Final report MO-2014-203: Fatal injury, Purse seine fishing vessel,
Captain M. J. Souza, 24 August 2014

Final Report

Marine inquiry MO-2014-203
Fatal injury
Purse seine fishing vessel, *Captain M. J. Souza*
24 August 2014

Approved for publication: September 2016

Transport Accident Investigation Commission

About the Transport Accident Investigation Commission

The Transport Accident Investigation Commission (Commission) is a standing commission of inquiry and an independent Crown entity responsible for inquiring into maritime, aviation and rail accidents and incidents for New Zealand, and co-ordinating and co-operating with other accident investigation organisations overseas. The principal purpose of its inquiries is to determine the circumstances and causes of the occurrences with a view to avoiding similar occurrences in the future. Its purpose is not to ascribe blame to any person or agency or to pursue (or to assist an agency to pursue) criminal, civil or regulatory action against a person or agency. The Commission carries out its purpose by informing members of the transport sector and the public, both domestically and internationally, of the lessons that can be learnt from transport accidents and incidents.

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Important notes

Nature of the final report

This final report has not been prepared for the purpose of supporting any criminal, civil or regulatory action against any person or agency. The Transport Accident Investigation Commission Act 1990 makes this final report inadmissible as evidence in any proceedings with the exception of a Coroner's inquest.

Ownership of report

Citations and referencing

Information derived from interviews during the Commission's inquiry into the occurrence is not cited in this final report. Documents that would normally be accessible to industry participants only and not discoverable under the Official Information Act 1982 have been referenced as footnotes only. Other documents referred to during the Commission's inquiry that are publicly available are cited.

Photographs, diagrams, pictures

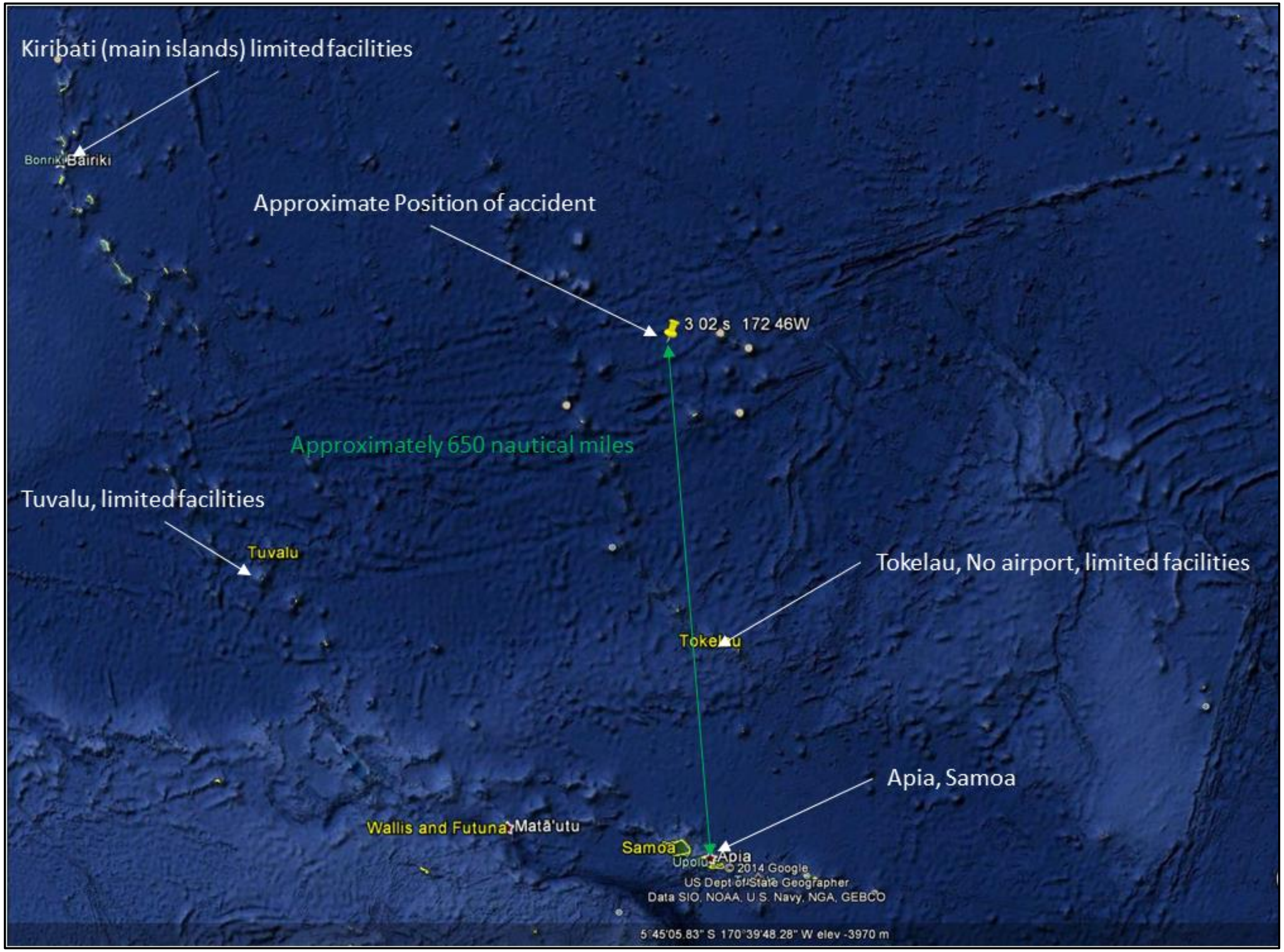
Unless otherwise specified, photographs, diagrams and pictures included in this final report are provided by, and owned by, the Commission.

Verbal probability expressions

The expressions listed in the following table are used in this report to describe the degree of probability (or likelihood) that an event happened or a condition existed in support of a hypothesis.

Terminology (adopted from the Intergovernmental Panel on Climate Change)	Likelihood of the occurrence/outcome	Equivalent terms
Virtually certain	> 99% probability of occurrence	Almost certain
Very likely	> 90% probability	Highly likely, very probable
Likely	> 66% probability	Probable
About as likely as not	33% to 66% probability	More or less likely
Unlikely	< 33% probability	Improbable
Very unlikely	< 10% probability	Highly unlikely
Exceptionally unlikely	< 1% probability	

The *Captain M. J. Souza* at Apia, Samoa, August 2014



Approximate position of the *Captain M. J. Souza* at the time of accident

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Abbreviations

kg	kilogram(s)
mm	millimetre(s)
SMS	Scrase Metallurgical Solutions
SSM	Safe Ship Management

Glossary

bight	the bent part of a rope that forms a loop
bowline knot	a knot used to form a fixed loop at one end of a rope
cable	a thick wire rope
crow's nest	a platform specially designed with a protective railing and fitted on the tallest mast of the a ship, where a crewmember stands and visually scouts for fish
cyclic loading damage	is a form of fatigue damage which that results in a reduction of strength due to repeated cyclic stresses
double-braided nylon rope	a nylon rope consisting of a braided inner core and a braided outer sheath
dye bomb	a bottle of dye released into the sea to stop fish swimming through as a net is closed, ensuring they do not escape
eye splice	a method of creating a permanent loop in the end of a multi-stranded rope by means of splicing
fatigue	the tendency of a material to fracture under repeated cyclic stresses
hydro-console	control station from where some of the ship's hydraulic equipment is operated
internal audit	an examination of a company's activities by its own employees
nautical mile	a unit used in measuring distances at sea, equal to 1,852 metres
ortza	a triangular metal frame to which one end of a net is attached. Various slings and shackles may be attached to an ortza
purse seine	a large net that encloses a school of fish and is then closed at the bottom by means of a line resembling a string used to draw shut the neck of a money pouch
realised breaking load	the RBL of a rope is the calculated, approximate breaking load of the intact rope, using an adjustment factor (called a Realisation Factor, 'fr'), after having breaking-load-tested individual strands of the rope
Safe Working Practices document	a document prepared by a vessel's owner to set the standards and norms that should be used to create a safe working environment. The

	document is to be read in conjunction with the vessel's Safe Ship Management manual
Safety Choker line	an additional rope attached to the net end, designed to prevent the loss of the net end in the event of the main sling rope failing
sling	rope connected at the by interweaving the strands at the end to form a sling
skiff	usually a flat- bottomed open boat of shallow draught
splice	a method of making a join in a rope by intertwining its individual strands
tying cord	whipping line to constrict the relative movement of the inner core and the outer sheathing of a double-braided rope
winch	a hauling or lifting device

Data summary

Vessel particulars

Name:	*Captain M. J. Souza*
Type:	fishing vessel
Limits:	unlimited excluding ice operations
Classification:	Maritime Operator Safety System
Length:	64.7 metres
Breadth:	12.82 metres
Gross tonnage:	1,468
Built:	Tacoma, Washington, United States
Propulsion:	one electro-motive diesel engine producing 2,648 kilowatts of power
Service speed:	12 knots
Owner/operator:	Talleys Group Limited/Amaltal Fishing Co. Limited
Port of registry:	Nelson
Minimum crew:	22

Date and time	24 August 2014, 1430[1]
Location	at sea, near Kiribati (650 nautical miles[2] north of Samoa)
Persons involved	22
Injuries	one fatal
Damage	equipment failure

[1] Times in this report are co-ordinated universal time +13 hours and are expressed in the 24-hour format.
[2] A nautical mile is a unit used in measuring distances at sea, equal to 1,852 metres.

1. Executive summary

1.1. The *Captain M. J. Souza* is a New Zealand-registered purse seine fishing vessel that was operating in the Pacific Ocean approximately 650 nautical miles north of Samoa.

1.2. On 24 August the vessel was engaged in a routine fishing operation when a nylon rope sling that was securing one end of the fishing net to the vessel broke. The weight of the net was then transferred to an approximately 48-millimetre-diameter nylon rope called a safety choker line, which was designed to retain the net end in the event of the rope sling failing.

1.3. The crew rigged another rope to alleviate the load on the safety choker line, then continued to close the net around the school of tuna. Soon afterwards the safety choker line broke at a bowline knot that had been tied in the rope and recoiled, striking one of the deck crewmembers in the head. The crewmember died instantly.

1.4. The Transport Accident Investigation Commission (Commission) found that the safety choker rope broke because it was in a deteriorated condition and was further weakened by the bowline knot that had been used to attach it to the net end.

1.5. The Commission also found that the broken rope was about as likely as not to have begun its life in service at a lower-than-typical breaking load for a rope of that size and construction. However, it could not be determined why, because the rope management plan on board was not effectively managing the purchase, storage, inspection and retirement from service of the ropes on board.

1.6. The Commission also found that the safety management system on board the *Captain M. J. Souza* provided good guidelines for the management and use of ropes on board. However, neither the crew nor the skipper nor shore management were ensuring that the safety management system was being adequately followed.

1.7. The Commission made a recommendation to the operator of the *Captain M. J. Souza* regarding improving its internal auditing procedures on board.

1.8. The key lessons arising from this inquiry included:

- tying a knot in a fibre rope will reduce its strength. It is therefore important to factor in this reduction in strength when tying a knot in a rope for a specific operation
- fibre ropes can fail due to cyclic tension loading, a form of fatigue damage that can be difficult to see in braided ropes. Mariners must look beyond rope surface appearance alone when deciding whether to retire ropes from service.

2. Conduct of the inquiry

2.1. On 25 August 2014 Maritime New Zealand reported a fatal accident on board the purse seine[3] fishing vessel *Captain M. J. Souza*. The Transport Accident Investigation Commission (Commission) opened an inquiry under section 13(1) of the Transport Accident Investigation Commission Act 1990 and appointed an investigator in charge.

2.2. On 27 August 2014 two investigators from the Commission flew to Apia, Samoa, where the *Captain M. J. Souza* was berthed. In the next three days the investigators interviewed the crewmembers and gathered evidence.

2.3. A failed rope, a sample rope of similar construction and a sling were removed from the vessel for forensic testing. The Commission engaged Scrase Metallurgical Solutions (SMS) in association with Metallurgical and Industrial Consultants Limited to determine the failure mode of the ropes and sling. SMS subcontracted to Bridon Cookes, which operates one of New Zealand's largest and most modern test beds, to conduct rope-related testing.

2.4. On 21 April 2015 the Commission obtained a new coil of rope from a known supplier of ropes to the *Captain M. J. Souza*, and engaged synthetic rope specialist, SWOS, based in the United States, to carry out tests to determine the rope's breaking strength.

2.5. On 26 June 2015 an interview was conducted with the operator's operations manager and evidence gathered in support of the investigation

2.6. On 23 June 2016 the Commission approved a draft report for circulation to interested persons. The Commission received and considered a substantive submission from the vessel's owner Talleys Group Limited. Any changes as a result of that submission have been included in this final report.

2.7. The Commission approved the report for publication on 29 September 2016.

[3] A purse seine is a large net that encloses a school of fish and is then closed at the bottom by means of a line resembling a string used to draw shut the neck of a money pouch.

3. Factual information

3.1. Purse seine fishing operation

3.1.1. Purse seine fishing aims to surround a school of fish quickly by means of a large net, then impound the fish by closing the bottom of the net. The net is cast vertically (Figure 1, 1.1) and has buoys attached to a float line at the top to keep the net afloat. The remainder of the net is then dropped into the water using a weighted line (Figure 1, 1.2). A steel cable[4] running through a series of purse rings at the lower end of the net is tightened or pursed to close the bottom of the net and prevent the fish escaping (Figure 1, 1.3).

3.1.2. The operation or 'set' starts by surrounding the school of fish with a net. One end of the net remains on board the fishing vessel while the other end is secured on a small boat called the net skiff. On the master's command the net skiff is launched from the ship, signalling the start of the set.

3.1.3. The skiff drags one end of the net into the water and holds it in position while the vessel quickly circles the fish, paying the net overboard as the vessel comes around to retrieve the skiff end of the net. The bottom of the net is then closed or pursed, trapping the fish inside.

3.1.4. The skiff end of the net is attached to an ortza[5] (see Figures 3 and 4). When recovering the net from the skiff, the ortza is hauled on board using a winch[6]. When the ortza is within reach, a double-braided nylon sling, already attached to the ortza, is secured to a stainless-steel post on the port side of the ship. The weight of the ortza and the net is transferred from the winch to the post.

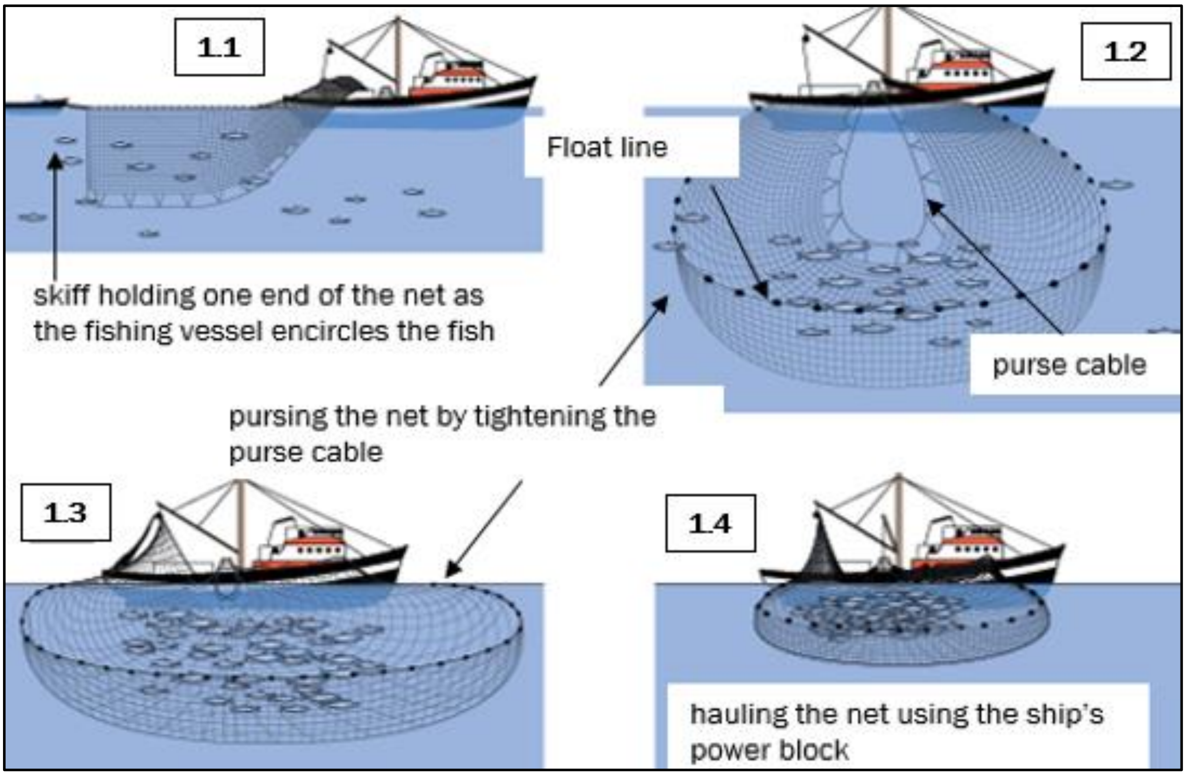

Figure 1
Purse seine operation
(Photo courtesy Encyclopaedia Britannica)

[4] A cable is a thick wire rope.
[5] An ortza is a triangular metal frame to which one end of a net is attached. Various shackles and slings may be attached to the ortza.
[6] A winch is a hauling or lifting device.

3.2. Narrative

3.2.1. The *Captain M. J. Souza* is a New Zealand-registered purse seine fishing vessel that operates predominantly in the Pacific Ocean.

3.2.2. On 24 August 2014 the vessel was fishing in the Pacific Ocean about 650 nautical miles north of Samoa. At about 1430 that day the crew detected a school of fish and manoeuvred the vessel into position to begin the purse seine operation.

3.2.3. Eight deck crew assembled on the deck and the skiff was launched. The crewmembers gathered at the forward end of the upper deck and stayed clear as the net was payed out.

3.2.4. Once the skiff had been manoeuvred into position the *Captain M. J. Souza* circled the fish and came back alongside the skiff to retrieve the end of the net.

3.2.5. Three crewmembers recovered the ortza and secured it with a sling to a stainless-steel post located on the port side of the ship (see Figure 2).

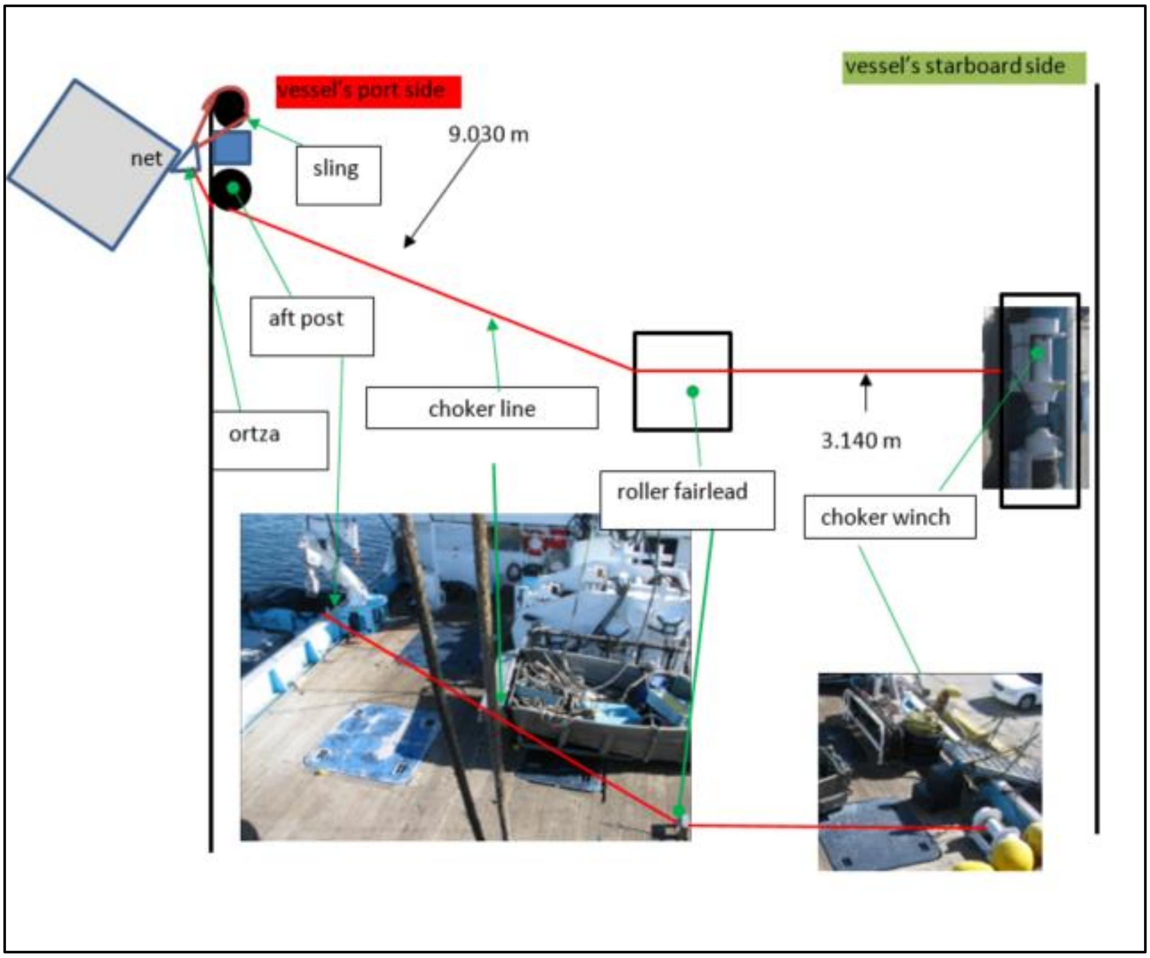

Figure 2
Location of the choker line on the upper deck

3.2.6. The crew also attached a 48-millimetre (mm) diameter double-braided nylon rope[7] called the 'safety choker line' (choker line) to the ortza as a backup in the event that the sling parted.

3.2.7. One end of the choker line was attached to the ortza using a bowline knot[8] (see Figure 5). The other end was attached to the choker winch on the starboard side of the vessel (see Figure 2).

[7] Double-braided nylon rope is nylon rope consisting of a braided inner core and a braided outer sheath.
[8] A bowline knot is used to form a fixed loop at one end of a rope.

3.2.8. Once the sling had been secured to the post and the choker line attached to the ortza, the winch operator started pursing in the cables to close the bottom of the net (Figure 1, 1.4).

3.2.9. About one minute into the pursing operation the sling parted and the weight of the net pulled the ortza outboard until the choker line took up the weight of the net. The ortza was at that point close to the sea surface.

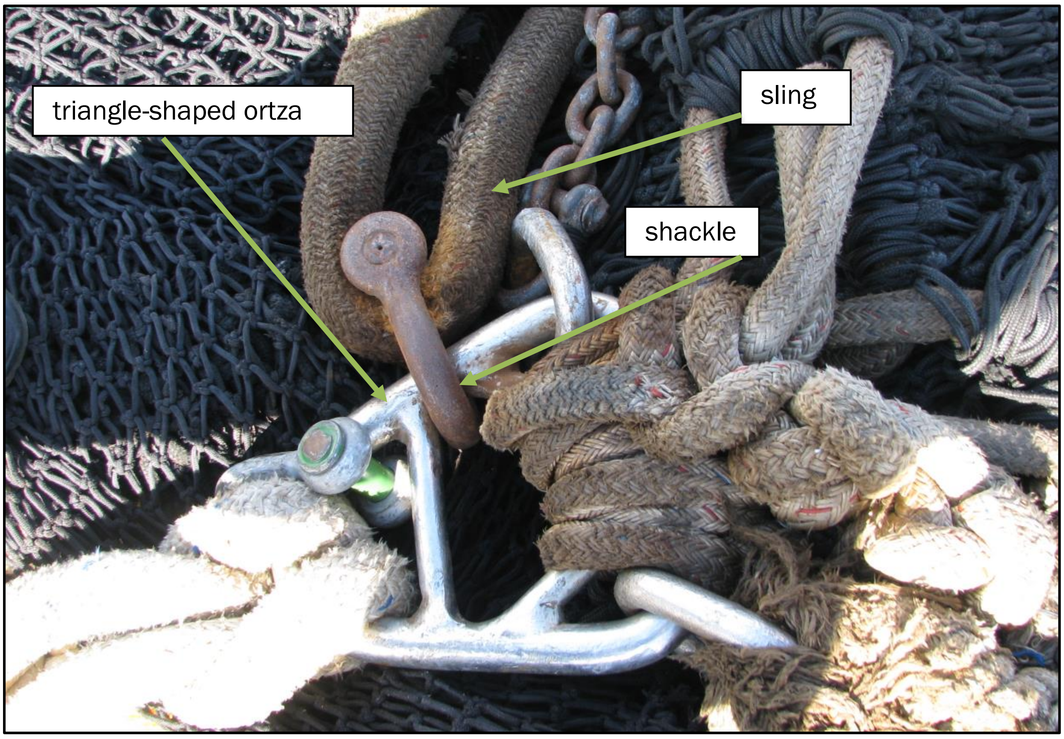

Figure 3
Photograph of an ortza on board the *Captain M. J. Souza*

3.2.10. The winch operator stopped the pursing operation as soon as he heard the sling part. A crewmember took a spare three-strand nylon rope, dived into the water and attached one end of the rope to the ortza. The other end of the rope was attached to a winch located on the forward port side of the upper deck to provide a better lead to pull the ortza back to the ship's side.

3.2.11. The surge drum winch was then used to raise the ortza as high as possible. The weight of the ortza and the forward end of the net were now being shared between the choker line and the three-stranded nylon rope.

3.2.12. While the ortza was being recovered the master, stationed at the crow's nest[9], ordered the winch operator to restart the pursing operation.

3.2.13. Five crewmembers stepped over the choker line, which was running transversely across the upper deck, and walked towards their stations on the port aft side of the vessel. They had been tasked with releasing dye bombs[10] into the water to stop the fish escaping beneath the hull of the vessel.

3.2.14. Two crewmembers who crossed over the choker line noticed that it was unusually tight and the rope's diameter appeared to have shrunk. This indicated that the rope was under severe strain.

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[9] A crow's nest is a platform specially designed with protective railing and fitted on the tallest mast of the ship, where a crewmember stands and visually scouts for fish.
[10] Dye bombs are bottles of dye released into the sea to stop the fish swimming through as the net is closed, ensuring they do not escape.

3.2.15. A few minutes after the pursing operation had restarted, the crew heard a loud bang. The choker line had parted at or near the bowline knot and snapped backwards, striking a crewmember, one of the deckhands, in the head. The deckhand died instantly.

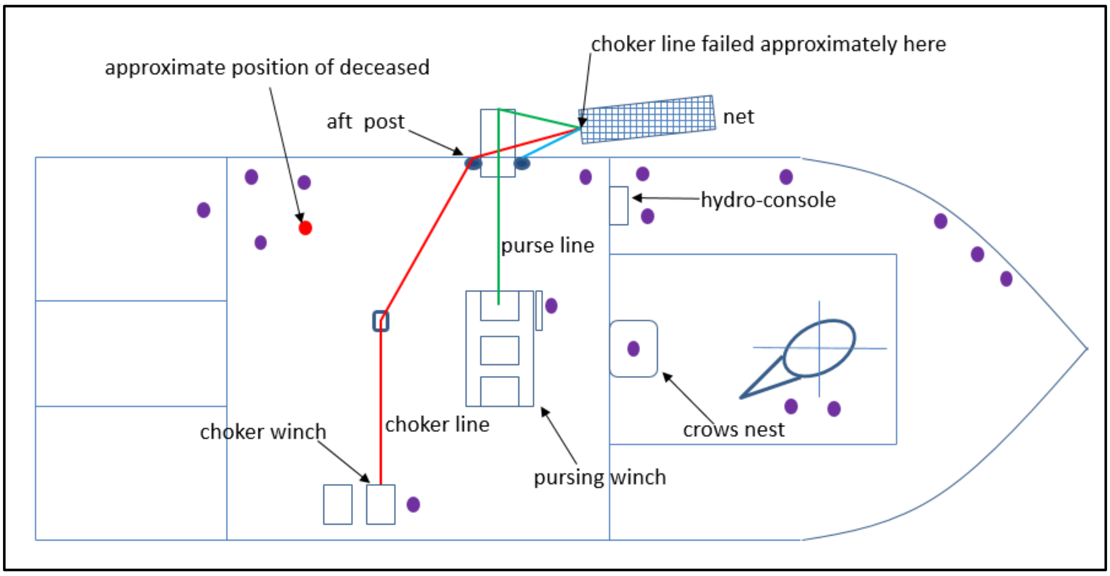

Figure 4
Location of the crew and equipment at the time of the accident

3.2.16. The vessel's operations manager was notified of the accident and gave instructions for the vessel to proceed to Western Samoa.

3.3. Choker line and sling

3.3.1. The choker line[11] was of double-braided nylon[12] construction and about 48 mm average diameter. One end of the rope was attached to the choker winch (Figure 2) while the other end was attached to the ortza by a bowline knot. The choker line was a backup for the sling and intended to support the weight of the ortza and the forward end of the net if the sling failed.

3.3.2. The ortza end of the choker line had originally had an eye splice[13], which had parted a few weeks prior to the accident. The broken eye splice was replaced with a bowline knot before the same choker line was put back into service, which was a departure from the procedures outlined in the Talleys safe working practice document.

[11] The SMS/Metallurgical and Industrial Consultants report (Appendix 1) initially identified the choker line to be consistent with a double-braided polyester rope, but on further inspection confirmed that the choker line was of double-braided nylon construction.
[12] The rope consisted of a braided inner core and a braided outer sheath.
[13] An eye splice is a method of creating a permanent loop in the end of multi-stranded rope by means of splicing.

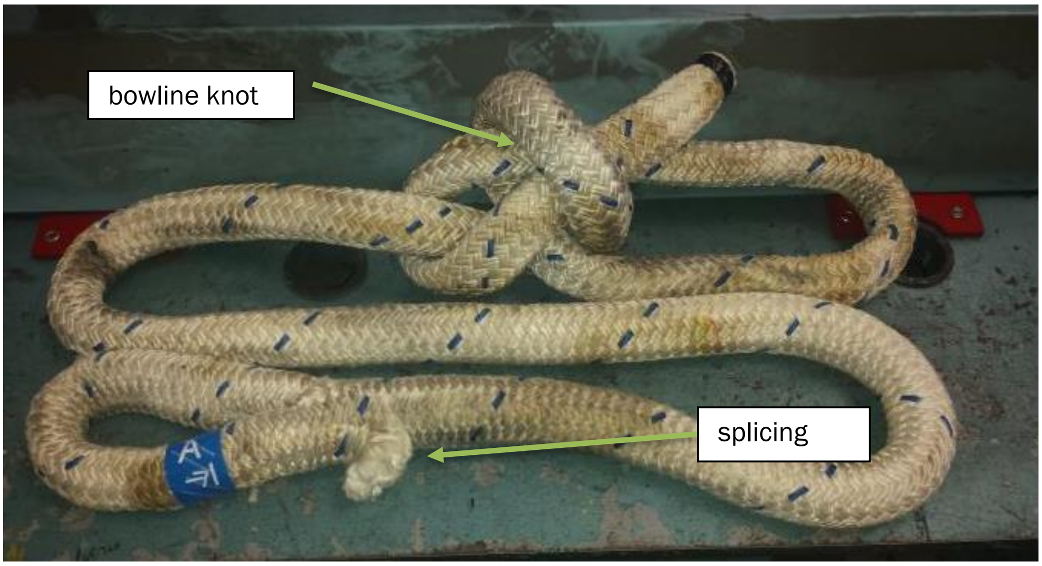

Figure 5
Sample rope with bowline knot on one end and eye splice on the other end

3.3.3. The sling was of double-braided nylon rope construction, about 50.8 mm in diameter and spliced[14] together at the ends to form a loop. The sling was only a few weeks old at the time of the accident.

3.4. Rope testing

3.4.1. The Commission retained the broken choker line, the broken sling and a reported new sample rope from on board the ship.

3.4.2. SMS was engaged by the Commission to examine the choker line, sling and new ropes and determine the cause of the failure.

Choker line inspection and testing

3.4.3. SMS made the following observations in its report (Appendix 1):

> The incident break started at approximately the same axial location all around the circumference of the rope, indicated by the red rectangle in Figure 2a [Figure 7]. No evidence of deliberate cutting, as might have occurred with a knife for example, was observed. No evidence of severe or localised abrasion was observed on the outer strand fibres.
>
> Deconstruction of the ropes for testing confirmed that they were of a double braid type with a braided cover over a braided core.
>
> The general damage morphology of the choker line was consistent with predominantly cyclic tension loading, a form of fatigue[15] damage.
>
> It is clear from the evidence that the choker line was in a deteriorated condition at the time it broke. Visual examination of the rope revealed extreme cyclic tension damage and the outer surface also resembled abrasion category 5-6. The ultimate failure was most likely caused by overload of the remaining relatively intact strands, after many fibres had already broken in service. This in service damage substantially reduced the strength of the rope, to the point that it exhibited a small fraction of its original breaking strength.

[14] Splicing is a method of making a join in a rope by intertwining its individual strands.
[15] Fatigue is the tendency of a material to fracture under repeated cyclic stresses.

The cover strands, and core strands, of an untested section exhibited tangled fibres and broken fibres, consistent with cyclic loading damage[16].

The choker line could not be tested as a complete rope, owing to its condition and the sample being too short to accommodate effective splicing, which is required to attach the rope to the testing equipment [the length of the recovered choker line was 3.7 metres; the minimum length required to attach the rope to the testing equipment was about 7 metres]. Instead, testing was performed on strands removed from the ropes, in accordance with international standard BS EN ISO 2307. This standard allows the testing of de-stranded ropes and applies a correction factor in a calculation of the realised breaking load[17] of the full-thickness rope.

Figure 6
Choker line
(Photo courtesy Scrase Metallurgical Solutions)

Figure 7
Broken end of choker line
(Photo courtesy Scrase Metallurgical Solutions)

[16] Cyclic loading damage is a form of fatigue damage that results in a reduction of strength due to repeated cyclic stresses.
[17] The realised breaking load of a rope is the calculated, approximate breaking load of the intact rope, using an adjustment factor, after having breaking-load tested individual strands of the rope.

3.4.4. The realised breaking load of the choker line was 10,036 kilograms (kg), which is about 19% of the expected breaking load of 52,752 kg[18](116300 Pounds) (see Appendix 2 for details of the referenced standard).

3.4.5. The report also estimated that the bowline knot further reduced the breaking load of the already weakened rope by about 33%, indicating that the breaking strength of the choker line may have been as low as 6,700 kg at the time of the accident.

Testing methodology and limitations

3.4.6. Owing to the condition of the damaged choker line and the difficulty of disassembling it, there is a possibility that the number of strands identified in the inner core of the choker line was 24, not 25 as identified in the test report (see Appendix 1). If the number of strands in the core was 24 and the average strengths of the outer braid strands and core braid strands were calculated separately, then the realised breaking load may have been as low as 8,584 kg, which is about 16% of the expected breaking load of 52,752 kg.

3.4.7. When the choker line parted at the bowline knot it recoiled. The Commission was unable to quantify what effect this had on the condition of the rope.

Inspection and testing of the sling

3.4.8. The following observations were made in the test report (see Appendix 1 for details).

> The strands were relatively intact at their initial separation but the fibres became more separated from each other towards the ends of the strands.
>
> The general outside condition of the rope appeared to be relatively free from damage, compared with the choker line, but exhibited some broken fibres protruding from the otherwise smooth surface. The sling had a very soft and supple feel. It could easily be squeezed in the circumferential direction by hand and move axially.
>
> The rope had 4 tying cords at various locations along its length [refer Figure 8]. Two of these had been made by tightly wrapping and finally tying many turns of black cord around the rope and these two cords appeared to be intact. The other two were loose and did not constrict the rope significantly. The core could easily be pulled out of the cover except where the two tight constrictions held it.

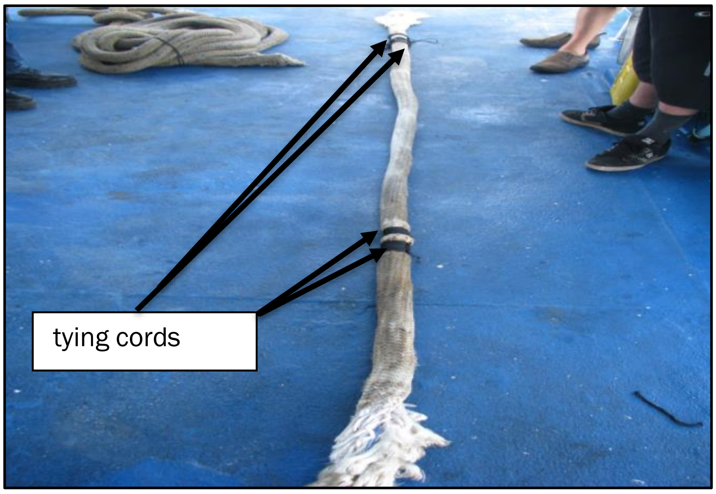

Figure 8
Sling rope core and cover bound by four tying cords

[18] Cordage Institute High Performance Double Braid Nylon Fiber Rope Standard: CI 1310-97.

Inspection and testing of a brand-new sample rope from a known supplier of ropes to the *Captain M. J. Souza*

3.4.9. The Commission contracted SWOS, synthetic rope testing experts based in the United States, to test a new two-inch (50.8mm), double-braided nylon rope manufactured by a known supplier of ropes to the *Captain M. J. Souza*. To test the rope, it was cut into three lengths. Each length had an eye splice at both ends. The test results showed that the ropes parted at an average breaking load of 53,8700 kg, which was more than the Cordage Institute standard's expected breaking load of 52,752 kg (see Appendix 3 for details).

Inspection and testing of a reported new sample rope of similar construction to the choker line, sourced from on board the *Captain M. J. Souza*

3.4.10. The sample rope was 32 metres in length and sourced from on board the *Captain M. J. Souza*. Visually the rope appeared to be in good condition compared with the choker line, but there was some indication of possible crushing and heat damage (see Figure 9). To test it, the rope was cut into five lengths, each six metres long. Two lengths had an eye splice at one end and a bowline knot at the other end. The remaining three pieces had eye splices at both ends.

Testing methodology and limitations

3.4.11. Owing to the elastic nature of the double-braided nylon rope, the rope's elongation during testing exceeded the maximum travel of the hydraulic ram that was used to stretch it to its breaking point. There was no testing equipment with appropriate test result graphing capability available in New Zealand that had a hydraulic ram of sufficient size. Therefore a low pretension load had to be applied at the early stages of testing to take up some stretch in each sample rope. A rope expert engaged by Talleys stated that this method may have produced inaccurate results. However, the opinion of the rope expert who conducted the tests was that pretensioning of the rope would have been very unlikely to introduce any appreciable error to the final test results. The Commission acknowledges the views of both experts. However, any error resulting from pre-tensioning the test rope during the test procedure is not significant to the result, which was that the rope failed at less than half its expected breaking load. The test results are tabled below:

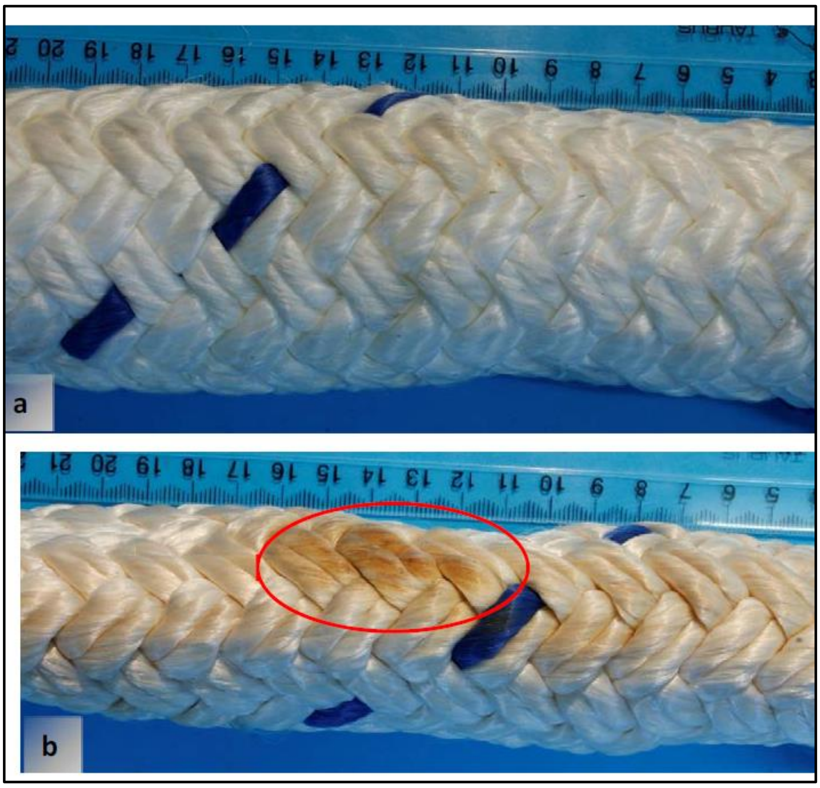

Figure 9
Reported new rope sample. Red ellipse indicates possible heat damage. (a) and (b) taken at same magnification showing the variation in diameter of the rope due to crushing

The test results are tabled below:

Eye splice –bowline	Actual breaking load	Expected breaking load	Actual breaking load shown as a percentage of the expected breaking load	Location of break
Sample A	15,676 kg	52,752 kg	29.7%	At bowline
Sample E	15,018 kg	52,752 kg	28.4%	At bowline

Eye splice at both ends	Actual breaking load	Expected breaking load	Actual breaking load shown as a percentage of the expected breaking load	Location of break
Sample B	20,174 kg	52,752 kg	38.24%	At splice
Sample C	24,258 kg	52,752 kg	45.9%	Centre of rope
Sample D	24,523 kg	52,752 kg	46.4%	Centre of rope
Average breaking load of B, C and D	**22,986 kg**	**52,752 kg**	**43.5%**	

4. Analysis

4.1. General

4.1.1. There are more than 1,200 New Zealand-registered commercial fishing vessels engaged in coastal and deep-sea fishing operations. Commercial fishing is a high-risk occupation that often takes place in a hostile and unpredictable environment, and involves working on the deck in the vicinity of winches, ropes and cables in tension.

4.1.2. The purse seine fishing vessel *Captain M. J. Souza* was one of nine deep-sea fishing vessels operated by Amaltal Fishing Company Limited. At the time of the accident the vessel was transitioning from the now-redundant Safe Ship Management (SSM) system to the new Maritime Operator Safety System administered by Maritime New Zealand.

4.1.3. The analysis discusses why the choker line and sling parted, the effectiveness of internal audits[19] in detecting and preventing deficiencies, the importance of having a rope management plan and the effect of fatigue on fibre ropes.

4.2. Why did the sling and choker line fail?

4.2.1. The breaking load tests conducted on the choker line showed that the realised breaking strength of the choker line may have been as low as 6,700 kg, which is significantly lower than the typical 52,700 kg breaking strength of a new 50.8 mm double-braided nylon rope[20] (see Appendix 2).

4.2.2. SMS observed in its report (Appendix 1) that the damage sustained by the choker line was generally consistent with fatigue damage, but the ultimate failure was most likely caused by overloading the remaining intact strands.

4.2.3. The report referred to fatigue as "the weakening of a material subject to cyclic stresses". The material, in this case a fibre rope, typically fails at an intensity considerably below its normal breaking strength. The SMS report stated:

> It is clear from the evidence that the choker line was in a deteriorated condition at the time it broke. Visual examination of the rope revealed extreme cyclic tension damage and the outer surface also resembled abrasion category 5-6. The ultimate failure was most likely caused by overload of the remaining relatively intact strands, after many fibres had already broken in service. This in service damage substantially reduced the strength to the rope, to the point that it exhibited a small fraction of its original breaking strength.

4.2.4. A rope of the diameter and construction of the choker rope has thousands of individual strands. A number of broken strands within the core of a rope is an indication that it is fatigued. The greater the percentage of broken to intact strands, the more advanced the stage of fatigue of the rope. Although the number of unbroken strands can give the appearance that the rope is still in good condition, the remaining unbroken strands will have a reduced strength due to cyclic fatigue.

4.2.5. When using a rope on board a ship it is important to know how long a rope can be safely used before fatigue sets in and degrades the rope's load-bearing capacity. The problem with braided-fibre rope that has an outer sheath is that it is virtually impossible to detect broken strands within its core, making it difficult to assess its overall condition visually. Therefore other means of assessing when to retire a rope from use are needed. The fatigue life of a rope can be predicted by modelling the life of the rope based on the load applied to it and the frequency of usage.

[19] An internal audit is an examination of a company's activities by its own employees.
[20] Taken from the Cordage Institute Standard. The Cordage Institute is an international association of rope, twine and related manufacturers, their suppliers and affiliated industries. Its mission is to educate on the proper use of industry products through the dissemination of standards.

4.2.6. SMS also found that the bowline knot on the choker line may have considerably reduced the strength of an already weakened rope. A National Transportation Safety Board safety alert (http://go.usa.gov/9e6P) reported that the strength reduction due to a bowline knot tied in a rope may be as much as 70%, even on a brand-new rope. These studies were based on nylon rope of much smaller diameter than the choker rope. The SMS report considered a strength reduction of as much as 33% for the larger ropes tested in this case.

4.2.7. It is not possible to say definitely what the actual strain on the choker rope was when it broke on board the vessel. It was necessary to use the realised breaking load method for testing the rope because there was insufficient rope to conduct a full breaking test. This method has a recognised limitation in accuracy. Also, it is not possible to say with any accuracy what the effect of using a bowline knot had on breaking strength.

The sling

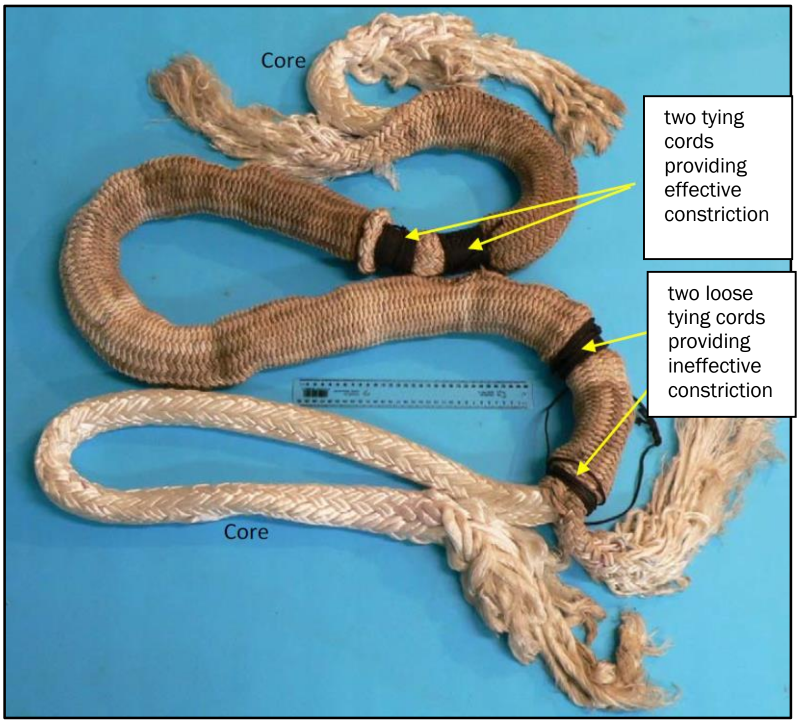

Figure 10
Sling with core pulled out, past two ineffective constrictions but held by two tight constrictions
(Photo courtesy Scrase Metallurgical Solutions)

4.2.8. The sling failed at the splice. The SMS report stated that it was difficult to determine whether the splice had been constructed in accordance with general industry guidelines. However, the presence of the tying cords[21] (see Figure 10) suggested that it had not. The report also stated that there were breaks at both ends, not straight cuts, indicating that a splice might have come apart gradually while in service. The sling then most likely experienced loads sufficient to cause the observed predominantly tensile breaks[22].

[21] Whipping line to constrict the relative movement of the inner core and the outer sheathing in a double-braided rope.

[22] Tensile breaks are breaks that are sustained when a material is being stretched or pulled.

Findings

1. The choker line broke, partly because it was in a deteriorated condition caused by extreme cyclic tension (fatigue) and some degree of abrasion, and partly because the bowline knot almost certainly caused a reduction in breaking strength.
2. The rope that was used to make the sling was reasonably new and in good condition. It is likely that the sling failed due to the splice coming apart in service, to a point where the strands ultimately parted under tensile load.

4.3. Rope management plan

4.3.1. At the time of the accident there was no formal recording or registering of ropes on board the *Captain M. J. Souza* and there was no requirement to do so. There was some generic advice on rope care in its Safe Working Practices document[23], but essentially the inspection and requisition of ropes were delegated to the ship's bosun. The shore management relied on the bosun's judgement and the skipper's oversight when evaluating the condition of ropes on board and making recommendations for the further use of those ropes.

4.3.2. It was reasonable to expect a person to be competent in examining the condition of a rope for what they could see. However, as mentioned above, visual examination alone will not provide a robust measure of rope deterioration. Guidelines on when to retire a rope from service as part of a rope management plan could have assisted the crew in this regard.

4.3.3. The company safety management system referenced the Cordage Institute standard as a guideline. The Cordage Institute states that an important tool for rope evaluation is a log, which includes data on the type of rope and the time in service and descriptions of the intended use and the established retirement criteria. The Cordage Institute also suggests that details of every inspection be entered into the log.

4.3.4. At the time of the accident there was no log or retirement standard documented in the safe ship management documents kept on board the ship.

4.3.5. The choker line and a reported new sample rope of similar construction were removed from on board for testing and examination. The test results showed that the choker line was only about 19% of the expected breaking load (52,700 kg) and the sample rope, which appeared to be in relatively good condition, was only about 40% of the expected breaking load.

4.3.6. There are a number of possible reasons for the reported new sample rope suffering a significant reduction in its strength. Manufacturing inconsistencies, ultraviolet degradation, heat abrasion, damage from previous usage and exposure to water or chemicals are all possible reasons.

4.3.7. Neither the crew nor shore management were able to determine with any certainty the origin of the choker line and the reportedly new sample rope. They were also unable to determine whether both the ropes originated from the same coil. There was no record of how long the choker line had been in use or how long ropes should be used prior to retirement. Consequently the origin of the sample rope was not able to be traced.

4.3.8. If the choker line originated from the same coil from which the sample was taken, it is very likely that it started its life in service at about 40% of the expected breaking load. The onset of fatigue due to cyclic tension was therefore very likely to have been accelerated because the ratio of the rope's breaking load to the normal service loads would have been significantly lower.

[23] This is a document prepared by a vessel's owner to set the standards and norms that should be used to create a safe working environment. The document is to be read in conjunction with the vessel's Safe Ship Management manual.

4.3.9. Since the accident the operator has started a rope register to log ropes' usage.

> **Findings**
>
> 3. The rope management plan on board the *Captain M. J. Souza* was not effectively managing the purchase, storage, inspection and retirement from service of the ropes on board.
> 4. It is about as likely as not that the choker rope that broke on board the *Captain M. J. Souza* began its life in service at a lower-than-typical breaking load for a rope of that size and construction.

4.4. Ship safety management system

4.4.1. At the time of the accident the *Captain M. J. Souza* was transitioning its safety management from the now redundant SSM system to the new Maritime Operator Safety System administered by Maritime New Zealand. Under the SSM code a ship's owner was required to engage a Maritime New Zealand-approved organisation to administer its SSM system. The Maritime Operator Safety System was introduced on 1 July 2014, about two months prior to this accident. On 1 July 2014 any vessel with a valid SSM certificate received a 'deemed' Maritime Transport Operator Certificate. At the time of the accident the *Captain M. J. Souza* held a valid deemed Maritime Transport Operator Certificate.

4.4.2. The Safe Ship Management documents provided extensive guidance on the safe working practices expected on board the ship, including working with various types of rope and twine and the breaking characteristics of synthetic ropes. All crewmembers were required to ensure that ropes were in good condition and had strength appropriate to their applications. Ropes were to be examined for abrasions and broken, deteriorated or displaced fibres.

4.4.3. Maritime rule Part 21 required an SSM organisation[24] to carry out an external audit of a ship prior to it gaining an SSM certificate. A subsequent external audit was required as part of the SSM certificate renewal process to ensure the vessel's continued compliance with the requirements of the SSM code[25]. In addition to the external audit requirements, the *Captain M. J. Souza* was internally audited by the vessel's shore managers when it berthed in New Zealand or American Samoa while discharging cargo.

4.4.4. The operator said that internal audits were conducted several times each year. An internal audit would normally consist of a 'walk around' the vessel and the subsequent compilation of a work list in consultation with the master and crew. The work list was actioned at the vessel's next suitable port of call.

4.4.5. An internal audit is a good tool for measuring the effectiveness of safety management implementation on board a ship. However, to be effective an audit should be well documented, deficiencies should be clearly identified and corrective actions agreed, and progress should be monitored until deficiencies have been closed out.

4.4.6. However, the operator was unable to produce documents for the audits, such as findings and any safety actions taken as a result of the audits. Lack of audit documentation had been an observation made during the previous SSM renewal audit in 2012 by the organisation responsible for administering the vessel's SSM system.

4.4.7. The *Captain M. J. Souza* was 35 years old at the time of the accident. There is evidence to suggest that the upkeep of the vessel was a matter of priority for the owners. For example, the SSM organisation was contracted by the owner to inspect the vessel annually, even though the SSM code only required surveys to be carried out twice in every five-year period.

[24] An organisation approved by Maritime New Zealand to administer a vessel operator's SSM system.
[25] An external SSM audit does not include an inspection of ropes on board the vessel.

4.4.8. The Safe Working Practices document, which was part of the ship's SSM system, was regularly updated and covered vessel-specific activity. The following extracts contained in the Safe Working Practices document are relevant to this accident.

> Crewmembers should be familiar with the various types of ropes and twines and their special uses on board and in particular with the breaking characteristics of synthetic ropes.
>
> Crewmembers should always ensure that they use ropes only for the purpose for which they are intended. Care should be taken that all ropes in use are in good condition and have strength appropriate to their application.
>
> Ropes should be examined frequently for abrasions and broken, deteriorated or displaced fibres or strand and other defects.
>
> A splice should be used where possible in place of a knot, which weakens rope to a greater extent.
>
> During the handling of mooring lines or other wires or ropes, crewmembers should take care not to stand in a bight[26].
>
> During the pursing operation, crewmembers should avoid standing in a position where they will be endangered should a wire break out from a sheave or roller for any reason.

4.4.9. However, contrary to the Safe Working Practices document:

- There were no documents on board to confirm the origin of the choker line and sample rope, or how long these ropes had been on board.
- The reported new sample of rope removed from the vessel was tested and found to break at an average breaking load of 22,993 kg, less than half of its expected breaking load of about 52,752 kg.
- The choker line had broken a few weeks previously while in use. The failed rope was in poor condition and should have been replaced, but instead it was put back into service.
- The broken splice at the end of the rope was replaced with a bowline knot.
- The location on deck where the crew routinely stood to throw dye bombs into the water was within the swinging radius of the choker line, which could come under sudden tension in the event of the sling failing.

4.4.10. The operator's Safe Working Practices document covered five topics that included safety on deck and safety in fishing operations. It described purse seining as a particularly dangerous method of fishing and outlined steps to reduce the risk of an accident. The document advised crew to avoid standing in positions where they would be endangered should a wire break out from a sheave or roller, and also to take care not to stand in the bight of a rope.

4.4.11. However, given the position from which the crew were required to stand and throw dye bombs into the water, this was practically unachievable (see Figure 4).

4.4.12. The *Captain M. J. Souza* had procedures and instructions for carrying out fishing operations safely, which included not standing in the vicinity of ropes. However, the instruction was generic and did not discuss vessel-specific risks, which in this case should have included the inherent risks faced by the person tasked with releasing dye bombs.

4.4.13. Since the accident the operator of the vessel has mitigated the risks by changing the location of the choker line. In doing so it has been moved away from the position where crewmembers would be expected to stand when releasing dye bombs into the water.

[26] A bight is the bent part of a rope that forms a loop.

Finding

5. The safety management system on board the *Captain M. J. Souza* provided good guidelines for the management and use of ropes on board. However, neither the crew nor the skipper nor shore management were ensuring that the safety management system was being adequately followed.

5. Findings

5.1. The choker line broke, partly because it was in a deteriorated condition caused by extreme cyclic tension (fatigue) and some degree of abrasion, and partly because the bowline knot almost certainly caused a reduction in breaking strength.

5.2. The rope that was used to make the sling was reasonably new and in good condition. It is likely that the sling failed due to the splice coming apart in service, to a point where the strands ultimately parted under tensile load.

5.3. The rope management plan on board the *Captain M. J. Souza* was not effectively managing the purchase, storage, inspection and retirement from service of the ropes on board.

5.4. It is about as likely as not that the choker rope that broke on board the *Captain M. J. Souza* began its life in service at a lower-than-typical breaking load for a rope of that size and construction.

5.5. The safety management system on board the *Captain M. J. Souza* provided good guidelines for the management and use of ropes on board. However, neither the crew nor the skipper nor shore management were ensuring that the safety management system was being adequately followed.

6. Safety actions

General

6.1. The Commission classifies safety actions by two types:

(a) safety actions taken by the regulator or an operator to address safety issues identified by the Commission during an inquiry that would otherwise result in the Commission issuing a recommendation

(b) safety actions taken by the regulator or an operator to address other safety issues that would not normally result in the Commission issuing a recommendation.

Safety actions addressing safety issues identified during an inquiry

Safety action taken by the operator of the *Captain M. J. Souza*

6.2. Since the accident the operator of the *Captain M. J. Souza* has mitigated the risk of the choker line parting and striking crewmembers by removing the rope from its current location and attaching it closer to the net and away from the position where crewmembers would stand while releasing dye bombs into the water.

6.3. The operator of the *Captain M. J. Souza* has started a rope register to identify the various ropes on board the ship and log their usage. This safety action partially addresses the safety issue relating to the requirement for an appropriate rope management system on board the ship.

6.4. The operator has reported that it has increased oversight of the vessel at turnarounds.

6.5. The operator contracted a consultant to carry out a comprehensive safety systems audit and report findings to management.

6.6. The operator updated the on-board Hazard Register to include the following amended sections.

> It is necessary that gear be checked on a regular basis and that as far as possible, crewmembers remain out of the likely path of travel of breaking gear, referred to as the Snap Back Zone.
>
> Try and anticipate where the force will go if a rope or line breaks. This area is referred to as the 'Snap Back Zone' and crew should be aware of where these zones are during fishing and other operations. Normally a rope or line under tension snaps back with a corkscrew motion - so stay out of the direct line of pull. Never apply tension to a kinked wire or line.
>
> Splices are much stronger than knots and should be properly matched to the lines or ropes with which they will be used. Listen for warning sounds that indicate excessive strain.

Safety actions addressing other safety issues

6.7. None identified.

7. Recommendations

General

7.1. The Commission may issue, or give notice of, recommendations to any person or organisation that it considers the most appropriate to address the identified safety issues, depending on whether these safety issues are applicable to a single operator only or to the wider transport sector. In this case, a recommendation has been issued to Talleys Group Limited, with notice of this recommendation given to Talleys Group Limited.

7.2. In the interests of transport safety, it is important that this recommendation is implemented without delay to help prevent similar accidents or incidents occurring in the future.

Recommendations

7.3. Despite internal audits being carried out several times each year, a damaged rope was reused and a bowline knot used to replace a broken splice. These were clear departures from the SSM system guidelines. Also, the instructions and guidelines available on the SSM system did not adequately address the issue of rope fatigue and the requirements for a retirement criterion and a usage log.

7.3.1. On 29 September 2016 the Commission recommended that the operator of the *Captain M. J. Souza*: review its internal auditing procedures to ensure that auditors make realistic assessments based on actual practices observed on board; and seek verification that documented procedures are being followed by the crew and they are appropriate for the task. Audit findings should be recorded together with any safety actions taken as a result of the audit. (020/16)

On 20 October 2016, the Chief Executive Officer of Talleys Group Limited replied:

> Since August 2014 we have implemented a programme to improve the Health and Safety culture on this vessel. This started wit an internal review of our Health and Safety Systems (ashore and on board) governing the *Capt M J Souza* and following that review, we have taken several steps to improve Health and Safety outcomes which include:
>
> 1. Heightened oversight of the documented H & S procedures on the vessel at turnarounds by the vessel manager and operations manager including debriefing key staff on the vessel on H & S compliance and addressing any new hazards that may have been identified during the trip;
> 2. Implementation of a revised assurance process on the vessel and ashore to provide evidence to shore based management that Talley's H&S protocols in fact being applied on board the vessel;
> 3. We have provided additional third party H & S training to the officers and crew of the vessel to ensure that they are aware of Talley's health and safety procedures, the hazards associated with their tasks and that they are operating safely;
> 4. Addressed and improved communication structures between senior management and senior vessel staff;
> 5. Setting out company expectations regarding H & S aboard the vessel and the consequences of departure from these expectations;
>
> Further, when the vessel returns to NZ after its current Pacific Season in December 2016, we have identified an independent Health and Safety expert who will take a trip on the vessel to audit its compliance and to report to management on the H&S culture on the vessel, their compliance with the Talley's & S programme and thereafter, if appropriate to put in place an effective change management programme.

8. Key lessons

8.1. Tying a knot in a fibre rope will reduce its strength. It is therefore important to factor in this reduction in rope strength when selecting a knot and rope for a specific operation.

8.2. Fibre ropes can fail due to cyclic tension loading, a form of fatigue damage that can be difficult to see in braided ropes. Mariners must look beyond rope surface appearance alone when deciding whether to retire ropes from service.

Appendix 1: Substantive part of rope testing report

METALLURGICAL & INDUSTRIAL CONSULTANTS LTD

MIC

Level 9, CMC Building
89-95 Courtenay Place
P O Box 2346, Wellington 6140, NZ

MIC ref: M1144; SMS Ref : 2014-1005
Your Ref: Inquiry number 14-203 and purchase order 6116

Date 29.1.15

Transport Accident Investigation Commission
P.O Box 10 323
The Terrace
Wellington 6143

Attention: Naveen Kozhuppakalam

TAIC ref: 14-203 Fatality on board Capt. MJ Souza

Examination and Testing of Fishing Ropes

3.1 Incident Rope

- The incident break started at approximately the same axial location all around the circumference of the rope, indicated by the red rectangle in Figure 2a.
- The break had an overall appearance somewhat resembling an open flower, fairly evenly rounded with 'feathered' ends to the strands, see Figure 2b.
- The break exhibited splaying of the outer strands over a length of between about 70 and 130 mm, mostly 80-120 mm and between about 30 and 80 mm, mostly 60-70 mm for the strands immediately beneath the outer strands. A few of these inner strands extended to about 130 mm in length.
- All strands exhibited similarly twisted fibres from manufacture.
- Eighteen of the outer strands were teased apart from adjacent strands and folded back to reveal a sub-surface layer of strands, see Figure 2c. This showed the inner surface of the outer strands and the sub-surface strands to be cleaner than the outside surface of the rope. The rope was free of significant foreign debris such as solid particulates, grease, weed and animal matter. It was reported by TAIC that the rope had not been cleaned after the incident.
- Many of the ends of the outer strand fibres were curled and tangled while the great majority were relatively straight and not substantially tangled, see Figure 2d.
- The fibres had broken at similar lengths at the end of the broken strands, up to about 30 mm, but mostly well within about 10 mm, see Figure 2d and Figure 2e.
- Within the folded-back outer layer strands, there were braided strands that had broken with all fibres poking through the strands for a short length, as indicated by the red circles in Figure 2e.
- The fibres in the sub-surface strands had broken within a length of about 30 mm of the end of each strand. These were also mostly relatively straight, see Figure 2f.
- The outside surface of the remainder of the rope, from the broken end to the cut end, had a partially woolly, or fuzzy, appearance in general along the entire length and around the entire circumference. Very many tufts, the ends of broken fibres in strands, were discretely present at strand crossover points, see Figure 3, where the adjacent strands were relatively undamaged. These tufts were revealed more clearly for the photograph by gently brushing the surface with a gloved hand in the opposite direction

to their general orientation which was towards the broken end. This made them stand up more from the surface, as shown by Figure 3a-c. They were darker than the relatively intact outer strands between them and the length of the protruding fibres was similar. Between the tufts, the adjacent lighter coloured surface strands exhibited no substantial abrasive wear. The observed damage morphology was uniformly distributed along the length of the rope. This damage morphology was consistent with extreme cyclic tensile loading[2], the latter represented by figure D002 on page 53 of the reference literature. Some abrasion was most likely also present, because the lengths of the tufts was similar. From the aspect of abrasion, the damage was judged to be in the category 5-6 in the Samson "Inspection & Retirement Pocket Guide, Abrasion Comparator"[3]. However, the damage more closely resembled cyclic tension loading than abrasion, owing to its uniform appearance, the damage through the rope section (see section "Examination after breaking load testing" below) and the general stiffness of the rope.

- The general resistance of the rope to deformation by hand was felt to be even all along its length. The rope could not easily be squeezed in the circumferential direction by a gloved hand. It was fairly hard, consistent with damage by cyclic tension loading (fatigue) in which fibres become tangled, some break and may even powder and fill voids. With the rope lying on the backing paper, supported by a concrete floor beneath, a length of 300 mm was selected at random. A hand was placed at each end of this region, the rope was then grasped and the hands were moved axially towards each other. This provided a crude axial compression test to measure the suppleness and looseness of the rope. Using a ruler alongside the rope, the axial movement of the rope was measured and found to be approximately 40 mm, i.e. the rope compressed by 40/300 x 100% = 13%.
- A single, relatively large tuft was present at about 2330 mm from the broken end, see Figure 3c.
- The length of the rope was approximately 3.7 m excluding the break.
- One strand was coloured blue and braided in such a way that the intermittent blue marking identified the cover of rope being consistent with a polyester, double braided rope[1].
- The outer strands of the rope were not prised apart in order to examine damage of the underlying strands, owing to the rigidity and tightness of the rope, and the desire to minimise further damage prior to the breaking load testing.
- No evidence of deliberate cutting, as might have occurred with a knife for example, was observed.
- No evidence of severe or localised abrasion was observed on the outer strand fibres, see Figure 3.
- No hockles, twists, kinks or corkscrews, which are not normally associated with braided ropes, were observed.
- The rope was observed to be slightly oval, i.e. consistently narrower in one direction. The diameter of the rope was, therefore, measured mutually at right angles in 10 places, roughly equally spaced along its length. The results are presented in Table 1.

Table 1 Diameter measurements along the rope, mm.

Broken end	1	2	3	4	5	6	7	8	9	10	Cut end
Narrow dimension	45.0	43.0	45.0	43.1	43.8	42.8	42.7	45.3	45.4	44.8	
Broad dimension	53.0	54.2	53.7	52.1	53.2	51.5	52.4	51.6	51.5	52.3	
Average	49.0	48.6	49.4	47.6	48.5	47.2	47.6	48.5	48.5	48.6	

The rope was between 6.1 and 11.2 mm different from one measurement to the other at the same location. The slightly oval shape was probably caused by the lay on the drum.

The average diameter was between 47.2 and 49.4 mm. This is fairly consistent, very close to the likely manufactured diameter and not indicative of permanent strain.

Visual examination after breaking load (BL) testing

Fifteen cover and fifteen core strands from the rope were examined after breaking load testing by BridonCookes. The following were observed:

- Deconstruction of the ropes for testing confirmed that they were of a double braid type with a braided cover over a braided core.
- The cover strands, see Figure 4, and core strands, see Figure 5, of an untested section exhibited tangled fibres and broken fibres, consistent with cyclic loading damage. This damage was uniform along the length and through the thickness of the exposed strands.
- After testing, the broken ends of the cover strands, see Figure 6a, and core strands, see Figure 6b, were 'feathery' and similar to the ends of the strands in the rope's incident break, see Figure 6c.

3.2 SLING ROPE

- Both ends exhibited a core that had separated from the cover, possibly at leg junctions. No tearing had occurred at the leg junction, see Figure 7. This rope had two, almost identical, very loose, broken ends, see Figure 8.
- The strands ended at different lengths from where they started to separate. The overall lengths of the breaks were about 480 mm at one end and about 500 mm at the other end, see Figure 8.
- The strands were relatively intact at their initial separation but the fibres became more separated from each other towards the ends of the strands.
- The strands and fibres appeared relatively clean and free of staining, other than a general, moderate discolouration and two localised coloured marks that looked like dye stain on one strand at each end, see Figure 8a and Figure 8b. No substantial foreign debris was observed.
- The general outside condition of the rope appeared to be relatively free from damage, compared with the Incident Rope, but exhibited some broken fibres protruding from the

otherwise smooth surface, see Figure 9. One second layer strand fibres had partially pulled out beyond the surface strands, as shown by the circle in the figure.

- The sling had a very soft and supple feel. It could easily be squeezed in the circumferential direction by hand and move axially. A compression test similar to that which was performed on the Incident Rope, using the same initial length was performed on this rope. The initial 300 mm was shortened to 160 mm, a 47% reduction.
- The rope had 4 constrictions at various locations along its length. Two of these had been made by tightly wrapping and finally tying many turns of black cord around the rope and these two cords appeared to be intact. The other two were loose and did not constrict the rope significantly. The core could easily be pulled out of the cover except where the two tight constrictions held it, see Figure 10.
- There was occasional faded blue marking on a strand, similar to that which was present on the Incident Rope.
- The Sling was approximately 3.4 m between the broken ends.
- No evidence of cutting was observed.
- No evidence of severe abrasion was observed.
- No hockles, twists, kinks or corkscrews, which are not normally associated with braided ropes, were observed.
- No evidence of cyclic damage was observed.

3.3 NEW ROPE

- The New Rope sample was relatively soft and flexible in many places, much more so than the Incident Rope but not as much as the sling. It could be squeezed circumferentially by hand to a reasonable degree in many places. However, there were 5 substantial regions (one region about 350 mm long) along its length, particularly where it had been flattened, that could not be squeezed at all and the rope felt rigid. The rope, see Figure 11a, was generally white but exhibited several patches of brown and several regions of flattening, see Figure 11b. These regions appear to have been damaged by either mechanical means or heat, or both.
- The surface was very smooth compared with the other two ropes with no noticeable breaks in fibres.
- An axial compression test was performed on this sample where the rope was flexible and compressible, in the similar manner to that which was used on the other two ropes. The 300 mm initial length reduced to 150 mm, a reduction of 50%.
- The rope was approximately 4.1 m long.
- No diameter measurements were made on this sample owing to the great variability caused by physical and/or heat damage.

Fifteen cover and fifteen core strands from the New Rope were visually examined after breaking load testing. The following were noted:

- Cover – no significant evidence of broken fibres along the de-stranded sample was observed, see Figure 12.
- Core – similar to the cover, see Figure 13.

4 MECHANICAL TESTING

Breaking load tests were completed in two ways, as follows:

Test 1 – Testing on full section thickness samples of the Remnant Rope with and without a bowline knot, see section 4.1.

Test 2 – Testing using rope strands on the Incident and New Rope, see section 4.2.

All testing was performed by BridonCookes using the international standard BS EN ISO 2307:2010[4].

4.1 TEST 1 – REMNANT ROPE SAMPLES

A 32 m length of rope, the Remnant Rope, was divided into full-thickness samples and tested for breaking load. This Remnant Rope was in relatively good and, possibly unused condition compared with the Incident Rope and in similar condition to the New Rope sample that was tested after de-stranding (see section 4.2 and BridonCookes' report in Appendix B for further information). That is, the condition was reported by BridonCookes to exhibit crushing and some discolouration.

The 32 m length provided a maximum of 5 shorter, cut lengths suitable for testing, as follows:

- Three samples were spliced at both ends for breaking load (BL) tests on the rope without knots and
- TAIC reported that a bowline knot had been used on the Incident Rope. Therefore, two samples were spliced at one end and knotted at the other end using a bowline to determine any influence imparted by the knot.

4.1.1 Breaking load of Remnant Rope

The three samples, (labelled B, C and D by BridonCookes) spliced at both ends gave breaking strength values of 20174, 24258 and 24523 kg, with an average of 22985 kg[5] (refer to Appendix A). The sample giving the lowest value broke at the splice. However, the value obtained is fairly similar to those obtained by the other samples that broke mid-sample. Unicord's stated "tensile strength" (breaking strength) for new rope is 125200 lb[6] (56790 kg).

4.1.2 Breaking load of Remnant Rope with a bowline knot

The two samples (labelled A and E by BridonCookes) gave breaking strengths of 15676 and 15018 kg and both samples broke at the bowline knot.

Evaluation of breaking load results

- The results obtained were consistent, though the sample that broke at the splice gave a slightly lower value than the other two similar samples. The manner in which the latter sample was arranged on the test machine was reported by BridonCookes not to have had an effect on the result.
- The average breaking strength of the rope samples without a knot was approximately 23 tonnes. This is 40% of the stated strength as new.
- The average breaking strength of the rope samples with a bowline knot was approximately 15.3 tonnes. This is 27% of the as-new breaking strength.

- The breaking strength of the rope samples with a bowline knot was approximately 66% of the strength of the rope samples without a knot. Since the breaks occurred at the knots, it is considered that the knot reduced the breaking strength by a third.

The results are presented in Table 2.

Table 2 Summary of BL values with and without bowline knots, kilograms.

	Number of samples	Values	Average	Location of break
Spliced both ends, no knots	3	20174 24258 24523	22985	2 at mid sample, 1 at splice
Spliced one end and bowline at other end	2	15676 15018	15348	Both at bowline knot

Stretch

The amount of stretch in samples B, C and D was 48%, 34% and 41% respectively.

The amount of stretch in the knotted samples was not determined owing to any possible slippage in the knot influencing the results.

4.2 Test 2 – De-stranded samples

4.2.1 Breaking load strength test method

The Incident and New Ropes were also tested by BridonCookes Ltd, Auckland, for BL strength. Owing to the condition of the two ropes, they could not be tested as complete ropes. In addition, the samples were too short to accommodate effective splicing to produce “eye” ends. Instead, testing was performed on strands removed from the ropes, in accordance with the international standard BS EN ISO 2307[4]. This standard allows the testing of de-stranded ropes and applies a correction factor in a calculation of the realised breaking load (RBL) of the full-thickness rope.

The method for selecting a portion of the samples for testing was recommended to BridonCookes by SMS. This and the testing programme used are provided in BridonCookes’ report[7] (refer to Appendix B).

Breaking load tests were also conducted on 3 strands removed from the cores of each of the Incident and New Ropes. Note that it is not known how close to the knot the break on the Incident Rope occurred.

4.2.2 Results

Detailed results from the testing of 15 strands from each of the cover and core of both the Incident and New Ropes are presented in Appendix B. The results are summarised in Table 3 which also includes BridonCookes’ calculated breaking loads for the full-thickness ropes.

BridonCookes verbally reported that during de-stranding, the Incident Rope was observed to release powdered fibres. This is consistent with damage by cyclic tension loading.

The degree of elongation, or stretch, of a rope can provide evidence of significant creep in a rope. The degree of elongation in the strands during testing to the peak load was recorded and the results have been evaluated by SMS. These are summarised in Table 3.

Table 3 Summary of BL test results, kilograms.

	Incident Rope		New Rope	
	Cover	Core	Cover	Core
Average	105	243	509	623
Standard Deviation	48.10	48.34	35.33	65.92
Range	10-200	153-352	428-565	466-710
No. of strands	48	25	48	25
Av. of all strands	174		566	
Calculated Realised Breaking Load (RBL) of rope (See note 1)	10036		32638 (new rope breaking strength as manufactured 56790[6])	

Note 1: A realisation factor for the rope, as per BS EN ISO 2307 of 0.790[4] was used.

Evaluation of BL results

The following were noted from the results:

- In order of strength, weakest to strongest were Incident Rope cover, Incident Rope core, New Rope cover and New Rope core.
- Not all strands broke completely. Some fibres were left unbroken. Nevertheless, the peak load was obtained.
- The cover of the Incident Rope was 43% as strong as its core and 21% as strong as the cover of the New Rope. This showed that the cover had suffered more damage than the core which is to be expected.
- In contrast, the cover of the New Rope was 82% of the strength of the core in the same rope.
- The core of the Incident Rope was less than 39% the strength of the core of the New Rope.
- The RBL of the complete, full-thickness, Incident Rope was 31% that of the New Rope and 17.7% of the BL of a new, as-manufactured rope from Unicord.
- The RBL of the complete New Rope was 57.5% of the expected strength of a new Unicord rope and an approximately similar percentage of similar ropes manufactured by, for example, Samson and NOVABRAID and the expected strength according to the BS EN ISO 2307 standard.
- The results of the de-stranded ropes samples should be used with caution because to permit testing, the strands should be substantially intact. That is, the calculation of RBL does not account for strands that might have been completely broken and therefore, not tested, but does account for strands in a deteriorated condition. As 15 strands from 48 in the cover and 15 strands from 25 in the core were tested, the results are considered to be fairly representative of all deteriorated strands.

- The standard deviations of the core strands in both ropes were greater than the standard deviations of the cover strands which is surprising. However, all standard deviations were of a similar order of magnitude.
- The form of the load v time (reported to be linearly equivalent to elongation) plots for the Incident Rope differed markedly from those of the New Rope, in that they exhibited much more 'noise' that was indicative of the peculiar morphology of the damaged strands, i.e. this 'noise' represented fibres that were tangled and perhaps some that were breaking during application of the load.

Stretch

The strands exhibited considerable elongation. The results are presented in Table 4.

Table 4 Elongation in the strands during testing to the peak load, mm.

	Incident rope		New rope	
	Cover	Core	Cover	Core
Average	35.8	49.5	53.0	49.8
SD	13.18	6.89	5.95	6.42
Range	8.7-55.2	35.9-62.9	37.9-60.6	40.3-59.9
Av. of all strands	42.7		51.4	

D. M. Standen Ltd reports[8] an elastic elongation percentage of complete nylon braided ropes of up to 46% before breaking. The obtained results were consistent with this figure.

To determine whether evidence of creep was present the following procedure was adopted:

The average peak BLs for the covers of the Incident and New Ropes were 105 and 509 kg respectively. Three of the tested strands with similar peak BLs to these averages were selected and their elongation at 30% peak BL determined from the load v time (elongation) graphs in Appendix B. The tested strands produced elongations values of:

Incident cover – 47% (strand 1), 44% (strand 3) and 36% (strand 6).

New Rope – 55% (strand 3), 47% (strand 9) and 55% (strand 14).

Since these results are consistent with stretch values reported in the literature for new rope, they are considered not significant enough to indicate the presence of creep.

Tests on core strands with bowline knot.

The results of BL tests on 3 strands from the cores of both the Incident and New Ropes are presented in Table 5.

Table 5 BL test results on strands with a bowline knot, kilograms (not summarised in BridonCookes' report).

	Incident Rope	New Rope
1	261	459
2	261	459
3	330	558
Average	284	492
Average of the strands without bowline knots (from Table 3)	243	623

In these tests, the breaks were reported to have occurred away from the knots and, therefore, reflect the strength of the strands rather than any adverse effect of the knot. The strength of the Incident Rope strands was slightly greater than the average of the 15 strands tested without bowline knots. In contrast, however, the strands of the New Rope all broke at lower loads than the average of the 15 strands without knots.

The results showed that the strength of the strands was not appreciably affected by the presence of bowline knots. This contrasts with the literature[3,7] which states that for complete ropes there could be as much as 50% reduction in BL strength. However, the data obtained in these tests are too few to draw significant conclusions. More and different samples would have to be tested to form any conclusions about the effect of bowline knots on strands. Moreover, the effect of a knot in a full-thickness rope might well be different from the effect of a knot on a single strand, owing to aspects such as friction and having a separate cover and core.

5 Chemical analysis

Chemical analysis using the Fourier Transform Infra-Red (FTIR) method was conducted on small pieces of the Incident and New Ropes by Flinders Cook Ltd, Auckland, to identify the polymer constituents of manufacture. This showed that the two rope samples were made of the same materials, nylon (polyamide) with a minor component of polyethylene terephthalate (PET) as a co-polymer. Flinders Cook's report[9] is provided in Appendix C. The two ropes gave spectra that are considered representative of identical materials.

6 Discussion

6.1 Summary of all BL test results.

Table 6 Summary of all test results, kilograms (% of average BL of the complete rope samples tested in Phase 2).

	Test 1 – full-thickness Remnant Rope (unused)			Test 2 – de-stranded rope			
				Incident Rope		New Rope	
	Splice/knot ends	Location of break	Avg. BL (% of stated BL*)	Complete rope calculated RBL (% of *)	Individual strands, averages	Complete rope calculated RBL (% of *)	Individual strands, averages
Without knot	Spliced both ends	Mid sample	22985 (40%)	10036 (17.7%)	174	32638 (57.5%)	566
With knot	Spliced one end, knot at other end	At knot	15348 (27%)	-	284	-	492

* The values are compared with the expected 56790 kg BL according to the manufacturer.

6.2 Key findings

Key findings from the examination and testing include the following.

6.2.1 Incident Rope

- The general damage morphology of the Incident Rope was consistent with predominantly cyclic tension loading, a form of fatigue damage. This was evidenced by the following:
    - Broken fibres from strands in the Incident Rope protruding through outside, adjacent strands.
    - Broken fibres in the core.
    - Tangled fibres in both cover and core strands.
    - Powdery remnant fibres released during de-stranding.
    - The damage morphology was fairly uniform, not localised, all along the Incident Rope and around its circumference.
    - The rope was harder and much less supple than the New Rope sample. This was demonstrated by the squeeze and crude axial compression tests.
    - The plots of load v time (elongation) being much less smooth than those of the New Rope.
- The BL of the Remnant Rope samples was about 23 tonnes which is about 40% of the minimum BL provided by the supplier.
- The BL of the Remnant Rope samples with a bowline knot was about 15 tonnes which is about 27% of the minimum BL provided by the supplier.
- The BL of the knotted Remnant Rope samples was 67% of that of the samples without a knot. This showed that the bowline knot reduced the BL strength of the rope by about a third and to about 27% of the manufacturer's stated BL.

- The RBL of the de-stranded Incident Rope was calculated to be about 10 tonnes which is about 30% of that of the New Rope sample and 17.7% of the manufacturer's stated BL.
- The RBL of the de-stranded New Rope was calculated to be about 33 tonnes which is about 57.5% of that expected of a full-thickness rope from the manufacturer.
- The RBL of the de-stranded Incident Rope was 44% of the BL of the tested Remnant Rope.
- The calculated strength (RBL) of the complete New Rope, based on its de-stranded samples, over-estimated the BL of the rope when its result was compared with that of the Remnant Rope.
- The damage on the Incident Rope resembled the illustration of extreme cyclic tensile loading provided in the document "Fiber Rope Inspection and Retirement Criteria, International Guideline CI 2001-04, Cordage Institute"[2]. This damage mechanism was distinguishable from abrasion damage because abrasion damage is usually more localised and internal fibres are not usually affected. Notwithstanding this, the surface appearance of the damage also partially resembled category 5-6 of the Samson Inspection and Retirement Pocket Guide, abrasion damage comparator[3], though the damage was more clearly defined and less general than if it had been predominantly abrasion damage. Both damage mechanisms can sometimes produce a somewhat similar external appearance, as illustrated in the literature[2,3,10], depending on the way in which the rope has been used.
- The materials of manufacture of the Incident and New Ropes were similar. This finding validated the identification of the rope type, the breaking load test results and visual comparisons.
- Chemical analysis determined that the ropes were manufactured predominantly from nylon. (The blue dyed strand in the ropes was not consistent with nylon ropes in the Samson and NOVABRAID ranges nor in the BridonCookes and Erling Haug AS ranges.) The markings could not be identified on Unicord's website. Nylon ropes are generally listed as suitable for fishing applications.
- The morphology of the broken ends of the tested pieces was similar to that of the incident break, indicating overload in tension.
- Creep is considered not to have been significant in the failure.

It is clear from the evidence that the Incident Rope was in a deteriorated condition at the time it broke. Visual examination of the rope revealed extreme cyclic tension damage (possibly also due to bending induced tension), and the outer surface also resembled abrasion category 5-6. The ultimate failure was most likely caused by overload of the remaining relatively intact strands, after many fibres had already broken in service. This in-service damage substantially reduced the strength of the rope, to the point that it exhibited a small fraction of its original breaking strength. While it could not be stated that the break occurred at a bowline knot, such a knot was reported to have been used and tests, and the literature, have shown that the presence of a bowline can dramatically reduce the strength of the rope.

It is possible that water and, perhaps, UV have caused a reduction of the BL of the rope. However, the extent to which crushing and, perhaps, heating causing the brown discolouration, have influenced the properties of the rope is not known.

TAIC reported that the Incident Rope might have broken at a bowline knot. (This could not be confirmed because the portion of the rope containing the knot was reported to have been lost in the ocean.) The BL of the complete Remnant Rope with a bowline knot, as tested in Test 1, was about 15 tonnes (67% of the BL without a knot). The calculated RBL of the Incident Rope in Test 2 was about 10 tonnes. The fact that no unbroken strands were accounted for in the tests of the de-stranded rope, and the subsequent RBL determination, suggests that the RBL may have been over-estimated. Nevertheless, if the reduction in BL of 33%, as shown by the Test 1 results, is applied to the RBL of the Incident Rope, giving 6.7 tonnes with a bowline knot, it can be expected that the Incident Rope might have experienced about 6.7 tonnes if it broke at the bowline knot. This load would then represent 12% of the expected BL of a new rope from the manufacturer.

The aspect of shock loading, whether it be an isolated incident or several incidents cannot easily be detected by visual examination and BL testing and, therefore, has not been considered in this examination. Shock loading may cause internal melting of fibres[2]. However, no significant evidence of melting was observed. Shock loading incidents are best investigated through records of the service history of the rope. The possibility of the Incident Rope snagging cannot be discounted and requires further investigation.

Similarly, creep (permanent cold strain) is best investigated through records, as this is also not easily detectable in a used rope and the rope may retain its full strength up to the time it fails, even though it might have suffered creep. Creep reduces the elongation at failure during BL tests. So, the fact that the rope stretched a lot prior to breaking suggests that creep had not occurred.

6.2.2 Sling

The core was very loose inside the cover, held only where two cords had been tied around the cover.

With the rope in the condition supplied, it is difficult to say that the splicing had not been performed effectively in accordance with general industry guidelines[11,12,13]. However, the presence of the tying cords strongly suggests that this was the case. Furthermore, that there were breaks at both ends and not straight cuts indicates that a splice might have come apart, perhaps somewhat gradually in service. The sling then most likely experienced loads sufficient to cause the observed predominantly tensile breaks.

6.2.3 Rope

Results from Test 1 of the Remnant Rope without a knot showed that the breaking strength was about 23 tonnes. This value is about 40% of the expected strength of a new rope of similar design and size manufactured by leading manufacturers. Note, however that the rope had also suffered some damage due to crushing on the drum and it is not known to what extent the rope had been influenced by the environment in which it had been kept. In other words, degradation from water and UV might have caused a loss in strength properties. This is to be expected.

The condition of the New Rope used in Test 2 showed that it had suffered considerable crushing, possible heat damage and a low RBL to the extent that it is expected, based on the standard that it would not be recommended by a rope inspector for use under typical loads.

It is presumed that the rope was made to have a BL of about 56.8 tonnes, as stated by the manufacturer. However, it might have been made to a lower BL rating.

6.3 COMMENT ON KNOTS

"Fiber Rope Inspection and Retirement Criteria"[2] states: "Unless the application is specifically designed to use knots, they must not be used unless the working load is reduced by an appropriate amount (based on 50% of published rope strength, unless specific contrary data is available). It is cause for retirement or downgrading if a knot is not called for and cannot be removed or the rope reveals structural damage due to knotting." The results obtained from tests on strands with bowline knots showed BL values not very different from those obtained from the strands without knots. Testing of individual strands may not, therefore, be representative of testing on complete ropes. In contrast, the results obtained from Test 1, showed that the rope's breaking load was reduced by about 33% with the presence of a bowline knot. Reported loss of strength values due to bowline knots differ in the literature from 25-30%[14] to be as high as 70%; so, the results obtained in the tests are consistent with the literature.

6.4 COMMENT ON NYLON

Nylon is known to absorb moisture. This property of the polymer has been well documented in the past[14,15,16]. The same literature states that the breaking load might be reduced by as much as 20% due to the absorption of moisture. However, this effect can be reversed to an extent by drying out the rope completely. It is expected that this change in property is considered when nylon rope is used in applications that expose the rope to water.

Nylon is also used where elasticity (stretch without permanent deformation) is required. Considerable stretch was noted in the tests.

7 CONCLUSIONS

1. The Incident Rope broke due to tensile overload after substantial in-service cyclic tension damage had occurred, probably accompanied by some external abrasion and possibly affected by the environmental conditions (water and UV).
2. It is asserted that the Incident Rope was in a substantially deteriorated condition at the time of failure.
3. The realised breaking strength of the Incident Rope was determined by calculation to be about 44% of the average of the BLs of the Remnant Rope samples.
4. The BL of the Remnant Rope was about 40% of the BL stated by the manufacturer for new rope.
5. The Incident Rope RBL was approximately 17.7% of the manufacturer's stated BL for new rope.
6. It is suggested that the load on the Incident Rope, if it broke at a bowline knot, might have been about 12% of the expected BL of a new rope from the same manufacturer.
7. The condition of the sling strongly suggested that a splice had not been created effectively.
8. It is asserted that the New Rope sample would most likely have provided less than expected properties had it been used in a similar manner to Incident Rope. This has been substantiated by the Test 1 results.
9. The results have been based on relatively few tested samples. It would be prudent to additionally consider testing intact, unused rope that has been exposed to UV and

seawater for a considerable period to determine what effect, if any these factors might have on the breaking load.

Geoff Scrase

Scrase Metallurgical Solutions in association with Metallurgical & Industrial Consultants Ltd

Note: Samples and specimens received by this office will be retained for three months from the date of this report. After this time components will be discarded unless we receive specific instructions to the contrary.

Appendix 2: High Performance Double Braid Nylon Fiber Rope Standard

HIGH PERFORMANCE DOUBLE BRAID NYLON FIBER ROPE STANDARD: CI 1310-97
July, 1997

Table 3
PHYSICAL PROPERTIES

Nominal Size[1] Diameter In.	(mm)	Size No.	Linear Density[2] lbs/100'	(ktex)	New Rope Min. Breaking Force[3] Lbs.	daN)	Design Factor Range[4]	Working Load Limits[5] Range Lbs (daN)
1/4	(6)	3/4	1.65	(24.6)	2,000	(890)	5–12	167 (74)–400 (178)
5/16	(8)	1	2.6	(38.7)	3,150	(1,401)	5–12	263 (117)–630 (280)
3/8	(10)	1 1/8	3.7	(55.1)	4,400	(1,957)	5–12	367 (163)–880 (391)
7/16	(11)	1 1/4	5.1	(75.9)	6,000	(2,669)	5–12	500 (222)–1,200 (534)
1/2	(12)	1 1/2	6.6	(98.2)	7,800	(3,469)	5–12	650 (289)–1,560 (694)
9/16	(14)	1 3/4	8.4	(125)	9,900	(4,404)	5–12	825 (367)–1,980 (881)
5/8	(16)	2	10.4	(155)	12,200	(5,427)	5–12	1,017 (452)–2,440 (1,085)
3/4	(18)	2 1/4	15.0	(223)	17,350	(7,717)	5–12	1,446 (643)–3,470 (1,543)
7/8	(22)	2 3/4	20.4	(304)	23,400	(10,408)	5–12	1,950 (867)–4,680 (2,082)
1	(24)	3	26.6	(396)	30,250	(13,455)	5–12	2,521 (1,121)–6,050 (2,691)
1 1/16	(26)	3 1/4	30.0	(446)	34,000	(15,123)	5–12	2,833 (1,260)–6,800 (3,025)
1 1/8	(28)	3 1/2	33.6	(500)	37,800	(16,813)	5–12	3,150(1,401)–7,560 (3,363)
1 1/4	(30)	3 3/4	41.5	(618)	46,450	(20,661)	5–12	3,871 (1,722)–9,290 (4,132)
1 5/16	(32)	4	45.7	(680)	51,000	(22,685)	5–12	4,250 (1,890)–10,200 (4,537)
1 1/2	(36)	4 1/2	59.7	(888)	66,000	(29,357)	5–12	5,500 (2,446)–13,200 (5,871)
1 5/8	(40)	5	70.0	(1,042)	77,300	(34,383)	5–12	6,442 (2,865)–15,460 (6,877)
1 3/4	(44)	5 1/2	81.0	(1,205)	89,300	(39,721)	5–12	7,442 (3,310)–17,860 (7,944)
2	(48)	6	106	(1,577)	116,300	(51,730)	5–12	9,692 (4,311)–23,260 (10,346)
2 1/8	(52)	6 1/2	120	(1,786)	130,700	(58,135)	5–12	10,892 (4,845)–26,140 (11,627)
2 1/4	(56)	7	134	(1,994)	145,800	(64,852)	5–12	12,150 (5,404)–29,160 (12,970)
2 1/2	(60)	7 1/2	165	(2,456)	179,300	(79,753)	5–12	14,942 (6,646)–35,860 (15,951)
2 5/8	(64)	8	181	(2,694)	196,600	(87,448)	5–12	16,383 (7,287)–39,320 (17,490)
2 7/8	(68)	8 1/2	217	(3,229)	232,600	(103,460)	5–12	19,383 (8,622)–46,520 (20,692)
3	(72)	9	237	(3,527)	251,700	(111,956)	5–12	20,975 (9,330)–50,340 (22,391)
3 1/4	(80)	10	288	(4,286)	299,700	(133,307)	5–12	24,975 (11,109)–59,940 (26,661)
3 1/2	(88)	11	345	(5,134)	357,300	(158,927)	5–12	29,775 (13,244)–71,460 (31,785)
4	(96)	12	420	(6,250)	427,700	(190,241)	5–12	35,642 (15,853)–85,540 (38,048)
4 1/4	(104)	13	488	(7,262)	494,600	(219,998)	5–12	41,217 (18,333)–98,920 (44,000)
4 1/2	(112)	14	561	(8,349)	558,400	(248,376)	5–12	46,533 (20,698)–111,680 (49,675)
5	(120)	15	656	(9,763)	648,000	(288,230)	5–12	54,000 (24,019)–129,600 (57,646)

(1) Diameter is approximate and is actually determined by linear density. See Safe Use Guideline (CI 1401), Page 4 A.
(2) Linear Density is considered standard. Tolerances are 3/16" - 5/16" diameters inclusive ± 10%, 3/8" - 9/16" inclusive ± 8% and 5/8" and up ± 5%. Ktex (kilotex) is the metric linear density value.
(3) New rope Minimum Breaking Force is based on data from a number of manufacturers and represents a value of 2 standard deviations below the mean, established by regression analysis.
(4) For dynamic applications, refer to Safe Use Guidelines (CI 1401) on page 4 A.
(5) Working Load Limit is determined by dividing the new rope Minimum Breaking Strength by the selected Design Factor. Important information is given in CI 1401-92.

Appendix 3: SWOS test results

Test Results

Project Name: TAIC

Focus Area: Testing

Product-Process: Quality Assurance

SWOS Document Number: TBD

Prepared By: Carson Briles

Version Control

Version	Date	Author	Change Description
1	05/06/15	Carson Briles	Initiate

1.0 Purpose

TAIC contracted SWOS to preform rope testing on a TAIC supplied rope sample. The purpose of this document is to provide the detailed results of the testing preformed at SWOS testing facility, of this rope sample. The procedures in this document are based on ISO 2307 standards for testing fiber ropes.

1.1 SWOS Test Facility Details

SWOS operates a variety of testing equipment ranging from 200lbs – 900,000lbs capacity. The test beds used in this testing are listed below. All testing equipment is calibrated yearly and checked periodically for accuracy based on E4-13 and comply with ANSI / NCSL Z540 and MIL-STD-45662A

1.1.1 900K Test Bed Details

Machine Capacity :	900,000 LBS
Serial Number:	14792
Verification Date:	8/14/2014
Manufacturer:	HB
Machine Mode:	Tension
Calibration Range:	90,000 LBS – 900,000 LBS

*Above test bed was used for break test cycle only

1.1.2 Small Test Bed Details

Machine Capacity:	100,000 LBS
Serial Number:	14792
Verification Date:	12/11/14
Manufacturer:	HB
Machine Mode:	Tension
Calibration Range:	5,000- 100,000 LBS

*Above test bed was used for conditioning cycles only

2.1 Rope Sample Inspection

Upon arriving at the [redacted] the rope sample was examined and measured to confirm its characteristics matched the specification. Results of inspection are listed below:

Size (measured with calibrated Pi tape)	2" (50.8mm)
Construction	Double Braid Nylon
Overall wear condition	Rope appeared to be new and un used. No defects were present.
Appearance	Nylon core with Nylon jacket (jacket included 1 single blue tracer)
Storage Location	Stored in an un-marked open cardboard box

4.0 Testing Results and Photos

4.1 Sample A

Peak load (breaking Load):	106,100 LBS. (48.13 tonnes)
Location of failure:	At the end of the tapered splice tail.
Elongation:	9" 228.6 mm
Comments:	Test was seen as a successful break and failure was seen at an estimated weak point.

4.2 Sample B

Peak load (breaking Load):	130,700 LBS. (59.28 tonnes)
Location of failure:	At the end of the tapered splice tail.
Elongation:	10" 254 mm
Comments:	Test was seen as a successful break and failure was seen at an estimated weak point.

4.3 Sample C

Peak load (breaking Load):	119,5000 LBS. (54.20 tonnes)
Location of failure:	At the end of the tapered splice tail.
Elongation:	9" 228.6 mm
Comments:	Test was seen as a successful break and failure was seen at an estimated weak point.

9

4.4 Result Averages

Sample	MBS	Elongation @ 28.349 tonnes	Nominal Diameter @ 28.349 tonnes
A	106,100 LBS 48.13 tonnes	9" 228.6 mm	1-60/64" 49.225 mm
B	130,700 LBS 59.28 tonnes	10" 254 mm	1-48/64" 44.5 mm
C	119,500 LBS 54.20 tonnes	9" 228.6 mm	1-48/64" 44.5 mm
Average	118,766.6 LBS 53.87 tonnes	9.3" 236.22 mm	1.813" 46.075 mm

Recent Marine Occurrence Reports published by the Transport Accident Investigation Commission

MO-2015-202	Containership *Madinah*, loss of person overboard, Lyttelton Harbour entrance, 2 July 2015
MO-2016-202	Urgent recommendation: Cruise ship *Azamara Quest*, contact with Wheki Rock, Tory Channel, 27 January 2016
MO-2011-202	Roll-on-roll-off passenger ferry *Monte Stello*, contact with rock, Tory Channel, Marlborough Sounds, 4 May 2011
MO-2014-201	*Dream Weaver*, flooding due to structural failure of the hull, Hauraki Gulf, 23 February 2014
MO-2010-206	Coastal container ship *Spirit of Resolution*, grounding on Manukau Bar, Auckland, 18 September 2010
MO-2014-202	Lifting sling failure on freefall lifeboat, general cargo ship *Da Dan Xia*, Wellington, 14 April 2014
11-204	Container ship MV *Rena* grounding, on Astrolabe Reef, 5 October 2011
13-201	Accommodation fire on board the log-carrier, *Taokas Wisdom*, Nelson, 11 July 2013
13-202	Bulk carrier, *IDAS Bulker*, pilotage incident Napier, Hawke's Bay, 8 August 2013
12-202	Fishing vessel *Torea*, collision with uncharted rock, Foveaux Strait, 24 August 2012
09-210	Bulk carrier, *Taharoa Express*, cargo shift, Port Taharoa, 16 December 2009
10-204	Inquiry 10-204: Bulk carrier *Hanjin Bombay*, grounding, Mount Maunganui, 21 June 2010
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