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THE OFFICE OF TRANSPORT SAFETY INVESTIGATION

*safe and reliable transport services for new south wales*

# Ferry Safety Investigation Report

## Cockatoo Island

19 February 2004

## *'Betty Cuthbert'* – Collision with wharf


Investigation Report

Passenger Transport Act 1990

# Office of Transport Safety Investigation

**The Australian Transport Safety Bureau's report of the investigation**

**into the Sydney Ferries accident involving**

**the collision of the ferry**

## *Betty Cuthbert*

**at Cockatoo Island on 19 February 2004**

# *Betty Cuthbert*

*Betty Cuthbert*

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# 1.0 Executive summary

At approximately 0920 on 19 February 2004, the Sydney Ferries river catamaran *Betty Cuthbert* collided with Parramatta wharf on the north-eastern corner of Cockatoo Island. Two passengers and the master were injured in the collision and the vessel sustained severe damage to the bow of its port hull. The wharf also sustained some damage.

After leaving Circular Quay at 0908 with 13 passengers and 3 crew on board the vessel had proceeded west at approximately 23 knots en route to Parramatta on a scheduled service. The master was controlling the vessel from the midships position in the wheelhouse and the general purpose hand and the cashier were in the wheelhouse with him.

At approximately 0920 the master received 'speed' and 'steering' alarms on the wheelhouse monitoring panel for the starboard propulsion system. At the time, the vessel was approaching Cockatoo Island from the east and was estimated to be approximately 200 m off Parramatta Wharf located on the north-eastern side of the island.

The master reacted to the alarms by attempting to reduce the speed of both main engines but only the port main engine slowed in response to his command. The starboard engine continued to operate at maximum ahead revolutions and the asymmetrical thrust caused the vessel to start turning towards the Island.

The master then attempted to slow the vessel by reversing the thrust of the rotatable propeller/rudder units. The port unit responded to his control input but the starboard unit did not rotate and continued to drive ahead at maximum revolutions. With the port unit now thrusting astern, and the starboard unit thrusting ahead, the vessel's rate of turn to port increased.

*Betty Cuthbert* was rapidly approaching Cockatoo Island and in the final few seconds before the impact the master attempted to de-clutch the starboard main engine and increased the speed of the port engine to provide 'full astern' thrust in an attempt to slow the vessel. Just before the collision he instructed the general purpose hand and the cashier to tell the passengers to brace themselves for a collision and in a last attempt to slow the vessel, he operated both main engine stop buttons.

Shortly thereafter, *Betty Cuthbert* struck Parramatta Wharf on Cockatoo Island at an estimated speed of between 15 and 18 knots. In all, from the time the master attempted to reduce the speed of both main engines after he received the 'speed' and 'steering' alarms, until the vessel collided with the wharf, the events had taken between 15 and 25 seconds.

Two passengers were injured and required hospitalisation and the master sustained a burn to his right leg. The vessel received damage estimated at $37 000. Damage to the wharf was estimated at $11 000.

Tests on the starboard manoeuvring control system, conducted after the accident, revealed that the speed transducer on the starboard main engine had failed. This caused the engine speed control and rudder/propeller control systems to be 'switched off'.

The collision was caused by a number of factors relating to the design and maintenance of the propulsion control system and the vessel operating procedures and the training of the master. In addition, Sydney Ferries have not adequately assessed the risks associated with various failure modes of the vessel's propulsion system in light of similar incidents in the past.

The investigation has identified a number of important safety actions. It is recommended that Sydney Ferries progress these safety actions through its safety management systems. The safety actions relate to:

- improvements to the vessel's operations manual
- maintenance for the flywheel speed transducers on their vessels
- the training of masters with respect to practicing contingency plans for control failures.

The report also recommends that Sydney Ferries should examine the propulsion control systems on all of their vessels in light of this accident and mitigate the risks of these systems failing.

## 2.0 Methodology

In accordance with OTSI's requirements, the investigation was conducted by the ATSB according to principles similar to those set out in Australian Standard AS 5022-2001, Guidelines for Railway Safety Investigation.

The report's terms of reference were to:

1. Identify the contributory factors which led to the accident;
2. Identify whether the incident type might have been anticipated and assess the effectiveness of the STA risk management strategies adopted;
3. Assess the adequacy of the emergency response to the incident as it affected the safety of all persons involved; and,
4. Advise on any matters arising from the investigation that would enhance the safety of ferry operations.

The objective of the investigation was to determine the circumstances surrounding the accident and provide information to prevent the recurrence of similar events.

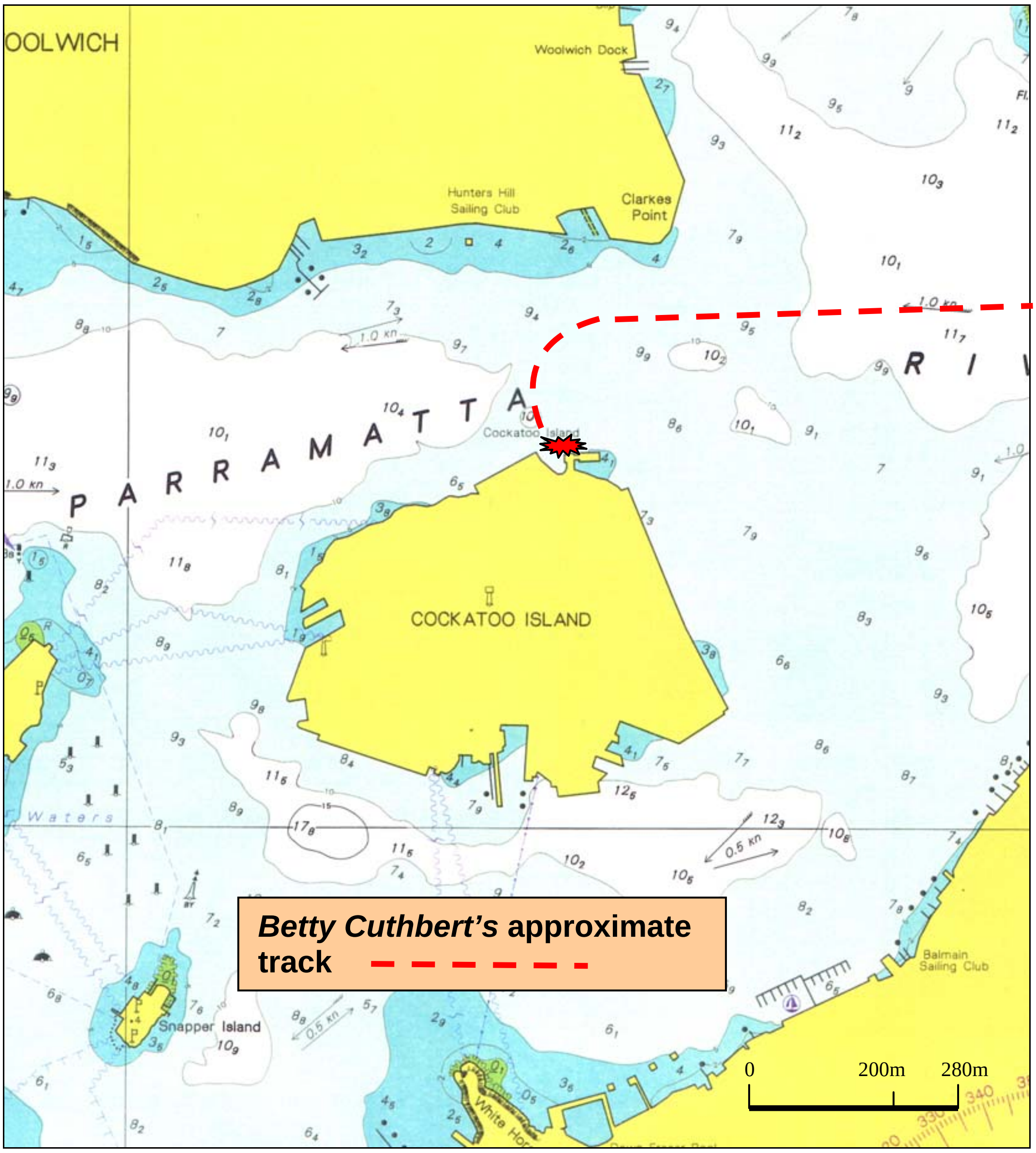
A systemic investigation approach was adopted to identify both human and organisational issues. The investigation has identified and analysed the issues relevant to the terms of reference and has recommended a number of safety actions.

The format adopted by this report is to present the factual information surrounding the accident, the analysis of those facts and the conclusions reached.

# 3.0 Factual information

## 3.1 Overview

At approximately 0920 on 19 February 2004, the Sydney Ferries river catamaran *Betty Cuthbert* collided with Parramatta wharf on the north-eastern corner of Cockatoo Island. Two passengers and the master were injured in the collision and the vessel sustained severe damage to the bow of its port hull. The wharf also sustained some damage.




## 3.2 The accident

At approximately 0908 on 19 February 2004, the Sydney Ferries river catamaran, *Betty Cuthbert* left Circular Quay on a scheduled passenger service to Parramatta. There were 13 passengers on board and three crew including the master. After leaving Circular Quay the vessel proceeded west, up the Parramatta River, making headway at approximately 23 knots. The master was controlling the vessel from the midships position in the wheelhouse and the general purpose hand (GPH) and the cashier were in the wheelhouse with him.

At approximately 0920 the master received ‘speed’ and ‘steering’ alarms on the wheelhouse monitoring panel for the starboard propulsion system. At the time, the vessel was approaching Cockatoo Island from the east and was estimated to be approximately 200 m off Parramatta Wharf located on the north-eastern side of the island.

The master reacted to the alarms by reducing the main engine speed setting levers on both Schottel control hand wheels. At the same time he asked the general purpose hand to go to the starboard engine room to investigate the alarms. He then noticed something else on the console and told the general purpose hand to wait. The port main engine was now slowing in response to the master’s command, however the starboard engine continued to operate at maximum ahead revolutions which caused the vessel to start turning to port.

The master could see that the vessel was turning to port and attempted to slow the vessel by rotating both Schottel control hand wheels to reverse the thrust of the Schottel units. The port Schottel responded to his control input but the starboard Schottel unit did not rotate and continued to drive ahead at maximum revolutions. With the port Schottel unit now thrusting astern and the starboard Schottel unit thrusting ahead, the vessel’s rate of turn to port increased.

The master could see that the vessel was rapidly approaching Cockatoo Island and he attempted to de-clutch the starboard main engine using the speed/clutch control lever on the hand wheel but failed. He also increased the speed of the port engine to ‘full astern’ in an attempt to slow the vessel. The vessel continued to turn sharply to port and close on Parramatta Wharf, the collision was only seconds away. At about this time the master instructed the general purpose hand and the cashier to tell the passengers to brace themselves for a collision and in a last attempt to slow the vessel, the master operated both main engine stop buttons on the main engine panel.

Shortly thereafter, *Betty Cuthbert* struck Parramatta Wharf on Cockatoo Island at an estimated speed of between 15 and 18 knots. In all, from the time the master attempted to slow both main engines after he received the ‘speed’ and ‘steering’ alarms, until the vessel collided with the wharf, the events had taken between 15 and 25 seconds.

Immediately after the collision *Betty Cuthbert*’s master instructed the crew to check for injured passengers. He contacted Sydney Ferry Control and Sydney Harbour Control to inform them of the accident and that two passengers had been injured. The time was 0921. The master then started the port main engine and berthed *Betty Cuthbert* alongside the pontoon adjoining Parramatta Wharf.

## 3.3 Injuries

The impact caused some passengers to lose their footing and a passenger who was standing on the fore deck was injured when she was thrown forward onto the starboard bow rail. A second passenger sustained an injury to her wrist. Both passengers were hospitalised. The master's lower right leg was burned when a kettle full of hot water located on the console at the rear of the wheelhouse was thrown forward by the impact. Subsequently, Sydney Ferries initiated a program to manufacture and fit holding brackets to hold generic issue kettles in place in the event of abnormal movement or stopping of the vessels.

## 3.4 Loss or damage

The bow of the *Betty Cuthbert*'s port hull, above the waterline, was severely damaged by the impact and the wharf had also sustained some damage to its timber facing and concrete deck.

*Betty Cuthbert* received damage to the shell plate and frames on the port hull, estimated at $37 000. Damage to Parramatta Wharf on Cockatoo Island was estimated at $11 000.

***Betty Cuthbert***

***Parramatta Wharf, Cockatoo Island***

## 3.5 Workers involved

### 3.5.1 Master

The master was 34 years old and was certified as a master class IV and a marine engine driver class II. He had completed his type rating on river catamarans in May 2002 and had been working as master on them since then. He had been permanently rostered as one of *Betty Cuthbert*'s masters for 6–8 weeks prior to the collision.

In the week before the accident, the master had been rostered off until he worked between 0615 and 2015 on the two days prior to the 19$^{th}$. On the day of the accident he had commenced duty at 0615 for a 14 hour shift. His fatigue index was 51 at the time of the incident.

## 3.6 Fatigue

The fatigue index score for *Betty Cuthbert*'s master was calculated using the Fatigue Audit InterDyne (FAID) software program using his work roster for the seven days prior to the accident. The FAID program is primarily a rostering tool which takes account an individual's duration and timing of work and break periods (including circadian effects) and the human limitations of sleep recovery over the preceding seven day period to calculate a fatigue index score for a given time. When used as an investigation tool the resultant fatigue scores may be used as a guide to indicate what effect fatigue may have had on an individual's performance.

The master's score of 51 at the time of the accident is well below the designated 'high' range of 80–100 and so fatigue is not considered to be a factor in the accident.

## 3.7 Health and fitness

Sydney Ferries masters and engineers require a medical examination every five years when they revalidate their certificates of competency. The master involved in the accident had a valid current medical certificate. There were no issues relating to medications or illicit drugs.

The master was breath tested after the accident by Water Police with negative results for alcohol.

## 3.8 Vessel information

### *3.8.1 Betty Cuthbert*

*Betty Cuthbert* is one of seven river catamarans in the Sydney Ferries fleet. These vessels operate commuter and tourist services within the confines of Port Jackson, Parramatta and Watson's Bay.

*Betty Cuthbert* was built in 1992 by NQEA Australia in Cairns. The vessel is twin hulled with welded aluminium hulls and a foam cored fibreglass (GRP) superstructure containing the passenger cabin, wheelhouse, engine rooms and toilets. The vessel is 36.8 metres in length, has a beam of 10.5 metres and a maximum draught of 1.35 metres. *Betty Cuthbert* has a displacement of 58 tonnes and can carry up to 230 passengers. The normal crew consists of two or three, depending on the passenger load and includes the master, a general purpose hand (GPH) and a cashier if there is more than 150 passengers.

The vessel is fitted with two Detroit 8V 92TA two stroke diesel engines which develop 373 kW at 2100 rpm. The main engines are clutched into reduction gearboxes which drive Schottel 360 degree steerable rudder/propellers located inside the line of each hull at the vessel's stern. The Schottel units have a 'puller' propeller which is forward facing for ahead thrust with the rudder section aft of the propeller. The vessel's designed operating speed is approximately 22 knots.

*Betty Cuthbert* is under New South Wales Waterways Authority survey and is classed as a 1E vessel for up to 230 passengers and 1D for passenger loads less than 150.

### 3.8.2 Vessel inspection

After the incident *Betty Cuthbert* was towed back to Sydney Ferries' maintenance shipyard at Balmain where the vessel's propulsion system was tested. The following checks were carried out to determine the cause of the control failure:

- Battery status
- Battery chargers

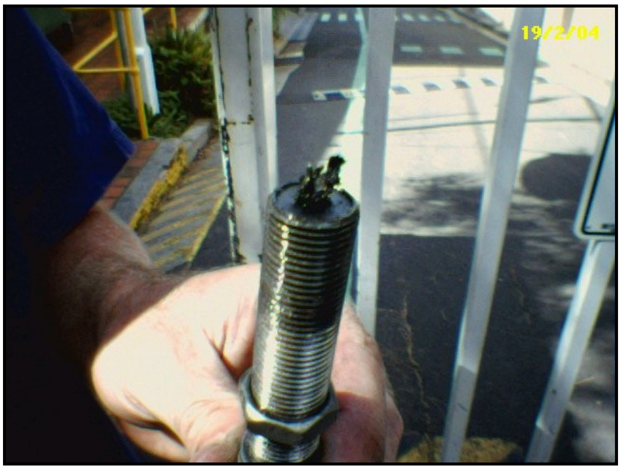
- Status and operation of the Speedronic control units
- 24 V system including wiring (engine control and Schottel unit control)
- Mechanical components of the control systems
- Emergency stops for the main engines, manual and electrical.

The investigation revealed that the starboard main engine's fuel rack was still in the full fuel (full speed) position and the starboard Schottel unit was in the ahead position. The main engine emergency stop had not been actuated and the normal engine stop was tested and found to operating correctly. No abnormalities were found in the 24 V supply system. These observations suggested that there was failure in way of the engine's speed control system (Speedronic) and/or the Schottel vectoring electronics. Further inspection revealed that the flywheel transducer for the main engine speed sensor had accumulated some ferrous debris which had caused the speed sensor to operate incorrectly.

This effective failure of the speed sensor resulted in the Schottel controls 'switching off' which meant that the Speedronic engine speed control and the Schottel unit remained in their last set position prior to the failure. In this case, with the Speedronic set at maximum engine speed and the Schottel unit vectored for maximum ahead thrust.

The report stated with regard to the master's attempt to declutch the main engine:

> It should be mentioned that the clutch arrangement does not allow for the engagement or disengagement whilst the engine rpm is at maximum, (the reason the Master was unable to clutch out).




***Starboard main engine flywheel speed transducer showing debris on end***

### 3.8.3 Engine control and monitoring system

*Betty Cuthbert's* main engines are controlled and monitored by independent electrical/electronic systems manufactured by the vessel's builder NQEA. The system provides for starting, stopping (both normal and emergency), monitoring and automatic shutdown for various engine parameters like lube oil pressure and cooling water temperature, clutch control and various engine/clutch instrumentation. The system also includes the various alarm panels and the electronic engine speed sensing unit which includes the flywheel transducer. There are various connections between the system and the Schottel control system including the engine speed sensor and the alarm panels.

### 3.8.4 Schottel control system

The Schottel control system consists of two parts:

- the Speedronic system which sets engine speed and controls the engaging and disengaging of the clutch
- the Co-Pilot control which is an electro-hydraulic control system for rotating the rudder/propeller units.

Both systems are integrated into a single operating hand wheel for each engine/clutch/propeller/rudder unit located in the wheelhouse at the three control positions, i.e. midships, port and starboard bridge wings.

The Speedronic system consists of:

- the speed/clutch control lever located on each control hand wheel
- a back-up swivel switch (located in the wheelhouse midships position) for emergency engine speed control
- the control electronics and the speed setting unit which are located in each engine room (the speed setting unit is a mechanical system with an electric motor and gears which drive a cable attached to the engine's governor).

After the engine is started, the Speedronic system is 'switched on' by the engine's control system (the NQEA system) and then the clutch and the engine's speed can be adjusted by the master using the speed/clutch control lever. The first 'step' in the control lever engages/disengages the clutch and further movement increases the engine speed. If the Speedronic control system fails, or there is a failure of the 24 V supply to the system, a relay drops out and activates the 'speed' alarm on the monitoring panel in the wheelhouse. This relay also connects the back-up swivel switch to allow the engine speed to be adjusted using this back-up control system.

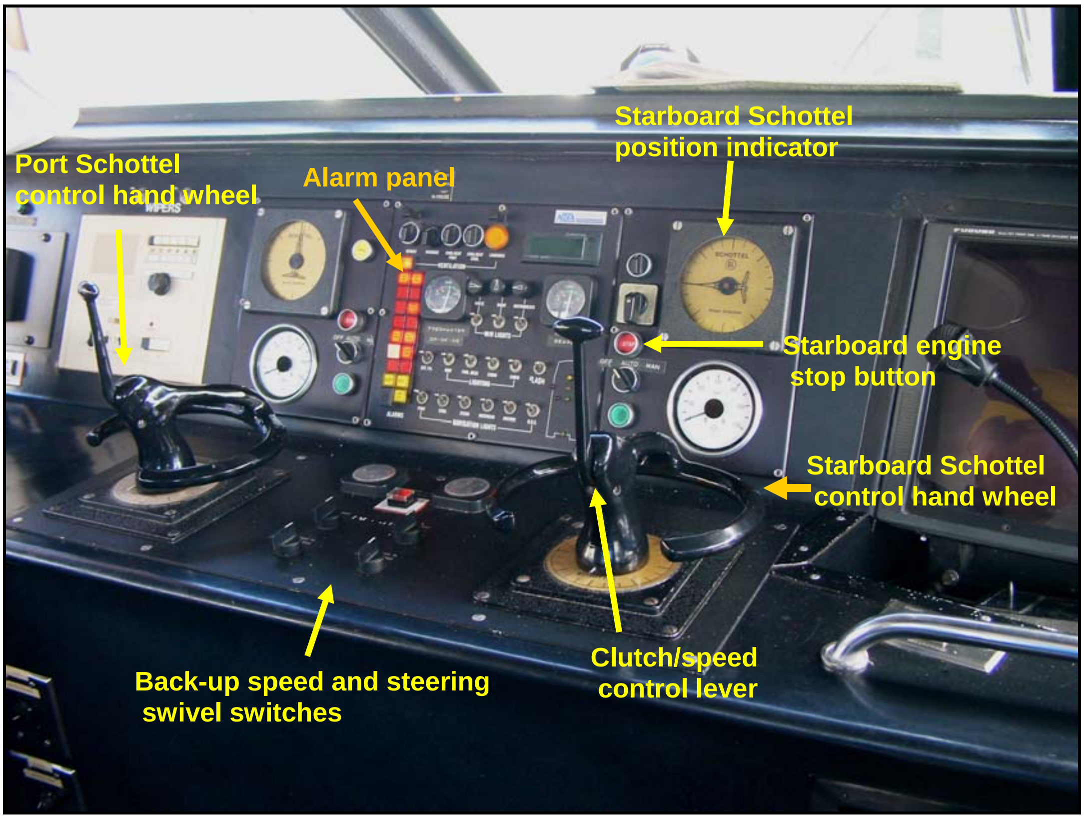
A clutch 'engaged' indicator light and a clutch control selector switch are located on the forward console in the wheelhouse midships position. In normal operation the switch is set to 'Auto' which means the clutches are controlled using the Schottel speed/clutch control lever on the hand wheels. The clutches are interlocked to prevent engagement above engine idle speed or disengagement at maximum engine speed.

The Co-Pilot control system for each rudder/propeller unit consists of:

- the control hand wheels located in the wheelhouse
- a back-up swivel switch (located beside the engine speed back-up swivel switch)

- an hydraulic pump (driven by the engine)
- an hydraulic motor and solenoid valve which rotates the rudder/propeller unit
- position feedback potentiometers for control and indication
- the electronic control unit located in each engine room.

After the engine is started, the Co-Pilot system is 'switched on' by the engine speed sensor. The master may then rotate each rudder/propeller unit by rotating the appropriate hand wheel in the wheelhouse. The Co-Pilot control system compares the position of the hand wheel with the position of the rudder/propeller unit, and operates the hydraulic solenoid valve to drive the hydraulic motor in the corresponding direction to rotate the unit to the desired position. A position indicator for each rudder/propeller unit is mounted at each control station in the wheelhouse. These indicators operate independently from the control system. In the event of a failure of the Co-Pilot electronic control system, a relay will automatically engage the back-up swivel switch and activate the 'steer' alarm on the monitoring panel in the wheelhouse. The back-up swivel switch is hard wired to the hydraulic control solenoid and is independent of the Schottel electronic control system.




***Wheelhouse midships control position***


***Wheelhouse engine control panel, Schottel control system-starboard engine room***

### 3.8.5 Main engine stops

*Betty Cuthbert* is fitted with two forms of main engine stops, the 'normal' system, and an emergency system. The usual method of stopping the main engines is via the 'normal' stop buttons located on the engine console to starboard of the midships control station in the wheelhouse. These buttons activate the stop solenoids on each main engine's governor. These stops are switches wired in parallel with the engine lube oil pressure and cooling water temperature trips. When the stop button is actuated, shut down occurs immediately by energising a solenoid which closes a flap on the engine's air intake to stop the engine.

There is also a pressure switch inhibitor with a 9 second delay timer which occurs only during main engine start up in order to build up oil pressure and inhibit the air flap from shutting down the main engine prematurely.

The 'emergency' stop mechanism is fitted outside the wheelhouse at the Emergency Fire Control stations located adjacent to the engine rooms at the stern of the vessel. In the event of a 24 V power supply failure, the air flap may be manually tripped by pulling a cable that shuts the air flap depriving the engines of combustion air.

### 3.8.6 Maintenance of the propulsion control system

*Betty Cuthbert*'s propulsion control system is not specifically included in the vessel's planned maintenance system. The system is tested, including the operation of the back-up steering controls, as part of the start up procedure each day. Defects are reported and repaired as required.

The flywheel transducer for the engine speed sensor would have been checked/renewed when the starboard main engine was replaced with an overhauled spare on 17 February 2003.

### 3.8.7 Digital emergency announcements

*Betty Cuthbert* is equipped with a push button information broadcast system, which is capable of playing pre-recorded announcements to passengers at the press of a button on the wheelhouse control panel. The system is described in the vessel operations manual.

Message No. 3 is described as the 'alert for impending incident/danger' and contains the following message:

> *Attention passengers! We are currently experiencing some difficulties. It is important to remain seated of if standing, hold onto something secure. Please listen carefully for instructions from the crew.*

Message No. 4 is described as 'incident has occurred' and contains the following message:

> *Attention passengers! An incident has occurred. Please remain calm and follow all instructions from the crew.*

## 3.9 Wharf details

Cockatoo Island is the largest of the island in Port Jackson and lies approximately two miles west of Sydney Harbour Bridge. It is owned by the Commonwealth Government and is currently administered by the Sydney Harbour Federation Trust. Parramatta Wharf lies on the north-eastern corner of the island and is used to access the island. The wharf is orientated in an east-west direction and has an adjoining pontoon. The wharf is timber piled and has a concrete deck which is faced with timber.

## 3.10 Environmental factors

On February 19, a high tide was predicted in Sydney at 1.86 m at 0826. At the time that *Betty Cuthbert* collided with Parramatta Wharf at 0920, the tide had not started to ebb. The weather forecast predicted fine conditions and slight seas with wind from the south/south-east at 10 to 15 knots. None of these environmental factors are considered to be relevant to the collision.

Visibility was good, and there was no other traffic in *Betty Cuthbert*'s immediate vicinity at the time of the accident.

## 3.11 Recorded information

*Betty Cuthbert* was not equipped with a data logger or event recorder at the time of the collision. There is no evidence, other than the statements of the crew, as to the sequence of events aboard the vessel.

## 3.12 Identified safety management systems

Sydney Ferries have an integrated Quality, Safety & Environmental management system based on the ISO 9001-2000 standard and the

International Safety Management (ISM) code. Implementation of the system started in July 2002 in response to a recommendation of the 'Taylor' report[1].

The management system is described in three levels of documentation. Level one consists of the Quality, Safety & Environmental Policy/Objectives Manual. Level two is the Quality, Safety & Environmental Procedures Manual. Level three consists of a number of functional shore and ferry procedures and operating instructions, which support the level two Quality, Safety & Environmental Procedures.

The level three document, Fleet Instructions Manual (FIM) contains general operational procedures for the whole fleet with vessel specific procedures contained in a Vessel Operations Manual for each vessel or class of vessels.

Section 2.6 of the Fleet Instructions Manual (FIM) (level three) provides instructions on vessel manoeuvring and includes contingency plans for control failures which refer to the vessel operations manuals. Section 5.2 of the FIM contains instruction for the operation of the safety and information message system.

The 'Vessel Operations Manual Rivercat Class' contains various relevant procedures including a description of the 'Main Engine and Steering Controls' (VOMRC03.2), 'Vessel Start-up Procedures' (VOMRC04.1), and the 'Fleet Emergency Response Plan'.

## 3.13 History of similar occurrences

There have been a number of instances where Sydney ferries river catamarans have experienced control failures and subsequently collided with other vessels or wharves in the past. Several of these accidents have involved the failure of at least one side of the vessel's main 24 V system with the consequent loss of control of either one or both main engines. Another incident involving *Nicole Stevenson* prompted a review of the propulsion control systems on the river catamarans.

On 13 March 2002, the river catamaran *Nicole Stevenson* was involved in a collision with another vessel while berthing. The master reported that the propulsion control system had malfunctioned and that he had lost steering. Although subsequent investigation did not reveal a fault with the system, the possibility of an intermittent fault could not be excluded. The incident prompted Sydney Ferries to engage Forgacs Ship Repair in conjunction with Schottel, to inspect all of the river catamarans' control systems. The scope of work included:

- Ship check the ship builder/OEM electrical drawings to the "as fitted" condition of the vessels and verify those anomalies;
- Review drawings and nominate any deficiencies;

[1] The Taylor report is a review of Sydney Ferries operations carried out by the Chief Executive of the Waterways Authority, Mr Matthew Taylor, assisted by Mr Peter Medlock and his associates. The report was commissioned by the Minister of Transport after a number of ferry accidents early in 2001.

- Make recommendations to enhance the serviceability/maintenance of electrical systems by improvements or additions to the drawing list;
- Review emergency operation of electrical supply on alarm and control systems when in “emergency” or supply “change over” modes.

The priorities are

- Power supplies
- Steering
- Engine Controls
- Alarm and monitoring
- Navigation
- Fire Alarms
- Lighting
- Other systems

Schottel completed the scope of work and made some small repairs to their equipment on various vessels. Their report stated that they found no faults on *Betty Cuthbert*’s control system and the speed and steering back-up controls and their automatic change-over operated satisfactorily.

There have also been incidents on other classes of ferries which are relevant to the *Betty Cuthbert* collision. One collision involved the First Fleet class vessel *Sirius* on 2 July 2002. The ferry was in the process of berthing when its starboard main engine shutdown. The ferry collided with the wharf but there was little damage. Subsequent investigations revealed that the signal wire from its flywheel speed transducer had been damaged and the engine control system had shut the engine down when the signal was lost.

## 3.14 Training for masters

Sydney Ferries have had a documented process for the initial type training of river catamaran masters for several years although the training has developed considerably since the introduction of the quality management system in July 2002. All Sydney Ferries crews including masters, engineers and GPHs, are required to hold the appropriate type rating for the vessel they are employed on. The type rating system is designed to ensure that the crews have a good working knowledge of their vessels including appropriate contingency plans for emergency situations.

The current Quality, Safety & Environmental Procedures Manual contains a procedure for ‘Familiarisation, Training and Assessment Programs’ (PROC64.06.01). This procedure sets out the general requirements in respect of personnel training including type rating for masters.

Type rating qualifications for masters and engineers require annual revalidation assessment. To maintain a type rating masters and engineers are required to have worked 24 shifts on the relevant vessel type in the previous 12 months with at least six of the shifts in the previous 3 months.

### 3.15 Emergency response actions

Neither of the relevant recorded emergency announcements was played by the master either before or after the collision. The GPH and the cashier were in the process of warning the passengers when the vessel collided with the wharf.

Immediately after the collision, *Betty Cuthbert*'s master contacted Sydney Ferry Control and Sydney Harbour Control to inform them of the accident and that two passengers had been injured. At approximately 0930 the Sydney Ferry *Susie O'Neill* arrived alongside *Betty Cuthbert* and the uninjured passengers were transferred to this ferry and dropped off at the Valencia Street Wharf.

At 0955 an ambulance arrived at the Valencia Street wharf and the ambulance officers were transported by *Susie O'Neill* back to *Betty Cuthbert* where the officers attended to the two injured passengers. The injured passengers were subsequently transferred to *Susie O'Neill* and then transported back to the Valencia Street wharf where they were transferred to the ambulance and then to Royal North Shore hospital. During this time, various officers from Sydney Ferries had arrived to investigate the incident as had Sydney Water Police who breath tested the master.

# 4.0 Analysis

## 4.1 The collision

*Betty Cuthbert* collided with Parramatta Wharf on Cockatoo Island at approximately 0920 on 19 February 2004. The vessel's speed at the time of impact was estimated to be between 15 and 18 knots. The failure of the starboard main engine speed sensor, while the vessel was passing close to the Island at full speed, initiated a series of events which led to the vessel taking an uncommanded turn to port which resulted in the collision between 15 and 25 seconds later. (In the absence of recorded data, this time is based on the master's estimate of the vessel's distance off the wharf when he received the alarms).

Ferrous debris had built up on the flywheel transducer for the speed sensor on the starboard main engine over a period of time. At about 0920 on the day of the accident, the flywheel transducer malfunctioned and caused a contact in the speed sensor's circuit to open and 'switch off' the Schottel Speedronic and Co-Pilot control systems. As fitted, the Schottel control systems do not fail in a safe mode, because when power is lost to the control systems (or they are 'switched off'), the engine speed settings and the Schottel unit position remain as they were before the failure. This meant that *Betty Cuthbert*'s starboard engine remained at maximum speed with the Schottel unit vectored for maximum ahead thrust.

The master received 'speed' and 'steer' alarms for the starboard propulsion system when the Schottel control systems 'switched off'. These alarms were his first indications of a problem with the starboard propulsion plant and were vital clues.

The vessel was making headway at approximately 23 knots (11.8 metres per second or 42.5 kilometres per hour) in close proximity to Cockatoo Island and the control failure had had no effect on the motion of the vessel. Both main engines were still running at full speed and the vessel's heading remained unchanged. At this point the master had time, if he had realised it, to spend some time diagnosing the fault. Various instruments were available to him including the starboard shaft tachometer, clutch 'engaged' indicator light and the Schottel position indicator to show that the starboard propeller was still driving ahead at maximum revolutions. He could still control the vessel's heading even with the starboard Schottel driving full ahead as the port system was still fully operational to provide steering (it is common practice to steer the vessel using only one Schottel unit when running full ahead).

The master was not sure what the alarms meant and his first thought was to send the GPH to the starboard engine room to look at the more comprehensive alarm panel there. He then reacted instinctively and attempted to reduce the speed of both main engines using the speed control levers on his hand wheels. His intention was to slow the vessel while the GPH inspected the starboard engine room.

The master's control input resulted in the port main engine slowing but the starboard engine continued to run at maximum speed. The resulting asymmetrical thrust caused the vessel to start turning to port so that the vessel was now, turning towards, and closing rapidly on Cockatoo Island. The master had unwittingly placed the vessel at great risk and had given himself very little time to decide what his next action should be.

The master then chose to reverse the thrust of both Schottel units with the result that only the port unit moved to the astern position. This increased the asymmetrical thrust and consequently the rate of turn to port increased. By this time a collision with the Island was probably inevitable. In a final attempt to slow the vessel the master increased the port engine's speed to increase the astern thrust. He also tried to declutch the starboard main engine, and, just before the collision, operated the 'normal' main engine stops. The starboard clutch failed to disengage, as it is interlocked to prevent declutching at high engine rpm, but the evidence suggests that the engines did stop in response the stop button actuation although this was probably just before, or as, the vessel struck the wharf.

Every instinctive and usually prudent action the master took in response to the engine 'speed' and 'steer' alarms, made the vessel's situation worse. If he had done nothing other than acknowledge the alarms the vessel would have maintained its heading and passed clear of the Island.

There were several safe courses of action available to the master after the failure of the speed sensor if he had made an adequate assessment the situation. The back-up speed and steering controls for the starboard engine and Schottel unit would have been operating if the master had thought to use them. Later, after the vessel had started to turn to port, if the master had operated the 'normal' starboard engine stop soon enough, he may have had sufficient time to regain control of the vessel.

The incident was costly in terms of the injuries sustained by the passengers and master and the material damage to the vessel and wharf but the consequences could have been far more severe in terms of human casualties if the ferry been crowded.

## 4.2 Propulsion control system

**Failure safety** The design of *Betty Cuthbert*'s propulsion control system was a factor which was directly causal in the collision. The failure of the speed sensor in the engine control system 'switched off' the Schottel control systems which initiated the accident. Any failure of the power supply to the Speedronic engine speed setting system leaves the engine running at its last setting. This is not the case on other vessels in the Sydney Ferries fleet, including some of the other river catamarans, where a similar failure of engine speed sensor would have resulted in an automatic engine shutdown. Indeed after the accident, Sydney Ferries modified *Betty Cuthbert*'s control system so that in the event of the magnetic pickup sensor failure (Speed Sensor), the only instrument that will cease to operate will be the corresponding RPM gauge, and the main engine and the steering control will operate normally. In case of complete failure of the 24 Voly DC, the speedtronic control will act the same as before and the engine fuel throttle and the steering controls will be locked in the last position set up, before the fault occurred.

The original design of *Betty Cuthbert*'s propulsion control system was undertaken by NQEA in 1991. They combined the requirements of the engine and clutch/gearbox manufacturers in respect of operating, monitoring and control with those of the propulsion system supplier, Schottel. The resulting system was approved by Det Norske Veritas, who were overseeing the building of the vessels. It is evident that the usual risks to the plant had been considered in the design process with the inclusion of appropriate interlocks, engine stops, alarms etc. (low lube oil pressure, cooling water temperature, gearbox oil pressure, overspeed, clutch engage/disengage speed interlocks etc.). The risk of the speed sensor system failing was probably also considered and the Schottel provisions in respect of automatic default to independent back-up controls were probably considered to be the appropriate design strategy (rather than an automatic engine shutdown). There are inherent risks with this design strategy particularly when considering the speed of the vessel, its often fine navigation margins, and the fact that it carries passengers. In addition, for the strategy to work effectively, the operator must have a very good knowledge of the system and be prepared to revert to the back-up controls as their first course of action.

In terms of their main engines and their control and monitoring systems there are some significant differences among the seven river catamarans in Sydney Ferries fleet. While four of these vessels have been refitted with a different engine type including the complete engine control and monitoring system, three including *Betty Cuthbert* still have the original engine type. One of these is fitted with a digital engine control system and the other two including *Betty Cuthbert* have the original engine control system manufactured by NQEA.

The vessels which have been fitted with the new engines have an engine monitoring and control system, which is provided by the engine manufacturer. These systems interface directly with the Schottel control systems and in the event of a speed sensor failure the engine is shutdown. While this provides some sort of failure safety, an engine shutting down automatically during a passage or during manoeuvres in confined waters may also represent a significant risk to the vessel which needs to be assessed.

**Back-up speed controls** While *Betty Cuthbert*'s back-up speed control swivel switches are automatically engaged in the event of a failure of the electronic system, (assuming the main 24 V system is still operational), it is not always clear to the operator when these controls are available. There is nothing to signal that the controls are active and there is no way the controls can be manually engaged in the wheelhouse.

On *Betty Cuthbert* the back-up steering controls can be engaged by actuating the adjacent switch. The start up procedure requires that these controls are tested every day and masters periodically manoeuvre the vessel using these controls as training. The master stated that he had performed such a drill in the previous month. The back-up speed controls, however, cannot be engaged manually and may only be tested 'with a physical interference of the electronic control card' (according to the VOMRC). As such the master although he was aware of function of these switches (which are adjacent to the back-up steering controls) apparently had not used them in the past either as a result of a failure or during a drill. On other river catamarans the back-up speed controls can be manually engaged, like the steering controls, for regular testing and drills.

**Emergency stop** *Betty Cuthbert*'s main engine 'emergency' stop system slows the engine to a stop very quickly when the air flap on the inlet manifold is closed. This system should be an effective defence in mitigating situations like the one faced by the master on the morning of 19 February 2004. However, as fitted and described in paragraph 3.8.5 above, it is unlikely that the 'emergency' stop system would have prevented the collision even if it had been operated.

The collision occurred between 15 and 25 seconds after *Betty Cuthbert* started turning to port, towards the Island. At the time, the master had realised that the normal starboard engine and Schottel unit controls were not functioning and that he had very limited time in which to take action.

Just before the collision, *Betty Cuthbert*'s master operated the 'normal' stops for the main engines which activated the stop solenoids on the engine governors. This had the effect of stopping the fuel to the engines which probably took some time to slow to a stop, particularly with the propellers still clutched in. This may explain the master's observation that the engines had failed to stop and the fact the engines were found to be stopped after the collision.

**Maintenance** The maintenance of *Betty Cuthbert*'s propulsion control system in respect of the flywheel speed transducer is also implicated in the accident. The accumulation of debris which led to its failure probably occurred over a period of time. Although it was tested during normal daily start-up procedures, inspection and testing of the transducer was not included in any periodic maintenance routine at the time of the accident, and had it been inspected/cleaned it is likely that the failure might have been prevented.

Proximity type speed transducers will fail at some time during their service life. Many engine manufacturers, who use electronic engine governing, fit two flywheel pick-ups to provide redundancy with an automatic default to the other transducer in the event of a failure. It is a sensible precaution to include inspection/testing of these components in a periodic maintenance regime where their function is critical.

Since the accident, Sydney Ferries has instigated a maintenance routine on *Betty Cuthbert*, and the sister vessel, whereby the flywheel speed transducer is inspected/tested every 500 hours at the time of a scheduled main engine service.

## 4.3 Operating procedures

Although the master was reasonably well experienced after spending the previous two years or so on river catamarans, he did not understand the significance of the simultaneous 'speed' and 'steering' alarms and thus did not assess the situation correctly. The vessel operations manual is designed to provide masters/engineers with sufficient information to enable them to safely operate the vessel. The vessel type specific training is based on the content of this manual. In the case of *Betty Cuthbert*'s master, the 'Vessel Operations Manual Rivercat Class', (VOMRC), did not provide him with an adequate description of the control system fitted on the vessel, its failure modes, alarms or appropriate contingency plans for various types of failures.

The VOMRC is used on all of Sydney Ferries river catamarans. The 'Main Engine and Steering Controls' section, (VOMRC03.2), contains a description of the propulsion control system, including some of the differences between the vessels, various operating instructions and some warnings. Section 1, 'Main Engine Controls', contains the only description of the engine control system on *Betty Cuthbert*:

> The speed control lever on the *Dawn Fraser* and *Betty Cuthbert* is part of the SCHOTTEL-SPEEDTRONIC system. The Schottel –speedtronic is an electronic remote control device. It serves the purpose of speed adjustment of the main engines combined with a speed dependable operation of the disengaging clutch. The speed control is 'way-dependable', analogous to the direction of the speed control lever. (i.e. a given way of the speed control lever will adjust the speed of the engine). In case of electronic failure the 'time-dependable' speed adjustment will be engaged automatically. The engine speed can then be controlled by means of swivel switch, time-dependably, by passing the electronics.

This description is drawn largely from the Schottel Speedronic manufacturer's manual and at best only describes the speed setting of the engine. The description is unnecessarily technical and for an operator would be confusing. There is no mention of the role of the NQEA engine control system particularly the role of the speed sensor and flywheel speed transducer. Importantly there is no mention of any 'speed' alarm in the event of an electronic control failure.

The section entitled 'Emergency Mode' contains further information of relevance on the emergency speed controls:

> For the *Dawn Fraser* and *Betty Cuthbert* the emergency speed control is part of the Schottel system through the 'Schottel-Speedtronic' control unit. Here only the engine that has experienced a failure will go to backup control.
>
> Simulation of failure on both these vessels can only be achieved with physical interference of the electronic control card.
>
> If failure occurs due to an intermittent fault, turning the Schottel electronic control box 'off' and then 'on' again can reset the system. If this is unsuccessful advise the Controlling Officers and contact relevant technicians.
>
> If 24VDC power is lost then neither the 'NORMAL' or 'EMERGENCY' modes of control will continue to operate. The last set engine speed and Schottel direction will be maintained. Manual shutdown of the main engines must be effected (this

can only be achieved at the Emergency Fire Control stations located on the exterior of the engine rooms aft).

While this section does explain what must be done in the event of a total failure of the 24V power it does not adequately explain the lesser failure experienced on *Betty Cuthbert* before the collision. Once again there is no mention of the 'speed' alarm.

Section 2, 'Steering Controls', contains a better description of the Schottel Co-Pilot system. The 'Emergency Operation' section does state:

In the case of steering failure:

- A relay will automatically engage the backup system.
- 'Steering failure' alarm will sound.

The procedure manual contains several warnings relating to the failure of the vessel's 24 V supply due to the incidents involving this type of failure in the past. Other types of failures of the propulsion control system are not adequately described and the manual does not contain a consolidated description of the alarm panel nor the meaning of the various alarms. There is no mention in the operation manual of a clutch interlock preventing declutching at high engine speed. If *Betty Cuthbert*'s master had had this information at the time that he received the initial 'speed' and 'steer' alarms he would have been in a position to make better decisions on his course of action and the collision might have been prevented.

## 4.4 Master's training

After the failure of the engine speed sensor, *Betty Cuthbert*'s master did not try to operate the back-up engine speed and steering controls or the main engine stop soon enough. He responded to an abnormal situation with an inappropriate strategy, which ultimately led to the vessel colliding with the wharf. If he had had a better working knowledge of the vessel's propulsion control system, including some regular training in using the emergency speed controls as well as the back-up steering controls, it is more likely that he would have reverted to these controls when it was evident that the normal hand wheel controls were not responding.

The master underwent initial river catamaran type rating training in May 2002 before he was appointed as master on river catamarans. The training included a competency assessment based on a document entitled 'Rivercat Master Training and Assessment Record'. The assessment comprised a series of check boxes in several sections. The 'Wheelhouse' section included items such as; 'Alarm panel', 'Schottel control', 'Backup Speed and Steering controls', 'Clutch controls'. The 'Machinery spaces' section included; 'Schottel electronics', 'Emergency control systems'. The training was conducted under the supervision of a training master who assessed *Betty Cuthbert*'s master as 'Proficient' (Demonstrates a high level of proficiency) against these elements of competency at the time. Since his initial type rating, the master had not undergone any further type training on river catamarans as he had been employed on them continuously since and thus met the assessment criteria to maintain the type rating.

The master's initial type training was, by necessity, somewhat generic given the number of different types of river catamarans in the fleet. It is unlikely that the differences between the various propulsion control systems would have been fully explained to the master with the limited time available for the training. What was emphasised in the training at the time, was the effect of a failure of the main 24 V supply system as there had already been several accidents involving this type of failure. The master assumed that there had been a failure of the 24 V system after the starboard engine and Shottel unit failed to respond to his control hand wheel inputs. This incorrect assumption was at least partly based on the emphasis on this type of failure in the initial type training and in the VOMRC.

A failure of the main 24 V system presents symptoms almost the same as those the master experienced on 19 February. The difference when the main 24 V system fails is that neither the back-up controls nor the wheelhouse engine stops function. It is a matter of concern that if the master had made this diagnosis, that he still proceeded with an inappropriate strategy which was to try to slow the vessel and then reverse the thrust. What has to be done in the event of a 24 V system failure is to cross-connect the 24 V system on the other engine if time permits, or to shut the engine down using the manual trip on the emergency stop.

The master's initial training had not prepared him adequately to deal with the situation that arose on the morning of 19 February. His subsequent experience on the vessels had taught him that when there was trouble reduce the vessel's speed and then investigate the problem. While this appears to be good practice (and is most of the time) with the control failure which occurred on *Betty Cuthbert* it was a strategy that was dangerous. Had he been able to regularly practice using the back-up speed and steering controls, he may have adopted this as his default strategy in the event of a 'speed' and/or 'steer' alarm.

The current initial type rating system is more comprehensive than the training undertaken by *Betty Cuthbert*'s master. However it is largely based on the content of the VOMRC and thus does not include adequate instruction and 'hands on' training for all of the various failures on the different propulsion control systems.

## 4.5 Risk management

Sydney Ferries' management of the risks associated with the operation of *Betty Cuthbert* contributed to the accident on 19 February 2004 in several ways:

- The failure of the flywheel transducer was reasonably foreseeable as were the consequences of such a failure.
- The Speedronic unit fails to what can be an unsafe mode unless the master has adequate knowledge, training and presence of mind.
- There had been a number of control failures on the vessels in the past and although they have involved the main 24 V system, the

procedures do not adequately describe the system nor the appropriate contingency plans for other types of failure.

The ISM Code requires that operational risks are assessed and critical operations have specific procedures. In compliance with the Code the objectives stated in the Sydney Ferries safety management system are to:

a) Provide for safe practices in ferry operations and a safe working environment.

b) Establish safeguards against all identified risks; and

c) Continuously improve safety management skills of personnel ashore and onboard ferries, including preparing for emergencies related to both safety and environmental protection.

The risks associated with *Betty Cuthbert*'s propulsion control system were readily identifiable both in the design phase and subsequently when incidents have occurred. The technical report on the river catamaran control systems commissioned after the *Nicole Stevenson* incident in 2002, while laudable, did not really address the underlying design or human issues. The river catamaran masters need to be absolutely conversant with the failure modes of their plant and have the appropriate procedures and training for the various contingencies. These vessels operate at high speed in confined areas with large numbers of passengers on board, the master must have an appropriate 'pre-packaged' plan in his mind for all foreseeable failures which could endanger his vessel.

Regular training for masters on vessels which are out of service (to minimise the risks) with various control faults would not be practical given the size of the Sydney Ferries fleet and its service requirements. However, a vessel handling simulator could provide a useful training tool to assist the master's in developing the appropriate contingency plans for various control failures.

## 4.6 Passenger announcements

The Vessel Operations Manual contains post collision emergency instructions, but nothing on what to do in the event of an impending collision.

The pre-recorded emergency announcement was generally defined as the method of warning passengers of an emergency, including collision. The announcement is verbose and does not convey a sense of urgency to passengers which would be desirable when preparing for an impending collision with a wharf or other vessel.

To a large extent, the crew were responsible for using their own initiative to identify the need for, and selecting a means of, warning passengers of the impending collision.

In the short period of time before *Betty Cuthbert* collided with the wharf, the master did not activate the emergency announcement, despite its easy one-touch operation. This was understandable in the circumstances given his preoccupation with the vessel's situation. This reinforces the expectation that humans under the stress of an unfolding emergency are unlikely to reliably carry out the desired behaviour unless that behaviour has been firmly established through training.

The GPH and the cashier took immediate action to warn the passengers, who fortunately were few in number, to hold on.

# 5.0 CONTRIBUTING FACTORS

Reason's model of accident causation (Reason, 1990, 1991, 1997)[2] suggests that serious industrial accidents are best understood by analysing the complex interrelationship between organisational processes, local task and environmental conditions, and the actions of the people directly involved. The model describes how latent organisational deficiencies allow or create conditions that predispose errors or violations, and how unsafe acts combine with local triggering events to produce a potential accident. However, an accident only occurs when the defences designed to prevent such an occurrence are inadequate. Reason's model can be applied to provide a structured framework for sorting, simplifying and mapping the dynamic relationship between the contributing factors in an accident or incident.

## 5.1 Absent or failed defences

Defences include the 'last minute' measures designed to prevent an accident or its consequences in the face of preceding technical or human failures. They include technology, such as detection or control systems, work processes or procedures, or human awareness of and/or response to a threat. The absent or failed defences (AFDs) identified in this investigation are:

- The Schottel Speedronic unit does not 'fail safely' in that it does not stop or return the main engine speed to idle if its control electronics fail.
- The back-up speed controls cannot be manually activated to be used for practice/drills.
- The 'normal' stop for the starboard main engine would not have been effective in preventing the collision due to its delayed operation.
- The master had not planned for this type of control failure and not practiced or drilled for it.
- The master did not activate the passenger warning system prior to the collision to warn the passengers of the impending collision.
- The vessel operating procedures did not adequately describe the propulsion control system, the alarm panel, or the operation of the clutch and did not suggest appropriate actions for the failure which occurred on *Betty Cuthbert*.

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[2] Reason, J. (1990). *Human error*. New York: Cambridge University Press.

Reason, J. (1991). Identifying the latent causes of aircraft accidents before and after the event. *Proceedings of the 22nd ISASI Annual Air Safety Seminar*, Canberra, Australia. Sterling, VA: ISASI.

Reason, J. (1997*). Managing the risks of organizational accidents.* Aldershot, UK: Ashgate.

## 5.2 Individual and team actions

Individual and team actions are the things that people did or failed to do – usually errors or violations – that triggered the accident. They are a normal part of everyday operations in all industries, and result from natural human limitations in combination with conditions inherent in the task or workplace.

The actions by an individual or team that contributed to this accident were:

- The master did not interpret the initial 'speed' and 'steer' alarms correctly.
- The master applied an incorrect contingency plan which resulted in the vessel taken an uncommanded turn to port.
- The master did not actuate the main engine stop, even though its activation is unlikely to have prevented the collision because of the time delay.

## 5.3 Task, environmental and human conditions

The conditions existing immediately prior to an accident or incident influence how people act, frequently increasing the likelihood of an error or violation being committed. These conditions involve the task itself (for example, complexity, workload), the environment (for example, temperature, lighting, noise), people's physical or mental states, and social, cultural or life circumstances.

A multitude of task, environmental and human conditions can be identified following any accident. It is important to distinguish between those that contributed to the event and those that may be otherwise interesting, but were not part of the accident chain. Relevant conditions in this accident are:

- The vessel was passing in close proximity to Cockatoo Island at considerable speed at the time of the control failure.
- The master's initial training did not adequately equip him with sufficient knowledge of the vessel's control system or what to do in the event of certain types of control failures.

## 5.4 Organisational factors

Organisational factors influence the conditions under which people work. They result from management decisions, systems, processes and cultural influences. They in turn produce task and environmental conditions, which may lie dormant and undetected for many years before combining with local conditions and human actions (errors and/or violations) to breach the system's defences.

The investigation identified that the following organisational factors contributed to this accident:

- There was no scheduled maintenance of the flywheel transducer for the engine speed sensor, although it is acknowledged that Sydney

Ferries has subsequently instituted a maintenance program to inspect and clean the speed sensors every 500 hours as part of its planned maintenance program.

- The vessel operations manual was deficient in that it does not provide an adequate description of the vessel's propulsion control system or its modes of failure.
- The risks associated with various failure modes of the vessel's propulsion control system have not been adequately assessed by Sydney Ferries.
- There has not been an adequate response to similar incidents in the past.

## 5.5 Additional findings

This section lists findings on additional system deficiencies that, while not contributing directly to this accident, are nonetheless significant and in need of corrective action.

- A data logger on board *Betty Cuthbert* capable of recording alarms, basic engine parameters and the 24 V system voltage would have been of considerable assistance in determining the cause of the collision. It is noted, however, that Sydney ferries is initiating a trial of a data logging system on one of the Harbour Cats.

# 6.0 Recommendations

The following recommendations are made with a view to preventing similar incidents in the future.

1. Sydney Ferries should review the 'Vessel Operations Manual Rivercat Class' and include more comprehensive descriptions of the vessel propulsion control equipment, its modes of failure and appropriate contingency plans, a consolidated description of the various alarms and a full description of the clutch control system.

2. Sydney Ferries should ensure that flywheel speed transducers are included in the planned maintenance regimes on all of their vessels.

3. Sydney Ferries should review the design of the main engine 'emergency' stop systems on all their vessels and ensure that there is no time delay in their operation.

4. Sydney Ferries should review the training of masters and provide opportunities to practice appropriate scenarios and contingency plans for control failures.

5. Sydney Ferries should consider the benefits of simulator training for their masters to assist them to develop appropriate strategies to deal with propulsion system failures.

6. Sydney Ferries should examine the propulsion control systems on all of their vessels in light of this accident and assess the failure modes of the systems to ensure that they are sufficiently 'fail safe' and that the masters have the appropriate knowledge and training.