



Marine Safety Investigation Unit



Transport Malta



MARINE SAFETY INVESTIGATION REPORT

**Safety investigation into the failure of a lifeboat wire rope fall
on board the Maltese registered passenger ship**

CELEBRITY CENTURY

while alongside in Kailuna Kona, Hawaii

on 26 February 2013

201302/030

MARINE SAFETY INVESTIGATION REPORT NO. 08/2014

FINAL

Investigations into marine casualties are conducted under the provisions of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011 and therefore in accordance with Regulation XI-I/6 of the International Convention for the Safety of Life at Sea (SOLAS), and Directive 2009/18/EC of the European Parliament and of the Council of 23 April 2009, establishing the fundamental principles governing the investigation of accidents in the maritime transport sector and amending Council Directive 1999/35/EC and Directive 2002/59/EC of the European Parliament and of the Council.

This safety investigation report is not written, in terms of content and style, with litigation in mind and pursuant to Regulation 13(7) of the Merchant Shipping (Accident and Incident Safety Investigation) Regulations, 2011, shall be inadmissible in any judicial proceedings whose purpose or one of whose purposes is to attribute or apportion liability or blame, unless, under prescribed conditions, a Court determines otherwise.

The objective of this safety investigation report is precautionary and seeks to avoid a repeat occurrence through an understanding of the events of 26 February 2013. Its sole purpose is confined to the promulgation of safety lessons and therefore may be misleading if used for other purposes.

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SGS Herguth Laboratories.

Shell Marine (US) Co., Houston.

GLOSSARY OF TERMS AND ABBREVIATIONS

AB	Able Seaman
AMOS	Asset Management Operating System - a commercially available planning system
Circ.	Circular
CP Propellers	Controllable Pitch Propellers
EDS	Energy Dispersive X-ray spectroscopy
Wire Rope	Rope used to lower and raise a tender boat or lifeboat
IMO	International Maritime Organization
ISM	International Management Code for the Safe Operation of Ships & Pollution Prevention
LR	Lloyd's Register
LT	Local Time
MSC	Maritime Safety Committee
MSIU	Marine Safety Investigation Unit
OEM	Original equipment manufacturer
RLA	Rapid Lubricants Analysis
SEM	Scanning Electron Microscope
Slushing	The process of applying grease or oil as a temporary protective coating against corrosion
SMS	Safety Management System
SOLAS	International Convention for Safety of Life at Sea, 1974 as amended
Tender boat	A boat used to ferry people from ship to shore; also serves as a lifeboat
USA	United States of America
UTC	Coordinated Universal Time
WPI	Wear Particle Index

SUMMARY

On 26 February 2013 at 0545(LT), *Celebrity Century* was anchored in Kailua Kona, Hawaii, commencing tender boat operations. When tender boat/lifeboat no. 10 (tender boat no. 10) was extended, and before lowering it, the forward wire rope fall parted, causing the tender boat to swivel on the aft hook. The tender boat remained hanging by the aft hook, which then ripped off its base, causing the boat to fall in the water, bow first, at an approximate angle of 45° and a height of 15 m.

The tender boat remained afloat upright. The fall caused damage to the tender boat's hull and upper structure. Subsequently, it was boarded by engineers and all fuel tanks were isolated. No flooding occurred and no oil spills were reported. A second ship's tender boat was used to tow the damaged tender boat ashore. As a precautionary measure, an oil boom was deployed around the damaged tender boat. A third tender boat was used to retrieve the floating equipment and life jackets in the water that fell from tender boat no. 10. At the time of the accident, no crew members were inside tender boat no. 10 and no injuries occurred.

The safety investigation found that:

- the wire rope had parted at a site of severe pre-existing corrosion wastage, which reduced the wire rope's cross-section and load carrying capacity;
- it required Scanning Electron Microscope (SEM) and Energy Dispersive X-ray spectroscopy (EDS) analysis to determine that the wire rope's crowns exhibited severe corrosion attack representing as much as 50% reduction in its cross-section. Therefore, a change in the internal cross-section of the wire rope would not have been evident by visual examination such as that performed by either the ship's crew or the contracted external technicians;
- the laboratory analysis of the grease from the failed wire rope revealed that it was contaminated with high concentrations of the elemental components of sea water as well as metals, including iron and zinc, thus precluding it from serving as an anti-corrosive protection;
- the extensive corrosion of the failed wire rope was due to lack of adequate anti-corrosive protection sometime during its life. The corrosion could have either initiated shortly after manufacture due to lack of grease, or as a result of

insufficient grease, premature loss of grease, and/or loss of grease protective properties during its service life;

- the Company had prepared processes for ordering, supplying, maintaining and inspecting the wire ropes; however, they were not integrated as an overall safety system to manage the long term integrity of the wire ropes.

Celebrity Cruises Inc. has adopted changes to its safety management system (SMS) policies with respect to the maintenance of wire ropes. Additionally, the Marine Safety Investigation Unit (MSIU) has made recommendations to the ship managers and the flag State Administration, aimed at enhancing inspection and maintenance of wire ropes on board.

1 FACTUAL INFORMATION

1.1 Vessel, Voyage and Marine Casualty Particulars

Name	<i>Celebrity Century</i>
Flag	Malta
Classification Society	Lloyd's Register
IMO Number	9072446
Type	Passenger
Registered Owner	Blue Sapphire Marine Inc.
Managers	Celebrity Cruises Inc.
Construction	Steel (Double bottom)
Length overall	250.0 m
Registered Length	217.06 m
Gross Tonnage	72458
Minimum Safe Manning	21
Authorised Cargo	NA
Port of Departure	Hilo, Hawaii
Port of Arrival	Kailua Kona, Hawaii
Type of Voyage	Coastal
Cargo Information	NA
Manning	850
Date and Time	26 February 2013 at 0545(LT)
Type of Marine Casualty or Incident	Less Serious Marine Casualty
Location of Occurrence	Port Area
Place on Board	Boat Deck
Injuries/Fatalities	None
Damage/Environmental Impact	None
Ship Operation	Anchoring
Voyage Segment	Anchored
External & Internal Environment	Gentle breeze, slight sea, moderate swell and good visibility. Air temperature recorded at 25°C and sea temperature was 23°C.
Persons on Board	2630

1.2 Description of Vessel

1.2.1 Ship overview

Celebrity Century was built by Jos. L. Meyer GmbH & Co. Yards in Papenburg, Germany in August 1994. As a passenger cruise liner, she is certificated to carry a total of 2,163 passengers and 861 crew members for a total complement of 3,024 persons.

The vessel is owned by Blue Sapphire Marine Inc., is managed by Celebrity Cruises Inc. and classed by Lloyd's Register (LR). *Celebrity Century* is registered in Malta.

Propulsive power is provided by a Man B&W Father-Son PTI combination engines, developing a total propulsive power of 29,244 kW. They drive two Lips B.V. Controllable Pitch (CP) propellers. The ship has a cruising speed of 22.3 knots.

1.2.2 Lifesaving appliances and davits

Celebrity Century is fitted with 16 Schat-Davit Under-Deck Stored Power Davits with Electric Boat Winches. The 16 Davit systems are installed to handle:

- two rescue boats, which also serve as lifeboats (nos. 1 and 2);
- ten lifeboats (nos. 3-8, 13-16); and
- four tender boat launches, which also serve as lifeboats (nos. 9-12).

Each of the lifeboats and tender boat/lifeboats is certificated to carry 150 persons; each rescue boat can carry 61 persons, for a total lifeboat carrying capacity of 2,222 persons. Eight single arm davits are installed, each for launching up to five inflatable life rafts, each of 25 persons capacity.

The vessel is set up with telescopic trolley arms/davits to trolley the boats out over the water, clear of the vessel in order to lower them. The davits are hydraulically operated with a stored power prime mover. The winches are electrically driven for lowering by gravity and hoisting by electric motor. The winches for the tender boat launches are also suitable for motorised lowering.

Schat-Davit Company provided detailed instructions and diagrams¹ for:

- mounting and assembling of the davits and for reeving and adjusting travelling wire ropes of lifeboats and tender boat launches; and
- mounting/dismounting and adjusting rollers on the outboard side main beam of the lifeboat davits and tender boat forward davits.

1.2.3 Tender boat no. 10, davits and wire ropes

Tender boat no. 10 is located on the port side on deck no. 6, approximately 15 m above the water (Figure 1). According to the vessel's staff captain, tender boat no. 10 is used on an average of six to seven times (down and up) per month.

Davits no. 10 was last load tested by Schat-Harding on 26 April 2010, approximately 34 months prior to the casualty. The certificate indicated that it was properly tested with the correct weight and “performed satisfactorily without any anomalies or permanent deformation.”

The wire rope falls on tender boat no. 10 were replaced in April 2010, approximately 34 months prior to the casualty and just prior to the davits' load test.



Figure 1: *Celebrity Century*'s port side, showing the location of the lifeboats and tender boats on Deck no. 6

¹ A detailed ‘Lubrication Diagram; Hoisting Wirerope; Lifeboat and Tender boat’ was supplied by Schat-Davit Company. The drawing was labelled proprietary and therefore is not reproduced in this safety investigation report. The lubrication diagram identifies the locations on the davits assembly to be lubricated.

1.2.4 Details of the parted wire rope

The wire rope that parted was manufactured and tested by Usha Martin Limited, India in 2008, in accordance with an order placed by Usha Martin Americas, Inc. The 1500 m of wire rope was of 14-7+7-7-1 Strand, 6 x 36 wire strand construction, with a nominal diameter of approximately 22 mm². The manufacturer issued an 'Inspection Certificate' upon completion of the specified work order on 4 July 2008.

The Company has a contract with a supplier for the wire ropes. In March 2010, Usha Martin Americas, Inc. Houston, Texas, supplied the Company with 20 coils of wire rope. Usha Martin US issued a 'Certificate of Conformance' at the time of sale. The wire ropes were delivered directly to the ship.

Celebrity Century used the wire ropes supplied in March 2010 to renew those fitted to davits no. 10 on 20 April 2010.

The certificates of quality provided by the manufacturer and supplier of this wire rope can be found at **Annex A**. A chronology of the wire rope can be found at **Annex B**.

1.3 Planned Maintenance and Inspections

1.3.1 Overview

The Company's procedures in its safety management system (SMS)³ provided guidance for the operational readiness, maintenance and inspections of all life-saving and fire-fighting equipment on board. All daily, weekly and monthly inspections are required to be performed by the chief officer-safety, under the supervision of the staff captain and in cooperation with the staff chief engineer. This includes monthly lubrication of the wire ropes and inspection for condition every three months.

The Company operated a planned maintenance system using an Asset Management Operating System (AMOS). The system provided the user with information on the required upcoming maintenance, recorded all the undertaken planned maintenance, and had a searchable historical maintenance log.

² This wire rope met the davits manufacturer's specifications.

³ *Celebrity Century* complied with the International Management Code for the Safe Operation of Ships and Pollution (ISM Code) and held a valid Safety Management Certificate.

In accordance with IMO's MSC.1/Circ.1206/Rev 1, all other inspections, servicing and repairs are to be conducted by the manufacturer's representative or other appropriately trained and certified persons.

1.3.2 *Celebrity Century* shipboard maintenance and inspections of wire ropes

As already stated above, the Company has a contract with a supplier for the wire ropes. Each ship is expected to order the specific wire ropes according to the specifications provided by the davits' manufacturer. The wire ropes are delivered directly to the ship. Each ship has a dedicated storage location for the wire ropes, which are stowed in a climate controlled environment⁴.

The SMS for Celebrity Cruises Inc. includes a Policy for the Operational Readiness, Maintenance & Inspections of Safety Equipment⁵. The policy in place at the time of the accident was in compliance with the International Convention for Safety of Life at Sea, 1974 as amended (SOLAS) requirements and states, in part:

Maintenance of the Fall Wires

In accordance with SOLAS III/20.4, falls used in launching shall be inspected periodically and renewed (replaced) when necessary due to deterioration of the falls OR at intervals of no more than five (5) years, whichever is earlier.

All Fall Wires are to be inspected periodically. The survival craft is to be lowered to the water or the wire is to be paid out otherwise in a manner that the wire bears no weight and there is no more than one layer left on the drum. The stationary parts of the wire (*i.e.* parts resting on or within sheaves and locking devices) must be given close attention during the inspection. The wire is to be cleaned and greased as needed.

A copy of the full policy⁶ can be found at **Annex C**.

The Company's AMOS system provides monthly job descriptions, or work orders, for all the work required in the Company Policy (**Annex C**).

⁴ In this case, the newly purchased wire rope was only kept under controlled conditions on board for about one month (prior to April 2010), when the wire rope was used to replace the falls on davits no. 10.

⁵ Issued by RCL Cruises Ltd. for Celebrity Cruises Inc.

⁶ This Policy is Revision 58 dated 28 February 2013, which is two days after the accident. Changes to the Policy in place at the time of the accident are noted in red.

These work orders were generated either at the time of build or at the time of installation of new equipment or components. The work orders may only be modified under the authority of the shore side operational support team. In such cases, a request for modification needs to be submitted and, if approved, is forwarded to the Company's AMOS Maintenance Team, who would input the final changes. The AMOS Team does not make changes without the proper approval from the relevant subject matter experts. Generation of work orders is not permitted on board the vessels. Only the AMOS Maintenance Team ashore can generate work orders for newly created jobs.

The inspection of the wire ropes' condition was undertaken by the shipboard personnel every three months. The last inspection of the wire ropes, prior to the accident, was carried out on 16 December 2012.

The history details in the AMOS system for the last inspection of tender boat no. 10 davits' wire rope states, in part:

- conducted detailed inspection of fall wire cable for signs of wear and tear; and
- looked for corrosion, abrasion, termination failure, birdcage, shock load damage and fatigue.

A copy of the shipboard maintenance procedures and job description planned for life-saving appliances, including tender boat no. 10 davits and wire rope lubrication are contained in **Annex D**.

With regard to greasing, the Company has a contract with specific vendors for petroleum products, including grease for wire ropes. Each ship is expected to order the appropriate product, based on the specific equipment used and specifications provided by the manufacturer. The davits' manufacturer recommended anti-corrosive grease for use on the davits and provided a list of acceptable products for the winches, grease points and wire ropes. They also allow comparable products to be used.

Celebrity Century personnel stated that 'Mobilarma 798' was the grease designated to be applied to the wire ropes to serve as a corrosion inhibitor⁷. Mobil describes their

⁷ Mobil recommends 'Mobilarma 798' for the lubrication and preservation of strands and running wire ropes in marine applications and impregnation of steel ropes during manufacture; however, the

798 product as a petroleum-based rust preventative grease, intended to serve as a wire rope lubricant and to prevent rust and corrosion under application and storage conditions. The lubrication of the davits' wire falls for tender boat no. 10 (Figure 2) was undertaken by the shipboard personnel every month. According to the staff captain, slushing of the wires was done by hand (no mechanical greasing). The method undertaken was to first clean off the old grease from the wire using diesel oil. After the wire was cleaned, the new grease was manually slushed on the wire⁸.

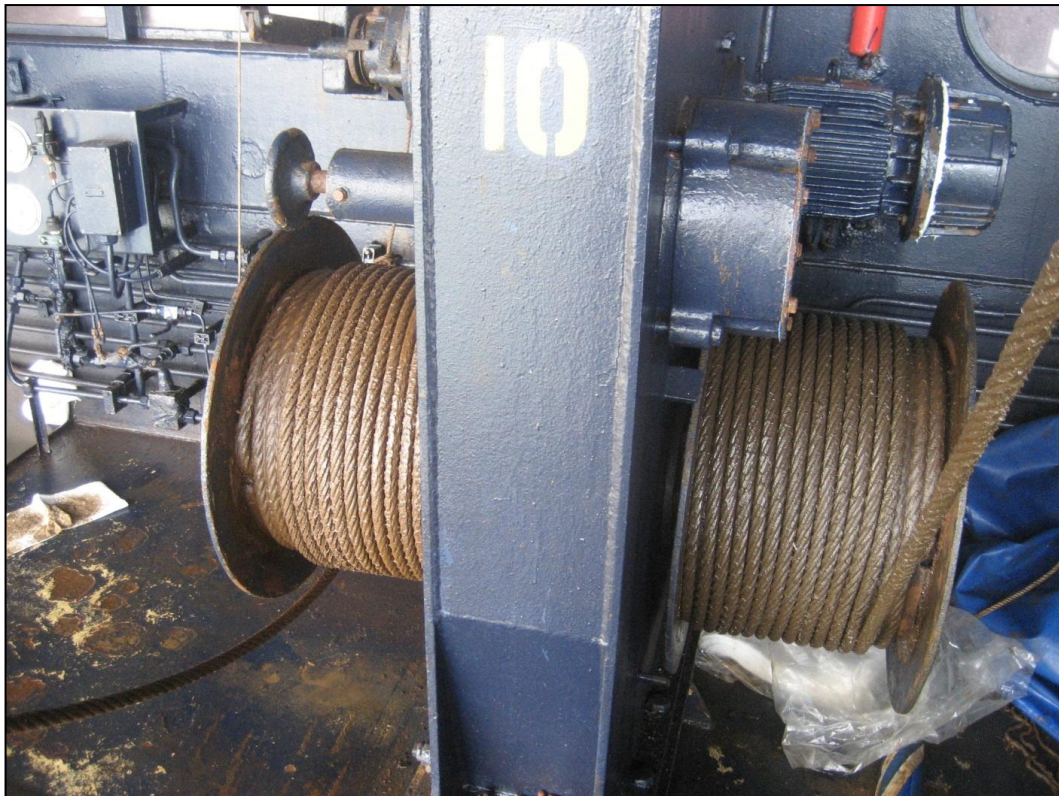


Figure 2: Wire rope on the winch drums for tender boat no. 10.

The last lubrication of the wire ropes on tender boat no. 10, prior to the accident, was carried out in January 2013.

product is compatible with other wire rope core impregnating materials that may have been applied during manufacture.

⁸ 'Mobilarma 798' is to be applied by brush or swab, by spray, dip, or bath if the product is first heated to 65°C and up to 80°C in a well-ventilated area. Only a thin coat should be applied; it becomes transparent to enable visual inspection.

1.3.3 *Celebrity Century* external inspections

Celebrity Cruises Inc. contracted Navalimpianti USA Inc. to perform annual examinations of the davits systems on board *Celebrity Century*. The Company provided copies of Navalimpianti USA Inc. Service Reports dated July 2012, a maintenance checklist dated August 2012 and an LSA – Davits Inspection Forms Collection with a date of 26 August 2012 (**Annex D**). None of the documents cited any specific issues regarding the integrity of the wire ropes for tender boat no. 10.

1.4 Relevant SOLAS Requirements

The current requirements for lowering and operating lifeboats as required by SOLAS 74, as amended, are contained in SOLAS Chapter III Part B: Life-saving appliances and arrangements:

- each lifeboat shall be launched, and manoeuvred in the water by its assigned operating crew, at least once every three months during an abandon ship drill (regulation III/19.3.3.3);
- falls used in launching shall be inspected periodically⁹ with special regard for areas passing through sheaves, and renewed when necessary due to deterioration of the falls or at intervals of not more than 5 years, whichever is the earlier (regulation III/20.4);
- inspection of the life-saving appliances, including lifeboat equipment, shall be carried out monthly (regulation III/20.7.2);
- launching appliances shall be:
 - maintained in accordance with instructions for on board maintenance as required by regulation III/36;
 - subjected to a thorough examination and operational test during the annual surveys required by regulations I/7 and I/8 by properly trained personnel familiar with the system; and
 - upon completion of the examination referred to in (.2) [above point] subjected to a dynamic test of the winch brake at maximum lowering speed. The load to be applied shall be the mass of the survival craft or rescue boat without persons on board, except that, at intervals not exceeding five years, the test shall be carried out

⁹ Refer to the Measures to Prevent Accidents with Lifeboats (MSC.1/Circ.1206/Rev.1).

with a proof load equal to 1.1 times the weight of the survival craft or rescue boat and its full complement of persons and equipment (regulation III/20.11.1).

1.5 Narrative

1.5.1 Pre-accident events

In the month preceding the accident, the crew members documented three failures in the Event and Root Cause Reports for tender boat no. 10: a winch brake failure, a hydraulic pipe failure and a motor clutch failure. All three occurrences were attributed to ‘Excessive Wear and Tear’.

1.5.2 The accident dynamics

On 26 February 2013 at 0545LT¹⁰, *Celebrity Century* was anchored in Kailua Kona, Hawaii, commencing tender boat operations. Tender boat no. 10 was being trolleyed out in preparation for lowering. There were no persons on board. The tender boat was not yet fully extended when the forward wire rope parted, causing the tender boat to swivel on the aft hook.

The tender boat was left hanging by the aft hook, which then ripped off its base, causing the tender boat to fall in the water bow first at an approximate angle of 45° and a height of 15 m. The tender boat remained afloat upright. According to the Able Seaman (AB) who was at the controls, there was no force on the hoist wire rope at the time of the accident. The brake lever had not yet been lifted to lower the tender boat. He stated that during the operation, everything appeared and sounded normal. He heard a loud ‘bang’ when the wire rope parted. There were no injuries to passengers or crew when the tender boat fell.

1.5.3 Emergency response

The wire rope failure and subsequent drop caused extensive damage to the tender boat’s hull and upper structure (Figures 3A and 3B).

¹⁰ Local Time, Kailua Kona, Hawaii, USA (Hawaiian-Aleutian Standard Time).



Figure 3A: Tender boat no. 10 - damage to upper structure



Figure 3B: Tender boat no. 10 - damage to the stern area from where the aft boat hook ripped out

The tender boat was boarded by ship's engineers and all fuel tanks were isolated. No flooding occurred and no oil spills were reported. A second tender boat was lowered

and used to tow the damaged tender boat ashore. An oil boom was deployed around it while sitting at the pier for precaution. A third tender boat was used to retrieve the floating equipment and life jackets in the water that fell from tender boat no. 10.

1.5.4 Post-accident events

The vessel remained in port while a damage survey was conducted by Lloyd's Register (LR). A short term 'Passenger Ship Safety Certificate' valid until 28 March 2013 was issued with a reduced lifeboat capacity of 2,074 persons.

During the senior surveyor's attendance on board, the other lifeboats and davits were inspected by the manufacturer's representative. All davits were tested and found to be satisfactory. A technician from the original equipment manufacturer (OEM) was scheduled to join the vessel in Hawaii, sail with the vessel, and do a further inspection of all the davits.

A contingency plan was put in place for the missing tender boat and it was confirmed that the tender boat commander and person in charge of the muster station were familiar with it and the redistribution of the persons assigned to lifeboat no. 10 (tender boat no. 10).

New wire ropes were ordered for all of the davits and the senior surveyor was informed that these would be changed by the ship's crew.

The damaged tender boat was sent for repair in Hawaii by the OEM. It was agreed that it would be required to undergo a load test of 200% of the fully loaded tender boat prior to its return to service. The davits of tender boat no. 10 was also to undergo a dynamic load test.

1.6 Safety Investigation

The MSIU representatives arrived on board *Celebrity Century* on 04 March 2013 in San Diego, California, USA and an inspection of the wire rope was carried out at the point where it parted. The wire rope had been left in position after the accident and as such was left exposed to weather conditions on the passage from Hawaii to San Diego. Although it appeared as if there was slight corrosion in the broken strands, it

was difficult to analyse it due to the amount of grease on the wire rope (Figure 4). There were also a few ‘fish hooks’ noted on the wire rope in the area around the part.



Figure 4: The parted wire rope

Efforts by the crew members were undertaken to ascertain exactly where the area that parted was located at the time of the accident but it was difficult to do so. An approximation was made as to where the parted wire rope section was in both the stowed position and an extended position of the telescopic trolley arms. The approximation had the area of the wire rope that parted around a sheave in both of the two positions, *i.e.* two different sheaves (Figure 5).



Figure 5: Parted wire rope at its approximate location prior to the accident

After the inspection of the wire rope had been completed by all parties concerned, the parted wire rope was cut into two five-metre sections and sent ashore for laboratory analysis. The wire rope was shipped for analysis to Lucius Pitkin Inc. (LPI), New York, New York.

As explained elsewhere, the vessel is set up with telescopic trolley arms/davits to trolley the lifeboats and tender boats out over the water, clear of the vessel in order to lower them. The trolley arm/davit for tender boat no. 10 was inspected and it was also operated during the inspection (extending and retracting it). There was no noted exceptional damages to the davits. All the sheaves appeared to be turning and there was no noted damage on any of the sheaves on this davits.

A barge with a crane and basket was brought alongside the vessel so that the areas of the davits that could not be reached or seen up close from the vessel, would be inspected. The representative of the davits' manufacturer visually inspected the equipment to assess any areas of damage. No major problems with the davits or the sheaves were identified. Some limited areas of rust on top of the trolley arm and a stationary sheave were identified but these were considered to have had no effect on the wire rope.

Informal interviews with shipboard personnel associated with the operation and maintenance of tender boat no. 10 were conducted. Samples of grease from the parted wire rope and from the on board supply of new/unused grease¹¹ were taken for analysis.

The vessel maintained records of all the maintenance undertaken on the gear and equipment associated with tender boat no. 10. Inspection and maintenance reports were found up to date.

1.7 Prior Accidents of Similar Nature

On 10 February 2013, the Maltese registered passenger vessel *Thomson Majesty* was berthed in Santa Cruz de La Palma when a lifeboat carrying eight crew members dropped to the sea and turned upside down. The forward wire rope had parted,

¹¹ The grease product used for slushing of the wire ropes was 'Mobilarma 798'.

causing the lifeboat to swivel on the aft hook. As the lifeboat reached an angle of approximately 45° to the horizontal, its end and the hook failed and the lifeboat dropped approximately 20 m to the sea. One crew member was thrown from the lifeboat as it entered the water and two crew members managed to escape from the upturned lifeboat by their own efforts. The remaining five crew members were subsequently declared deceased.

1.8 MSIU Safety Alert

As a result of the safety investigation into the lifeboat accident on board *Thomson Majesty*, MSIU Safety Alert 01/2013 was issued in February 2013. The MSIU Safety Alert made several recommendations regarding the potential hazards, lubrication and inspection of wire ropes. A copy of MSIU Safety Alert 01/2013 can be found in **Annex E**.

2 ANALYSIS

2.1 Purpose

The purpose of a marine safety investigation is to determine the circumstances and safety factors of the accident as a basis for making recommendations, to prevent further marine casualties or incidents from occurring in the future.

2.2 Cause of the Wire Rope Failure

The destructive and non-destructive testing of the wire rope carried out in the laboratory revealed that the wire rope did not part due to mechanical abrasion or similar damage; it had parted at a site of severe pre-existing corrosion wastage, which reduced the wire rope's cross-section and its load carrying capacity.

2.2.1 Conditions of the failed wire rope

Two sections of the failed steel wire rope from tender boat no. 10, each approximately 3.6 m long, containing mating fractured ends, were submitted to Lucius Pitkin, Inc.¹² (LPI) for materials evaluation and failure analysis (Figure 6).

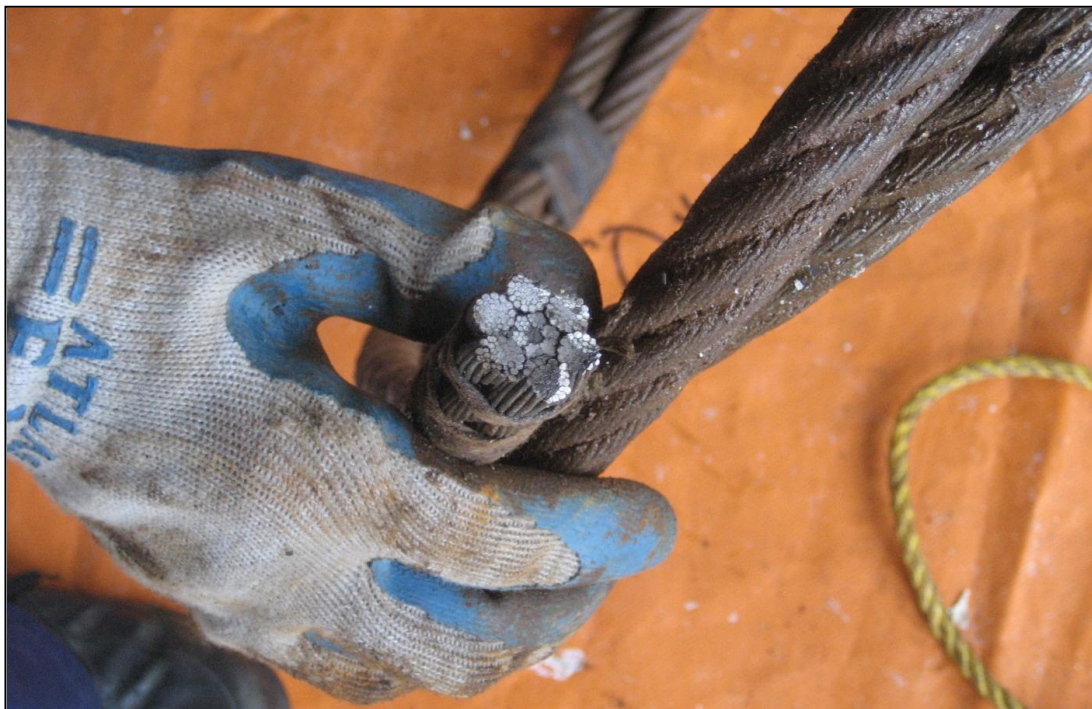


Figure 6: End of the wire rope cut for analysis

¹² Lucius Pitkin, Inc. New York, New York.

LPI concluded that failure of the wire rope was directly attributable to severe corrosion attack of the strand wires. The corrosion attack reduced the wire rope's cross-sections to such an extent that the wire rope could no longer withstand the applied stress, resulting in a single occurrence overstress fracture of the wire rope.

Visual examination, analysis of SEM¹³ images, EDS¹⁴, metallographic examination and tension tests were conducted and revealed that:

- the wire measured approximately 22 mm diameter, right lay regular lay arrangement, 6 x 36, IWRD, Warrington Seale¹⁵;
- the entire wire rope surface exhibited brown and light brown corrosion product deposits;
- dried grease was evident with the corrosion product;
- the outer surface of the wire rope and the wire material were free of any pre-existing defects;
- wire fracture ends were severely corroded;
- wire crowns exhibited severe corrosion attack representing as much as 50% reduction of cross-section;
- initial zinc coating had depleted during service;
- tensile test results on a portion of the wire rope, remote from the fracture, showed the breaking strength of the wire rope had been decreased by at least 25% of the rated load; the reduction in strength at the location of the fracture was likely to be greater than 25%; and
- the presence of chlorine indicated that sea water, which sprays on wire ropes during service, accelerated the corrosion of the wire rope.

¹³ Scanning electron microscope.

¹⁴ Energy dispersive X-ray spectroscopy.

¹⁵ This is the same as stated on the manufacturer's and seller's certification reports.

The wire rope failure was attributable to severe corrosion at the failure site. The severe corrosion of the wire rope was attributed to lack of adequate protection from exposure to the marine environment. In this case, the wire rope protection was expected to be provided by frequent application of anti-corrosive grease.

LPI also offered some conclusions regarding the condition of the grease coating on the wire rope:

- there was evidence that the grease coating on the subject wire rope had dried over a long service period;
- the wire rope had either not been sufficiently greased so as to protect the wire ropes from the corrosive marine environment; or
- the wire rope had experienced premature loss of grease leading to extensive corrosion attack, which reduced the wire cross-section and load carrying capacity of the wire rope.

A copy of the wire rope evaluation report can be found in **Annex F**.

2.2.2 Condition of the grease: grease test results

Samples of grease from the parted wire rope (used grease) and from the on board supply of 'new/unused' grease were sent for analysis to Shell Rapid Lubricants Analysis (RLA), Shell Marine (US) Co., Houston, Texas. The Shell RLA website states:

Shell RLA reports indicate the condition of the oil or equipment of a particular sample through traffic light signals:

Green – NORMAL: no action;

Yellow – ATTENTION: monitor and take action;

Red – ACTION: needs immediate attention.

RLA reported that the used grease had been classified 'ACTION'. The analysis revealed high levels of sodium and iron in the used grease and there were indications of the presence of large particles (greater than 3 to 5 microns) in the product.

The RLA Report on the 'new' (*i.e.* unused) Mobilarma 798 classified the sample for 'ATTENTION'. It was determined that because of the differential iron content and

WPI (Wear Particle Index), products of corrosion may have been present in the grease.

However, these values may be the result of contamination (relatively small - less than 0.5% to 1%) of the 'new' grease. This could possibly be the result of leeching from a metal container or from the hand slushing which, by its nature, requires deck hands to reach into the container to replenish the grease. As this sample had been labelled as 'new'¹⁶, it warranted further query when it had not tested as 'NORMAL'.

The set of grease samples¹⁷ were sent to SGS Laboratories, Vallejo, California for analysis. The analysis of the new/unused product was consistent with the manufacturer's specification and was then used as a baseline for evaluating the used grease sample. The laboratory inspection of the grease from the failed wire rope (used grease) revealed that it was contaminated with high concentrations of the elemental components of sea water as well as metals, including iron and zinc, thus precluding the latter from serving as an anti-corrosive protection. Galvanic zinc and iron in the used grease are the result of corrosion.

The analysis also suggested that differences in lithium and zinc, between the baseline product and the used grease, might suggest a mixture with a different product. Although the presence of lithium may be an indication of another product being mixed with the grease found on the wire rope, this may not be a problem; in fact, lithium can serve as a lubricant.

Copies of the Certificates of Analysis of the new and used grease samples can be found in **Annex G**.

2.3 Cause of the Corrosion of the Wire Rope

As already indicated, the severe corrosion of the wire rope was attributed to lack of adequate protection from exposure to the marine environment. There were a number of potential reasons why the corrosion occurred.

¹⁶ The laboratory lost the first set of samples for testing. There are not enough details available regarding the source of the second set of samples to be able to arrive at conclusions with any confidence.

¹⁷ Collected on scene.

The wire rope was manufactured in accordance with accepted standards and was initially zinc coated. The standard for manufacture was not in conflict with the davits' manufacturer specifications. It met all of the physical dimensions and load carrying capacity; however, the wire rope was manufactured 'Dry'. Thus, no grease was applied during the manufacturing process. The details for the wire rope presented on the 'Certificate of Conformance' issued by Usha Martin US are almost identical to those on the 'Inspection Certificate' issued by Usha Martin Limited, India. The wire rope lubrication is cited as 'Dry' in both instances. The dates are approximately 21 months apart, which implies that the wire rope was maintained in the manufactured condition, (*i.e.* without grease) throughout this period.

There is no information regarding either where or how the wire coil(s) were stored for the two years (between 2008 and 2010), *i.e.* the time when they were manufactured in February 2008, and eventually sold in March 2010. The coils could have been exposed to damage to their zinc coating either during transit or storage. Once purchased, the wire coils were forwarded directly to the ship and within a month used to replace the wire ropes on tender boat no. 10. There is no information regarding the initial greasing of the wire ropes, but the ship's process for greasing was manual slushing. This is comparable neither to the application of lubrication during manufacture nor was it likely to penetrate to the inner core of the wire rope.

Diesel oil¹⁸ was being used on a monthly basis¹⁹ by the ship's crew to remove old grease. The elevated level of zinc in the used grease could have resulted from the diesel oil (used to clean the wire ropes), cutting the galvanic protection from the wire, leaving it bare and vulnerable to corrosion. Moreover, if not permitted to dry completely, the diesel oil could remain within the wire strands. If any residual diesel oil remains within the strands when new grease is added, it will leech out over time and change the consistency of the newly applied grease (more to a liquid than a solid), allowing the new grease to be washed off by exposure to the marine environment. High levels of chloride (ion) indicated sea water impingement on the wire rope. This suggested that the wire rope was bare at some point in time.

¹⁸ Diesel oil has 'traditionally' been used in the maritime sector as a solvent; however, recent awareness of its negative environmental impact has raised questions regarding its frequent use.

¹⁹ It is not clear why this was done every month. There is no mention of the use of any solvent on the ship's monthly job description for wire rope lubrication.

Grease is applied to the wire ropes as a protection from the marine environment, *i.e.* the grease provides a barrier between the metal and water. If there is even a small portion of the wire rope that is left bare, then the water and its salts will begin to break down the metal and cause corrosion.

Even if new grease is then applied to this bare section, any water, which either remains on the surface or penetrates the strands, will act on the metal and corrosion would continue. This internal corrosion is the most difficult to spot. Furthermore, corrosion is pervasive, *i.e.*, once it starts, unless it is identified and exceptional action is taken, even if new grease is added, the corrosion process would continue.

Over its service life, the wire ropes on a tender boat are subjected to more exposure. Tender boat no. 10 experienced high usage and extensive lowering and raising of the wire ropes when compared to non-tender boat lifeboats. Tender boat no. 10 was routinely used by *Celebrity Century* to ferry passengers between the ship and the dock when the ship is at anchorage. Tender boat no. 10 also served as one of the lifeboats required by SOLAS for this passenger vessel.

Lifeboats and tender boat/lifeboats are required by SOLAS to be lowered and manoeuvred once every three months. The wire ropes for lifeboats and tender boats are also inspected monthly in accordance with AMOS and the inspection guidance provided in the Company's Policy for the 'Operational Readiness, Maintenance & Inspections of Safety Equipment.' This translates to 16, up and down evolutions a year for each lifeboat and tender boat.

According to the vessel's staff captain, tender boat no. 10 is used on an average 6 to 7 times, down and up, per month. This translates to a minimum of 72 up and down evolutions per year. Each time the tender boat is lowered and raised, the wire rope is subjected to tension and extension over the sheaves and the potential for the wire rope to open slightly. Each time offers the opportunity for any unprotected portion of the wire to be exposed to moisture and corrosion.

According to the Company, every time a boat is lowered in any position from its original nesting place, a logbook entry is made²⁰. However, the logbook entries

²⁰ Copies of the log book entries were not readily available.

remain as individual log entries and the overall usage of the tender boat is not captured as data for further analysis. The number of evolutions may or may not be significant; but without a review of the data, there is no way of knowing.

2.3.1 Adequacy of the Company's procedures

The wire ropes were being maintained, inspected, and regularly replaced in accordance with international standards. As yet, one of the wire ropes failed. The Company had in place a number of procedures, all with the intent of preventing an accident such as this. The Company had made the effort to fulfil its mandates to not only comply with the international requirements, but also to take the initiative to provide policies and procedures for the operational readiness, maintenance and long term viability of the wire ropes. Yet, these efforts did not prevent the wire ropes of tender boat no. 10 from corroding and one of them failing in service.

It was fortunate that there were no injuries as a result of this accident, but it affords the opportunity to review where the gaps in safety barriers existed and what may be done in future to bridge them.

2.3.1.1 Wire rope maintenance

The Company's AMOS system provided a monthly job description for the wire ropes' lubrication which states:

- lower the boat to the sea level and grease the wire remaining on the drum;
- grease the rest of the wire while hoisting one man by each block, one man on the winch deck;
- use wire lubricating machine; and
- use approved lubricant as per Schat-Harding Manual.

The method of manually greasing the wire rope falls was not in accordance with the Company's work orders in their planned maintenance system; however, the Company stated that prior to the accident, there was no policy in place mandating the use of the greasing machine. For the person responsible for maintenance, the Company expectations were not clear.

The AMOS system job description clearly stated "Use Wire Lubricating Machine." The source of the monthly job description is the company's planned maintenance

system (*i.e.* AMOS). The Company uses the terms ‘job descriptions’ and ‘work orders’ interchangeably. These work orders were developed, and may only be developed, by the AMOS team ashore. They may also be only revised through a system of written requests and justification to the AMOS team by the ship’s representative.

For the officer(s) tasked with the safety of the equipment, they may have looked up the grease manufacturer’s guidance or they may have reverted to what they know from their own experience has been acceptable in the past on this or other ships. The manufacturer’s guidance states that their product can either be applied, as received, by brush or swab, or by spray, dip or bath, if the product is first heated to between 65°C and 80°C in a well-ventilated area. The manufacturer recommended that only a thin coat should be applied because it becomes transparent in service to enable visual inspection.

The method of cleaning the wire rope with diesel oil was *not inconsistent* with the Company’s work orders in their planned maintenance system. No guidance regarding the method of cleaning was provided; nor was a link made between the guidance and the manufacturer’s instructions. The manufacturer’s guidance stated that “for best results, rusty or dirty wire ropes should be wire brushed and cleaned thoroughly with solvent and dried prior to application of the Mobilarma 798.” There is no prohibition to the use of diesel oil for cleaning.

The diesel oil itself is a solvent and can act as a lubricant, albeit not the recommended lubricant for the application. If the diesel oil is not permitted to dry completely, it may leech out later and create other problems. In other words, the use of the diesel oil to clean and subsequently manually apply grease was inconsistent neither with the Company policy nor with the grease manufacturer’s instructions.

There are benefits to the use of a lubrication machine, most notably the consistent pressure applied to the grease, which could force the lubrication deeper into the wire rope’s strands and the greater potential for consistency of application of the lubricant. The use of the lubrication machine would also offer the opportunity to evaluate it for long term marine use. When the grease is applied manually, there can be no

consistency, as each individual will have unique abilities - and there will be no reliable evaluation data generated.

Given that (according to the Company), prior to the accident on *Celebrity Century*, there was not a policy mandating the use of the greasing machines, there seemed to be an indication of a ‘disconnection’ between the Company, their AMOS system and the shipboard personnel. The AMOS system specifically cites the use of the wire rope lubricating machine in the monthly job description. Without a Company policy reflecting the same expectations, *i.e.* the use of the wire rope lubricating machine, the shipboard personnel did not have clear guidance on what they were expected to do. Left up to the individual in charge, there was no consistency of usage.

2.3.1.2 Wire rope inspections

The reduced cross-section of the failed wire rope was evident neither from visual inspection nor measurement. The failed wire rope measured approximately 22 mm in diameter, the same measurement for the ‘as-provided’ condition. It required SEM and EDS analyses to accurately determine that the wire rope crowns exhibited severe corrosion attack representing as much as 50% reduction of cross-section.

This issue of wire rope inspection was addressed in the MSIU’s safety investigation into the *Thomson Majesty* accident²¹. The safety investigation report into that lifeboat accident made the point that there was no internationally agreed criteria on, say, the extent of the inspection *vis-à-vis* the actual length of the wire rope which is to be inspected and the number of wraps on the winch drum, which needs to be paid out and inspected.

The *Thomson Majesty* safety investigation report further highlighted that there were no specific requirements for non-destructive testing reports and detailed record keeping of the tests carried out and the testing / inspection methodology used, especially for areas where the wire rope could risk deterioration. Moreover, irrespective of whether or not the person conducting the inspection had wire rope inspection skills and knowledge, maintenance was not carried out in vacuum. Without an inspection regime and a *detailed* history of the findings (inspection

²¹ Vide MSIU Safety Investigation Report 05/2014 at <http://mti.gov.mt/en/Pages/MSIU/Safety-Investigations-2013.aspx>

records), the judgement of any person may be subjective. The *Thomson Majesty* safety investigation attributed this to, *inter alia*, the consequences of lack of a detailed history of periodic inspections. It was further remarked that it would have been very difficult for any inspector / technician / crew member to make an informed decision on whether the wire rope could remain in service, by which latest time it needed to undergo its next periodic inspection, or whether it necessitated immediate withdrawal.

Applying the same thoughts and concerns to the *Celebrity Century* accident, aside from the skill and expected experience of a service provider, wire rope inspections on board *Celebrity Century* (and any other SOLAS vessel) were also being carried out without established international practices on the detection of general deterioration of the wire rope.

It has already been remarked in this sub-section that the use of sophisticated technology in an engineering laboratory was required to accurately determine that the wire rope crowns exhibited severe corrosion attack. However, even if that was not the case, in line with the analysis of the *Thomson Majesty* accident, the inspection of the wire rope may be potentially susceptible to (what is termed as) *recognition error of the non-detection type*. Thus, it would have been very probable that due to, *inter alia*, the unavailability of specific tools and techniques to inspect the inner strands of the wire rope, corrosion on the inner strands would have been missed even if it was not at a level which could have compromised the wire rope strength in the short term. Non-detection errors could have been influenced by a number of factors, two of which being dirt / grease and unsatisfactory access to the specific areas.

One has only to look at the cross-section of the failed wire in an area remote from the break to realise that someone inspecting that section would not have recognised the changes. Therefore, this change in internal cross-section of the wire rope would not be evident by visual examination such as that performed by either ship's crew or an external technician.

The visual examination of the wire rope by the engineering laboratory revealed that the entire wire rope surface exhibited brown and light brown corrosion product deposits. In addition, dried grease was evidently contaminated with the corrosion product. This does not necessarily mean that either the ship's crew or the external

technician would have arrived to the same conclusion. A ship's crew may not have the skill level to determine the difference between corrosion products and dirt.

The external technician produced the last Inspection Report in August 2012, approximately six months prior to the casualty in February 2013. Given that no definitive date can be attributed to the initiation of the corrosion, the likelihood of internal corrosion being present cannot be ruled out.

The wire rope was ordered via a contract and manufactured to meet the physical dimensions and standards required for installation with the davits. It was then forwarded directly to the ship. Although certificates of manufacture and certificates of conformance provide documents to the shipboard personnel assuring compliance with the ordered standard, there is no understanding of the implications of receiving wire ropes that do not have any grease applied during manufacture. Even if the shipboard personnel apply grease immediately upon installation, even by using a greasing machine, there is no guarantee that they will manage to penetrate into the inner core of the wire rope.

The monthly maintenance allows the use of any solvent to remove the surface grease, but does not consider the implications of this frequent process of removal and replacement. The manufacturer recommended application of a thin coat because it should be transparent enough to view the wire rope strands. The manual slushing process had no such guidance included and it is likely that the idea of 'more is better' had been applied to these wire ropes.

The Company processes for ordering, supplying, maintaining and inspecting the wire ropes are independent of each other. That is, the long term integrity of the wire ropes was/is not being managed systematically. These problems only serves to emphasise that this is a complex issue and simple solutions will not resolve it.

Since this accident, Celebrity Cruises Inc. has amended some of its procedures²². These procedures are similar to those previously required by SOLAS, but these changes are, once again, piece meal and do not serve to solve the overriding issue of managing the integrity of wire ropes throughout their service life. Then, the

²² *Vide* Section 4, 'Actions Taken'.

procedures are only applicable to Celebrity Cruises Inc. and do not serve the maritime community at large.

Wire rope integrity management is not restricted to either Celebrity Cruises Inc. or even a few other ships or companies. It is an international maritime issue that merits attention at an international level. It is an issue that needs to be considered from the manufacturing stage through replacement, and all stages of maintenance and inspection in between.

THE FOLLOWING CONCLUSIONS, SAFETY ACTIONS AND RECOMMENDATIONS SHALL IN NO CASE CREATE A PRESUMPTION OF BLAME OR LIABILITY. NEITHER ARE THEY BINDING NOR LISTED IN ANY ORDER OF PRIORITY.

3 CONCLUSIONS

Findings and safety factors are not listed in any order of priority.

3.1 Immediate Safety Factor

- .1 The fall of the lifeboat to the water was the result of a parted wire rope fall that was severely corroded at the break point.

3.2 Latent Conditions and other Safety Factors

- .1 The wire rope experienced severe internal corrosion due to a lack of adequate corrosion inhibitor at the site.
- .2 The wire rope was manufactured without a protective corrosion inhibitor coating and it remained as such for at least 21 months.
- .3 The wire rope was being cleaned with diesel oil on a monthly basis. Diesel oil may have been removing enough of the grease to allow portions of the wire rope to remain bare long enough for corrosion to start. Moreover, residual diesel oil may have remained within the wire rope strands and then leached out over time, causing dilution of the grease and permitting corrosion.
- .4 The manual slushing method being used was similar to that described by the grease manufacturer; however it was not being applied in a thin coat.
- .5 The shipboard and external inspections did not identify the corrosion of the inner strands of the wire rope.
- .6 The difficulties to inspect the inner strands of wire ropes could have potentially led to a *recognition error of the non-detection type*.
- .7 The Company processes for ordering, supplying, maintaining and inspecting the wire ropes were being conducted independently. The long term integrity of the wire ropes was not being managed as an overall safety system.

3.3 Other Findings

- .1 The method of cleaning the wire rope with diesel oil was not inconsistent with the Company's work orders in its planned maintenance system.
- .2 The method of manually greasing the wire ropes was not in accordance with the Company's work orders in their planned maintenance system; however it was not inconsistent with the Company's policies.

4 ACTIONS TAKEN

4.1 Safety actions taken during the course of the safety investigation

During the course of the safety investigation, changes were effected to the Company's SMS policies.

On 24 August 2013, a revision of the Company's Operational Readiness, Maintenance & Inspections of Safety Equipment to Celebrity Cruises was issued²³. The new Policy is similar to the SOLAS requirements of 2001, requiring the wire ropes to be turned end-for-end within two years and replaced within four years²⁴.

Changes are shown in Red. The new Policy states, in part:

*Maintenance of the **Wire Falls***

Wire falls used in launching shall be **turned end to end at intervals of not more than every two years** and renewed (replaced) when necessary due to deterioration of the falls OR at intervals of no more than **four (4) years**.

All **Wire Falls** are to be inspected periodically. The survival craft is to be lowered to the water or the wire is to be paid out otherwise, in a manner that the wire bears no weight and there is no more than one layer left on the drum. The stationary parts of the wire (*i.e.* parts resting on or within sheaves and locking devices) must be given close attention during the inspection. The wire is to be cleaned and greased as needed.

²³ This policy is Revision 65 dated 24 August 2013.

²⁴ The previous SOLAS requirement for wire ropes to be turned end-for-end at intervals of not more than 30 months and renewed after no more than five years is no longer applicable. However, SOLAS regulation III/20.4 does not prohibit turning wire ropes end-for-end.

Since the accident, the wire rope lubricating machine has been placed in service on board *Celebrity Century*. The Company stated, “[p]resently, there is still not a company policy, however, Celebrity Marine Operations has directed all ships to purchase the equipment (if not already on board) and has developed a Standard Operating Procedure.”

5 RECOMMENDATIONS

In view of the conclusions reached and taking into consideration the safety actions taken during the course of the safety investigation,

Celebrity Cruises Inc. is recommended to:

08/2014_R1 consider training relevant crew members on inspection and maintenance of wire ropes, wire rope construction, performance and deterioration, safe use and handling of wire ropes and wire rope rejection criteria.

The Merchant Shipping Directorate within Transport Malta²⁵ is recommended to:

08/2014_R2 bring the findings of this safety investigation report to the attention of ship owners and managers of Maltese registered ships.

²⁵ No recommendations have been made to the Merchant Shipping Directorate within Transport Malta to raise the matter with the International Maritime Organization in view of the recommendation made in section 5 of the MSIU’s safety investigation report **05/2014**.

LIST OF ANNEXES

- Annex A Wire Rope Certificates
- Annex B Chronology of the Wire Rope
- Annex C Company Policies, Procedures and Schedule for Renewal, Maintenance and Inspection of Wire Falls
- Annex D Navalimpianti Service Reports, Maintenance Reports and Inspections
- Annex E MSIU Safety Alert 01/2013
- Annex F Evaluation of Failed Tender Boat Wire Rope, Celebrity Cruises Inc., 25 April 2013
- Annex G Certificates of Analysis of New and Used Grease Samples