow the master to navigate and manoeuvre the vessel from a centrally located seated position **(Figure 13)**. The raised chair provided masters with a clear view forward and to the sides, and two large rear view mirrors allowed them to see aft. The vessel had CCTV cameras located on the bridge, the bow, the after deck and in the passenger cabin. CCTV monitors fitted on the bridge allowed the master to use the cameras to assist navigation and monitor what was happening on board.

The traditional, ship's type helm wheel was located immediately in front of the master's chair, and the bridge console's rudder angle indicators and main engine instrumentation were positioned in front of the wheel. The main propulsion system's

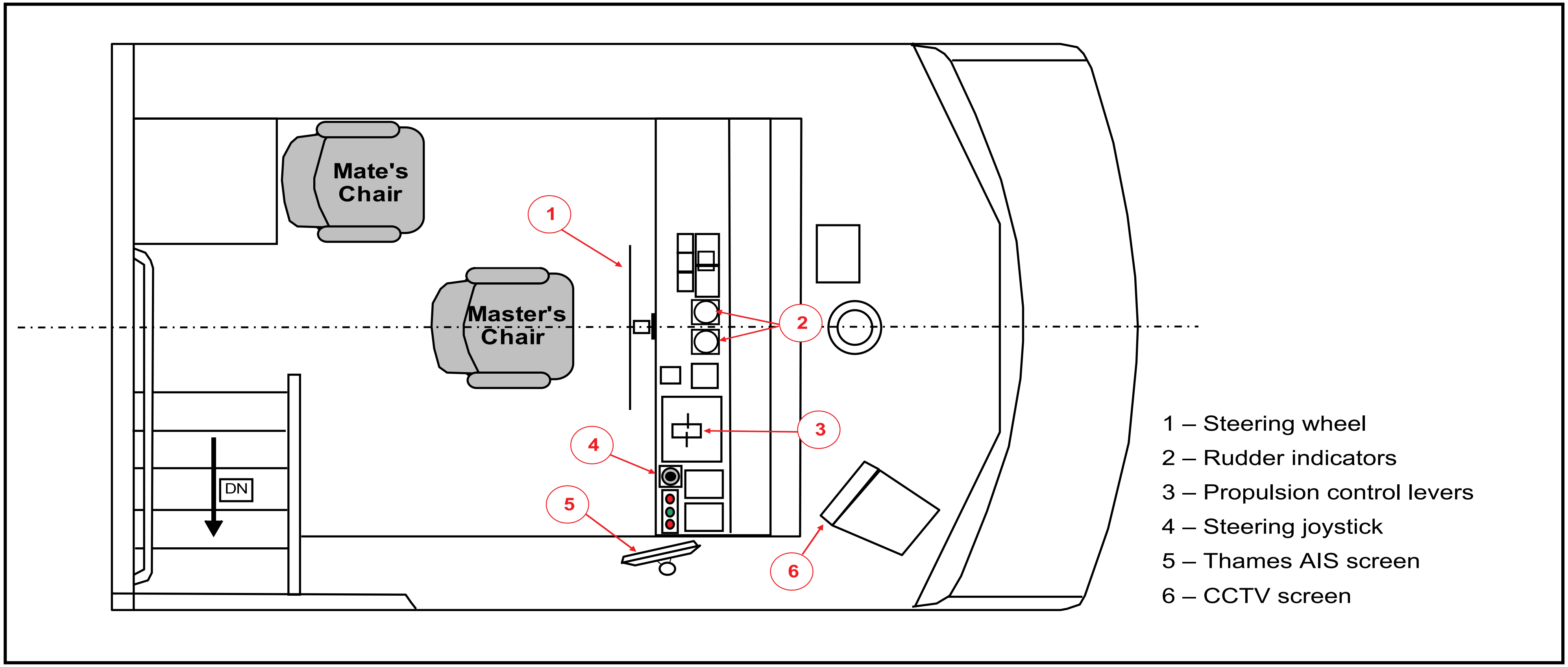


Figure 13: Bridge layout

combined gearbox and engine speed control levers were offset slightly to starboard. The steering joystick was positioned outboard of the propulsion control levers and could not be easily reached from the seated position. The propulsion and steering controls on board Thames Clippers' River Runner 200 craft were positioned on the armrests of the master's chair.

1.10 PROPULSION SYSTEM

1.10.1 Original propulsion system

At build, the River Runner 150 Mk3 craft were fitted with two 4 blade contra-rotating high-speed controllable pitch propellers (CPP) (one per hull). The propellers were each driven by a Caterpillar 3406E marine diesel engine via a ServoGear HD gearbox. The maximum output of each engine was 448kW at the maximum speed of 2,100rpm. The idle speed of the engines was 900rpm with the gearbox engaged and 750rpm when disengaged.

The CPP was controlled from the bridge using a double combinator lever arrangement. Adjustment of the combinator lever setting simultaneously altered the propeller speed and pitch in accordance with the vessel's power curve characteristics. For manoeuvring purposes, the engine speed was set at 1,400rpm by pushing the constant speed button on the combinator panel. In this mode, adjustment of the combinator lever position altered the propeller pitch only.

The Caterpillar engines had their own electronic control systems which received speed signals from the ServoGear central transmission control unit. The engine control system did not provide load control, but was designed to shut down the engine if it lost oil pressure or if it over-sped.

The ServoGear central transmission control unit provided voltage, pitch, speed and overload failure alarms. It also had an automatic pitch shedding function which was activated when the propeller pitch was too high for the shaft speed. To engage the gearboxes, the engines had to be running at idle speed and the propeller pitch setting had to be below 10%.

During the vessel's sea acceptance trials in June 2001, a set of emergency stopping trials was conducted to establish the time and distance taken to stop the vessel in the water from full speed ahead. In the first trial, the combinators were pulled from full ahead to neutral and the vessel was allowed to come to a stop without using astern thrust. In the second trial, the combinators were pulled back to neutral from the full ahead position (2,100rpm), left there for 5 seconds and then moved to full astern (2,100rpm). *Moon Clipper* came to rest from 26 knots in 18 seconds (equating to one and a quarter ship's lengths). On completion of the sea acceptance manoeuvring trials, NQEA recommended that, other than for emergency stopping purposes, the engine speed astern should not be allowed to exceed 1,500rpm.

1.10.2 Drive train modifications

Thames Clippers found the CPP systems on board *Moon Clipper* and *Sun Clipper* to be less reliable and more maintenance intensive than the fixed pitch propeller systems fitted to the larger River Runner 200 craft. The River Runner 150 craft were also considered to be less manoeuvrable, and in 2008 the company arranged for AIMTEK to replace the CPPs with fixed pitch propellers.

AIMTEK replaced the vessels’ original CPPs, hollow drive shafts and unidirectional gearboxes with 5 blade fixed pitch propellers, solid drive shafts and Twin Disc MGC05135 SC Quickshift reversing gearboxes **(Figure 14)**. The Caterpillar engines were not changed, but the ServoGear central control unit was replaced by a Twin Disc EC300 Power Commander electronic propulsion control system. Twin Disc quickshift propulsion control levers **(Figure 2)** replaced the original combinator lever arrangement on the bridge console. The two independent propulsion control levers had a central neutral position where the engines ran at idle speed with the gearboxes disengaged. Moving the levers forward or aft engaged the gears ahead and astern respectively, with engine and therefore propeller speeds increasing proportionately with lever movement.

These propulsion machinery design changes were approved by the MCA and, once fitted, a set of manoeuvring trials was conducted. During the trials, the vessels’ new handling characteristics were assessed and the electronic propulsion control system was programmed to provide optimum performance. The maximum engine speed remained at 2,100rpm but, due to the power characteristics of the new propellers, the idle speed was reduced to 680rpm. The 2.04 to 1 ratio gearbox reduced the propeller shaft speed to approximately half that of the engine.

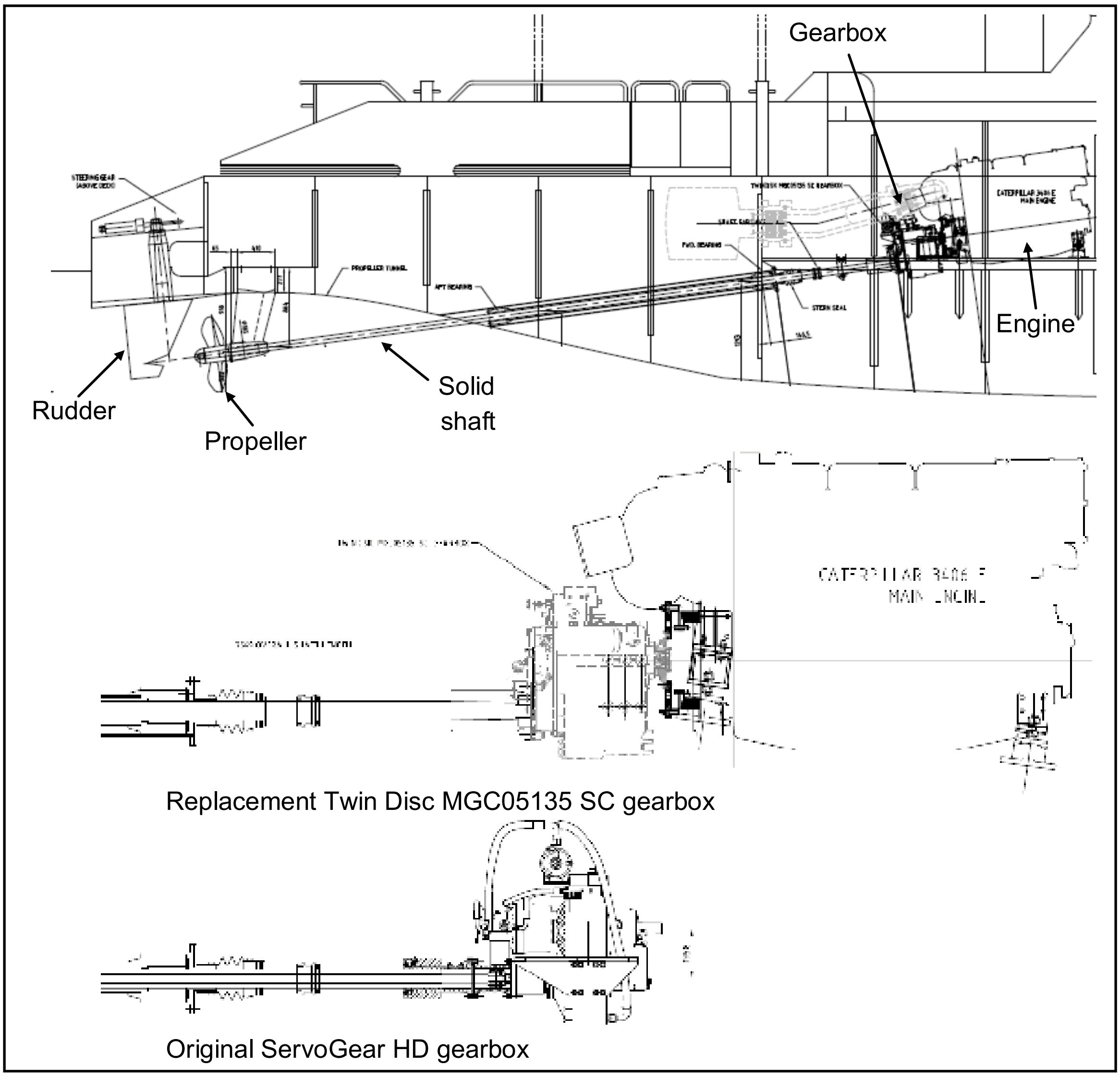


Figure 14: *Moon Clipper* drive train modifications

1.10.3 Propulsion control strategy

As the main engines on the River Runner 150 Mk3 craft had no load control, care had to be taken to prevent them from stalling or being damaged as a result of overloading when attempting to reverse the rotational direction of the propeller shafts. Following the drive train changes, the propulsion management system was programmed to provide a 10 second delay before allowing the gearboxes to engage astern when the control levers were pulled directly from full ahead to full astern. This allowed time for the propeller shafts to slow down before the gearboxes were engaged astern. When full astern was demanded by the master from any setting other than full ahead, the automatic time delay function was inactive.

In order to protect the engines and reduce the risk of stalls during normal manoeuvring operations, Thames Clippers developed a procedural control strategy based on the outcome of its craft handling trials and its operational experience. Its masters were trained to pull the control levers back from their ahead settings to the *'gear engaged ahead'* position and then pause for a few seconds before moving them through neutral to the astern position. This allowed the inertia of the engine to act as a braking force and help decelerate the propeller shaft to an acceptable speed prior to the gearbox being engaged astern. Thames Clippers did not stipulate a maximum shaft speed for the reversing procedure and the strategy had not been formally documented.

The shaft reversing sequence was the same on the River Runner 200 craft, however, the first of that class, *Hurricane Clipper*, was originally fitted with shaft brakes that were designed to stop the shafts rotating before the gearboxes engaged astern. The shaft brakes were later removed due to the rapid wear rate of their friction pads.

1.11 STEERING SYSTEM

1.11.1 Directional control

The River Runner 150 catamarans handled in a similar manner to conventional twin screw ships, but as lightweight, highly powered craft with widely spaced contra rotating propellers, *Moon Clipper* and *Sun Clipper* were very responsive to changes in both rudder angle and propulsion control lever settings.

At high speeds, the rudders were used to steer the vessel, and at low speeds manoeuvring was achieved using a combination of rudder movements and propulsion control lever adjustments. Driving the starboard propeller astern and the port propeller ahead provided transverse thrust that pushed the stern to port. Driving the port propeller astern and the starboard ahead had the opposite effect. The masters were trained to steer the vessels predominantly by eye and feel rather than reference to the instrumentation provided on the bridge console.

1.11.2 Hydraulic steering gear

Moon Clipper's hydraulic steering gear control system[4] **(Annex C)** was designed and manufactured by Tescorp (NQ) Pty Ltd. Her two balanced spade type rudders (one per hull) were rotated from their centre position through an angle of 30º to port or starboard by fluid linked hydraulic cylinders, which were powered by one of two

[4] Steering gear control system – controls the actual movement of the rudders.

independent engine-driven pumps **(Figure 15)**. The primary hydraulic pump was directly driven by the port engine and the secondary back-up pump was driven by the starboard engine. The primary and secondary systems had their own hydraulic oil circuits and reservoirs.

1.11.3 Steering control

On River Runner 150 craft, a traditional ship's type helm wheel **(Figure 13)** was provided as the main means of steering control and a joystick was provided as an emergency back-up. The wheel was directly connected to an orbital helm hydraulic steering pump which formed part of the main hydraulic power-assisted steering control system[5] **(Figure 15)**. The helm pump was hydraulically linked to the port engine-driven hydraulic steering pump which was put on load by the manual rotation of the wheel. In its normal power-assisted steering mode, the helm wheel was easy to turn. If the port engine stopped, the hydraulic circuit was no longer power-assisted but the helm pump could still be used to move the rudders, but much greater effort was required to turn the wheel.

In the event of the failure of the primary steering system, the emergency electro-hydraulic back-up system could be activated by pressing the emergency steering control selection button **(Figure 2)** on the bridge console. This electrically connected the steering control joystick to the secondary starboard engine-driven hydraulic steering system.

The main helm wheel provided manual full-follow up steering control, ie. when the master turned the wheel the rudders began to move, and kept moving until he stopped turning the wheel. To return the rudders to midships, the wheel had to be returned to its midships position. The emergency joystick provided non-follow up control, ie. when the joystick was held over to port or starboard, the rudders moved until the joystick was released or the rudders reached their limit of travel. When the joystick was released it returned to its central position but the rudders remained stationary.

1.11.4 Steering control configuration change

On 24 July 2009, Thames Clippers issued a fleet operations memo **(Annex D)** instructing its masters to use the joystick as the main means of steering control, and the wheel as the emergency back-up. The company's decision to switch from the primary steering gear control system to the secondary system was influenced by a longstanding problem it had been experiencing with internal leakage across the valve blocks of the shared steering gear hydraulic control circuit. The leakage was due to wear and was causing the starboard hydraulic oil reservoir to overflow as the oil was migrating from the primary circuit to the secondary circuit.

The MCA was aware of the company's decision to reconfigure the vessels' critical steering system and had no objection to the change. AIMTEK was not formally consulted prior to the changeover, but retrospectively reported that there were no technical reasons why it would have recommended against the change.

Although reconfiguring the steering system appeared to solve the oil migration problem, within a few months, the two River Runner 150 catamarans started to suffer joystick failures **(Annex E)**. On 10 May 2011 and 14 May 2011 respectively,

[5] Steering control system controls how the ship is steered ie. Sends commands from the navigating bridge.

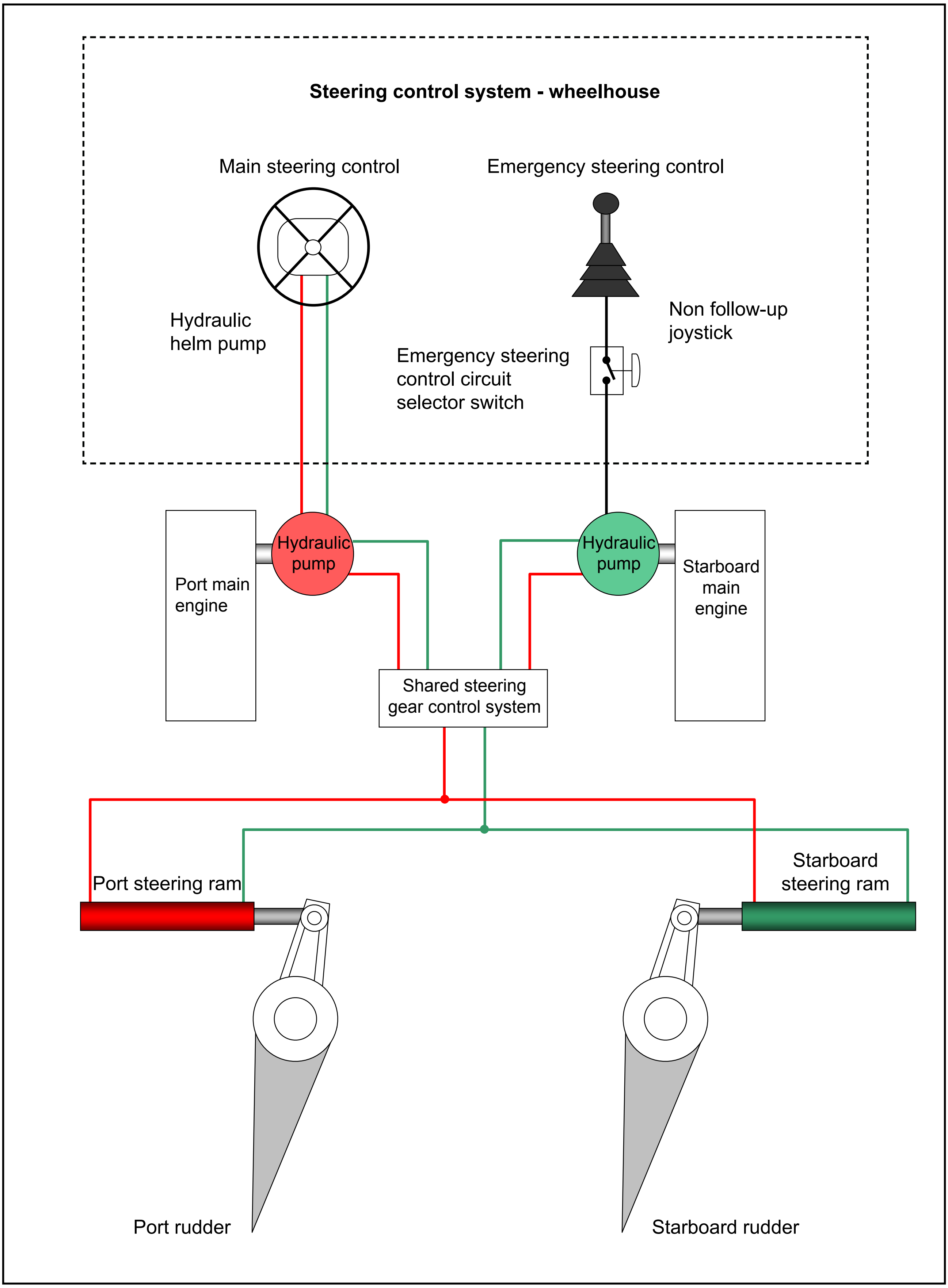


Figure 15: Simplified illustration of the steering gear control system

Thames Clippers replaced the original joysticks fitted to *Sun Clipper* and *Moon Clipper* by NQEA with a new type. The new joysticks **(Annex F)** were manufactured by Kobelt Manufacturing Ltd (Kobelt) and were thought, by Thames Clippers, to be more sturdy and robust than those fitted at build.

As a consequence of the steering gear configuration change, both the main and emergency steering control circuits were live at the same time. This allowed the vessels' masters to alternate between the joystick and the helm wheel to manoeuvre the vessel. This practice became common, with the wheel often being used at high speed when small rudder movements were required, but the joystick was preferred at lower speeds and when manoeuvring alongside the piers.

1.11.5 Kobelt 7165 joysticks

Kobelt was an established Canadian company that had been manufacturing and supplying marine steering and engine control systems internationally for over 50 years. It designed and manufactured complete steering systems as well as individual steering system components. The Kobelt model 7165 compact single axis joysticks procured by Thames Clippers were designed to control positioning devices by providing either on/off or infinite positioning. The non-follow up on/off version of the 7165 joystick was fitted to *Moon Clipper* and *Sun Clipper* **(Figure 16)**.

The non-follow up joystick was fitted with a spring **(Figure 16)** that was designed to return the operating lever back to its central position when released. The centring spring fitted to the 7165 joystick was a closely wound helical coil type spring. It had crossover type hooks and was manufactured from grade 302, spring temper, stainless steel. The spring's theoretical cycle life was over 10,000,000 cycles for torsional stress and 159,331 cycles for bending stress.

When the joystick's operating lever was moved to port or starboard, the cams connected to the bottom of the lever acted on one of the joystick's two micro-switches. This sent a signal to one side of the steering gear control system's electric solenoid, which in turn opened the hydraulic circuit and caused the rudder to move. When the joystick was released, the lever returned to its central position and the signal to the solenoid was cut. This closed the hydraulic circuit and locked the rudders in the set position.

The infinite positioning version of the Kobelt 7165 joystick used a potentiometer and feedback signal from the rudder tiller arms to provide follow-up steering. In a Kobelt designed electro-hydraulic steering system, the followup version of the 7165 joystick was typically used for main steering control and the non-follow up version was used as back-up.

1.12 HIGH-SPEED CRAFT CODE

1.12.1 United Kingdom and European Union regulatory requirements

When *Moon Clipper* was first brought in to service on the River Thames in 2006, she was considered to be a Class V passenger ship[6] and, like Thames Clippers' other vessels, was issued a UK Domestic Ship Safety Management Certificate by the MCA. During the mid-2000s the status of all fast craft, including Thames Clippers' River Runners, intended for use on domestic voyages within the UK were

[6] Class V passenger ships – ships engaged only on voyages in UK category A, B and C waters.

Figure 16: Kobelt model 7165 compact single axis joystick

reassessed by the MCA in accordance with the UK regulatory requirements[7]. Under the regulations, most fast craft were required to comply with the conditions set out in the appropriate edition of the International Code of Safety for High Speed Craft (2000) (HSC Code).

The HSC Code contains the requirements for the design and construction of HSC engaged on international voyages. It stipulates the equipment which shall be provided on board the craft and sets out the conditions for their operation and maintenance. The basic aim of the Code is:

> *to set levels of safety which are equivalent to those of conventional ships required by the International Convention for the Safety of Life at Sea, 1974, as amended, (SOLAS) and the International Convention on Load Lines, 1966, by the application of constructional and equipment standards in conjunction with strict operational controls.*

HSC intended for use on international voyages must comply fully with the HSC Code, as well as any other applicable international requirements. The MCA determined, on a craft-by-craft basis, the extent to which the Code was to be applied to HSC engaged solely on domestic voyages. In 2008, under the provisions of the HSC Code, the MCA issued *Moon Clipper* a High-speed Craft Safety Certificate and a Permit to Operate **(Annex G)**.

1.12.2 Permit to Operate

Under the conditions of her permit, *Moon Clipper* was allowed to operate on the River Thames between Putney and Margaretness from her base port at Trinity Buoy Wharf. Although originally designed to carry up to 115 passengers, the River Runner 150 craft were certificated to carry 138 passengers on the River Thames up to a maximum distance of 1 mile from a place of refuge. The MCA allowed *Moon Clipper* to operate under charter further east in category C[8] waters where the significant wave height[9] could not be expected to exceed 1.2m. In these circumstances, her maximum passenger-carrying capacity was reduced to 115.

Other conditions of the Permit to Operate required the crew to keep a record of the passengers carried during each voyage, and to maintain an all round lookout on the bridge at all times when the craft is underway. In order to maintain an all round lookout, two officers were required to be present on the bridge. However, it had been agreed with the MCA that the mate only needed to join the master on the bridge when the vessel was proceeding at high-speed on the eastern section of the commuter route.

1.12.3 Passenger information

In accordance with Chapter 18.2.5[10] of the HSC Code, *Moon Clipper*'s crew were required to count the number of passengers prior to each departure. This passenger information also needed to be recorded ashore so that it was available to the search

[7] The Merchant Shipping (Passenger Ships on Domestic Voyages) Regulations 2000 and the Merchant Shipping (High Speed Craft) Regulations 2004.

[8] Category C waters - tidal rivers and estuaries and large, deep lakes and lochs where the significant wave height could not be expected to exceed 1.2 metres at any time.

[9] Significant wave height - is the average crest-to-trough height of the highest one third of the zero-upcrossing waves in a specified period.

[10] HSC Code Chapter 18.2.5: Operational requirements - Information on passengers.

and rescue services if needed. In addition, the PLA required all passenger vessels operating within its port limits to input their passenger numbers on to the electronic Thames AIS[11].

The deckhands on board Thames Clippers' larger vessels were responsible for recording the passenger figures, but as *Moon Clipper* did not carry a deckhand, the task fell to the mate. The mate was expected to write down the passenger numbers on the vessel's paper log sheets **(Annex A)** and input the same data on to the Thames AIS. *Moon Clipper*'s AIS computer terminal was located on the starboard side of the bridge console **(Figure 13)**. It had a display screen touch-pad function that could be used to input the necessary passenger data on to the Thames system.

In order to reduce the level of distraction on the bridge, the company provided each vessel with a portable hand-held AIS keypad. The wireless keypads allowed the crew to enter the necessary passenger information on to the AIS from the passenger cabin. The wireless signal reception in the passenger cabin on board the River Runner 150 craft was weak, and their crew had found the remote hand-held devices to be unreliable. Because of this, it had become common practice to leave the portable keypad on the table at the back of the bridge.

Throughout the day of the accident, the passenger figures on *Moon Clipper* were recorded by the master on the bridge **(Figure 7)**. Typically, after departing each pier, the mate opened the wheelhouse door and shouted the passenger numbers up to the master from the passenger cabin. On the occasions that the mate joined the master on the bridge while underway, the master still recorded the figures. On several occasions, the figures recorded by the master were not the same as those shouted out by the mate.

1.12.4 Safety management system

The HSC Code requires the management of a company operating HSC to exercise strict control over its operation and maintenance by the application of a quality-management system. Chapter 18.2 of the Code states that:

> *The company shall ensure that the craft is provided with adequate information and guidance in the form of technical manual(s) to enable the craft to be operated and maintained safely. The technical manual(s) shall consist of a route operational manual, craft operating manual, training manual, maintenance manual and servicing schedule. Arrangements shall be made for such information to be updated as necessary.*

The Code calls on Administrations to ensure that craft are provided with adequate information and guidance in the form of technical manuals to enable safe operation and maintenance. The MCA achieved this through an assessment of the available information and guidance, and through the application of The International Management Code for the Safe Operation of Ships and for Pollution Prevention (ISM Code).

[11] Thames AIS - Since 1 June 2007, all passenger and commercial vessels of over 40m length or 50gt were required to carry a special transponder and laptop computer. This equipment provides information on the vessel's location to both PLA and other vessels operating in the area. The crew on each vessel are required to log the number of passengers on board before they cast off, as this information can be critical in the event of an incident.

Up until 2008, Thames Clippers' safety management system (SMS) was based on the requirements set out in the UK regulations[12] governing domestic passenger ships. Following the MCA's decision to apply the HSC Code to Thames Clippers' River Runner craft, the company was obliged under EU regulations[13] to ensure its SMS complied with the ISM Code. Working closely with the MCA, Thames Clippers enhanced its domestic SMS and, in 2008, was issued an ISM Code Document of Compliance (DOC). In addition, a Safety Management Certificate (SMC) was issued to each of the company's HSC.

Thames Clippers' safety management system comprised an overarching safety management manual (SMM) and the supplementary craft-specific operational and maintenance documentation prescribed in Chapter 18 of the HSC Code. The operational documents included craft operation and maintenance manuals, route operating manuals, training manuals, checklists, operational memos, and the company's emergency management procedures. A copy of the company's SMM and the vessel's operating and maintenance manuals were held on board *Moon Clipper*.

Moon Clipper's emergency procedure for collisions **(Annex B)** included a list of actions to be taken after a contact with a fixed object, and an aide-mémoire to help the master record relevant information. The list of actions included mustering the passengers and conducting a headcount.

1.12.5 Craft Operation and Maintenance Manual

The River Runner 150 Mk3 craft *Operation and Maintenance Manual* was written by NQEA in 2001. It comprised the following five parts:

Part 1 – Description

Part 2 – Operation

Part 3 – Failure Mode and Effects Analysis

Part 4 – Maintenance

Part 5 – Tests and Trials

Part 1 of the manual provided general information about the vessels' particulars, class and survey standards, machinery and systems, fire-fighting equipment and protection standards, and lifesaving appliances (LSA).

Part 2 contained basic instructions, precautions and suggestions for the operation of the vessels' equipment and explained her systems. It also described the vessels' handling characteristics and service restrictions. The service restrictions and operating envelope described in the manual were those developed in 2001 for Loughlink's intended Belfast operations and reference was made throughout to a manning level of 4 crew (master, mate and 2 deckhands).

At the time of the accident, *Moon Clipper* was fitted with two 65-person liferafts and one 14-person flotation device. The text in the LSA section of the manual stated that the River Runner 150 craft carried three 65-person reversible liferafts, while

[12] The Merchant Shipping (Domestic Passenger Ship) (Safety Management Code) Regulations 2001.

[13] EU Regulation 336/2006 – Implementation of the International Safety Management Code.

its liferaft launching and escape plans showed four 65-person liferafts. AIMTEK had supplied revised plans **(Figure 10)**, but these had not been inserted into the manuals.

Part 3 of the manual contained the detailed failure mode and effects analysis (FMEA)[14] carried out by the ship builder. Part 4 gave general instructions regarding the maintenance of the vessels' structure, equipment and outfit. Part 5 contained copies of the original harbour and sea acceptance trials undertaken in July 2001.

The Operation and Maintenance Manual had not been amended following the propulsion drive train changes, and referred to the original CPP systems throughout. The steering control system changeover was also not reflected in the manual.

1.12.6 Critical systems

The ISM Code requires shipping companies to identify critical equipment and technical systems, the sudden operational failure of which may result in hazardous situations. NQEA identified the following systems and equipment as being critical:

- Directional control system
    - Steering control system
    - CPP and main engine RPM control system
- Machinery systems
    - Engines
    - Gearboxes
    - CPP shafting thrust system
- DC electrical system
- Fuel system
- Combustion air system

In accordance with the requirements of the HSC Code, an FMEA process was applied to the identified critical machinery and control systems. The process considered the loss of main steering control as a result of a hydraulic oil leak, filter blockage or port main engine shut down. The corrective action identified was the transfer of control to the emergency back-up joystick. The subsequent loss of backup steering control was also considered for the same causes. In both instances the probability was considered to be reasonably remote. Loss of main and emergency DC electrical supply to the backup steering control system was also considered, and the probability was assessed to be low. These failure modes were all simulated during the vessel's sea acceptance trials, and the outcomes recorded in the Operation and Maintenance Manual.

[14] FMEA is an examination of the craft's systems and equipment to determine whether any reasonably probable failure or improper operation can result in a hazardous or catastrophic effect.

1.12.7 Seating arrangements

The HSC Code includes a set of minimum design requirements for passenger accommodation spaces and seating arrangements[15]. The Code requires a seat to be provided in the vessel's enclosed accommodation spaces for each passenger and crew member on board. The HSC Code states that:

> *Seats and their attachments, and the structure in the proximity of the seats, shall be of a form and design, and so arranged, such as to minimize the possibility of injury and to avoid trapping of the passengers after the assumed damage in the collision design condition according to 4.4.1. Dangerous projections and hard edges shall be eliminated or padded.*

The Code also contains criteria for the fitting of safety belts and safety belt design.

A total of 114 passenger seats had been fitted in the main passenger cabin **(Figure 17)** on board *Moon Clipper.* There was a steel handrail **(Figure 18)** on the back of each seat, and lap belts had been fitted to seven of the seats in the front row. According to the vessel's safety plans, a space next to the cabin's starboard aft access door had been allocated for use by a wheelchair using passenger. The passenger who was thrown from his wheelchair was seated close to the port forward access door.

Thames Clippers' vessels periodically broadcast pre-recorded safety announcements that recommended passengers remain seated while the vessel was underway. This was not a formal requirement and the passengers were allowed to stand up and move around if they chose to. There was also no requirement to use the safety belts during normal operations, and none were worn on the day of the accident.

1.13 MAINTENANCE MANAGEMENT SYSTEM

The ISM Code requires shipping companies to establish procedures to ensure their ships are maintained in accordance with relevant rules and regulations, and the instructions provided by equipment manufacturers. In order to achieve this, companies should provide maintenance management systems that ensure:

- inspections are held at appropriate intervals;
- any non-conformity is reported with its possible cause, if known;
- appropriate corrective action is taken; and
- records of these activities are maintained.

Thames Clippers' maintenance management system (MMS) had been developed to meet the requirements of the Code, and the company's maintenance procedures were set out in the SMM. The main elements of the maintenance management system were:

- planned maintenance

[15] HSC Code – chapter 4.5 Accommodation and escape measures: Seating construction.

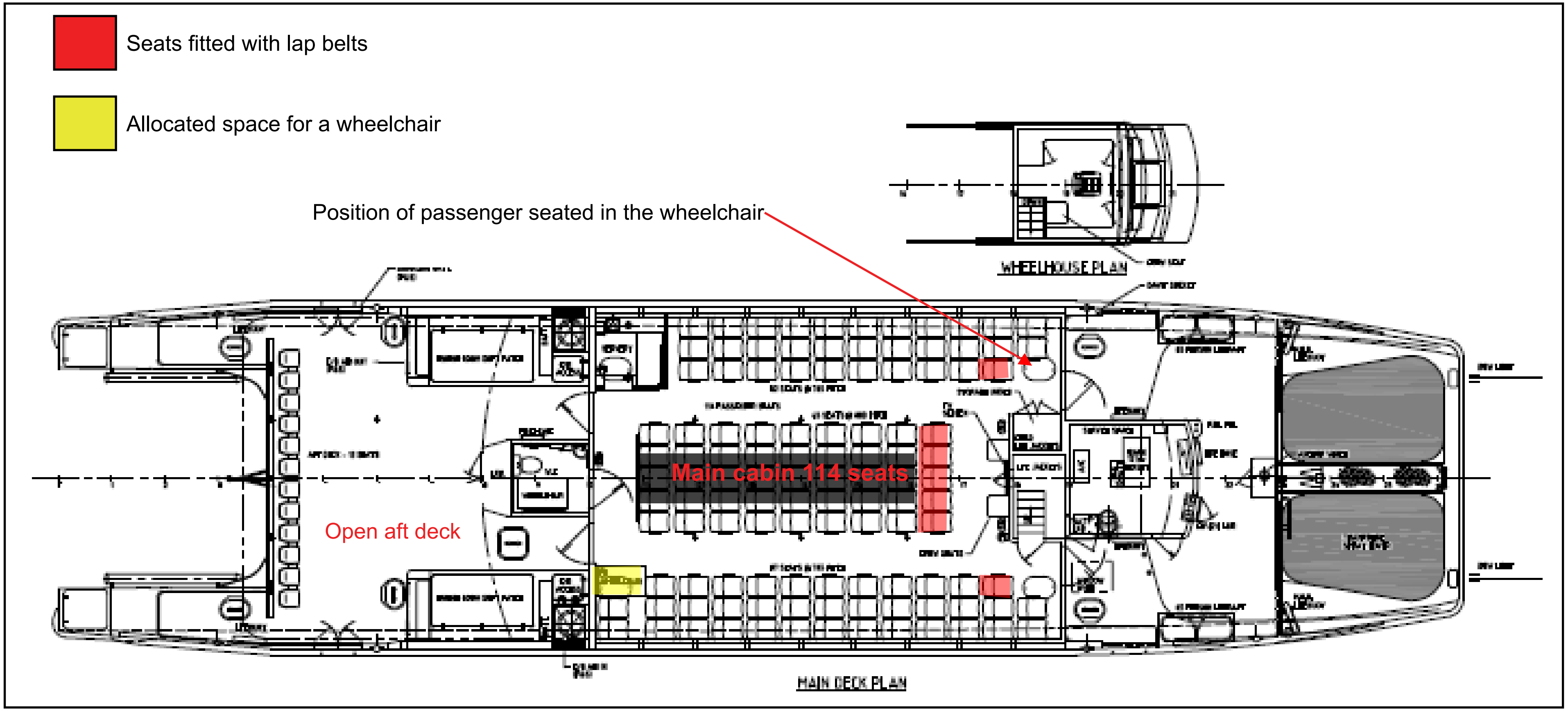


Figure 17: Seating arrangements in the passenger cabin

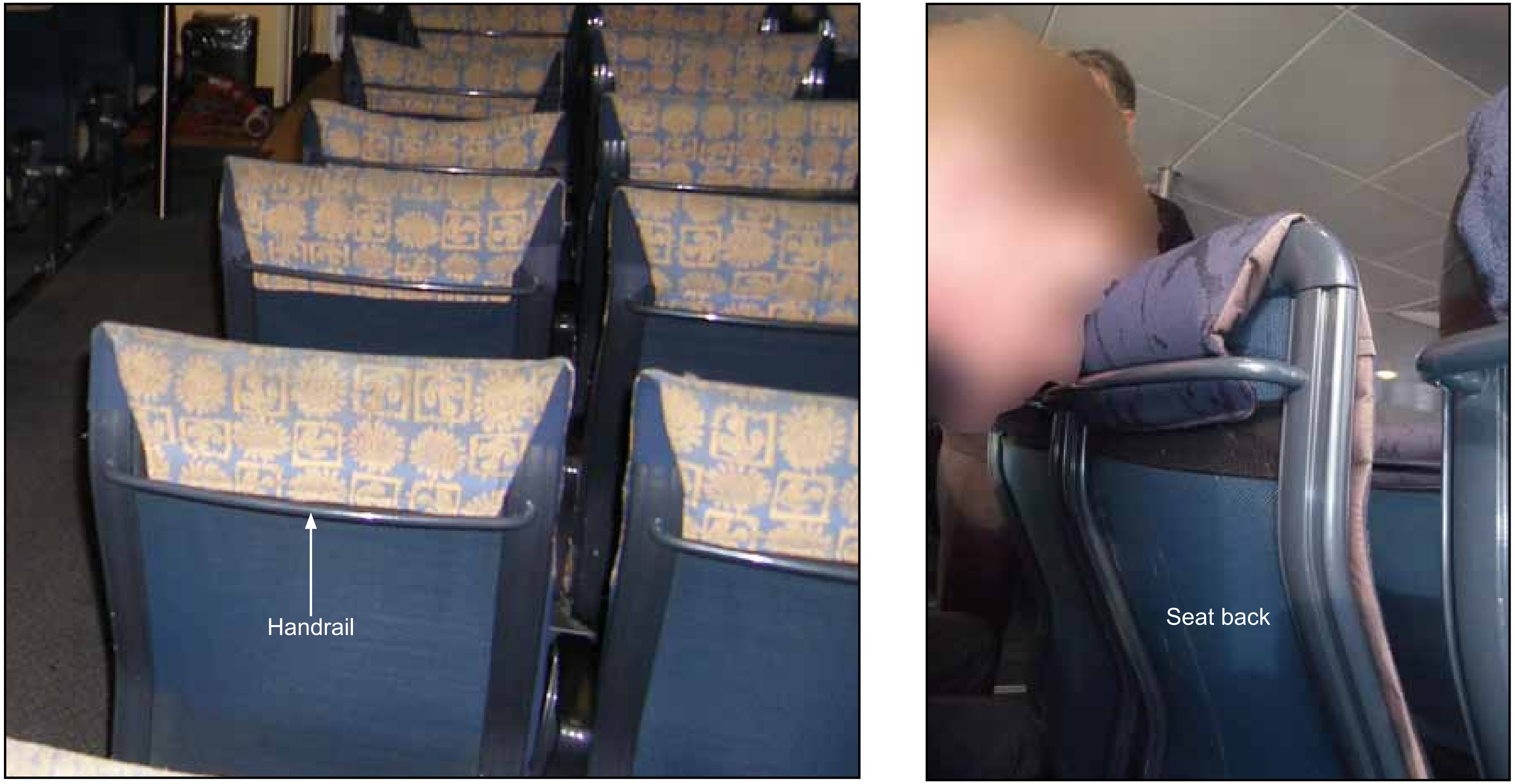


Figure 18: Handrails on the back of the seats in the passenger cabin

- corrective maintenance
- communication
- handover from maintenance to operations
- administration
- spare parts support

The majority of the maintenance was carried out by the company's team of shore-based service engineers. The team of marine and electrical engineers was managed by the company's head of engineering and worked to a set shift pattern. During the day, the duty engineers carried out the vessels' pre-service checks and responded to any defects reported by the masters. The majority of the planned and corrective maintenance was undertaken overnight when the vessels were out of service.

Each vessel's planned maintenance schedules were compiled based on a combination of information from the original equipment supplier, the craft's Operation and Maintenance Manuals and the experience gleaned by the company during its 12 years operating HSC. The periods between maintenance schedules were either calendar based or governed by recorded running hours. Once a work schedule was complete, its maintenance report form was returned to the office, where it was filed and its details entered on to the company's electronic database by the MMS administrator.

The steering systems were tested and inspected daily by the master and service engineers prior to the vessels entering service. In addition, the planned maintenance system included a scheduled 6-monthly maintenance of the steering gear hydraulic system for the River Runner 150 craft. This schedule required the service engineers to check the system operating pressures and renew the hydraulic reservoir's return filter and breather element. There were no maintenance schedules for the steering joysticks or the steering control systems as a whole.

Corrective maintenance was based on a defect reporting process that was followed by both the operators and the shore-based maintainers. The defects were recorded on the vessel's daily log sheet **(Annex H)** and entered on to the electronic system ashore by the MMS administrator.

1.14 ISM CODE AUDITS

The MCA carried out an office based ISM Code DOC audit at Thames Clippers' operating base on 31 January 2011. The auditor identified four non-conformities and made two additional observations. Three of the non-conformity notes raised related to the maintenance of the company's ships and its ships' equipment. The auditor found that the company had not identified all the critical equipment on its vessels, and defects to some critical systems had been outstanding for almost 2 years. The non-conformities raised were not directly associated to any of the contributory circumstances that led to the accident.

The MCA also carried out a general inspection on board *Moon Clipper* 2 weeks before the accident, and found no deficiencies on board. The company carried out an internal SMS audit on board *Moon Clipper* the week after the accident. The audit report contained several low level observations, but no non-conformities were identified.

The internal and external audits and inspections did not identify that the documents required by the HSC Code had not been amended to reflect the propulsion machinery and steering control system changes.

1.15 POST ACCIDENT SURVEYS, INSPECTIONS AND TRIALS

1.15.1 Kobelt joystick

The Kobelt joystick that had been reported as feeling loose on the morning prior to the accident, was removed the following day by Thames Clippers' engineers. Once removed and inspected, it was immediately apparent that its centring spring was missing **(Figure 19)**. Despite an extensive search of the spaces behind the bridge console, the missing spring was not found.

It was noted that when the joystick was moved to its extremities, it often stuck in a position where it was acting on the corresponding micro-switch. When the joystick was stripped down for closer inspection, a general level of wear was evident on the contact faces of both the micro-switches and the operating cams **(Figure 19)**. The joystick's corrugated rubber skirt was found to be holed in several places.

On 12 January 2012, Thames Clippers advised the Marine Accident Investigation Branch (MAIB) that a similar Kobelt joystick fitted on board *Storm Clipper* to control her water jet buckets had failed. On this occasion, the company's service engineers recovered the centring spring **(Figure 20)**. The spring had failed close to the root of one of its crossover hooks. The joystick had been fitted in October 2011 and was new at that time. Five days later, the centring spring of the new Kobelt joystick fitted to *Moon Clipper* after the accident in October, also failed **(Figure 20)**. Again, the spring was recovered and was found to have suffered a similar fracture at the root of the spring hook.

This information was passed to Kobelt's head office in Canada, and was the first report the company had received of such a failure. Kobelt had sold 294 of its type 7165 non-follow up joysticks in the 2 year period prior to the accident, and all the springs fitted were of the same type and had been supplied by the same spring manufacturer. The spring manufacturer was instructed to investigate the cause of the failures and establish what improvements could be made. Its investigation concluded that the springs failed because they had suffered fatigue fractures at the small radius of the crossover hook. It recommended that the design of the hook be changed **(Figure 20)** to eliminate the small radius, and the grade of the stainless steel improved to increase the ultimate tensile strength of the spring. The recommended changes, adopted by Kobelt, increased the spring's theoretical cycle life for bending stress from 159,331 cycles to over 10,000,000 cycles.

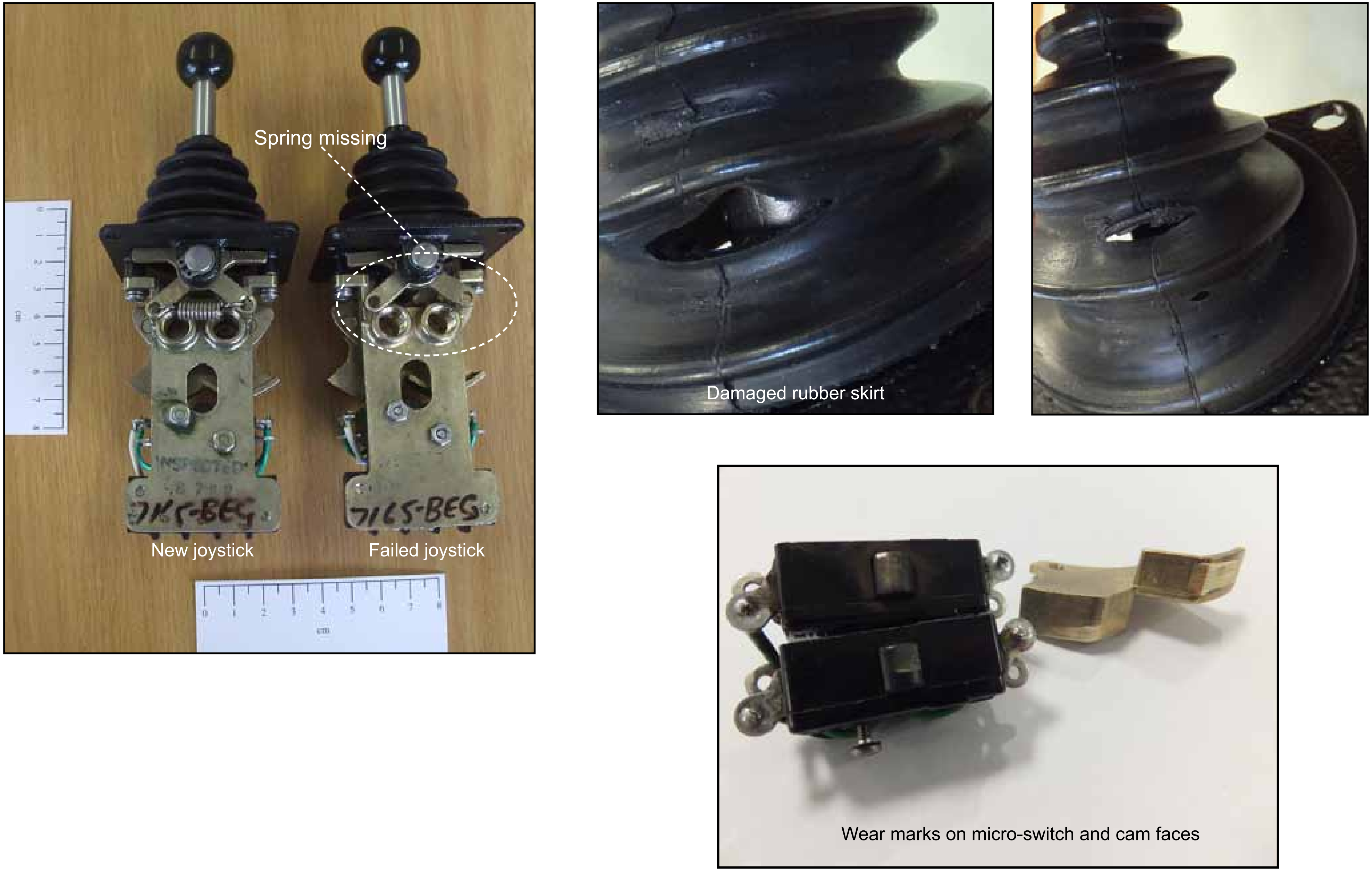
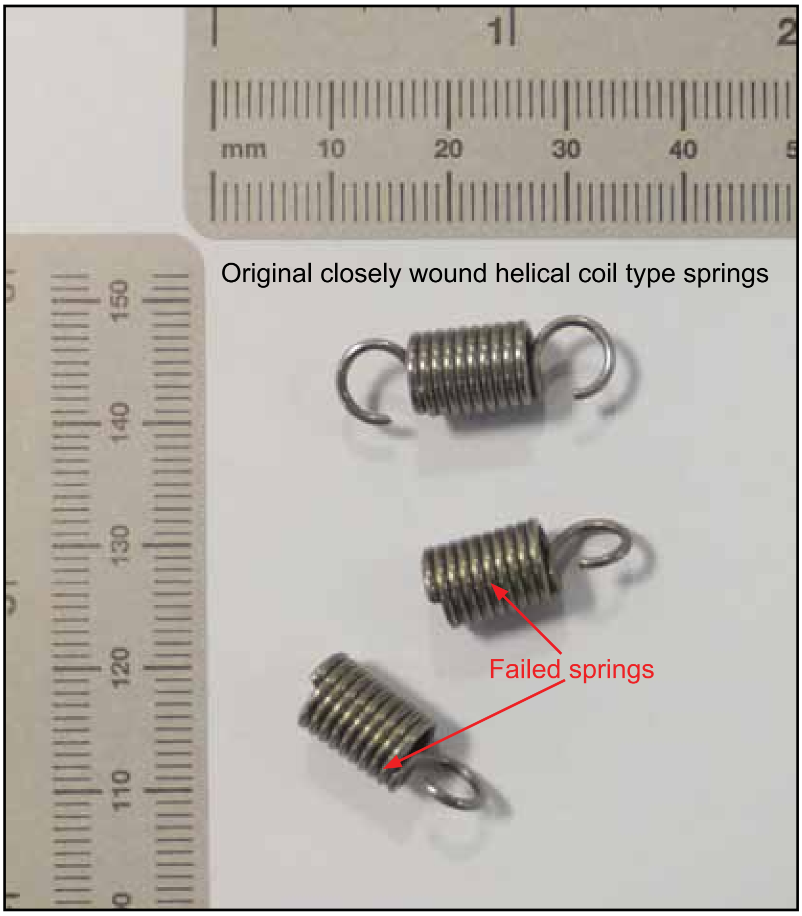
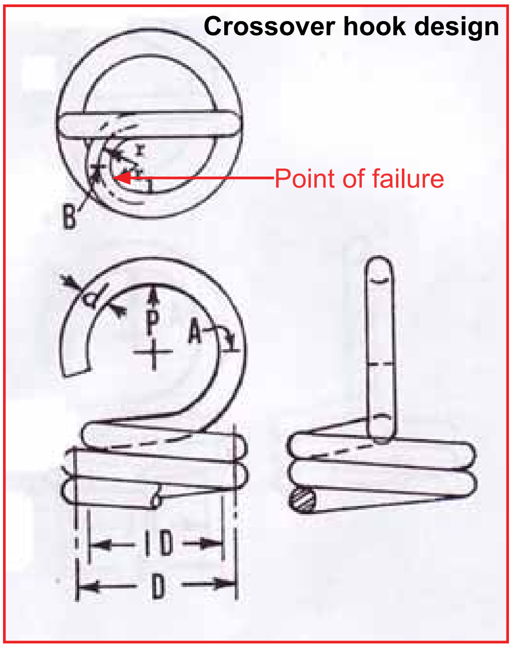


Figure 19: Failed joystick





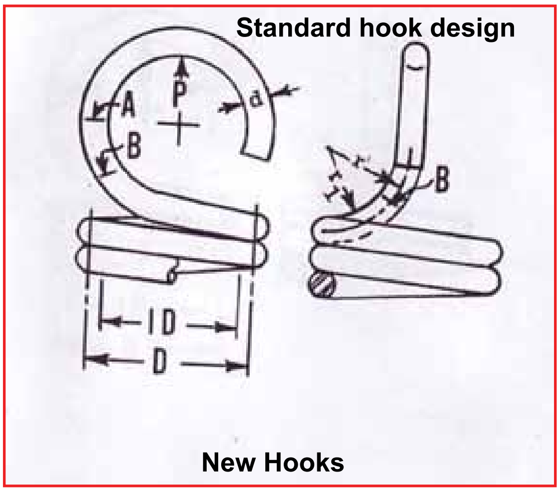


Figure 20: Spring design changes

1.15.2 Electronic propulsion control system

On 6 October 2011, a Twin Disc propulsion control system diagnostics engineer attended the vessel and interrogated the control system's electronic history. The engine stall was recorded as a *transmission input sensor fault* in the alarm log data summary **(Annex I)**. From the data retrieved, the engineer was able to establish that the starboard propulsion control lever was set to full astern and the propeller shaft was rotating at 280rpm ahead when the engine stalled.

1.15.3 Manoeuvring trials

Several practical manoeuvring demonstrations and trials were conducted for the MAIB on board *Moon Clipper* and *Sun Clipper* after the accident. The vessel's handling characteristics at full speed, and the procedure for reversing the propeller shaft rotation at lower speeds, was demonstrated. A set of steering control trials was conducted, and timings for rudder movement recorded. The effectiveness of the transverse thrust provided by the propellers was also demonstrated.

Using the joystick steering control, it took 5 seconds for the rudders to move from midships to the hard over (30º) position. It took twice that time to swing them from hard over in one direction to hard over in the other direction. It took 12 seconds to move the rudders from hard over to hard over using the wheel. A single revolution of the wheel moved the rudders through an angle of about 13º and it took four and a half rotations of the wheel to move the rudders from hard over in one direction to hard over in the other. The times observed were similar to those recorded during the vessel's sea acceptance trials in Australia in 2001.

In the final set of tests, the joystick was held over to port while the wheel was simultaneously rotated to starboard. It was noted that the rudder went hard over to port and the wheel had no effect. It was also noted that the wheel rotated freely to starboard with little or no resistance, but when operated normally, a significantly higher level of resistance was experienced.

1.15.4 Passenger questionnaires

The details of 10 of the injured passengers were passed to the MAIB after the accident. Each was subsequently sent, and requested to complete, a marine accident passenger feedback questionnaire. Of those 10 passengers, 8 completed and returned the questionnaires. An additional passenger, who had not been injured, contacted the PLA and provided his feedback on the events immediately following the contact.

None of the passengers that provided feedback saw the vessel's approach to the pier and therefore were unable to brace themselves prior to impact. None of them recalled any passenger information announcements being made after the accident, or a headcount being conducted prior to their disembarkation. The majority of responders said they did not know what had happened, and five said they were concerned that the vessel might sink.

In general, the responders had significant concerns about the co-ordination of the crew's emergency response efforts. Several passengers expressed feelings of empathy for the crew because they thought that they must not have been trained to deal with such incidents. The questionnaires contained no positive feedback relating to the actions of the crew after the accident.

1.16 SIMILAR INCIDENTS

1.16.1 MAIB incident database

In the past 5 years, twelve machinery or machinery control failures resulting in contact, collision or grounding accidents to passenger vessels on the River Thames were reported to the MAIB. Four of those involved Thames Clippers' vessels, three of which were River Runner HSC.

In September 2011, *Storm Clipper* made contact with Lambeth Bridge when her steering gear jammed over to port. The cause of the failure was not established, but the company replaced many of the steering system's old components.

In March 2011, *Moon Clipper* was making an approach to London Eye Pier at night when she veered to port and made heavy contact with the moored vessel, *London Rose* **(Figure 21)**. On that occasion, the cause of the steering failure was found to be an electrical fault. When the master realised what was happening, he put the joystick to starboard and immediately pulled the starboard main engine control lever astern. The master initially thought he had stalled both main engines, and quickly became confused and lost his situational awareness. He did not attempt to use the wheel to steer the vessel, and when he attempted to reset both engines he stopped the running port engine. There were 16 passengers on board at the time but none were injured and only minor damage was caused to the stem of *Moon Clipper*'s port bow. As a result of the lessons learnt from that accident, Thames Clippers had engine stall alarm lights fitted on the River Runner 150 vessels' bridge consoles.

In October 2008 *Cyclone Clipper* was damaged when she made contact with a pier after losing steering control. The master stalled both engines on that occasion when he pulled the levers to full astern. A female crew member suffered minor injuries and was taken to hospital for treatment. Earlier in 2008, *Meteor Clipper* went aground after steering had been lost and the engines stalled.

1.16.2 River Runner class steering control failures

A review of the River Runner 150 craft steering gear and steering control systems' maintenance and defect histories identified that three steering control system failures had been reported by masters on board *Moon Clipper,* and seven on board *Sun Clipper* following the changeover in 2009 to joystick steering as the primary means of steering control. Prior to the changeover, only one steering failure was reported. Following the fitting of the Kobelt joysticks in March 2011, two joystick faults were reported on board *Sun Clipper* prior to this accident.

On 17 January 2012, when the second joystick centring spring failed on board *Moon Clipper*, the master reported the defect to the fleet controller and a service engineer was sent to the vessel. Again, the decision was made to return the vessel into service without rectifying the fault. When the vessel was taken out of service at the end of the day, the defective joystick was removed and replaced with a spare.

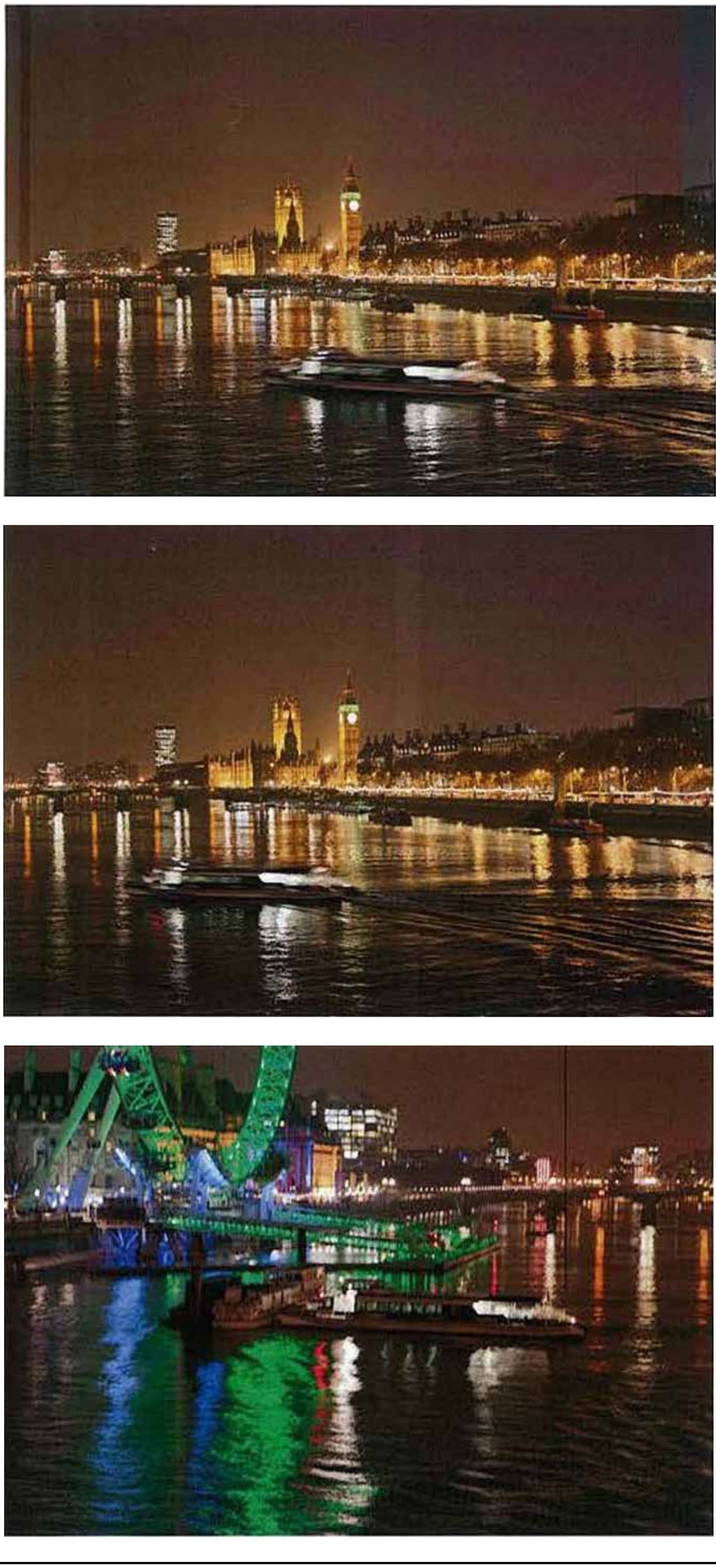


Figure 21: *Moon Clipper*'s contact with moored vessel *London Rose* (March 2011)

1.16.3 River Runner class engine stalls

The engine stalls mentioned in paragraph 1.16.1 all resulted in contacts or groundings and therefore were reported to the MAIB. Accepted theoretical accident statistic models[16] suggest that for each of these reported engine stalls there would have been many more that did not result in an accident. The fleet memos **(Annex J)** issued by Thames Clippers supports this, and *Moon Clipper*'s engine diagnostics alarm history contained seven previous *transmission input sensor fault* alarm conditions for 2011. Although this alarm condition can be triggered by other engine shut down conditions and the loss of the sensor itself, it is likely masters had stalled *Moon Clipper'*s engines on other occasions.

[16] H W Heinrich's Safety Pyramid (1931), F E Bird's Accident Triangle (1969) and ConocoPhillips Marine Safety Pyramid (2003).

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 THE ACCIDENT

2.2.1 Cause of the contact

The circumstances that led to *Moon Clipper*'s contact with Tower Millennium Pier on 5 October 2011 resulted from the use of a critical component within the vessel's steering control system that had earlier been identified as defective. When the master used the joystick to alter course to port, he had intended to apply a small amount of port helm, but the joystick stuck and the rudders went hard over. This caused an unintentionally high rate of turn to develop that the master was unable to arrest in time to prevent the collision due to the vessel's high speed of approach and the stalling of the starboard main engine.

2.2.2 Cause of the injuries

Most of the injuries suffered by the passengers and crew were caused by them hitting projections and hard edges when they were thrown forward without warning on impact. The HSC Code requires dangerous projections and hard edges to be eliminated or padded. The River Runner 150 craft were built to meet the requirements of the HSC Code in 2001, and the seating arrangements were considered to be compliant at that time.

The majority of injured passengers who had been seated in the main cabin, suffered cuts and bruises to the head and face following heavy contact with the steel handrails on the backs of the seats in front of them **(Figure 18)**. The handrails presented a hard edge at head height as the seated passengers jack-knifed forward on impact, and they were not padded. The seats on board the newer River Runner 200 craft did not have similar handrails. When CRE bought its River Runner craft, they were intended for use as domestic passenger vessels, and the HSC Code was not applied. Although it is often difficult and commercially disadvantageous to retrospectively apply improvements to design standards to existing vessels, the potential benefit of providing padding around the handrails fitted to the back of the seats on the River Runner 150 craft would be significant, and might be considered a reasonably practicable step to take.

The passenger in the wheelchair suffered a deep cut to his head because it hit the sharp edge of a fire alarm call point positioned directly in front of him. Although he was not seated in the space allocated for a wheelchair user, had he been directed to the designated space, he would still have been thrown from his wheelchair because he was not restrained by a safety belt.

The vessel's pre-recorded safety announcements recommended passengers to sit down. However, for many reasons such as short transit times and sight-seeing opportunities, some passengers chose to stand on the after deck. Similarly, some seats were fitted with lap belts, but no one chose to use them. Had all the passengers and crew been seated, and wearing three point safety belts at the time of impact, there would probably have been no injuries at all. However, it would not have been reasonably practicable to implement such rigorous and potentially time consuming measures, considering the relatively low levels of risk involved.

2.3 BRIDGE TEAM PROCEDURES

2.3.1 Continued use of the defective steering control joystick

The master had realised that the steering control joystick was faulty at the start of his shift and, having consulted the duty engineer, he decided to keep his vessel in service and use the wheel to steer. Although the vessel remained in service with a known defect on a critical system, the master had identified a control measure that, if fully implemented, would have prevented the accident.

The joystick's electrical circuit was not isolated and, once *Moon Clipper* was back in service, the master reverted to using the joystick periodically to manoeuvre. This action was probably influenced by the bridge console's ergonomic layout, taking into consideration the length of time the master spent on the starboard side of the bridge recording the passenger figures. From that position, the joystick was within easy reach, and took little effort to use. As time passed by, the master used the joystick more and more frequently. It stuck over to both port and starboard on several occasions during the day **(Figure 4)**, but on those occasions the vessel had been in clear water and the master was able to recover the situation without incident.

Four months after the accident, when the centring spring on *Moon Clipper*'s replacement joystick failed, the same decision was made and the vessel was returned into service without the fault having been rectified. Again, the joystick was not isolated and the master reverted to using both the joystick and the wheel, and predictably, the circumstances that led to the heavy contact with Tower Millennium Pier were repeated. Fortunately on that occasion, they did not result in a similar accident.

2.3.2 Recording of the passenger figures

The passenger figures were not being recorded in accordance with Thames Clippers' SMS or the PLA's requirements on board *Moon Clipper* throughout the day of the accident. The figures were being recorded by the master instead of the mate, and were being entered into the AIS after the vessel had left the piers. These practices were probably adopted because the remote AIS keypads were unreliable, and the short transit times between some of the piers made it difficult for the mate to go to the bridge to do the task.

The recording of the passenger figures by the master while his vessel was underway served as a distraction and represented a hazard to safe navigation. It is clear from the bridge CCTV that the undertaking of this task, during the 70 second passage across the river immediately before the steering control failure, adversely affected the master's approach to the pier and his response to the developing situation.

2.3.3 Speed of approach

The master was aware that *Moon Clipper* was running about 3 minutes behind schedule when he left London Bridge City Pier. Thames Clippers' commuter service timetable allowed 4 minutes to complete the passage across the river, berth alongside Tower Millennium Pier, and alight and board passengers. The time taken to complete the passage just prior to the accident was half that taken on the reverse westbound passage 40 minutes earlier. Although the vessel did not exceed the PLA's 12 knot limit, *Moon Clipper* was still making 12 knots with about 100m to run. The speed and direct nature of the approach taken to the pier was almost certainly influenced by the fact that *Moon Clipper* was running behind schedule and the master was trying to make up time.

Moon Clipper was about 80m from Tower Millennium Pier and closing at between 10 to 12 knots when she veered to port, giving the master less than 15 seconds to react. Despite this, the master continued his approach and attempted to use his rudders and propellers to recover the situation. This appeared to indicate that the master was used to making fast approaches and was very confident in his vessel's handling characteristics. However, the speed of approach significantly magnified the consequences of the steering control failure, and when the master realised his vessel was not responding as anticipated, he stalled the starboard engine and, from that point on, there was little he could do to avoid the contact.

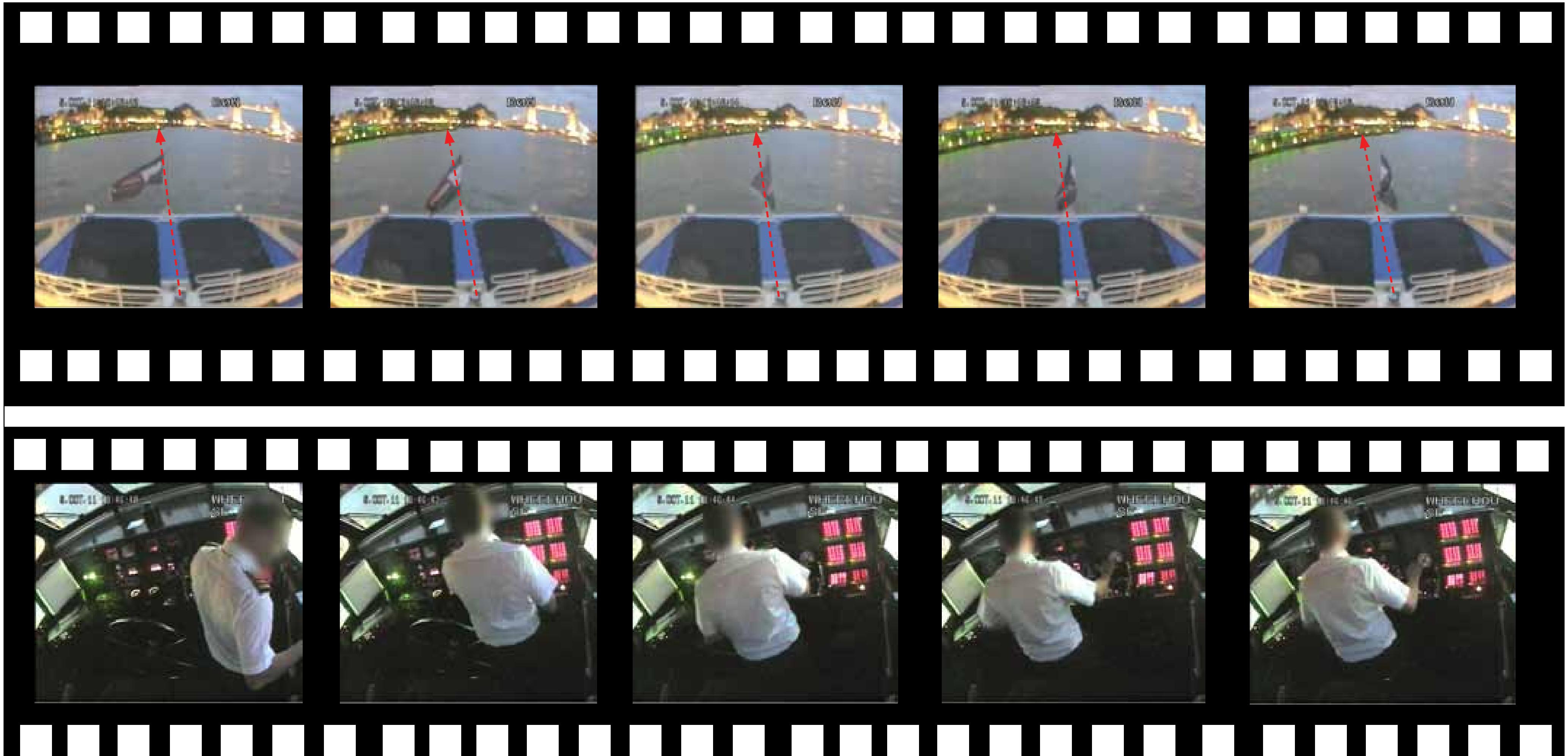
2.3.4 Response to the steering control failure

Moon Clipper's bridge CCTV recordings **(Figure 22)** allowed the investigation to establish in detail the circumstances leading up to the steering control failure, and analyse the actions taken by the master during his attempt to avoid the contact.

Nineteen seconds before *Moon Clipper* hit the pier, the master was standing on the starboard side of the bridge and was writing the passenger numbers in the log sheet. He then turned to face forward and placed his right hand on the steering joystick and his left hand on the propulsion control levers. The master used the joystick to alter the vessel's heading to port, then moved slightly towards the centre of the bridge and placed his left hand on the wheel and his right hand on the levers. Although he had intended to apply a small amount of port helm, the joystick had stuck, and the rudders would still have been moving to port 2 to 3 seconds after he released the joystick.

The master was probably unaware of the developing situation at this point as he began to turn the wheel to starboard. It is likely, taking into consideration the results of the trials conducted after the accident (paragraph 1.15.3), that the master would have felt an unusually small amount of resistance when he moved the wheel. When the master looked down towards the rudder angle indicators, he probably saw the rudders were either still moving to port or were stuck hard over. As *Moon Clipper*'s rate of turn was increasing, the master appeared not to be concerned by the situation, and he began to ease back on the starboard propulsion control lever.

With 11 seconds to contact, the master put the steering joystick over to starboard and appeared to be looking towards the rudder angle indicators again. Two seconds later he pulled the starboard lever to full astern. At that time, the joystick was stuck over to starboard and the rudders were likely to have reached an angle of about 15º to port. Almost immediately after putting the starboard lever to full astern, the



19 seconds to contact:

The master was facing to starboard and was entering the passenger figures in paper log sheet. *Moon Clipper* was making 12 knots over the ground and was heading for the far end of the pier.

17 seconds to contact:

The master was facing forward with his left hand on the propulsion control levers and his right hand on the joystick.

15 seconds to contact:

The master moved left towards centre of bridge. He put his left hand on the handwheel and his right hand on the levers.

14 seconds to contact:

The master attempted to arrest the vessel's swing to port using the handwheel. He looked down and noticed the rudders were either hard over to port or still moving to port.

13 seconds to contact:

With *Moon Clipper*'s rate of turn to port increasing, the master began to pull back the starboard propulsion control lever.

Figure 22: *Moon Clipper*'s approach to Tower Millennium Pier (CCTV time local + 3 minutes)

11 seconds to contact:

The master put the joystick to starboard and looked towards the rudder angle indicators.

9 seconds to contact:

The master looked forward and put the starboard control lever to full astern.

7 seconds to contact:

The starboard main engine stalled and the starboard steering system hydraulic low pressure alarm activated.

5 seconds to contact:

The master attempted to steer to starboard using the handwheel.

3 seconds to contact:

Moon Clipper making 8 to 8.5 knots over the ground.

Figure 22 continued: *Moon Clipper*'s approach to Tower Millennium Pier (CCTV time local + 3 minutes) starboard engine stalled and its alarm lamp illuminated. In addition, the starboard steering system's hydraulic failure alarm sounded on the bridge console's machinery alarm panel.

Moon Clipper was now approaching the pier at about 8.5 knots and the master appeared to make a final attempt to avoid the contact by using the wheel to turn to starboard. The master only moved the wheel through a small angle and did not appear to put the port shaft astern. It is possible that the steering gear had hydraulically locked, but it is also likely that, with less than 5 seconds to impact, the master had become confused and lost some of his situational awareness.

2.4 JOYSTICK FAILURE

Moon Clipper's Kobelt joystick centring spring probably suffered a fatigue fracture and failed on the day of the accident. Without the spring, the joystick lever did not self-centre correctly when released and its cams tended to stick on the micro-switches. This introduced the risk of a continuous electrical signal being sent to the steering gear's directional control solenoid. Taking into account the two subsequent joystick spring failures on board Thames Clippers' vessels, which had been in service for similar lengths of time, it is almost certain that the centring spring suffered a fatigue fracture because it had exceeded its expected cycle life for bending stress.

Kobelt's reaction to the reported spring failures was swift and decisive. Despite having received no previous reports of similar spring failures, it took immediate action to improve the spring's design specification and increase its theoretical cycle life. However, it should be noted that Kobelt's non-follow up 7165 spring return joystick was not designed for use as the primary means of steering control during continuous manoeuvring operations. For such applications, Kobelt recommended its follow up type 7165 joystick with potentiometer and feedback loop.

2.5 STALLING OF THE ENGINE

It is clear from the number of incidents discussed in paragraph 1.16, that the River Runner HSC were susceptible to engine stalls if the propulsion control levers were pulled directly from ahead to astern when the vessels were manoeuvring at conventional speeds. The risk of stalling the engines was increased when the vessels were travelling at higher speeds and when the lever movements were more rapid.

When the starboard main engine stalled on the approach to Tower Millennium Pier *Moon Clipper* was making between 8.5 and 10 knots over the ground against a 2 knot tidal stream and the starboard propeller was still rotating ahead at 280rpm. The torque developed by the engine and the inertia stored in its flywheel was not sufficient to overcome the opposing torque generated by the inertia of the propeller shaft rotating ahead when the gearbox was engaged astern. This caused the engine speed to drop to the point at which it stalled. When *Moon Clipper* made heavy contact with a berthed vessel on her approach to London Eye Pier 7 months earlier, the starboard shaft was rotating ahead at 260rpm and the control lever was set to 60% astern when the engine stalled.

The engines fitted to the River Runner craft, and other HSC, need to be lightweight and therefore tend to have small flywheels. These characteristics make the risk of engines stalling during manoeuvring higher on the River Runner HSC than on conventional propeller-driven vessels.

As the engines were not fitted with load control and the propeller shafts did not have brakes, the propulsion control strategy was heavily reliant on the skill of the master. However, the number of similar incidents discussed in paragraphs 1.16.1 and 1.16.3 clearly demonstrates that, despite the levels of training provided, it is difficult to eradicate a master's natural impulse to immediately demand full astern in circumstances such as steering control failures if his vessel is approaching another vessel or a fixed object at speed.

2.6 MACHINERY CONFIGURATION CHANGES

2.6.1 Steering system

Thames Clippers' decision in 2009 to switch round the primary and secondary modes of steering gear control was a significant contributory factor in this accident. The intervention increased the likelihood of the River Runner 150 craft suffering steering system failures and adversely affected the master's ability to maintain a lookout and monitor the instrumentation on bridge console.

The original non-follow up joystick fitted at build was intended to be used as a back-up means of steering control in an emergency situation and, as Thames Clippers' maintenance records clearly showed, it was prone to failure and was not robust enough for continual use. The introduction of the Kobelt 7165 joysticks in May 2011, initially appeared to resolve the reliability issues experienced with the original joysticks over the previous 18 months. However, it became apparent following the three similar spring failures that the in-service life expectancy of the Kobelt joystick, when used as the primary means of steering control on board the River Runner craft, was less than 5 months. The other signs of wear found when the joystick was stripped down **(Figure 19)** further support this assessment.

When the joystick was in use, both the port and starboard steering control systems were live at the same time. This allowed the masters to alternate between using the joystick and the wheel as they moved around the bridge. However, with both control systems live at the same time, it was also possible for opposing helm demands to be sent simultaneously from the bridge to the independent port and starboard engine-driven hydraulic systems. In such circumstances, the risk of hydraulically locking the steering gear would have been increased.

The bridge had been ergonomically designed to be steered using the wheel while seated in the master's chair. From this centrally located, elevated position the master had the best available internal view of the instrumentation on the bridge console and external view through the bridge windows. However, as the joystick could not easily be reached from the seated position, the masters tended to stand while manoeuvring. Although the masters typically manoeuvred these vessels by feel, and seldom looked at the instrumentation on the bridge console, it was more difficult to monitor the rudder angle indicators from the starboard side of the bridge when the non-follow up joystick was being used. Furthermore, in order to get a good view through the windows the master often had to move around the bridge and stand on the tips of his toes.

The steering system as a whole had been subjected to an FMEA process during build and had been formally assessed and approved by LR. Although the MCA and AIMTEK saw no technical reason to challenge Thames Clippers' decision to switch round the main and emergency modes of steering gear control, had a formal technical assessment and approvals process been pursued, it is possible that the issues discussed in this chapter would have been highlighted and addressed prior to the change.

The number of steering control failures experienced on board the River Runner 150 craft following the configuration change, and the potential consequences of future failures, demand that Thames Clippers reassess the craft's original steering system FMEA, and seek formal technical approval from the MCA.

2.6.2 Propulsion drive train

The drive train changes carried out by Thames Clippers in 2008 were intended to improve the propulsion system's reliability and the vessels' handling characteristics, and therefore increase vessel safety. However, it was apparent that the intervention inadvertently increased the likelihood of the vessels' engines being overloaded and stalling.

Undoubtedly, the replacement of the original CPP system with the fixed pitch propellers and reversible gearbox reduced Thames Clippers' maintenance burden, increased the propulsion system's overall reliability and improved the handling characteristics of the vessels. However, the original CPP Servogear propulsion control system's manoeuvring mode and power reduction function provided engineered barriers designed to reduce the risk of overloading the engines. In addition, NQEA's recommendation to limit the engine speed to 1,500rpm when the propellers were placed astern, offered a further procedural control designed to further protect the engines.

The Twin Disc propulsion control system did not provide similar load limiting or load shedding functions and no formal manoeuvring limits were set. The only overload protection provided for the engines by the electronic propulsion control system was the gearbox engagement time delay function, which had only been configured for the emergency stop procedure. Because of this, the propulsion control strategy for the River Runner 150 craft placed a high reliance on the skill and competence of the operator to reduce the likelihood of stalling the engines.

Even though the propulsion drive train changes were designed and carried out by the vessels' builder and were formally approved by the MCA, it is apparent from the number of similar engine stalls discussed in paragraph 1.16.1 that there is a strong case for Thames Clippers to carry out a review its propulsion control strategy for the River Runner 150 vessels. As part of that review, the company should explore all reasonably practicable technical options that are available to them in order to assist its masters and reduce the risk of stalling the engines.

2.7 EMERGENCY RESPONSE

2.7.1 Command and control

The feedback received from the passenger questionnaires after the accident pointed to weaknesses in command and control during the emergency response. Several of the passengers felt that the crew were unable to cope because they were suffering from shock and had not been trained to deal with such emergency situations.

The passengers' perceptions were most probably influenced by the lack of communication and information flow during the crew's initial response to the accident. As the master did not make any information broadcasts following the contact, the passengers did not know what had happened and did not receive any reassurance. Furthermore, because the initial efforts of the mate and the CSA were concentrated on the injured passengers in the main cabin, the passengers on the after deck were not checked.

Once manoeuvring control had been re-established and *Moon Clipper* was safely berthed alongside, the master referred to his emergency procedure checklists. This action prompted the mate's damage assessment but did not lead to the passengers being formally mustered or a headcount being undertaken prior to their disembarkation and their dispersal from the pier as recommended in the emergency procedure checklist for collisions **(Annex B)**.

2.7.2 Crew resources

It was apparent that crew resources were severely stretched following the contact. However, the crew were experienced in the roles they had on board *Moon Clipper* and had participated in regular emergency drills. Furthermore, they had completed all the training courses required of them by the STCW Code and the company's SMS.

According to *Moon Clipper*'s craft operation manual, NQEA originally envisaged that a crew of four would be required to safely operate the River Runner 150 Mk3 craft. That manning level was based on the anticipated crew resources required for her intended operations in Northern Ireland. It was expected that two deckhands would be needed during normal mooring operations and all four crew would be needed to prepare the LSA and control the passengers in an emergency. However, due to the type and location of operations undertaken by Thames Clippers, the MCA set the safe manning level at three.

In addition to the reduction in the number of crew required to operate the River Runner 150 craft on the River Thames between Putney and Margaretness, the anticipated competency levels were also lowered. As the Thames Clippers' HSC were typically secured to the piers by one rope, only one person was required during mooring and unmooring operations. Therefore, instead of carrying two qualified deckhands, *Moon Clipper* carried a CSA, and the mate was tasked to secure and let go the ropes.

The mate also had a key command and control role to play during the emergency, and was responsible for the overall control of the passengers. However, as he was the only person competent to secure the vessel alongside and carry out the damage assessment, he had to leave the CSA to manage the passengers alone for short periods during the initial first-aid stage of the emergency response. Had the third crew member been a qualified deckhand, the mate could have delegated those tasks and remained with the passengers.

The crew had received crisis management and human behaviour training, and had been told the benefits of identifying and utilising willing and capable passengers. After the contact, some of the injured passengers were helped by their fellow passengers, but the crew had little or no control over this process and the lack of co-ordination and control of all the resources available almost certainly led to the aggressive stance taken by one passenger to the mate.

The crew's response to the emergency situation was adversely affected by the injury to the CFR and, possibly, to a lesser extent, the CSA. Even though the CFR was not a recognised member of crew on board *Moon Clipper* and was not allocated an emergency role on the muster list, he was trained to assist in an emergency situation and was categorised as a crew member when he served on board the larger River Runner 200 craft. However, since the CFR was not formally a member of the crew and was not always carried, his incapacitation should not have led to the crew being overwhelmed due to a lack of resources.

This was a low level emergency situation where the damage to the vessel was limited, the injuries suffered were minor, and the number of passengers on board was less than half *Moon Clipper*'s maximum carrying capacity. Had either the damage to the vessel or the extent of the injuries been greater, the crew's ability to cope would have been questionable, particularly if there had been a need to abandon to the liferafts.

2.7.3 Dispersal of the passengers

As the crew resources were extremely stretched immediately following the accident, and some passengers were venting their frustration, disembarking the uninjured passengers appeared to be the best option available. However, because the pier was not manned by either LRS or Thames Clippers' staff at that time of day, there was no one to assist in the mustering of passengers at a safe assembly point ashore, where a headcount could have been carried out.

It is likely that the vast majority of marine accidents involving passenger vessels on the River Thames will result in passengers having to be disembarked via the river's piers. If, as seen in this instance, the passengers and crew are not going to be formally assembled and accounted for prior to being allowed to disperse, then there is little benefit in recording passenger numbers in the first place.

Taking into account the emergency response shortfalls identified following this accident, and the lack of resources available to assemble and account for passengers following an emergency disembarkation via the piers, it is apparent that there is a strong case for both Thames Clippers and the MCA to review and enhance the current crew manning levels and/or competency requirements for the two River Runner 150 craft.

2.8 SAFETY MANAGEMENT

2.8.1 Application of the HSC and ISM Codes

The domestic passenger ship safety management code was not considered appropriate for UK domestic HSC due to the speeds at which they travel. Therefore the MCA required Thames Clippers to apply the risk based methodology set out in the HSC Code and develop an SMS that complied with the ISM Code. Although several SMS related documentation issues were identified during this investigation, it was evident that the company had made significant improvements to its SMS and its MMS following the application of the HSC and ISM Codes.

It was also apparent that, in line with the objectives of the ISM Code, Thames Clippers had aggressively promoted a strong safety culture among its employees and demonstrated a desire to strive for continual improvement. The drive train changes were carried out to improve operational performance and reliability, and the engine stall alarms were fitted as a result of lessons learnt by the company from previous incidents.

The safety and maintenance management improvements made by Thames Clippers, in close consultation with its local MCA office, over the past 5 years demonstrate the benefits associated with the application of these international standards to domestic high-speed passenger craft.

2.8.2 Audits and inspections

Even though the major changes carried out to the River Runner 150 craft were approved by the MCA, the ISM Code audit process failed to identify that some of the core documents required by the HSC Code had not been amended to reflect them. The lack of current operational information and guidance in the River Runner 150 craft operation and maintenance manuals constituted an ISM Code non-conformity. Given the level of resource Thames Clippers has committed to enhancing the company's SMS and MMS, after 5 years these anomalies should have been identified and addressed.

SECTION 3 - CONCLUSIONS

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

1. *Moon Clipper*'s contact with Tower Millennium Pier resulted from the use of a critical component within the vessel's steering control system that had earlier been identified as defective. [2.2.1]

2. The steering control system joystick's centring spring suffered a fatigue fracture and failed after less than 5 months' use because its designed estimated cycle life had been exceeded. [2.4]

3. The Kobelt 7165 non-follow up joystick was not designed for, or robust enough for, the type of continual use it was exposed to on board *Moon Clipper* when used as her primary means of steering control. [2.4]

4. Thames Clippers' River Runner HSC were susceptible to engine stalls when the bridge propulsion control levers were pulled directly from ahead to astern. [2.5]

5. The steering control system and propulsion drive train configuration changes carried out by Thames Clippers were intended to improve system reliability and therefore vessel safety. However, it was apparent that both interventions probably contributed to the accident. [2.6]

3.2 OTHER SAFETY ISSUES IDENTIFIED DURING THE INVESTIGATION ALSO LEADING TO RECOMMENDATIONS

1. It was apparent that crew resources were severely stretched following the accident. Had either the damage to the vessel or the extent of injuries been greater, the crew's ability to cope would have been questionable, particularly if there had been a need to abandon to the liferafts. [2.7.2]

2. Thames Clippers had made significant improvements to its SMS and MMS following the application of the HSC and ISM Codes in 2008. However, *Moon Clipper*'s Craft Operation and Maintenance manuals did not reflect the major drive train and steering control configuration changes undertaken by the company. [2.8]

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

1. The majority of injuries suffered by the passengers and crew were the result of them hitting projections and hard edges when they were thrown forward on impact. [2.2.2]

2. Although the vessel remained in service with a known defect on a critical system, the master had identified a control measure that, if fully implemented, would have prevented the accident. [2.3.1]

3. The recording of the passenger figures during the 70 second passage across the river immediately before the steering control failure, distracted the master and adversely affected his approach to the pier and his response to the developing situation. [2.3.2]

4. The speed of approach significantly magnified the consequences of the steering control failure. [2.3.3]

5. The emergency response by the crew lacked command and control; information broadcasts were not made, passengers were allowed to disperse without a headcount having been taken, and passenger resources were not fully co-ordinated. [2.7.1]

SECTION 4 - ACTION TAKEN

Collins River Enterprises Ltd (Thames Clippers) has:

- Submitted a proposal for approval by the MCA to reposition the River Runner 150 craft's steering control system joystick and propulsion control levers from the bridge console to the arms of the master's chair.
- Added a 3-monthly schedule for the replacement of the steering joystick centring spring to its planned maintenance system.
- Re-labelled the main and emergency steering controls on the bridge console to reflect the configuration changes made in 2009.
- Issued a fleet operational memo reminding its employees of the company's procedure for recording passenger numbers and the importance of eliminating unnecessary distractions from the bridge.
- Hard wired the Thames AIS wireless keypads in the passenger cabins on board *Moon Clipper* and *Sun Clipper*.
- Undertaken to:
    - Carry out a comprehensive review of its masters' type rating and revalidation process, paying specific attention to berthing, hydraulic steering systems, engine restart procedures and minimum critical system requirements.
    - Carry out a thorough review of all its craft operating manuals and update the River Runner 150 manuals to reflect the current status of the vessels.
    - Investigate and apply a suitable method of padding the steel handrails on the passenger cabin seats.
    - Provide enhanced additional crisis management and human behaviour training to its CSAs.
    - Provide additional crew resource management training for its masters.
    - Provide an emergency passenger announcement prompt card on the bridges of its vessels.

The **Port of London Authority** has:

- Conducted a thorough investigation into the circumstances of the accident and has worked closely with Thames Clippers to resolve some of its concerns.
- Written a letter to Transport for London, repeating its concerns about the out of hours staffing levels of the river's major piers.

Kobelt Manufacturing Ltd has:

- Improved the design standards for the centring springs fitted to its 7165 type non-follow up joysticks.
- Advised its worldwide network of distributors of the spring failures and subsequent design changes.
- Instructed its distributers to replace the existing springs with the new springs.
- Changed the springs fitted to all the joysticks used by Thames Clippers.

SECTION 5 - RECOMMENDATIONS

Collins River Enterprises Ltd (Thames Clippers) is recommended to:

2012/139 Carry out a review of the current crew resources and critical system configurations on board its River Runner 150 craft, in order to ensure that:

- The crew are sufficiently resourced to operate the vessels safely and deal with all reasonably foreseeable emergency scenarios.
- All reasonably practicable technical options have been considered in order to minimise the level of reliance placed on the operator to prevent engine stalls.
- The current steering control system configuration, and any future proposed changes, fully meet all appropriate technical standards.
- The information, guidance and FMEA contained in the craft operating manuals fully reflect the vessels' current machinery configurations.

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

2012/140 Assess the actions taken by Collins River Enterprises Ltd as a result of the safety issues identified in this report including, specifically:

- Seeking reassurance that the company's steering control system changes have been subjected to an appropriate technical review process.
- Verifying that the manning and competency levels on board Thames Clippers' River Runner 150 vessels are appropriate.

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

Marine Accident Report

INVESTORS IN PEOPLE