Report on the investigation of

the injury to person on

Dart 8

while berthing at Europort Terminal, River Thames

on

21 March 2004

Marine Accident Investigation Branch
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Report No 12/2004
September 2004

Extract from

The Merchant Shipping

(Accident Reporting and Investigation)

Regulations 1999 – Regulation 4

The fundamental purpose of investigating an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 1999 is to determine its circumstances and the causes with the aim of improving the safety of life at sea and the avoidance of accidents in the future. It is not the purpose to apportion liability, nor, except so far as is necessary to achieve the fundamental purpose, to apportion blame.

NOTE

This report is not written with liability in mind and is not intended to be used in court for the purpose of litigation. It endeavours to identify and analyse the relevant safety issues pertaining to the specific accident, and to make recommendations aimed at preventing similar accidents in the future.

CONTENTS

GLOSSARY OF ABBREVIATIONS AND ACRONYMS

COSWP	-	Code of Safe Working Practices
DfT	-	Department for Transport
ETA	-	Estimated time of arrival
ICS	-	International Chamber of Shipping
IMO	-	International Maritime Organization
ISO	-	International Organisation of Standardisation
kN	-	kilonewton
MCA	-	Maritime and Coastguard Agency
MGN	-	Marine Guidance Note
OCIMF	-	Oil Companies International Marine Forum
PPE	-	Personal protective equipment
SMS	-	Safety management system
UHF	-	Ultra high frequency
UTC	-	Universal Co-ordinated Time

SYNOPSIS

All times are UTC.

At 1030, on 21 March 2004, *Dart 8*, a Bermudan registered roll on/roll off cargo vessel, was making fast at her usual berth on the River Thames when a mooring line parted, sprang back and seriously injured the vessel's bosun. The wind had been blowing off the berth at a speed of about 25 knots, with occasional stronger gusts. The vessel had been stemming a strong flood tide.

The master was holding the vessel alongside by using the thrust from the main engine and the two forward bow thrusters, while the crew on mooring stations fore and aft sent lines ashore. The forward mooring team consisted of the bosun, who was in charge, and four seamen. Strong wind initially hampered the crew's attempts to throw heaving lines on to the berth, however, they managed to get one head line fast ashore from each of the two forward winches. At the time of the accident, the bosun was bending on a heaving line in preparation for sending a third head line ashore.

A sudden strong gust of wind caught the vessel, and the bosun became aware that a lot of weight was coming onto the two head lines. He ordered the seamen on each winch to slacken their lines. The seaman on the port winch heard the order, probably because he was downwind of the bosun, and he slackened his rope. However, the seaman on the starboard winch did not hear the order, and the rope on his winch suddenly parted with such force that it recoiled and struck the bosun, fracturing his right leg.

During the MAIB investigation, the starboard winch was tested and no defects were found. The winch was designed to render when an adverse force of about 20 tonnes was applied. Detailed analysis of the rope has shown that the estimated residual minimum breaking load, prior to it parting, had reduced from 770kN to 94.2kN, less than half that required to render the winch. Visual inspection of the rope indicated severe deterioration, caused by abrasion, over a length of about 6 metres in the vicinity of where it passed around a roller fairlead.

The ad hoc inspections of mooring ropes which had been carried out, had not identified the abrasion, and the consequent dangerous condition of the rope that failed.

As a consequence of this accident, the managers of *Dart 8* have implemented a planned maintenance regime for the mooring ropes used on their vessels.

Recommendations regarding the safe working practices associated with the use of mooring ropes, have been made to *Dart 8*'s managers. The Maritime and Coastguard Agency (MCA) is recommended to consider current concerns about mooring rope control and safety, and to issue a Marine Guidance Note (MGN) on the subject to replace the current one, M.718, which was issued in 1975.

Figure 1

Dart 8

SECTION 1 - FACTUAL INFORMATION

1.1 PARTICULARS OF *DART 8* AND ACCIDENT

Vessel details (See Figure 1)

Registered owner	:	British Linen Shipping
Manager	:	Ropner Ship Management Ltd.
Builder	:	Kawasaki Heavy Industries, Sakaide
Ship type	:	Ro-ro cargo
Launched	:	1980
Flag	:	Bermuda
Port of registry	:	Hamilton
Gross tonnes	:	22,748
Classification	:	Bureau Veritas
Length overall	:	176.98m
Beam	:	26.55m
Draught	:	8.52m
Engine type	:	Diesel
Propulsion	:	Single screw
Maximum speed	:	18 knots
Deck complement	:	2 masters, chief officer, second officer, third officer, bosun and 10 seamen
Nationalities	:	British, Irish and Romanian
Common language	:	English

Accident details

Time and date	:	1030 on 21 March 2004
Location of incident	:	Europort terminal, River Thames
Injuries/fatalities	:	One injury

1.2 BACKGROUND

Dart 8 is a freight only ro-ro ferry, which makes continuous and regular scheduled crossings between the Europort terminal at Dartford on the River Thames and Zeebrugge. Each round trip takes 24 hours, and she has scheduled port layover periods of about 12 hours, 3 times a week.

Dart 8 was designed and built as a ro-ro freight and container vessel, and was converted in China in 1999 by her present owners and managers for the specific trade in which she is engaged. She has been sailing between Dartford and Zeebrugge, with the present crewing arrangement of mostly British masters and chief engineers and Romanian officers and crew, since that time.

1.3 NARRATIVE

(All times are UTC)

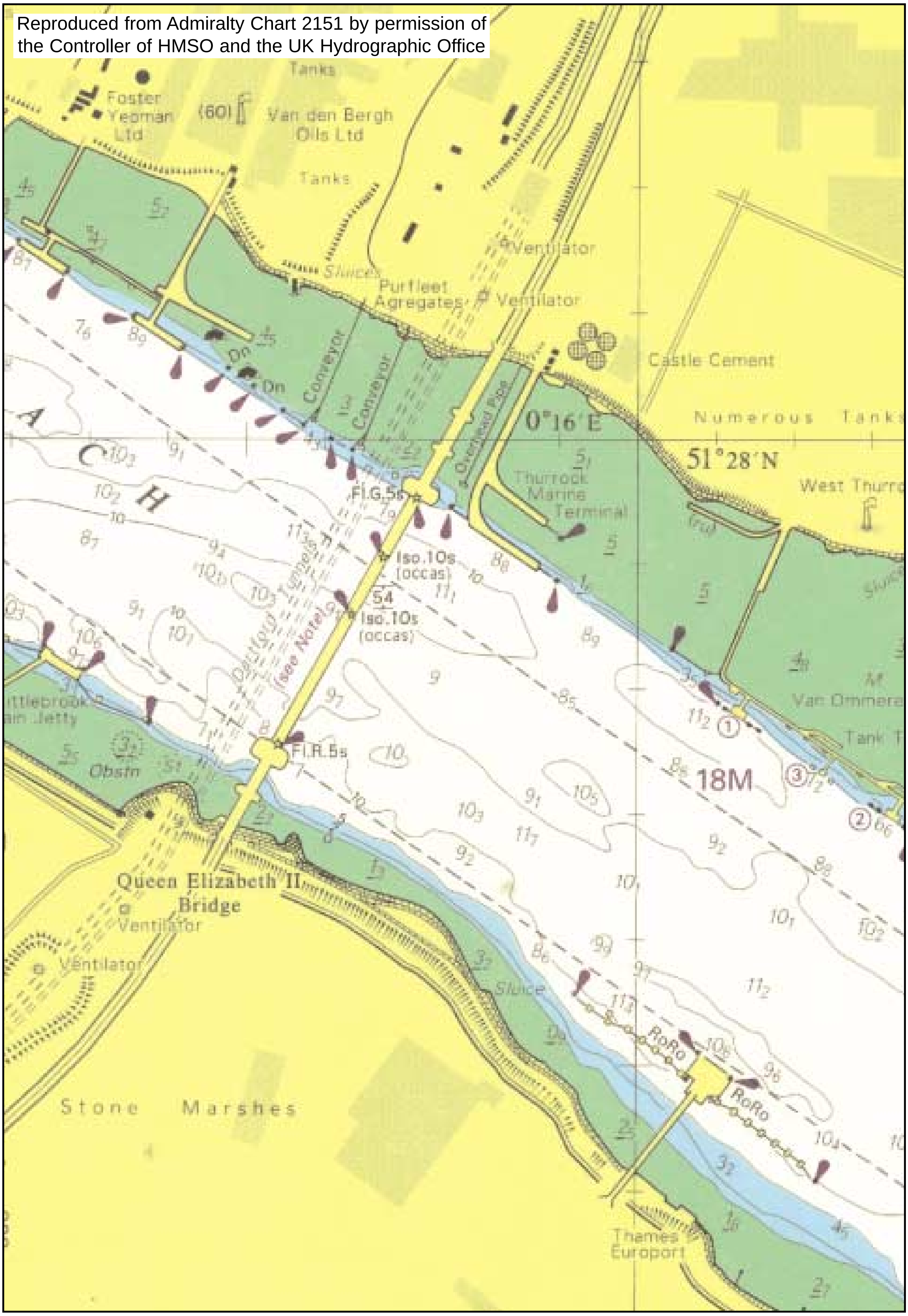
Dart 8 left her usual berth at Zeebrugge at 2300 on Saturday 20 March 2004, having been delayed from sailing at her scheduled departure time by 4½ hours, due to strong winds. She arrived off the berth at Dartford at 1000 the next day, 5 hours later than the scheduled time.

When she reached the River Thames, her master requested a weather report and was informed that the wind at the berth was south-west, 24 to 34 knots. At the ship's position at that time it was about 25 knots. The master requested a tug to assist him in berthing, however, none were available for at least an hour. The ship managers leave the decision whether or not to take a tug, to the master's discretion. The rule of thumb used by *Dart 8*'s master, was to take a tug if the wind was 30 to 35 knots, depending on the state of the tide. On this occasion, the master assessed the situation and decided that, as there was a favourable spring flood tide, it was safe to berth the vessel without tug assistance.

Dart 8's second officer proceeded aft with his mooring team, and the bosun, who had 5 years experience on the vessel, went forward with his team of four seamen. All the officers and crew were suitably attired with personal protective equipment (PPE).

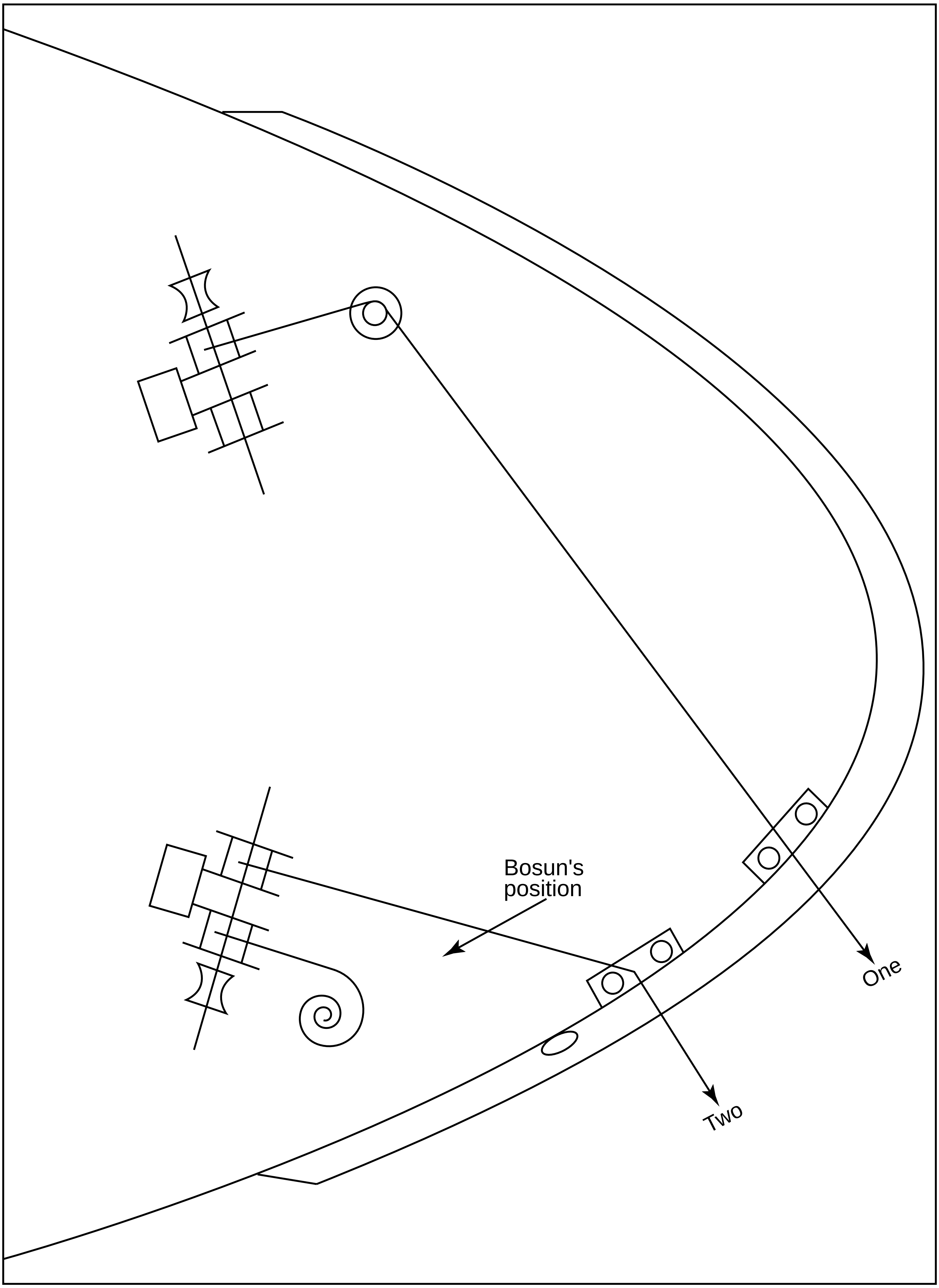
The bridge was manned by the master, who had the con, a helmsman, and the chief officer, who looked after communications to and from the mooring teams. Communications between the bridge and the mooring stations forward and aft were conducted in Romanian. The chief officer then translated and relayed the information to the master in English.

The master swung the vessel off the berth in preparation for berthing starboard side to heading into the strong flood tide **(Figure 2)**. The port anchor was let go and the vessel was manoeuvred alongside the berth using engines and thrusters. The windlass brake was left open until *Dart 8* was alongside. It was then tightened, and the port mooring winch was put into gear in preparation for sending the first lines ashore **(Figure 3)**.



Extract of chart showing Europort terminal, River Thames

Figure 3



On the day of the accident, the strong offshore wind hampered the crew's efforts to get a heaving line ashore, and it took four attempts before they finally succeeded. It was the usual practice to send ashore and secure the forward springs first so that the master could use them to help keep the stern alongside. However, on this occasion, the master instructed the forward mooring team to send any of the ropes ashore as quickly as possible. This was partly due to concern over the late arrival of the vessel, and partly because the shore gangs were positioned to receive the head lines first.

The forward team sent the first head line from the port outboard winch drum, and then another from the starboard inboard winch drum **(Figures 4 & 5)**.

When *Dart 8* was almost in position, the master asked the chief officer to go aft and prepare to deploy the stern door, while he held the vessel alongside using the main engine, rudder and two bow thrusters. Due to the high windage area provided by the aft superstructure, masters of ships using this berth prefer to deploy the stern ramp as quickly as possible, as this helps to hold the stern firmly alongside. By this time, the second officer had already made fast two breastlines aft.

At the forward mooring station, the bosun was standing just forward of the starboard winch immediately adjacent to the starboard inboard rope, as he was preparing the third, and final, head line for sending ashore. The two mooring rope winch drums, of the ropes already fast ashore, were both in-gear, because the vessel was not in position. The bosun became aware that a lot of weight was coming onto the two ropes, possibly due to an increase in wind. He shouted to the two winch operators to slacken the ropes on their winches. The seaman operating the port winch heard the order and immediately slackened his rope. The seaman operating the starboard winch did not hear the order, possibly because he was standing across the wind from the bosun. All the weight then came onto the rope on his winch.

Moments later, at about 1030, the rope on the starboard winch parted where it passed through the ship's side around an open roller fairlead **(Figure 6)**. The inboard end recoiled with such force that it struck the bosun's lower legs, inflicting a double fracture to his right leg and severe bruising to his left leg. As he fell, his head hit a set of mooring bitts, causing his nose to bleed. One of the seamen immediately called the chief officer using the bosun's UHF radio, and, speaking Romanian, informed him of the accident. Speaking in English, the chief officer then told the master on the bridge. The off-duty master, who was also on the bridge at the time, called for an ambulance to attend *Dart 8*. The duty master then appraised the local freight office of the situation, and continued berthing the vessel.

The ship's first-aid team and off-duty master went forward to assist the bosun. The off-duty master instructed the first-aid team to comfort him, and to ensure he remained warm and calm until the vessel was made fast and paramedics were on board.

Figure 4

Starboard winch drums

Figure 5

Starboard winch arrangement

Figure 6

Open roller fairlead

Dart 8 was secured alongside at about 1050, and an ambulance drove on to the vessel immediately the ramp was down. However, the freight on board prevented the ambulance from driving close to the forecastle, and the paramedics had to leave it on the lower deck and go by foot to attend to the patient.

By 1120, the patient's legs had been immobilised, first-aid had been administered, and he had been strapped into a stretcher. He was then transferred to hospital.

1.4 ENVIRONMENTAL FACTORS

At the time of the accident, the wind at the berth was 25 knots from the south-west, and the sky was overcast. The local forecast was for 24 to 34 knots winds from the south-west, which would veer to the west and then north-west later as a low pressure weather system passed over the UK. As the berth is aligned north-west/south-east, the wind was blowing directly off the berth.

There was a strong spring flood tide and high water was due at 1411 that afternoon.

1.5 CREW DETAILS

The on-duty master at the time of the accident had much experience of working on ferries, and had served on board *Dart 8* as master for the previous 3 years.

Apart from the two masters and the chief engineer, the remaining complement were Romanian.

The deck crew consisted of a bosun, who had served as bosun on board *Dart 8* for 5 years, and 10 seamen, the majority of whom had also served on the vessel since she began trading on the Dartford/Zeebrugge route 5 years previously.

According to the ship's safety management documentation, the common language spoken on board was English.

1.6 THE MOORING ROPE

The following is the original specification of the mooring line that parted:

Material	A melt blend of high tenacity polyester and polyolefin fibre
Diameter	64 mm
Type	8 strand plaited, Type L, Ref No. 64
Measured linear density	2.21Kg/m approximately
Minimum breaking force	770 kN [From Marlow data sheet Fybaline 8 Xtra, Issue 1, 10/03]
Strand construction	Outer yarns : 18 twisted yarns, from fibrillated tape. These are helically wound around the inner tapes. Inner yarns: 31 fibrillated tapes, loosely twisted around a single core.

The precise age and history of the rope could not be established.

1.7 MOORING ARRANGEMENTS

There was no specific guidance laid down by the ship's managers on the use of tugs during berthing, however, the master's rule of thumb, when berthing at the Europort terminal, was to use tug assistance when the wind was blowing 30/35 knots or more. An additional factor the master took into consideration, when deciding whether to use a tug during the berthing operation, was the state of the tide. At the time of the accident, there was a strong flood tide, which the vessel stemmed during the berthing operation. In the master's opinion, the strength of the prevailing wind, combined with the good manoeuvring control of the vessel afforded by the tidal conditions, meant that the use of a tug during the berthing of *Dart 8* on this occasion was not necessary.

The normal mooring arrangement for *Dart 8* on the Europort terminal berth was two springs fore and aft, three head lines and a varying number of stern lines. The normal procedure was to deploy the spring ropes first and, when these were secure, to bring the vessel alongside the berth using the main engine and bow thrusters, before deploying the head lines and stern lines. Deployment of the ship's stern ramp onto the jetty ramp also helped to hold the ship alongside the berth while the remaining ropes were made fast.

SECTION 2 – ANALYSIS

2.1 ACCIDENT SCENARIO

The bosun was injured when one of two mooring ropes being used to hold *Dart 8's* bow alongside the berth, broke. The tension in the breaking rope caused the line to whiplash, and strike the bosun's legs with sufficient force to break one and injure the other. The bosun had been standing immediately adjacent to the line while preparing a third mooring rope for deployment ashore.

The two parts of the rope were retained and were inspected on board by the MAIB. It was decided that further professional analysis would be required to ascertain why the rope had failed. The rope was taken ashore by the MAIB and forwarded to Tension Technology International for analysis.

The rope was said by witnesses to have parted where it passed through the roller lead. Subsequent measurement of the broken parts of the rope confirmed this to be the case.

2.2 THE MOORING WINCH

The mooring winch in use was of the hydraulic powered, double drum type. All winch systems are required to have a safety device that releases the tension in a controlled manner once it increases to a preset maximum force. These requirements are stated in ISO Standards 3730 and 7825.

The safety device on this winch consisted of two pressure relief valves designed to lift at 210 bar, equating to a force of about 196kN. Therefore, when the mooring winch is in-gear, and the tension on the rope increases, the winch should render or slacken the rope once the force reaches 196kN.

After the accident, the forward mooring winch and hydraulic pump were tested by a company of test engineers, with an MAIB inspector present, and found to function in normal operation correctly. The winch hauling capability was also tested and found to be 147kN with a 150 bar pump pressure.

It was not possible to test the winch render capability while the vessel was in operation. The two safety relief valves were removed at a later date and tested in a workshop. The valves were found to be in good condition and showing slight signs of wear, which suggested that they had operated in the past. During the workshop test, the two pressure relief valves were tested: the first was found to lift at 193.5 Bar and give full flow at 205.1 Bar, and the second one lifted at 215.9 Bar and gave full flow at 221.5 Bar. These figures are consistent with the information contained in the original drawings, and the MAIB believes, therefore, that the winch was operating correctly at the time of the accident.

It was normal practice to use the winch in its self-tensioning mode to maintain tension on the rope as the tidal height and draught/trim of the vessel varied during loading or discharge. In self-tensioning mode, the winch was designed to apply a force of about 150kN to the rope.

2.3 THE MOORING ROPE

The ship managers believed that the mooring rope was manufactured and supplied to the vessel in October 2003, with a certificated minimum breaking load of 770kN. However, the correct certificate for the rope could not be positively identified and, although its size, construction and designed breaking load has been determined, its actual age and history could not be established.

All mooring ropes were supplied to the ship with certificates from their manufacturers. Thereafter, the certificates were filed on board and the mooring lines were deployed and, in time, moved and end-for ended without the changes being documented.

The two sections of the broken mooring rope were sent to independent experts, Tension Technology International, for analysis. Their full report is included at **Annex 1**.

The report concludes that the estimated residual rope strength in the area of failure had reduced by 87.7%, from 770kN to 94.2kN. The report states that "*external abrasion damage was the dominant feature seen on all parts of this rope, being visually assessed to vary between mild remote from the failure, to extreme within the failure zone*", and concludes that "*if the rope was in this extreme abraded condition before the failure, then the rope appears not to have been routinely inspected in accordance with industry guidelines and recommendations. Inspection according to the guidelines would have resulted in the rope being rejected as unfit for service before the failure*" **(Figures 7 & 8)**.

The report also states that it is possible that bending of the rope over an acute edge under high tension might also have contributed to the failure of the rope. The MAIB looked further at this possibility. The rope was stowed on a winch drum and deployed as a head / breast line **(Figure 4)**. The angle the rope made, as it passed through the roller lead from its stowage position on the starboard winch, was not acute, being about 120°. It offered further protection against abrasion and wear because it was a roller lead as opposed to a fixed one. The roller lead was inspected and found to be well maintained and in good working condition. The ship's side opening in way of the roller lead was also closely inspected for signs that the rope had jumped from the roller lead and suffered damage from the steel edge of the opening; no evidence could be found to support this theory. Additionally, the vertical displacement between the winch, the roller lead, and the shore bollard, would not have allowed the rope to ride up and off the top of the lead.

Taking the above evidence into account, the MAIB believes that the rope was in poor condition prior to being deployed on the morning of 21 March.

Figure 7

Figure 8

Views of the parted mooring rope

Bearing in mind the normal operating force of 147kN applied by the self-tensioning winch, it is hard to understand why the rope had not broken before, if, as the analysis suggests, its breaking load had reduced to 94.2kN. No explanation for this anomaly is offered, but, for the purposes of the MAIB investigation, the precise extent of the deterioration in the rope's performance is not important. All the evidence suggests that the deterioration in the rope's performance was such that it broke before the winch rendered, and this was a major factor in the accident.

The MAIB has considered how the rope came to be in such a poor condition, and has concluded that, either:

1. The rope was older than the ship's managers believed. It had probably been in use from the starboard winch considerably longer than they had thought, and, accordingly, severe abrasion had occurred in the area where it passed through the ship's side around the roller fairlead; or

2. The rope was used at another mooring location where it was deployed through a fixed lead, possibly at an acute angle, and had been moved to the starboard winch some time prior to the accident **(Figure 9)**.

Figure 9

Panama lead in use for a spring

2.4 INSPECTION, CARE AND MAINTENANCE OF MOORING ROPES

One of the masters on *Dart 8*, along with the chief officer, inspected the mooring ropes approximately every 3 weeks. However, this routine was not part of the ship's planned maintenance procedures, and the results of the inspections were not documented. It was also usual practice for the bosun to report any defects he discovered with the mooring equipment.

The ad hoc and informal mooring rope inspections carried out on board the vessel did not uncover the poor condition of the rope that failed.

M Notice M.718 does not give sufficient information about the inspection of mooring ropes, and safety factors that need to be taken into consideration when working with ropes.

The ISM Code clearly states that a company SMS should include procedures to identify equipment which may cause a hazardous situation in the event of a sudden operational failure. It also states that the SMS should provide for specific measures aimed at promoting the reliability of such equipment. A vessel's mooring ropes are arguably just such equipment, and the MAIB believes they should be subjected to a regime of regular and frequent inspection and maintenance. This could be achieved by including the mooring ropes in the vessel's planned maintenance system.

Periodic inspections of mooring ropes need to be carried out in a structured and thorough manner if they are to be effective in identifying serious problems. To this end, the planned maintenance procedure should contain reference to detailed instructions and guidance on the correct methods of inspection. Suitable instructions and guidance are detailed in the OCIMF publication entitled *Mooring Equipment Guidelines*. A relevant extract from this publication is included at **Annex 2**.

In order to be able to identify possible problems arising with mooring lines, it is important that the history of the rope is known. A good documentary record should be an important feature of any improved inspection and maintenance routine.

2.5 THE ACTIONS OF THE BOSUN

The ship managers' anchoring and mooring operations document states: "*if ropes/wires are under strain personnel should remain in a position of safety as far as possible*", and the document makes reference to the MCA's *Code of Safe Working Practices for Merchant Seamen*.

Chapter 25 of the COSWP clearly states what action members of a ship's crew shall take during mooring operations, and states "*when moorings are under strain all personnel in the vicinity should remain in positions of safety, in particular avoiding all 'snap-back' zones*".

The bosun was wearing the required personal protective equipment (PPE) including hard hat, working shoes and gloves. However, when the accident occurred, he had been standing close to, and in the snap-back zone of a rope which he knew was made fast ashore, and which he had ordered to be put under tension. Furthermore, just prior to the incident he had become concerned about the amount of tension on the two ropes that were deployed, and had ordered them to be slackened.

The MAIB inspected the area and determined that it was unnecessary for the bosun to have been preparing the third rope while standing in one of the deployed rope's snap-back danger zones. The bosun was experienced, and had completed numerous mooring operations on the vessel. It is surprising, therefore, that it was his normal practice to prepare the third head line in a snap-back danger zone, despite the fact that the forecastle on *Dart 8* is large enough for him not to do so. The MAIB believes that the supervisor lost the perspective essential for effective safety oversight when he became personally involved in the handling of the ropes. As a result, he might not have realised that the position in which he was standing was a potentially dangerous one. The very good advice contained in the relevant section of OCIMF's *Mooring Equipment Guidelines,* and particularly the diagram shown in Figure 6.6 of that publication, should be drawn to the attention of even the most experienced seamen **(Annex 2)**.

2.6 INTERNAL COMMUNICATIONS IN MULTINATIONAL CREWED VESSELS

The general practice on board *Dart 8* was for communications during mooring operations to be carried out in Romanian, and for the chief officer to translate the gist of any message into English, for the benefit of the master on the bridge. The Romanian officers and crew were selected, in part, for their ability to speak English. Neither of the masters, nor the chief engineer, spoke Romanian.

After the accident, one of the seamen took charge of the bosun's UHF radio and, speaking in Romanian, called the chief officer to inform him of the situation. At that time, the chief officer had left the bridge and was on his way down aft to prepare to lower the stern ramp. Although the master would have heard the message, he would not have understood it until the chief officer subsequently translated it for him. This would have led to a delay in the master appreciating the gravity of the situation. Fortunately, on this occasion, there were no adverse consequences.

The MAIB believes that the vessel's common language should be used for radio communications during operations, so that all listeners can understand the messages being sent. If the common language is used for routine occasions, it is more likely to be used during an emergency, when its use could be a significant safety factor.

2.7 FATIGUE

The bosun had worked 8 hours in the previous 24 hours, and 10 hours in the 24 hours prior to that.

The master worked a routine of 12 hours on 12 hours off with the other onboard master, and had taken over responsibility for the vessel at midnight, ship's time.

The vessel had 3 lay-overs each week when the vessel stayed alongside and missed out one crossing.

The MAIB has concluded that neither the master, nor the bosun or crew, were fatigued at the time of the accident.

SECTION 3 - CONCLUSIONS

3.1 SAFETY ISSUES

- The vessel's managers believed the broken rope was only 6 months old at the time of the accident. However, the certificate for the rope could not be positively identified and, therefore, its age and history are unknown. [2.3]

- Independent analysis concluded that the rope's residual strength, in the area where it parted, had reduced by 87.7% from 770kN to 94.2kN. [2.3]

- The rope was in poor condition prior to being deployed on the morning of the accident due to severe abrasion. [2.3]

- The rope was either older than thought by the vessel's managers or it had been used in another position on board where it had been deployed through a fixed fairlead. [2.3]

- The mooring ropes on *Dart 8* were inspected periodically but this was on an ad hoc basis and the inspections were not documented. [2.4}

- The on board inspections of the mooring ropes did not identify the poor condition of the rope. The MAIB believes that mooring ropes should be inspected frequently as part of the formal planned maintenance system. [2.4]

- Current guidance given in M Notice M.718 does not give detailed advice on the inspection of mooring ropes or personal protection when handling ropes. [2.4]

- Officers are likely to need guidance on how to inspect ropes effectively, and suitable guidance is contained in the OCIMF publication *Mooring Equipment Guidelines*. [2.4]

- The bosun was standing in an unsafe position at the time of the accident. He may have been unaware that his position was dangerous and, therefore, the attention of even experienced seamen should be drawn to the relevant passages in the OCIMF publication *Mooring Equipment Guidelines*. [2.5]

- By involving himself in the handling of the ropes, the bosun lost the perspective essential for effective safety oversight. [2.5]

- Internal communications during operations were routinely carried out in Romanian despite the master's inability to speak that language. Communications should be carried out in the common language on board which, in the case of *Dart 8*, was English. [2.6]

- The vessel's chief officer, who had been relaying orders to and from the mooring teams, left the bridge before the vessel was made fast to lower the stern ramp.[2.6]

SECTION 4 - ACTION TAKEN

MAIB

The MAIB sent a letter to the ship managers shortly after receipt of the rope analysis report. The letter proposed that the ship managers implement a system of mooring rope identification and control, and, as a matter of urgency, identify, replace or repair any mooring ropes on their vessels which are found to have severe localised abrasion.

Ropner Ship Management

The vessel's management company produced a report on the accident, and the recommendations arising from it included:

1. Improving the advanced warning of weather conditions at the berth.

2. Individually tagging mooring ropes upon delivery, to ensure continuity of rope certification.

3. A log of rope deployment and maintenance to be maintained.

4. Regular inspections of mooring ropes and winches to be entered into the vessel's planned maintenance system.

5. The risk assessment for mooring operations to be reviewed in light of the accident.

SECTION 5 - RECOMMENDATIONS

The Maritime and Coastguard Agency is recommended to:

2004/224 Review the contents of the current M Notice, M.718 (issued in May 1975), which deals with mooring, towing and hauling equipment, with a view to issuing new guidance on this subject, bearing in mind current concerns arising from this and other recent accidents. The new guidance note should cover, among other things, guidance on the need for regular and effective inspection of mooring ropes and how to carry out inspections. To this end, it is recommended that similar guidance to that published in OCIMF's publication entitled *Mooring Equipment Guidelines,* Section 6.3.5 and Appendix C should be referred to. The guidance should also include the need for effective supervision, rope handling information and personal safety advice to all those involved in mooring operations.

Ropner Ship Management Ltd is recommended to:

2004/225 Review current operational procedures with respect to the chief officer leaving the master without support on the bridge during mooring operations before the vessel is made fast.

2004/226 Ensure that routine and emergency operational radio communications are conducted in the vessel's common language.

2004/227 Review and ensure that all officers and crew are fully familiar with the company's anchoring and mooring operation instructions and risk assessment regarding their personal safety. In particular, the instructions should highlight the dangers of working in snap-back danger zones as described in MCA's publication entitled *Code of Safe Working Practices for Merchant Seamen*, and which is described in OCIMF's publication *Mooring Equipment Guidelines*.

Marine Accident Investigation Branch
September 2004

ANNEX 1

Report into the examination, sampling and testing by realisation method to determine rope residual strength and likely cause of failure of an 8-strand polypropylene rope

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REPORT

EXAMINATION,SAMPLING AND TESTING BY REALISATION METHOD TO DETERMINE ROPE RESIDUAL STRENGTH AND LIKELY CAUSE OF FAILURE OF AN 8-STRAND POLYPROPYLENE ROPE

FOR

MARINE ACCIDENT INVESTIGATION BRANCH

Report No. TTI-JN-2004-266-R

Date	Rev.	Description	Prepared by	Authorised by
26/05 04	02	Final -- issued to MAIB	JN	SJB

Distribution:

Client: MAIB Attention: Graham Inseal

Internal: TTI Ltd Attention: Steve Banfield

CONTENTS

TERMS AND ABBREVIATIONS

TTI	Tension Technology International
MAIB	Marine Accident Investigation Branch
Rope	Rope is made up of 4 pairs of **strands,** plaited together
Strand	Strand is made up of a number of **rope yarns** twisted around a loosely twisted assembly of inner tapes and one core yarn
Polyester/polypropylene melt blend	Extrusion-blended material used to produce the rope yarns and tapes
Tensile Test	Method of determining the response of materials to a load or tensile [pulling] force
Breaking load	Maximum force recorded during a tensile test.
Breaking strain	The extension of the material under test, at breaking load, expressed as a % of the original length of the sample.
Abrasion	In ropes, can be either external abrasion to the surface of the rope, or internal abrasion caused by relative movement of the rope elements
Dry Minimum Rope Strength	Depending on the fibre used in rope construction, some ropes may have a reduced tensile performance when wet. All assessment of rope performance is done on the basis of the rope being dry.
Realisation	Method by which an estimate of rope strength can be made, from knowledge of the strength of its individual components
Residual Strength	Ratio of the estimated breaking strength [by realisation] of the rope to its minimum specified breaking strength. Expressed as a %
KiloNewton kN	Unit of force, 10 kN is approximately 1 Tonnef
Tension-tension load cycling	Typical condition experienced by ropes used in mooring and towing applications, where the load on the rope varies in a cyclical manner between high and low values. This is a source of fatigue in a rope, and can lead to a loss of strength.

EXECUTIVE SUMMARY

The rope is confirmed by MAIB to be a Marlow 8 strand [4x2] plaited Fybaline rope of 64 mm diameter. From the Marlow data sheet 'Fybaline 8 Xtra, Issue 1, 10/03, the minimum dry breaking breaking strength is 78.5 tonnef, 770 kN.

Two segments from the rope, one containing an eye and the other cut from the remainder of the rope [for the purposes of this report, referred to as 'non-eye'], were provided for examination. Each contained its respective half of the fail zone.

External abrasion damage was the dominant feature seen on all parts of this rope, being visually assessed to vary between mild , remote from the failure, to extreme, within the failure zone.

Mild internal strand-on-strand abrasion, and the general cleanliness of the rope elements away from the abrasion points suggest the rope is relatively new.

The rope was found to have failed at a zone of extreme abrasion damage, where it was estimated to have a residual strength of 12.3% of its specified Minimum Dry Breaking Strength.

The table below shows the estimated strength and % residual strength of the rope from two positions, remote from and within the fail zone.

Summary of estimated dry rope strength and % residual strength

Minimum Dry Rope Breaking Load Marlow Data Sheet, Issue 1, 10/03 Fybaline 8 Xtra **78.5 Tonnef , 770 kN**	**Br Load** **Tonnef**	**Residual Strength** **%**
Remote from fail zone	**49.3** [484 kN]	**62.8**
Within the fail zone	**9.6** [94 kN]	**12.3**

Inspection of both segments of the rope within the fail zone revealed that for the **non-eye segment**, it had suffered extreme abrasion damage to approximately half of its circumference, the remaining damage being classed as severe. For the **eye segment,** extreme damage was distributed around the whole circumference up to a distance of about 2 metres back from the fail point.

Close examination of the rope halves at the fail point suggest that bending over an acute edge under high tension may have been involved in the failure.

However, TTI are not aware of the circumstances of this accident, and are therefore not able to link these observations to the incident itself. For example, it is not known if the extreme external abrasion was caused during the deployment when the failure occurred, or was caused by previous usage.

Testing a portion of the eye segment rope away from the failure zone, to estimate the general condition of the rope, revealed that the rope retained 62.8% of its Minimum Dry Breaking Strength. The sample was taken from an area visually assessed to have suffered mild abrasion. The rope had progressively worse abrasion damage as the fail zone was approached., and it would be expected that the performance would also deteriorate.

The eye was found also to have severe external abrasion damage, due to the protective sleeve having been displaced in use, exposing the eye of the rope to abrasion caused by mooring fixtures. The damage is such that it had the potential to be a source of failure in its own right. No tensile measurements were been made on the rope elements in this area.

During tensile testing of damaged rope elements, all failures occurred at sites of external damage.

If the rope was in this extreme abraded condition before the failure, then the rope appears not to have been routinely inspected in accordance with industry guidelines and recommendations [references 1-5]. Inspection according to the guidelines would have resulted in the rope being rejected as unfit for service before the failure.

Recommendations

An inspection of the vessel and deck equipment should be conducted to ascertain whether such severe abrasion damage could have been caused during the deployment when the failure occurred**.**

Examination of the fibres in the strand ends would determine if the rope had been passed around an acute edge, that would have exacerbated the strength loss.

1. INTRODUCTION

1.1 Preamble

This report is submitted to the Marine Accident Investigation Branch in response to their request to conduct a technical investigation into the failure of an 8-strand plaited rope, confirmed as a Marlow Fybaline construction, 64 mm diameter

2. DETAILED REPORT

2.1 Visual examination of rope.

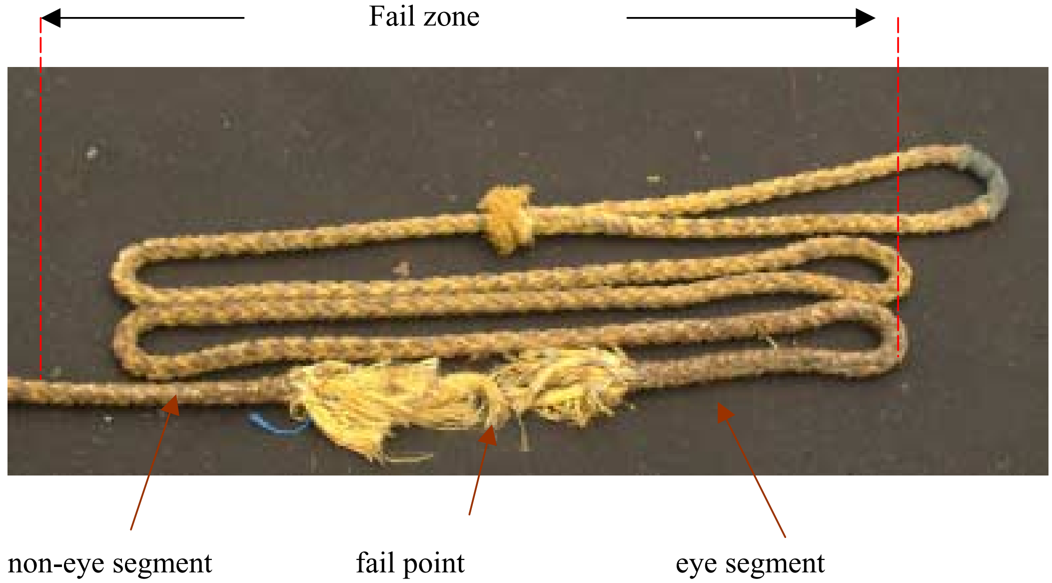
Visual examination of the rope was in accordance with OCIMF, ACI and CMI guidelines.-

The rope construction, is as follows:

Type		8 strand plaited, Type L, Ref No. 64
Measured linear density		2.21 Kg /m approximately
Minimum Breaking Force	**kN**	770 [From Marlow data sheet Fybaline 8 Xtra, Issue 1, 10/03]
Strand construction		
	Outer yarns	18 twisted yarns, from fibrillated tape. These are helically wound around the inner tapes
	Inner yarns	31 fibrillated tapes, loosely twisted around a single core yarn.

Photograph 1 is a general view of the rope as received by TTI. It consisted of two parts, a long segment that terminated in an eye [referred to as 'eye segment'], and a shorter segment that had been cut from the remainder of the rope ['non-eye segment']. Each segment contained its respective half of the fail zone.

Photograph 1 General view of rope

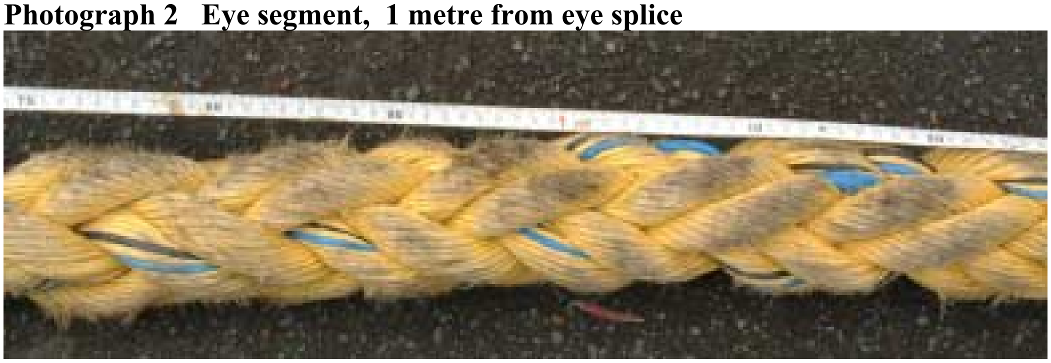


External abrasion is clearly seen over both segments. It was found to vary both in degree and also the amount of the rope circumference affected. It was difficult to show this by photograph, and the qualitative terms 'mild, modest, severe and extreme' will be used to describe the degree of damage found.

With regard to the eye segment, photographs 2-6 show the rope condition of the eye segment along its length, from close to the eye up to the fail zone. Photographs 7 and 8 show the extreme abrasion damage, over 100% of the circumference of the eye segment at the fail point.

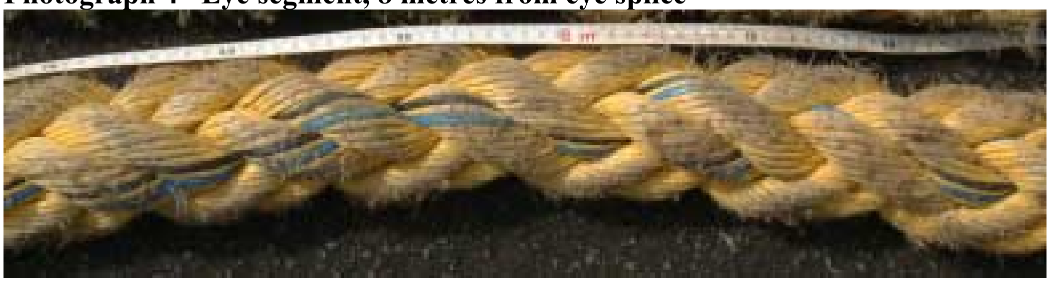
Remote from the fail zone, this abrasion is at a relatively low level , mild, but gets progressively worse as the fail zone is approached. At about 3 metres from the fail zone, the rope has suffered extreme external abrasion, this damage extending to approximately 50% of its circumference. Severe abrasion is present over the remainder of the circumference. Extreme damage to 100% of the rope circumference occurred within the fail zone up to the fail point.

Photograph 2 Eye segment, 1 metre from eye splice



Photograph 3 Eye segment, 3 metres from eye splice

Photograph 4 Eye segment, 8 metres from eye splice



Photograph 5 Eye segment, 12 metres from eye splice

Photograph 6 Eye segment 13 metres from eye splice [adjacent to failure]

Photograph 7
View of upper face of rope close to fail zone, eye segment, showing extreme abrasion

Photograph 8
View of lower face of rope close to fail zone, eye segment, showing extreme abrasion

Although not part of this investigation, it can be seen that the protective sleeve has rucked back to expose the rope to severe abrasion at the positions, highlighted by the double arrows, Photograph 9. This damage extended to about 75% of the circumference, and about 15 cm in length. If left to decline further, there would have been an increased chance of failure at the eye.

Photograph 9 Eye showing positions of excessive abrasion

With regard to the non-eye segment, extreme damage was found on about 50% of the circumference, the remainder being severe, close to the fail point. From about 1.5 metres away from the fail point, the damage was severe over 100% of the circumference, ie the extreme damage was no longer present.

Photographs 10 and 11 show the difference in the degree of damage at the fail point of the non-eye segment

Photograph 10
View of upper face of rope close to fail zone, non-eye segment, showing severe abrasion

The upper face had suffered severe abrasion damage.

Photograph 11
View of lower face of rope close to fail zone, non-eye segment, showing extreme abrasion

Where there has been this extreme abrasion, in both segments, there are areas within these abrasion zones where large amounts of rope material have disappeared.

Photograph 12 shows a general view of the fail zone, both halves, with the loose strands arranged to present a clearer view.

The left hand part is the eye segment, and the right hand part is the non-eye segment. It can be seen, particularly with the non-eye segment, that the yarn elements of several of the strands have all failed in a very localised area. In the case of a simple tensile failure, a more random distribution of failed ends would be expected. For the eye segment, there is a much reduced occurrence of rope elements failing in a very localised area.

Photograph 12 General view of fail zone

eye segment failed ends in close proximity to one another

Two lengths of rope were selected for further visual analysis and tensile testing. Both were from the eye segment, one remote from, and the other within, the fail zone

Photograph 13 shows the opened-up ‘remote’ sample from the eye segment, and Photograph 14 shows the opened-up ‘within’ sample.

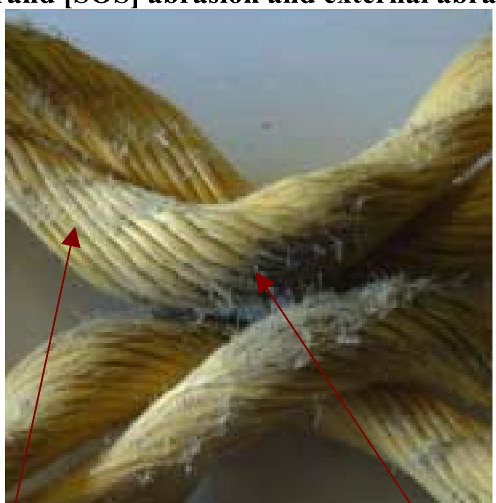
Photograph 13 General view of rope elements, ‘remote’ sample

Photograph 14 General view of rope elements, ‘within’ sample

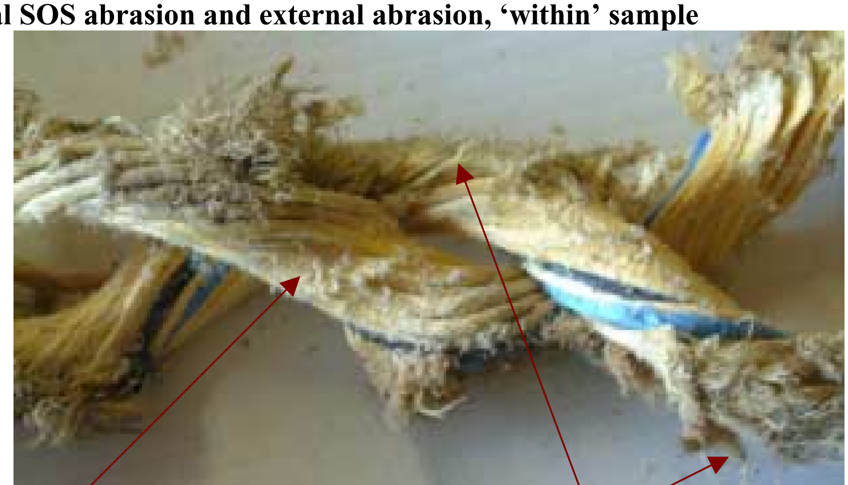
It can be seen that a substantial quantity of completely severed rope elements were released by the opening up process on the 'within' sample. Also, the degree of damage to the strands was significantly greater when compared to the 'remote' sample.

Internal abrasion, caused by touching strands moving relative to one another was also seen. Photograph 15 shows this type of abrasion damage, along with the external abrasion, as found on the 'remote' sample, and Photograph 16 shows the same abrasion mechanism as found on the 'within' sample.

Photograph 15
Internal strand-on strand [SOS] abrasion and external abrasion, remote sample



Photograph 16
Internal SOS abrasion and external abrasion, 'within' sample



It can be seen that both SOS and external abrasion are significantly worse on the adjacent sample. However, the dominant mechanism of damage to the rope is quite clearly external abrasion.

Photograph 17 shows what remains of the inner elements of a strand when opened up. The strand selected was considered to be in slightly better condition than the remaining 7. All of the outer rope yarns were completely severed at some position along the length of the sample., and are not shown.

Only 3 of the 31 inner tapes, and the single core yarn, could be considered as having any integrity as load bearing elements. The remainder were either completely severed or had sufficient damage as to render their tensile performance exceedingly low.

Photograph 17 Inner tapes from a strand within the fail zone

To summarise the observations:

- TTI is not aware of the detail of the failure, and can only comment on the observations and measurements made on the rope at TTI premises.

- At the fail zone, both the rope segments showed the effects of extreme external abrasion. For the eye segment, this extreme abrasion was found to extend around the entire circumference, and back from the zone for about 2 metres. Beyond this, the extreme damage was found to be present on about 50% of the circumference for a further 1.5 metres.

- The non-eye segment within the fail zone also displayed extreme abrasion, but this was restricted to approximately half of the rope circumference, extending about 1.5 metres away from the fail point.

- Thus there is a distinct difference in the damage to the rope on either side of the fail point, suggesting that different conditions existed on either side of the fail point at the time of the failure incident.

- On opening up a rope sample taken from within the fail zone of the eye segment, many of the yarns and tapes of the inner assembly were found to be either completely severed or badly damaged

- External abrasion of of a less extreme nature was seen on the remainder of the rope. It was judged that, for the eye segment, damage was relatively mild close to the eye splice, but showed increasing severity as the fail zone was approached.

- Strand-on-strand abrasion was found to be mild, suggesting that the rope had not experienced excessive or long-term tension-tension load cycling.

- The non-eye segment had 4 strands where the failure position of the rope yarns and tapes were all in close proximity to each other, both within a strand and between the strands. This normally would suggest that bending around an acute edge was involved in the failure. Inspection of the failed ends of the rope yarns and tapes did reveal abrasion damage in a significant number of them. If it is required, further investigation using Scanning Electron Microscopy can be used to determine this point with greater certainty.

- As a separate issue, the rope material in the eye was seen to have suffered serious abrasion, this being due to the lack of protection from the sleeve material. In use,the sleeve had moved to reveal the parts of the rope eye it was designed to protect from contact with attachment points, such as bollards

2.2 Tensile results and dry rope residual strength by realisation

2.2.1 Tables of results

Table 1 shows the results of the tensile tests on the rope sample taken about 2 metres from the eye splice, ie remote from the fail zone, and Table 2 shows the results from a rope sample taken from within the fail zone of the eye segment. This is the zone that had severe abrasion damage around the entire circumference.

Table 1 Tensile results, remote from fail zone

	Outer rope yarn		Inner tape	
	Br Load N	Br Ext %	Br Load N	Br Ext %
1	2061.0	6.9	909.0	4.9
2	2196.0	7.3	1071.0	6.3
3	2429.0	8.2	1122.0	6.4
4	2018.0	7.0	1014.0	6.0
5	2409.0	8.0	1130.0	6.5
6	2128.0	7.1	1156.0	6.6
7	2545.0	8.8	1048.0	6.3
8	2112.0	7.4	958.0	6.2
9	1953.0	6.4	1026.0	5.6
10	2131.0	7.6	1034.0	6.4
Mean	2198	7.5	1047	6.1
SD	196.2	0.7	77.2	0.5
CV	8.9	9.4	7.4	8.4
Core	2344	8.3		
Black	2984	10.0		
Blue	2003	6.7		

The results are in line with the visual observations. Where external abrasion was evident, tensile failures started within these areas. The effect of the extreme external abrasion within the fail zone are very clear [Table 2]

Table 2 Tensile results, within the fail zone

	Inner tape modest damage		Inner tape severe damage	
	Br Load N	Br Ext %	Br Load N	Br Ext %
1	890.0	5.5	890.0	5.2
2	980.0	5.7	222.0	2.1
3	1032.0	6.3	825.0	5.3
4			691.0	4.9
5			270.0	3.6
6			47.0	1.9
7			178.0	3.0
8			475.0	3.9
9			634.0	4.1
10			424.0	4.0
Mean	967	5.8	466	3.8
SD	71.8	0.4	287.9	1.2
CV	7.4	7.1	61.8	31.3

2.2.2 Estimate or rope strength by realisation

Table 3 provides a summary of the estimated dry rope strength, by realisation, and % residual strength. The method of realisation is described in BS EN 919:1995,'Fibre ropes for general service-Determination of certain physical and mechanical properties'

Table 3

Summary of estimated dry rope strength and % residual strength

Minimum Dry Rope Breaking Load, new Marlow Data Sheet 10/03 Fybaline 8 Xtra **78.5 Tonnef , 770 kN**	**Br Load** **Tonnef**	**Residual Strength** **%**
Remote from fail zone	**49.3** [484 kN]	**62.8**
Within the fail zone	**9.6** [94 kN]	**12.3**

Tables 4 and 5 show the calculations that provide the data shown in Table 3.

Table 4 Residual strength calculation for rope remote from the fail zone

		Strands	Yarns	Ave BL kN	Sum BL kN
Outer structure strand with markers					
outer yarn		4	16	2.198	140.672
outer yarn black		4	1	2.984	11.936
outer yarn blue		4	1	2.003	8.012
Outer structure strand with no markers					
outer yarn		4	18	2.198	158.256
Inner structure					
inner tape		8	31	1.047	259.656
core yarn		8	1	2.344	18.752
aggregate yarn break load	kN				597.3
realization factor					0.81
dry rope calculated break load	kN				483.8
minimum new dry break load	kN				770.0
residual strength	%				62.8

Table 5 Residual strength calculation for rope within the fail zone

		Strands	Yarns	Ave BL kN	Sum BL kN
Outer structure					
outer yarn		8	18	0.000	0
Inner structure					
inner tape	Modest damage	8	3	0.967	23.208
inner tape	Severe damage	8	20	0.466	74.56
core yarn		8	1	2.344	18.752
aggregate yarn break load	kN				116.5
realization factor					0.81
dry rope calculated break load	kN				94.4
minimum new dry break load	kN				770.0
residual strength	%				12.3

The strength of the rope in the fail zone was 12.3% of its Minimum Dry Rope Breaking Load.

3. CONCLUSIONS AND RECOMMENDATIONS

External abrasion damage was the dominant feature seen on all parts of this rope.

The rope was found to have failed at a zone of extreme abrasion damage, where it was estimated to have a residual strength of 12.3% of its specified new Minimum Dry Breaking Strength.

Inspection of both segments of the rope within the fail zone revealed that one segment [non-eye] had suffered extreme abrasion damage to approximately half of its circumference, whilst for the other [eye] segment this damage was distributed around the whole circumference for a distance of about 2 metres back from the fail point.

Close examination of the rope halves at the fail point suggest that bending over an acute edge under high tension may have been involved in the failure.

Testing a portion of the rope away from the failure zone, to estimate the general condition of the rope, revealed that the rope retained just over 62% of its Minimum Dry Breaking Strength.

The eye was found also to have severe external abrasion damage, due to the protective sleeve having been displaced in use, exposing the rope to abrasion caused by mooring points.

If the rope was in this extreme abraded condition before the failure, the rope appears not to have been routinely inspected in accordance with industry guidelines and recommendations [references 1-6]. Inspection according to the guidelines would have resulted in the rope being rejected as unfit for service before the failure.

Recommendations

An inspection of the vessel and deck equipment should be conducted to ascertain whether such severe abrasion damage could have been caused during the deployment when the failure occurred**.**

Examination of the fibres in the strand ends would determine if the rope had been passed around an acute edge, that would have exacerbated the strength loss.

References

1. "The selection, use, care, inspection and maintenance of non-metallic ropes and cords" United Kingdom Defence Standard DEF STAN 40-7/1.
2. "Mooring Equipment Guidelines", 2nd Edition, Oil Companies International Marine Forum 1997.
3. "Admiralty Manual of Seamanship' III 1983
4. "The selection, use and care of man-made-fibre ropes in Marine applications". British Standard BS 4128 1967 : Now lapsed, not replaced.
5. Cordage Manufacturers Institute, Recommendations for Rope Safety, 1984.

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4. APPENDICES

Appendix 1

Testing Apparatus and testing conditions

Photo 8 shows the tensile testing instrument used to perform the tests. Bollard grips were used to clamp the samples.

The machine is a Testometric Micro 500, Serial No 500-123

Calibration performed by Denison Mayes Group, 10 June 2003, Certificate No. 64800

Photograph 1 Bollard grips used for tensile testing

Testing conditions were:

Gauge Length 835 mm

Xhead Speed 200 mm/minute

ANNEX 2

Extracts from mooring equipment guidelines, second edition 1997, OCIMF

6.3.5 *Handling, Maintenance and Inspection*

A summary of recommendations is provided in Appendix C. Since synthetic ropes are common on smaller ships, a more detailed discussion concerning them follows below:

Safety hazards

Synthetic lines can pose a great danger to personnel if not properly used. Handling of mooring lines has a higher potential accident risk than most other shipboard activities.

The most serious danger is snap-back, the sudden release of the static energy stored in the stretched synthetic line when it breaks.

When a line is loaded, it stretches. Energy is stored in the line in proportion to the load and the stretch. When the line breaks, this energy is suddenly released. The ends of the line snap back, striking anything in their path with tremendous force.

Snap-back is common to all lines. Even long wire lines under tension can stretch enough to snap back with considerable energy. Synthetic lines are much more elastic, increasing the danger of snap-back.

Synthetic lines normally break suddenly and without warning. Unlike wires, they do not give audible signals of pending failure; nor do they exhibit a few visible broken elements before completely parting.

Line handlers must stand well clear of the potential path of snap-back, which extends to the sides of and far beyond the ends of the tensioned line. Figure 6.6 illustrates potential snap-back danger zones.

As a general rule, any point within about a 10 degree cone around the line from any point at which the line may break is in danger. A broken line will snap back beyond the point at which it is secured, possibly to a distance almost as far as its own length. If the line passes around a fairlead, then its snap-back path may not follow the original path of the line. When it breaks behind the fairlead, the end of the line will fly around and beyond the fairlead.

If an activity in a danger zone cannot be avoided, the exposure time can at least be reduced by observing some simple rules. When it is necessary to pass near a line under tension, do so as quickly as possible. If it is a mooring line and the ship is moving about, time your passage for the period during which the line is under little or no tension. If possible, do not stand or pass near the line while the line is being tensioned or while the ship is being moved along

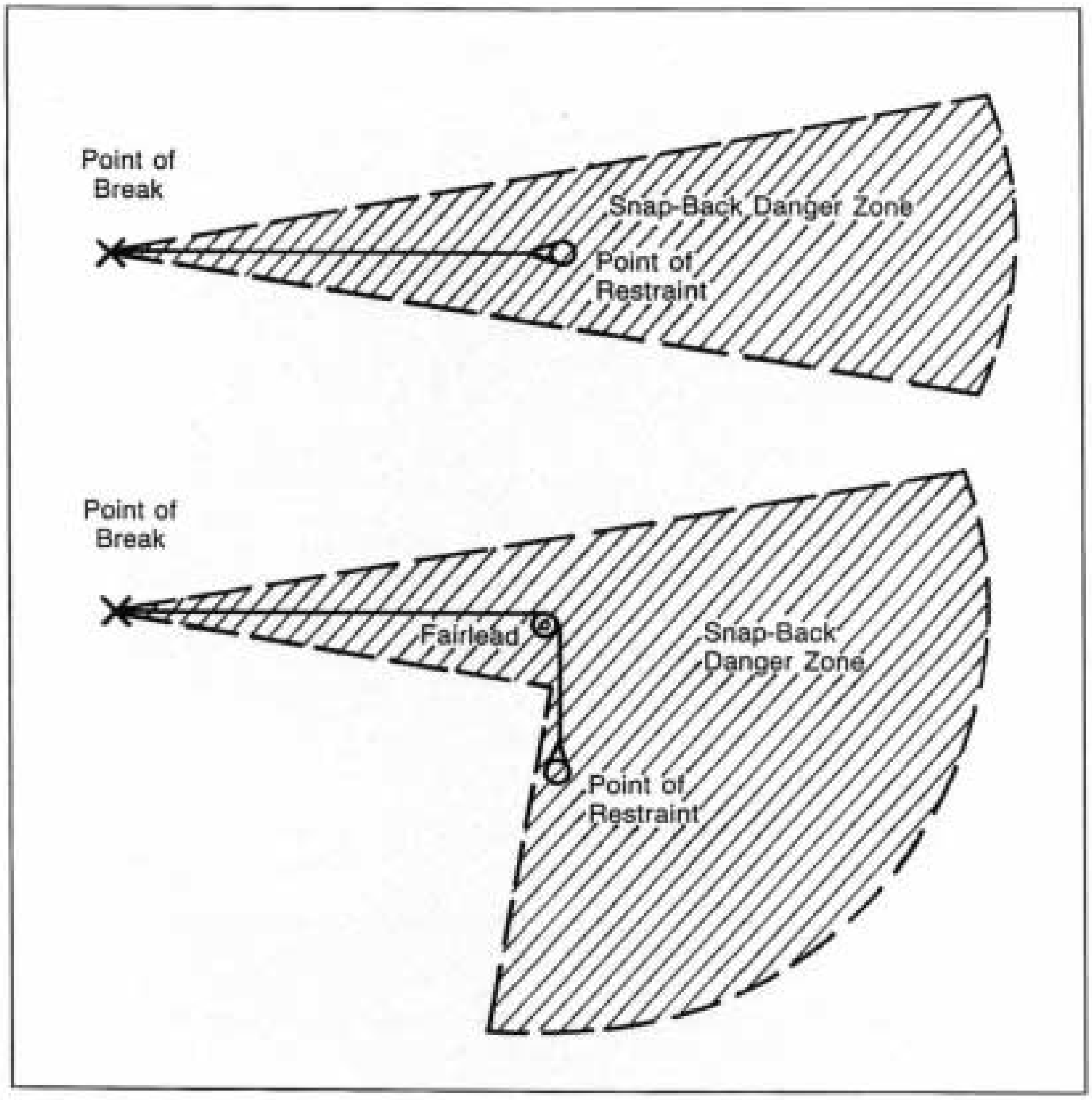

FIGURE 6.6: EXAMPLES OF SNAP-BACK DANGER ZONES

the pier. If you must work near a line under tension, do so quickly and leave the danger zone as soon as possible. Plan your activity before you approach the line. Never have more people than necessary near the line. If the activity involves line handling, make certain that there are enough personnel to perform it in an expedient and safe manner. Instruct observers to stand well clear.

Handling

Crews handling synthetic lines which must be stopped off and made fast to bitts need good training in accident prevention. Surging of lines on winch drum heads, which used to be common practice with natural fibre rope, is not recommended for synthetic lines, polypropylene in particular. The nature of the fibres, combined with the high loads, make it necessary to walk back the winches rather than surge in order to provide slack when stopping off and making fast. Stoppers made of polyester are recommended. They should be used in the double line configurations, where a half hitch is placed over the bitts and the two ends of the stopper are crossed over and under the line being stopped off. Training should include action to be taken during a break-out incident, namely, clearing the area to prevent injuries.

When holding and tensioning the line on the warping drum end, capstan or bitt, the line handler must not stand too close. When the line surges, he could be drawn into the drum or bitt before he can safely take another hold or let go. He should stand back and grasp the line about 1 m (3 ft) from the drum or bitt.

Synthetic lines are not very resistant to cuts and abrasion, and should not be exposed to conditions which might damage them. If they are used in fairleads previously used with wires, make certain the fairleads have not become grooved or roughened by the wires. It may be necessary to grind the fairleads smooth.

Care should be taken when dragging synthetic lines along a deck. Avoid sharp edges and rough surfaces. Small lines should be carried instead of dragged when possible.

When dirt, grit or rust particles are allowed to cling to and penetrate into synthetic ropes, internal abrasion will result. The rope should be brushed or cleaned before storing.

Twisted ropes can be harmed by kinking, which may form into hockles if not properly removed. When a kink forms, the load must be removed and the kink gently worked out.

Twisted rope must be coiled in the proper direction. Most lines are right-hand lay and should be coiled clockwise. When removing new rope from a coil, suspend the coil on a shaft and rotate it.

Winch-mounted synthetic lines should be end-for-ended after about two years to distribute wear, unless inspection dictates a shorter schedule.

Storage
Synthetic lines should be stored in clean, cool, dry surroundings. Excessive heat can damage synthetic fibres, especially polypropylene and polyethylene. Do not store synthetic ropes near steam pipes or against bulkheads which may reach high temperatures.

Ultraviolet rays from sunshine can damage fibres. Polypropylene and polyethylene are especially vulnerable. The potential degree of damage increases as rope size decreases. Never store small polypropylene or polyethylene ropes in direct sunlight.

Synthetic fibres are also subject to chemical damage. Their susceptibility depends on the chemical and the fibre. Nylon is attacked by acids and bleaching agents. Polyester is attacked by some alkalis. Industrial solvents, including paint thinners, will damage most synthetic lines if they are stored in paint lockers or near paints and paint fumes.

Oil and petroleum products will not normally damage synthetic fibres. Nonetheless, care should be taken to avoid contact with them. If a rope becomes oily, it is more difficult to handle. Dirt and grit will adhere to the oil and cause internal abrasion of the rope. If the line becomes oily or greasy, it should be scrubbed with fresh water and a paste-like mixture of granulated soap. For heavy accumulations of oil and grease scrub the line with a solvent such as mineral spirits; then rinse it with a solution of soap and fresh water.

Inspection and replacement
Synthetic lines should be examined frequently while in service. They should be checked for obvious signs of deterioration before each use and undergo a thorough inspection at least once each year.

Some signs of damage such as hockling, cuts, surface abrasion and fusion are readily visible. Others are not as evident. While it is not possible to prescribe definitive retirement criteria, the following sections discuss the types of damage and wear experienced by ropes and provide general guidelines.

Cuts
The degree of damage caused by a cut depends on the depth and extent of the cut and on the rope construction. Each strand of a three-strand, six-strand or eight-strand rope carries a substantial portion of the load. If any one strand is significantly weakened by a cut, then the strength of the entire rope is significantly decreased. In general, any cut which penetrates through 25% of the area of one or more strands critically weakens the rope. The rope should be cut and spliced or retired.

Double braid ropes have many more strands. In conventional synthetic fibre double braid ropes the cover and the core each carry about 50% of the load. Thus, one or several cut strands in the cover normally do not significantly reduce the strength. If more than about 10% of the entire cover strands are cut, then the double braid rope should be retired.

In the case of the newer types of synthetic line such as the aramid fibres, almost the entire load is carried by the inner core. Therefore, should the external sheath be damaged the internal load bearing fibres may rapidly degrade through exposure to ultraviolet rays or through mechanical wear. It is consequently advisable to inspect these lines on a regular basis with a view to pre-emptive repair as necessary.

External abrasion and fusion
A moderate amount of external abrasion is normal and can be tolerated in most synthetic ropes. The abrasion is evident as a general fuzzy appearance. If abrasion reduces the solid diameter by more than about 5%, then the rope should be retired. If the abrasion is localised and the remainder of the rope is in good condition, then the rope may be respliced.

Severe localised abrasion may be of concern. Severe abrasion of even one strand in three-strand, six-strand or eight-strand rope can significantly reduce the strength of the strand and upset the rope structure. The abrasion affects a number of yarns as it extends along the strand, so the degree of damage is not necessarily proportional to the depth of abrasion. If the abrasion on any one strand penetrates more than about 15% of the strand area, the rope should be cut and spliced.

Internal abrasion
Internal abrasion is caused by the strands and yarns rubbing against each other as the rope undergoes cyclic loading. It is a form of fatigue entirely different from the type of fatigue experienced in metals.

The rope should be examined for signs of inter-strand abrasion. Carefully open the structure of three-strand, six-strand or eight-strand rope to examine the surfaces of the strands at points where they contact each other. A general fuzzy appearance at the points where strands rub against each other is an indication of moderate internal abrasion. If the abrasion has progressed to the extent that some yarns are worn through, the rope should be retired.

Internal abrasion in double braid rope is harder to detect because it may appear to be normal external abrasion. Closely examine the broken yarns which appear on the strands at the surface. If they have broken in the valleys between the strands, then it is internal abrasion. This internal abrasion probably extends throughout the entire rope structure. If it is severe, it has significantly decreased the rope strength and the rope should be retired.

Hockling
Hockling normally occurs only in twisted ropes. A hockle resembles a knot in the rope, as shown in Fig. 6.7. Hockles greatly reduce the strength of the rope. When a hockle appears in a rope which is otherwise in good condition, it should be cut out and the rope spliced.

Hockles occasionally occur in the individual strands of three-strand, six-strand and eight-strand ropes. Such hockles upset the balance of load carried by the strands. The rope should be cut and spliced.

Broken Core
The core of a double braid rope may break under high load without resulting in immediate rope failure. Under load, the rope will have a smaller diameter at the point of core break. Under no load, the rope may bend more freely at this point. If the core is broken, the double braid rope should be retired.

Ultraviolet Damage
Ultraviolet rays from the sun destroy the strength of polypropylene and polyethylene fibres. The weakened fibres can easily be rubbed off the surface of the rope. The significance of the

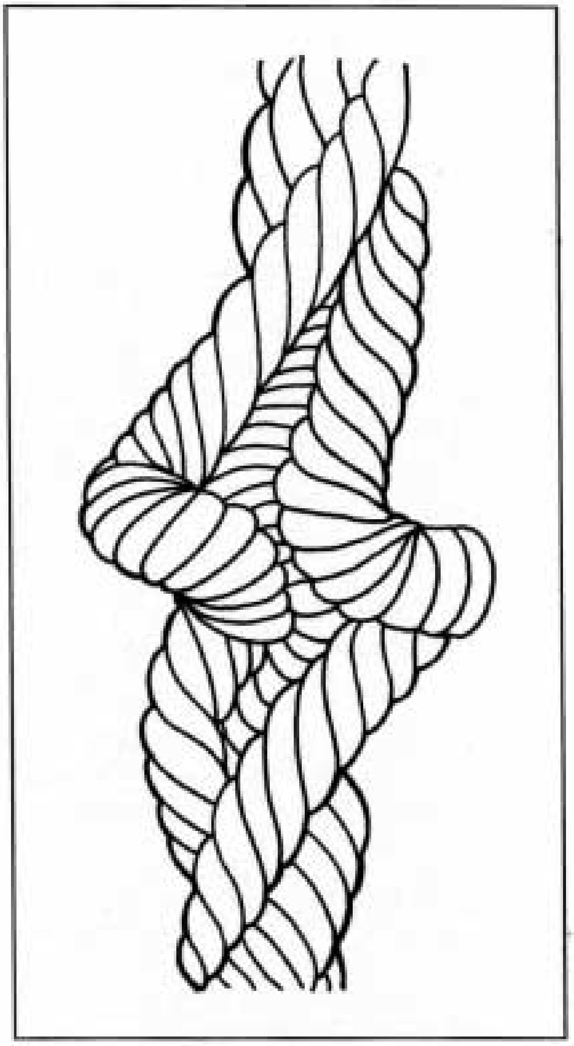

FIGURE 6.7: EXAMPLE OF HOCKLE IN 3 STRAND ROPE

damage depends on the size of the rope. Small ropes, less than about size 3 (24 mm diameter), should be retired when there is evidence of significant ultraviolet damage. Larger ropes are normally not as seriously damaged because only the yarns on the surface of the rope are affected.

Aramid fibres are also vulnerable to ultraviolet rays. They are normally covered by jackets of another material for protection. If the jacket is damaged and the aramid fibres exposed to sunlight, deterioration may follow. If the jacketing of an aramid rope is damaged, it should be repaired in accordance with the manufacturer's instructions.

Chemical damage

Some synthetic rope materials can be damaged by chemical attack. Nylon is affected by acids. The products of rust can be acidic and weaken nylon. If a nylon rope has been significantly discoloured by rust beyond the surface yarns, the affected portion should be cut out or the entire rope should be discarded.

Paints, paint thinners and even the fumes of paints and thinners can damage some synthetic fibres. Ropes should not be stored in the same room as paints and thinners. If a rope has become soaked in paint or thinners, it should be discarded.

Splices

The proper techniques for splicing common types of synthetic rope are described in seamanship manuals and manufacturers' literature and are not covered here. Ropes should be spliced by experienced personnel with reference to the applicable splicing instructions.

Splices in used ropes should be examined for signs of wear. Look for strands which have slipped in the splice and tucks which have become undone, as these upset the load balance. The transition between the splice and the rest of the rope should be examined for signs of internal abrasion which may concentrate at this point. In double braid rope splices, look for any indications that the splice is pulling apart.

Eyes

Abrasion and fusion at the inside back of the eye are common problems. Wear occurs at this point as the rope angle is changed under load around a bollard or hook. On eyes which are protected by thimbles, one should examine the rope in the mouth of the thimble for abrasion. If significant abrasion or fusion is found, the eye should be respliced.

In double braid rope, one should examine the crotch of the eye for broken strands. Make certain the splice is not pulling out. It may be possible to resplice small double braid rope. Large used double braid rope is very difficult to resplice and the rope may have to be replaced.

Appendix C
Care, Handling, Inspection and Replacement of Fibre Ropes

C.1 CARE AND HANDLING

Following are some recommendations for the care and handling of fibre ropes:

- New fibre rope of right-hand lay construction should be uncoiled from the centre of the coil in a counter-clockwise direction. When re-coiling it, the rope should be coiled in a clockwise direction. If it is a left-hand lay rope, the opposite would apply. If the rope is on a reel, the reel should be placed on a spindle or a rod to allow the reel to revolve freely. The rope should not be removed from over the end of the reel or while the reel is lying on its side.

- The ropes should be flaked down with as large a flake as possible to avoid kinking the ropes when storing them.

- Excessive build-up of turns in rope or loss of turns should be avoided. Excessive twist should be worked out of the rope by hand before loading.

- A capstan or winch drum rotating clockwise will add turns to a right-hand laid rope and one turning counter-clockwise will remove turns. To avoid this, the rope should frequently be turned end for end on winch drums.

- Ropes should not be dragged over sharp or rough edges, or along the ground, as they could pick up abrasive particles.

- Chafing at chocks and fairleads and on edges of dolphins and piers should be avoided where possible. All metal fittings should be smooth, and ropes protected against chafing by the use of anti-chafe devices such as leather jackets. Winch drums should be as smooth and free of rust as possible. Chocks and fairleads should be in a similar condition. If chocks are of the roller type, they should be free running.

- Ropes should not be exposed unnecessarily to sunlight.

- Fibre ropes should not be exposed to heat. They should never be dried by placing them near heaters.

- Contamination of ropes by chemicals or fumes, especially by acids and alkalis, should be avoided. If contamination is suspected, ropes should be hosed down and washed to avoid damage.

- Sharp bends on a rope should be avoided. Wire lines and synthetic ropes should not be placed on the same bollard or mooring hook.

- Extreme care should be exercised when easing out synthetic ropes from around bitts, cleats or other holding devices, to avoid sudden slipping of the line. Factors contributing to slipping are the low coefficient of friction between synthetic ropes and steel and the large elongation of synthetic ropes under load. Nylon and polypropylene are particularly prone to slipping.

- Due to the high stretch of synthetic ropes, large amounts of energy can be stored in a line under load. Sudden failure of the rope can then result in a potentially dangerous snapping back of the line.

- Mooring ropes should never be knotted. Knots weaken a rope considerably, even after they are removed.

- A left-hand rope should not be coupled to a right-hand rope.

C.2 INSPECTION OF FIBRE ROPES

Fibre ropes lose strength and deteriorate through normal use and must eventually be replaced. Weak points and potential areas of failure can be detected and the line repaired or retired before it parts in service.

For inspection, the rope should be laid out and the inspector should run the rope between his hands, examining about a foot length at a time. As he proceeds, he should rotate the rope and open the strands or spread the yarns to expose the strand interior surfaces and fibres.

C.3 REPLACEMENT OF FIBRE ROPES

The following guidelines will aid in determining when a fibre rope should be replaced:

- *Fibre deterioration*. The rope should be retired if the fibre is breaking up or if powdered fibre is present.

- *Damage due to external wear*. For this purpose, an unused rope sample may be helpful for comparison. If strand crowns are worn down considerably, the rope should be retired. If a significant number of outer yarns are also severed, the rope should no longer be used as a mooring line.

- *Local abrasion*. Heavy chafing or fusion of surface fibres are indications of severe abrasion. If these sections are localised, they can be removed and the rope spliced in accordance with the manufacturer's recommendations.

- *Hockles*. Hockling of fibre ropes indicates a severe reduction in rope breaking strength. The hockle should be cut out, if possible, or the rope removed from mooring service.

- *Chemical attack*. This may be indicated by staining, or by the ease with which filaments or fibres from the yarns can be plucked or rubbed off. If the rope has been chemically damaged, it should be removed from service.

- *Attack by heat*. This may be manifested by glazing of the rope surface. In extreme cases, local fused sections on synthetic rope indicates heat through friction and considerable loss of strength can be expected.

When inspecting mooring lines it is best to be conservative. Cut out damaged places if warranted and splice following manufacturer's recommendations. If damage is not localised, retire the rope.