Report 06-201

passenger freight ferry
Aratere

heavy weather incident resulting in cargo shift

Cook Strait

3 March 2006

Abstract

On Friday 3 March 2006 at about 1644, the passenger freight ferry *Aratere* unexpectedly rolled very heavily to starboard and sheared to port while on passage from Wellington to Picton in heavy weather in Cook Strait. About 30 minutes later the ship rolled heavily several times as the Master attempted to alter course to bring the weather onto the ship's port bow and gain more clearance from the land. At about 1739, approximately one hour after the initial very heavy roll and shear, the *Aratere* again rolled very heavily to starboard and sheared to port.

During the periods of heavy rolling, some of the rail and vehicular cargo stowed on board the *Aratere* shifted and fell over after some of the securing lashings broke. This resulted in the *Aratere* developing a list of about 5° to starboard, which the crew were unable to reduce until the ship arrived in Picton.

Four passengers and one crew member suffered minor injuries but did not require hospitalisation.

Although the available evidence showed that the safety of the ship was unlikely to have been compromised, the suddenness and extent of each of the rolls were uncomfortable for all on board, frightening for some and injurious for a few.

Safety issues identified included:

- the knowledge of the handling characteristics of the ship in following and quartering seas
- the efficiency of the cargo lashing system on board the ship
- the suitability of some of the management systems to provide adequate training and backup to the ship's master
- the inexperience and lack of training of the Night Master in the use of some of the onboard systems
- the adequacy of procedures covering the dissemination of information from the International Maritime Organization.

Safety recommendations were made to the Director of Maritime New Zealand to cover some of these issues. Due to the safety actions taken by Interislander no safety recommendations have been made to it.

Photograph courtesy of Interislander

The *Aratere* in the Marlborough Sounds

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Abbreviations

°	degrees
AC	alternating current
ARPA	automatic radar plotting aid
BRM	bridge resource management
DC	direct current
DGPS	differential global positioning system
dir'n	direction
ECDIS	electronic chart display and information system
GM	metacentric height
GPS	global positioning system
HW	high water
IMO	International Maritime Organization
ISO	International Organisation for Standardization
kg	kilogram(s)
kt	knot(s)
kW	kilowatt(s)
m	metre(s)
m.rad	metre radians
MAIB	Marine Accident Investigation Bureau
Maritime NZ	Maritime New Zealand
max	maximum
MetService	New Zealand Meteorological Service
MSC	Maritime Safety Committee
N	north
NIWA	National Institute of Water and Atmospheric Research
nm	nautical mile(s)
NW	north west
OOW	officer of the watch
ro-ro	roll on – roll off
s	second(s)
S	south
SE	south-east
SOLAS	International Convention for Safety Of Life At Sea
SSE	south-south-east
STCW-95	International Convention on Standards of Training, Certification and Watchkeeping, 1978 as amended in 1995
UMS	unmanned machinery space
UTC	co-ordinated universal time
VDR	voyage data recorder
W	west

Glossary

articulated rudder	a rudder with an active trailing edge, or flap, that increases its turning efficiency
autopilot	a device that automatically controls the steering of a ship on a selected course
beam	the width of a vessel or in a direction perpendicular to the fore and aft line of a vessel
bollard pull	a measure of the static pull a vessel can exert
bow thruster	a small athwartships propeller mounted in a tunnel at the forward part of a ship, used to manoeuvre the ship at slow speeds
course	direction steered by a ship
gross tonnage	a measure of the internal capacity of a ship; enclosed spaces are measured in cubic metres and the tonnage derived by formula
helm	the amount of angle that the rudder is turned to port or starboard to steer the ship
port	left-hand side when facing forward
quarter	that part of a ship between the beam and the stern
rake	a number of rail wagons coupled together to form a length that will fit on a particular ship
shear	when the ships head suddenly moves to one side or another under an external influence
ship's head	the direction in which the bow of the ship is pointing
significant wave height	the height of the average of the highest one third of the waves
sound	to determine the depth of liquid in a tank or enclosed space
spring tide	tidal undulation that has the lowest low water, and highest high water, in a series
stabilisers	fin stabiliser systems use one or more pairs of hydrofoil shaped fins projecting from a vessel's bilge area. Vessel speed and the angle of the fins in the water determine the amount of lift generated and whether it is upward or downward. The stabiliser system senses the degree of ship movement and signals the stabiliser fins to return the vessel to an even keel
starboard	right-hand side when facing forward
tidal current	the horizontal movement of water due to tide
tidal stream	same as tidal current
westing	the distance travelled, or the angle of longitude measured westwards, from either a defined north-south grid line or a meridian
yawing	the failure of a ship to hold a straight course, turning from side to side

Data Summary

Vessel particulars:

Name:	*Aratere*
Type:	passenger freight ferry
Class:	✠ 1A1 car and train ferry A, general cargo carrier RO/RO DG-P
Classification:	Det Norske Veritas
Length:	150.00 m
Breadth:	20.25 m
Gross tonnage:	12 596
Built:	1998, Hijos de J. Barreras S.A. in Vigo, Spain
Propulsion:	four 3680 kW diesel generators driving four 2600 kW electric motors coupled in pairs through a reduction gearbox to two 4-bladed fixed-pitch propellers
Service speed:	19.5 kt
Owner:	Toll NZ Consolidated Limited[1]
Operator:	Interislander
Port of registry:	Wellington
Minimum crew:	12

Date and time:	3 March 2006 at about 1644[2]
Location:	Cook Strait
Persons on board:	crew: 35 passengers: 344
Injuries:	crew: one minor passengers: 4 minor
Damage:	extensive damage to rail and vehicular cargo minor damage to railings and lashing equipment on the ship
Investigator in charge:	Captain Iain Hill

[1] New Zealand Railways underwent several changes of standing as a company after 1987, as did the rail ferry division. The current names, Toll NZ Consolidated Limited for the company and Interislander for the rail ferry division have been used throughout this report for consistency.
[2] Times in this report are New Zealand Daylight Time (UTC + 13 hours) and are expressed in the 24-hour mode.

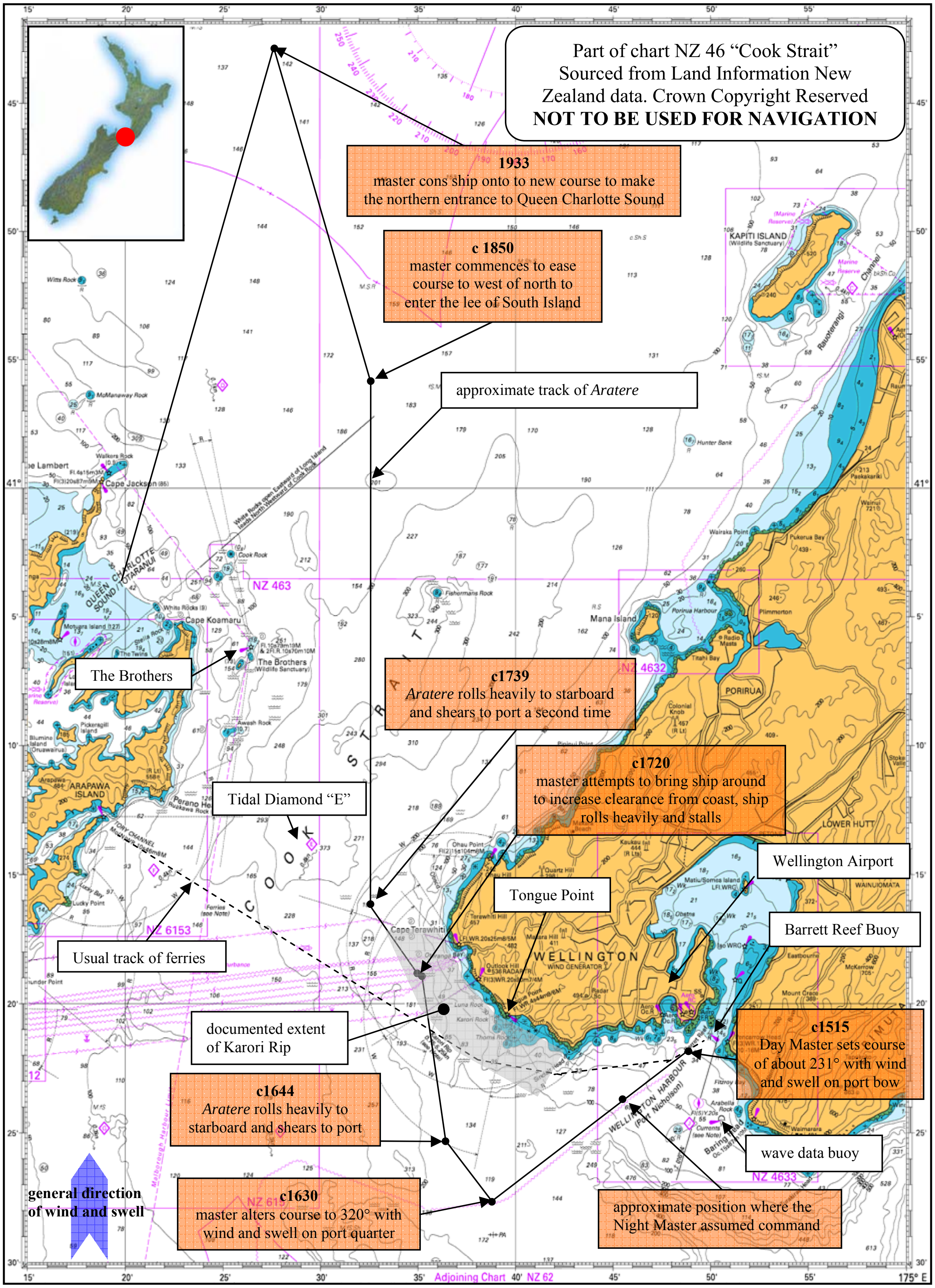


Figure 1
General area of the incident

1 Factual Information

1.1 History of the voyage

1.1.1 On Friday 3 March 2006 at about 1343, the *Aratere* berthed at Wellington ferry terminal after its third Cook Strait crossing of the day. The *Aratere* arrived behind schedule due to a combination of adverse tidal currents and adverse weather conditions in the Cook Strait.

1.1.2 The weather had been forecast to deteriorate during the day, and the Day Master and watchkeeping officers had monitored the weather during the crossing from Picton. While the Aratere was in Wellington, the Day Master studied the weather forecasts and used the operator supplied computer program that gave him access to the most up to date New Zealand Meteorological Service (Metservice) data available. The Day Master used this data to ascertain the actual sea state and weather at the entrance to Wellington Harbour and in Cook Strait.

1.1.3 The Day Master verified that the expected weather was within his criteria before deciding to sail for Picton. The Day Master decided that as the weather and sea state were forecast to deteriorate that he would have to implement the operator's heavy weather procedures. The Day Master told the officer of the watch (OOW) who was about to go off duty of the requirement for heavy weather lashings, and asked him to inform the incoming OOW of this requirement.

1.1.4 At about 1447, after cargo operations had been completed and the passengers embarked, the ship left the ferry terminal. The crew completed the final lashings on the trucks and rail wagons as the ship crossed Wellington Harbour.

1.1.5 At about 1513 as the Aratere approached the entrance to Wellington Harbour, using all 4 propulsion motors and 3 of the available 4 diesel generators, the ship's stabilisers were extended and set to automatic operation.

1.1.6 At about 1515, the ship passed Barrett Reef Buoy (see Figure 1) at the entrance to Wellington Harbour. The Day Master decided on a course of about 231°, a more southerly route than usual, but normal under such sea and weather conditions. Such a course kept the swell on the port bow until such time as the course could be altered to make either Tory Channel entrance or a course through the Strait to the northern entrance to Queen Charlotte Sound with the sea and swell abaft the beam.

1.1.7 Once clear of the Harbour entrance, the autopilot was engaged and the propulsion motors were placed in rough sea mode with the controls set between 7 and 8 to limit the power and hence the speed of the ship, so as not to stress unduly the structure of the ship and to provide the most comfortable ride for the passengers.

1.1.8 At about 1515, the Night Master arrived on the bridge for an emergency drill (which was cancelled due to the weather) after which he was to relieve the Day Master. However, the Day Master wanted to retain command until he had made enough distance off the south coast of North Island to be able to turn towards Tory Channel eastern entrance safely. The Night Master remained on the bridge observing the Day Master and the ship's performance until he was comfortable with the ship's performance. The Day Master handed over the command of the ship to the Night Master at about 1545 with the ship still on a course of about 231°. The Day Master then left the bridge.

1.1.9 After assuming command, the Night Master spoke by cell phone to the Master of the Arahura, which had just left Tory Channel, about the weather conditions at Tory Channel entrance. The Night Master then decided not to risk using Tory Channel but to take the longer northern route. Shortly after making his decision, the Night Master was contacted by the Marlborough District Council Harbourmaster who advised him that, although he was not closing Tory Channel entrance, he thought that the use of the northern entrance would be a better option in the prevailing conditions. The Night Master advised the MDC Harbourmaster that he had already decided to make for the northern entrance.

1.1.10 At about 1630, when the ship was about 7.2 nautical miles (nm) off Tongue Point Light the Night Master, having consulted with the rest of the bridge team, ordered the ship's head to be altered to 320° to transit Cook Strait. This alteration was also intended to bring the sea and swell onto the port quarter. The duty navigating officer later stated that "we discussed exactly what we were going to do before we did it".

1.1.11 The ship settled onto the new course and the bridge team observed the ship to be yawing about 4° to 5° either side of the intended track and moving easily in the seaway at a speed of about 17 knots (kt) through the water.

1.1.12 At about 1644, when the ship was about 5.5 nm off Tongue Point Light, the Aratere unexpectedly rolled very heavily to starboard, the ship's head sheared about 10° to port and the speed through the water increased to about 19 kt.

1.1.13 The Night Master immediately adjusted the helm to bring the ship back onto course. However, he was concerned that the ship may shear again on the designated course, so, after discussion with the remainder of the bridge team, he adjusted the course to about 340°.

1.1.14 The Day Master, who was below decks during the heavy roll, immediately made his way to the navigating bridge to assist the Night Master in any way he could. The Day Master remained on the bridge to assist until about 1933 when the ship turned towards the northern entrance. The other deck officers, including the Chief Officer, Second Officer, and the off-duty Third Officer also made their way to the bridge.

1.1.15 After the heavy roll, the ship developed a starboard list of less than 5°. The Night Master ordered that an inspection of the cargo decks be undertaken and the results reported back to the navigating team. After details of the damage had been received, the Chief Officer and the Boatswain returned to the cargo decks to take photographs and returned to the bridge at about 1705.

1.1.16 The Aratere was being set to the north by the strength of the wind. The Night Master stated later that after some time he became concerned that although the ship had a good margin of clearance off the land and once past Cape Terawhiti the Strait opened out, he did not have as much clearance off the land as he would have liked.

1.1.17 After further discussion with the bridge team when challenges were requested the Night Master decided to attempt to bring the ship's head around to about 220° and put the weather on the port bow to increase the distance off the North Island coast before continuing to the north.

1.1.18 At about 1720, the Night Master ordered manual steering to be engaged and the helm to be put to hard to port (about 43°). However, as the ship turned, its speed dropped to about 4 kt and the helm only brought the ship's head to about 245°. The change in heading induced heavy rolling, so the Night Master, after being advised by the Day Master that he thought that the turn should be aborted, aborted the attempt to bring the ship's head to 220° and ordered the helm to be put hard to starboard (about 43°) and brought the ship's head back initially to about 320°, and then to about 335°.

1.1.19 When the ship was steadied on the new heading the autopilot was re-engaged. The bridge team observed the ship to be keeping to the course more easily than on the previous heading, yawing about 5° either side of the median set course.

1.1.20 At about 1739, the Aratere again rolled very heavily to starboard, the ship's head shearing about 16° to port and the speed through the water increasing from about 19 kt to about 24.3 kt. The Night Master immediately ordered the helm to be adjusted to bring the ship back to course and then further around to starboard to a heading of about 000°.

1.1.21 After the heavy rolling, the starboard list increased to about 5° and the Night Master requested that the engineering staff sound all spaces to ensure that the watertight integrity of the vessel had not been compromised. The Night Master ordered that no further rounds of the cargo spaces be undertaken until the ship reached sheltered waters, but that inspections of the cargo spaces were to be made using the closed circuit television security system.

1.1.22 At about 1850, as the ship gained some benefit from the lee of the South Island and the swell appeared to be diminishing, the Night Master, after consultation with the bridge team, slowly brought the ship's head around, initially to 355° then 345° and at about 1923, 335°.

1.1.23 At about 1933, the Night Master and bridge team considered that the swells had flattened out sufficiently to attempt to bring the ship's head around to make for the northern entrance to Queen Charlotte Sound. The Night Master ordered the ship's fourth diesel generator to be started and increased the ship's speed before ordering the helm put hard to starboard and made the turn for the northern entrance. The Night Master elected to make the longer turn to starboard in order not to increase the list to starboard caused by centrifugal forces during the turn.

1.1.24 The Aratere then continued on passage to Picton without further incident, berthing at about 2230.

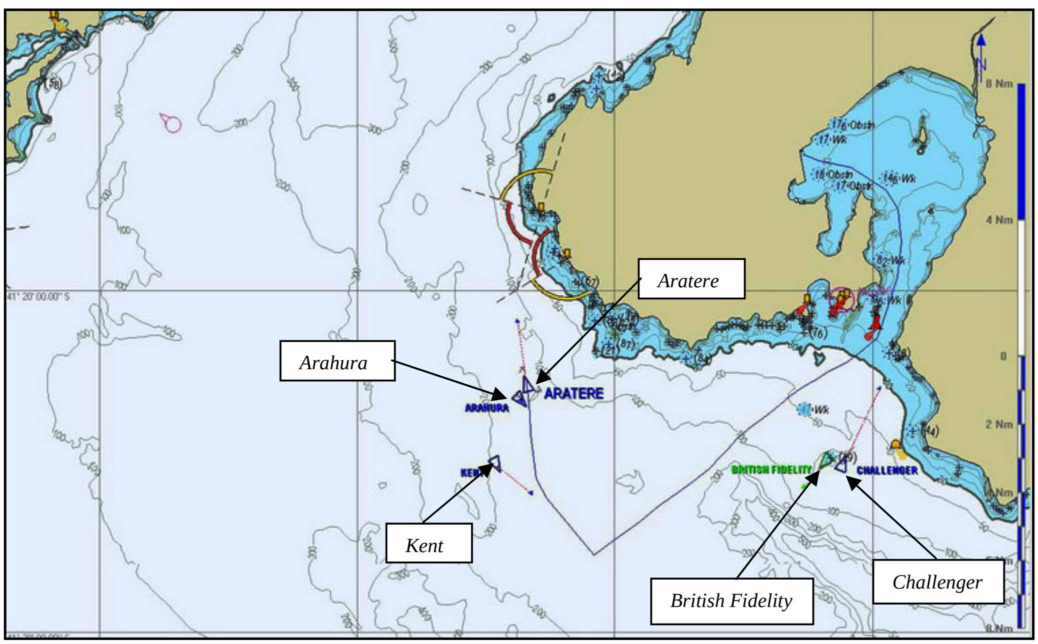


Figure 2
Automatic Identification System screenshot for 1700 3 March 2006 showing the *Aratere*'s track and other ships in the vicinity at the time

1.2 Vessel information

1.2.1 The *Aratere* was a passenger and freight ferry operated by Interislander (the operator), a division of Toll NZ Consolidated Limited (the owner). The ship was certified to carry a total of 399 persons and was capable of carrying both rail and vehicular cargo. The *Aratere* was in class with Det Norske Veritas and was built in Spain in 1998. When the vessel was built it was designed to comply with the International Convention for the Safety of Life at Sea 1974 as amended (SOLAS), a convention adopted by the International Maritime Organization (IMO).

1.2.2 The ship traded on a scheduled service between Wellington and Picton with a service speed of 19.5 knots. The duration of a fair weather voyage from berth to berth was about 3 hours and comprised 3 sections: a 40-minute transit of Wellington Harbour, an 80-minute crossing of Cook Strait, and a 60-minute transit of the Marlborough Sounds. The turnaround time at each end of the voyage was about one hour.

1.2.3 The *Aratere* was powered by up to 4 diesel-driven DC generators that provided electrical power as required, via frequency converters, to 4 AC electric propulsion motors; 2 to each shaft. The 2 electric motors on each shaft either singly or together drove a fixed-pitch propeller through a reduction gearbox. The maximum power rating of the propelling machinery was 10 400 kilowatts (kW).

1.2.4 Before sailing, the Day Master elected to use the ship's propulsion power in rough sea mode. This utilised 3 of the available 4 diesel generators to provide power to all 4 of the propulsion motors. The fourth diesel generator was on standby ready for use. During the crossing, the propulsion motors were on a setting of between 7 and 8 out of 10, to stop the ship being driven too hard in the prevailing conditions.

1.2.5 Two articulated rudders, one aft of each propeller, provided steering. An articulated rudder is one where the rudder is articulated by a simple mechanical arrangement that moves a hinged trailing edge of the rudder at a higher ratio than the main spade. The ratio is normally double so that a rudder angle of 35° will result in the trailing edge moving to 70° from the fore and aft line. The rudders could be used either linked, where both rudders moved in the same direction to the same degree, or independently, where the direction and the degree of each rudder was controlled independently. In addition, the *Aratere* had 2 bow thrusters, each with a maximum power rating of 1000 kW, equivalent to 13 tonnes bollard pull.

1.2.6 The *Aratere* had 3 cargo decks. The lower cargo deck was capable of carrying cars and small vans; it was reached by a hydraulically operated ramp from the middle cargo deck. The lower cargo deck was not generally used mainly due to time constraints during port stays. The middle cargo deck (rail deck) was capable of carrying both rail and vehicular cargo and was accessed via a stern ramp through watertight doors and was, when the doors were closed, totally enclosed. The upper cargo deck (vehicle deck) was capable of carrying vehicular cargo only, including trucks, and was accessed via a ramp onto the open deck at the stern.

Stability information

1.2.7 Ships are loaded to maintain sufficient stability for the safety of the ship and its crew, passengers and cargo. The transverse stability of a ship determines, among other things, its roll period. A ship with a high transverse stability is said to be "stiff" and has a short, quick roll period, whereas a ship with a low transverse stability is said to be "tender" and has a longer, slow, roll period. Decreasing the stability too far would make a ship unstable and unsafe.

1.2.8 Figure 3 provides a basic explanation of stability and the terms and definitions associated with it showing a ship's hull at an angle of heel to the waterline **WL** of **θ** (theta) degrees. When the hull is immersed in water, the buoyant force from the water pressure acts through a point **B**, the centre of buoyancy. This force is equal and opposite to the displacement **Δ** of the vessel which acts downward through the centre of gravity **G**.

The centre of buoyancy is initially on the centreplane, but when the vessel is rolled to an angle **θ**, the change in immersed underwater shape causes it to move to a point $\mathbf{B^1}$. At this angle the lines of action of the forces of buoyancy and displacement are separated by the horizontal distance from **G** to **Z**.

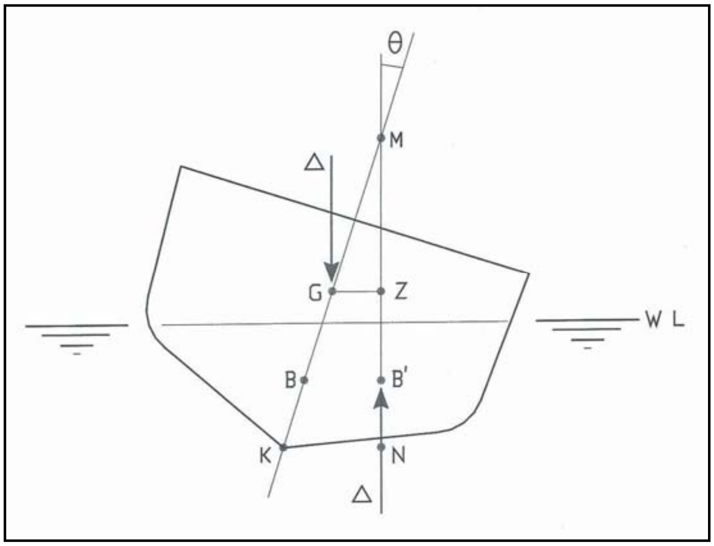


Figure 3
Basic stability diagram

The distance **GZ** is the righting lever, and is an important indication of a ship's stability at angles of heel over about 10°. Large values of **GZ** mean that the forces have a longer lever arm and the ship will return to the upright position more rapidly. Negative values of **GZ** mean that the ship will capsize.

At the intersection of the vertical line through $\mathbf{B^1}$ and the centreplane of the vessel is the metacentre **M**. The height of **M** above **G** is the metacentric height **GM** and is a useful measure of stability at angles of heel up to around 10°. Large values imply that a vessel is stiff, small values imply that it is tender, and negative values imply that it is unstable. **GZ** is related to **GM** by the equation $\mathbf{GZ = GM(\sin\theta)}$**.**

Point **K** is a reference point on the keel of the ship. Point **N** is a point level with **K** on the vertical line through $\mathbf{B^1}$. The distance **KN** is used for analytical purposes and is represented in **KN** tables.

The actual **GM** of the *Aratere* at the time of the incident was 1.71 m.

1.2.9 An independent naval architect calculated and drew a curve of statical stability or GZ curve for the *Aratere* using the loading data as applicable to the 3 March 2006 crossing. This curve is shown in Figure 4. The differences in the curve produced by the naval architect and that produced by the ship (the blue line in Figure 4) are minimal and probably due to the differences in the way the effects of free surface were treated.

1.2.10 The independent naval architect was asked about the accuracy of the GZ curve especially at large angles of heel. His opinion was as follows:

> The stability data for the rail ferry Aratere was prepared by the builder Astillero Barreras using a Foran analysis system, and was approved by DnV on 3/3/99. The data appears to have been competently prepared, and includes GZ curves and Cross Curves up to angles of heel of 80 degrees.[3]

[3] While the onboard stability system indicates GZ results only to 60 degrees, the stability handbook has data to 80 degrees of heel.

There is no reason to suspect that GZ information at high heel angles (say, over 50 degrees) is overstating the stability of the vessel. Important factors that may affect the quality of the GZ information are the level of care that has been taken in defining the watertight boundary of the vessel, the manner in which free surfaces in tanks are treated, and the underlying VCG [vertical centre of gravity] calculation. However these are all items that can affect the results no matter what the heel angle, and as a matter of course they are all evaluated at the appropriate level of accuracy during the calculation process.

It is not unusual for GZ curves to be conservative at higher angles of heel, and for the vessel to actually have more stability than may be indicated by the curves. This is usually due to items of watertight or semi-watertight structure high up in the vessel being ignored during the calculations, and the flooding of water onto decks (or downflooding) being much slower in practice than is assumed in the analysis.

As part of an earlier study for Toll Holdings Ltd I carried out an independent stability analysis for Aratere, using a completely different system, and can confirm that I was able to produce results that were almost identical to those in the stability book at all heel angles. For convenience this analysis ignored all structure above the vehicle deck and focsle decks, whereas there are in fact significant accommodation spaces and casings above these levels. I am therefore confident that the GZ curves in the stability book are a conservative representation of the actual stability of this vessel.

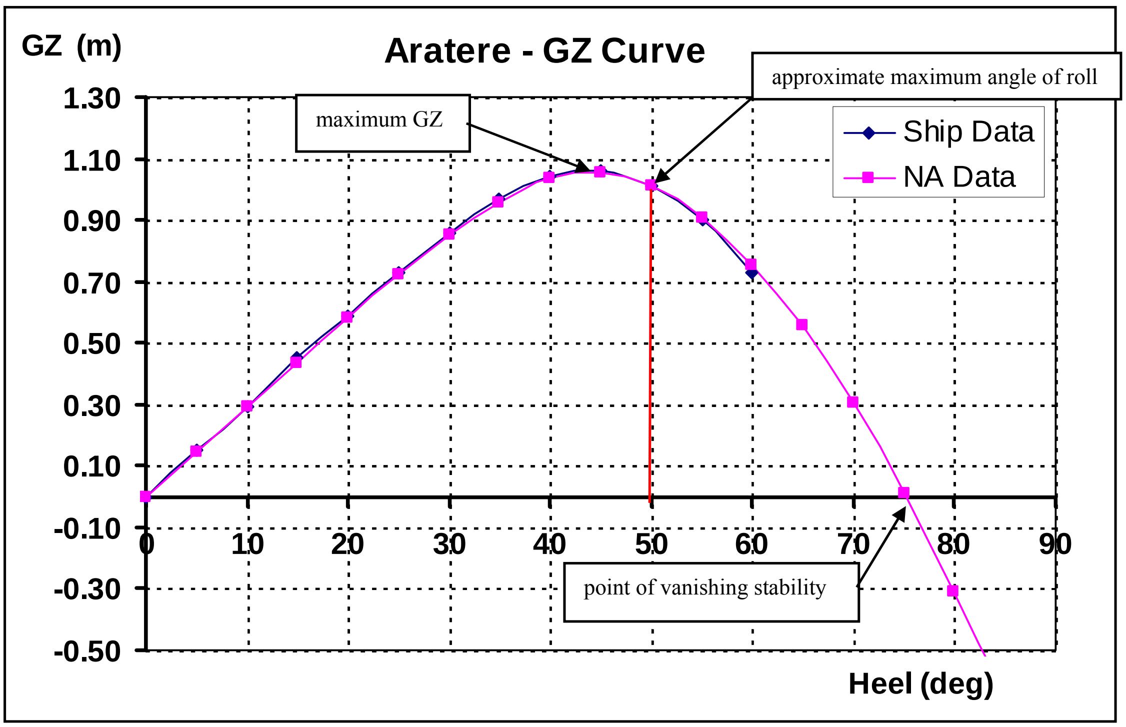


Figure 4
The *Aratere*'s GZ curve for 3 March 2006 sailing

1.2.11 The GZ curve shows that the maximum GZ or righting lever occurs at about 45°, and the point of vanishing stability or where the vessel will capsize, was at about 75°. The GZ at the approximate maximum angle of roll on the day of the incidents was about 1.01m. From data contained in the *Aratere*'s stability documentation it was ascertained that the angle of deck edge immersion was about 33° and the openings' flooding line was at an angle of heel of about 49°.

1.2.12 To comply with the relevant IMO, SOLAS and Maritime rules the *Aratere* was required to meet certain conditions with regard to stability as detailed below:

Function	Minimum requirement	Actual	Acceptable
Flooding angle	> 40°	49°	✓
Area under CSS* 0° to 30°	0.055 m.rad	0.230 m.rad	✓
Area under CSS 0° to 40°	0.090 m.rad	0.398 m.rad	✓
Area under CSS 30° to 40°	0.030 m.rad	0.168 m.rad	✓
GZ above 30°	0.20 m	1.060 m	✓
Angle for maximum GZ	25°	45°	✓
GM corrected for free surface	0.15 m	1.71 m	✓
GM for passenger ship under IMO Resolution A.265(VIII)	1.10 m	1.71 m	✓
GM for passenger ship intact stability	0.71 m	1.71 m	✓
GM for passenger ship under SOLAS 90	0.99 m	1.71 m	✓

* Curve of statical stability

1.2.13 When the *Aratere* was transferred from its original Bermudan registry to the New Zealand registry, it was transferred as a SOLAS compliant ship and thus complied with Maritime Rule Part 40B Design, Construction and Equipment SOLAS Ships.
Maritime Rule 40B.7 Subdivision and Stability states (in part):

> The owner of a ship must ensure that the ship complies with –
>
> (a) the relevant requirements of the Code of intact stability for all types of ship covered by IMO Instruments adopted by the assembly of IMO by resolution A.749(18); and
>
> (b) the relevant requirements relating to intact stability of Part B of Chapter II-1 of SOLAS

Chapter II-1 of SOLAS concerns Construction – subdivision and stability, machinery and electrical installations. This chapter states (in part):

> The master of the ship shall be supplied with the data necessary to maintain sufficient intact stability under service conditions to enable the ship to withstand the [specified] critical damage.

Navigating bridge and equipment

1.2.14 The navigating bridge of the Aratere was designed on an integrated bridge principle with 3 manoeuvring consoles manufactured and fitted by Norcontrol. The main console was located forward on the centreline of the wheelhouse, and 2 smaller "docking" consoles were located at the port and starboard extremities of the wheelhouse. All the consoles had controls for:

- bow thrusters
- engine
- steering
- telephone communications
- whistles
- very high frequency (VHF) radio communications
- searchlights
- screen wipers
- electronic chart display and information system (ECDIS)
- readouts for
  - wind direction and velocity
  - ship's rate of turn.

1.2.15 The main console (see Figure 5) was also fitted with:

- 2 DB2000 automatic radar plotting aid (ARPA) radars that could be linked into the ECDIS
- 2 differential global positioning system (DGPS) receivers
- gyro compass controls
- medium-frequency radio communication equipment
- high-frequency radio communication equipment
- digital selective calling
- one AP2000 autopilot
- steering motor controls
- stabiliser fin controls
- navigation light controls
- anchoring controls.

1.2.16 The AP2000 was an adaptive autopilot with track-keeping functions connected to the main DB2000 computer, a magnetic compass and a distribution unit. The distribution unit provided connections for feedback from the rudders and connections to the steering gear and to external alarms. At the time of the incident, the autopilot was set with a maximum 10° setting for rudder and counter rudder.

1.2.17 The stabiliser fin controls allowed for automatic operation of the stabilisers, which was the usual method of operation. The controls also allowed for a range to be set to encompass the ship's calculated GM. At the time of the incident, this was set to a different GM range from the range that encompassed the calculated GM of the ship.

1.2.18 The *Aratere* was fitted with 2 gyro compasses and a transmitting magnetic compass. The gyrocompasses were Sperry/Plath Navigat X, mod 10 compasses, which had a standard freedom of roll of 35°. The 2 gyro compasses and transmitting magnetic compass were linked by an alarm system that compared the headings from each instrument. If the heading on any one of the instruments differed above a preset limit from the heading of the other 2 instruments, an alarm would sound to warn the OOW of a possible instrument malfunction. None of the bridge team had any recollection of this alarm sounding at any time during the incident voyage.

1.2.19 The *Aratere* was fitted with a voyage data recorder (VDR). A VDR is designed to continuously maintain sequential records of pre-selected data items relating to the status and output of the ship's equipment and command and control of the ship. The VDR achieves this by electronically recording signals from many items, including helm position, radar, engine settings, courses steered, speed, depth of water, relative wind direction, and bridge voice conversations. This data could be downloaded for analysis ashore, for training, quality assessments or accident and incident investigations.

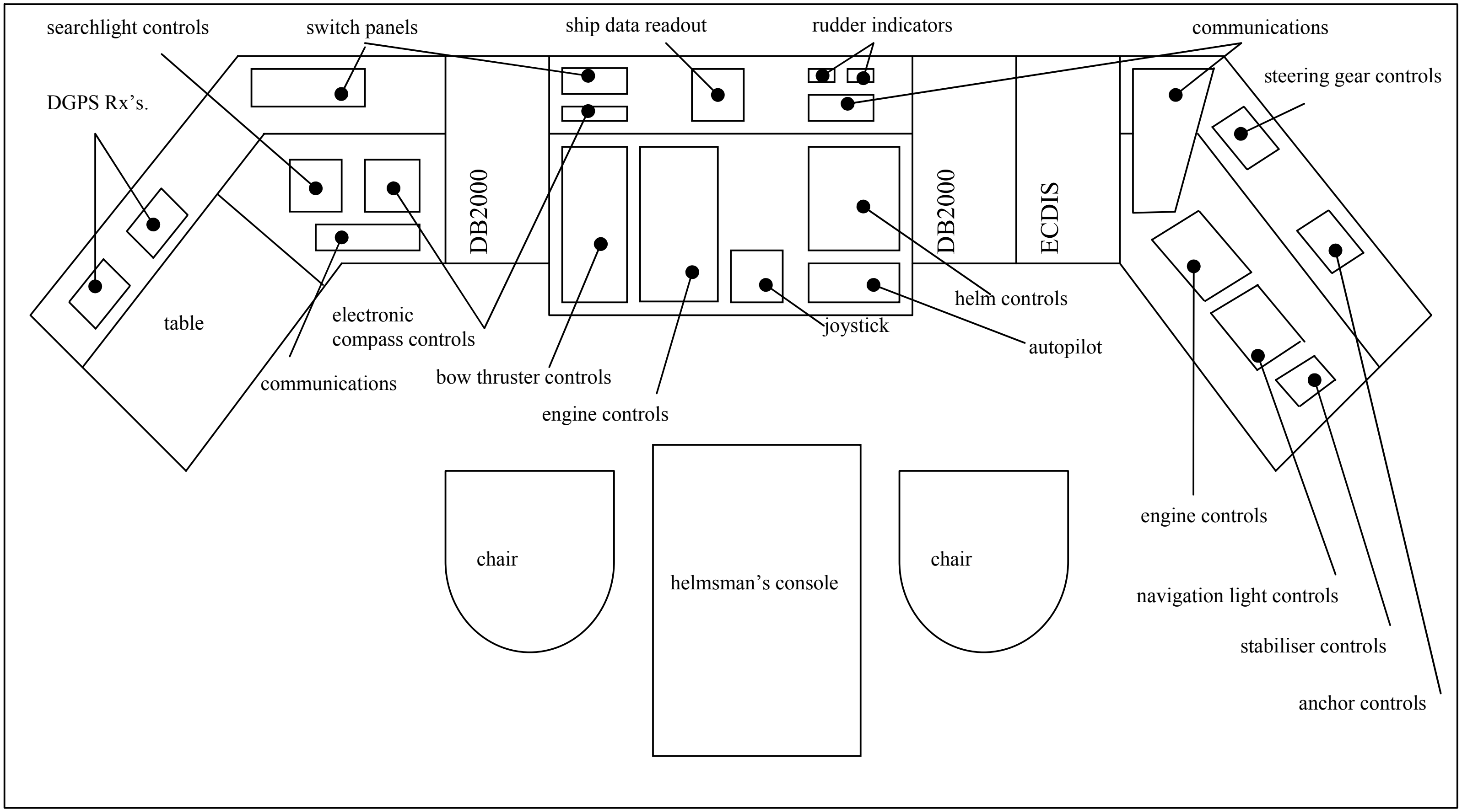


Figure 5
Bridge equipment layout diagram - the *Aratere*

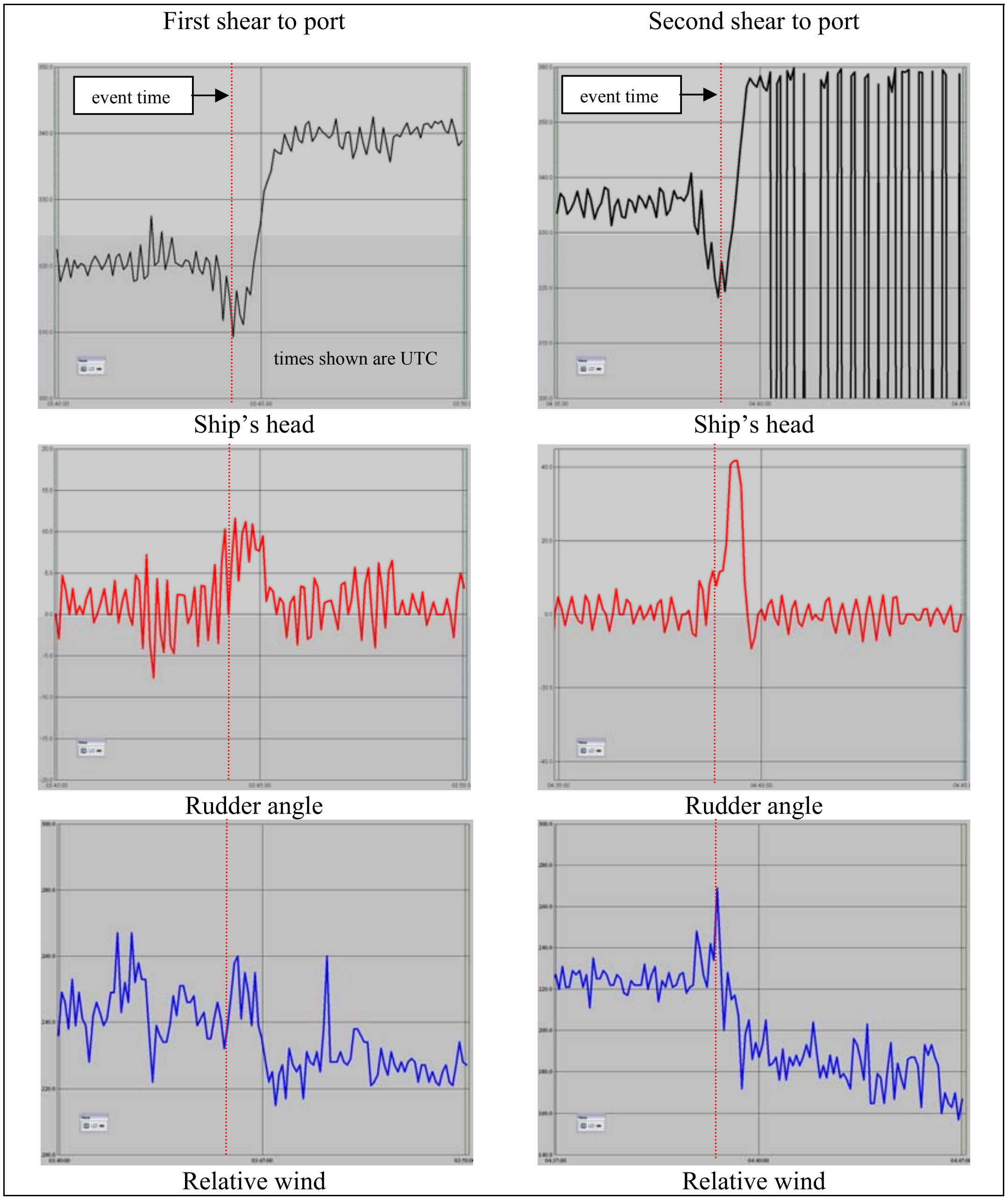


Figure 6
Printouts of downloaded VDR information

1.2.20 After the incident the VDR data was downloaded and made available for analysis. The Commission also sent the data to the United Kingdom's Marine Accident Investigation Bureau (MAIB) for independent analysis. The analysis of the VDR information by the MAIB stated, in part:

> With the aid of the separate reports of this accident supplied to the MAIB, the VDR data from the vessel was examined to determine her changes in heading around 0344Z and 0439Z, when the vessel is reported to have listed up to 50° to starboard. Recorded heading information indicates that the ship's heading altered a maximum of 11° to port during the first event, and 19° to port during the second, whereas witness accounts reported the alterations to be considerably larger.
>
> To determine the degree to which the vessel's heading was altered on both occasions, the ship's movement was analysed using GPS [global positioning system]

positional data and relative wind, both of which were independent from the ship's gyro input. The GPS data was downloaded and displayed at intervals of one second. From these, it is evident that the GPS aerial remained within a 15m corridor during the first event, and a 24m corridor during the second event [see Figures7 and 8]. Had the ship broached, while the ship's ground track might have remained similar as the ship slid transversely, the ship would have then been perpendicular, or near perpendicular, to the sea and wind on completion.

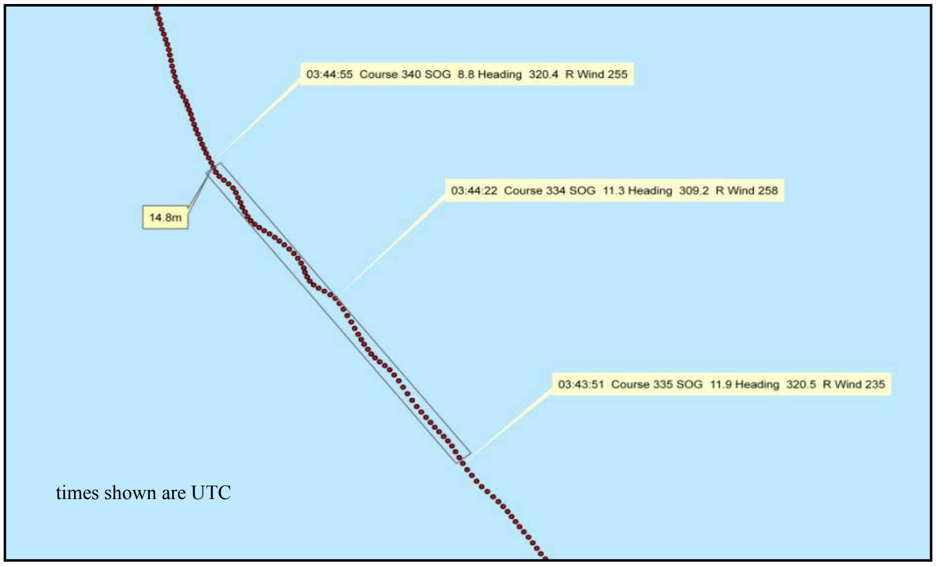


Figure 7
The MAIB's plot of the *Aratere*'s position at one-second intervals from GPS co-ordinates for the first shear to port

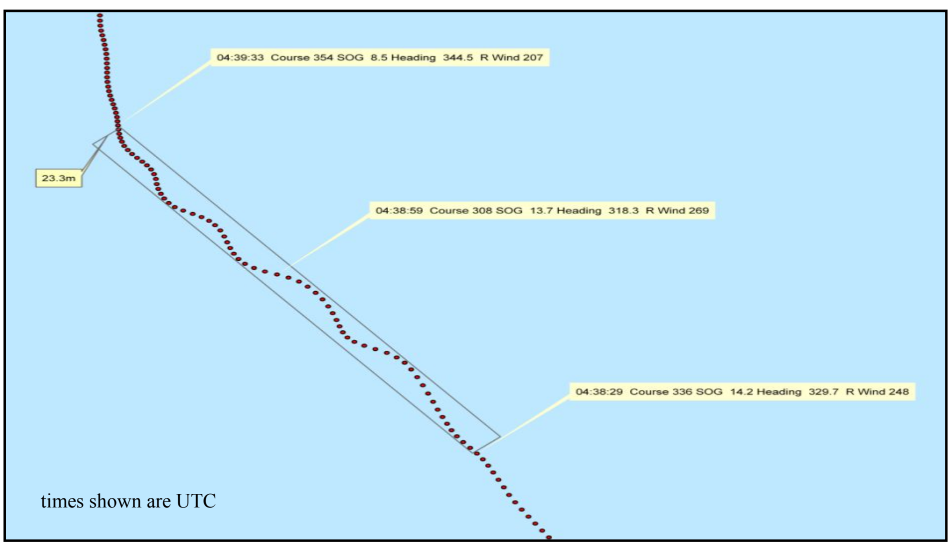


Figure 8
The MAIB's plot of the *Aratere*'s position at one-second intervals from GPS co-ordinates for the second shear to port

Accordingly, it would then have taken the ship some time and distance (advance) to resume her original course, particularly noting the time taken to resume course following the attempted course reversal at 0419Z. As there is no indication of such movement from the GPS plots, there is little evidence, other than witness accounts and the fact that the gyro's operating parameters were momentarily exceeded, it is unlikely the ship's heading altered significantly more than indicated by the recorded gyro input. The fluctuations in the recorded relative wind during the two events are consistent with this hypothesis.

1.2.21 The gyrocompass manufacturer was requested to give its own opinion regarding the accuracy of the gyro heading through the incident voyage, given that during both extreme rolls the compass briefly exceeded one of its operating parameters. The Managing Director of Northrop Grumman Sperry Marine GmbH & Co. advised:

> Regarding your description personal eye witnesses by crew and passengers have described the actions of the ship and described a very rapidly heading change of up to 90 degrees. On the other hand the VDR recorded a maximum deviation of some 14 degrees in the one instance and 11 degrees in another.
>
> After analyzing your given description we came to the following conclusion:
>
> 1. The recorded heading in the VDR seems to be normal in this kind of weather condition and with the given time stamps reflecting the monitored heading.
> 2. With the reported 50 degrees heeling the gyro compass in regards of the physical behavior of such spinning mass systems would have after the instance a great heading deviation and according to the Schuler Time Constant this deviation would become smaller over a time frame of about 3 hours until the gyro compass reached again the actual true heading.
> 3. After the incident the heading was reported to behave normal without reported errors. So the only conclusion is that the recorded heading in the VDR is correct.

1.3 Personnel information

1.3.1 The Day Master first went to sea in 1971, gaining his Master Foreign Going certificate of competency in 1980. He joined Interislander in 1981 and had been sailing as Master since 1994. He had been master on board the *Aratere* for the previous 4 years.

1.3.2 The Night Master first went to sea in 1981, gaining his Master Foreign Going certificate of competency in 1992. In 1997 he initially joined Interislander, then other companies on the Cook Strait service eventually rising to the rank of Master, rejoining Interislander in that capacity in August 2005. He had served on board the *Aratere* since rejoining Interislander. The Night Master stated later that he thought that he would require about 18 months to fully understand the *Aratere* in its entirety.

1.3.3 The Third Officer first went to sea in 1998, gaining her Commercial Launch Master certificate of competency. In about 2000 she gained employment with Interislander as a caterer, then applied for and was granted a navigating cadetship with the company. In 2005 she gained her Second Mate Foreign Going certificate of competency.

1.4 Climatic conditions

1.4.1 The coastal waters forecast issued at 1258 on 2 March 2006 and valid until midnight 3 March 2006 for sea area Cook was as follows:

> COOK
> *STORM WARNING IN FORCE*
> Northwest 15 knots developing early afternoon and rising to 35 knots overnight. Changing southerly early morning then rising to 50 knots Friday night. Sea becoming high. Southerly swell rising to 5 metres. Northerly swell 1 metre, dying out. Poor visibility in squally showers Friday evening.
>
> OUTLOOK FOLLOWING 3 DAYS: Southerly easing Saturday 20 to 30 knots, becoming early Sunday northwest 20 to 30 knots. A change late Sunday southerly 15 to 25 knots, then becoming early Monday northwest 25 to 35 knots with rough sea. Heavy southerly swell, easing early Sunday.

1.4.2 The amended coastal waters forecast issued at 0855 on 3 March 2006 and valid until midnight 3 March 2006 for sea area Cook was as follows:

> COOK
> *STORM WARNING IN FORCE*
> Southerly 35 knots rising to 50 knots from late afternoon. Sea becoming high. Southerly swell rising to 5 metres. Poor visibility in squally showers developing this evening.
>
> OUTLOOK FOLLOWING 3 DAYS: Southerly easing Saturday 20 to 30 knots, becoming early Sunday northwest. A change late Sunday southerly 15 to 25 knots, then becoming early Monday northwest 25 to 35 knots with rough sea. Heavy southerly swell, easing early Sunday.

1.4.3 MetService stated that coastal weather forecasts are a general indication of average conditions expected in a particular coastal area. The forecasts are for open waters within 60 nm of the coast and do not apply to enclosed areas such as small bays and harbours.

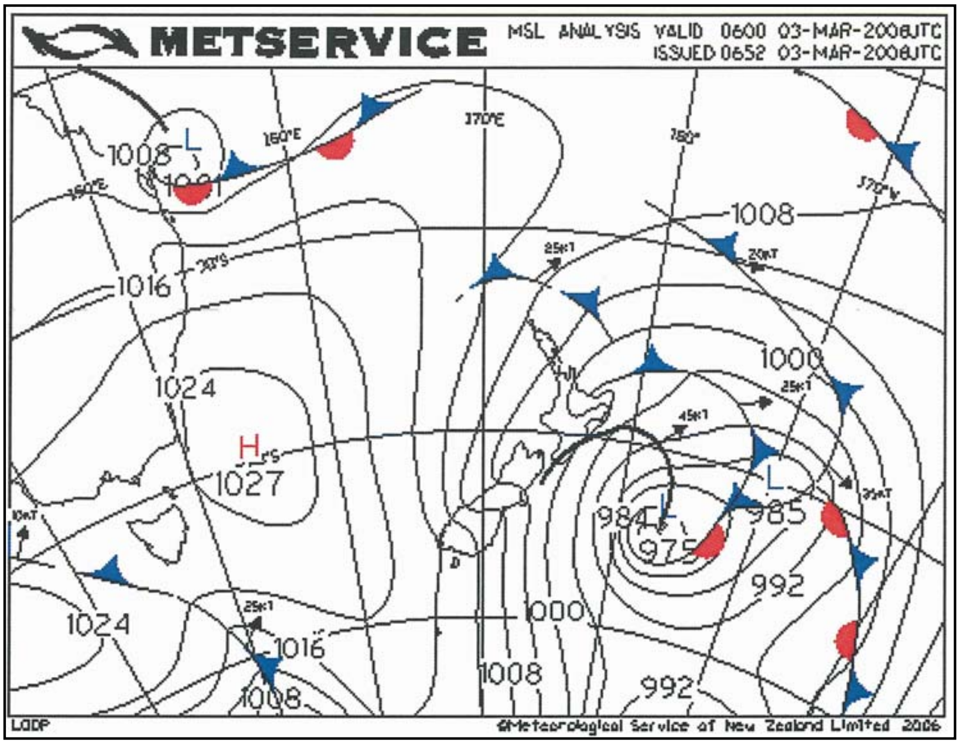


Figure 9
Mean sea level analysis for 1800 3 March 2006

1.4.4 MetService provided an aftercast of the weather that would have been experienced in Cook

1.4.5 Strait at the time of the incident as shown below:

- **Situation** – On 3 March 2006 a depression was deepening near the Chatham Islands and moving slowly east. An anticyclone was nearly stationary over the western Tasman Sea [see Figure 9].
  Between these two systems, and particularly between the Chathams and the South Island, there was a strong southerly air stream.

- **Weather conditions: -** Cook Strait: 1500 – 1900 NZDT 3 March 2006
  Wind: Southerly in the range 35 to 40 knots. The wind speed probably reached its maximum speed in this area during this time.
  Sea state: the combined (swell and sea) significant wave height was between 5 and 6 metres and the maximum wave height was between 7.5 and 10 metres.
  Waves were probably higher between Cape Terawhiti and Tory Channel due to the tidal current in Cook Strait towards the south (against the wind) during the rising tide in Wellington between 2:54pm and 8:55pm.

Visibility was good – about 20 kilometres.

1.4.6 MetService also provided details of the wind experienced at salient points around Cook Strait as shown below:

Time	Wellington Airport			Tongue Point			The Brothers		
	Dir'n.	Speed	Max Gust	Dir'n.	Speed	Max gust	Dir'n.	Speed	Max gust
1600	190°	37 kts	51 kts	160°	45 kts	59 kts	170°	46 kts	58 kts
1700	180°	32 kts	51 kts	160°	43 kts	56 kts	180°	48 kts	60 kts
1800	200°	38 kts	52 kts	180°	34 kts	59 kts	180°	43 kts	61 kts
1900	200°	28 kts	59 kts	180°	26 kts	48 kts	180°	44 kts	60 kts

1.4.7 The predicted tides for Wellington detailed in the New Zealand Nautical Almanac for 3 March 2006 were:

Wellington							
Low water		High water		Low water		High water	
0213	0.4	0830	1.7	1454	0.5	2055	1.7

1.4.8 The range of tides tabulated in the New Zealand Nautical Almanac for Wellington was 1.03 m for the spring range and 0.93 m for the neap range. The range at the time of the incident was 1.2 m and therefore a large spring tide.

1.4.9 Tidal stream rates were shown on the chart for specific geographical positions designated by a magenta diamond shape enclosing a letter, known as a tidal diamond. The rates shown were for average spring or neap tides referred to high water at Wellington. For a tidal range greater than normal (e.g. full or new moon coinciding with perigee) the rates will be increased roughly in proportion. The spring rates for diamond E, as shown in Figure 1 were:

Position	Time	Direction	Rate
E	1555	192°	1.7 kts
	1655	192°	2.3 kts
	1755	192°	2.3 kts
	1855	192°	1.9 kts

1.4.10 The New Zealand Nautical Almanac states in the section concerning tidal streams the following:

> The tidal streams in and around Cook Strait are unreliable, and masters are warned to exercise every precaution when navigating in the vicinity. The streams often run in one direction for 8 to 10 hours, while cases have been reported of them going so for 18 hours and more. When the streams have been running in one direction, for say 8 to 10 hours, it has been found that the opposite stream is much weaker and, in some cases, hardly noticeable. The maximum rates shown on the chart, which are usually attained at springs, are also liable to be experienced at any other time. In the vicinity of Karori Rock and Cape Terawhiti a rate of up to 7 knots is frequently experienced, but as a rule it does not last for more than about an hour. Small vessels are warned to keep well clear of tide-rips, as they may lose steerage way and may, in extreme cases, capsize.

1.4.11 The Admiralty Sailing Directions New Zealand Pilot (NP51) states the following about Cook Strait:

> Cook Strait is particularly affected by the frequency and strength of NW and S to SE winds due to the close proximity of high land on both sides producing a funnel effect; these are the only violent winds but they give rise to the worst storms experienced in New Zealand waters, averaging about 25 each year. Strong to gale force NW winds are very localised, but S gales affect the whole strait. Gales from SE, which are experienced more often, are strongest in the W part of the strait around Cape Campbell, and over the N parts of Marlborough Sounds.

Broken water is experienced in Cook Strait; this may in part be due to the influence of a cold bottom current being forced to the surface. When the flow is strong, heavy tide-rips occur in the vicinity of the deep submarine canyons in the strait.

During gales, very rough seas are a feature of Cook Strait. The heaviest seas are caused by S gales, which can produce very high and dangerous swells, particularly across the strait S of Wellington Harbour and N and S of The Brothers islands.

Strong tidal streams are found between Cape Terawhiti and Sinclair Head causing the Karori Rip, an area of extreme overfalls and tide-rips which may be experienced up to 2¾ miles offshore. The area should normally be avoided, particularly with the NW-going stream.

Depending on meteorological conditions, the NW-going stream lasts from HW until 5 hours after HW Wellington; the stream is then SE-going until 1 hour before HW. The rate of the stream may exceed 5¼ kt at spring tides, under certain meteorological conditions.

Between Cape Terawhiti and Karori Rock, 3½ miles SSE, less broken water will be found 4 to 5 miles offshore, but conditions farther offshore may be dangerous for small craft.

1.5 Waves and wave actions

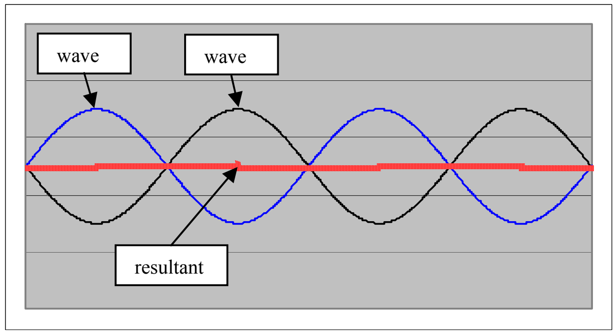
1.5.1 Waves are created by wind blowing over water. As they travel away from the area where they are generated, they evolve into long, smooth-crested waves called swell waves. Local wind can also generate waves. These are called sea waves and have short, choppy shapes. However, if the wind is strong enough and blows for long enough the sea waves can start to emulate swell waves.

1.5.2 Swell waves can travel for long distances in deep water without losing the energy they acquire from the wind. But as they travel into shallow water their shape and direction change. In shallow water, the waves slow down and change direction, the crests bend, and their vertical profile becomes steeper. They eventually become so steep that they become unstable, breaking and losing most of their energy in the surf zone.

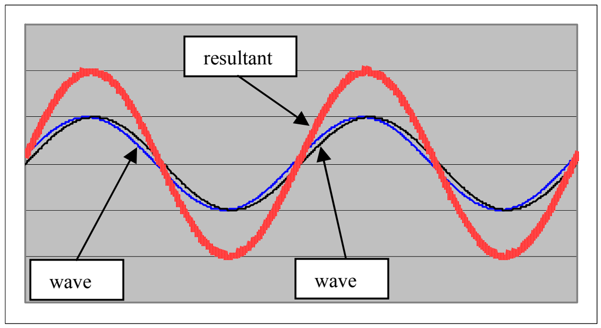
1.5.3 When swell waves arrive from a direction other than perpendicular to the shallows the waves will bend, trying to conform to the contours of the sea bed. This bending of the waves is known as refraction and results from the inshore portion of the wave being slowed more than the portion still in deep water. This refraction will cause a change in both height and direction in shallow water.

1.5.4 When a tidal stream runs against a sea and swell, it causes the sea to become steeper and the wave period to decrease. Conversely when a tidal stream runs with a sea and swell, it causes the sea to flatten and the wave period to increase.

1.5.5 The National Institute of Water and Atmospheric Research (NIWA) was consulted on the effect of the Karori Rip. Karori Rip consists partially of an upwelling of bottom water with different characteristics from those of the upper layers of water; which can cause the Rip to act like a wall, reflecting waves that impinge on it. This could cause the formation of 2 swell trains. The Night Master and the Third Officer both stated later that during the incident passage across Cook Strait, they were aware of what appeared to be 2 swell trains, one from a 210° direction and one from a 170° to 180°direction.



Two equal amplitude waves combining in opposition giving a zero



The same 2 equal amplitude waves almost synchronised giving double the resultant

Figure 10
Diagram showing the minimum and maximum resultants of 2 waves combining

1.5.6 NIWA opined that, although possible, it was unlikely that there were 2 swell trains and it was more likely that the observers had noted a swell train and a large sea wave train.

1.5.7 When 2 or more wave trains meet, one becomes superimposed upon the other. When the crests and troughs coincide with each other, the combination of the 2 wave crests will produce a higher than normal wave and the combination of the 2 wave troughs will produce a deeper than normal trough. This gives rise to a wave with a total height that can be several times the height of the average wave (see Figure 10).

1.5.8 NIWA maintained a wave rider buoy situated off Baring Head in position (see Figure 1). Data from the buoy was available to the master of the *Aratere* either from the Interislander/MetService "MetConnect" service, the Beacon Hill signal station or the MetService duty forecaster. Readings on the 3 March 2006 were:

Date	Time	Maximum wave height (m)	Significant wave height. (m)	Zero crossing period (s)
3 March 2006	1500	11.14	5.17	8.51
	1600	9.37	5.64	8.46
	1630	9.28	5.14	8.28
	1700	9.01	5.26	8.24
	1730	7.36	4.95	7.95
	1800	8.47	5.07	8.69
	1830	8.02	5.12	8.18
	1900	9.09	5.30	8.17
	1930	8.43	6.14	8.45
	2000	8.43	6.14	8.45

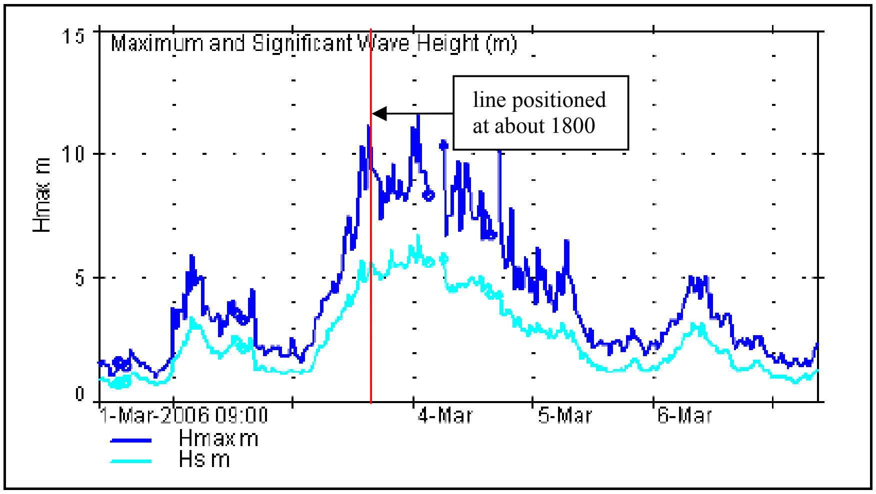


Figure 11
Significant wave height graph

1.6 Ship's dynamic behaviour in following and quartering seas

1.6.1 On 19 October 1995, the Maritime Safety Committee (MSC) of IMO approved Circular MSC/Circ.707 on "guidance to the master for avoiding dangerous situations in following and quartering seas" (see Appendix 3). MSC invited member governments to bring the guidance to the attention of shipmasters and other interested parties of the shipping industry as they deemed appropriate.

1.6.2 As the New Zealand Government's representative at IMO, Maritime New Zealand[4] (Maritime NZ) would have received this Circular. Maritime NZ confirmed it had the Circular but could find no record of to whom it had sent the Circular, neither could Interislander find any record of having received the Circular, nor did it have any recollection of having seen the Circular. Several other shipping companies in New Zealand were surveyed but none of them had any knowledge of this Circular.

1.6.3 At the time of writing, the contents of Circular MSC/Circ.707 were under revision by the sub-committee on stability and load lines, and on fishing vessels' safety at IMO, details of which were contained in IMO document SLF 49/5/4.

1.6.4 MSC/Circ.707 contained:

- descriptions of dangerous phenomena affecting ships in following and quartering seas including:
  - surf riding and broaching-to
  - the reduction of intact stability caused by riding on a wave crest at midship
  - synchronous rolling motion
  - parametric rolling motion
  - a combination of various dangerous phenomena
- dangerous navigational conditions
- operational guidance
- details of how to avoid dangerous conditions
- explanation of the operational guidance

[4] The Maritime Safety Authority's name changed on 1 July 2005 to Maritime New Zealand. The Current Name Maritime New Zealand and the abbreviation Maritime NZ have been used throughout the report for consistency.

- necessary training items and cautions
- diagrams indicating dangerous zones of operation.

From the information and formulae contained in MSC/Circ.707 and the data from the table below, diagrams were prepared to depict the status of the *Aratere* at the times of the heavy rolling (see Figure 12 and Figure 13).

Item	Source	Code	first roll	second roll
Length between perpendiculars of the ship	ship data	L	137.00 m	
Breadth of the ship hull	ship data	B	20.50 m	
Draught of the ship hull	ship data	D	5.31 m	
Actual ship speed through water	VDR data	V	18 kt	
Mean wave period	wave buoy	T	8.26 s	8.20 s
Encounter wave period	obs. ship video	T_E	12 s	14 s
Natural rolling period	ship data	T_R	10.37 s	
Metacentric height of the ship	ship data	GM	1.71 m	
Average length of the wave	NIWA	λ	220.00 m	
Encounter angle of the ship to wave	Ship co.-wave dir'n.	χ	30°	15°
Significant wave height	wave buoy	$H_{1/3}$	5.20 m	4.99 m
Block coefficient of the ship	ship data	C	0.39	

Condition	Requirements	Calculation	Ship in dangerous zone?
For successive high wave attack	average wave length is larger than 0.8 x ship length and	$\lambda > 0.8 \times 137$ m 220 > 109.6 m	✓
	significant wave height is larger than 0.04 x ship length	$H_{1/3} > 0.04 \times 137$ m 5.20 m or 4.99 m > 5.48 m	✗
	encounter wave period is nearly equal to double (1.5 – 2.8 times) observed wave period	$T_E = (1.5 - 2.8) \times 8.26$s 12s = 12.39 – 23.13s $T_E = (1.5 - 2.8) \times 8.20$s 14s = 12.30 – 22.96s	✗ ✓
For synchronous and parametric rolling motions	T_E is nearly equal to the natural rolling period of the ship T_R or $T_E \approx T_R/2$	$T_E \approx T_R$ 12s - 14s ≈ 10.37s $T_E \approx T_R/2$ 12s – 14s ≈ 5.185s	✓ ✗

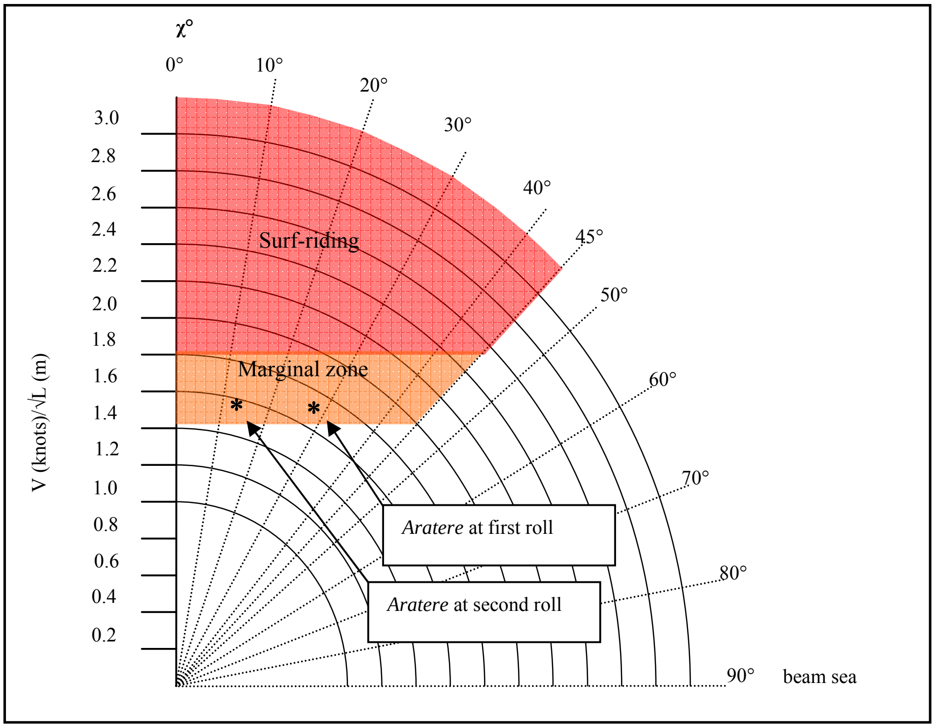


Figure 12
Diagram indicating dangerous zone due to surf-riding

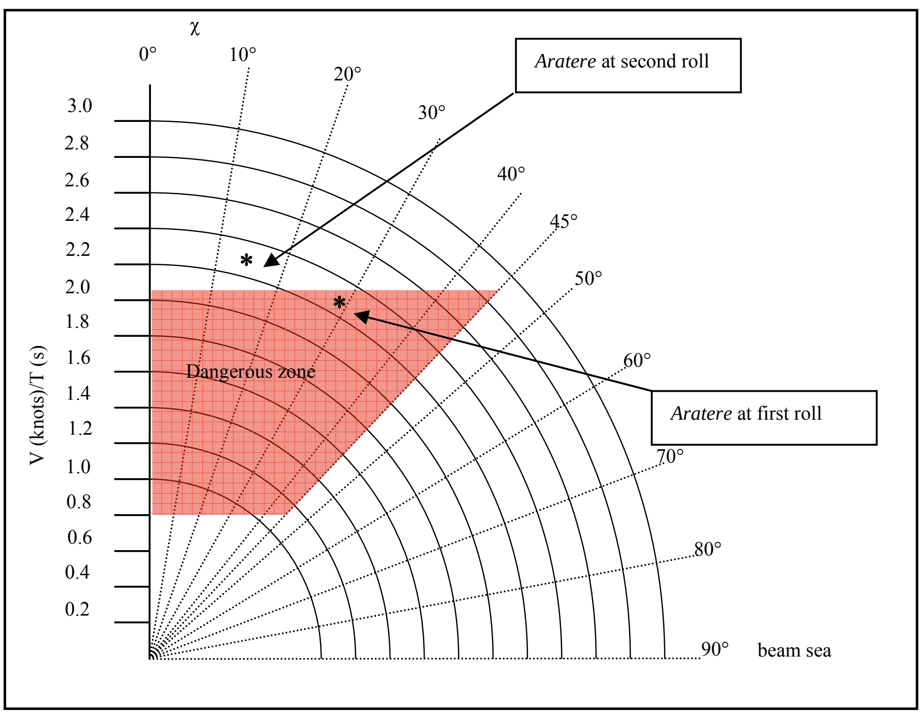


Figure 13
Diagram indicating risk of successive high wave attack in following or quartering seas.

1.6.5 MSC/Circ.707 describes the terms used in some detail. However, the Circular, being written for experienced mariners by experienced mariners is less descriptive about the term "broaching". The generally accepted meaning of the term amongst mariners is "the unplanned and uncontrolled turning of the vessel so as to present the vessel's broadside to the wind and waves".

1.6.6 Interislander engaged the services of a Professor Emeritus at the University of California, who was an acknowledged expert in the behaviour of ships in following and quartering seas. His summary was, in part:

> The ship's behaviour is consistent with a situation in which a large wave approaching from the port quarter impulsively forces the stern to starboard and simultaneously exerts a large rolling moment to starboard. The wave moves forward along the ship and, when wave crest is near amidships, the transverse stability is reduced below its mean or still water value, diminishing the ship's ability to resist the rolling moment. The ship may momentarily be caught up with the wave in what is referred to as "surf riding", increasing its speed and prolonging this position of reduced stability. The wave crest continues to move forward and the stability once again increases to become greater than the still water value as the crest nears the bow, a trough comes to the amidships position and a second crest nears the stern.
>
> The ship's response was most probably the combined result of several effects causing large one-sided rolling moments to starboard combined with an oscillatory wave-induced moment. If these moments were to be concurrent with the presence of a wave crest near amidships, i.e., the wave that forced the stern to starboard, the resulting dynamic roll could be larger than it would be if the ship experienced similar heeling moments in still water …
>
> …In an extreme case broaching may occur in which directional control is lost and the ship slews violently. This was not the present situation as the rudders enabled the ship to maintain directional control after the initial yaw. The ship's response was most probably the combined result of several effects causing large one-sided rolling moments to starboard combined with an oscillatory wave-induced moment all of which coincided with the presence of a wave crest near amidships.

1.7 Damage

1.7.1 The *Aratere* sustained minor damage to fixtures and bulkheads on the vehicle and rail decks but this did not compromise the watertight integrity of the ship.

1.7.2 Six rail wagons and their contents sustained damage, 5 being severely damaged. A container fell off one UK-type rail wagon causing minor damage to the wagon. This type of wagon was specifically designed for transporting containers. Three ZH-type wagons on the port inner rake fell to starboard against the starboard inner rake, and 2 ZH type wagons on the starboard inner rake had fallen to starboard against the starboard outer rake. ZH type wagons were high capacity box wagons (see Figure 14).

1.7.3 When the rail wagons fell over they did not remain parallel to the rail tracks, rather each wagon slewed to a varying angle to the track. Before coming to rest. The outer4 casings of the wagons were damaged to such an extent that the contents of the wagons were either visible or had spilled out onto the rail deck

1.7.4 Six commercial vehicle units, 9 campervans and 32 private vehicles were damaged to varying extents during the incident.

1.8 Operating procedures and requirements

1.8.1 Heavy weather procedures for the *Aratere* were detailed in the Operations Manual, in addition to the normal departure checks, with references to the Safety Manual (see Appendix 1).

1.8.2 Interislander had neither a formalised procedure nor limiting criteria to assist the Master in command in the decision on whether to sail or not. The Master had to assess whether he considered it to be safe for the ship to sail. The Master's authority was designated in the introduction to the Safety Manual as follows:

- MASTER'S AUTHORITY
  The masters are appointed by, and derive their authority from, the managers of the ship. They are at all times the manager's senior representative on board.

  Nothing in this manual removes from the master their authority to take any steps and issue any orders, whether or not they are in accordance with the contents of this manual, which they consider necessary for the preservation of life, the safety of the ship, cargo or for pollution prevention.

- GOOD SEAMANSHIP
  Nothing written in this manual relieves the master and his crew of their legal responsibilities and their duty to act in accordance with good seamanship and their own skills and judgement. Indeed if the particular circumstances require it they must depart from the requirements of this manual

1.8.3 Although masters occasionally aborted sailings, such cancellation decisions were taken on the basis of passenger and crew safety and comfort rather than what the ship itself could withstand.

1.8.4 Interislander provided masters with tools to assist in assessing situations. It had contracted with MetService for the use of up-to-date MetService data through a dedicated computer program (MetConnect). Interislander had also contracted with NIWA and Wellington Regional Council to be able to access the data from the wave rider buoy off Baring Head. It also encouraged masters to communicate with ships at sea and in port for updates on the weather conditions being experienced.

1.8.5 Interislander's Operations Manager had assessed the weather conditions during the early morning of 3 March 2006 when he was travelling from Picton to Wellington on one of the ferries. He was aware that the weather was forecast to deteriorate during the evening and Interislander's disruption team had been warned that ferry sailings were likely to be cancelled at some time. However, he stated later that the weather had deteriorated faster than he had anticipated and he had not started to monitor the weather conditions actively prior to the *Aratere's* sailing.

1.8.6 The Interislander Safety Manual laid down the procedures for change of command and stated:

> Change of command is normally to be carried out as follows:
>
> - alongside a berth or at a safe anchorage
> - no on board emergency in progress
> - entered in the logbook; and
> - the relieved master is no longer in command
>
> If the ship is not keeping to schedule the change of command may take place when the ship is at sea.

However, no procedures were laid down as to the content of the handover to be given at the change of command. Interislander generally expected that the content of handover would be based on the masters' certificates of competency training based on the principles of good seamanship. The certificates of competency held by the masters and officers on board at the time were compliant with the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers 1978 as amended in 1995 (STCW 95).

1.8.7 Master's familiarisation training was laid out in Interislander's Masters' Training Manual. The manual was ship specific and contained job-specific checklists signed and dated by both the instructor and the master covering all relevant ship systems and equipment. The manual also contained a new or transferred employee familiarisation section to be completed featuring general and specific safety information and safety equipment information.

1.8.8 Interislander's Masters' Training Manual contained a trainee's checklist that was supplemented by training guidelines for specific tasks. The training was given by 3 "training masters" who met after the initial training to decide if a trainee had reached a satisfactory standard or if further training was required in specific areas.

1.8.9 Specific training for the handling of the *Aratere* in heavy weather at sea was not included in the familiarisation or training programme. Nor were any details on the handling characteristics of the ship in following or quartering seas.

1.8.10 Interislander did not have any formalised procedures on the content of handover between the deck officers in charge of a cargo watch in port, rather relying on the officers' certificates of competency training based on the principles of good seamanship.

1.8.11 Guidance in taking over a navigational watch was contained in STCW 95 Section A-VIII/2 Part 3 and taking over a deck watch in port was contained in STCW 95 Section A-VIII/2 Part 4. This guidance was mirrored in Maritime Rule Part 31A, Amendment 1 Crewing and Watchkeeping Unlimited, Offshore, and Coastal (Non-Fishing Vessels); (see Appendix 2). However, no guidance was contained in either document regarding the content of a handover of command whilst at sea.

1.8.12 Interislander's approved passage plan covered the normal routes between Wellington and Picton and return, using either Tory Channel or the northern entrance. The passage plan did not contain any prescribed route for use in heavy weather; rather Interislander left the decision on what route to take up to the master in command at the time. Standard operating practice for departing Wellington during southerly heavy weather was for the ships to proceed to the southwest to increase the westing before turning to a northerly direction for passage through the Strait. This had the benefit of keeping the seas and swells either on the bow or on the quarter, however, this practice and the constraints on how far south to proceed had not been documented by Interislander.

1.9 Lashings and lashing equipment

1.9.1 Procedures for the loading and lashing of cars, commercial vehicles and rail cargo were contained in The Interislander Loading and Discharging Manual. However, this Manual did not specify the actual lashings required on road vehicles, but rather, gave a diagrammatic layout of the preferred location of lashing points on road vehicles. The Loading and Discharging Manual assumed a maximum roll angle of 30° for the ship. With respect to the lashing of cars the Manual stated, in part:

> The lashing of cars and caravans is at the master's discretion. This is dependent on both current and forecast weather and any other conditions that the master may wish to take into account.

1.9.2 Section 7.2.1. of the Loading and Discharging Manual contained details of securing of cargo/commercial vehicles to deck, and stated:

- all commercial vehicles, semi trailers, road trains, buses, luggage trucks and similar vehicles must be secured with lashings. Jacks and chocks should be used as required
- lashings should be attached to the securing points on the vehicle in such a way that the angle between the lashing and the horizontal and vertical planes lies between 30 degrees and 60 degrees
- wheels should be chocked to provide additional security in adverse conditions
- vehicles should be left in gear and brakes applied; and
- semi trailers must not be supported on their landing legs during sea transport unless they are specifically designed for that purpose and so marked.

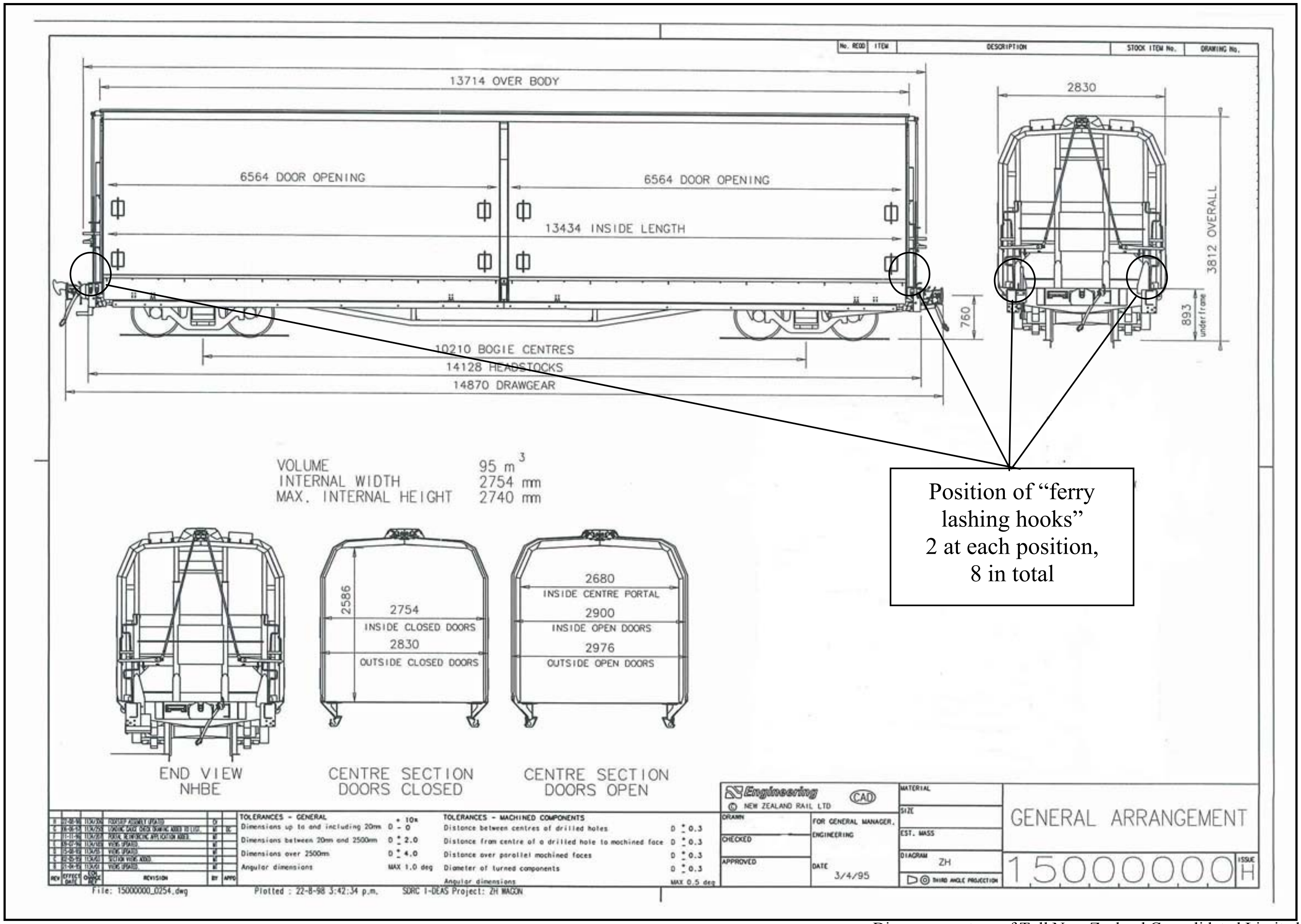


Diagram courtesy of Toll New Zealand Consolidated Limited

Figure 14
Diagram showing dimensions of a ZH wagon

1.9.3 Section 7.2.5. of the Loading and Discharging Manual contained details of securing of railway wagons to the deck, and stated (in part):

- Each four wheel wagon has provision for four tie downs and each bogie wagon has provision for eight tie downs. When wagons are loaded these must all be in place and firmly secured at all times
- Empty bogie wagons' lashings may be reduced to three lashings per side in fair weather
- A number of tie downs at the after end of the rake must be placed into deck fittings forward of the wagon attachment so that the rake is held firmly against either the buffer stop or wheel skid
- When short rakes of wagons or special loads are not held against the buffer stops they must be pushed onto a wheel skid at the forward end of the rake and the tie downs at the forward end of the leading wagon must be placed in the deck fittings aft of the wagon attachment. Skids may only be used when weather conditions are favourable and with the approval of the master
- The remainder of the tie downs should be as near as possible at right angles to the wagons.

1.9.4 The majority of the damage that occurred to the rail wagons occurred to ZH type wagons. These wagons were modified from an original ZA type wagon by fitting a high capacity body constructed mainly out of fibreglass on a steel frame. Each wagon's end was fitted with a pair of "ferry hook" lashing points welded to the main chassis at the left- and right-hand extremities making a total of 8 securing points per wagon.

1.9.5 During loading and discharging operations one officer was appointed to be in charge of the vehicle deck and one in charge of the rail deck. Their responsibilities as laid down in the Cargo Securing Manual included:

- to take charge of the rail deck or vehicle deck during loading and discharging as required
- when in charge to ensure that cargo is safely and efficiently discharged or loaded; and
- after completion of loading to check that all cargo is properly secured.

Also appointed to the vehicle deck was a vehicle deckman whose duties were:

- to take instructions from the mate in charge and convey this to the crew. They are also responsible together with the duty officer and the crew for directing, stowing and lashing of trucks and cars on the vehicle deck.

1.9.6 SOLAS-classed ships were required by Regulations VI/5 and VII/6 of SOLAS 1974 as amended to ensure that cargo units and cargo transport units were loaded, stowed and secured throughout the voyage in accordance with the Code of Safe Practice for Cargo Stowage and Securing approved by the Administration, which should be drawn up to a standard at least equivalent to the guidelines developed by IMO. These Regulations were part of the amendments to SOLAS introduced in 1991

1.9.7 The IMO Maritime Safety Committee (MSC) Circular MSC/Circ. 745 issued on 13 June 1996, stated (in part):

> Member Governments are invited to bring these guidelines to the attention of all parties concerned, with the aim of having Cargo Securing Manuals carried on board ships prepared appropriately and in a consistent manner, and to implement them as soon as possible and, in any case, not later than 31 December 1997.

1.9.8 Maritime Rule, Part 24B Carriage of Cargoes – Stowage and Securing, came into force on 30 June 2005 and implemented the stowage and cargo securing requirements of Regulation 5, Chapter VI of SOLAS. This Rule also covered New Zealand and foreign ships of 45m or more in length that undertook either coastal or international voyages after loading cargo at a New Zealand port; requiring them to stow and secure the cargo in accordance with the appropriate requirements of the IMO Code of Practice for Cargo Securing and to have an approved Cargo Securing Manual within 12 months of the entry into force of Part 24B.

Vehicle securing points

1.9.9 Maritime Rule Part 24B required that road freight vehicles having a gross mass of 3.5 tonnes or more must have vehicle securing points that complied with the provisions of International Standard ISO 9367-1. However, the Rule for road freight vehicles did not come into force until 30 June 2007, 2 years after the Rule for ships came into force. The Rule made no reference to the other complimentary International standard ISO 9367-2 or to the applicable New Zealand Standard NZS 5444.

1.9.10 International Organization for Standardization (ISO) standards ISO 9367-1 Lashing and securing arrangement on road vehicles for sea transportation on ro-ro ships - Part 1 commercial vehicles and combinations of vehicles, semi trailers excluded, issued in 1989, and ISO 9367-2 - Lashing and securing arrangement on road vehicles for sea transportation on ro-ro ships - Part 2 semi trailers, issued in 1994, covered the international standard for lashing points on trucks and trailers.

1.9.11 Maritime NZ and Standards New Zealand jointly developed a New Zealand Standard covering lashing points on road vehicles for sea transportation on ro-ro ships. This Standard, NZS 5444 anchorage points for vehicles, was issued in 2005.

1.9.12 After the incident a truck-lashing point that had broken off the parent vehicle was retrieved from the vehicle deck (see Figure 15). This lashing point was sent for independent analysis of the strength of the weld that secured the lashing point to the truck. The analysis report stated (in part):

> The metal bracing has failed due to overload in the base material to which the bracing was attached.
>
> One end of the bracing showed the failed base material below the weld. There were no signs of fatigue or defects within the welds at either end of the bracing. The weld between the bracing and the base material was sound and seems to be of a high quality as no failure has initiated in it.

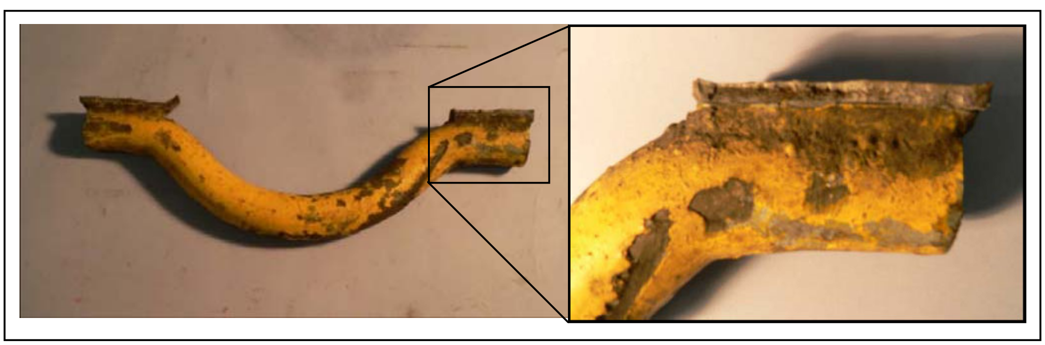


Figure 15
Truck lashing point, magnified end showing failure of base metal below the weld

Portable lashings on the *Aratere*

1.9.13 When the *Aratere* was constructed, a Cargo Securing Manual was prepared for the ship at the request of the shipyard on behalf of the owner. This Manual was approved by Det Norske Veritas, the classification society, on behalf of the Bahamian Administration.

1.9.14 The *Aratere*'s Cargo Securing Manual was designed for practical use of the crew on board. However, common practice amongst the crew was to use the Interislander Loading and

Discharging Manual in preference to the Cargo Securing Manual. The Cargo Securing Manual contained details of the number and disposition of lashings for various types of road and rail vehicles and details of the lashings carried on board. The calculations for the number of lashings and their strength in the Manual assumed a maximum roll angle of 20°. In addition to the ship and cargo-specific information, the Manual contained a wealth of generic information on non standard lashings and lashing equipment.

1.9.15 The lashings on board the *Aratere* for securing both the road and rail cargo consisted of:

- a series of flush and raised cloverleaf sockets set in a pre-designated pattern into and onto the rail and road vehicle decks. These sockets were set at intervals of about 2.2 m to 2.3 m longitudinally and at variable transverse intervals commensurate with the width of either rail or road cargo
- "Trailer Lash" webbing strap lashings with double straps each with a mean breaking load of 8.5 tonnes. The straps were fitted with a ratchet mechanism at one end, which attached to the deck with an "elephants foot" connector, and a "D" shackle with hook attached at the other end.

The webbing lashing was constructed from 100% woven polyester looped around a securing pin then fed around the "D" shackle pin and back through the ratchet mechanism. This allowed the webbing to be tightened by winding it around the ratchet mechanism. At least one full turn of the webbing was required around the ratchet mechanism to allow it to bind itself effectively (see Figure 16).

1.9.16 Both the Loading and Discharging Manual and the Cargo Securing Manual contained details of the requirements for inspecting and maintaining the portable lashing fittings. Both Manuals required that the portable lashings should be inspected before every use and discarded if damaged. The Loading and Discharging Manual was more proscriptive than the Cargo Securing Manual in what defects to look for.

1.9.17 The spacing of the deck lashing fittings on the *Aratere* was greater than that on the other Interislander ships. Consequently, the lashings used on the Aratere often had more longitudinal offset than those on the other vessels, resulting in reduced lashing effectiveness.

1.9.18 The *Aratere* was the only Interislander ferry to use web lashings. The other ships used chains to lash the road and rail wagons. The IMO-recommended maximum stretch for web lashings was 5% at 80% of the breaking load. However, chains, due to their different construction and material, exhibited about 0.5% stretch at their proof load.

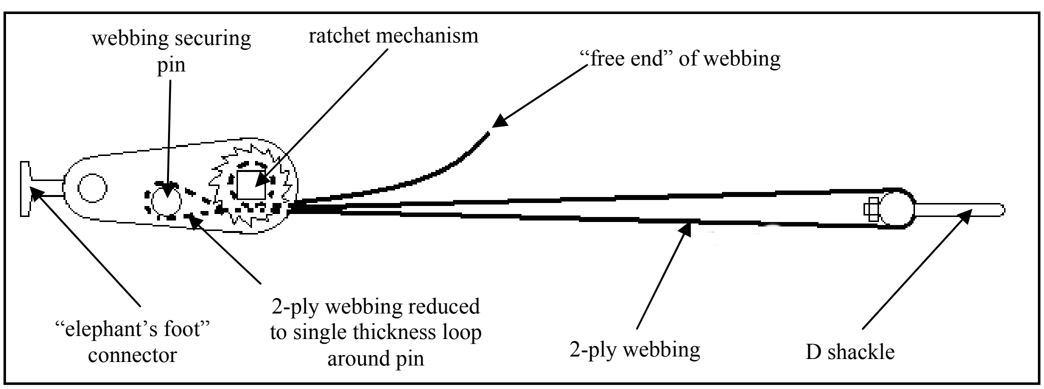


Figure 16
Diagram of web lashing

1.9.19 Two broken web lashings and 2 intact web lashings, one nearly new web lashing and one in average condition were sent for independent analysis to determine:

- the reason for the failure of the broken lashings
- the condition of the lashings prior to failure.

the intact lashings were tested to failure to determine the maximum load and position of failure.

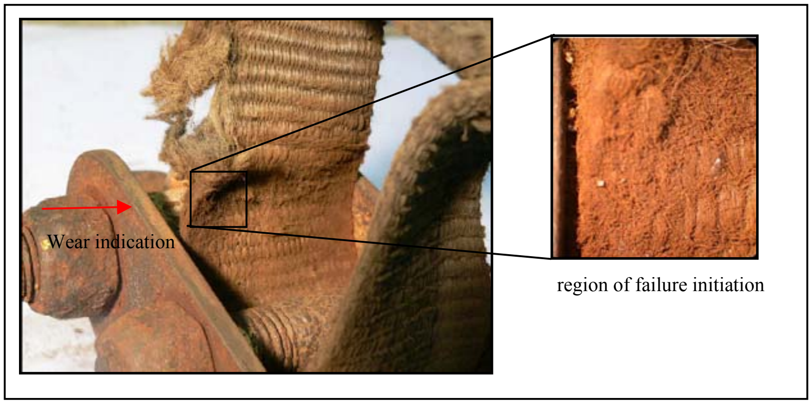


Figure 17
Region of failure initiation in brown intact strop (sample 1) and also wear located on deck attachment.

The analysis report stated, in part:

Sample 1 – Brown intact strop

Failure of a portion of the webbing in the brown intact strop (sample 1) occurred at the bolt on the deck attachment, this is shown in Figure 17. Substantial wear had occurred to the webbing where it contacted the bolt. The length of the failed portion of webbing was consistent with the bolt thread which the webbing contacts with. Indications of wear were present on the top edge of the metal plate on the deck attachment, adjacent to the failed portion of webbing, caused by contact with the webbing as shown in Figure 17.

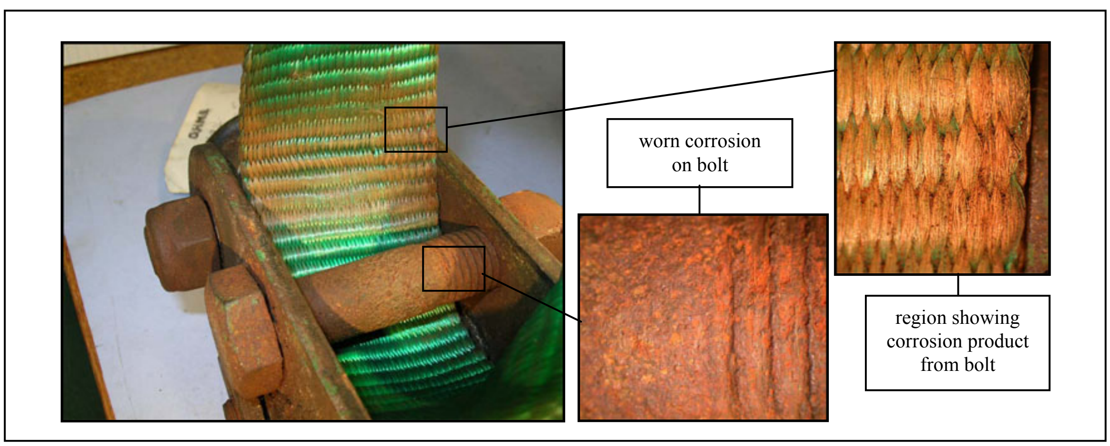


Figure 18
Region of wear around bolt, green intact strop (sample 4)

Sample 4 – Green intact strop

The green intact strop was in good condition and appeared relatively new. Signs of wear and of embedded corrosion product were present in the webbing around the bolt (see Figure 18).

The bolt was corroded but appears to be relatively new compared with the bolts examined in the other three samples. The surface of the bolt was rough and the thread of the bolt with this corrosion was very sharp. Wear damage was noted on the edges of the green strop where it had contacted the edge plates on the deck attachment.

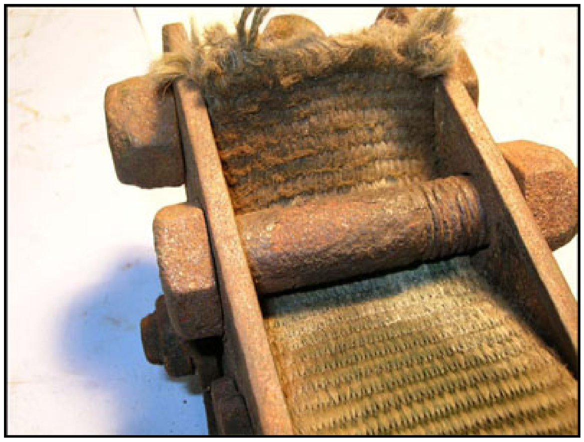


Figure 19
Location of failure in brown broken strop "A"

Sample 2 – Brown broken strop "A"

The brown broken strop "A" (sample 2) failed at the location of the bolt on the deck attachment. The frayed webbing on the strop indicates that failure has initiated from the same end as the threaded end of the bolt. The length of thread on the bolt that has been in contact with the strop is consistent with the width of fraying on the strop, indicating that the bolt thread has contributed significantly to the initiation of failure (see Figure 19).

There was extensive corrosion product and failed fibres present within the webbing in the region of contact with the bolt.

Corrosion product and failed surface fibres are present in this representation and the overall condition of the webbing is well worn.

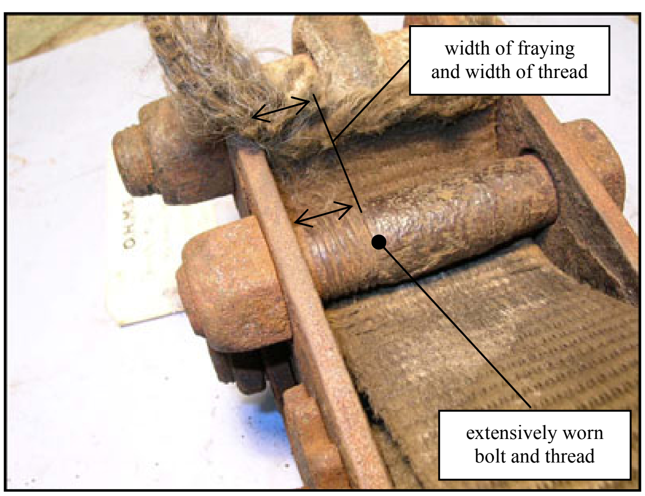


Figure 20
Location of failure in brown broken strop "B" and extensive wear on bolt and thread

Sample 3 – Brown broken strop "B"

The brown broken strop "B" failed in the same place as the brown broken strop A, location of the failure in the brown broken strop "B" can be seen in Figure 20. This figure also shows the high amount of wear on the strop around the bolt.

The condition of the webbing overall is similar to the brown broken strop "A", this being well worn. The bolt was heavily corroded and rough.

The brown and green intact strops (samples 1 and 4) were both tested in tension to investigate the maximum load before failure and the location of the failure. The results were as shown below:

Sample	Maximum securing load	Breaking strength (certified)	Maximum tensile load
1	10 000 kg	14 300 kg in "U" configuration	3 875 kg
4			13 325 kg

General securing of equipment

1.9.20 Other than a ship operator's responsibility to ensure the safety of a ship, its crew and its passengers, there was no known standard covering the securing of general equipment on ships or items fitted for passenger hospitality and entertainment. Generally, equipment should be secured under a master's authority in accordance with good seamanship and the judgement of those senior officers to whom the tasks had been delegated. All areas of the ship were subject to regular inspection by the nominated ship's safety officer. Additionally, the master, chief engineer and shore management also carried out regular inspections.

1.10 Bridge resource management and human factors

1.10.1 Bridge resource management (BRM) is the use and co-ordination of all the skills and resources available to the bridge team to achieve the established goal of optimum safety and efficiency.

1.10.2 The use of BRM helps to eliminate the potential for one-person error, and aids the flow of information between members of the bridge team, and between the bridge team and the outside world. Part of the flow of information between members of the bridge team is challenge and response and the use of closed-loop communication to ensure that orders and information are correctly heard and understood.

1.10.3 When challenge and response is encouraged, the other members of the bridge team can reasonably challenge an order or information to ensure that it is correct and that the most suitable option available has been chosen.

1.10.4 When used effectively, BRM ensures that all the bridge team members share a common view of the intended passage, maintain situational awareness, anticipate dangerous situations, acquire all relevant information and act upon it in a timely manner, avoid an error chain being formed, and avoid preoccupation with minor problems.

1.10.5 Human factors is that branch of science and technology that includes what is known and theorised about human behavioural, cognitive and biological characteristics that can be validly applied to the specification, design, evaluation, operation and maintenance of products, jobs, tasks and systems to enhance safe, effective and satisfying use by individuals, groups and organisations.[5]

1.10.6 Almost all teams require some degree of authority gradient, which can be defined as the balance of decision-making power or the steepness of command hierarchy in a given situation, otherwise roles are blurred and decisions cannot be made in a timely fashion. However, members of a crew or organisation with a domineering, overbearing or dictatorial team leader

[5] Christensen, Topmiller, and Gill 1988. Human factors definitions revisited. *Human Factors Society Bulletin,* 31, 7-8.

experience a steep authority gradient where expressing concerns, questioning, or even simply clarifying instructions requires considerable determination on the part of the team members who perceive their input as devalued or unwelcome. Conversely, members of a crew or organisation where the authority gradient is too low or "flat" have a overly relaxed attitude toward crosschecking each other's actions or confirming other information. Effective team leaders consciously establish a command hierarchy appropriate to the training and experience of the team members.

1.10.7 Humans can suffer from hazardous attitudes from which hazardous thoughts develop and affect the standard of their decision-making. These attitudes depend upon an individual's characteristics and the type of environment in which they are operating. Factors that can influence decision-making are commercial pressure, peer pressure and the corporate environment in which the decisions are made.

1.10.8 Three hazardous thoughts and their opposite safe thoughts, may have been relevant to the Night Master of the Aratere when he assumed command from the Day Master:

Hazardous thought	**Safe thought**
I can do it	Why take chances?
It won't happen to me	It could happen to me
We've always done it this way	It's about time we changed

1.10.9 Human errors can be divided into 2 main categories;

- unintended actions or inactions such as skill-based errors, which generally occur on highly practised routines that may involve extensive training and experience. The 2 main forms of skill-based errors are:
  - memory lapse, such as "I forgot to", where a person forgets to perform an intended action
  - slips, such as "Oops I didn't mean to", where an action was performed when there was no intention to perform it
- intended actions or inactions such as:
  - rule-based mistakes, such as "I saw the situation was X so I did Y". These errors occur in situations where the person has the necessary expertise, but applies it incorrectly.
  - knowledge-based mistakes, such as "I didn't know how to do it properly". These errors occur when a person is dealing with a new problem.
  - routine adaptations, such as "everybody does it this way", where the violation of rules or procedures is part of normal working practices. These adaptations do not comply with work procedures, often because of poorly defined or designed work practices
  - exceptional adaptations, such as " I know that this is not the right way, but I thought it would be okay this time". These are violations of rules or procedures that occur in response to unusual circumstances, such as a problem. These adaptations tend to be one-time breaches of work practices.

1.10.10 Local conditions are conditions associated with the immediate context or environment in which operational events occur. In terms of individual actions, these conditions include characteristics of individuals, the task and/or the environment. When such conditions are safety issues or increase accident risk, they can be termed local hazards or local threats. Local conditions can influence incident development by increasing the likelihood of a particular individual action or increasing the likelihood of another local condition.

1.10.11 When an unexpected event occurs, an individual's workload suddenly increases as they react to the situation. The effect of this sudden increase in workload can be minimised by having practised contingency plans in place, thus saving the need to go through the involved cognitive process of forming a plan, evaluating whether it would be successful then implementing it. Contingency planning reduces an individual's workload and the likelihood of load shedding.

1.10.12 One aspect that can have a large impact on human behaviour is the risk of having an accident. However, the accuracy of an individual's risk perception is often poor when dealing with familiar tasks in familiar environments. It appears that an individual operates with a "zero" level of risk perception.[6] That is, the individual does not believe there is any chance of an accident occurring by doing the task that way.

1.10.13 With routinisation, operators become more concerned about the mechanics and accomplishment of tasks than their meaning. Thus an operator can underestimate the amount of risk that routine tasks can pose for the safety of the ship. Good crew resource management ensures that routine tasks are adequately supervised and that appropriate procedures are implemented to reduce this routinisation.

1.11 Previous occurrences

1.11.1 On 18 August 2002 at about 0200, the *Aratere* departed from Picton for passage to Wellington with a cargo of 4 rakes of rail on the rail deck and a vehicle deck nearly full with a cargo of trucks. In Cook Strait the wind and sea were from the south south-west with the wind gusting between 30 and 55 kt.

1.11.2 At about 0416 when the *Aratere* was parallel to but further to the south of the usual course and steering a course of about 088° in a depth of water of about 55 m off the south coast of Wellington, the ship encountered wave conditions that caused the ship to roll 20° to port followed by a 17° roll to starboard.

1.11.3 At the time of the ship's roll to port, the lashings securing the rail wagon at the after end of the starboard outer rake of wagons parted or pulled through, allowing the wagon to tip over. The action of this wagon tipping over derailed the wagons at the after end of the 2 inner rakes.

1.11.4 The master hove-to and allowed the crew to re-lash the derailed wagons where they lay, and then proceeded to Wellington, berthing at about 0515.

1.11.5 This occurrence was not investigated by either the Commission or Maritime NZ. However, Interislander carried out an internal investigation focussing on the suitability of the ship's lashing system.

1.11.6 One of the recommendations in the Interislander report was to investigate the use of chain lashings on board the *Aratere*. This recommendation was duly investigated and a decision made to implement a system of chain lashings that used pneumatic tensioners. To this end, when the ship was in drydock in 2005 the required compressor and piping were installed. However, the associated portable lashing equipment was not on board as it had not been budgeted for during the 2005/2006 financial year.

1.12 Previous safety recommendation

1.12.1 Following the near grounding, due to loss of mode awareness, of the *Aratere* (Marine Occurrence Report 04-214) where Interislander could find no record of, nor had any recollection of, receiving MSC Circular MSC/Circ. 1061, despite Maritime NZ showing that Interislander was on the list of recipients of an email copy of the Circular, the Commission recommended on 17 June 2005 to the Director of Maritime Safety that he:

[6] Summala, H. 1988. risk control is not risk adjustment: The zero-risk theory of driver behaviour and its implications. *Ergonomics, 31*, 491-506.

review the procedures for distribution of International Maritime Organization circulars to ensure all affected parties promptly receive International Maritime Organization documentation and the distribution and receipt are adequately recorded.(045/05)

1.12.2 The Director of Maritime NZ replied to the final safety recommendation. The reply dated 1 July 2005 was (in part):

> The Maritime Safety Authority accepts the intent of this recommendation for a review of our internal procedures for distribution of IMO circulars. It is our view that documentation of receipt of IMO circulars should be achieved during the routine ISM audit process on board, thereby ensuring that the intended recipient, i.e. the vessel's Master, has received the required information, rather than the company only.

2 Analysis

Decision to sail

2.1 The Day Master based his decision to sail on the information available to him at the time, his experience of having sailed the Cook Strait route for a number of years as master and the information he had gathered on the weather and sea conditions on the previous crossing. In his time as an officer and as master on the Cook Strait route he would probably have encountered weather as bad as, if not worse than the conditions on the day.

2.2 The Day Master used the MetConnect service to augment his knowledge of the prevailing conditions before making his decision. This service was contracted from MetService by Interislander and provided up-to- date information on swell, wind, weather, radar imagery, satellite imagery, coastal and inshore weather forecasts and swell forecasts. By using this computer program the Day Master should have been able to anticipate what conditions the ship could face in the Strait. However, despite all his preparations the conditions changed faster than anticipated.

2.3 His decision to sail was therefore based on experience and as the company did not have any guidelines, other than that of good seamanship, laid down on what were and were not acceptable conditions, the master did not have any benchmark against which he could gauge his decision.

2.4 At the time that he made his decision to sail, no sailings had been cancelled and several ferries were still at sea (see Figure 2) so he had no reason to believe that his venture would be any less successful than that of the other ships sailing or about to sail. Therefore his decision to sail was appropriate although the weather conditions deteriorated faster than forecast.

2.5 The Day Master's selection of rough sea mode for the engines, so as not to place undue stress on the ship, and his decision to take the undocumented heavy weather route were also appropriate and resulted from his ship-handling training and experience as a master mariner, and that his recognition of the dangers of sailing in heavy weather.

2.6 Had the management of Interislander had more formalised, documented criteria on acceptable conditions for sailing, the masters would have had clear guidance in marginal conditions.

2.7 Had the company had more rigorous monitoring of the conditions when they were marginal, the company would have been more able to give appropriate advice to masters on the decision to sail.

Lashings and lashing system

2.8 Having decided to sail, the Day Master ordered the duty officer to instigate heavy weather procedures. As there was no procedure for ensuring that this order was correctly heard or understood, such as some form of closed-loop communication, a possibility arises that this order was never correctly received, although the incoming duty officer understood that heavy weather lashings were to be applied.

2.9 Because the Loading and Discharging Manual, which was in common use in preference to the Cargo Securing Manual, did not specify the actual number or disposition of lashings to be used in any weather let alone heavy weather, the duty officer was therefore left to interpret the number of lashings required from past experience and training. However, for lashings to work effectively they should be accurately placed and be tightened to the correct tension as laid out in the Cargo Securing Manual.

2.10 Because the deck lashing fittings on the Aratere were spaced at about 2.2 m intervals the correct spacing and angles of the portable lashings were difficult to achieve. As the ship had been in service for several years, the lashing crew probably applied a routine adaptation in that the lashings had always been done this way, or possibly an exceptional adaptation considering that "it would be okay this time".

2.11 The duty officers and the lashing crew may have had a poor risk perception of the familiar task that they were carrying out. They may have had a zero level of risk perception believing there was no chance of an accident occurring by doing the task in whatever way they did.

2.12 The requirement to check each lashing for suitability before use would have been an onerous but, as shown, vitally necessary task. The lashing crew could have suffered from routinisation of this task of having to check individual lashings several times a day. Thus they may have become more concerned about the mechanics and accomplishment of the task rather than its meaning.

2.13 The disposition of "lashing hooks" on certain designs of railway wagon, notably those that tipped over, and the positioning of the rakes of wagons within the ship precluded the lashing gang from spacing the lashings effectively. The provision of extra lashing points on the ZH wagons would have allowed for the lashings to be more correctly angled and would have probably reduced the possibility of the wagons tipping over.

2.14 If the lashings had been set at a length greater than that recommended, the amount of stretch of the lashings could have been sufficient to allow the lashed items to tip over or move without the lashings parting.

2.15 The angle to which the ship rolled on each occasion was considerably in excess of the angle of roll that the lashings were designed to withstand. Therefore, it could have been expected that at least some of the lashings would fail.

2.16 The independent analysis of the lashings taken from the *Aratere* showed that all the lashings showed signs of deterioration. The majority of the wear appeared to be where a small loop of webbing was held in place around a carbon steel bolt in the deck attachment fitting. On all the lashings this bolt was corroded and as a result was rough. Consequently, when under load, the fibres on the inside of the webbing at this point started to tear and the area became packed with corrosion product. This product would then have acted as an abrasive, causing damage to all the fibres in the region. The load testing of the 2 intact lashings showed a significant loss in strength of the webbing in this region.

2.17 The intact lashings that were analysed were picked at random from the lashings on board the *Aratere* and could be considered as a representative selection of available lashings, showing that the ones that failed on 3 March probably failed at a breaking load that was significantly below that of their original strength as a result of the deterioration.

2.18 The SOLAS requirement on cargo lashing was issued in 1991 followed by the MSC circular on Cargo Securing Manuals in 1996 and recommended to be in force in 1997. The relevant Maritime Rule did not come into force until 2005, and required ships to have Cargo Securing Manuals by 30 June 2006. Had the Aratere been registered in New Zealand from the date of its construction, it would not have had to comply with the requirements for cargo securing until after the date of the incident.

2.19 Maritime Rule 24B came into force on 30 June 2005 and required ships to comply by 30 June 2006. However, road vehicles did not have to comply until 30 June 2007. The Rule only covered commercial vehicles and combinations of vehicles, specifically excluding the semi-trailers that constituted a large proportion of the *Aratere*'s cargo. The ship owner could have been presented with the problem that the ship was able to comply with the lashing requirements, but the cargo could not. Therefore, the cargo may not have been optimally lashed.

2.20 As Maritime NZ and Standards New Zealand had jointly developed a relevant New Zealand Standard covering lashing points on road vehicles which was issued in 2005, it may have been prudent for reference to be made to this Standard in Maritime Rule 24B which came into force on 30 June 2005.

2.21 When the ship rolled heavily, several of the railway wagons fell over. The available evidence suggests that this was due to failures in either the lashings or the lashing systems. With continued heavy rolling the wagons could have possibly moved further than they actually did. However, to move further they would have had to overcome the friction between the rail deck and the sides of the wagons, which having been damaged in the fall may have increased the friction. Any continued further movement would have been in short bursts as the movement forces overcame the frictional forces. Because of this the wagons would not have gained much momentum.

2.22 Eventually, some of the wagons could have come to rest against the side of the rail deck. The sides of the rail deck were constructed from steel and for the majority of the length of the rail deck were not the outside hull of the ship but a bulkhead that separates the rail deck from the passenger and crew access spaces and tanks thus making the ship virtually twin skinned. It was unlikely that any of the wagons would have been able to gain enough momentum to pierce this bulkhead, let alone the outer hull and thus compromise the watertight integrity.

2.23 However, had enough of the rail wagons moved far enough to one side or the other, the ship could have developed a greater final list than it did.

Command, and command hand-over

2.24 The Night Master had been a master for Interislander for less than a year. He had undergone familiarisation training on board the *Aratere* and had completed Interislander's specific training programme for masters. However, available evidence suggested that in his period of employment as master at Interislander he had not encountered sea and weather conditions as were prevalent at the time of the incident. However, he had probably encountered similar sea and weather conditions while serving on other vessels engaged in the Cook Strait trade.

2.25 The Night Master arrived on the navigating bridge in plenty of time for the change of command to acquaint himself with the conditions before assuming command. In this way, a smooth changeover in command took place.

2.26 When the Day Master handed over command to the Night Master, he included in his handover what he considered to be relevant at that time, although, he did not include that the settings of the autopilot and stabilisers had been amended from the default position during a previous crossing. He may have assumed that the Night Master knew of such changes, as he was aware that the power to the propellers was being limited by the ship being in rough sea mode and amendments to the autopilot and stabiliser settings were not unusual in such conditions.

2.27 When the Night Master assumed command from the Day Master it was in effect a junior less experienced master assuming command from a much more senior and experienced master. A junior master, depending on the authority gradient, is less likely to question the senior master on the wisdom of sailing or pursuing the endeavour when the senior master has skilfully and successfully conned the vessel out of harbour and into Cook Strait. However, the Night Master may have suffered from any one or more of the hazardous thoughts of "I can do it", "It won't happen to me" or "We've always done it this way".

2.28 As the ship was fitted with articulated rudders, where 10° of helm equated to about 20° of helm on a conventionally ruddered ship, the change to the autopilot settings probably had little bearing on the outcome of the incident. The stabilisers were set to just outside the required zone of operation. Because this zone was relatively broad and encompassed a range of GM's the slight variation in the setting from the optimum also probably had little bearing on the outcome of the incident. A checklist or aide-mémoire would assist the masters in ensuring relevant items were not overlooked.

Stability

2.29 Although the *Aratere* appeared to have a maximum heel of 50° to the horizontal plane when it rolled heavily it is unlikely that the angle of heel to the waterline was as great as 50°. The angle of the ship to the horizontal plane was the sum of the angle of the wave to the horizontal plane and the angle of heel of the ship to that wave. The greater the angle of the wave to the horizontal on which the ship was positioned on, the less the angle of heel required by the ship to achieve 50°. This would explain why downflooding did not occur when the ship assumed an angle of 50° to the horizontal, which was greater than that required to submerge the openings' flooding line.

2.30 At the time of the incident the *Aratere* complied with all the requirements for stability. Its corrected GM was over 0.6 m greater than the requirements as specified under IMO Resolution A265 and over 0.7 m greater than that required under SOLAS 90. The maximum GZ over 30° was over 5 times greater than the minimum required by the regulations.

2.31 From the *Aratere*'s stability data, a calculation was made that showed that the point of vanishing stability was at about 75°, after this point the GZ became negative and instead of a righting lever a capsize lever existed and the vessel would have capsized. The GZ at the estimated maximum angle of roll was 1.01 m positive and very near to the maximum GZ of 1.06 m. With such a righting lever it is unlikely that the vessel would have capsized. However, at the time of the incident the ship was behaving dynamically in a seaway not heeling in still water, so some of the parameters could have changed but would not have changed sufficiently to make capsize likely.

2.32 From the information supplied by the independent naval architect and his considered opinion on the veracity of the GZ curve, especially at large angles of heel, the Commission has no reason to doubt the accuracy of the GZ curve, or the amount of residual dynamic stability of the ship and its ability to resist further rolling and possible capsize. Such was the amount of residual dynamic stability above the angle to which the ship rolled that it would have been possible for the ship to roll to a greater angle and still recover.

The incidents

2.33 Although the available evidence showed that the safety of the ship was unlikely to have been compromised, the perception of the amount of roll and the seriousness of the situation by all on board may have been heightened by the suddenness and extent of the rolls. These rolls would have made conditions on board uncomfortable for all. For some others the experience would have been frightening, and it was injurious to a few.

2.34 When the Night Master took command, the ship was already settled onto a south-westerly course. He was aware that usual practice was to continue in that direction until it was clear to turn to the north-west. However, the training he had received from Interislander did not contain any guidance on how long he should continue to the south-west before altering to the north-west. Each master was left to make the decision individually based on good seamanship and previous experience. Whilst allowing each master some latitude in their decision, it may have been more prudent for Interislander to have captured the knowledge and experience of its current and previous masters and incorporated this information into new masters' training and general guidelines, possibly as minimum and maximum limits to which the ship was recommended to go.

2.35 The Night Master elected to continue on the course set by the Day Master as he was aware that this was usual practice, and elected to leave the engines in rough sea mode recognising the dangers of the situation and also resulting from his training and experience as a master mariner. After every alteration of course he and his team carefully evaluated the motion of the ship to see how the ship was handling the weather, indicating that he and his team continued to be mindful of the dangers.

2.36 The MSC circular giving "guidance to the master for avoiding dangerous situations in following and quartering seas" may have been sent by Maritime NZ to Interislander. However, no record of its being sent to Interislander could be found, nor did the procedures in place at Maritime NZ at the time adequately document to whom this information was sent, if at all, or if it had been received by anyone. Therefore, Interislander and its masters were denied the benefit of this guidance, which although not mandatory could have been considered best practice.

2.37 The Commission concludes that had the Night Master had the benefit of the knowledge contained within MSC/Circ.707 and the consequential diagrams specific to the *Aratere* he would have been better informed and could have made different decisions with regard to the time of the course alteration, the course set and the speed of the *Aratere*, to remain outside the marginal and dangerous zones

2.38 Safety recommendation 045/05 made to Maritime NZ after occurrence 04-214 called for a review of the distribution of IMO circulars and the associated documentation, but this was not retrospective. However, it appears that there may have been some IMO circulars previously issued that had not been distributed to relevant shipping companies. Maritime NZ should instigate a system by which it can ensure that all parties have received all relevant current IMO circulars.

2.39 At the time of the first roll the Aratere was just in the marginal zone for surf riding and just in the dangerous zone for the high wave attack. The ship's natural rolling period was also close to the encounter wave period placing the ship in the dangerous zone for synchronous and parametric rolling motions.

2.40 At the time of the second roll the Aratere was just in the marginal zone for surf riding but not in the dangerous zone for high wave attack. The Aratere started to surf at the time of the second roll as evidenced by the increase in the speed of the ship through the water at that time. However, this speed increase only lasted for about 45 seconds, although it felt much longer to the bridge team. The Night Master regained control of the direction of the ship thereby preventing the ship continuing to surf and the possibility of broaching and capsize.

2.41 Operating as it was in heavy weather with large and increasing swells, the ship was in conditions that could have been conducive to broaching. A master must take all reasonable actions to mitigate that risk. The Night Master thought he had but would have benefited from the knowledge in MSC/Circ. 707 and would most likely have done more.

2.42 To broach, a ship has to come broadside, or beam on, to the wind and waves and remain captured there without enough engine power to provide effective steering out of the situation. A ship therefore either broaches or it does not; there are not degrees of broaching. To capsize in this condition, the ship has to remain captured by the wind and waves long enough for the waves to produce a capsizing moment and thus capsize the ship.

2.43 The Commission concluded that the vessel did not broach for the following reasons:

- despite some of the perceptions of various crew members, the course of the ship did not alter sufficiently during either of the shears (see Figure 6) to bring the ship beam on to the sea and swell. This was evidenced by the gyro records contained on the VDR
- when a ship broaches it goes beam on to the wind and waves, so, the relative wind direction would be either 090° or 270°. The graphical representation of the data downloaded from the VDR (see Figure 6) of the relative wind shows that the relative wind direction did not reach 270° during the first heavy roll, and only reached 270° momentarily during the second heavy roll. Relative wind direction is the direction of the wind relative to the ship's head in 360° notation. This input relies on information transmitted from the anemometer independent of all other inputs and would not be affected by any errors from other equipment such as gyro compasses
- when a ship broaches it remains captured by the wind and waves without the power to steer out of the situation. From comparisons of the rudder angle graphs with the ship's heading (see Figure 6) at the time of each shear, it can be seen that the rudders were effectively counteracting the shear to port and actively steering the ship back towards the set heading
- the Commission's conclusion is also supported by the independent analysis of the VDR data by the MAIB and also by the opinion of the manufacturer of the gyro compass.

2.44 In response to submissions received on the veracity of the gyrocompass data, the Commission concludes that the data from the VDR showed that the gyrocompass in use functioned throughout the incident with either the autopilot or the helmsman reacting to the compass heading and adjusting the helm to keep the ship on course within reasonable parameters. This can be seen from a comparison of the ship's heading graph and rudder angle graph.

2.45 The gyrocompasses on the ship had operating parameters, of which one, the 35° roll, was exceeded. Such parameters have a large degree of safety incorporated and it is unlikely a gyro compass as fitted would fail when only momentarily in excess of the roll parameter.

2.46 Had the gyrocompass in use sustained errors in the readout from the heavy rolling then the alarm system fitted would have alerted the bridge team to the problem. The alarm was not heard by any of the bridge team so it would be reasonable to accept that the alarm did not sound and that therefore the gyro compass did not suffer from directional instability.

2.47 Had the gyro compass failed totally, the heading would have remained constant and an alarm would have sounded. The data from the VDR would have indicated a straight line (flatlining) on the heading graph; a steady straight line could not be found on this graph during analysis of the VDR data. From analysis of the ship's heading graph in Figure 6, no flatlining could be found during either heavy roll.

2.48 Alternatively, had the extreme rolls caused the gyro to have been precessed well away from its true heading, the effect would have been a large deviation from true that would reduce, while oscillating either side of true, over a period of several hours. That there were no reported problems steering the ship after either of the extreme rolls, and no evidence of such on the VDR, leads to the conclusion that the gyro compass functioned correctly throughout the voyage.

2.49 Had the gyro compass in use failed then until either the other gyro compass or the transmitting magnetic compass was switched online the ship would have had no directional stability, the bridge team would not have known in what direction they were heading and the ship would have meandered off course driven by the wind and waves. This did not happen as can be shown from the ship's heading graph and neither of the other compasses was switched online.

2.50 There was little indication to the bridge team that the ship was going to make an extreme roll. However, when the roll occurred, the Night Master's action of first bringing the ship back on course then adjusting the course to bring the seas further astern was probably a “gut reaction” or an intuitive skill-based decision based on his seamanship training that putting the ship with the seas more on the beam was likely to cause heavier rolling and running with the seas was likely to be a better option.

2.51 Although running with the seas put the ship closer to the coast of the North Island, the Night Master was confident that the ship would pass clear of any dangers. However, as the ship was set towards the coast by the wind and seas he, and the bridge team, became concerned at the closeness of the coast. That concern led him to try to move further from the coast. Not having the benefit of extensive experience with articulated rudders, the Night Master probably did not fully appreciate the effects of putting the rudders hard over with the limited power available to him in rough sea mode. So when he attempted to increase the distance from the coast he effectively “stalled” the ship as it came round into the wind. His only alternative at this time was to turn the ship back again and try and increase the distance off by running at a more oblique angle to the coast. This was, unfortunately, on a course close to the one where the first extreme roll had occurred.

2.52 At the time of both unexpected extreme rolls, the ship was in the vicinity of, but not in, the Karori Rip. The normal fair weather route for the ferries had the ships transiting the Karori Rip, and whilst this should not be a problem for ships with such size, engine power and handling characteristics the effects of the Rip were not well documented for varying weather conditions. It was possible that the Rip had an effect on the wave patterns in the Strait at the time of the incident and therefore affected the Aratere. Further investigation and documentation of this phenomenon would provide valuable information to the masters of ships transiting the Strait.

2.53 It was unlikely but not impossible that the Aratere was affected by 2 swell trains. The wave trains that the Night Master and Third Officer observed were more probably a swell train and a wind wave train. However, whatever the nature of the trains they would have combined synchronously to produce higher-than-normal waves at certain points and lower-than-normal waves at others.

Bridge resource management

2.54 In response to submissions received on the level of BRM exhibited, the Commission concludes that although there were instances where the BRM was less than optimal, in general the BRM was working effectively throughout for the reasons outlined below.

2.55 Before the Night Master decided on the change of course from the south-westerly direction to the north-westerly direction he discussed with the bridge team what to do and when, showing that the bridge team shared a common view of the intended passage and allowed for challenge and response.

2.56 After the first heavy roll the Night Master again discussed the best course to set with the bridge team, which had by then been supplemented with other members of the navigation department including the Day Master. This again allowed for a common view to be established and allowed for different options to be examined and a consensus to be obtained before he made the final decision.

2.57 The use of challenge and response was shown when the Day Master challenged the Night Master’s attempt at distancing the ship from the coast after the commencement of the manoeuvre; the Night Master’s response was to abort the manoeuvre.

2.58 Throughout the incident, the Night Master and crew used the principles of BRM to ensure that decisions were based on sound judgement by including all members of the bridge team in the decision-making process, considering all other options put forward by other members of the team, having closed-loop communication and keeping the remainder of the ship’s crew and passengers advised of actions through appropriate announcements.

2.59 Although the use of BRM was exhibited throughout the incident and was in general used to best advantage, there were instances when the use of BRM was less than optimal:

- when the Day Master challenged the Night Master's aborted turn to distance the ship from the coast, better BRM may have been for the Day Master to advise the Night Master on the correct use of the articulated rudder system and engine power systems in the prevailing conditions and suggested another attempt at turning as the team had agreed that a turn away from the coast was the best course of action
- although the whole bridge team was involved in the discussions as to the best course to take and challenge and response was requested and received, no member of the bridge team challenged the course chosen when the ship was being set towards the land. It is unlikely that none of the persons on the bridge noticed that the ship was being set towards the land as this was actively discussed amongst the bridge team prior to the decision to attempt the turn away. To operate effectively there was probably some degree of authority gradient amongst the bridge team, had this gradient been too steep towards the Night Master, expressions of concern or questioning actions may have been stifled. However, at the time of the attempted turn, the bridge team, which was providing support and advice to the Night Master, consisted of the majority of the navigating officers on board, including a senior master and a senior chief officer where the gradient would have been shallow or may even have been away from the Night Master.

3 Findings

Findings are listed in order of development, not in order of priority

3.1 On 2 occasions the *Aratere* encountered waves larger and steeper than others, causing the ship to roll heavily.

3.2 Although the available evidence indicated the safety of the ship was unlikely to have been compromised the suddenness and extent of each of the rolls made it uncomfortable for all on board, frightening for some and injurious for a few.

3.3 The *Aratere* was in the dangerous or marginal zones with respect to possible surfing, reduced intact stability, broaching and parametric resonance.

3.4 From the available evidence, the ship's response was the combined result of several effects causing large one-sided rolling moments to starboard combined with an oscillatory wave-induced moment, all of which coincided with the presence of a wave crest near amidships.

3.5 The Day Master's decision to sail, based on the information available and his own experience, was reasonable.

3.6 The operator had not provided any guidelines, other than that of good seamanship, on what were and were not acceptable weather and sea conditions to assist masters in deciding when to sail.

3.7 Conditions in Cook Strait deteriorated more rapidly than forecast and more rapidly than the Day Master and Operations Manager anticipated.

3.8 Other ships of similar size and power were at sea in the Strait at the time the Day Master made the decision to sail and during the *Aratere*'s crossing, none of which experienced similar problems.

3.9 The Night Master arrived early on the bridge for handover of command and the Day Master departed late from the bridge. This ensured a smooth handover of command and although some information was not contained in the handover, the handover was carried out appropriately.

3.10 Had the MSC Circ./707 guidance material on avoiding dangerous situations in following and quartering seas been available to Interislander and its masters, the Night Master and his team would have had an increased awareness of the danger the vessel was in. They could then have made different decisions on the choice of when to turn and the speed and course of the ship and would probably have been able to ensure that the ship was not operating in either the marginal or the dangerous zones.

3.11 The Night Master, and others of the navigating team, had received training in ship handling in various conditions during their certification process. The MSC/Circ.707 contained additional information and guidance that were not in the syllabus for Master Mariner when the Night Master gained his certification.

3.12 The training the Night Master received after he joined Interislander did not contain sufficient guidance on the use of the undocumented heavy weather route, nor did it include sufficient information on the handling characteristics of the *Aratere* in heavy weather and procedures in the use of articulated rudders.

3.13 Although the Night Master and bridge team used BRM principles to ensure that a common view of the passage and the intended actions was held, and that all possible options were explored before committing to their intended plan, at times its use was less than optimal.

3.14 Although the Night Master and bridge team were aware that the ship was closing a lee shore their attempt to distance the ship from the shore was unsuccessful.

3.15 The righting lever (GZ) at the *Aratere*'s estimated maximum angle of roll was of such a magnitude to make the possibility of capsize unlikely, and to ensure the safety of the ship was not compromised after a cargo shift created a 5° list

3.16 The angle to which the ship rolled on each occasion was greater than the designed maximum roll angle for the cargo lashings, which subsequently failed due to a combination of loss of strength from wear and corrosive contamination at the securing bolt, and lashings being at incorrect angles and tension.

3.17 The failure of the cargo lashings resulted in extensive damage to both rail and road cargo.

3.18 Owing to the lack of closed-loop communication there was a misunderstanding between the Day Master and both the deck duty officers with regard to the number of lashings required on the road deck cargo.

3.19 Because there were discrepancies between the Loading and Discharging Manual in general use and the Cargo Securing Manual the deck duty officers probably had to interpret the number of lashings required using their previous experience and training.

3.20 The positioning of the ferry lashing hooks only at the ends of the ZH wagons probably exacerbated the possibility of incorrect lashing.

3.21 Because of the repetitive nature of the task the deck duty officer and the lashing crew could have been affected by any or a combination of poor risk perception, routine adaptation or exceptional adaptation.

3.22 The evidence suggested that the procedure for checking the lashings for suitability for continued use and the segregation of unsuitable lashings was probably not robust enough and was prone to routinisation by the crew.

3.23 Difficulty in correctly lashing commercial road vehicles would be expected when the requirements for the installation of suitable lashing points on ships and vehicles had differing compliance dates.

3.24 The *Aratere* was correctly certified and manned at the time of the incident and the *Aratere* complied with all national and international regulations applicable to its stability.

3.25 The omission from Maritime Rule 40B of reference to the lashing point requirements for semi trailers, which constitute a large proportion of the cargo carried by the *Aratere,* could lead to cargo being presented for shipment that does not comply with safe lashing procedures.

3.26 The procedures that Maritime NZ had in place, as the Government's representative at IMO, for the promulgation and recording of information from IMO, at the time of the issuance of MSC/Circ. 707 were less than optimal to ensure that all relevant parties received the information.

4 Safety Actions

4.1 Since the incident Interislander has implemented the following actions:

4.1.1 In relation to the decision to sail:

- contracted for the supply of a 5 day significant wave height forecast for Cook Strait twice a week
- when the significant wave height is forecast to be greater than 4 m, the Interislander management team closely monitors the expected and actual significant wave height
- when the actual significant wave height exceeds 4 m the Interislander management team, taking into account all available relevant information have to approve each ferry sailing
- if the ferry sailing is approved by the management team, the final decision on whether to sail rests with the master in command at the time.

4.1.2 In relation to the Interislander's fleet:

- the handling characteristics of the ships are being further investigated as to under what conditions they may shear or behave in an unexpected manner
- having polar diagrams created to forecast their susceptibility in Cook Strait to the phenomena described in MSC/Circ. 707
- having the results from the above incorporated into the integrated management system.

4.1.3 In relation to on board familiarisation:

- the familiarisation programme to be reviewed to include testing the understanding of all officers, including masters being familiarised
- the familiarisation programme to include 12-monthly reviews in addition to the ongoing programme of internal audit and verification
- familiarisation training to be completed before any newly introduced equipment is used.

4.1.4 In relation to officer's and command handover:

- a review of the handover process to ensure that the handovers include
    - closed-loop communication as to cargo requirements
    - closed-loop communication as to changes to equipment settings from the default settings
    - closed-loop communication as to the adequacy of cargo lashings for the intended voyage
- checklists to be updated to reflect the above closed-loop communications, and the pre-departure checklist to include the review of the MetConnect weather.

4.1.5 In relation to capturing relevant knowledge

- develop guidance notes on factors to be taken into account when deviating from the standard passage plan, e.g. heavy weather route and Karori Rip
- reviewing all previous master's knowledge where available
- reviewing all current rules, regulations, codes, guidelines and other documentation where available
- development of an IT based database of this information to be available on board all fleet ships.
- develop training to assist staff in managing stress and the impact of stress on decision making.
- ensuring that newly appointed master's spend time as chief officer before assuming command and a complete review of promotion and succession planning

4.1.6 In relation to cargo lashings and further to the decision to change the lashing system to chain lashings since the previous incident

- the Loading and Discharging Manual has been amended, deleting all references to lashing requirements and directing the reader to the Cargo Securing Manual
- further define lashing requirements against anticipated weather conditions
- reinforce the supervisory responsibilities of the Chief Officer and Bosun on the lashing crew
- checklists to be developed to log satisfactory completion of lashings
- lashing of cargo to be defined as a critical process
- the periodicity of inspection and audit of lashings and the lashing process to be increased and entered into the planned maintenance system
- a full review of the lashing arrangements across the fleet with particular attention to the Aratere
- installed 90 extra lashing points around the forward and aft areas of the Aratere's rail deck to improve the lead angles of the lashings.
- develop communication with clients to ensure that:
- Interislander has input into the ongoing and future development of lashing points on rail wagons
- shippers are made aware of required lashing points at the time of booking.

4.1.7 The Night Master is to be given further training and familiarisation on board the company's ships.

4.1.8 Carry out a full review of the integrated ship management system, with the reviewed system to be implemented and followed up by way of a programme of internal audits and other verifications.

4.1.9 Immediately after the incident, ZH wagons were modified by fitting chain loops around strong points in the centres of the wagons to allow 2 extra lashings per side to be attached. The ZH wagons were later further modified by fitting permanent lashing points capable of taking 2 extra lashings per side in lieu of the chain loop.

4.2 In view of the actions taken by Interislander, no further safety recommendations covering these aspects have been made to Interislander.

4.3 On 11 January 2007 the MSC issued Circular MSC.1/Circ.1228 Revised guidance to the master for avoiding dangerous situations in adverse weather and sea conditions. This Circular was promulgated by Maritime NZ on 2 February 2007. In view of this action, no safety recommendation covering this aspect has been made to Maritime NZ.

5 Safety Recommendations

Safety recommendations are listed in order of development, not in order of priority

5.1 On 12 June 2007 the Commission recommended to the Director of Maritime NZ that she:

5.1.1 advise all affected shipping companies in New Zealand of all current IMO circulars and documents, and how each may acquire them. (017/07)

5.1.2 Draft an Amendment, by the most appropriate means, to Maritime Rule Part 24B carriage of cargoes – stowage and securing for the Minister's consideration. The amendment to ensure that the rule includes reference to the appropriate International Standards Organization standard for lashing and securing arrangement on road vehicles for sea transportation on ro-ro ships - Part 2 Semi trailers, and if applicable the current New Zealand Standard covering lashing points on road vehicles for sea transportation on ro-ro ships. (018/07)

5.2 On 19 July 2007 the Director of Maritime New Zealand replied:

5.2.1 017/07
Maritime New Zealand (MNZ) accepts the intent of this recommendation, however, would note that it has procedures in place to ensure operators do receive circulars when they are issued by the IMO.

MNZ will investigate the supply of an electronic listing of historic circulars which will be provided to SOLAS shipping operators in New Zealand.

5.2.2 018/07
An amendment for Rule 24B to include ISO standard for lashing of semi trailers is planned for the 2007/2008 year. This is detailed in the MNZ guidance notice issue 02-2007.

5.3 On 23 July 2007, in view of the response and action taken by Maritime New Zealand, safety recommendation 018/07 was "closed – acceptable" by the Commission.

Approved on 24 July 2007 for publication

Hon W P Jeffries
Chief Commissioner

Appendix 1

HEAVY WEATHER

This procedure applies when there is, or when there is expected to be, adverse sea or wind conditions which may affect the safety of the ship, cargo or passengers.

MASTER RESPONSIBLE FOR:

- ❑ Ship and cargo secured ready for any expected weather conditions
- ❑ All departments informed
- ❑ Announcement to passengers, (see heavy weather announcement in safety manual.

DUTY MATE RESPONSIBLE FOR:

- ❑ Rounds made prior to leaving sheltered waters with particular attention to the securing of:
  - ♦ stern door, gangway doors, bunker doors and portholes
  - ♦ cargo, rubbish bin, funnel doors, loose equipment
  - ♦ forecastle hatches and door, anchors and mooring lines
  - ♦ lifeboats and liferafts, (lifeboat drain plugs out); and,
  - ♦ equipment in galley, pantries and restaurants
- ❑ Ventilators and air pipes, covered/closed as necessary
- ❑ Scuppers and drains clear
- ❑ Rounds made as the ship reaches the open sea and frequently thereafter until the ship reaches sheltered waters, entry made in the bridge log book.
- ❑ I.R's on continuous cargo watch when required.

THE BRIDGE OFFICER OF THE WATCH IS RESPONSIBLE FOR: -

- ❑ Speed and/or direction the ship is heading is adjusted to reduce excessive pounding or rolling
- ❑ Stabilisers operating if beneficial, (if in doubt put them out).

ENGINE ROOM WATCHKEEPER RESPONSIBLE FOR: -

- ❑ Equipment in the engine room spaces is adequately stowed and secured.
- ❑ Stabilisers are in an operable condition
- ❑ Fuel tanks, lub. oil storage and service tank levels are such that overflowing may only occur under extreme conditions.
- ❑ Duty service tanks have sufficient content so that the outlet/rundown to running machinery will not be exposed and allow air to enter service lines during extreme motion of the vessel.
- ❑ Standby fuel is sufficiently full as above.
- ❑ Engine room casing doors are shut, so that water will not enter engine room spaces.
- ❑ Train deck floodwater drain tanks are empty and that equipment to pump them out is in an operable condition.

Appendix 2

Part 31A, Amendment 1 Crewing and Watchkeeping Unlimited, Offshore, and Coastal (Non-Fishing Vessels)
Appendix 1 - Navigational Watchkeeping at Sea

(7) Taking over the watch

(a) The officer in charge of the navigational watch must not hand over the watch to the relieving officer if there is reason to believe that the latter is not fit for duty and therefore is not capable of carrying out the watchkeeping duties effectively, in which case the master must be notified.

(b) The relieving officer must ensure that the members of the relieving watch are fully capable of performing their duties, particularly as regards their adjustment to night vision. Relieving officers must not take over the watch until their vision is fully adjusted to the light conditions.

(c) Prior to taking over the watch, relieving officers must satisfy themselves as to the ship's estimated or true position and confirm its intended track, course and speed, and UMS controls, if fitted, and must note any dangers to navigation expected to be encountered during their watch.

(d) Relieving officers must personally satisfy themselves regarding the -

- (i) standing orders and other special instructions of the master relating to navigation of the ship; and
- (ii) position, course, speed and draught of the ship; and
- (iii) prevailing and predicted tides, currents, weather, visibility and the effect of these factors upon course and speed; and
- (iv) procedures for the use of main engines to manoeuvre when the main engines are on bridge control; and
- (v) navigational situation, including but not limited to -
  - (aa) the operational condition of all navigational and safety equipment being used or likely to be used during the watch; and
  - (bb) the errors of gyro and magnetic compasses; and
  - (cc) the presence and movement of ships in sight or known to be in the vicinity; and
  - (dd) the conditions and hazards likely to be encountered during the watch; and
  - (ee) the possible effects of heel, trim , water density and squat on underkeel clearance.

(e) If at any time the officer in charge of the navigational watch is to be relieved when a manoeuvre or other action to avoid any hazard is taking place, the relief of that officer must be deferred until such action has been completed.

(2) Taking over the watch

(a) Officers in charge of the deck or engineering watch must not hand over the watch to their relieving officer if they have any reason to believe that the latter is not capable of carrying out Watchkeeping duties effectively, in which case the master or chief engineer must be notified accordingly. Relieving officers of the deck or engineering watch must ensure that all members of their watch are fully capable of performing their duties effectively.

(b) If, at the moment of handing over the deck or engineering watch, an important operation is being performed, that operation must be concluded by the officer being relieved, except when ordered otherwise by the master or chief engineer officer.

Taking over the deck watch

(c) Prior to taking over the deck watch, the relieving officer must be informed of the following by the officer in charge of the deck watch -

(i) the depth of the water at the berth, the ship's draught, the level and time of high and low waters; the securing of the moorings, the arrangement of anchors and the scope of the anchor chain, and other mooring features important to the safety of the ship; the state of main engines and their availability for emergency use; and

(ii) all work to be performed on board the ship; including the nature, amount and disposition of cargo loaded or remaining, and any residue on board after unloading the ship; and

(iii) the level of water in bilges and ballast tanks; and

(iv) the signals or lights being exhibited or sounded; and

(v) the number of seafarers required to be on board and the presence of any other persons on board; and

(vi) the state of fire-fighting appliances; and

(vii) any special port regulations; and

(viii)the master's standing and special orders; and

(ix) the lines of communication available between the ship and shore personnel, including port authorities, in the event of an emergency arising or assistance being required; and

(x) any other circumstances of importance to the safety of the ship, its crew, cargo or protection of the environment from pollution; and

(xi) the procedures for notifying the appropriate authority of any environmental pollution resulting from ship activities.

(d) Relieving officers, before assuming charge of the deck watch, must verify that -

(i) the securing of moorings and anchor chain is adequate; and

(ii) the appropriate signals or lights are properly exhibited or sounded; and

(iii) safety measures and fire protection regulations are being maintained; and

(iv) they are aware of the nature of any hazardous or dangerous cargo being loaded or discharged and the appropriate action to be taken in the event of any spillage or fire; and

(v) no external conditions or circumstances imperil the ship and that it does not imperil others.

Appendix 3

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MSC/Circ.707
19 October 1995

Ref. T1/2.04

GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN FOLLOWING AND QUARTERING SEAS

1 The Maritime Safety Committee, at its sixty-fifth session (9 to 17 May 1995), approved the annexed Guidance to the master for avoiding dangerous situations in following and quartering seas, with a view to providing masters with a basis for decision making on ship handling in following and quartering seas, thus assisting them to avoid dangerous phenomena that they may encounter in such circumstances.

2 Member Governments are invited to bring the Guidance to the attention of shipmasters and other interested parties of the shipping industry as they deem appropriate.

3 The Maritime Safety Committee has decided to review the Guidance in the future with a view to improving it, in particular with respect to large ships, on the basis of new technical developments and in the light of experience gained from its application.

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ANNEX

GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN FOLLOWING AND QUARTERING SEAS

1 GENERAL

1.1 When sailing in severe following or quartering seas, a ship is likely to encounter various kinds of dangerous phenomena, which may lead to capsizing. Although the dynamic behaviour in following and quartering seas is not yet covered in present stability standards, much progress has been made in recent years towards understanding the physics of capsize mechanisms and identifying potentially critical conditions.

1.2 The sensitivity of a ship to dangerous phenomena will depend on the actual stability parameters, hull geometry, ship size and ship speed. This implies that the vulnerability to capsizing and its probability of occurrence in a particular sea state may differ for each ship.

1.3 The guidance aims at giving seafarers caution on dangerous phenomena that they may encounter during navigation in following and quartering seas, and providing the basis for a decision on ship handling in order to avoid such dangerous situations. It provides advice on safe and unsafe combinations of ship speed and course relative to waves, in a simplified form of a polar diagram. The diagram does not take into account the actual stability and the dynamic characteristics of an individual ship, but provides a general unified boundary of safe and unsafe combination of the operational parameters for all types of conventional ships covered by IMO instruments.

1.4 For the ships which are equipped with an on-board computer, the Administrations are encouraged to use specially developed software which would take into account the main particulars, actual stability and dynamic characteristics of the individual ship in the real voyage conditions. Such software should be approved by the Administration.

2 PRECAUTIONS

It should be noted that the operation guidance is not the criteria to guarantee the safety absolutely. A ship could be unsafe even outside the dangerous zone defined in this guidance if the stability of the ship is insufficient and several dangerous phenomena characteristic for following and quartering seas happen simultaneously. Therefore, the ship master should pay attention that the ship maintains a good state of stability and do not carelessly navigate in severe following and quartering seas.

3 DANGEROUS PHENOMENA FOR SHIPS IN FOLLOWING AND QUARTERING SEAS

3.1 Dangerous ship responses in following and quartering seas

The period with which a ship travelling in following and quartering waves encounters the waves becomes longer than in head or bow waves, and principal dangers caused in such situations are as follows:

.1 Surf-riding and broaching-to

When a ship is situated on a steep forefront of high wave in following and quartering sea condition, the ship can be accelerated to ride on the wave; this is known as surf-riding. When a ship is surf-ridden, the so-called broaching-to phenomenon may occur, which endangers the ship to capsize as the result of sudden change of ship's heading and unexpected large heeling.

.2 Reduction of intact stability caused by riding on the wave crest at midship

When a ship is riding on the wave crest, the intact stability will be decreased substantially according to the ship form. The amount of stability reduction is nearly proportional to the wave height and the ship may lose the stability when the wave length is one to two times of ship length and wave height is large. This situation is especially dangerous in following and quartering seas, because the duration of riding on wave crest, i.e. the time of inferior stability, becomes longer.

.3 Synchronous rolling motion

Large rolling motions may be excited when the natural rolling period of a ship coincides with the encounter wave period. In case of navigation in following and quartering seas this may happen when the transverse stability of the ship is marginal and therefore the natural roll period becomes longer.

.4 Parametric rolling motion

Unstable and large amplitude roll motion will take place if the encounter wave period is approximately equal to half of the natural roll period of the ship. This type of rolling can occur in head and bow seas where the encounter wave period becomes short. In following and quartering seas, this can occur particularly when the initial metacentric height is small and the natural roll period is very long.

.5 Combination of various dangerous phenomena

The dynamic behaviour of a ship in following and quartering seas is very complex. Ship motion is three-dimensional and various detrimental factors or dangerous phenomena such as additional heeling moment due to deck in water, water shipping and trapped on deck or cargo shift due to large roll motions, may occur in combination with the above-mentioned phenomena simultaneously or in a sequence. This could create extremely dangerous combination which may cause ship capsize.

3.2 Dangerous navigation conditions in following and quartering seas

There exist two kinds of critical conditions of encounter waves under which the dangerous phenomena as above-mentioned are excited:

.1 When the ship speed approaches to the phase velocity of wave

When the ship speed is so high that its component in the wave direction approaches to the phase velocity of wave, the ship will be accelerated to reach surf-riding and broaching-to (paragraph 3.1.1). The critical speed for the occurrence of surf-riding is considered to be $1.8\sqrt{L}$ (knots), where L is ship length. It should be noted that there is a marginal zone ($1.4\sqrt{L} \sim 1.8\sqrt{L}$) below the critical speed, where a large surging motion may occur, which is almost equivalent to surf-riding in danger. In these situations, a significant reduction of intact stability (paragraph 3.1.2) may also be induced with longer duration; and

.2 When the ship speed is nearly equal to the group velocity of wave

When the ship speed component in the wave direction is nearly equal to the wave group velocity, that is a half of the phase velocity of the dominant wave components, the ship will be attacked successively by high waves. The expectable maximum wave height of the successive waves can reach almost twice of the observed wave height of the sea state concerned.

In this situation, the reduction of intact stability (paragraph 3.1.2), synchronous rolling motions (paragraph 3.1.3), parametric rolling motions (paragraph 3.1.4) or combination of various dangerous phenomena (paragraph 3.1.5) may occur and create the danger of capsize.

4 OPERATION GUIDANCE

The shipmaster is recommended to take the following procedures of ship handling to avoid the dangerous situations when navigating in severe following and quartering seas.

4.1 Ship condition

This guidance is applicable to all types of conventional ships navigating in rough seas, provided the stability criteria specified in resolutions A.167(ES.IV) and A.562(14) for merchant ships, and resolutions A.168(ES.IV) and A.685(17) for fishing vessels or an equivalent are satisfied.*

4.2 Wave condition

The following and quartering seas mean here that the wave direction relative to the ship course is within 0º to 45º from the ship's stern, as shown in figure 1.

* Refer to the Code on Intact Stability for All Types of Ships covered by IMO Instruments, adopted by the Organization by resolution A.749(18).

4.3 How to avoid dangerous conditions

.1 For surf-riding and broaching-to.

The master should reduce ship speed to less than 1.8√L (knots) to prevent surf-riding, referring to figure 2.

It should be noted that even in lower ship speed than that specified above the dangerous large surging can occur as shown in figure 2. Since a remarkable surging acceleration with long period is a sign of the dangerous large surge motion, the master should reduce the speed in such case, too.

.2 For successive high wave attack

When the average wave length is larger than 0.8 x ship length and the significant wave height is larger than 0.04 x ship length, and at the same time some indices of dangerous behaviour of the ship can be clearly seen, the master should pay attention not to enter in the dangerous zone as indicated in figure 3. When the ship is situated in this dangerous zone, the ship speed should be reduced to prevent successive attack of high waves.

The course change is also possible in order to escape this zone. However, large course change is undesirable, because it may induce an adverse effect by approaching to the beam sea condition which is also dangerous for stability. The combination of appropriate speed reduction with a slight change of course will be another possible choice of ship handling according to figure 3.

When the encounter wave period is nearly equal to double (i.e. about 1.5-2.8 times) of the observed wave period, the ship is considered to be situated in this dangerous zone. This relation is indicated in figure 3.

.3 For synchronous rolling and parametric rolling motions

The master should prevent a synchronous rolling motion which will occur when the encounter wave period TE is nearly equal to the natural rolling period of ship TR. Large rolling motions which occur under the condition of TE≈TR/2, that is the parametric rolling should be also prevented. The encounter wave period TE is a function of V/T as shown in figure 3. By using this relation, the master can know whether his ship will encounter the synchronous and parametric rolling or not.

When reducing speed in order to avoid any of above critical conditions, the master should take into consideration the minimum speed required for maintaining course control in waves and wind. The procedures to execute the operation guidance is represented by the "Operation diagram for the master", which is shown in the appendix.

5 EXPLANATION OF OPERATION GUIDANCE

5.1 Definition of symbols used

L	length between perpendiculars of the ship (metre)
B	breadth of the ship hull (metre)
d	draught of the ship hull (metre)
V	actual ship speed (knot)
T	mean wave period (second)
TE	encounter wave period (second)
TR	natural rolling period (second)
GM	metacentric height of ship (metre)
λ	average length of the wave (metre)
χ	encounter angle of the ship to wave (degree), as shown in figure 1
H1/3	significant wave height (metre)

5.2 Method of obtaining data necessary to use operation guidance

1. V: Estimate the actual ship speed in an appropriate way.

2. χ: Obtain by visual observation. The wind direction can be referred as the same as the wave direction. If the sea condition is not visible, the radar image can show wave crest trains and wave direction.

3. T: Measure the period of heaving motion of foam on the sea surface generated by breaking wave with the use of a stop watch. The time duration of N cycles is to be measured and divided by N to get the average wave period. When the wave length λ is determined either by visual observation in comparison with the ship length or by reading the mean distance between successive wave crests on the radar image of waves, T can be calculated by the following equation:

$$T = 0.8 \sqrt{\lambda}.$$

4. T_E: Measure the period of such a ship motion as pitching by using a stop watch.

5. TR: Measure the period of rolling motions preferably when the ship is in calm sea; alternatively, this value is roughly estimated by the following equation:

$$TR = 2CB/\sqrt{GM}$$

where:

C = 0.373+0.023(B/d)-0.043(L/100), or by equivalent determination of coefficient C.

6 NECESSARY TRAINING ITEMS AND CAUTIONS TO EXECUTE THE GUIDANCE

6.1 Understanding of stability of ship

The ship should satisfy the stability standard specified in resolutions A.167 (ES.IV) and A.562 (14) for merchant ships and resolutions A.168 (ES.IV) and A.685 (17) for fishing vessels or equivalent.* Therefore, the master should have knowledge on the stability of his ship for every possible loading conditions whether it satisfies the above standards of stability, or equivalent standards.

6.2 Measurement or estimation of natural rolling period

The natural rolling period of a ship depends on the loading condition of the ship. Therefore, it is desirable to measure the natural rolling period in calm sea on every occasion of departure after cargo loading or unloading. A stop watch can be used for the measurement.

6.3 Measurement of wave period and observation of wave direction

The wave period is measured by a stop watch, and the wave direction is estimated by visual observation or by watching radar image. The practice of wave and wind observation is common for the shipmasters of selected ships (World Meteorological Organization (WMO)).

* Refer to the Code on Intact Stability for All Types of Ships covered by IMO Instruments, adopted by the Organization by resolution A.749(18).

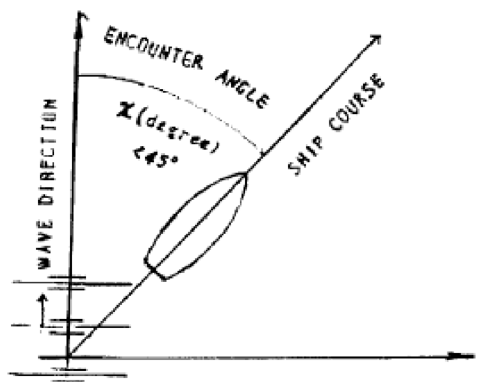

Figure 1-Definition of encounter angle χ

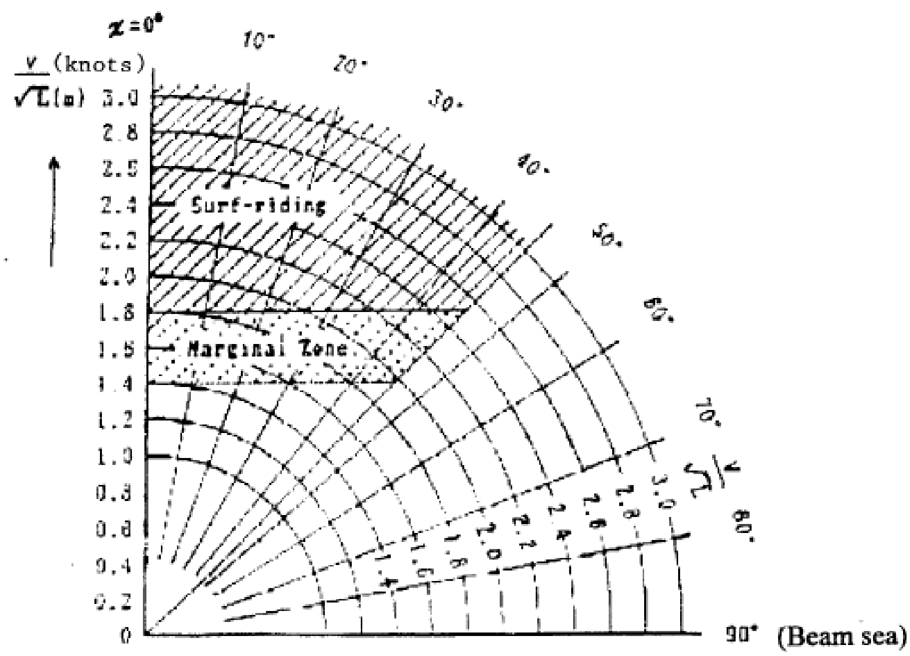

Figure 2-Diagram indicating dangerous zone due to surf-riding

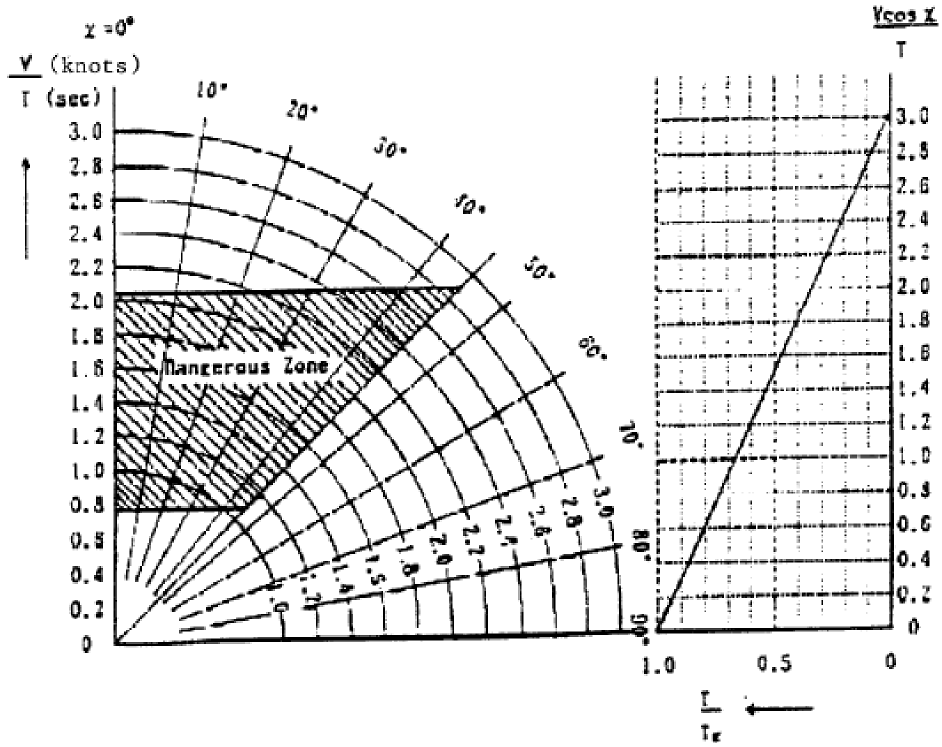

Figure 3 - Diagram indicating dangerous zone of encountering to high wave group and relation between mean wave period and encounter wave period in following and quartering seas

APPENDIX

OPERATION DIAGRAM FOR THE MASTER

Ship: Satisfaction to IMO stability criteria or equivalent

↓

Wave: Wave length > 0.8 × ship length, $H_{1/3}$ >0.04 × ship length
Estimate λ, T, and χ, where $T = 0.8\sqrt{\lambda}$.

↓

Ship course: Wave direction is 0° to 45° from the stem.

↓

Encounter wave period, T_E

↓

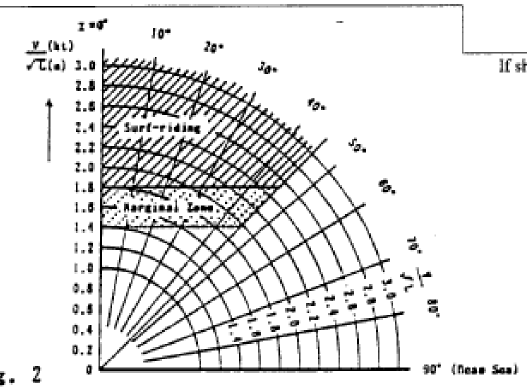

Fig. 2

If ship's speed:

→ (1) in Surf-riding zone
Reduce to speed zone (2),

→ (2) in marginal zone
Reduce to speed zone (3),
when felt large surging.

→ (3) beyond the zones

↓

Next step

↓

Plot V(knot)/T(s) versus χ on Figure 3.

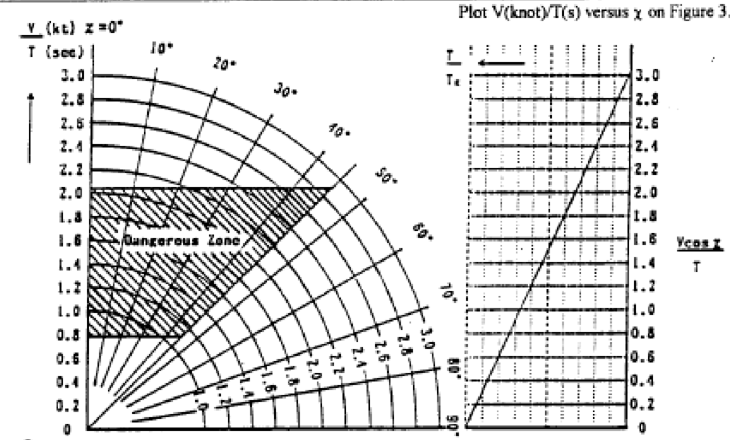

Fig. 3

↓

If V/T (χ) is in the dangerous zone, reduce the speed to come out of the zone.

↓

If V/T (χ) is beyond the dangerous zone, keep speed and course. — Judge T_E

↓

If T_E is nearly equal to T_R or T_R /2, reduce the speed further.*

* Take into consideration the minimum speed for maintaining course control of the ship.

Recent Marine Occurrence Reports published by the Transport Accident Investigation Commission (most recent at top of list)

06-205	fishing vessel, *Lady Luck*, collision and subsequent foundering, Motiti Island, Bay of Plenty, 23 June 2006
06-203	fishing vessel *Venture*, grounding, Tipi Bay, Tory Channel, 19 April 2006
05-211	container ship *Spirit of Resolution,* collision with bridge, Onehunga, 8 October 2005
05-210	restricted limit passenger vessel *Milford Mariner*, engines' stall resulting in grounding, Harrison Cove, Milford Sound, 18 September 2005
05-208	passenger freight ferry *Santa Regina*, near grounding, Tory Channel eastern entrance, 9 June 2005
05-207	freight and passenger ferry *Santa Regina* and private launch *Timeless*, collision, off Picton Point, Queen Charlotte Sound, 2 May 2005
05-206	passenger/freight ferry *Arahura*, loss of propulsion, Cook Strait, 24 April 2005
05-205	restricted limit passenger vessel *Black Cat*, control cable failure and collision with rock wall Seal Bay, Akaroa Harbour, 17 April 2005
05-202/204	passenger freight ferry *Aratere*, steering malfunctions, Wellington Harbour and Queen Charlotte Sound, 9 February and 20 February 2005
05-201	passenger ferry *Quickcat* and restricted passenger vessel *Doctor Hook*, collision, Motuihe Channel, 4 January 2005
04-219	restricted limit passenger vessel *Tiger 111*, grounding, Cape Brett, 18 December 2004
04-217	fishing vessel *San Rochelle*, fire and foundering, about 96 nm north-north-west of Cape Reinga, 27 October 2004
04-216	passenger freight ferry *Aratere*, total power loss, Queen Charlotte Sound, 19 October 2004
04-215	restricted limit passenger vessel *Southern Winds*, grounding, Charles Sound, Fiordland, 15 October 2004
04-214	passenger freight ferry *Aratere*, loss of mode awareness leading to near grounding, Tory Channel, 29 September 2004
04-213	restricted limits passenger ferry *Superflyte*, engine room fire, Motuihe Channel, Hauraki Gulf, 22 August 2004