ANNEX A

MCA Prohibition Notice dated 2 May 2004 and Prohibition Notice Addendum dated 3 May 2004

mca
Maritime and Coastguard Agency

PROHIBITION NOTICE

Merchant Shipping Act 1995, Section 262

Name and Address of person on whom this Notice is served

To Mr S. Collins, Wapping Pier, King Henry's Stairs
Wapping High Street. London E1W 2NR

Trading as (*)

Collins River Enterprises

Inspector's full name

I, Roderick Willis Shaw

Inspector's Official Address

of MCA London Office
Central Court, Knoll Rise
Orpington BR6 0JA

Official Telephone No.

01689 890 400

hereby give you notice that I am of the opinion that the following activities, namely

The Passenger Certificate for STAR CLIPPER is withdrawn

which are ~~(*) being carried out by you / likely to carried out by you~~ / under your control aboard

Name of Ship
Official Number

STAR CLIPPER

involve, or will involve (*) a risk / an imminent risk, of (*) serious personal injury / ~~serious pollution of navigable waters.~~
(*) I am further of the opinion that the said matters involve contraventions of the following statutory provisions

Provisions contravened

M.S.Regulations

The reasons for my opinion are

Reasons for opinion

Following fatal accident the mooring arrangement on this vessel needs to be assessed and the vessel modified as per technical solutions to be advised.

and I hereby direct that the said activities shall not be carried out by you or under your control (*) immediately ~~/ after~~

Date & time

(*) and / ~~or~~ the ship shall not go to sea
(*) ~~unless the said contraventions and matters have been remedied in the manner stated in the schedule which forms part of the Notice~~

2nd. May 2004

(Signature) (Date of Issue)

being an Inspector appointed under Section 256(6) of the said Act and entitled to issue this Notice.
(*) Delete as necessary

 (Previously Form IP/A)

NOTES

1. *If this Notice does not have immediate effect, you can ask the Inspector who issued the Notice either:-*
   (a) to cancel it; or
   (b) to change the date and time after which the activities mentioned in the Notice must stop.

   You must ask him to do so before the time and date specified on the face of this document. Such a request will not constitute a request for arbitration - see Note 4 below.

2. *If you do not stop the activities which the Notice tells you to stop, you may be liable to prosecution.*

3. *This Notice does not remove liability for failing to comply with any legal requirement, including any failure which caused the Inspector to give you this Notice.*

4. *You can ask for this Notice to be taken to arbitration. The arbitrator can decide:-*
   (a) whether the reasons and other matters mentioned in this Notice by the Inspector were a proper basis for the Inspector's opinion: and
   (b) whether what the Inspector told you to do in the Notice is reasonable.

   To refer the Notice to an arbitrator, you, as the person mentioned at the head of this Notice, should write to the Inspector giving:-
   (a) your official address;
   (b) the date of the Notice and the name and official number of the ship concerned;
   (c) a statement of what you disagree with, and of why you disagree.

   This written request will constitute a Notice of Reference.

5. *Time Limit - a Notice of Reference must be sent to the Inspector within 21 days of "the date of service" of the Prohibition Notice. It is advisable to get a receipt for the Notice of Reference, or to send it in the post by Recorded Delivery.*

6. *You have to do what this Prohibition Notice tells you to do until, and unless, the arbitrator decides otherwise. If this Notice does not tell you to do something immediately you can ask the Inspector to cancel or change the Prohibition Notice at the same time that you ask for the Notice to be referred to an arbitrator.*

7. *If the arbitrator says that the Inspector's opinion was invalid or not based on reasonable grounds, or that any directions included in the Prohibiiton Notice were unreasonable, he may cancel or modify the Notice. In such a case, and where the Notice specifically required the ship should not depart, the arbitrator may additionally award compensation in respect of any loss suffered as a consequence of the service of the Notice or the directions if contained.*

8. *The conduct of arbitration will be governed by the relevant rules of law on arbitration in England and Wales, in Scotland or in Northern Ireland, as appropriate. The arbitrator's decision is binding on all parties.*

Safe Ships Clean Seas

Maritime and Coastguard Agency

ADDENDUM TO PROHIBITION NOTICE

The Prohibition Notice withdrawing the Passenger Certificate for **STAR CLIPPER** is hereby suspended until 1200 hours on Friday 7th May 2004 on the following conditions :

1. that the midships mooring bollard used to assist berthing and passenger transfer shall not be used until their suitability has been assessed.

2. similar bollards on the other vessels within the fleet are also banned until the assessment has been completed.

3. all crews to be briefed on the circumstances of this action.

4. with the midships mooring bollards prohibited from use the Captains are to use their best judgement on the alternative bollards available.

5. Captains to be instructed that during this interim period and the use of alternate mooring positions, extreme caution is to be taken particularly when wave action from a passing vessel is experienced during passenger transfer.

The MCA London office will have discussions with a naval architect and also a welding adviser in order to consider the proposed solution which will be discussed with CRE for fleet implementation.

S. Collins to report on the Risk Assessment conducted regarding the temporary mooring arrangement pending final design and vessel modification.

....
Captain Rod. Shaw

3rd. May 2004

Shipname SKY CLIPPER
Official Number

MSF 1705 REV0400 (SCHEDULE)

Schedule to Prohibition Notice

The suspension of the Prohibition Order is extended until 1200 hours, 1st July 2004

Passenger Certificate and Domestic Safety Management Certificate
dated 18 February 2004

Maritime and Coastguard Agency

PASSENGER CERTIFICATE AND DOMESTIC SAFETY MANAGEMENT CERTIFICATE

This certificate shall be supplemented by a Record of Equipment and Information (MSF 1242) which must be carried on board

CERTIFIED TRUE COPY OF ORIGINAL DOCUMENT
Signature S. Blandell
Date 20.02.04
Maritime and Coastguard Agency

PARTICULARS OF SHIP

Name of Ship	**STAR CLIPPER**
Official Number	721956
IMO Number	
Gross Tonnage	
Name of	COLLINS RIVER ENTERPRISES, Wapping Pier, king Henry's stairs, Wapping High Street. London.E1W 2NR.
Address	

THIS IS TO CERTIFY THAT:

1 The ship has been surveyed and found to comply with the applicable Merchant Shipping Regulations for Passenger Ship Construction, Life-Saving Appliances, Fire Protection, Collision Avoidance, Radio Installations, and Navigational Equipment.
2 The ship is fit to ply on voyages within the limits stated on the Record of Equipment and Information which supplements this Certificate.
3 The ship is fit to carry the numbers of passengers shown below, under the conditions indicated.
4 The Safety Management System of the ship has been audited and that it complies with the requirements of the Safety Management Code for Domestic Passenger Ships.
5 An Exemption Certificate ~~has been issued~~ / has not been issued.

UK Class	V	V				
Mode	Cat C water daytime	Cat C Water night-time				
Maximum Number of Passengers allowed	62	62				
Minimum Number of Crew	2	3				

See also Operational Limits and Notes.

This Certificate is valid until **1 February 2005** unless previously cancelled, subject to the Annual Surveys and Safety Management System Audits being completed and endorsed on the Certificate.

Completion date of survey and verification on which this Certificate is issued	18 February 2004
Last date of out of water bottom inspection prior to the issue of this Certificate	2 February 2004
Date of Stability Verification / ~~Inclining~~ / ~~Heel Test~~ / Lightweight	18 February 2004

Place of Issue: Orpington Marine Office

Signed: [signature]
(Signature of Authorised Official issuing the Certificate)

Date of Issue: 18 February 2004

Name: p.p. B D Hopkins

MARITIME AND COASTGUARD AGENCY mca ORPINGTON

Domestic Safety Management Mid-Term Audit Range Dates **2 May** and **2 August**

Place		Signed	
Date		Name	

Certificate Number: **OR 000029**

ENDORSEMENT FOR ANNUAL SURVEYS AND SAFETY MANAGEMENT AUDITS WHICH MUST BE COMPLETED EACH YEAR BETWEEN THE RANGE DATES SPECIFIED

	Annual Survey	Bottom Inspection	Domestic Safety Management Mid-Term Audit
	Range Dates: **2 February** and **1 February** Note: Maximum period between consecutive annual surveys is 15 months	In accordance with MGN 217(M) if appropriate * delete which not appropriate	Range Dates: **2 May** and **2 August** Note: Must be conducted when vessel in service, normally between 3 and 6 months after annual survey
1st	Signed Name Place Date Official Stamp	Type: waiver / outwater * Signed Name Place Date Official Stamp	Signed Name Place Date Official Stamp
2nd	Signed Name Place Date Official Stamp	Type: waiver / outwater * Signed Name Place Date Official Stamp	Signed Name Place Date Official Stamp
3rd	Signed Name Place Date Official Stamp	Type: waiver / outwater * Signed Name Place Date Official Stamp	Signed Name Place Date Official Stamp
4th	Signed Name Place Date Official Stamp	Type: waiver / outwater * Signed Name Place Date Official Stamp	Signed Name Place Date Official Stamp

mca
Maritime and Coastguard Agency

SUPPLEMENTARY RECORD OF EQUIPMENT AND INFORMATION FOR A DOMESTIC PASSENGER SHIP

This document must be kept on board and be available for inspection at all times

1. PARTICULARS OF SHIP

Name of Ship	**STAR CLIPPER**
Official Number	721956

S Blendell
20.02.04
Maritime and Coastguard Agency

Date on which keel was laid or ship was at a similar stage of construction	1992

2. OPERATIONAL LIMITS

RIVER THAMES ABOVE A LINE DRAWN NORTH/SOUTH THROUGH THE EASTERN EXTREMITY OF DENTON WHARF PIER, GRAVESEND.

NOTES.

The minimum crew for up to (1) 200 passengers shall be 2 for daytime operations; and (2) 150 passengers shall be 3 for night-time operations.

THE FREEBOARD MARK ON THE SIDES OF THE VESSEL MUST NOT BE SUBMERGED AT ANY TIME.

3. PASSENGER AND CREW NUMBERS

UK Class	V	V				
Mode	Cat C water daytime	Cat C Water night-time				
Maximum Number of Passengers	62	62				
Minimum Number of Crew	2	3				

Revision Date	18 February 2004

3. PASSENGER AND CREW NUMBERS (Cont.d)

	Location	Area	Number of Passengers	Number of Seats
On Deck				
In Cabins			62	62

4. CREW DETAILS

Minimum Certification Requirements for Master	Boatmaster's licence.
Minimum Numbers of holders of Certificates of Proficiency in Survival Craft and Rescue Boats	
Other certification requirements	

5. STABILITY DETAILS

~~Subdivision /~~ Loadline marked on ships side at amidships	Survivability Standard	Freeboard / Clear Height at side	Measured from a line...below main deck level at side	Extreme draft amidships	Remarks with regard to alternative service conditions
yes	One Compartment		765mm		

Last date of out of water bottom inspection prior to the issue of this Certificate	2 February 2004

6. CARGO DETAILS

Maximum permitted weight of cargo in cargo spaces	

Revision Date	18 February 2004

7. LIFESAVING APPLIANCES AND EQUIPMENT

1	Total number of persons for which life-saving appliances are provided	110	
		Port Side	Starboard Side
2	Total number of lifeboats	-	-
2.1	Total number of persons accommodated by them	-	-
3 ***	Description of lifeboat davits (inc.S.W.L.)	-	
4	Number of Rescue Boats	-	
4.1	Number of Rescue Boats (included in in total lifeboats shown above)	-	
4.2 ***	Description of Rescue Boat davits(inc.S.W.L.)	-	
5 **	Number and Type of liferafts	2 x RFD	
5.1	Total number of persons accommodated by them	110	
5.2 ***	Description of Liferaft davits(inc.S.W.L.)	-	
5.3 **	Type / Manufacturer of Marine Evacuation System (if fitted)	-	
6	Number of Buoyant Apparatus	-	
6.1	Number of persons capable of being supported	-	
7	Total number of lifebuoys	4	
7.1	Number of lifebuoys with lines	2	
7.2 *	Number of lifebuoys with lights	-	
7.3 *	Number of lifebuoys smoke signals	-	
7.4 *	Number of lifebuoys smoke signals and lights	2	
8.1	Number and type / manufacturer of Lifejackets for persons over 32 kg	65 Sea master	
8.2	Number and type / manufacturer of Lifejackets for persons under 32 kg	8 Seamaster	
8.3 **	Number and type / manufacturer of Inflatable Lifejackets	-	
8.4	Number and type / manufacturer of Buoyancy Aids for persons over 32 kg	-	
8.5	Number and type / manufacturer of Buoyancy Aids for persons under 32 kg	-	
9.1	Number of rocket parachute distress flares	-	
9.2 *	Number of Hand held flares	-	
9.3 *	Number of Buoyant Smoke Signals	-	
10 *	Number of Line Throwing Apparatus	-	
11	Means of recovering persons from water	ladder + scramble nets	
12 *	First Aid Equipment category and number	one	

* These items must be kept within valid dates

** These items must have record of service within dates specified by manufacturer

*** These items to be load tested every 5 years and records kept

Note : See also Section 14 - Approved Variations of Equipment

8. DETAILS OF NAVIGATIONAL SYSTEMS AND EQUIPMENT

1.1	Standard magnetic compass *	yes
1.2	Spare magnetic compass *	NO
1.3	Gyro compass *	NO
1.4	Gyro compass heading repeater *	NO
1.5	Gyro compass bearing repeater *	NO
1.6	Heading or track control system *	NO
1.7	Pelorus or compass bearing device *	NO
1.8	Means of correcting heading and bearings *	NO
1.9	Transmitting heading device (THD) *	NO
2.1	Nautical charts / Electronic chart display and information system (ECDIS)*	NO
.2	Backup up for ECDIS	NO
2.3	Nautical publications - Description and Area covered	NO
2.4	Backup up arrangements for electronic nautical publications	NO
3.1	Receiver for a global navigational satellite system / terrestrial radio-navigational system *	NO
3.2	9 GHz radar *	PROVIDED
3.3	Automatic radar plotting aid (ARPA) *	NO
3.4	Automatic tracking aid *	NO
3.5	Electronic plotting tracking aid *	NO
4	Automatic Identification System (AIS)	NO
	Voyage data recorder (VDR)	NO
6	Speed and distance measuring device (through the water) *	NO
7	Echo sounding device *	NO
8	Rudder, Propeller, thrust, pitch and operational mode indicator *	PROVIDED
9	Communications to emergency steering position	NO
10	Daylight signalling lamp *	NO
11	Radar reflector *	NO
12	International Code of Signals	NO

* Alternative means of meeting this requirement are permitted. In case of other means they shall be specified.

9. DETAILS OF RADIO EQUIPMENT

1	**VHF Radio Installation**	Manufacturer	Type
1.1	DSC Encoder	-	-
1.2	DSC Watch Receiver	-	-
1.3	Radiotelephony	1 x Sailor	RT2048
2	**Secondary Means of Alerting**	-	-
3	**NAVTEX receiver**	-	-
4 **	**EPIRB**	-	-
5 *	**Number of hand held two-way VHF radiotelephone apparatus**	2 x ICOM	IC21
6	**SART**	-	-

Other Radio Equipment	-	-

Methods used to ensure availability of Radio Facilities		
1	Duplication of Equipment	
2	Shore-Based maintenance	
3	At-sea maintenance capability	

* Batteries of these items must be kept within valid dates

** These items must have record of service within dates specified by manufacture

Revision Date	18 February 2004

10. FIRE PROTECTION AND DETECTION

Where necessary reference can be made to identified plans		
1	Fire extinguishers: Type and Location	2 x Foam, 4 x water, 1 x dry powder,
	Fixed fire extinguishing system : Details	2 x 25kg CO2 Engine room.
2	Structural Fire Protection: Details	
3	Fire Pumps	1 x mechanical 1 x manual
4	Fire Hoses and Nozzles (include Type)	2 x Mechanical + 2 vari nozzles
5	Fire Bucket and Scoop	
6	Fire Blanket	
	Fire-fighters Protective Equipment)(Clothing, boots, gloves, axe, helmet, safety lamp)	
8	Breathing Apparatus: Description (If self-contained Breathing Apparatus: Number, Type and details of spare cylinders)	
9	Emergency Lighting	yes
10	Fire Detection System	yes
11	Fire Alarm System	yes

11. MACHINERY

1	Main Engines		
	Number	2	
	Manufacturer	SCANIA	
	Type	DS11c	
	Year	1992	
	Number of Cylinders	6	
	Diameter of Cylinders	127 mm	
	Length of Stroke	145 mm	
2	Shaft and Propeller : Type and Year	Jet Drive	
3	Remote Stops / extended spindles	2 x Fuel Shut Off 2 x Engine Stops	
4	Generators		
	Number	-	
	Type	-	
	Power	-	
5	Electrical Equipment	24 v	
6	Steering Gear	Hydraulic / Manual	
7	Bilge Pumps	4 x Electrical 6 x Mechanical	
8	Machinery operation manuals	-	

12. EXEMPTIONS FROM STATUTORY REQUIREMENTS

Regulation	Date of Issue	Comment

Revision Date	18 February 2004

13. SURVEYOR REMARKS

Coastguard Station at which SAR Plan is held	LONDON

14. APPROVED VARIATIONS OF EQUIPMENT

Item Number	Details of Variation	Conditions

I certify that this Record is correct in all respects.

Office	Orpington Marine Office	Signed	
Date	18 February 2004	Name	C L Knowles

NOTES

- The certificate is to be displayed in a conspicuous place on board ship, where it will be legible to all persons on board, and be so displayed and legible while the certificate remains in force and the ship in use. The penalty on summary conviction is a fine not exceeding the appropriate statutory maximum.
- The Certificates and its endorsements indicate that the vessel fully complies with the Record of Equipment and Information, plus terms of the condition of issue at the time of the survey / audit.
- **The certificate may be cancelled if any of the following events occur in service of if requirements in the text of the certificate and supplement are infringed.**
- The vessel is not maintained in accordance with the appropriate regulations; or
- Any accident occasion resulting in the loss of life or serious injury to any person; or
- Any material damage affecting the seaworthiness or efficiency of the ship, either in the hull or in any part of the machinery; or
- Any alterations or renewal in the ship's hull, machinery, or equipment which may affect the efficiency or the seaworthiness of the ship;
- A written report signed by the owner or Master must be made within 24 hours after the occurrence of such an event or as soon thereafter as possible. Under the Merchant Shipping Acts failure to comply with the requirements could make the offender liable to a fine up to the appropriate Statutory Maximum. The report should be sent to the nearest Maritime of Coastguard Agency office.

Class	Description
III	Ships engaged only on voyages in the course of which they are at no time more than 70 miles by sea from their point of departure and not more than 18 miles from the coast of the United Kingdom, and which are at sea only in favourable weather and during restricted periods;
IV	Ships engaged only on voyages in Category A, B, C or D waters;
V	Ships engaged only on voyages in Category A, B or C waters;
VI	Ships engaged only on voyages with not more than 250 passengers on board, to sea, or in Category A, B, C or D waters, in all cases in favourable weather and during restricted periods, in the course of which the ships are at no time more than 15 miles, exclusive of Category A, B, C or D waters, from their point of departure nor more than 3 miles from land;
VI(A)	Ships carrying not more than 50 passengers for a distance on not more than 6 miles on voyages to or from isolated communities on the islands or coast of the United Kingdom and which do not proceed for a distance of more than 3 miles from land; subject to any conditions which the Secretary of State may impose.

- A Class III or VI vessel may only proceed on a voyage to sea in favourable weather and in daylight during the restricted Summer period (Between 1 April to 31 October inclusive).
- **Under the Merchant Shipping Acts it is a criminal offence to send or take a ship on a voyage or excursion (whether or not this involves going to sea) in such a dangerously unsafe condition that the life of any person is likely to be thereby endangered.**
- If the number of passengers carried exceeds the number allowed by this certificate, the Master or owner will be liable to a penalty on summary conviction of a fine not exceeding the statutory or indictment by imprisonment for a term not exceeding two years, or a fine, or both.
- In the event of the ship being transferred to new owners, the certificate at once lapses, without the need for formal cancellation. It may be renewed if appropriate conditions have been met.
- The certificates indicated that the condition of the items examined at the time of the survey or verification met the necessary requirements. It does not confirm that these requirements were met after this date.

Notes Cont.d >

- If any of the space measured for passenger accommodation is used for any other purpose, a reduction in passenger numbers should be applied proportionate to the reduction in deck area as detailed in Section 3 of the Supplementary Record of Equipment - Passenger and Crew Numbers.
- The appropriate Load Line markings shall not be submerged.
- The passengers numbers recorded on the certificate are based on an average mass of 75 kg per person including hand luggage. Where this figure is significantly exceeded an appropriate assessment should be carried out, based on the likely effect upon the stability of the vessel and escape / evacuation arrangements. If necessary passenger numbers carried should be reduced.
- The ship must at all times be kept as clean, free from oil, chemical, and other refuse, as practical.
- The ship's equipment must be kept in an efficient condition.
- No loose containers of any hazardous material, e.g. petrol, may in any circumstances be carried in the ship.
- The ship shall not be used for towing any other vessel, boat or craft, except in cases of emergency.
- The person in charge (included in the crew) shall be a person certified / licensed by the Maritime and Coastguard Agency to act in that capacity.
- The ship's bottom is to be inspected out of water annually unless prior approval for waiver is obtained from MCA. In any case a bottom inspection out of water is required as follows:
  - At least 2 inspections within the 5 year validity of this certificate
  - At intervals not to exceed 36 months
  - At any other times whenever the surveyor is not satisfied, by examination in the water, that the vessel remains in good condition, and in particular where criteria set out in MGN 217 Appendix E * (or its replacement) are not met.
  - If a waiver is granted the name of the MCA Principal Surveyor and Marine Office which approved the in-water survev is to be recorded in addition to the survevor's endorsement
- Any regulations or instructions of the Local Authority are to be obeyed
- The annual and renewal survey can take place up to 3 months before the anniversary date.

DOCUMENT CONTROL - MSF 1242

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The Test House Report – T40821 dated 3 June 2004. Laboratory Report
Examination of a Fractured Bollard Mounting Plate Weld and Associated
Material from the Thames River Craft *Star Clipper*

The TEST HOUSE

THE TEST HOUSE JOB AND REPORT REFERENCE: T40821

LABORATORY REPORT
EXAMINATION OF A FRACTURED BOLLARD MOUNTING PLATE WELD AND ASSOCIATED MATERIAL FROM THE THAMES RIVER CRAFT *STAR CLIPPER*

For: MARINE ACCIDENT INVESTIGATION BRANCH
First Floor
Carlton House
Carlton Place
Southampton
SO15 2DZ

This report comprises:
Title Page 1
Text Pages 1 to 11
Figure sheets 1 to 32
Appendices 1 to 5 (six sheets)

UKAS Disclaimer: This project includes tests and examinations, some of which were completed against UKAS accredited procedures. The scope of laboratory accreditation does not, however, include the analysis of test data or the offering of professional opinions.

LABORATORY REPORT: EXAMINATION OF A FRACTURED BOLLARD MOUNTING PLATE WELD AND ASSOCIATED MATERIAL FROM THE THAMES RIVER CRAFT *STAR CLIPPER*

For: Marine Accident Investigation Branch, First Floor, Carlton House, Carlton Place, Southampton, SO15 2DZ

THE TEST HOUSE (CAMBRIDGE) LTD REFERENCE: T40821
RECEIPT DATE (SAMPLE MATERIAL): 6 MAY 2004
RECEIPT DATE (CLIENTS WRITTEN INSTRUCTION): 11 MAY 2004
REPORT DATE: 3 JUNE 2004

1. INTRODUCTION

Instructions to examine the fractured weld and associated items were received from Mr W Hart of Marine Accident Investigation Branch (MAIB). The fractured weld and bollard were reported to have originated from the aft end of the port side passenger access way of the Thames passenger craft STAR CLIPPER.

MAIB reported that the bollard and its mounting plate had been torn from the vessel whilst it was mooring under power at St. Katharine's Pier, and that after detachment from the vessel. the bollard had collided with a member of the public, causing fatal injuries.

Objective of the laboratory based failure analysis was to identify the reason, or reasons, which had contributed to the catastrophic failure of the weld. To attain the objective, an agreed examination and testing protocol aimed to:

- Establish the mode of weld failure
- Establish the fractured weld size and volumetric quality
- Confirm the weld metal type and consequent typical tensile and shear strengths
- Determine the tensile strength of the vessels walkway construction plate materials
- Quantify by hardness tests, any deleterious influence of welding on parent material in way of casualty weld Heat Affected Zone (HAZ) regions.

On completion of the laboratory examination and testing phase, The Test House (TTH) was to offer its conclusions and opinion in respect of the probable failure mechanism.

2. BACKGROUND INFORMATION

We were given to understand that the subject bollard was one of four, which had been retrofitted to the vessel to suit current operational practice. The four bollards were mounted at the forward and aft outboard corners of a raised passenger access-way into the vessels covered forward section, two being mounted at the port (casualty) side, and two at the corresponding starboard side. It was further reported that the current (casualty) type bollard and base plate design had evolved empirically through a series of modifications, which had been effected to combat earlier less catastrophic modes of bollard failure. The empirical evolution of the currently fitted bollard type, we understand, had progressed via three stages as follows:

(i) Bollard fabricated from tubular aluminium alloy material and secured by four bolts
(ii) Bollard fabricated from tubular stainless steel and secured by six bolts through a base mounting of increased size
(iii) Bollard fabricated from solid stainless steel bar and secured by six bolts through a base mounting of similar size to (ii).

The base mounting of the casualty mark (iii) bollard type was secured to an insert plate, which had been recently fillet welded to the outer vertical (forward to aft and port to starboard) plates and the walkway chequer plate floor. The evolution to the mark iii bollard design of significantly heavier construction and the inserting of new plate material into the walkway floor were, we understand, a collective response to distortion and structural failure of the two earlier bollard designs.

We understand that operational mooring practice involved securing the vessel to a pier side bollard via a 24mm diameter three strand polypropylene rope of 8.1 ton breaking strain, which was tied off on one of the subject bollards. Engine power and forward motion against the rope was then used to bring the vessel alongside the floating pier. It was during mooring the vessel via the above practice that the recently completed insert plate fillet weld failed catastrophically, allowing the bollard and attached insert plate to be propelled clear of the vessel via the reacted strain energy in the mooring rope.

The fractured insert plate repair had, according to the client, been completed via the Tungsten Inert Gas (TIG) welding process, and included the use of a 4043 type consumable filler wire and high purity argon gas shielding. The weld procedure we understand had not, however, been formally documented in a Weld Procedure Specification (WPS), or validated by a Procedure Qualification Record (PQR). We similarly understand that the completing welder retained no appropriate formal welding qualification for the subject welded joint. The repair, we also understand, had also been completed without advice or services of a naval architect in respect of materials specifying, suitability of the weld procedure, or suitability of the local vessel structure to support both the bollard and subsequent service loads.

The client advised that all original construction plate materials were of BS1470: 1987 grade 5083 type. Information in respect of the specified temper condition was, however, less clear, as was the grade and specification of the insert plate material. The repair work contractor reported that the insert plate material was an off-cut of either unalloyed grade 1055 (95% Al), or more likely alloy grade 6082 (Al-Si-Mn-Mg) in an unspecified temper condition.

3. SAMPLE MATERIAL AND RECEIPT INSPECTION

To complete its laboratory based failure analysis, TTH was provided with the detached aft port side bollard, both halves of the fractured insert plate weld and four lengths of TIG welding consumable, all of which are shown in figures 1 and 2.

3.1 Welding Consumable

The four lengths of welding consumable were of standard 2.4mm diameter by 1 metre length. One end of each length was embossed with a monogram and the alloy grade reference number 4043 (figure 3), which positively identified the consumable as a relatively low strength Aluminium 5% Silicon alloy type. The opposite wire ends were embossed with the number sequence 3.2245 (figure 4), the significance of which is not currently fully recognised.

3.2 Bollard and Attached Inserted Mounting Plate

The bollard was supplied attached to the torn out walkway insert plate by six M10 stainless steel bolts, each secured with an appropriate stainless steel nut, washers and locking nut at the insert plates underside (figures 5 and 6). Though none of the six securing bolts appeared damaged, all but the aft outboard underside washer exhibited evidence of severe deformation. Although it is conceivable that some distortion of the washers could have occurred during installation of the bollard, the pattern and severity of the damage appeared more consistent with deformation of the insert plate preceding its detachment. A combined weight of 14.169kg for the bollard, mounting plate and fixings was established via a calibrated load cell prior to disassembly.

The bollard had been fabricated from austenitic stainless steel bar and plate. The main body comprised a 76.1mm diameter round bar of 200mm height. The top crossbars measured 44.4mm diameter, and were positioned on 130mm centres from the base plate. The fabrication practice, and the fillet weld joining the main bollard body to the base plate in particular, had caused significant distortion of the base plate (figures 7 and 8) resulting in up to 3mm distortion across both axes of the plates underside mounting face. The apparent distortion of the bollard mounting plate was considered to be a deleterious feature, which could have contributed to both distortion of the thinner walkway member during installation, and poor load distribution across the bolted interface in service. The three fabrication welds in the bollard appeared free from evidence of both cracking and casualty related distress.

The bollard and 6mm nominal thickness insert plate had become detached from the vessel by fracturing of the joining weld. The fracture event was also accompanied by significant deformation of the insert plate.

The inboard insert plate edge appeared to have only been welded at the forward end. Fracture had occurred through the throat (the shortest distance from the weld root to the weld face or cap) of the weld length present, and though the plate had been restrained at both inboard corners, significant upwards deformation was apparent (figures 9 and 10). The outboard edge was fully welded and fracture had occurred through the throat of the full weld length. In the case of this edge, fracture was accompanied by upward deformation around the forward bolt hole and severe downwards indenting of the bollard base into the insert plates aft outboard corner (figures 11, 12 and 13). The forward edge exhibited evidence of welding along its full length, and fracture had again occurred through the throat of the full weld length. The weld fracture at this plate edge was accompanied by upward deformation of the plate around both bolt holes (figures 14 and 15). The aft plate edge exhibited evidence of a weld along its full length, and fracture yet again had propagated through the throat of the full weld length. The deformation at this plate edge was upwardly directed at the inboard corner bolt hole, in contrast with the outboard corner, which exhibited downwards indenting of the bollard base into the insert plates outboard corner (figures 16 and 17).

The deformation pattern of the insert plate and weld fracture surface features appeared collectively consistent with a progressive shear fracture having consistently occurred through the weld throat, and having originated at the inboard side close to the location at which partial welding of this side had commenced.

The fractured area of weld metal was characterised by the weld run length at each of the four sides and the average apparent fractured throat thickness as follows.

Inboard side: 155mm x 4.05mm = $628mm^2$
Forward side: 200mm x 5.26mm = $1052mm^2$
Outboard side: 265mm x 5.14mm = $1362mm^2$
Aft side: 284mm x 4.40mm = $1250mm^2$
The sum of the sheared weld metal areas for the four sides equated to a total casualty weld metal shear area of $4292mm^2$.

3.3 Underside Fracture Half

The underside fracture half comprised only the forward, outboard and aft ends, and is shown in figure 18. The piece had been close cropped from the raised passenger access way floor support structure and contained three sides of the fractured insert plate weld, the double skin outboard side plates, forward chequer plate, forward under-floor transverse member and the double skin aft end transverse plates.

The under-floor forward transverse member and the aft transverse inner skin member both exhibited pronounced buckling damage (figure 19). Though it was possible to conclude that buckling had resulted from a force acting in the vessels transverse direction. It was not, however, possible to determine from the evidence if the damage had pre-dated fitting of the insert plate, or whether, as appears more likely, it was contemporary with the casualty incident.

The fractured forward section of weld exhibited evidence of continuous unfused root bead roll-through, and what appeared to possibly be consumable wire entrapments in the weld root (figures 20 and 21). The weld showed evidence of both surface breaking and sub-surface gas porosity, and evidence of intermittent local excess penetration, or burn-through the chequer plate (figure 22).

In areas of the fractured outboard weld section, where a land of parent plate was evident under the root, the weld exhibited a reasonably consistent root profile. This contrasted with areas in which no parent material land existed underneath the weld root, in which areas evidence of excessive root bead roll-through and penetration were both apparent (figures 23 and 24). The weld metal contained evidence of both fine gas porosity and areas exhibiting lack of root fusion.

The fractured aft weld section exhibited a reasonably consistent weld root profile over most of its length. The corner transition from the outboard weld section, however, again exhibited evidence of an unfused root bead and an unfused consumable wire entrapment protruding beyond the weld root (figures 25 and 26). Evidence of fine surface breaking gas porosity was apparent in both the weld metal deposit and the adjacent high temperature HAZ.

Collectively, the fractured weld metal was seen to contain a wide range of welder attributable defects, some of which had in part been facilitated by inconsistency of the joint fit up. Though gas porosity in the weld metal volume and lack of root fusion would, undoubtedly, have reduced weld strength, the deposited weld volume was demonstrably still sufficiently strong for it to have fractured only after very significant prior deformation of the insert plate.

4. FRACTOGRAPHIC EXAMINATION

A section of the fractured inboard weld side (PC1) was removed from the insert plate edge (figure 27). Three similar samples (PC2, PC3 and PC4) were removed from the forward, outboard and aft weld sections of the underside fracture half respectively (figure 28). The sample set was ultrasonically cleaned in acetone and subsequently examined via a Scanning Electron Microscope (SEM). Characteristic features and defects identified during the examination were as follows.

4.1 PC1 – Inboard Weld Side

The fracture in this, the initiation region, was of generally low ductility, and had exposed areas of what appeared to be underfilled regions in the second phase aluminium-silicon eutectic network (figure 29).

4.2 PC2 – Forward Weld Side

The fracture in this section of the insert plate weld was again of generally low ductility, and exhibited evidence of what appeared to be underfilled regions in the second phase aluminium-silicon eutectic network (figure 30). The weld was seen to exhibit intermittent lack of root fusion and tearing (figure 31), gas porosity (figure 32 and 33), and interdendritic solidification porosity (figure 33).

4.3 PC3 – Outboard Weld Side

The fracture in this section of the insert plate weld was again of generally low ductility, and had propagated largely through the aluminium-silicon eutectic phase (figure 34). The weld metal fracture surface was again seen to exhibit evidence of gas porosity (figures 35 and 36), and local isolated interdendritic solidification porosity (figure 36).

4.4 PC4 – Aft Weld Side

The fracture in this section of the insert plate weld was again of generally low ductility and had propagated largely through the aluminium-silicon eutectic phase (figure 37). Evidence of underfilling was again apparent within the eutectic second phase (figure 38). The weld metal fracture surface was seen to exhibit evidence of widely distributed gas porosity (figures 39 and 40) and interdendritic solidification porosity (figure 40).

5. METALLOGRAPHIC EXAMINATION

A single weld cross section metallographic specimen was removed from each of the four sub samples (PC1, PC2, PC3 and PC4) which had earlier been removed to facilitate detailed fractographic examinations. The specimens were Bakelite mounted and prepared by conventional metallographic techniques to a 1-micron diamond finish. The specimen set was then subjected to a final preparation stage involving vibratory polishing via a 0.03-micron silica colloidal suspension.

The prepared specimen set was subsequently examined in the unetched and Kellers reagent etched conditions. Characteristic features and observations identified in each of the specimens examined were as follows.

5.1 PC1 – Inboard Weld Side

The weld exhibited a highly convex cap and lack of fusion along most of the insert plate fusion boundary (figures 41 and 42). The weld metal exhibited fine dispersed gas porosity throughout, and concentrations of larger pore clusters both close to the fusion boundary and at a weld run junction (figure 43). The upper weld cap surface exhibited a local network of surface breaking shrinkage porosity in the aluminium-silicon eutectic phase (figure 44).

The fracture was confirmed to have propagated through the aluminium-silicon eutectic network (figure 45) with little to no evidence of ductile strain damage.

5.2 PC2 – Forward Weld Side

This specimen contained the fractured insert plate weld and an underside fillet weld joining the walkway plate to a stiffener.

The underside weld exhibited evidence of lack of fusion along the stiffener fusion boundary (figures 46 and 47). The weld root exhibited evidence of clustered gas porosity and solidification shrinkage porosity (figure 48). A second site of porosity at the walkway plate fusion boundary also exhibited evidence of associated shrinkage porosity and cracking (figure 49), which in this case was surface breaking. Weld metal microstructure exhibited no significant evidence of an aluminium-silicon eutectic phase. The weld metal did, however, exhibit widespread evidence of intermetallic particles, and based on this evidence, we concluded that the weld had been completed with a high strength 5000 series type consumable, and probably resulted from original vessel construction.

The fractured insert weld had apparently comprised at least three weld runs (figure 47) and, based on the prevailing microstructure, had been completed with a 4043 type filler wire. The weld exhibited a poor toe profile and had fractured close to the insert plate fusion boundary (figure 47). The weld metal exhibited evidence of fine gas porosity clusters close to the plate fusion boundaries (figure 47), and very widespread shrinkage porosity in the weld root (figure 50).

The casualty fracture was confirmed to have propagated through the aluminium-silicon eutectic network (figure 51), with little to no evidence of ductile strain damage. Detailed examination of the fracture path confirmed that both gas and shrinkage porosity defects were present at the fracture edge.

5.3 PC3 – Outboard Weld Side

The weld at this side of the insert plate appeared to have been completed in two different phases. The two vertical plates had been joined at their edge with what appeared, microstructurally, to be a 5000 series type welding consumable. The initial weld metal remnant exhibited a very high density of gas porosity (figures 52 and 53), a weld root crack (figure 54), and both solidification porosity and cracking in the weld metal penetration beyond the inboard plate edge (figure 55). The insert plate weld had then been fused to the earlier weld metal with what, microstructurally, appeared to be lower strength 4043 type consumable, consistent with the sample of welding consumable supplied. The volumetric weld metal content of the later completed insert plate joining weld was seen to exhibit significantly less evidence of defects, and a much lower volume of gas porosity in particular.

The casualty fracture was confirmed to have propagated through the recently completed joining weld, which had been completed with a lower strength 4043 type welding consumable. The remnant of earlier higher strength, highly porous weld metal, to which one side of the joint had been fused, was thought to represent an original shipyard construction weld. Detailed examination of the fracture path confirmed that fracture had propagated largely through the aluminium-silicon eutectic network and isolated local areas of solidification porosity (figure 56). In common with most fillet weld shear fractures in aluminium-silicon alloy weld metals, the fracture edge exhibited little if any evidence of microstructurally detectable ductile strain damage.

5.4 PC4 – Aft End Side

The joint at the aft end of the insert plate appeared to comprise a recent attachment weld to original construction welding exhibiting both multiple weld defects and post welding corrosion damage (figures 57 and 58).

The original construction welding included an underside fillet weld between the inner vertical member and floor plate (figure 59). The weld exhibited lack of fusion over approximately half the vertical leg fusion boundary, and widely dispersed gas porosity. A second weld had then joined the two vertical member ends to the floor plate (figure 60). This weld exhibited gross gas porosity, shrinkage porosity, and solidification cracking (figure 61). The weld root and void space between the two plates was also seen to have suffered very extensive post construction corrosion damage (figures 58 and 60). A third weld then appeared to have been introduced to join yet a second horizontal plate to the already three-part fabrication (figure 62).

The casualty weld (figure 62) appeared to have fused the insert plate to the third phase of the earlier construction welding. The fracture appeared to have propagated through the root of the earlier phase weld metal, in a region exhibiting widespread evidence of shrinkage porosity (figure 63). The outer weld cap side of the fracture had propagated through the aluminium-silicon eutectic phase of what was thought to be a 4043 type weld metal (figure 64), and consequently the weld metal associated with the recent insert plate repair. The recently completed repair weld at this location exhibited full fusion and significantly less evidence of gas porosity than was apparent in the original construction welding.

6. CROSS WELD VICKERS HARDNESS SURVEYS

To characterise weld metals and the degree of cross joint strength match; additional specimens were removed from the inboard side (specimen PC1/H) and forward side (specimen PC2/H) of the fractured insert plate weld. The two specimens were cold mounted and prepared for hardness surveying as cross weld metallographic specimens. Test results for the two specimens surveyed are reported in Appendix 1 and Appendix 2.

The survey reported for the inboard side repair weld and insert plate (Appendix 1), showed weld metal hardness to overmatch that of the insert plate parent material. The hardness survey also identified a substantial weld HAZ, which extended through the full under weld plate thickness and some 15mm outward from the weld toe. The three indents placed beyond the apparent HAZ softening (welding re-annealed region), suggested that the insert plate parent material was of relatively low strength and had probably not been previously heat-treated or strain hardened.

The survey reported for the forward side of the weld repair (Appendix 2), identified parent plate materials of higher hardness and consequently of higher strength. The original construction fillet weld metal was seen to slightly undermatch the adjacent parent plate materials, a phenomenon not unusual in the welding of high strength aluminium alloys. The test data from the fractured weld appeared significantly more variable, and included areas both undermatching and over matching the original construction parent plate materials.

7. TENSILE TESTS OF PARENT PLATE MATERIALS AND VERIFICATION OF INSERT PLATE ALLOY TYPE

Tensile test specimens were removed from three items of original construction, and from the recently inserted bollard mounting plate material. The largest practical test specimen was prepared from each area and in a location that had not suffered visually apparent strain damage or welding related thermal damage. The certified test results for the four specimens are reported in Appendix 3.

The two port side forward to aft vertical plates (specimens Mk 1 and Mk 2) exhibited properties consistent with a high strength 5083 type material in the H14 or equivalent condition. The chequer plate (specimen Mk 3) was of a lower strength, and one equivalent to only the grade 5083 annealed condition. The inserted bollard mounting plate was of a yet lower strength, the combined tensile properties equating to those of an alloy grade 6082 in the T4 (annealed and naturally aged) condition, rather than any of the specified property sets for grade 1050 aluminium. The chemical analysis completed by agents acting to the instructions of TTH, subsequently also confirmed the material to be of alloy 6082 (Al-Si-Mn-Mg) type (see Appendix 4).

The use of a very low strength aluminium alloy insert plate material in a region of the vessel that was known to have suffered earlier deformation appears anomalous in the extreme, as does the contractors lack of certainty as to what material grade had actually been inserted. The apparent low strength of the insert plate material would demonstrably have facilitated the initiation of deformation at lower service loads than would have been the case had a more appropriate high strength material been used.

8. SUMMARY

8.1 The bollard had been fabricated from austenitic stainless steel bar and plate. The fillet welding of the body to the base had resulted in up to 3mm distortion of the base mounting face, which would have seriously compromised both its subsequent fitting to the walkway and distribution of resolved service loadings.

8.2 The bollard had been fitted to a recently inserted 6mm thick low strength aluminium mounting plate. The inserted plate had been fully fillet welded around its forward, outboard and aft sides. The inboard side of the insert plates aft end had fouled with the vessel's superstructure, and consequently only the forward end of the plates inboard side had been welded.

8.3 The insert plate had been welded with a low strength aluminium-silicon alloy of 4043 consumable type. This contrasted with original shipyard welding, which appeared to have been completed with a higher strength 5000 series aluminium-magnesium type alloy filler.

8.4 The insert plate and attached bollard had been torn from the walkway floor. The failure process had resulted in very substantial deformation of the mounting plate and bollard securing holes. The two close proximity original construction under-floor transverse members had also experienced severe buckling deformation.

8.5 The deformation apparent in the mounting plate and fractographic features were both consistent with weld fracture having initiated in the forward welded section of the inboard side. The weld fracture had exposed evidence of welder attributable root defects and lack of weld fusion, along with levels of gas porosity and shrinkage porosity commonly seen in aluminium weld metals.

8.6 Original shipyard construction welds were also seen to exhibit evidence of welder attributable defects comprising lack of weld fusion, cracks and higher levels of gas and shrinkage porosity than had been seen in the recently completed insert plate weld metal. Though such defects were present in the original construction welds, none were seen to have either grown under the service stress or contributed to the current failure.

8.7 The insert plate weld had failed by low ductility shear, through a total cross sectional weld area of $4292mm^2$. A simple estimate of the necessary upper bound stress (Appendix 5) to fracture the apparent weld cross sectional area confirmed that a service load could not have generated the necessary fracture force within the mooring ropes rated capacity. This observation then leads to a scenario in which the weld fracture occurred by a progressive tearing action, which was initiated and sustained at a much lower stress, and one that was demonstrably within the ropes rated capacity.

8.8 Vickers hardness testing confirmed that the insert plate weld metal over matched the insert plate parent material, and thereby served to confirm that the inserted parent plate was of very low strength. The shipyard construction weld metal was, in contrast, seen to slightly undermatch the original high strength parent materials, as is usually the case in high strength aluminium alloys. The position in the composite weld involving shipyard and repair contributions appeared less clear, with areas of weld metal both over and undermatching the parent materials.

8.9 Tensile testing of parent materials confirmed properties in original plain plate construction materials consistent with the BS 1470:1987 grade 5083 high strength H14 condition. The walkway chequer plate was of a significantly lower strength, and one equating to the BS 1470:1987 grade 5083 annealed condition. The insert plate was found to exhibit an even lower tensile strength, and was subsequently confirmed to be of alloy 6082 type in the annealed and naturally aged condition.

9. CONCLUSIONS AND DISCUSSION

We conclude that failure had resulted from a shear stress overloading of the recently completed insert plate fillet weld. Prior to catastrophic failure, by detachment of the insert plate and mounted bollard, the mounting plate and original underfloor structure had undergone very significant deformation in reacting to the resolved casualty loading. Evidence suggests that a number of factors had co-contributed to the ultimate failure, these appeared to include the following.

- Design suitability, or otherwise, of the walkway floor structure for mounting of the bollard
- Poor fabrication of the bollard and mounting plate distortion in particular
- The use of a low strength aluminium insert plate for subsequent mounting of the bollard
- Specifying of the insert weld repair procedure with respect to specified weld size and the use of a low strength 4043 type aluminium-silicon alloy consumable
- The presence of welder attributed defects in the fractured weld metal volume

Considering the various contributory factors. The design, or lack of same, would appear to be the most dominant factor. The insert plate and under-floor transverse members had patently undergone very severe plastic deformation and buckling damage respectively. A satisfactory design, by contrast, should have stressed the structural members in a purely elastic manner.

The insert plate had undergone a very significant amount of plastic deformation, some of which must have occurred prior to shear fracture of the repair weld. The use of a low strength aluminium insert plate in what should have been perceived as a high stress area appears perhaps the next most dominant contributory issue. The partial welding of the plate along the inboard high service stress side, would have both reduced the available attachment weld volume and facilitated progressive weld shearing at a peak stress significantly lower than the peak stress estimated in Appendix 5.

The weld metals low strength type and workmanship issues including poor bollard construction and the volumetric quality of the insert plate weld metal would appear collectively to represent tertiary contributions.

The original shipyard welding included in the various specimens examined, appeared to have been completed with a higher strength aluminium-magnesium 5000 series type consumable. Though the original welding exhibited a higher incidence of weld metal and welder attributable defects, none of the welds examined were seen to have failed or fractured in service.

The contractor completing the insert plate repair had presumably elected to use the lower strength aluminium-silicon 4043 type consumable to exploit its greater fluidity and significantly reduced risk of shrinkage porosity and cracking. The presence of a continuous network of low melting point aluminium-silicon eutectic phase in the consumable contributes positively to offsetting of solidification losses in the weld volume, but in practice leads to weld metals exhibiting both reduced strength and ductility. This in turn leads to reduced capacity for accumulation of any initial overload stress as plastic strain energy or deformation.

To estimate a potentially more realistic estimate of the casualty force reacted through the mooring rope, we would suggest that the client generate a stress-strain relationship by tensile testing the rope. This relationship could then be used to establish the prevailing force at a rope strain energy equal to the kinetic energy of the propelled bollard and mounting plate mass.

Report prepared and authorised by

8.7.04

D Ellin
Director and Head of Laboratory

T40821 APPENDIX 5 Sheet 1

ESTIMATE OF WELD FRACTURE STRESS AND REVIEW OF PROBABLE FRACTURE PROCESS

Area of sheared weld metal (report section 3.2) = $4292 mm^2$

Typical as welded tensile strength of 4043 consumable
(Bostrand Consumable Guide) = $150 N/mm^2$

Assume weld metal shear strength to be half the tensile strength and assume, due to weld defects, that strength is no better than the typical minimum

then weld shear strength = $\frac{150}{2} = 75 N/mm^2$

Then assuming simultaneous fracture of all the casualty weld,

fracture force (F) = shear stress x weld area

= 75 x 4292

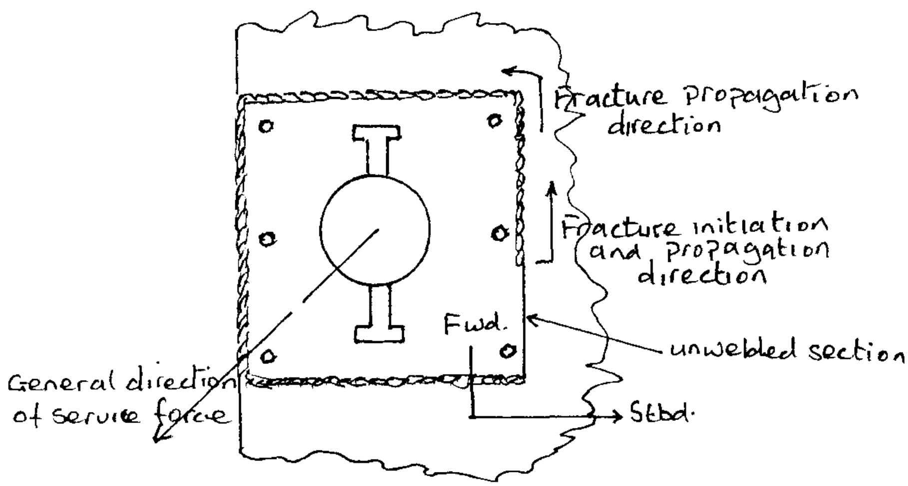
F = 321.9 kN

The above represents a conservative upper bound force, as it assumes that the whole weld fails by simultaneous shear, and no account is take of the moment arising from the rope contact point.

If account is taken of the moment, the force to account for simultaneous weld fracture is still beyond the mooring ropes rated capacity. This therefore confirms that weld fracture occurred at a lower stress and by a mechanism of progressive tearing.

Fractographic evidence suggested that fracture had initiated at the end of the inboard side weld and had propagated in a forward direction as shown in the following sketch.

T40821 APPENDIX 5 Sheet 2



Assume the forward inboard weld section only failed by simultaneous shear, then fracture force (F)

F = shear stress x weld area

= 75 x 628

= <u>47.1 kN</u>

The above conservative force, which again takes no account of the reduction arising from the bollards height (movement), is well within the ropes capacity.

The above force estimates confirm that the insert plate weld could not have fractured simultaneously, but had failed by progressive tearing.

The client is consequently recommended to consider estimating the fracture force by a process involving an energy balance approach as follows.

(i) Determine the ropes stress strain relationship by uniaxial tensile load test

(ii) Relate the projectiles necessary kinetic energy to the ropes stored potential energy and consequently to a force.

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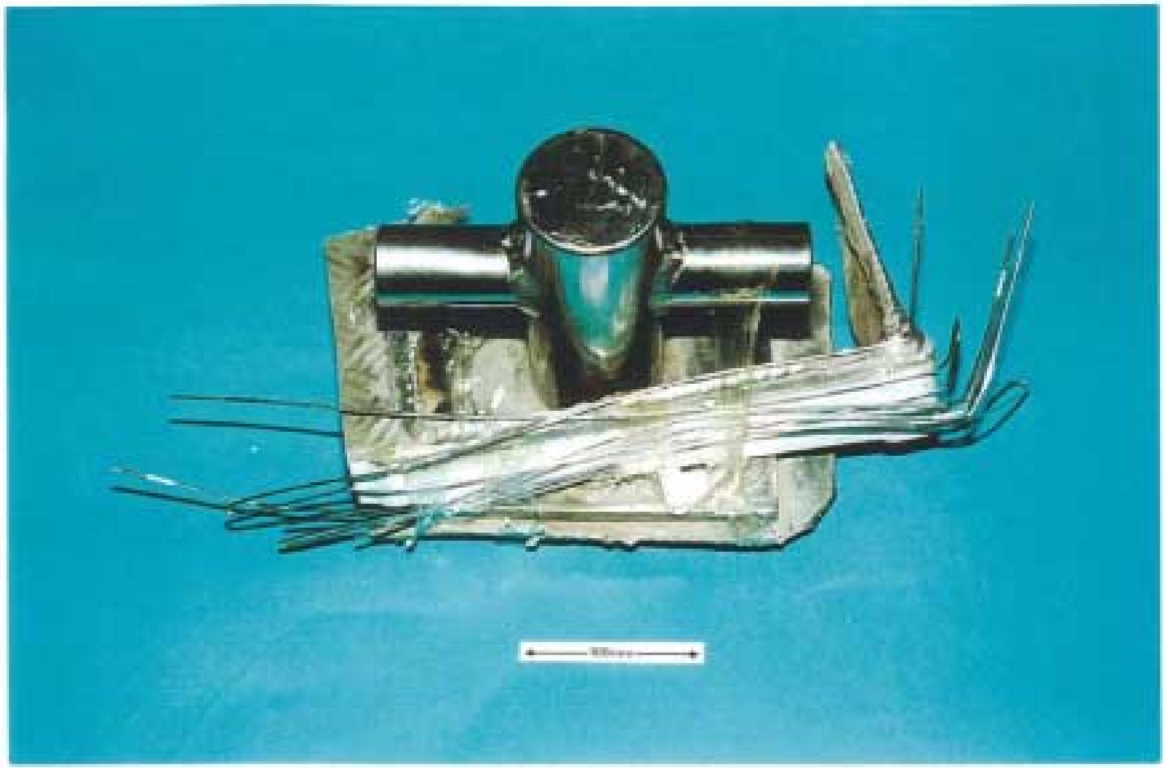

Figure 1: Forward port side bollard and associated material from STAR CLIPPER, shown as received.

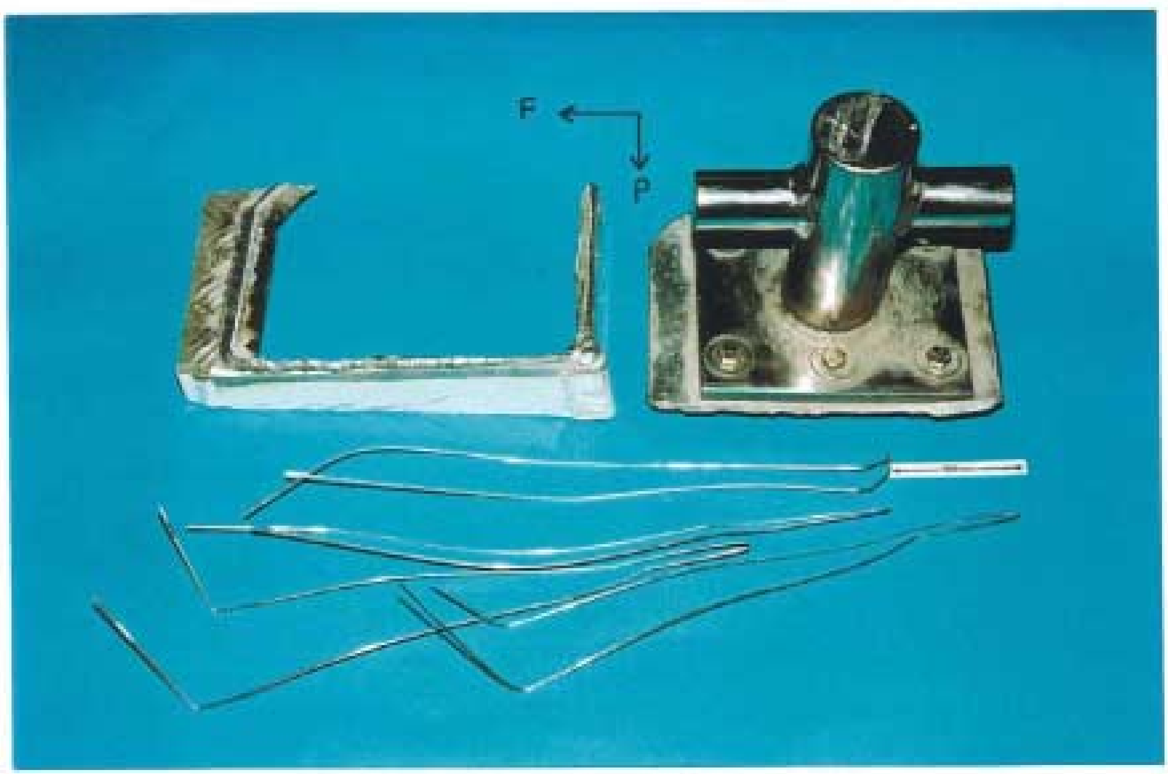

Figure 2: Sample material, shown after unpacking and oriented in respect of vessel installation (F = forward, P = port).

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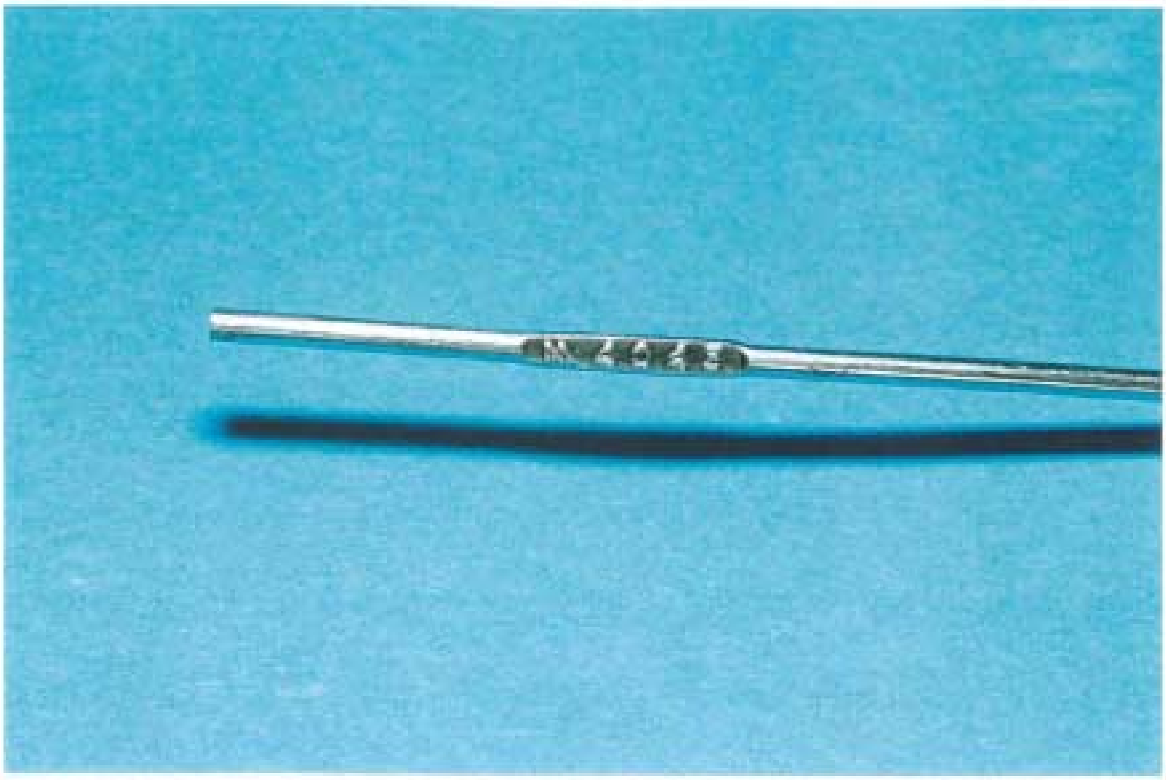

Figure 3: Alloy grade (4043) embossed at one end of the welding consumable lengths supplied.

Figure 4: Embossed number sequence apparent at the opposite welding consumable wire ends.

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Figure 5: Bollard, shown still bolted to the walkway insert plate.

Figure 6: Underside of detached insert plate, showing nut and locking nut securing arrangement.

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Figure 7: Underside view of bollard, showing welding related distortion of the base plate.

Figure 8: Side view of bollard, showing welding related base plate distortion.

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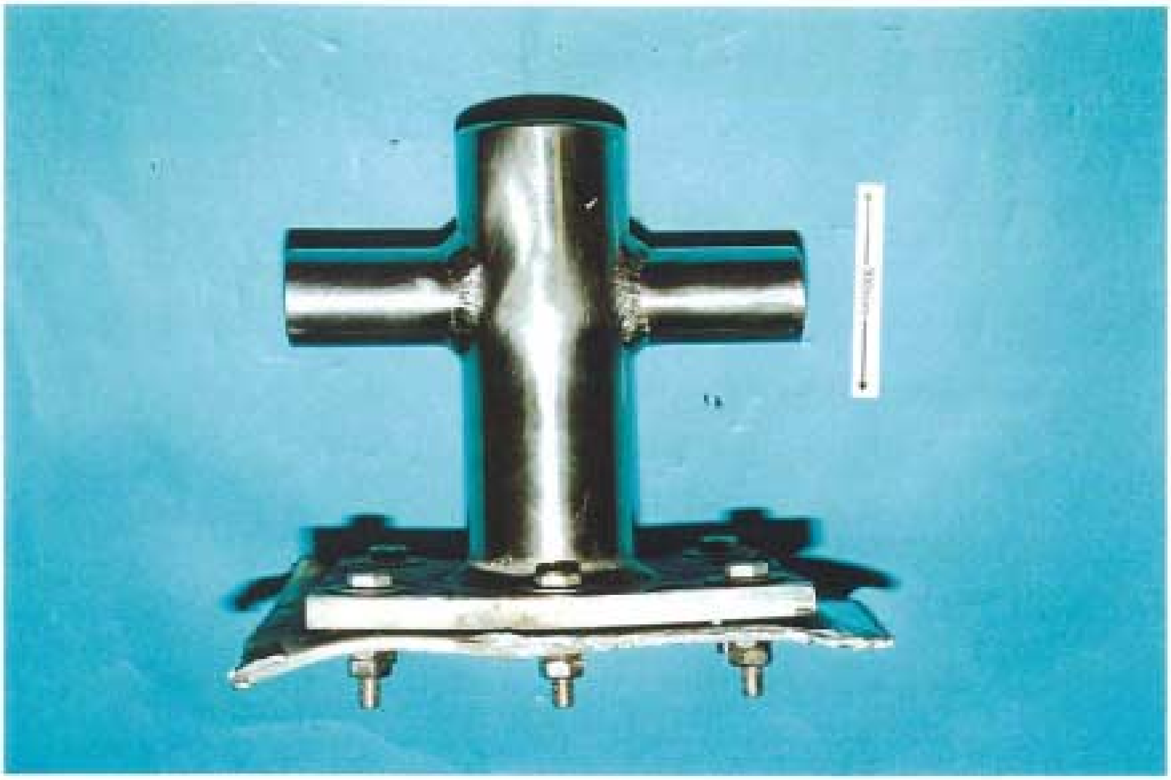

Figure 9: Bollard and insert plate viewed from inboard side.

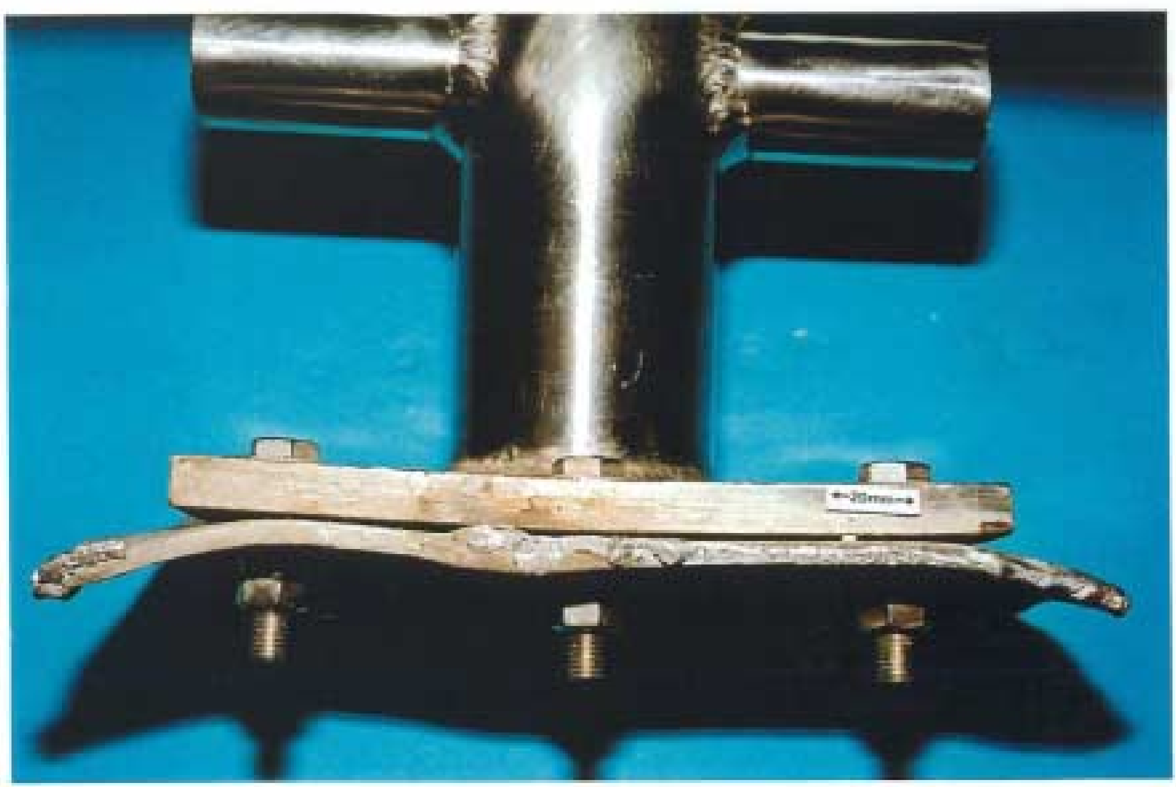

Figure 10: Detail of above, showing fracture in weld metal that was present at the forward end only.

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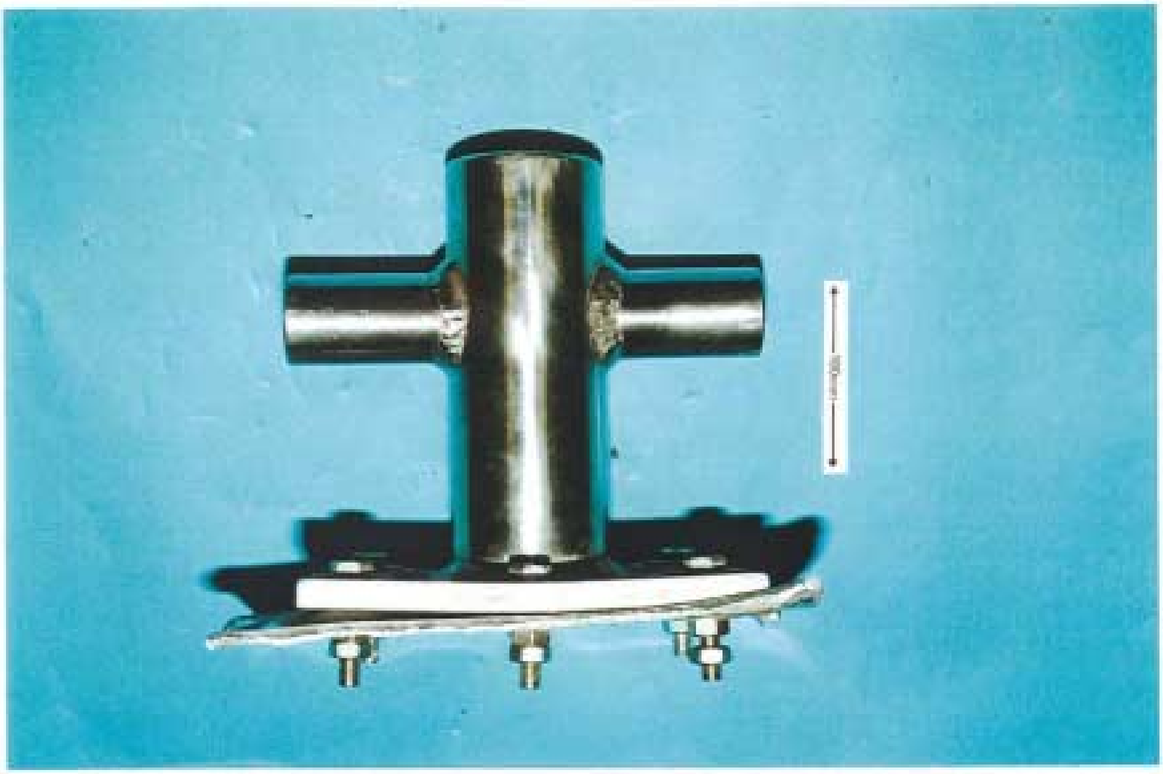

Figure 11: Bollard and insert plate viewed from outboard side.

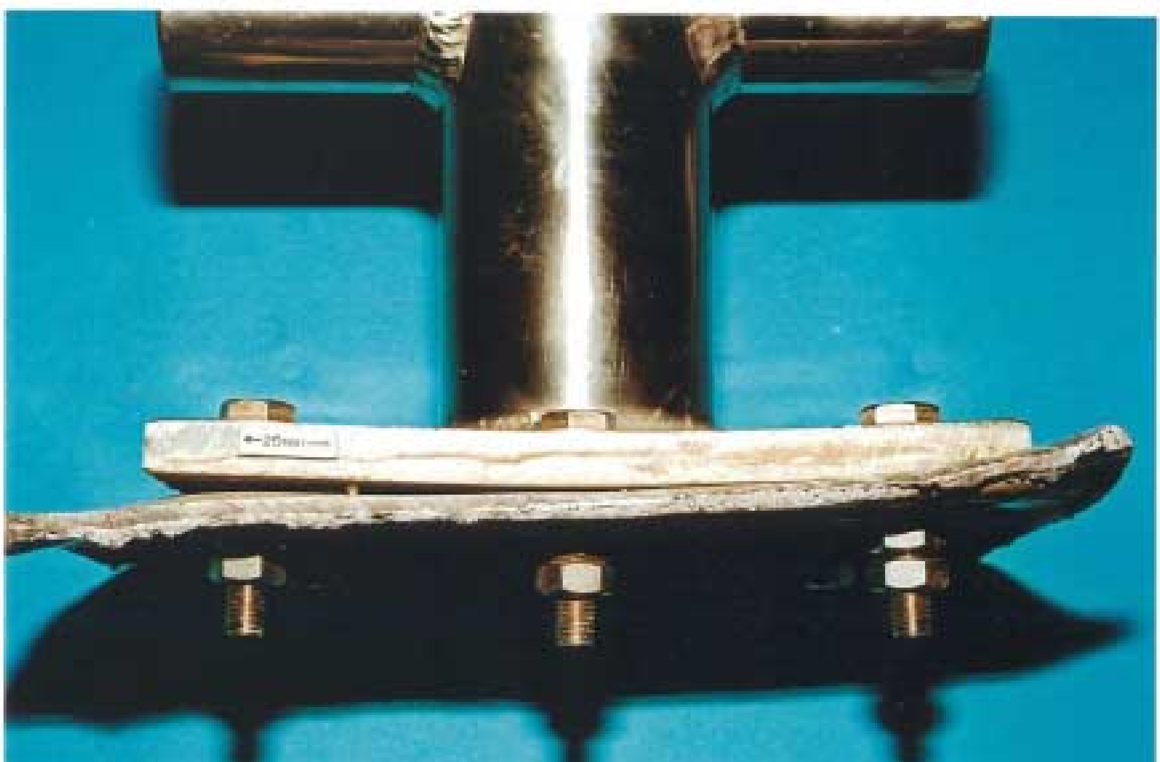

Figure 12: Detail of above, showing fractured weld metal.

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Figure 13: Insert plate, showing bollard base downwards indenting of the aft outboard corner (lower right corner of field).

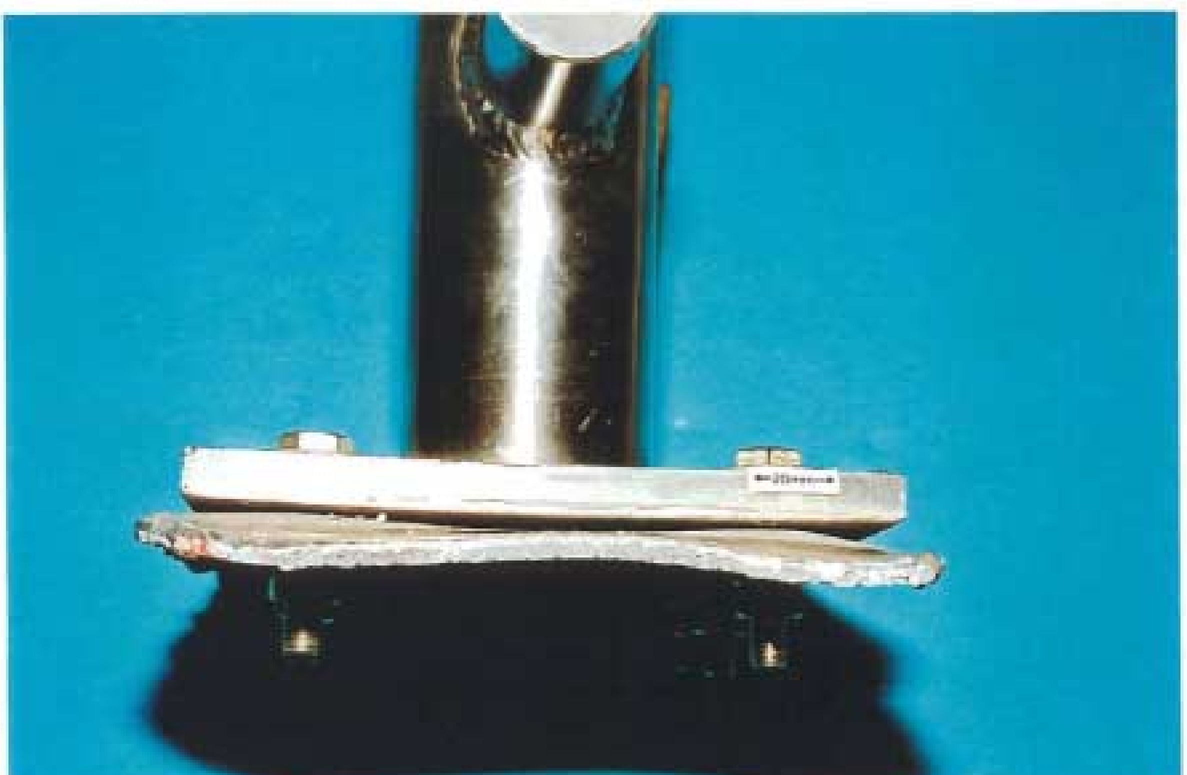

Figure 14: Bollard and insert plate viewed from forward end.

Figure 15: Detail of figure 14, showing fractured weld metal.

Figure 16: Bollard and insert plate viewed from aft end.

Figure 17: Detail of figure 16, showing fractured weld metal.

Figure 18: Underside fracture half comprising the forward end, outboard side and aft ends only.

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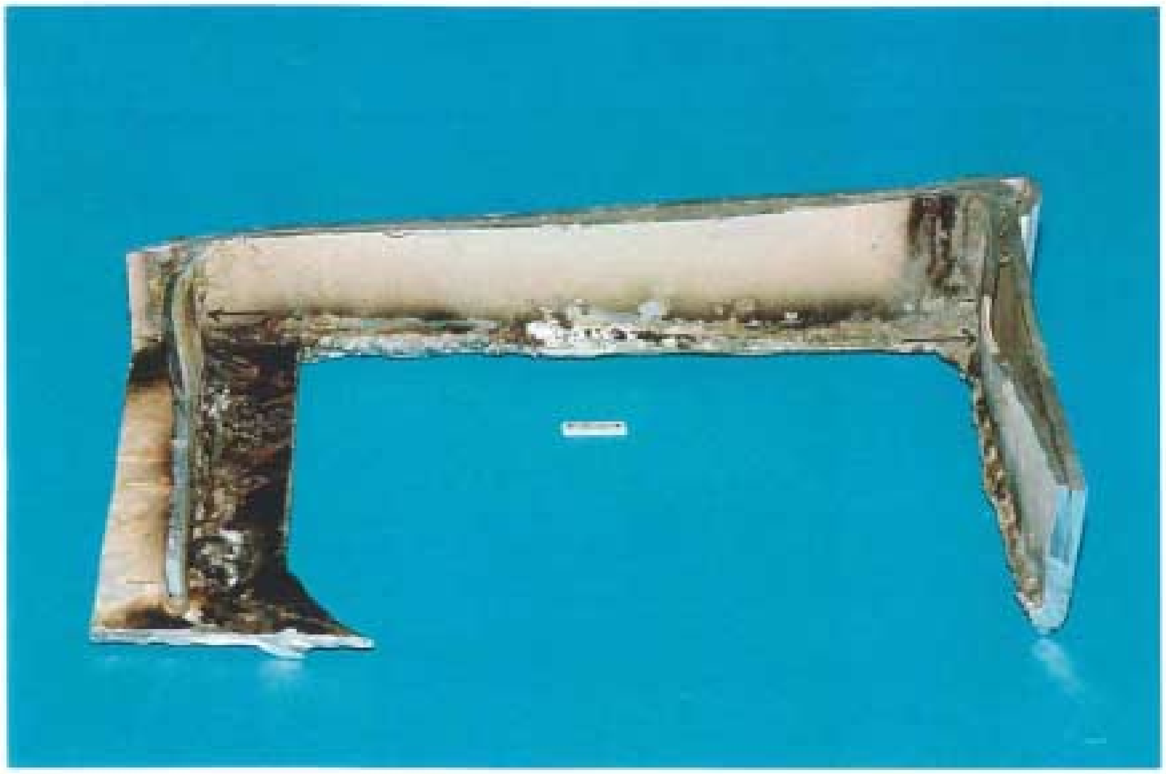

Figure 19: Under-floor section, showing buckling damage to forward and aft transverse members (arrowed).

Figure 20: Under-side fractured forward weld section.

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Figure 21: Detail of figure 20, showing unfused root bead roll-through and possible entrapped consumable welding wire in weld root.

Figure 22: Under-floor forward section, showing local excess penetration or burn-through the chequer plate (arrowed) from the insert weld to the upper chequer plate surface.

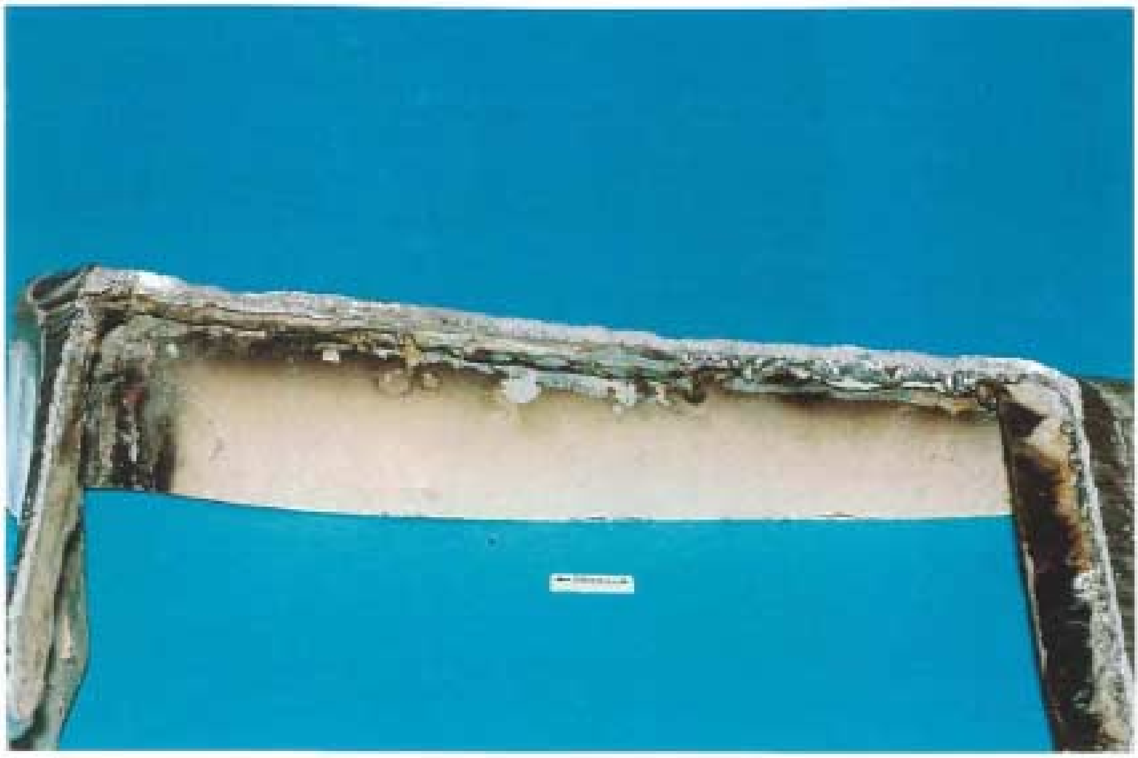

Figure 23: Under-side of fractured outboard weld section.

Figure 24: Detail of above, showing area of excessive root penetration.

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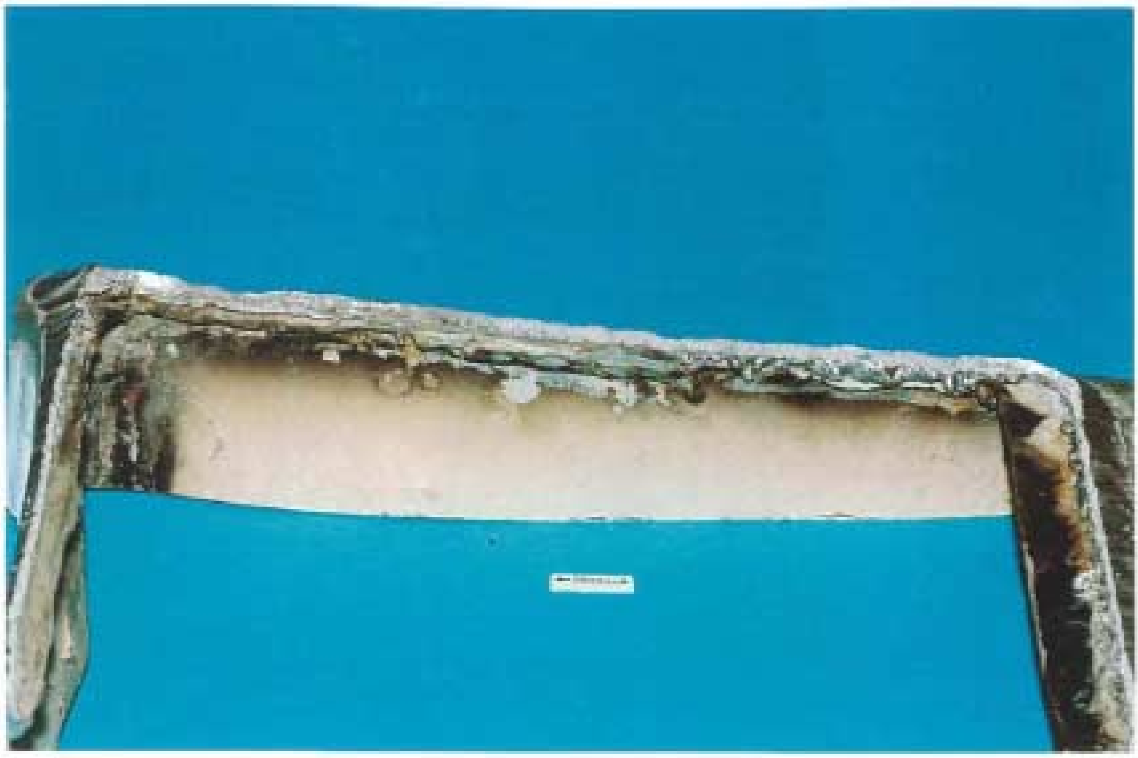

Figure 23: Under-side of fractured outboard weld section.

Figure 24: Detail of above, showing area of excessive root penetration.

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Figure 25: Under-side of fractured aft weld section.

Figure 26: Detail of above, showing weld root defects in the corner transition region from the outboard weld side.

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Job reference: T40821 **STAR CLIPPER**

Figure 27: Sample (PC1) removed from inboard weld side and which was subjected to detailed examination.

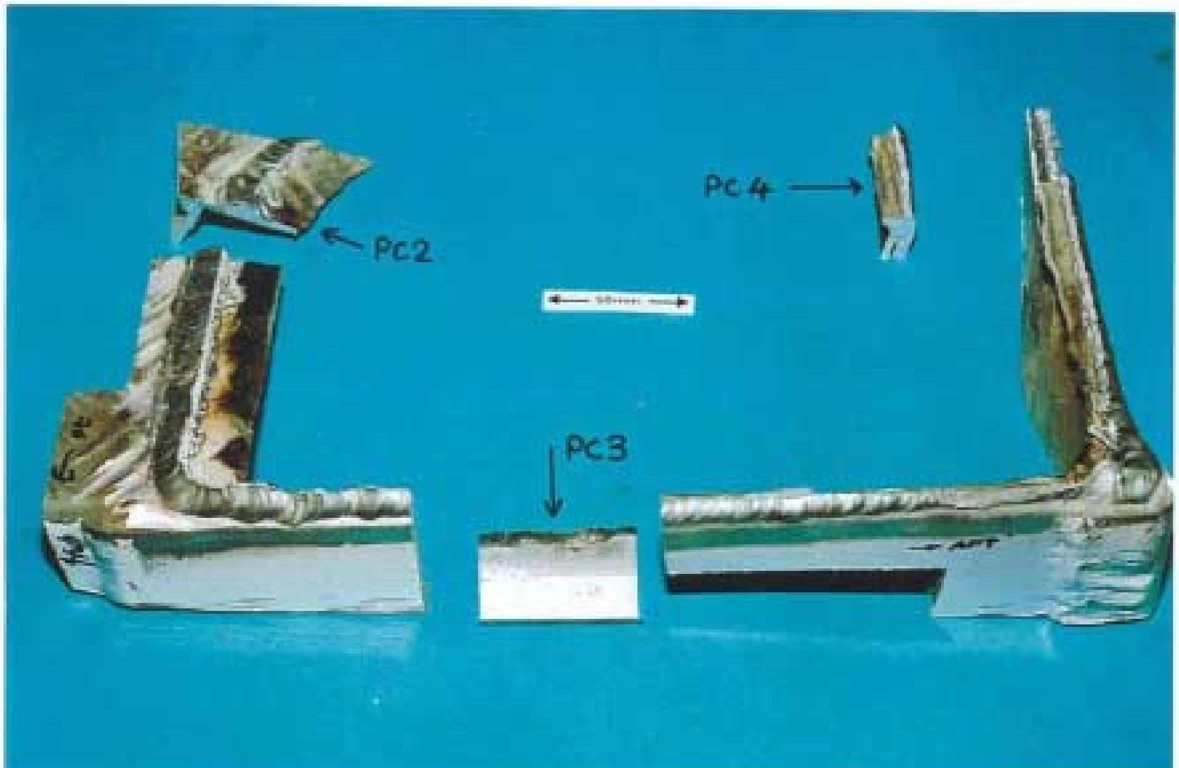

Figure 28: Samples (PC2, PC3 and PC4) from the forward, outboard and aft weld sides, and which were subjected to detailed examination.

Client: MAIB, Southampton, SO15 2DZ
Job reference: T40821 **STAR CLIPPER**

Figure 25: Under-side of fractured aft weld section.

Figure 26: Detail of above, showing weld root defects in the corner transition region from the outboard weld side.

Client: MAIB, Southampton, SO15 2DZ
Job reference: T40821 **STAR CLIPPER**

Figure 27: Sample (PC1) removed from inboard weld side and which was subjected to detailed examination.

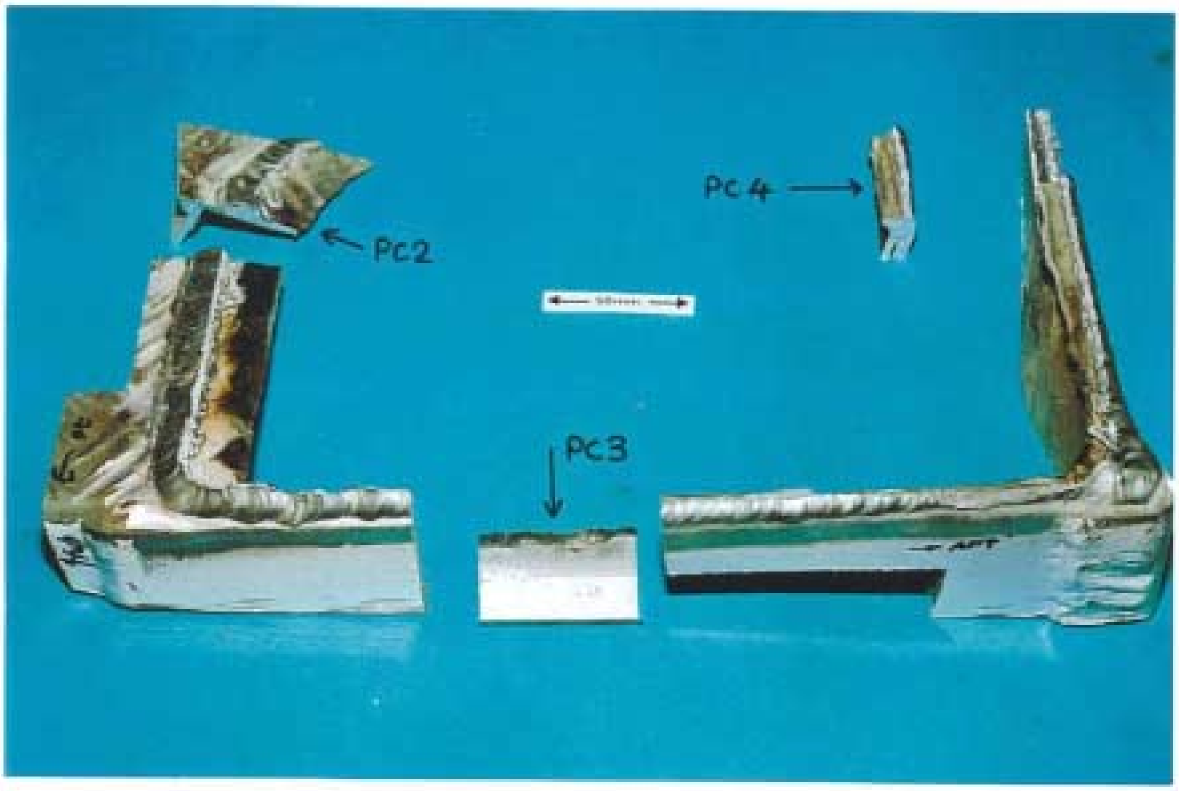

Figure 28: Samples (PC2, PC3 and PC4) from the forward, outboard and aft weld sides, and which were subjected to detailed examination.

ANNEX D

Tension Technology International Ltd – Report TTI-NOH-2004-274 dated 4 August 2004 – "Final Report on the Examination and Tensile Testing of a Polypropylene Rope Strop, and Calculations to Establish the Likely Rope Stored Energy Involved in the Vessel Bollard Failure of the *Star Clipper*"

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FINAL REPORT ON THE EXAMINATION AND TENSILE TESTING OF A POLYPROPYLENE ROPE STROP, AND CALCULATIONS TO ESTABLISH THE LIKELY ROPE STORED ENERGY INVOLVED IN THE VESSEL BOLLARD FAILURE of 'THE STAR CLIPPER'

For

MARINE ACCIDENT IVESTIGATION BRANCH

Report No. TTI-NOH-2004-274

Date	Rev.	Description	Prepared by	Authorised by
29 June 04	1	Draft for consideration by MAIB	**N O'Hear**	**J Nichols**
04 Aug 2004	2	Revised draft for consideration by MAIB. Contains text changes and annexe additions	**N O'Hear**	**J Nichols**
16 Nov 2004	3	Final Report, with one correction to Figure 6. Footer page dating remains 04 August 04	**J Nichols**	**N O'Hear**

Distribution:

Client: MAIB — Attention: Wim Hart

Internal: TTI Ltd — Attention: N O'Hear, S Banfield

Signed on behalf of TTI:

J. Nichols
Consultant

CONTENTS

Abbreviations

TTI	Tension Technology International Ltd
MAIB	Marine Accident Investigation Branch
MBL	Minimum Breaking Load ['Force' is also used in place of 'Load']
KN/daN	kiloNewton/decaNewton 10kN=1000kgf [1 tonnef]approximately, 1daN=1 kgf approximately
kn	International nautical mile per hour
PP	Polypropylene

DEFINITIONS

Staple Fibre	Discrete length of filamentary material, in this case produced by cutting of continuous filament polypropylene
Spun [spinning]	Process by which staple fibre is consolidated to form a textile yarn
Reference Tension	Tension imposed on rope during dimensional measurements. Defined in BS EN 919:1995 '*Fibre ropes for general service-Determination of certain physical and mechanical properties*' Reference Tension [daN]= $d^2/8$, where 'd' is the rope diameter in mm
Rope assembly	Term used to refer to the construction of the item under investigation. It is neither a grommet[endless loop] or strop [single span with a spliced eye at each end]

1 Executive Summary

This report forms part of an investigation into the fatal accident on 2nd May 2004 at St. Katherine's Pier, involving the 'Star Clipper'. In brief, the accident was caused by a bollard on the vessel shearing off from its mounting and being propelled through the air. The bollard hit and killed a waiting passenger.

In this report, the tensile properties and condition of the polypropylene mooring line are investigated and three possible scenarios for the path of the bollard through the air, following its parting from the vessel deck, are calculated. These calculations are based on the rope tensile properties and information provided by MAIB from their site investigation.

The breaking strength was found to be 65kN, and with an elongation to break of 15%. This is less than the new strength which should have been in circa 80 kN, representing a loss of 18%.

For a used rope, without any obvious external damage beyond that which may be expected on a 'fair wear and tear' basis, it is not unusual to measure loss of strength of around 10% from new. Causes for this include abrasion between the rope strands and a variety of fatigue mechanisms of the rope elements. Unfortunately, there are many other possible causes that may be used to explain the higher loss found during this investigation and only further investigation will allow a more precise explantion to be offered. As the rope did not fail, there seems little to be gained by pursuing this aspect for the purposes of this report.

Also, the TTI test at NEL was not designed to measure the rope strength, but to simulate as closely as possible the rope assembly. To establish new dry rope strength, the original manufacturer [ie not the supplier of the rope assembly] may well have used a different method of test. The mode of failure, close to one splice, is in line with what would be expected from the particular design of splice used in the assembly.

The Certificate of Warranty [Annexe 1] provides a statement of the breaking strength of the rope, but appears not to make a statement about the strength of the assembly made from the rope. Again, since the rope did not break, this is not a factor in the accident.

From the mass and trajectory of the bollard it is possible to deduce the kinetic energy on the vessel if it were moving or the thrust if it were stationary. The trajectory of the bollard is not known exactly so 3 scenarios were examined. It is likely that, at the time of the accident, the vessel's speed would have been not less than 0.55 km/hr [0.3 knots] and not more than 2.32 km/hr [1.3 knots].

One scenario involves the bollard being projected over the facing barrier on the pier without making contact either with it, its stanchions or the pier bollard.

A second scenario involves the vessel bollard being deflected upwards by one of the pier barrier angled stanchions.

A third possible scenario is that the bollard moved first horizontally in line between the vessel's bollard and the pier bollard, struck the pier bollard where it bounced upwards in an arc to clear the near fence, hit the passenger and then hit the far fence.

Inspection of the pier bollard is recommended, and it is understood that this is to be undertaken by MAIB in the near future. Also, it is understood that MAIB will have paint samples from the vessel and pier bollards analysed, as well as samples from the barrier paint coatings.

2 Introduction

This report constitutes part of the investigation into a fatal accident, being conducted by MAIB, that occurred during a mooring manoeuvre at St Katherine's Pier on May 2 2004. The accident involved a bollard being displaced from its mounting on the deck of the 'Star Clipper' when under a load imposed on it by the rope assembly in question.

The stored energy in the rope assembly was sufficient to propel the bollard over a pier barrier and to hit a waiting passenger. The bollard continued its trajectory for a short distance after striking the passenger, before coming to rest.

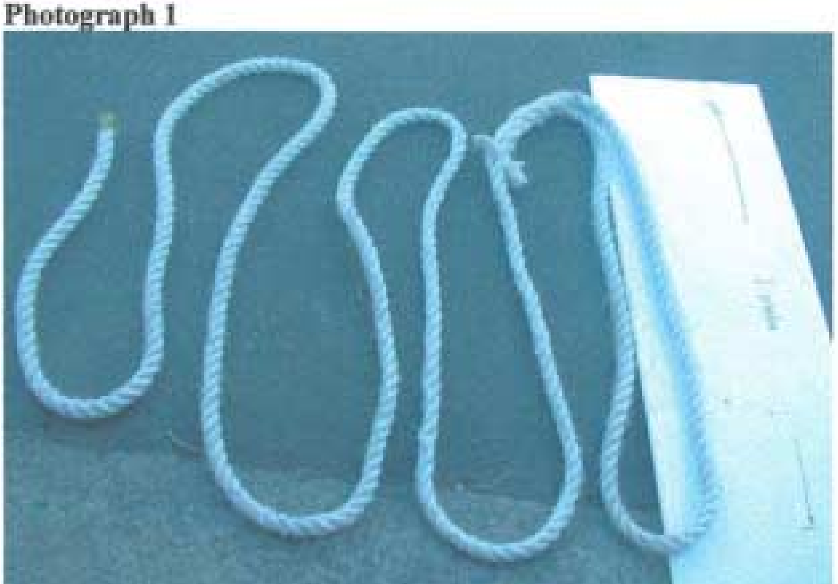
The physical testing of the rope material, from which the rope assembly was made, will provide the basic data, in combination with information from the site investigation, to allow:

- a calculation to be made of the recoil energy characteristics of the rope
- the development of three scenarios for the bollard trajectory
- an estimate of the load at the point of the bollard failure
- an assessment of vessel power at the time of failure

3 Visual examination

Photograph 1 shows the rope as received at TTI premises in Arbroath. The rope specification was provided by MAIB[Annexe 1], being stated to be a 24 mm diameter 3-strand construction, of polypropylene spun staple fibre yarns.

Photograph 1



According to BS EN 699:1995 '*Fibre ropes for general service-Polypropylene*' this rope is defined as a '3-strand hawser laid polypropylene rope [Type A]'.

From Table 1 of the Standard, a 24 mm diameter rope will have a Minimum Breaking Force of 7970 daN, 8.12 tonnef.

On a point of detail, it may be seen from Annexe 1 that whilst the certificate refers to a Minimum Breaking Strength of 8.1 tonnef for the rope, there is no confirmation on the document of the Maximum Safe Working Load of the assembly, which is made from the rope.

Table 1 shows some initial measurements made on the rope assembly.

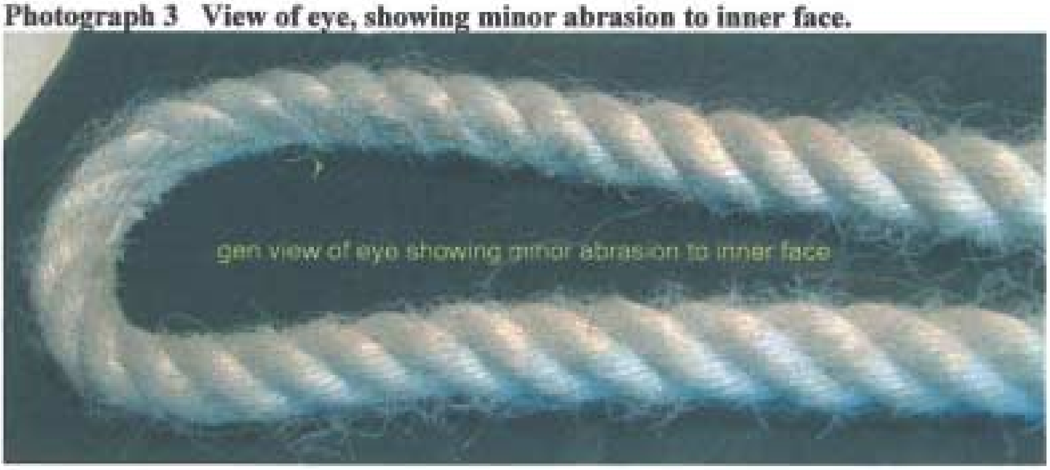
Table 1 Initial measurements on rope as received by TTI

Reference tension	70 daN [70kgf approximately]
Diameter [average of 3 measurements]	22.7 mm
Layflat length of eye	1050 mm approximately
Splice length	250 mm approximately
Total length	6500 mm approximately

The assembly appeared in good condition, Photograph 2 showing a view of the rope used in the assembly. Photograph 3 is a view of the eye, showing minor abrasion to its inner face, where it has been in contact with bollards or other mooring devices.

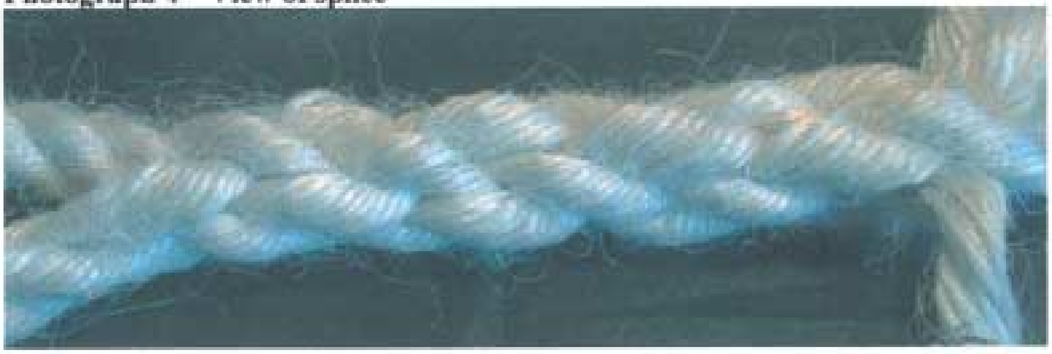
Photograph 2 General view of rope condition

Photograph 3 View of eye, showing minor abrasion to inner face.

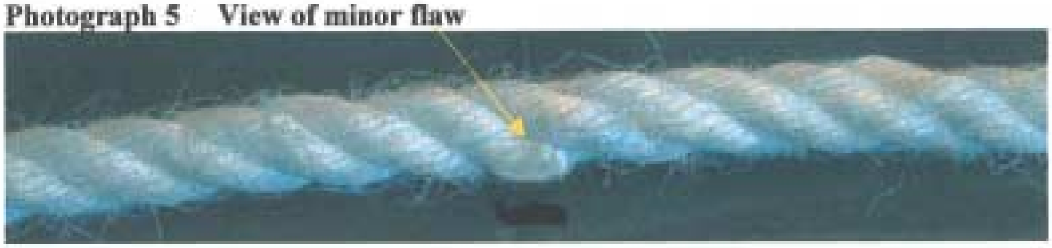


Photgraph 4 shows the splice used to create the single eye, and Photograph 5 shows the one minor problem seen in the 'rope part' of the assembly, a raised loop, maybe caused by the rope catching on an object.

Photograph 4 View of splice



Photograph 5 View of minor flaw



The hairy appearance of the rope assembly is part of its construction, designed to give natural fibre 'handle' and to a synthetic fibre rope.

To conclude this section, the visual examination revealed no serious issues regarding the rope condition or its method of manufacture.

4 Tensile testing

This part of the investigation was sub-contracted to:

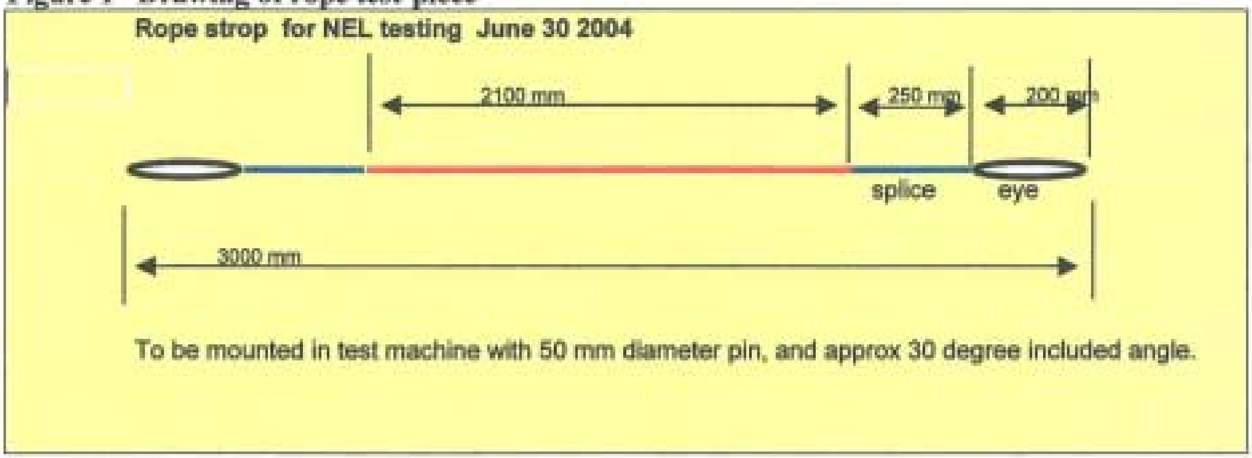
TUV NEL Ltd,
East Kilbride,
Glasgow
G75 0QU

This is the National Engineering Laboratory, and NEL and TTI have worked together for many years on rope research and rope failure investigations. Their technical facilities and experience in all aspects of rope testing amply qualifies them for the work undertaken in this investigation.

The testing was conducted on Friday, 2 July 2004, conducted by R Hone [NEL] and witnessed by J Nichols [TTI]. The rope assembly as received could not be tested, as an eye on each end was required to mount it in the test machine.

Figure 1 shows a drawing of the test-piece prepared by TTI, and Photograph 6 shows it mounted in the test machine at NEL.

Figure 1 Drawing of rope test-piece



Photograph 6 Test strop mounted in test machine at NEL

Photograph 7 shows a view of the upper part of the test machine, where the force and displacement transducer devices, load cell and LVDT respectively, are located.

The data for load and extension is captured digitally and stored as an Excel spreadsheet file.

Photograph 7 Upper view of the test machine

The test parameters were based on Annexe C [normative] of BS EN 919:1995 '*Determination of the load-elongation co-ordinates on a special test piece*', but modified to suit the circumstances of this investigation.

The overview of the test procedure is to cycle the strop between its reference tension and 30% of its Minimum Breaking Load [MBL], 10 times, to condition the rope in preparation for the final test to destruction. The information on how the load varies with elongation, from the test to destruction, is used to calculate the stored energy. The conditioning cycles are necessary to bed in the new splices, and thus to restore the structure as closely as possible to the condition it would have been in just prior to the failure.

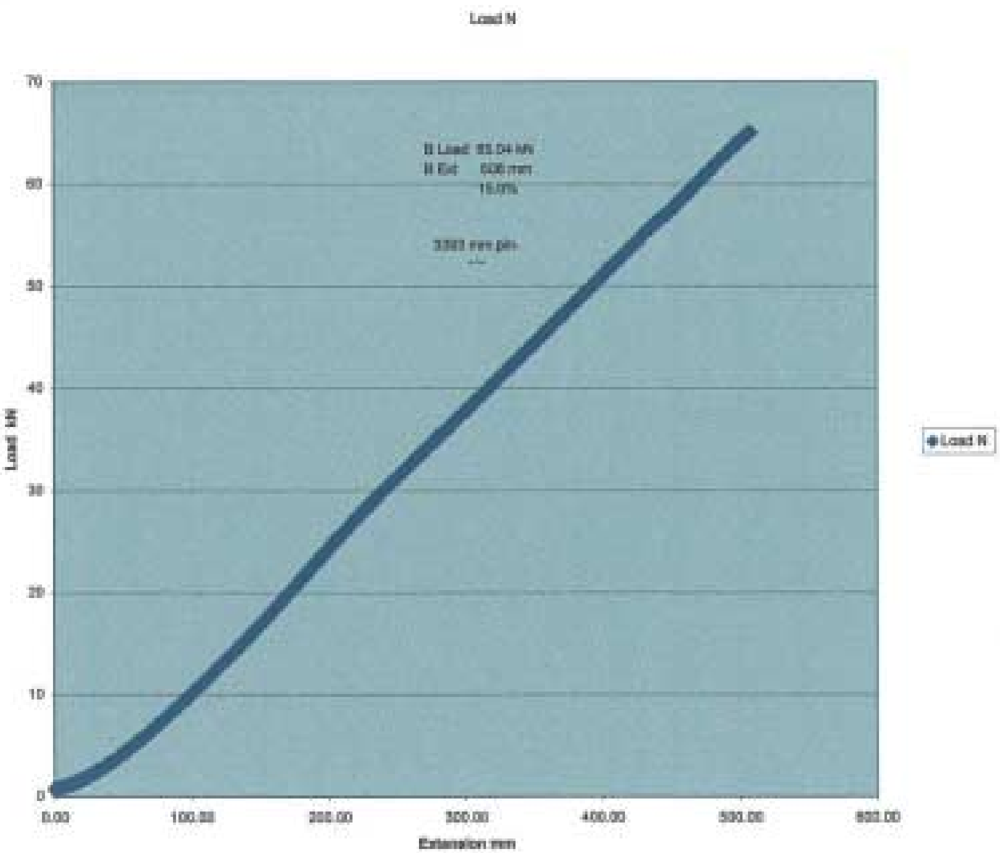
The test procedure was as follows:

1. Traverse speed set to 250 mm/minute
2. Load and mm extension data pairs were measured at a rate of 5/second
3. Take strop to reference tension of 0.7 kN as start point for the test
4. Commence conditioning cycles by pulling the strop until 30% MBL is reached, 23.9 kN, and return to reference tension.
5. Repeat procedure, until 10 cycles have been achieved
6. The 11th pull is the final test to destruction
7. Note the pin-to-pin measurement before the final pull to destruction. This forms the basis for calculating the % breaking extension

As an additional check, pin-to-pin measurements were recorded at the start of each conditioning cycle, as was the load and mm extension data from the test machine.

Annexe 2 is the Certificate of Test issued by NEL, and Figure 2 shows the load/elongation curve for the test to destruction. Annexe 3a is the Certificate of Calibration for force measurement and Annexe 3b is an internal NEL document of the calibration of the displacement measuring device, the LVDT.

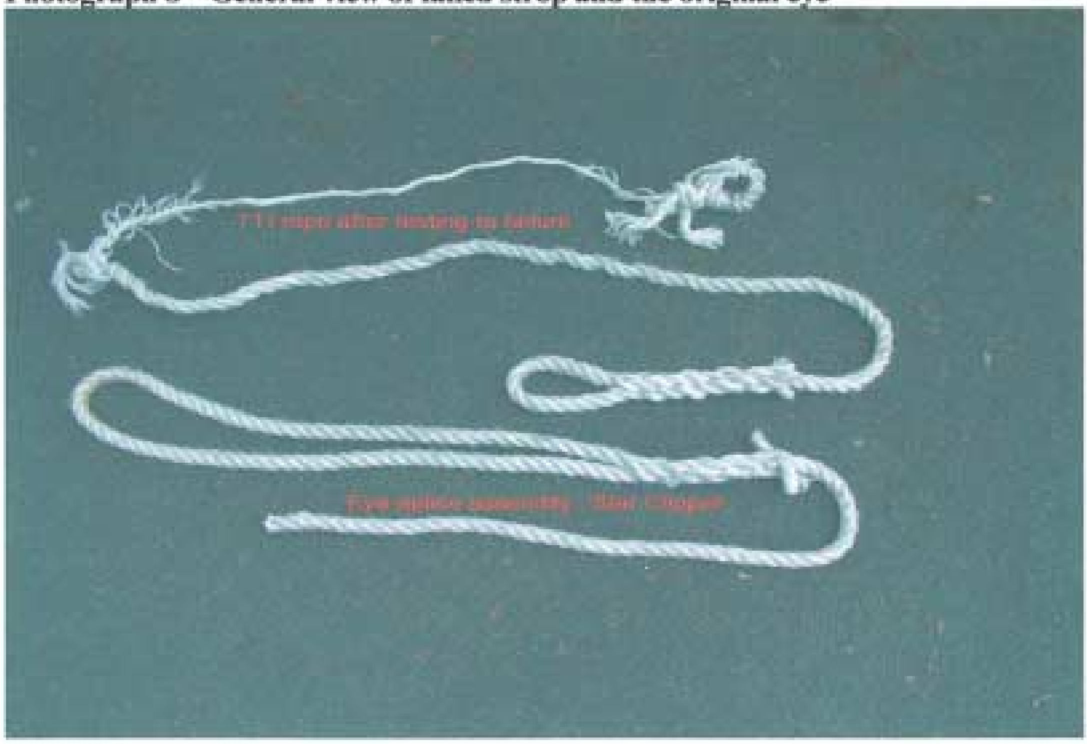
Figure 2 Load/ mm extension curve for final pull to destruction of strop



The Breaking Load was 65.04 kN, 6.63 tonnef.
The Breaking Extension was 508 mm, 14.97%

The failure was just below one of the splices, and Photograph 8 shows a general view of the failed strop with the original eye for comparison

Photograph 8 General view of failed strop and the original eye



5 Load, Energy and Trajectory Calculations

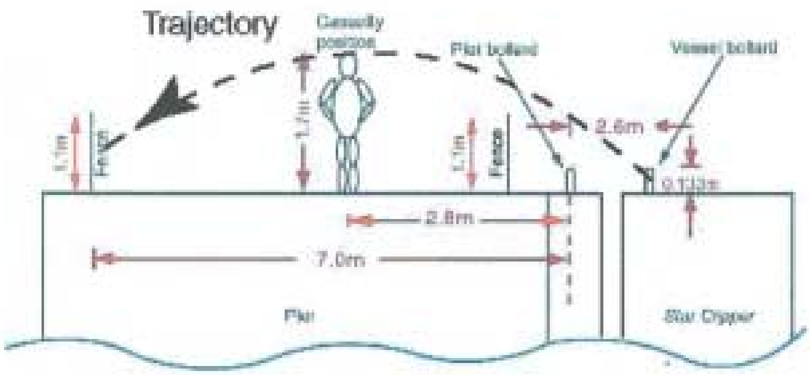


Figure 3 General view of accident scene, in plane of flight of bollard

The trajectory of the bollard is broadly known, as illustrated by Figure 3. The bollard was ripped out from the vessel deck and flew upwards to strike the victim's head. The bollard continued and is believed to have hit the far fence. Since the fence is 1.1 m high and the victim was struck at a height of 1.7m, the bollard descended after striking the victim.

In this section of this report, three possible scenarios are examined. The first is that the bollard's trajectory described a parabola between the ship's bollard and far fence as shown in Figure 3. The second is that the bollard was deflected upwards by hitting a diagonal brace of the first fence and started its parabolic motion above the fence at an indeterminate height. The third possible scenario is based on the premise that the vessel bollard was deflected upwards off the pier bollard

5.1 Methodology

The methodology used is as follows:
Set three co-ordinates on the trajectory

a) Starting height at distance zero (0 to 0.133 m)
b) Set height at victim impact (= 1.7 m) and distance at impact (= 5.4 m from bollard)
c) Set height at far fence impact (0 to 1.1m) and distance at impact (= 9.6m from bollard)

Calculate the velocity and launch angle required to fit the trajectory from Newton's Laws of Motion.

Any standard physics reference text, on the subject of dynamics and projectiles will provide a detailed background explanation and derivation of the theory used in this study.

Annexe 4 shows the basic equations of motion for an object moving in a straight line under constant acceleration, that form the basis of projectile theory. Figure 4 is a qualitative representation of the dynamics of the system.

a) Separate velocity into horizontal and vertical components

$v_x = v_0\cos\theta_0$ and $v_y = v_0\sin\theta_0$ where v_x and v_y are the horizontal and vertical components of velocity and θ_0 is the launch angle.

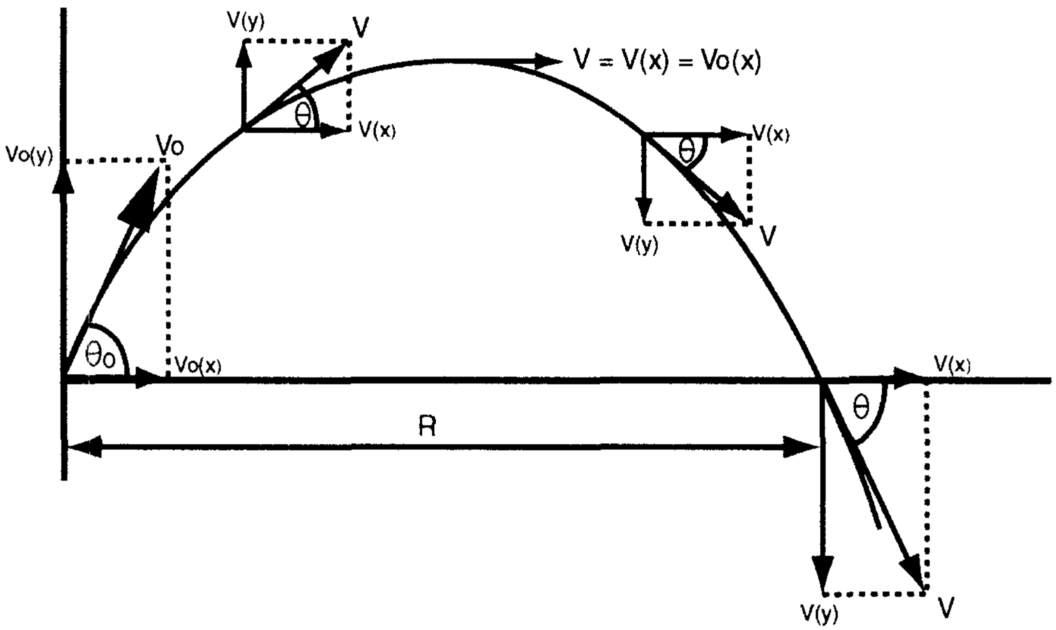


Figure 4 - Projectile Motion

b) Using $v = v_0 + at$, $r = v_0t + ½ at^2$, and $v^2 = v_0^2 + 2ar$ calculate iteratively the bollard height at the victim and fence until the required trajectory is found.

c) Calculate the kinetic energy for $½mv^2$ and determine the initial vessel velocity assuming no engine assistance

d) Calculate the force and elongation in the rope to store the kinetic energy

e) Calculate the proportion of full vessel thrust to exert this force on the rope assuming the vessel is stationary

5.2 Example Calculation

Trajectory Co-ordinates

Bollard at 0m,0 m
Victim at 5.4m, 1.7m
Far Fence at 9.6, 1.1m

Trajectory (wrt startng height)			**Stored Energy in Rope**	
Angle wrt Ground (°)	29.78		Break Elongation %	14.97%
Angle (radians)	0.520		Break Strength (kN)	65.04
Velocity (m/s)	11.7			
Vx	10.1		Rope Elongation (%)	4.14%
Vy Initial (m/s)	5.80		Rope Length (m)	2.6
Max Height (m)	1.72		Rope Load (kN)	17.98
Time to Max Height (s)	0.59		Energy in Rope (Joules)	968
Impact at Height (m)	1.70		**Velocity of Bollard**	
Time to Return Impact (s)	0.65		Weight of Bollard (kgs)	14.169
Distance travelled to Downward Impact (m)	6.60		Initial Velocity of Bollard (m/s)	11.7
			Initial Velocity of Bollard (km/hr)	42
Vy at Upward Impact (m/s)	0.58			
Time to Upward Impact (s)	0.53		**Velocity of Vessel**	
Distance travelled to Upward Impact (m)	5.40		Vessel Displacement (tonnes)	60.7
			Velocity (m/s)	0.179
Horizontal Distance (m)	2.6		Velocity (km/hr)	0.64
Time to Horizontal Distance (s)	0.256			
Height @ Horizontal Distance (m)	1.2		**ALTERNATIVELY**	
Horizontal Distance (m)	5.4		**Thrust of Vessel**	
Time to Horizontal Distance (s)	0.532		Max Extimated Thrust (kN)	109
Height @ Horizontal Distance (m)	1.7		% Vessel Thrust on Rope	16.5%
Horizontal Distance (m)	9.6			
Time to Horizontal Distance (s)	0.946			
Height @ Horizontal Distance (m)	1.1			
Target Data (wrt Gound)				
Starting Height (m)	0.00			
Height 1 Victim (m)	1.7	0		
Distance 1 (m)	5.4			
Height 2 Far Fence (m)	1.1	0		
Distance 2 (m)	9.6			

Table 2 - Example Calculation

Scenario 1

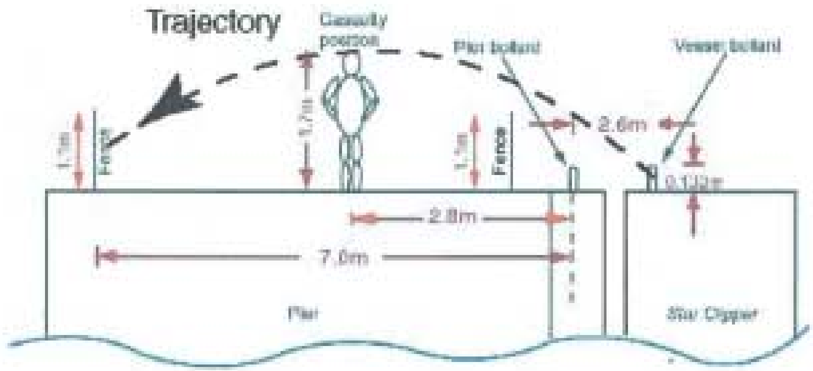


Figure 3 – Trajectory – Scenario 1

The scenario involving the least energy is if the bollard was launched in an arc as illustrated in [repeated] Figure 3 and is a cross-section view in the plane of the bollard flight.

Figure 5 shows a plan view of the incident, courtesy of MAIB, that shows the line of flight of the bollard, and from which the horizontal dimensions shown in figure 4 are derived.

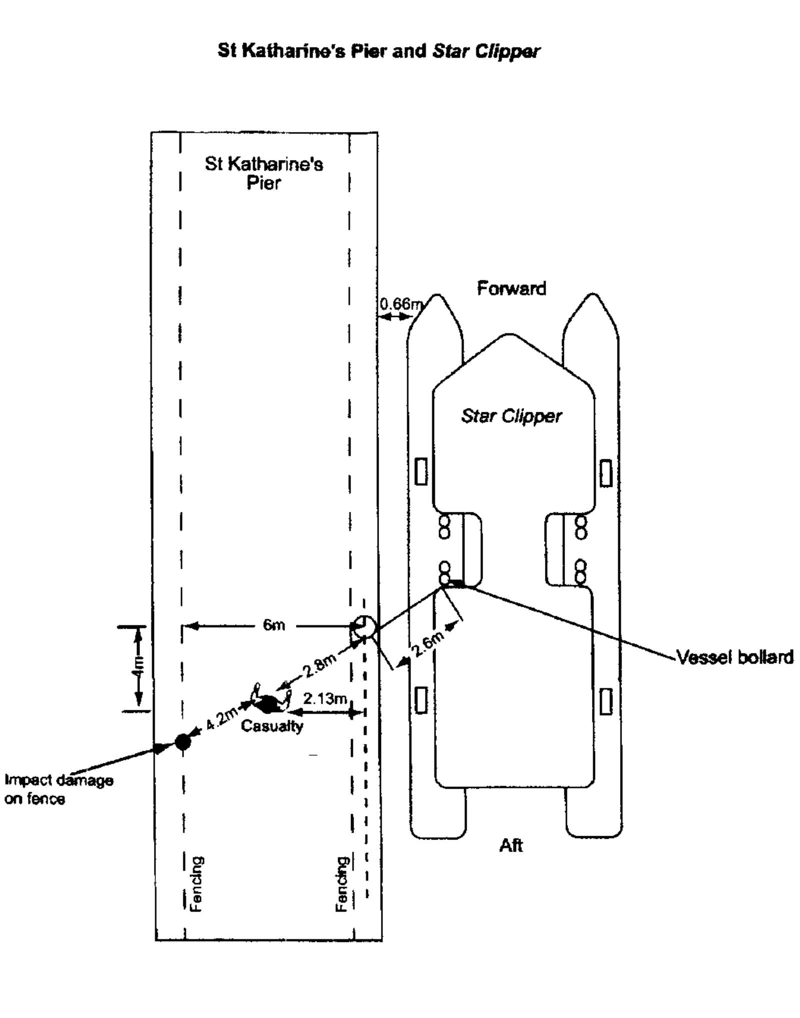


Figure 5 Plan view of accident scene

Figure 6 is the cross-section [end] view of the scene, again courtesy of MAIB, at right angles to the long direction of the pier.

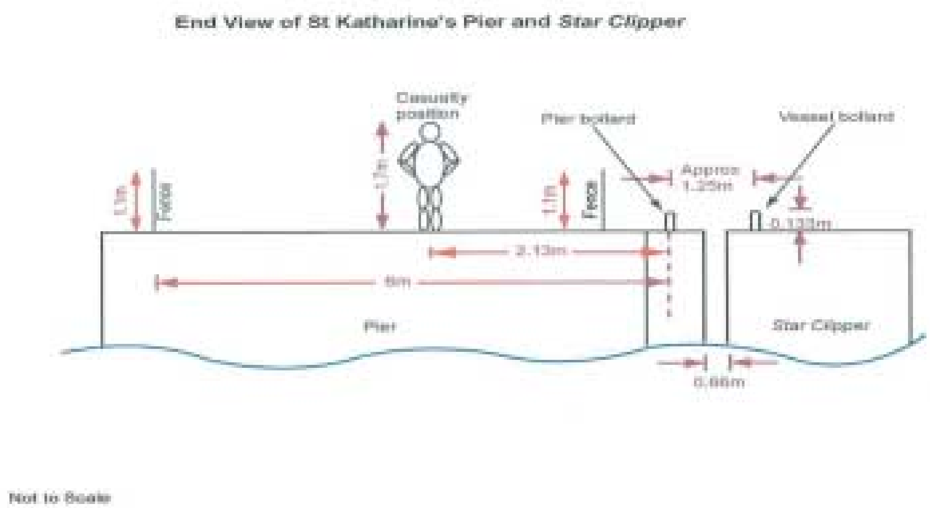


Figure 6 End view of accident scene

It is assumed that the bollard hit the far fence (furthest from the Star Clipper), that no energy was expended as a result of hitting the victim and that the bollard was not deflected. No account has been made for wind resistance which would slightly increase the required energy. This approach gives a lower limit on the amount of energy required to cause the accident in the way described by the witness statements and subsequent measurements of the site.

For each possible trajectory, there is a single value of velocity and angle required to launch the bollard. This converts to a single value of kinetic energy. A number of possible variations have been tried; changing the height of the starting point and changing the height at which the bollard hit the far fence. None of these make a significant difference to the overall result.

The results for this scenario are given in Table 2. Two vertical starting positions of the bollard were tried; at 0m and at 0.1m. Impact on the far fence was tried at 1.1m, 0.6m and 0m.

Examining these results it can be seen that there is relatively little sensitivity to these variables. The vessel speed is.0.65 km /hr or less to impart the required kinetic energy for the trajectory.

Variables	**Flight Starts at Ship's Bollard**					
Starting Height (m)	0.00	0.00	0.00	0.10	0.10	0.10
Height 1 Victim (m)	1.7	1.7	1.7	1.7	1.7	1.7
Height 2 Far Fence (m)	0	0.6	1.1	0	0.6	1.1
Rope Loading						
Rope Load (kN)	15.34	16.50	17.98	15.33	16.56	18.13
Rope Elongation (%)	3.53%	3.80%	4.14%	3.53%	3.81%	4.17%
Energy in Rope (Joules)	704	815	968	703	820	984
Bollard						
Initial Velocity of Bollard (m/s)	10.0	10.7	11.7	10.0	10.8	11.8
Initial Velocity of Bollard (km/hr)	35.9	38.6	42.1	35.9	38.7	42.4
Angle wrt Ground (°)	35.74	32.59	29.78	34.63	31.40	28.52
Velocity of Vessel						
Vessel Displacement (tonnes)	60.7	60.7	60.7	60.7	60.7	60.7
Velocity (m/s)	0.152	0.164	0.179	0.152	0.164	0.180
Velocity (km/hr)	0.55	0.59	0.64	0.55	0.59	0.65
or						
Thrust of Vessel						
Max Extimated Thrust (kN)	109	109	109	109	109	109
% Vessel Thrust on Rope	14.1%	15.1%	16.5%	14.1%	15.2%	16.6%

Table 2 – Results Scenario 1

5.3 Scenario 2

There are many alternatives that give very different input energies. For example if the bollard had hit the first fence on a diagonal strut and then bounced up, with the rope wrapping around the first fence the action would have been similar to the bowling of a cricket ball. This straighter trajectory would have caused the bollard to hit both the victim and the far fence with a significantly higher velocity. This is illustrated in Figure 7.

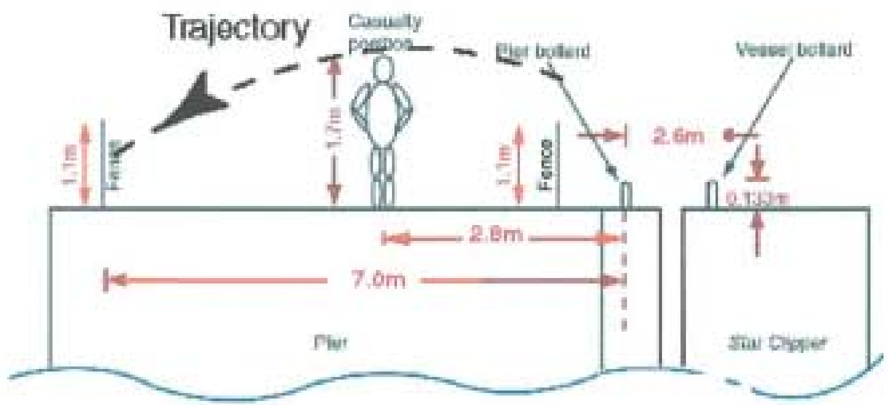


Figure 7 Trajectory Starting above Second Bollard

Variables	Flight Starts at Second Bollard					
Starting Height (m)	2.60	2.60	2.60	1.60	1.60	1.60
Height 1 Victim (m)	1.7	1.7	1.7	1.7	1.7	1.7
Height 2 Far Fence (m)	0	0.2	0.261	0	0.6	1.1
Rope Loading						
Rope Load (kN)	32.50	49.91	64.90	13.89	16.72	21.46
Rope Elongation (%)	7.48%	11.49%	14.94%	3.20%	3.85%	4.94%
Energy in Rope (Joules)	3,161	7,453	12,603	577	837	1,378
Bollard						
Initial Velocity of Bollard (m/s)	21.1	32.4	42.2	9.0	10.9	13.9
Initial Velocity of Bollard (km/hr)	76.0	116.8	151.8	32.5	39.1	50.2
Angle wrt Ground (°)	-16.07	-17.07	-17.38	11.96	8.80	6.12
Velocity of Vessel						
Vessel Displacement (tonnes)	60.7	60.7	60.7	60.7	60.7	60.7
Velocity (m/s)	0.323	0.496	0.644	0.138	0.166	0.213
Velocity (km/hr)	1.16	1.78	2.32	0.50	0.60	0.77
or						
Thrust of Vessel						
Max Extimated Thrust (kN)	109	109	109	109	109	109
% Vessel Thrust on Rope	29.8%	45.8%	59.5%	12.7%	15.3%	19.7%

Table 3 - Results Scenario 2

As can be seen above, by allowing the bollard to bounce off obstacles, there is a wide range of energies possible; that are consistent with the bollard hitting both the victim and the far fence. The rope was 2.6m long so 1.6m and 2.6m over the first fence were tested in this analysis.

If the vessel were under some power, the thrust of the engines would add to the load on the rope arising from kinetic energy of the vessel's motion. Under thrust, therefore the forward speed necessary to cause the rope to break would be less than if there were no thrust. Since the rope did not break, the absolute limit to the vessel's forward motion can be established by assuming that the vessel's engine was providing no thrust at the time of the accident. The limit to the energy is then that which would cause the mooring rope to break. Under no power this would be at a vessel speed of 2.32 km/hr. This gives the upper limit of vessel speed.

5.4 Scenario 3

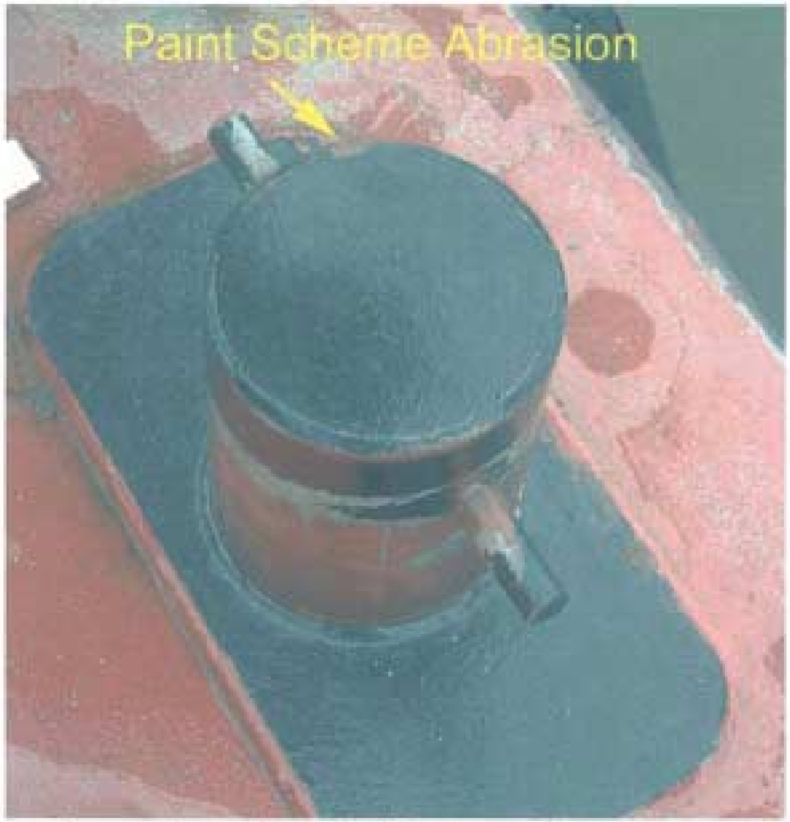
It seems reasonably likely that the ship's bollard struck the pier bollard and was bounced upwards.

The elongation under load of the rope was between 3.5% and 14.5% or 90 to 350 mm. When the bollard broke off, it would have flown back in a straight direction in line with the rope. It would not have been significantly deflected by hitting an obstacle within the rope's elongation or the first 90 to 350 mm (depending on load), or, more accurately, if it had been deflected, the rope's pull would have tended to restore the original direction of flight. This indicates that the bollard would have passed the lip on the vessel, essentially in a straight line. After the rope pulled back these few hundred mm's it would have gone slack. However the bollard would have continued in a straight line until it hit something. The first obvious obstacle is the bollard on the pier. It seems very likely the ship's bollard collided with the pier bollard and that it was deflected upwards from there. Further examination of the pier bollard is recommended.

The fact that the rope did not remain on the pier bollard indicates that it was either not thrown over the pier bollard's pins or that, since the eye was long and the rope was slack it was able clear the pins. It is also possible that the eye was over one pin and not over the second.

The orientation of the bollard pins were essentially in line with the likely initial flight of the ships bollard. This may have contributed to the rope's eye clearing the bollard pins.

An inspection of the photograph provided, does show loss of paint at the top edge of the bollard in a place that seems to be consistent with path of the rope



Photograph 9 – Pier Bollard [courtesy of MAIB]

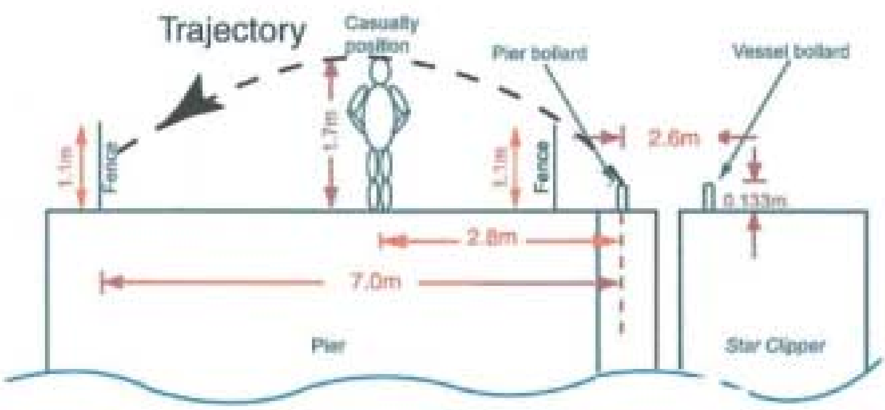


Figure 8 - Trajectory Starting at Second Bollard

Variables	Bollard Bounces off Pier Bollard		
Starting Height (m)	0.1	0.1	0.1
Height 1 Victim (m)	1.7	1.7	1.7
Height 2 Far Fence (m)	0	0.6	1.1
Rope Loading			
Rope Load (kN)	12.66	13.32	14.05
Rope Elongation (%)	2.91%	3.07%	3.23%
Energy in Rope (Joules)	480	531	591
Bollard			
Initial Velocity of Bollard (m/s)	8.2	8.7	9.1
Initial Velocity of Bollard (km/hr)	29.6	31.2	32.9
Angle wrt Ground (°)	43.89	42.14	40.60
Velocity of Vessel			
Vessel Displacement (tonnes)	60.7	60.7	60.7
Velocity (m/s)	0.126	0.132	0.140
Velocity (km/hr)	0.45	0.48	0.50
or			
Thrust of Vessel			
Max Extimated Thrust (kN)	109	109	109
% Thrust on Rope	11.6%	12.2%	12.9%

Table 4 Results Scenario 3

Although this scenario shows the lowest energy requirement, the starting point is the second bollard. Some energy would have been expended on hitting the bollard so this analysis gives an underestimate of the vessel kinetic energy. The lower limit of vessel energy is given by Scenario 1.

5.5 Limits

The foregoing demonstrates that, provided the vessel was not under power, the vessel speed could not have been less than 0.55 km / hr and not more than 2.32 km/hr. If the vessel were under power the limits move down. This corresponds to loads in the rope between 15 and 65 kN with corresponding energies of 700 to 12,600 Joules.

From discussions with Dr. David Ellin of the Cambridge test house, the tensile strength of the surrounding structure of the bollard was in the order of 20 tonnes. This is considerably more than the maximum strength of the rope (65 kN) and points to a progressive failure mechanism, where the bollard is levered off the deck. Under these circumstances it is feasible that the load on the bollard was quite low.

6 General Observations

After the accident, the rope was found detached but near the final position of the ship's bollard. An explanation as to the mechanism that allowed it to become detached is as follows. The rope will remain tight on the bollard so long as it is under tension. When the tension is released the pressure on the tuck is relieved and the rope becomes loose and able to slip off the bollard. Photograph 10 shows an example of a bollard and the rope attachment method used.

The mooring rope used is quite light in relation to the forces that could be imposed on it. Clearly the bollard should have been able to withstand the mooring force, but had it been stronger, the installed rope could have become overloaded and broken. The energy of lash back is extremely high and, even without the mass of the ship's bollard, breaking ropes alone can cause fatal injuries.

Photograph 10 – Rope Reeved to Bollard [courtesy of MAIB]

ANNEX E

Passenger Ship Construction Classes III to VI(A) – Instructions for the Guidance of Surveyors

PART XIII

ANNUAL SURVEYS

13.1 General

13.1.1 Surveyors should satisfy themselves at the annual surveys that the hulls and skin fittings of passenger ships are in good condition, the principal structural scantlings are maintained, the arrangements and details are in accordance with the MCA's requirements, and the ship is in all respects fit for the service intended.

13.1.2 Any proposals for altering the structure which may affect the main or local strength of the ship, should be submitted for consideration. In the case of a Classed ship, the surveyor should obtain a copy of the Classification Society's letter to the owner or ship-repairer approving the proposals for the alteration, and place it on the ship's file for record purposes together with a stamped approved copy of any associated drawing.

13.2 Examination of the Outside of the Hull etc.

13.2.1 The outside of the hull, rudder, and all outside fittings are to be thoroughly examined by the surveyor at each annual survey when the ship is presented in dry dock, or on blocks or on a grid.

13.2.2 The surveyor should make his inspection of the outside of the hull after it has been cleaned and before it has been painted, cemented or otherwise coated.

13.2.3 Sufficient clearance should be arranged under the hull to allow ease of access with adequate artificial lighting provided to the surveyors satisfaction.

13.2.4 Access to the upper parts of the outside of the hull and around the rudder should be by means of a safe arrangement of scaffolding and associated ladders securely fastened in way to meet statutory safety standards.

13.3 Inside the Hull

13.3.1 A surveyor has the authority to, and may at his discretion, require any part of the ships deck and side linings, deck coverings etc., to be removed, and any tank opened up and cleaned as he considers necessary, to enable him to ascertain the condition of the ships internal structure. However, unless the surveyor decides otherwise the frequency of inspection of the various items should be as follows:-

ANNEX F

Merchant Shipping Notice - M718

DEPARTMENT OF TRADE

MERCHANT SHIPPING NOTICE No. M.718

MOORING, TOWING, HAULING EQUIPMENT ON ALL SHIPS

Notice to Builders, Owners, Masters or Skippers, Officers and Men of Merchant Ships and Fishing Vessels

1. Operations such as mooring, towing and trawling impose very great loads upon ropes or warps, gear and equipment. The Code of Safe Working Practices for Merchant Seamen and the Code of Safety for Fishermen set out certain precautions which should be taken but the circumstances of recent accidents show that greater emphasis should be given to considering the system as a whole.

2. Because of the imposed loads, sudden failure in any part of the system may cause death or serious injury to personnel. Preferably winches or windlasses should be constructed to give warning of undue strains by stalling at well below half the designed maximum safe working load of the weakest element in the system and to afford further protection by walking-back at about half the design safe load. Where that is impracticable, the layout of the installations should be such as to avoid men being stationed or necessarily working in the bight of warp or rope formed by the lead from the winch or windlass round and through the fairleads and over-side. In any case, the consequences of failure in any part of the system must be carefully considered and effective precautions taken.

3. Particular attention is drawn to the need to ensure that pedestal roller fairleads, lead bollards, mooring bitts etc are *(a)* properly designed to meet all foreseeable operational loads and conditions, (b) correctly sited and (c) effectively secured to a part of the ship's structure which is suitably strengthened. Investigation of one accident showed that due to corrosion fatigue a roller pin fractured at a sharp change of section machined atthe lower end. The place of fracture was inaccessible to inspection and maintenance being just below the housing surface. In another instance, the welding between fairlead pedestal and deck failed. It is essential that such welding should be preceded by careful preparation of the plate edges and carried out by a fully competent welder. In a third case, a bollard which was pulled out had been secured to a deck pad by bolts of inadequate diameter and loose nuts.

4. All fixed and running gear including ropes should be *carefully maintained* and *regularly inspected* against wear, damage and corrosion. At all times when the gear is under load, men essential to the operation should be as far as possible in a protected position and others should keep clear of the area. Immediate action should be taken to reduce the load should signs of excessive strain appear in any part of the system.

Department of Trade
Marine Division
London
May, 1975

(MS 7/7/0177)

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Marine Information Note - MIN 176 (M+F) - Safety Alert Mooring Cleat Failures

Maritime and Coastguard Agency

MARINE INFORMATION NOTE

MIN 176 (M+F)

SAFETY ALERT

SAFETY ALERT

MOORING CLEAT FAILURES

Notice to: Owners, Managers, Skippers, Designers, Naval Architects, Builders, Repairers and Chandlers

Summary

Key Points –
- Owners of small boats should immediately inspect fittings and their supporting structure used in mooring.
- Mild steel fastenings through decks should be checked visually.
- The load on moorings should be minimised.

Introduction / Background

A number of recent incidents, including a fatality, have raised concern because of the failure of the attachment of mooring bollards or cleats to the deck.

Investigations indicate:

The under deck stiffening was inadequate.

Holding down bolts were corroded.

There was no planned maintenance regime in place; and,

Berthing operations were placing excessive force on moorings when coming alongside.

Key Learning Points:
Owners and operators should:
Inspect mooring fittings to ensure that they are:
Of adequate strength;
Adequately stiffened under the deck (stiffeners and backing plates);
Adequately secured under deck; and All in good condition (deck, supporting structure, and fittings);

Examine mild steel bolts subjected to a salty atmosphere annually, and if necessary replace every two years or replace with stainless steel bolts. Similarly, where the attachment is welded, a careful examination should be made.
When berthing a boat, as far as practical minimise the load on the moorings. For example, it is preferable to turn the boat to stem the stream before manoeuvring alongside and reduce speed to the minimum before stopping by use of the mooring ropes.
Always be aware of hazards involved in berthing, especially from ropes and wires coming under tension, and the need to keep a safe distance from them.
Pay attention to the type, size, quality and condition of mooring ropes.
Ensure that shore fixtures are suitable.

DESIGNERS,BUILDERS, SUPPLIERS & REPAIRERS should:

ensure that fittings, their connections and the supporting structure of vessels are designed and constructed to withstand the anticipated loading.

Risk Assessments:

Guidance on carrying out risk assessments is contained within Marine Guidance Note MGN 20 (M+F).

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Department for Transport

The MCA is an executive agency of the Department for Transport

MCA (south-east district) - instruction to check bollard and deck connections on Class V passenger vessels dated 10 May 2004

Maritime and Coastguard Agency
An executive agency of the Department for Transport

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All class V owners & operators

Your ref:

Our ref:

10 May 2004

MOORING ARRANGEMENTS

Last weekend there was a tragic accident on the River involving a mooring bollard.

The exact cause & mechanism of failure is yet to be determined however it is considered that the way the bollard was attached to the deck may be a contributory factor.

There was an apparent lack of stiffening/strengthening under deck in way of the bollard.

We will be checking attachment however in the interim can owners please carry out checks for this support structure. We require an answer – positive or negative - within 7 working days.

The opportunity should also be taken to examine the bollard/deck attachment be it bolted or welded.

Thank you for your co-operation

B D Hopkins
Surveyor-in-Charge
South East District

ANNEX I

PLA instruction to check - instruction to check bollard and deck connections on vessels carrying 12 passengers or less

13 May 2004

To All Owners of PLA Licensed
Passenger Vessels (Carrying 12 & Under)

Dear Sir / Madam

IMPORTANT

FAIRLEADS, CLEATS, MOORING & TOWING BOLLARDS

Following the recent "STAR CLIPPER" incident on Sunday 2nd May 2004, which you will be aware, resulted in the tragic loss of life of a member of the public; I am writing to you to stress the following:

- As a matter of urgency, you are advised to make an immediate check on all deck/mooring equipment. The condition of bollards, cleats and fairleads, and the way in which they are attached to the vessel, should be examined for any defects or corrosion.

- It is the owner's responsibility to ensure that the condition of and functionality of **all** deck equipment is maintained to a high standard. Be advised that such equipment will be given an increased level of priority in all future inspections. Any signs of splitting, deformation, loose or missing securing screws or rotting/corroding seating or bases may result in a licence being withheld until the defect is properly addressed.

- The recently published Inland Waters Small Passenger Boat Code stresses that: "The vessel should be fitted with bollards or cleats of adequate strength" *(Section 20.2)*. As advised in a previous correspondence, the PLA recommends that you obtain a copy of the Code in order to adhere to its requirements. The PLA's inspection criteria have been reviewed in respect of the Code, and will be amended accordingly in the near future.

- It is understood that independent MAIB and MCA investigations into the STAR CLIPPER incident are taking place. The PLA will take full account of any recommendation resulting from these investigations with regard to its licensing regime.

Finally, I do accept that by and large the standards are high concerning deck equipment. Nevertheless, masters of vessels should be instructed to carry out regular checks to identify any signs of deterioration in the equipment.

Yours Faithfully

PETER G H SMITH
MARINE SURVEYOR

cc Captain C Mendoza HM (U)
Captain G Dickins HM (L)
Captain J Parkes MASM

ANNEX J

Operating procedure - TCOP 021 and related risk assessment dated 3 May 2004

OPERATING PROCEDURE No.	TCOP 021	Date written	03/05/2004
Title	Mooring arrangements for embarkation and disembarkation of passengers – Sky, Storm & Star Clipper	Date issued	03/05/2004
No. pages this procedure	1	Issue No.	001

Introduction

This procedure is introduced to abide by the recommendations of the Maritime Coastguard Agency following the incident of 2nd May 2004 whilst embarking passengers at St Katherine's Pier.

It also reflects the outcome of the risk assessment following the above incident to minimise the potential failings which could occur.

Procedure TCOP 020

This procedure is written to formalise the process, when fetching at pier stops for the purposes of embarkation and disembarkation of passengers during the day to day routine operation of Thames Clipper passenger service.

- Prior to the approach to the pier head, the Mate will ensure his or her life jacket is on and adjusted correctly.
- On coming along side the mate will have already secured the mooring line to the main deck lower twin post bollard (The mooring line will be secured and checked for wear prior to commencing the days service). The Master of the vessel will bring the vessel along side the pier head close enough for the Mate to step onto the pier, and make secure the vessel to the pier's bollard.
- Only when the Mate and Master are satisfied the vessel is safely secured will the movement of passenger be allowed.

Contravention to the above procedure will be deemed gross misconduct and summary to instant dismissal.

Written by .... Scott Ellis (Safety Manager)

Approved by .... Sean Collins (Managing Director)

Risk Assessment :- To ensure necessary precautions have been taken to minimise any risk or injury to any persons involved in the operation of embarkation or disembarkation of both passengers and employees of Collins River Enterprises (T/A Thames Clippers). To minimise the following potential risks, the recorded actions are to be implemented during the operation.

The assessment applies to the operation of Storm Clipper, Sky Clipper and Star Clipper.

Potential Risks	Actions for avoidance
Potential of Mate falling in water when coming along side pontoon.	1. Mate not to step onto pontoon until vessel is stationary alongside pier 2. Mate to wear life jacket correctly fitted and adjusted.
Potential hazard of mooring line to break under load.	1. Mooring lines to be checked daily prior to commencement of service and stated day log sheet mooring lines have been checked. 2. Mooring lines to be checked for serviceability during day by Mate and Master. 3. Minimum amount of engine thrust to be used to enable vessel to sit 'snugly' alongside.
Risk of failure of mooring post / bollard on vessel.	1. ONLY to secure mooring line to strong point fixing on main deck. (Twin Post Bollard on main deck) 2. Minimum amount of engine thrust to be used to enable vessel to sit 'snugly' alongside.
Risk of mooring line coming loose on bollard	1. Mooring line to have spliced eye with minimum of 6 splices, and eye to be looped through twin post bollard.
Risk of passengers trying to embark or disembark too early	Passenger doors to be kept closed under the supervision of the steward or stewardess until both Master and Mate satisfied vessel is safely moored