MAIB

MARINE ACCIDENT INVESTIGATION BRANCH

Marine Accident Report 5/99

Report of the Inspector's Inquiry
into the loss of

mv *GREEN LILY*

on the 19 November 1997
off the East Coast of Bressay, Shetland Islands

MAIB
is an

INVESTOR IN PEOPLE

August 1999

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of the Department of the Environment
Transport and the Regions: London

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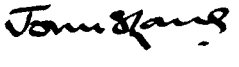
25 June, 1999

The Right Honourable John Prescott MP
Deputy Prime Minister and Secretary of State
for the Environment, Transport and the Regions

Sir

I have the honour to submit the report into the loss of mv *Green Lily* which occurred on 19 November 1997 off the East Coast of Bressay, Shetland Islands.

I have the honour to be
Sir
Your obedient servant



J S Lang
Rear Admiral
Chief Inspector of Marine Accidents

Extract from
The Merchant Shipping
(Accident Reporting and Investigation)
Regulations 1994

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

CONTENTS

Glossary of Abbreviations and Acronyms

AB	Able Seaman
AHTSV	Anchor Handling Tug/Supply Vessel
ARCC	Air Rescue Co-ordination Centre
BTA	British Tug Owners' Association
CAST	Coastguard Agreement on Salvage and Towage
CSM	Continuous Survey, Machinery
ECR	Engine Control Room
EPIRB	Emergency Position Indicating Radio Beacon
ETA	Estimated Time of Arrival
ETV	Emergency Towing Vessel
GO	Gas Oil
gt	Gross tonnage
IFO	Intermediate Fuel Oil
ISM Code	International Safety Management Code
kN	kiloNewtons
MHz	MegaHertz
MRSC	Maritime Rescue Sub-Centre
OS	Ordinary Seaman
PGA	pressure compensated – air speed setting
RNLI	Royal National Lifeboat Institution
ro-ro	roll-on roll-off
rpm	revolutions per minute
SafCon	Safety Construction
SAR	Search and Rescue
SOLAS	Safety of Life at Sea
STCW 95	Standards of Training, Certification and Watchkeeping for Seafarers 1995
SWL	Safe Working Load
UTC	Universal Co-ordinated Time

Marine Safety Agency (MSA) and The Coastguard Agency (TCA) merged in April 1998 and are now known as the Maritime and Coastguard Agency (MCA).

Synopsis

This accident was notified to the Marine Accident Investigation Branch (MAIB) by Shetland Coastguard at 0951 on Wednesday 19 November 1997. The investigation was upgraded to an Inspector's Inquiry on 20 November and was undertaken by Captain D A Wheal and Mr A M Rushton with Mr J S Withington, Principal Inspector appointed as Inspector in Charge.

Green Lily was a Bahamian registered, 3,624 gross tonnage, single engined, refrigerated general cargo vessel, built in 1978 and lengthened in 1984. The vessel loaded frozen fish in Lerwick Harbour, Shetland Islands, and sailed for the Ivory Coast early on 18 November 1997. The weather on departure was south-east force 7, increasing to severe gale force 9, and eventually storm force 10. Early on the morning of 19 November and when only 15 miles south-east of Bressay, a sea water supply line fractured in the engine room. The flooding was controlled and pumping out had begun when the main engine stopped suddenly. Unsuccessful attempts were made to restart the engine while the vessel drifted north-west at about 1.5 – 2 knots before the weather. Shetland Coastguard was advised of the situation, and "Pan Pan" messages were transmitted followed by "Mayday Relay" broadcasts. Three tugs, the harbour tug *Tystie* and the anchor handling tugs *Gargano* and *Maersk Champion*, prepared to proceed to the scene of the casualty. *Maersk Champion* got underway once her deck cargo had been discharged. A Coastguard helicopter was tasked and the Lerwick RNLI lifeboat launched.

A tow by *Gargano* was initially successful but parted after about 51 minutes. An attempt by the Coastguard helicopter Lima Charlie (LC) to lift off non-essential crew was aborted due to vessel movement. *Tystie* then made a second tow connection but this failed after five minutes. *Green Lily*'s starboard anchor was let go to slow the vessel's drift towards land. The lifeboat then approached and successfully rescued five crewmen before weather and sea conditions prevented further attempts. *Maersk Champion* snagged the starboard anchor of *Green Lily*, but as the tug pulled her head into the wind, the anchor cable parted. Meanwhile the Coastguard helicopter lifted off the ten remaining crew members with the master and second engineer being the last to leave. The helicopter winchman, who had remained on deck, was swept into the sea and lost. With *Green Lily* aground and starting to break up, the rescue attempt was suspended overnight and resumed the following day when the body of the winchman was found and recovered.

The vessel had undergone an extensive dry dock and repair period in May/June 1997. On departure from Lerwick she was seaworthy with no known deficiencies and was manned with appropriately qualified and experienced officers.

The cause of the grounding was the lack of propulsion and failure to restart the main engine to arrest the drift of the vessel towards the shore in the prevailing environmental conditions. Contributory causes included flooding of the engine room, failure to reset the mechanical over-speed trip, inadequate knowledge of the cooling water system, failure of towage attempts and inadequate teamwork.

Recommendations are aimed at improving operational teamwork and the probability of effecting a successful tow in similar circumstances.

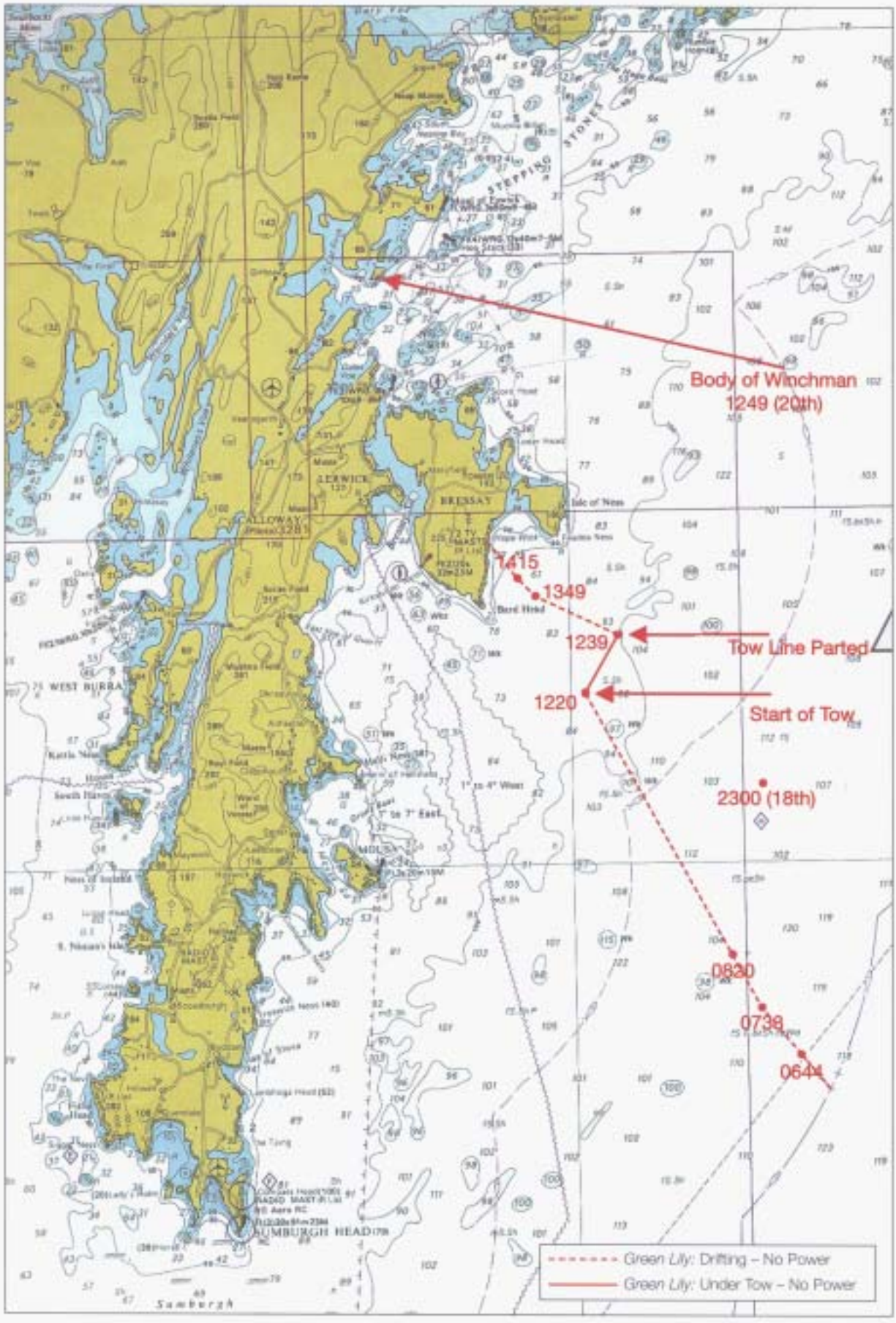
MV GREEN LILY [photograph courtesy of FotoFlite]

SECTION 1
Factual Information

All times are UTC.

1.1 PARTICULARS OF VESSEL AND INCIDENT

Name	:	*Green Lily*
Official No	:	725369
Port of Registry	:	Nassau, Bahamas
IMO Number	:	750 8324
Gross tonnage	:	3,624
Deadweight	:	4,348 tonne
Overall Length	:	107.68m
Breadth	:	14.74m
Maximum Draught	:	5.46m
Year of Build	:	1978 (vessel extended 1984)
Type	:	Refrigerated Cargo
Main Engine	:	B&W ALPHA Diesel 12U28L-VO MCR 2339 kW at 775rpm
Propulsion	:	Controllable pitch propeller
Generators	:	3 × 170 kW 380 V 50 Hz 1 × 100 kW Emergency
Owner	:	Green Lily Corporation, 80 Broad Street, Monrovia, Liberia
Manager	:	Green Management A/S, Norway
Classification Society	:	Lloyds Register + 100A1 +LMC; Lloyds RMC; UMS
Date and Time	:	19 November 1997, 0644 UTC
Place of Incident	:	East Coast of Bressay, Shetland Islands
Injuries	:	None to crew
Fatalities	:	Helicopter winchman lost in sea
Damage	:	Total loss, after being driven ashore



Shetland Islands – East Mainland

1.2 BACKGROUND TO VOYAGE

Green Lily was owned by the Green Lily Corporation, Monrovia, Liberia, and managed by Green Management A/S, Minde, Norway. At the time of the accident the management company, together with its sister company, Nomadic Shipping A/S, managed 17 vessels world-wide.

During the early part of 1997 Green Lily was dry docked and repaired in Gdynia, Poland. She then bunkered in Copenhagen, and sailed to the Faeroe Islands to load frozen fish for discharge in France and a Black Sea port. On completion of this voyage, the vessel returned to western Europe, and arrived in Ålesund, Norway on 8 November 1997. Loading started on arrival and was completed late on 13 November.

The following day, *Green Lily* left Ålesund for Lerwick where additional frozen fish was to be loaded for discharge at Abidjan and Lagos.

1.3 NARRATIVE

1.3.1 *Green Lily* arrived in Lerwick on 15 November and berthed alongside Morrison Berth at the end of Holmsgarth Quay. Cargo work started on arrival with completion expected late evening on 17 November. The cargo loaded was frozen fish for eventual discharge at Abidjan, Ivory Coast.

As the master planned to sail the following morning, he contacted the port authority to discuss arrangements for departure and was advised to leave in daylight because of vessels berthed ahead and astern of his berth. The use of two tugs was also recommended due to the high wind and the proximity of the other vessels. The master checked the weather forecasts for the following day and interpreted them as giving south-east force 7 outside Lerwick, with no improvement predicted over the next few days. By 2300 on 17 November cargo loading had finished, the hatches were closed and all paperwork completed.

1.3.2 At 0700 the following morning, the steering gear was tested. The main engine was started and checked before control was transferred to the bridge. When the pilot boarded at about 0830 he discussed the weather, the unberthing operation and the passage out of the harbour with the master. At 0855, the vessel singled up with two tugs making fast. At 0903, lines were let go and the vessel manoeuvred off the berth and started making her way out of Lerwick Harbour. The departure went according to plan with both tugs being let go at 0912 and 0918 respectively. At 0923, when abeam the pilot disembarked to the tug *Knab*. At 1000, full away was rung and the sea passage started. The master set the main engine pitch control at about half ahead to reduce pitching.

Having cleared the isle of Bressay, the vessel encountered severe force 9 weather from the south-east. She made little headway in the prevailing conditions and effectively became hove to on a south-south-east heading. After discussions between the master and the chief engineer, the main engine revolutions were reduced from 750 to 710. This was to avoid undue strain on the engine. At about 1300, the chief officer, together with the second officer and three seamen, went aft to resecure mooring ropes which had broken loose from their lashings. Following the master's instructions the ropes were transferred to an upper deck but, in the process, the chief officer and one of the seamen were injured. Both were bruised but the chief officer's leg was fractured. With the chief officer now confined to his cabin, the two remaining deck officers went on to six-hour watches.

1.3.3 During the afternoon the weather intensified to storm force 10, still from the south-east, with the vessel pitching heavily in high seas. The main engine pitch control remained in the half ahead position with the main engine revolutions restricted to 710. At 2300, the vessel's position was 60° 01'.9N, 00° 50'.9W, approximately 8 miles south-east of Bressay.

The vessel continued to ride out the weather until about 0530 on 19 November when a sea water supply line to the fire and general service pump in the engine room fractured. The second engineer, who was on watch, tried to isolate the line to stop the flooding. Realising the situation was getting out of hand he called the chief engineer at 0545. The chief engineer, on entering the engine room, ordered the rest of the engineering crew to be called and for attempts to be made to stop the leak. He then went to the bridge to inform the officer of the watch. The master was called, told of the problem and informed that attempts were being made to stop the inflow of sea water. Meanwhile, the main engine continued to operate as usual with all engine gauges on the bridge reading normally. The main engine pitch was reduced at the request of the chief engineer, to lessen the amount of water being thrown up by the flywheel while attempts to contain the inflow continued.

At 0610 the main engine stopped of its own accord.

The chief engineer informed the master that the main sea inlets had been shut and that he was hoping to restart the main engine. With the pitch control being set to different positions from the bridge, several attempts to do so were made.

Meanwhile, the vessel's position was plotted every 15 minutes to assess the speed and direction of the drift. At 0644, her position was 59° 55'.3N, 00° 49'.2W, approximately 14 miles south-east of Bressay. The master called Shetland Coastguard on VHF Channel 16, giving the vessel's position, stating that the engine had stopped, that repairs were being attempted and that the vessel was drifting north-west at between 1.5 and 2 knots. The master said the problem concerned the main engine cooling system and that he had been in contact with the owners.

This was acknowledged, and *Green Lily* was asked to report again in 20 minutes.

1.3.4 While waiting for her next report, Shetland Coastguard enquired about the availability of tugs in the area. At 0714, *Green Lily* called to say she was still unable to start the main engine, that she was continuing to drift north-west at about 2 knots, and that her position was 59° 56'.0N, 00° 50'.4W. Shetland Coastguard and the master then agreed that if, after a further ten minutes, they were unable to start the main engine, a "Pan Pan" message should be transmitted. Meanwhile, Shetland Coastguard contacted Lloyd's and arranged for tug brokers to be told. At 0730, the master telephoned Green Management in Norway so the chief engineer could discuss the situation with the superintendent. At 0733, *Green Lily* told Shetland Coastguard that she was still unable to start her main engine, that she was continuing to drift north-west at about 1.5 – 2 knots, and that her present position was 59° 56'.4N, 00° 51'.1W. Shetland Coastguard broadcast a "Pan Pan" message at 0740.

At 0754, with no response to the "Pan Pan" message, *Green Lily* informed Shetland Coastguard that she still could not start her main engine. Details of the fuel carried on board were also passed. Shetland Coastguard continued to explore the local tug situation and, in particular, the availability of *Maersk Champion*, an anchor handling tug lying alongside in Lerwick Harbour. Meanwhile the chief engineer told the master that although the flooding situation was now under control the main engine refused to start. The vessel was therefore without propulsive power and drifting.

At 0820, *Green Lily* reported that she was continuing to drift in a north-westerly direction at 2 knots and in position 59° 57'.8N, 00° 52'.5W, approximately 10 miles south-east of Bressay. A second "Pan Pan" was broadcast at 0836 and Bristow SAR at Sumburgh was given a situation report.

1.3.5 From his plot, the master calculated that a drift of 1.5 – 2 knots to the north-west would put him aground within about 7 hours. Following agreement with the master a "Mayday Relay" was broadcast by Shetland Coastguard at 0844.

Three tugs responded to the situation.

The harbour tug *Tystie* was already preparing to leave Sullom Voe. The anchor handling tug *Gargano* declared herself available at 0911 and estimated being with the casualty some 1.5 – 2 hours after leaving harbour. At about this time, the charterer confirmed that the anchor handling tug, *Maersk Champion*, would be available once her deck cargo had been discharged. *Tystie* departed Sullum Voe at 0914 as *Gargano* prepared to leave Lerwick.

Green Management informed the master of *Green Lily* that the tug *Tystie* was on her way and would arrive well before the anticipated time of grounding. Shortly afterwards, Shetland Coastguard told the master that *Gargano* would be the first tug to arrive on the scene and should be used for the tow. The master agreed. At 0927, *Tystie* informed Shetland Coastguard that she expected to be with *Green Lily* in 5 hours time. Shetland Coastguard received confirmation from *Green Lily* that the flooding in the engine room was under control and that there was power on deck to operate the windlass. At about this time, the electrical engineer, who was standing-by in the engine room, started the harbour generator as a precaution in case the flooding affected the main generators.

1.3.6 At 0951 a second "Mayday Relay" was broadcast, drawing a response from the 15,806 gt tanker, *Sidsel Knutsen*, which was, at that time, 23 miles south-east of *Green Lily*. She was asked by Shetland Coastguard to proceed towards the casualty and stand-by on arrival. Use of a Coastguard helicopter was considered, but judged unsafe due to the high winds.

At 1021, Shetland Coastguard suggested to *Green Lily*'s master that he should consider which members of his crew were non-essential and could be made available for early evacuation should the situation deteriorate. The master acknowledged this advice but reasoned that with tugs due within an hour, the situation remained under control.

Gargano came in sight of *Green Lily* at 1055 and discussed her requirements for connecting a tow. At about this time *Tystie* was off Point Skaw encountering very heavy weather. In Lerwick meanwhile, *Maersk Champion* was starting to unload her deck cargo; she expected to finish by about 1230.

Although *Tystie* expected to be late on scene, Shetland Coastguard considered that together with *Maersk Champion*, the two would be useful stand-by vessels, providing back up to *Gargano*.

1.3.7 As *Gargano* approached, *Green Lily*'s master sent the second officer, second engineer and two able seamen (ABs) forward. They wore lifejackets and, between them, carried a VHF radio and two Schermuly rocket lines. *Gargano* approached *Green Lily*'s starboard shoulder, stern to sea. At 1124 a rocket was fired successfully and the tug's messenger line was

attached to the rocket line. This was pulled in by hand by those on board Green Lily and placed on the port drum of the windlass. The towline was passed through the panama lead, winched on board and secured onto a set of bitts at 1148 ready for towing.

The second engineer then returned to the accommodation while the second officerand the two ABs remained forward in the forecastle head. Gargano informed Shetland Coastguard that the tow was connected and they were paying out the towing wire. Shetland Coastguard said that due to anticipated berthing problems in Lerwick, the tow should be taken to Dales Voe where Green Lily could anchor. Tystie was requested to meet the vessels there to assist as necessary. At 1211, Sidsel Knutsen arrived on scene and stood-by. The tow started at 1218 and, within two minutes, Green Lily had steerage. She was approximately 3 miles south-east of Bard Head in position 60" 04'.2N, 00" 59'.3W and making good 4.8 knots on a heading of 035". Shortly afterwards, Sidsel Knutsen was released by Shetland Coastguard to continue her voyage.

At 1226, Shetland Coastguard advised, and Green Lily agreed, that the "Mayday" should be cancelled, thereby freeing the 2182 KHz radiotelephone distress frequency for open use. The Coastguard helicopter was asked to remain on stand-by in case the situation changed.

At 1239, some 21 minutes after the tow had started, the towline parted, leaving Green Lily in position 60" 05'.6N, 00" 57'.7W, approximately 3 miles east of Bard Head.

View of MV *GREEN LILY* from aft deck of *GARGANO* prior to connection of tow

1.3.8 After the tow parted, *Gargano* retrieved the remains and told *Green Lily* she would prepare another rope, and, when ready, would attempt to re-connect. With the timing of the second tow attempt uncertain, the ABs on the forecastle returned aft to the messroom while the second officer went to the bridge where he found both the chief and second engineers together with the master. Shetland Coastguard informed *Maersk Champion* and the Coastguard helicopter of the changed situation and requested a Bristow's SAR flight to be ready at 1300 to evacuate non-essential crew from the casualty. The master of *Green Lily* had already been asked to have his non-essential crew ready for evacuation should the need arise. The chief and second engineers then went below to the chief officer's cabin to prepare him for evacuation. At this time, Lerwick RNLI lifeboat was also requested to launch as a precaution. *Tystie* meanwhile was still closing and in position 60° 08'.55N, 00° 52'.36W, about 4 miles to the north-east of *Green Lily*.

At 1258, the Coastguard helicopter was asked to get airborne to assist *Green Lily*. A short time later the Air Rescue Co-ordination Centre (ARCC) at Kinloss was requested to establish a 5 mile diameter exclusion zone around the incident to a height of 5000 feet. At 1305 *Maersk Champion* departed Lerwick and headed towards *Green Lily* via Bressay Sound. At 1318, *Gargano* reported she would be unable to attempt a second tow for at least another hour. On hearing this, *Tystie* requested she be allowed to attempt to secure a line aboard the casualty. The Coastguard helicopter callsign Lima Charlie (LC) had by now arrived and was asked to stand-by while *Tystie* attempted to pass a tow line.

1.3.9 *Tystie*'s intention was to close *Green Lily*'s starboard bow to pass a heaving line and follow this with the messenger and a towing wire. During *Tystie*'s approach, *Green Lily* confirmed she had power on the forecastle. *Tystie* informed the casualty that Shetland Coastguard had asked that both anchors be made ready for use as a last resort.

Shetland Coastguard contacted *Green Lily* direct and urged that non-essential crew be made ready for evacuation. Complying with this request, the master instructed the chief engineer to assemble five non-essential crew, including those injured, for possible evacuation. The chief officer and ordinary seaman (OS), together with the radio officer, cook and an AB were nominated. They were told to assemble on the port side of No 3 hatch near the entrance to the superstructure to prepare to abandon ship. In fact the crew members assembled just inside the entrance. Until this moment Shetland Coastguard had been unaware that two injured men were on board.

The Coastguard helicopter LC then approached and informed *Green Lily* of the airlift procedures to be followed. Once in the hover the helicopter lowered the hi-line and the second officer and two crewmen held it as instructed. However, at 1348, due to the weather conditions and the movement of *Green Lily*, it was decided to delay the airlift operation until *Tystie* had secured a tow and the vessel's head had been turned into the wind. At 1349, *Green Lily* was in position 60° 06'.5N, 00° 01'.6W, and approximately one mile from the shore.

The RNLI lifeboat arrived on scene at 1350.

With *Tystie* approaching the bow, the master of *Green Lily* sent the second officer and an AB forward. They were followed shortly afterwards by the electrical engineer and the third officer. The heaving line and messenger were successfully passed at 1342, followed by the towing wire. At 1402 the tow was secured. *Tystie* then moved off slowly while paying out the towline but, five minutes later, it parted. Shetland Coastguard then suggested *Green Lily* drop her anchors to slow her progress to allow *Maersk Champion* time to get into position to

use her grapnel on the anchor cable. *Green Lily*'s master sent the second and third officers forward again to let go the anchors. The engineer fitter and an AB were also sent forward. The chief engineer was instructed to tell the rest of the crew to prepare for evacuation.

By 1415 *Green Lily* was less than one mile from the shore. Three minutes later the starboard anchor was let go and 5 shackles were run out before the brake was secured. An attempt to let go the port anchor was then made but when released it only moved a short distance and then stopped. Despite applying power to the windlass the anchor and its cable would not move. The vessel continued to drift towards the shore and the starboard anchor had the effect of turning her head marginally into the wind. At 1427 the RNLI lifeboat coxswain informed *Green Lily* that he could attempt to get people off the port side if they were ready. At about 1432, with the starboard anchor deployed and the port anchor cable still stuck, all those forward returned aft.

1.3.10 The lifeboat approached *Green Lily*'s lee side and, over several manoeuvres made in very difficult conditions, rescued five members of the crew; the third officer, the cook, two ABs and the engineer fitter. With little sea room available, the lifeboat moved off and stood-by. In the meantime *Maersk Champion* had arrived on the scene at 1431 and had manoeuvred herself to starboard of *Green Lily*. She snagged the deployed anchor cable after eight minutes and, by 1443, was turning *Green Lily* into the wind. LC moved in again and lowered the hi-line which was held by three of the crew while the winchman was lowered onto the deck on the port side by No 3 hatch.

As the first two crewmen were being prepared for lifting, the starboard anchor cable parted.

The helicopter evacuation started at 1444 with two crew members being winched up at a time. Because of the prevailing conditions, lack of sea room and a suitable lee, the lifeboat was unable to assist but continued to stand-by. While the crew were being winched off, the chief engineer returned to the engine room and shut down both main generators. On returning to the deck, he found the master still on the bridge and shouted to him to come quickly, as only three crew members and the master were still aboard. The master, after telling Shetland Coastguard at 1450 that he thought the vessel was aground, went down to the main deck where he was lifted off with the last crew member, the second engineer. The winchman remained on deck to await the return of the lifting harness. By this time the vessel was rolling about 60° either side of vertical with seas sweeping over the deck.

1.3.11 At 1456, while attempting to lower the winch cable to recover the winchman, the hi-line became snagged in the rigging. At the same time the helicopter crew became aware the winchman was no longer on deck and had been swept into the sea. Unable to free the hi-line and, with increasing danger to the helicopter, it had to be cut.

With a damaged winch cable and unable to assist any further, the helicopter left, and landed the ten survivors at Clickimin. It then returned to Sumburgh to fit a replacement winch.

Gargano also left the scene at this time because one of her crew had been injured but the lifeboat, *Tystie* and *Maersk Champion* remained in the area. By 1510, *Green Lily* was firmly aground and had started to break up in position 60° 08'.25N, 00° 03'.55W.

The lifeboat returned to Lerwick to land her five survivors at 1520 before returning to assist in the search for the winchman. A 121.5MHz EPIRB signal was picked up at 1533 with a light reported in the water at 1540. An RAF helicopter arrived from Lossiemouth at 1550 and confirmed sighting the light, but conditions prevented further investigation. The

lifeboat returned at 1559, but was unable to close the wreck because of debris, the weather, sea conditions and the onset of darkness. A light was seen in the water at about 1605 but, since no approach could be made, details were passed to Shetland Coastguard before the lifeboat returned to Lerwick Harbour at about 1630. *Tystie* remained on scene until she was released at 1555, leaving *Maersk Champion* searching for the winchman until 1707 when she, too, was released by Shetland Coastguard.

The RAF helicopter continued a shore search using night vision aids until 1704 when she had to return to Sumburgh to refuel. At 1715, the coastal search was called off with the onset of darkness and the dangerous weather conditions.

1.3.12 The following day at 0756, an Atlantic 402 fixed wing aircraft from Inverness overflew the site and reported debris along the coastline, but no ship nor pollution. At about 0800, the search resumed using land-based coastguards and two helicopters. At 1249, a body was recovered off the South Isle of Gletness by one of the helicopters and brought to Clickimin for transfer to Gilbert Bain Hospital. It was formally identified as that of the missing winchman.

1.4 VESSEL CERTIFICATION

All statutory survey certificates were valid.

Green Lily had been issued with several certificates pertaining to her anchor cables. All certification was in respect of 40mm chain, proof-loaded to 640kN with a breaking strain of 896kN.

1.5 PARTICULARS OF CREW

1.5.1 The vessel had been issued with a Bahamian Safe Manning Certificate in accordance with SOLAS 1974 (1989 Amendments), Regulation 13 (b) which specified a total minimum manning level of 14 persons. At the time of the incident *Green Lily* had a crew of 15.

1.5.2 The master was a Croatian national, had been at sea since 1976 and had obtained his Croatian Master's Certificate in 1984. He was issued with his current Bahamian Master Mariner's Licence on 17 March 1997. Most of his experience had been in deep sea cargo vessels, sailing as master for the last four years. He joined Green Management in September 1996 as master, serving on *Green Flake* and *Green Freesia* (sister ship of *Green Lily*) for periods of four months at a time interspersed with leave. He joined *Green Lily* on 8 November 1997 in Ålesund, Norway.

The chief officer was a Croatian national, had been at sea since 1965 and had obtained his Croatian Mate's Certificate in 1970. He was issued with his current Bahamian Chief Officer's Licence on 30 October 1996. He joined *Green Lily* in Ålesund, Norway on 8 November 1997. He had previously served on *Green Lily* between August 1996 and January 1997.

The second officer was also a Croatian national, and had served at sea since 1989. He obtained his Croatian Ship's Mate's Certificate on 1 June 1993, and was issued with his current Bahamian Ship's Mate's Licence on 13 August 1997. His experience had been on general cargo vessels, ro-ro vessels and coastal shipping. He sailed on *Green Tulip* between May and June 1997, and had been on leave before joining *Green Lily* on 9 August 1997.

The third officer was a Philippine national, had served at sea since 1989 and was qualified to act as officer-in-charge of a bridge watch. His current certificate was issued on 26 July 1997 by the Republic of the Philippines. He joined *Green Lily* on 11 August 1997, at Gdynia, on completion of the vessel's dry docking.

1.5.3 The chief engineer was a Croatian national and, after completing a Marine Engineering course at Rijeka University, went to sea in 1979. After three years on deep sea cargo vessels, he worked ashore. He returned to sea in 1989, serving on local Yugoslavian general cargo vessels until 1995 when he joined Green Line Management. After service as second engineer on *Green Freesia* and *Green Tulip*, he was promoted to chief engineer on *Green Tulip* in 1997. He left her in August and joined *Green Lily* as chief engineer at Ålesund, Norway on 8 November 1997. He qualified as a First Class Marine Engineer in March 1989 and was issued with a Marine Engineer, Class 1 Certificate by the Bahamian Authorities in August 1996.

The second engineer was a Croatian national and went to sea as an apprentice in 1968. After sea service on a variety of vessels, he obtained his current Republic of Croatia Certificate as a Marine Engineer in July 1992. He had sailed on both deep sea and coastal vessels and joined Green Line Management in December 1996. He sailed on *Green Freesia* as second engineer until March 1997 when he went on leave. He joined *Green Lily* in June 1997 when the vessel was in dry dock in Gdynia.

The third engineer/electrician was a Croatian national. He qualified as an electrician in 1969 and had served at sea for various periods up to 1992 and regularly since then. During this time, he sailed as an electrician on tankers, bulk carriers and general cargo vessels. In December 1996 he joined Green Line Management and sailed as an electrician on *Green Violet*, leaving the vessel in May 1997. He joined *Green Lily* on 8 August 1997 as an electrician while the vessel was in dry dock in Gdynia.

1.5.4 The radio officer was a Philippine national and qualified as a radio officer in 1978. He held a First Class Marine Radio Telegraph Operating Licence issued by the Bahamian Authorities on 5 March 1996. He was issued with course certificates in Satellite Communication and GMDSS in 1994.

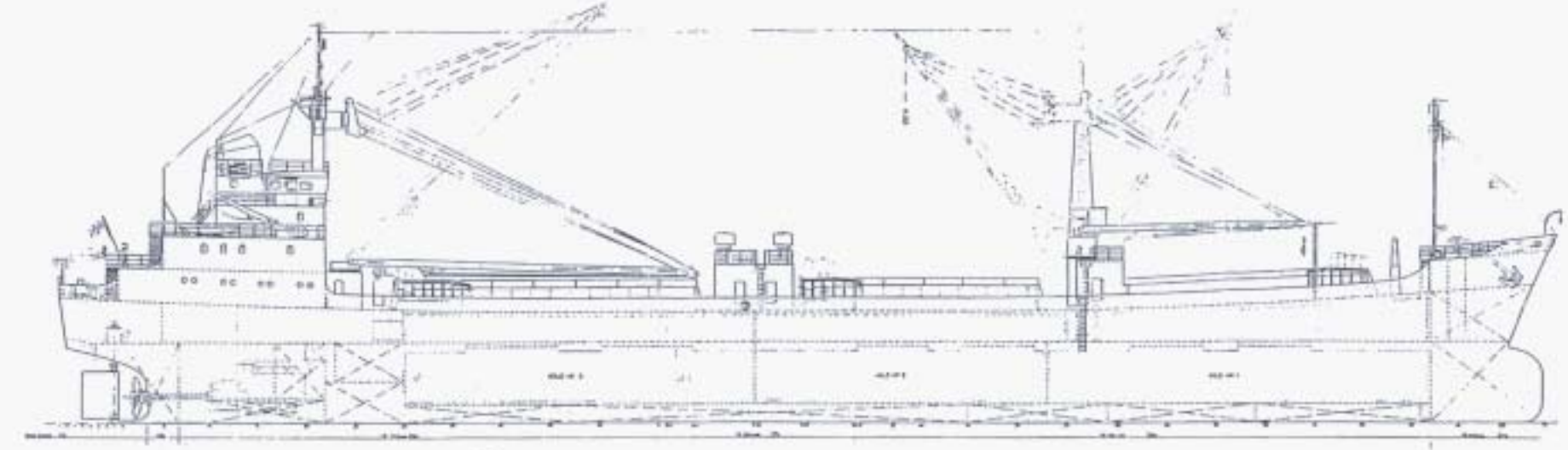
1.6 DESCRIPTION OF *GREEN LILY*

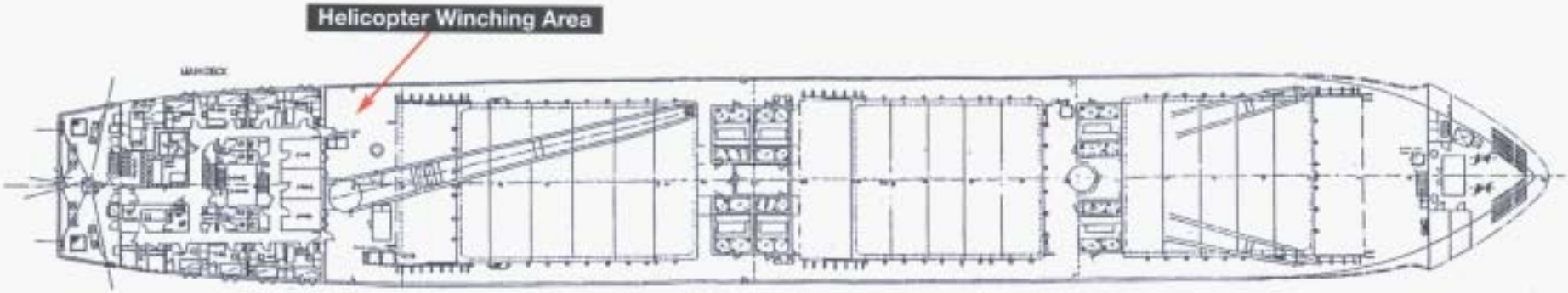
1.6.1 The vessel was a steel refrigerated cargo vessel with accommodation and engine room aft. Originally a geared general cargo vessel built in India in 1978, she was lengthened and converted to a general and/or refrigerated cargo vessel in 1984 at a Netherlands shipyard. She had three cargo holds, numbered forward to aft 1, 2 and 3, with 'tween decks and single pull, multi-section steel hatch covers on the main deck. Two 12.5 tonne cranes were mounted on a twin pedestal between Nos 1 and 2 hatches, with a 10 tonne crane mounted on a pedestal just forward of the bridge and aft of No 3 hatch. A hold cooler house was fitted on the main deck between hatches Nos 2 and 3, with a mast house between hatches Nos 1 and 2.

1.6.2 The accommodation block aft consisted of four levels, the bridge deck, boat deck, upper deck and main deck. The officers' cabins were on the upper deck with the crew cabins on the main deck.

Access forward to the forecastle from the accommodation block was via port and starboard steel weathertight doors at main deck level.

MV *GREEN LILY* — General Arrangement





1.6.3 The mooring arrangement on the forecastle consisted of an electric motor driving the windlass through rack and pinion-operated dog clutches, together with port and starboard drum ends. Four sets of double bitts were fitted, two port and two starboard, with two sets of roller fairleads, a panama fairlead and a steel ring forward. Pedestal rollers were fitted forward of the drum ends.

The starter for the windlass motor was in the forecastle store with local controls on the forecastle, aft of the windlass. The starter box was fitted with an isolator switch, running and source lights, and a heating switch.

Green Lily was not equipped with an insurance wire.

1.7 VESSEL MAINTENANCE

1.7.1 For the last few years it was the management's practice to take their refrigerated cargo vessels out of service for a period of about three months during the off season. In this lay-up, the opportunity was taken to carry out general maintenance including dry docking and survey work. *Green Lily* was taken out of service on 19 May 1997 and underwent a repair and maintenance period in Gdynia in May and June 1997. She was in dry dock for six days for general hull maintenance and inspection of the underwater fittings. The anchor cables were ranged, the propeller polished and anodes renewed. Other maintenance work carried out included the completion of the Hull Special Survey (IV) and the CSM programme. Under this programme, all sea connections were surveyed and credited.

1.7.2 The sea water cooling and ballast system aboard *Green Lily* had, as expected in a 20 year old vessel, suffered some deterioration in the pipework. This was evident from the copy telexes passed by the vessel to the company prior to dry docking. An extract is shown below:

PIPING
01. DISCH. PART FROM S.W. PUMP FOR REEF. PLANT RENEW.
02. S.W. IN/OUT PIPE FOR A.E. F.W. COOLERS – RENEW
03. S.W. IN/OUT PIPE FOR M.E.F.W. AND L.O.COOLERS – RENEW
04. MAIN S.W.SUCTIONS VALVES – CLEAN, INSPECT
05. MAIN TRANSFER PIPE BTWN BOTH S.W. SUCTION TO BE INSPECT.

Many of these items listed were only part line renewal or elbow replacements, and it would not be unusual for additional lengths and pipe fittings to be added while the refit was in progress.

The dry dock company invoice for this work identifies a total of 30 sections of sea water and ballast piping renewed, together with 56 elbows and 10 stub pipes. The pipework was of varying diameter, ranging from 21mm to 139mm with a combined length of 37 m. All replacement pipework was specified to be either hot galvanised or galvanised mild steel. In addition to the repair period, the vessel was alongside a lay-by berth for a further period awaiting a suitable charter. During this time further maintenance work was carried out using contract labour and materials. *Green Lily* re-entered service on 19/20 August 1997.

1.7.3 During July/August 1997, a number of visits were made by Lloyd's Register surveyors during which time the Hull Special Survey and the Docking Survey were completed. Statutory periodical load line inspections and SafCon annual/intermediate surveys were also completed.

1.7.4 Subsequent to this repair and dry docking period, the only major defect recorded occurred during the voyage to the Black Sea in October 1997. A piston seized in No 2 generator requiring the renewal of a complete cylinder block. This was ordered from the manufacturers and delivered to the vessel in Ålesund. The block was fitted by ship's staff and a test run carried out. The generator was back in service prior to departure from Ålesund.

On departure from Lerwick, the vessel was fully in Class with no outstanding defects or repairs.

1.8 ENVIRONMENTAL CONDITIONS

The events in this report occurred entirely within sea area Fair Isle.

The shipping forecasts issued by the Meteorological Office for sea area Fair Isle in respect of wind were as follows:

17 November 1997:

0505: south-easterly 6 to gale 8, perhaps severe gale 9 later;
1305: south or south-east 6 to gale 8, perhaps severe gale 9 later;
1700: south-east 6 to gale 8, occasionally severe gale 9; and
2358: south-east 6 to gale 8, occasionally severe gale 9.

18 November 1997:

0505: south-easterly 6 to gale 8, occasional severe gale 9 or storm 10.

The actual wind conditions experienced outside Lerwick when *Green Lily* departed on the morning of 18 November were south-east force 9 to 10. These conditions prevailed on 19 November.

Sunset on 19 November was at 1521.

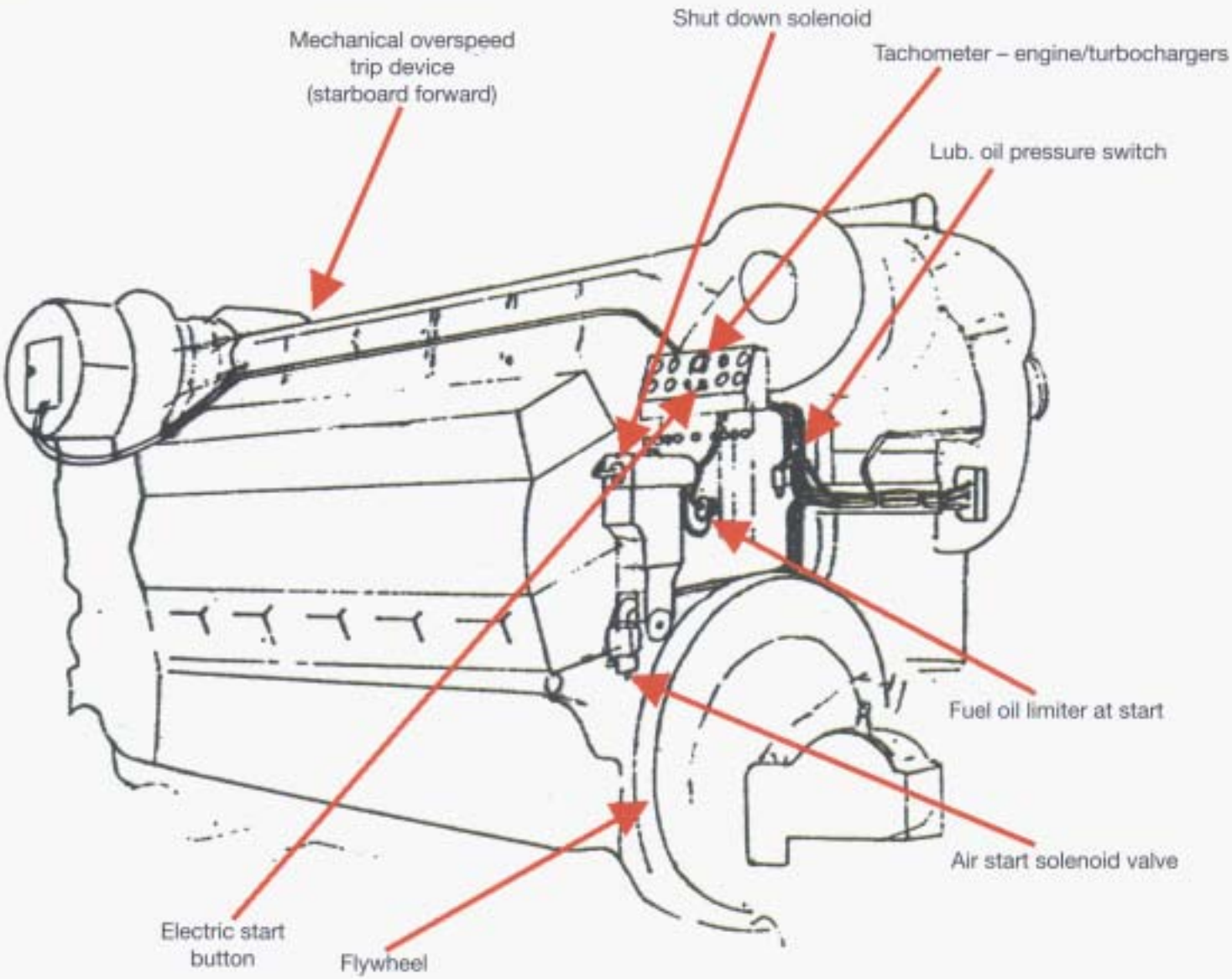
1.9 MAIN ENGINE DETAILS

1.9.1 The main engine installed in *Green Lily* was a B&W Alpha Propulsion System consisting of a U28LU main engine connected to an Alpha gear, propeller equipment, remote control etc. The complete system is known as U28L-VO.

The main engine was a 12 cylinder vee type diesel engine with a designed continuous service rating of 2880 bhp at 750 rpm. The corresponding revolutions for the four bladed controllable pitch propeller at this engine speed is 180 rpm.

The Alpha's electro-pneumatic control system had two control panels, one on the bridge, the other in the engine room alongside the main engine. This system included manual pitch and engine control, clutch engagement and disengagement, electric engine start and auto engine/pitch loading facility. A full instrumentation and alarm facility was also fitted, covering both the main engine and gear box.

MV *GREEN LILY* — General Configuration of Main Engine



1.9.2 The main engine was fitted with engine driven lub oil, cooling water and fuel oil pumps, driven from geared power take offs at the forward end of the engine. Electrically driven stand-by pumps for lub oil, sea water and fresh water cooling were also fitted, remote from the main engine. The engine was fitted with a standard Woodward PGA hydraulic governor incorporating a stop solenoid. This could either be energised by manual operation or by alarm conditions of low lub oil pressure, high bearing temperatures, or high fresh water cooling temperatures. A mechanical over-speed trip driven off the main engine was also fitted. An additional safety feature fitted into the start circuits was a lub oil pressure switch to prevent the starting of the main engine before adequate lub oil pressure had built up. The governor and start circuitry were positioned on the port side, aft at the flywheel end of the main engine while the over-speed trip mechanism was positioned on the starboard side, forward, at cam shaft level. Other circuitry relating to clutch control, pitch position indicators, pitch/engine load control, and 24V and 240V power failure relays were contained within a terminal box fixed on the side of the gear box.

At the time of departure from Lerwick, the main engine, gear box and controls were all functioning correctly with no evidence of any malfunction or reduced performance.

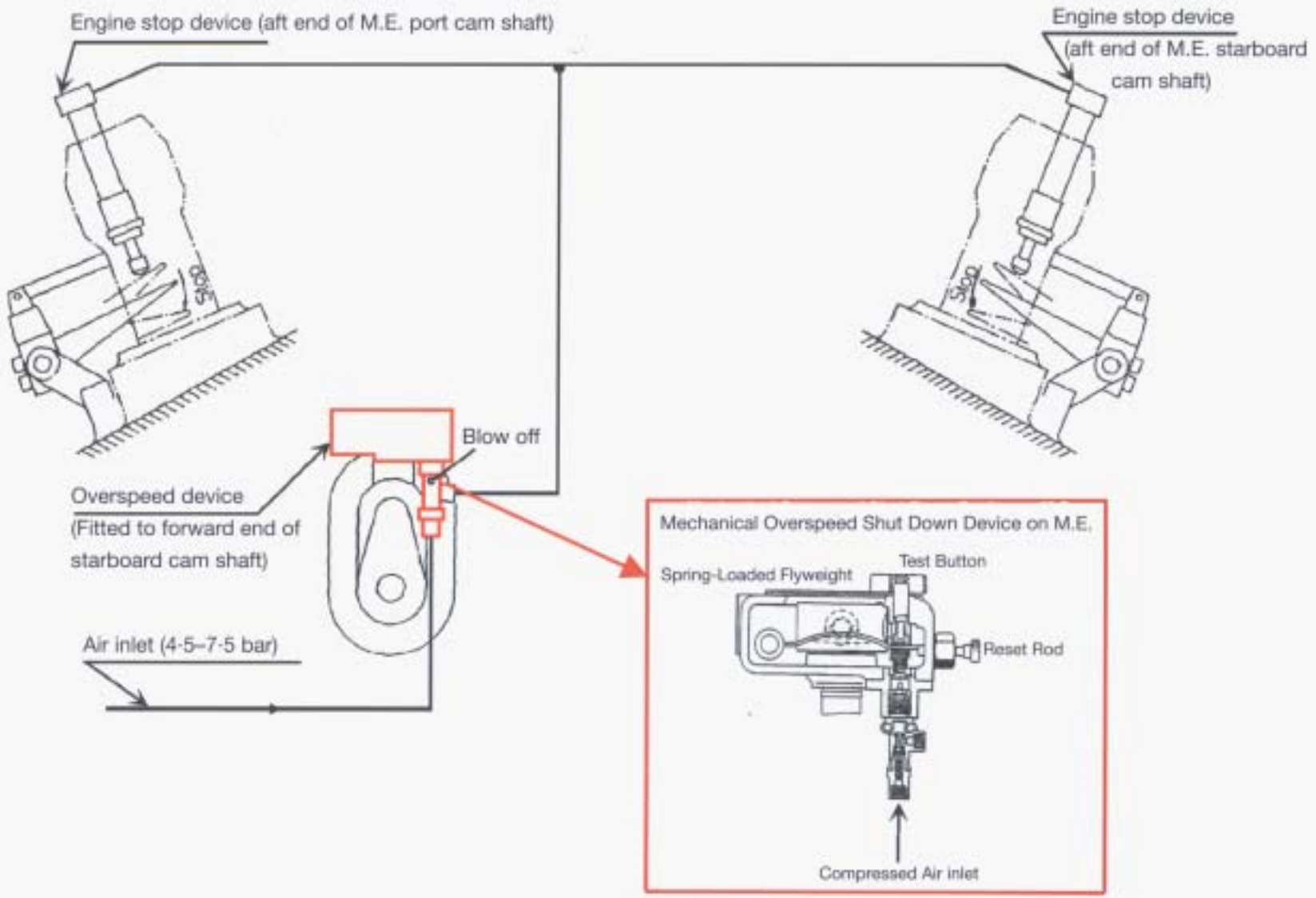
1.10 MAIN ENGINE SHUT DOWN DEVICES

1.10.1 Two separate devices were fitted to this engine, a combined electrical and hydraulic system incorporated within the engine governor, and a mechanical over-speed trip mechanism.

The stop device in the governor consisted of an electrically operated solenoid valve fitted to the hydraulic speed control system. This solenoid was of the "energise to operate" type requiring electrical power to open the valve. When activated by a 24V supply, either by an alarm condition or manually via the stop button, the solenoid moved downward unseating a ball valve in the hydraulic pressure system. The movement of this ball valve allowed the pressurised hydraulic oil to drain down into the governor sump. With the hydraulic pressure removed, a spring operated piston moved the fuel regulating shaft into the "zero fuel" position, thus stopping the engine. On removal of the power supply, the valve closed and the hydraulic system reverted to normal operation.

1.10.2 The engine-driven, mechanically operated, over-speed tripping device was fitted at the front end of the engine and consisted of a spring-loaded flyweight acting on a compressed airball valve. In the event of the engine over-speeding, the spring-loaded flyweight moves outward pushing an operating arm downward. The downward movement of this arm causes the ball valve to open admitting compressed air to two stop cylinders, one on each fuel pump regulating shaft, forcing the linkage of the fuel pump regulator shaft into the stop, or "zero fuel" position. At the same time, the operating arm becomes locked into the down position. Once tripped, manual resetting was required to allow the operating arm to return to the upper position, venting of the engine stop devices, and release of the fuel pump regulating shaft. Without being reset, the fuel pump regulating shaft remained in the "zero fuel" position.

MV *GREEN LILY* — Arrangement of Mechanical Shutdown System



1.11 FAILURE OF MAIN ENGINE

1.11.1 At approximately 0530 on 19 November, the second engineer became aware of water gushing into the engine room from a broken sea water suction pipe leading to the fire and general service pump. Despite shutting various valves, the water continued to enter the engine room. Realising that the position was becoming serious, he called the chief engineer at about 0545. After a quick inspection, the chief engineer ordered the rest of the engineering crew to be called and, using wooden plugs, he initiated attempts to plug the hole in the broken sea water pipe.

1.11.2 At about 0600, with the water level rising in the engine room, the chief engineer asked the bridge to reduce the main engine revolutions to try to reduce the amount of water being thrown up by the partially submerged engine flywheel. At about the same time, he ordered the second engineer to close the main sea valves together with other secondary valves. Shortly after he asked for a reduction in the engine speed, at 0610 the main engine stopped.

The water level continued to rise until it was described as being "about 100mm above the floor plates".

Attempts were made to start the main engine using the electric start system, but it failed to operate. The main engine was started a number of times through by-passing the electric start and holding the fuel rack over by hand. On release however, the fuel rack reverted to the stop position and the engine stopped. With none of the engineers finding any obvious reason for the continual operation of the engine shut-down mechanism, further attempts to restart the engine were abandoned. On hearing that a tow had been arranged no further investigative work was carried out.

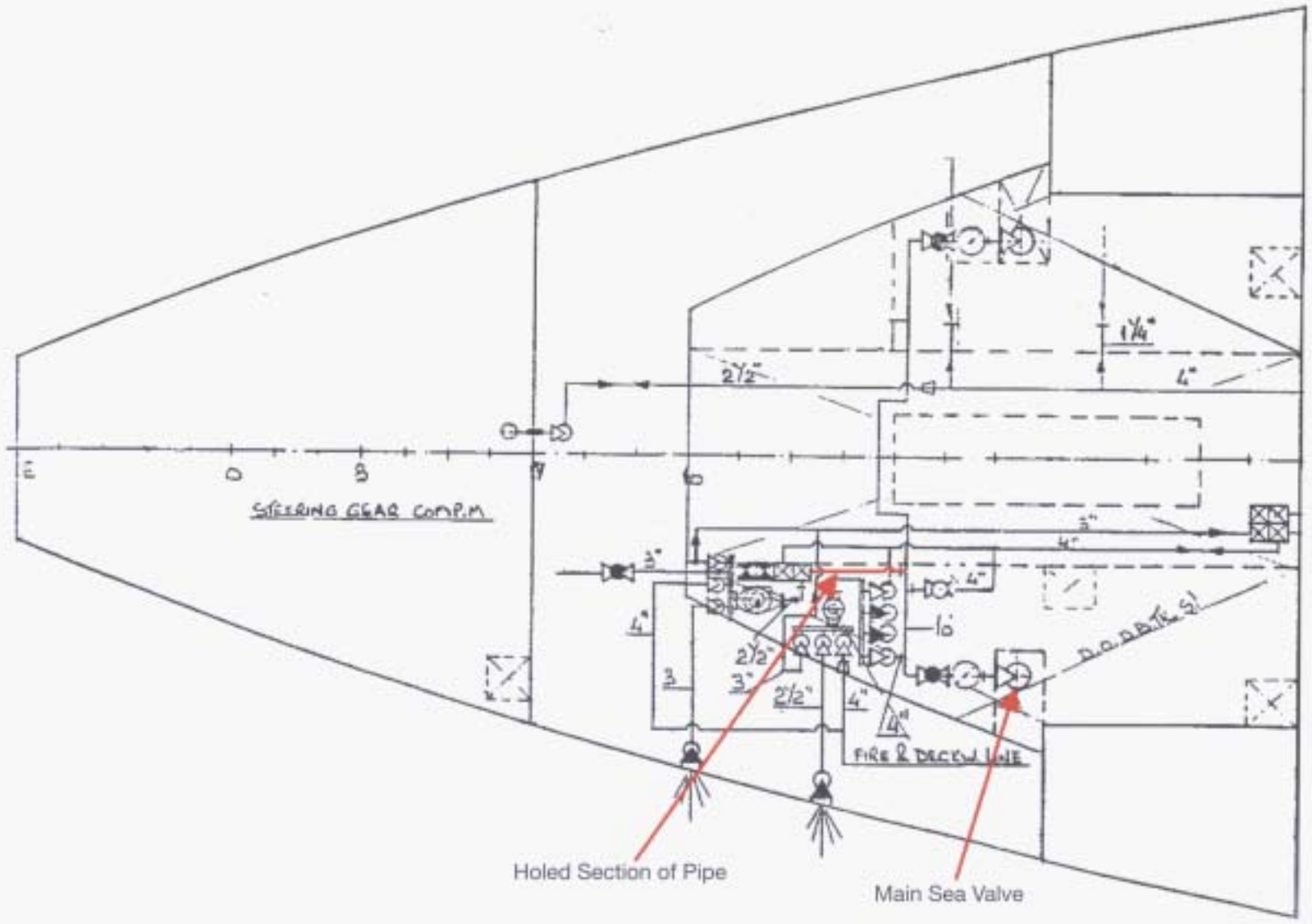
1.12 ENGINE ROOM CONDITIONS

1.12.1 With water above the floor plates and rising, the rolling action of the vessel generated considerable surface water movement giving rise to a wave action within the engine room. The effect of these "waves" or surges at, or close to, floor plate level was to either submerge or splash the pumps and other machinery periodically. Electrical equipment installed at this lower level was placed at risk.

1.12.2 The height of the floor plates relative to the height of the engine bedplate was about 100mm. This allowed reasonable access to the crankcase door for maintenance purposes. With a mean level of some 100mm above the floor plates, water would not only have been moving around the engine room from the motion of the vessel, but large amounts of it would have been thrown up by the rotating flywheel of the main engine. In addition to electric motors driving auxiliary pumps, various other items of electrical equipment connected with the main engine control systems were well within the splash zone.

Attempts were made to minimise the effects of splashing by covering some of the electric motors with plastic sheeting. The increasing volume of water moving about in the engine room seriously reduced the effectiveness of the sheeting.

General Service Pump Piping Arrangement



1.13 SEA WATER COOLING SYSTEM

The sea water cooling main consisted of a 250mm diameter pipeline linking the port and starboard main sea water inlets. The following sea water pipes were connected to it:

On the starboard side:

Main engine cooling and fresh water generator	125mm diameter
Air compressor cooling	25 " "
Direct connection to ballast main	100 " "
Sea suction to bilge and ballast pump	100 " "
Sea suction to fire and general service pump	100 " "

On the port side:

Diesel generator cooling	125mm diameter
Reefer plant cooling	40 " "
AC plant cooling	100 " "

A 100mm diameter pipeline comes directly off the starboard sea chest to provide an auxiliary sea water supply line to either the engine driven sea water cooling pump or to the electrically driven main sea water pump.

All sea water pipelines were of galvanised steel with system connections inboard of the main sea water suction isolation valves. Each supply line was fitted with an isolation valve, either close to the system connection, or at the item of machinery being served.

1.14 FLOODING OF ENGINE ROOM

1.14.1 The pipeline that fractured was the 100mm diameter sea suction line to the fire and general service pump on the starboard side aft of the engine room. The fracture occurred between the connection to the sea water main and the isolating valve fitted to the pump. Flooding could only have been prevented by the immediate closing of both main sea water inlet valves.

The hole in the pipe was reported to be about 100mm in diameter which, with an average draught aft of 5m, would result in a pressure of about 0.5 bar and an inflow of about $3m^3$/min.

Both the fire and general service and the bilge pumps were being used to control the flooding which, given their combined output of about $2m^3$/min, reduced progressive flooding to $1m^3$/min.

1.14.2 Allowing 65% permeability, an estimate of the volume of space below the floor plates is in the order of $21m^3$ with another $8m^3$ for the 100mm depth above the floor plates. With progressive flooding at $1m^3$/min, the maximum height of the sea water would have been reached about 29 minutes after the pipe fractured. Three other considerations affect this time scale:

a. there was a period early on in the incident when neither the fire and general service pump nor the bilge pump were being used;

b. the pumps were stopped so that the intake filters could be cleared;

c. once the main sea valves were shut, the water inflow would have slowed down, but not stopped as the sea water lines would have drained back down into the engine room through the broken pipe.

With the broken pipe being discovered at about 0530 and the main engine recorded as stopping at 0610, there is a rough correlation between the flooding and the recorded time scale.

1.15 LERWICK – PORT ARRANGEMENTS

1.15.1 Lerwick is a natural harbour on the west side of Bressay Sound which divides Mainland and the isle of Bressay. The town of Lerwick is the capital of the Shetland Islands and is located on Mainland. The principal activities of the port are fishing, and the offshore oil and gas industries for which it is a major supply base. The port handles general cargoes, is the terminal for a number of ferries and is a calling place for cruise vessels. The port authority is Lerwick Harbour Trust.

During 18 and 19 November 1997, many vessels were berthed alongside in Lerwick sheltering from the weather.

Although advice on the procedure for sailing was sought and accepted from Lerwick Harbour Trust by the master of *Green Lily*, the port authority had no power to prohibit the master from sailing simply on grounds of the known adverse weather conditions prevailing outside Lerwick on the morning of 18 November. After manoeuvring the vessel clear of Morrison Berth and proceeding seawards, the pilot disembarked from *Green Lily* off Victoria Pier. This was a standard practice in adverse weather.

1.15.2 Prior to this accident, it was normal practice for Shetland Coastguard to telephone Lerwick Harbour Port Control daily at about 0800 to update its register of tugs in port. The term "tugs" was taken to include all oil-related vessels, including diving support vessels, stand-by vessels, platform support vessels and anchor handling vessels. After the 19 November, the procedure was changed and a list of all vessels in Lerwick is now faxed to Shetland Coastguard daily at 0900.

Although it is common for vessels alongside in Lerwick to maintain a VHF radio watch, there is no requirement to do so. Similarly, the port authority does not require vessels alongside to be equipped with a telephone connection. On the morning of 19 November, contact was initially made with *Maersk Champion* by Lerwick Harbour Port Control on VHF radio and, subsequently, by the deputy harbourmaster in person.

1.15.3 *Maersk Champion* was unable to render immediate assistance to *Green Lily* because her deck cargo prevented use of her towing equipment and had to be discharged. However, Holmsgarth Quay, where she was berthed, could not be used because of quay congestion and the strength of the wind which exceeded the operational limits of the shore crane. Arrangements were therefore made to berth the vessel at Green Head Base. This involved *Maersk Champion* having to discharge ballast to reduce her draught. The crane at Green Head Base was then found to be inoperative and another had to be found. A partially dismantled crane undergoing annual inspection, and owned by Lerwick Harbour Trust, had to be rebuilt and moved to Green Head Base.

1.16 SHETLAND COASTGUARD

1.16.1 On receiving the initial call from *Green Lily* at 0644 on 19 November, Shetland Coastguard immediately began making enquiries to establish the availability of tugs in the area.

With the agreement of *Green Lily*'s master, a "Pan Pan" broadcast was made at 0740. No response was received.

Because of her dedicated towing equipment and her crew's experience in securing tows at sea, *Maersk Champion* was identified as the best available option in the prevailing conditions. Immediate efforts were made to seek clearance from her owner to use her for salvage operations. *Gargano* was not considered to be an option at this time as she was registered as a supply vessel and was understood to be undergoing repair.

1.16.2 Because of the weather conditions outside the harbour, Shetland Coastguard considered that the Lerwick Harbour Trust tugs were unsuitable. At that time the nearest Coastguard tug was over 220 miles away at anchor in Staffin Bay, Isle of Skye, and too far to be in a position to assist. Although two large purse seine net fishing vessels were alongside in Lerwick, neither had a crew. They were unavailable for immediate salvage work.

1.16.3 The Coastguard helicopter at Sumburgh was alerted and a "Mayday Relay" was initiated at 0844 in an attempt to get a response from any other available tugs in the area.

After *Gargano* had declared herself to be an anchor handling tug and available at 0911, Shetland Coastguard decided to use her in a first attempt to secure a tow. As a precaution, *Maersk Champion* was requested to continue preparations for discharging her deck cargo and to act as a back-up to *Gargano*. By this time, *Tystie*, some 40 miles away in Sullom Voe, had been tasked by Shetland Coastguard. It was intended that she should continue to proceed, to provide assistance to *Gargano* during the tow and to act as a back-up should *Gargano*'s tow fail.

1.16.4 At 0951 a second "Mayday Relay" broadcast by Shetland Coastguard brought a response from *Sidsel Knutsen*, a 15,806 gt tanker which was in the vicinity. She was immediately tasked to close *Green Lily*. The intention was for her to provide a weather lee while *Gargano* secured a tow.

As a precautionary measure against the situation deteriorating, Shetland Coastguard advised the master of *Green Lily* to consider which members of his crew were non-essential so they could be ready to evacuate at short notice.

Once *Gargano* had secured a tow to *Green Lily*, Shetland Coastguard recommended *Gargano*'s master to proceed to Dales Voe where *Green Lily* could be anchored. This decision was made after Lerwick Harbourmaster had stated that no berth was available in Lerwick due to congestion, and *Gargano*'s master had said he intended turning *Green Lily* to starboard to head north to find some lee.

Shortly after the tow started at 1229, Shetland Coastguard, with the agreement of *Green Lily*'s master, cancelled the "Mayday", thereby freeing the radiotelephone distress frequency of 2182kHz. However, with the exception of *Sidsel Knutsen*, all units were requested to remain on stand-by as a precautionary measure should the situation deteriorate. All units on scene were communicating on VHF radio without need of the 2182kHz distress frequency.

1.16.5 The tow with *Gargano* parted at 1239. Shetland Coastguard immediately arranged for the Coastguard helicopter and Lerwick RNLI lifeboat to proceed to the casualty. They also advised *Green Lily*'s master to prepare non-essential crew for leaving the vessel. *Gargano*'s master told the Coastguard that he would attempt to resecure the tow but when it became apparent that this would take at least another hour, the master of *Tystie* offered to put a towline on board *Green Lily*.

At 1319, Shetland Coastguard requested the Coastguard helicopter LC, which had just arrived on scene, to stand-by while *Tystie* attempted to secure a tow. *Tystie* was now approximately 1.5 miles from *Green Lily*.

Prior to *Tystie* passing a towline, her master relayed the Shetland Coastguard's advice to *Green Lily*'s master that he should have both anchors ready for letting go as a last resort. This would provide *Maersk Champion*, which had already left Lerwick, with a chance of securing a tow by using her grapnel on an anchor cable. Shetland Coastguard urged *Green Lily*'s master to have non-essential crew ready for evacuation.

The master of *Green Lily* agreed to release five crew members, two of whom were injured. Shetland Coastguard then agreed to the helicopter pilot's declared intention to lower a winchman onto the vessel. However, the pilot subsequently said the vessel's motion was such that lowering a winchman would not be safe, and that he would wait until *Tystie* had secured a towline and swung *Green Lily* head to wind.

1.16.6 Although the lifeboat arrived on scene shortly afterwards, the Shetland Coastguard did not ask the coxswain to approach *Green Lily* to evacuate non-essential crew while *Tystie* attempted to secure a tow.

After the towline from *Tystie* parted, Shetland Coastguard immediately advised *Green Lily*'s master to prepare to evacuate his crew and to let go an anchor with as much cable as possible.

Throughout this incident, the operation was co-ordinated by Shetland Coastguard. No on-scene commander was appointed.

The Coastguard advise that, dependent on a number of factors, including the location, scale and complexity of an incident, various on-scene roles may be assigned by the Search and Rescue Mission Co-ordinator (SMC) to assist him/her in the co-ordination of the incident. If required, an On-Scene Commander (OSC) can be designated to co-ordinate the search and rescue mission on- scene. An OSC should ideally be capable of remaining on scene for an extended period of time and of communicating with all on-scene search and rescue units and the vessel in distress. Other qualifying factors include suitable manning and equipment levels, on-board facilities and search and rescue knowledge.

1.17 TUGS AND SALVAGE ARRANGEMENTS

Three tugs were used during the course of the incident. Their particulars are detailed in Annex 1.

1.17.1 *Gargano*

Gargano was registered in the United Kingdom on 19 June 1997. Since taking over as her

manager, Gulf Offshore Ltd had been progressively re-equipping the vessel so she could perform the various functions required for a particular charter. The vessel was currently engaged in tanker assistance work in the North Sea.

She arrived in Lerwick on 16 November to shelter from the forecast weather.

The master held a UK First Mate (Foreign-Going) Certificate of Competency with a Class 2 Extended European Command Endorsement. He had worked at sea since 1969, had experience in a wide variety of vessel types and served as master for about 15 years. Prior to the incident, he had worked on board *Gargano* for about six months, serving one month on/one month off. His experience of supply vessels dated from 1977 and he had previously served on board supply vessels and anchor handling tugs, as both mate and master. In March 1997, he was involved in a successful salvage operation in force 6 to 7 weather conditions. Since joining *Gargano* the vessel was operated initially as a dedicated anchor handling tug to a lay barge, then used in rig shift operations and, latterly, in tanker assistance work.

When *Gargano*'s master became aware of *Green Lily*'s situation on 19 November he discussed the possibility of salvage with his manager during a routine telephone call at 0810. He considered the prospects of a successful tow in the prevailing conditions were low because the two wire towing pendants on board, each measuring 29m × 64mm diameter with a hard eye at one end and a soft eye at the other, were not readily accessible. He also thought the pendants would be too heavy for use in securing a tow to a coaster where the relative movement between the two vessels was likely to be high.

He also considered that the double nylon towing pendant on board, measuring 20m × 35mm circumference, was too large and too heavy for a relatively small vessel such as *Green Lily*. However as the depth of water allowed sufficient catenary, he judged that a nylon pendant would not be needed as a shock absorber.

The master believed that 40mm diameter wire pendants would have been more suitable for use in the circumstances but none were available.

The master also recognised that the polypropylene hawser he intended to use was lighter than the towing gear normally employed for such work. It was only later, at 1213, after the polypropylene hawser had been passed to *Green Lily*, that he voiced this concern.

Due to *Maersk Champion*'s higher freeboard and greater manoeuvrability, *Gargano*'s master felt that *Maersk Champion* was a more suitable vessel for connecting a tow in the prevailing conditions but, when it became apparent that *Maersk Champion* was not available, he decided he had a moral obligation to render such assistance as he was able and make an attempt to secure a tow. He decided to provide whatever help he could and declared himself available at 0911. *Gargano* got under way shortly afterwards.

When deciding which towing gear to use, the master of *Gargano* was unaware, and made no attempt to establish, whether *Green Lily* had power available forward to connect the tow.

Green Lily was heading south-west with the wind on her port beam. The master of *Gargano* passed clear instructions to *Green Lily* for securing the tow. The plan involved *Green Lily* firing a rocket line and attaching a messenger to it. Once it had been received on board *Gargano* his crew would bend on a mooring line to which a towline would be secured. *Green Lily* would then heave in, first the mooring line, and then the tow for it to be

connected. In the event, the rocket line was successfully fired but no messenger was passed. *Gargano* provided one and this was heaved on board *Green Lily* but her crew took it to be the tow line and placed its eye on the bitts. Eventually the intended towline was heaved on board and secured. Prior to the towline being made fast Lloyd's Open Form was agreed between *Gargano*'s manager and *Green Lily*'s underwriters.

As a precautionary measure against chafing, the master of *Gargano* advised *Green Lily* to protect the tow rope where it passed through the panama fairlead. This was acknowledged by *Green Lily* and some nylon sacking was wrapped around the rope where it passed through the fairlead. In an attempt to reduce shock loading on the towline, the master of *Gargano* also recommended that *Green Lily* should steer to follow directly astern of *Gargano*. Although this was attempted, *Green Lily* moved off line and the tow rope eventually parted just inboard of her fairlead. At the time of failure, *Gargano*'s towing gear comprised the full length of the 140m × 88mm diameter polypropylene hawser, and approximately 400m of main towing wire.

Although the polypropylene hawser had been used before, the master considered it to be in good condition. The rope had a certificated breaking strain of 137 tonne.

The main towing wire measured 1,000m × 64mm diameter and had a certificated breaking strain of 279 tonne.

The two wire towing pendants each had a certificated proof-loading of 109.6 tonne. Although no breaking strain was indicated on the relevant certificate, it is reasonable to assume that the towing pendants, each also measuring 64mm diameter, had a breaking strain, when new, in the order of 279 tonne.

A Towing Vessel Approvability Certificate placing her in the "Unrestricted Towing" category was issued to *Gargano* by Noble Denton Europe Ltd[1] on 14 November 1996. The towing pendants satisfied the certificate's requirements for number, length and minimum breaking load.

The master of *Gargano* manoeuvred his vessel stern to sea off *Green Lily*'s starboard shoulder to take advantage of what little lee existed and because he judged that even with the use of his bow thruster, he would be unable to stay head to sea while preparing to connect the tow. *Sidsel Knutsen* had not yet arrived to provide a lee.

Although the lee provided by *Green Lily* prevented large seas breaking on *Gargano*'s deck, she still shipped occasional swells, one of which washed a member of the crew across the deck so that he landed heavily against some stanchions. He injured his lower back, hip and thigh.

Realising that *Green Lily* would have drifted on to the rocks before he was ready to connect a second tow, and to avoid further risk of injury to his crew on deck, *Gargano*'s master aborted further preparation.

1 Noble Denton Europe Ltd is an organisation of marine engineering consultants and surveyors. One of its functions is to issue, on request, a Towing Vessel Approvability Certificate. Vessels issued with such a certificate have approval to conduct the type of towing specified provided they comply with the rules of the scheme and that their equipment and specification are maintained to the standards required by the Noble Denton Guidelines for Approvability of Towing Vessels.

1.17.2 *Tystie*

Tystie was operated as a harbour tug in Sullom Voe by Shetland Towage Ltd.

The master held a Mate's (Home Trade Passenger Ship) Certificate of Competency with a Near Continental Command Endorsement.

He joined Shetland Towage Ltd in 1977 and had spent 15 months as mate with the remaining period as master on tugs. He had experience in tugs of 400 gt and above with bollard pulls of between 38 and 56 tonne, mainly operating in Sullom Voe. He had previous experience of salving and towing vessels in gale force conditions but the conditions which prevailed on 19 November 1997 were exceptional.

Tystie was released by Sullom Voe Terminal at 0828 on 19 November and the master was put on stand-by by the owner at 0831. From the outset, the master believed he had little chance of successfully securing a tow to *Green Lily* but was prepared to give whatever assistance he could.

The towing gear used on board *Tystie* included the following:

a. a Steelite towing pendant measuring 22m × 64mm diameter with a minimum breaking strain, when new, of 166 tonne;

b. a Supermix towing spring measuring approximately 9m × 80mm diameter with a minimum breaking strain, when new, of 96.4 tonne;.

c. a deep sea towing wire measuring 1,000m × 48mm diameter with a certificated minimum breaking strain of 148 tonne.

While underway from Sullom Voe in the high sea state, *Tystie* sustained some damage to her fast rescue craft stowed on the foredeck. Her port side smoke float was also washed from its stowage bracket into the sea and ignited.

Having secured a towline to *Green Lily*, and while attempting to pay out the towing wire, a fault occurred in the winch control mechanism. The operating speed of the winch became restricted and resulted in excessive load being taken by the towing gear causing it to fail. The master had considered using the emergency release to overcome the control mechanism problem, but feared that a riding turn might develop on the towing winch. The gear parted after approximately 70m of towing wire had been paid out. The Supermix towing spring was connected to the Steelite towing pendant by a cow hitch. This caused the Steelite rope to cut through the Supermix rope when the excessive load was taken. Shetland Towage Ltd has since decided to replace all cow hitch connections with a joining link manufactured from two thimbles.

The difficulties experienced in connecting the tow were compounded by the decreasing availability of sea room. Once it had reduced to about one mile, *Tystie*'s master was reluctant to manoeuvre inshore of *Green Lily*.

An inspection of the winch control system later found that the remote control secondary cylinder piston collet assembly had become slack. This had allowed the piston to jump from its location in the piston rod. With it sliding freely on the piston, the required motion to the main operating slide valve was not possible. The system has since been repaired and, as a precautionary measure, a six-monthly inspection of these cylinders has been included in the company's planned maintenance schedule.

1.17.3 *Maersk Champion*

Maersk Champion was an anchor handling tug/supply vessel operating in the North Sea.

The master had been working on supply vessels for 21 years of which 14 had been in command. He was very experienced in anchor handling and towing but had little experience of salvage work.

The towing gear used by *Maersk Champion* was approximately 150 – 200m × 76mm diameter towing wire and a 100 tons SWL grapnel.

According to the Coastguard's standing instructions and the final report of an Emergency Towing Study, dated May 1995 and prepared for the Coastguard Agency by the Emergency Towing Study Team, *Maersk Champion* was an ideal type of vessel for use in the circumstances prevailing on 19 November.

The following are extracts from the Emergency Towing Study Final Report:

> *"ETVs (Emergency Towing Vessels) of 125 tbp (tons bollard pull) are better able to cope with severe weather and more capable of towing the larger casualties. An ETV of 100 tbp can handle large vessels but is better able to do so in areas less prone to severe weather conditions,"* and
>
> *"An AHTSV (Anchor Handling Tug/Supply Vessel) is more suited to the tasks an ETV may be expected to undertake than the traditional salvage tug."*

Although identified as the best option available, *Maersk Champion* was not ready for immediate use because of her deck cargo. There was a significant delay while arrangements were made for it to be discharged and, because of this, it was envisaged she would only be used as a last resort.

In the event, *Maersk Champion* did become available shortly after 1300. She sailed from Lerwick with the expectation that she would tow *Green Lily* by her anchor cable. To achieve this it would be necessary to connect the tow by use of a grapnel.

The use of a grapnel is not a conventional means of securing a tow in an emergency and failed because *Green Lily*'s anchor cable was insufficiently strong to withstand the rigours in the prevailing circumstances. *Green Lily*'s cable parted approximately 3m from the anchor.

Maersk Champion's log of events is listed in Annex 2.

1.18 *GREEN LILY*

1.18.1 Shipboard contingency plan

The only instructions for handling emergencies on board *Green Lily* were laid down in the Shipboard Contingency Plan. The following is an extract:

"7. ***Emergency – General Situations***

7.0 Engine or Control System Failure/Breakdown

1. Main engine failure/breakdown

(a) Inform the master.

(b) Use rudder (bow thruster) to the best advantage.

(c) Exhibit "Not under command" signal.

(d) Prepare anchoring if in shallow water.

(e) Broadcast warnings to vessels in vicinity.

Note: Do not forget to cancel the broadcasted warning when the main engine failure has been restored."

1.18.2 Events leading up to crew evacuation

Prior to making his final decision to depart Lerwick on the morning of 18 November, the master of *Green Lily* had monitored the weather forecast. The forecasts were all giving south-east force 6 to 8, perhaps occasional severe gale 9. However, the master optimistically took the average prediction of force 7 when deciding whether or not to sail. He had sailed in similar weather before and was confident in his vessel's ability to make satisfactory progress in such conditions. He was also conscious that adverse weather was forecast for several days ahead and that if he chose not to sail, the vessel would be delayed. There was no external pressure to sail on the morning of 18 November; the decision was his and his alone.

The unberthing operation went according to plan and no problems were detected with either machinery or equipment.

1.18.3 After leaving Lerwick and the lee provided by Bressay, it became apparent that the vessel was making very little headway and was effectively hove to. The prevailing weather conditions were worse than the master had expected. Although he had the option to turn around and return to Lerwick, he decided not to. Despite the weather forecasts predicting winds up to force 9, the master had not taken the precaution of ensuring that the aft mooring ropes were stowed in a more sheltered location. This resulted in them breaking free from their lashings, and consequent injuries to two crew members who were transferring the ropes to an upper deck. One of the injured was the chief officer.

Following the main engine failure on 19 November, the master made immediate contact with the vessel's manager in Norway, who subsequently made arrangements for the commissioning of *Tystie* to provide assistance. However, when it became apparent that *Gargano* would be on the scene much earlier than *Tystie*, the Shetland Coastguard's recommendation to secure a tow to *Gargano*, in preference to *Tystie*, was readily agreed by the master of *Green Lily* and subsequently endorsed by Green Management.

At 0820, *Green Lily* was 10.3 miles from the nearest land which lay to the north-west. By 0837 the master calculated that with a drift of 1.5 to 2 knots to the north-west, his vessel would be aground in seven hours. However, at drift rates of 1.5 knots and 2 knots from 0837, using the position recorded for 0820, the vessel would have grounded 6.9 hours and 5.2 hours later respectively. The master had chosen to use 1.5 knots rather than 2 knots as his estimated rate of drift.

1.18.4 Communications between *Green Lily*'s master and external bodies during the incident were not impaired by language difficulties and were conducted mainly on VHF radio Channels 10 and 16. On a number of occasions the master was prompted to ensure that agreed actions were being undertaken effectively on board. Communications on board *Green Lily* were by telephone, direct speech or portable VHF radio. VHF radios were held by the master, second officer, third officer and electrical engineer and communications were carried out on Channel 72.

Communications between the second officer and the master were conducted, at least occasionally, in Croatian which the third officer, a Philippine national was unable to understand.

1.18.5 While *Tystie*'s towline was being connected there was an apparent windlass electrical power failure, which meant that the towline had to be hauled on board by hand. The cause of the power failure has not been determined, but was only temporary, since windlass power was subsequently used in an attempt to walk out the port anchor cable when it became stuck. The reason for the port anchor cable becoming stuck has not been determined. It is possible the stowed cable had fallen over in its locker due to the excessive motion, and this had prevented it from running freely.

It was the master's decision to release the starboard anchor with only five shackles and then let go the port anchor. His intention had been to end up with nine shackles out on the starboard side and 4 on the port. When the port anchor cable became stuck, no attempt was made to pay out more anchor cable. With only five shackles of cable the effect of the starboard anchor was limited in reducing the rate of drift. It did, however have some effect in partially turning the vessel head to wind. This was further assisted when *Maersk Champion* managed to secure a grapnel to the anchor cable and started to tow.

1.18.6 Crew evacuation

Throughout the incident, the master was reluctant to evacuate any personnel while the possibility of securing a tug remained. After the first tow failed, he agreed to the evacuation of five non-essential crew and made arrangements for them to stand-by at the forward port side accommodation entrance from the main deck.

It was only when he was prompted by Shetland Coastguard to release non-essential crew members on arrival of the Coastguard helicopter, that the master indicated that two of them were injured.

The master realised that the only way of evacuating his crew was by helicopter or lifeboat, but he expected most of them to be taken off by the lifeboat. He was hopeful that the vessel might still be saved by *Maersk Champion* or by anchoring. Until the point when all hope of saving the vessel was lost, he was faced with a dilemma of whether or not to release all the crew.

1.18.7 During the evacuation of five crew members to the lifeboat, a number of bags were carried by them. There is conflicting evidence as to the nature and size of the bags, but the coxswain believed that the crew's insistence that they take their bags with them considerably hampered and delayed the evacuation.

1.19 GREEN MANAGEMENT

Crisis Operation Team

1.19.1 During the incident, a Crisis Operation Team was convened at the offices of Green Management in Norway. It comprised the managing director, the senior superintendent, a master mariner, the chartering manager, the crew manager and the quality assurance manager. A second superintendent participated in the initial stages and then travelled to Lerwick to liaise on site.

1.19.2 Communication between the master of *Green Lily* and the Crisis Operation Team was by INMARSAT and telex.

1.19.3 The suitability of available tugs was discussed by the team and while it was appreciated that none of those immediately available was ideal there was no hesitation in accepting that the nearest vessel thought capable of securing a successful tow should be used.

1.19.4 The method of securing the tow was left to the master and was not discussed.

1.19.5 Prior to the first tow connection, the use of anchors was considered by the team, but was thought unnecessary. Later, when the first towline parted, use of the anchors to prevent the vessel drifting towards the shore was put to the master.

1.19.6 The gravity of the situation was not fully recognised by the team until the first towline parted. Only then was it appreciated how little time remained to evaluate alternative measures.

1.20 COASTGUARD HELICOPTER LIMA CHARLIE (LC)

1.20.1 Before starting winching operations, a hi-line brief was given by the Coastguard helicopter LC to the master of *Green Lily*. Although the helicopter pilot requested the winching to take place from the top of the aft hatch, the crew assembled between the aft hatch and the accommodation which afforded them protection from the weather.

1.20.2 Having lowered the hi-line, LC experienced difficulties starting winching operations and the attempt was aborted. An alternative winching area on the forecastle was considered but discounted because *Tystie* was using it while attempting to secure a tow. It was decided to wait until the vessel had been turned head to wind before trying again.

Once it became apparent that winching was the only option left to evacuate the ten remaining crew members, the helicopter started to do so in extremely hazardous conditions. The winchman landed on the deck between the aft hatch and the superstructure and it was from there that the subsequent winching operation took place.

An investigation into the loss of the winchman was carried out by the Air Accidents Investigation Branch (AAIB) and its Bulletin No: 4/98 is at Annex 5.

1.21 LERWICK RNLI LIFEBOAT

1.21.1 The lifeboat was a Severn Class vessel and was approximately six months old in November 1997. She had a crew of six, including the coxswain/mechanic who had been with the

Lerwick lifeboat for 30 years and coxswain for 19. The weather conditions on 19 November were the worst he had ever worked in.

1.21.2 The lifeboat was launched at 1310 and tasked to stand-by the casualty. After it arrived on scene at 1350, the situation deteriorated to such an extent that the coxswain considered that evacuation should start immediately. By this time the starboard anchor had turned *Green Lily*'s head marginally into the wind. At 1427, the coxswain informed *Green Lily*'s master that he would try to take people off from the port, lee, side if they were ready. He then manoeuvred the lifeboat along the port side of the vessel but found no-one visible on deck. After remaining there for a while, he manoeuvred clear to prevent unnecessary damage to the lifeboat. At 1436, the coxswain urged *Green Lily*'s master to evacuate, whereupon some crew members appeared on deck. He manoeuvred the lifeboat alongside and embarked five people. In the process the lifeboat's starboard bow was damaged.

When *Green Lily* had been turned fully head to wind by *Maersk Champion*, no residual lee existed and the lifeboat was unable to manoeuvre alongside again.

1.22 EMERGENCY TOWING VESSELS

1.22.1 "Safer Ships, Cleaner Seas"

The following are extracts from the Report of Lord Donaldson's Inquiry into the prevention of pollution from merchant shipping, entitled "Safer Ships, Cleaner Seas":

> *"20.12 If assistance is going to be successful, a tug has to be able to reach the crippled ship quickly. The tug has to be strong enough for the job, properly equipped and furnished with an expert crew. There must be some way to make a very strong connection between the two vessels, sometimes in atrocious weather..."*

> *"23.122 Vessels which are in distress, or which have lost power and are in danger of grounding or being in a collision, need immediate assistance. Current arrangements for this are inadequate, because there is not enough capacity around UK shores for emergency towing ..."*

> *"23.123 Recommendation 85. The UK Government should set up a system to ensure that tugs with adequate salvage capacity are available at key points around UK shores ..."*

1.22.2 Emergency Towing Study

"Safer Ships, Cleaner Seas" was published in May 1994 and the Secretary of State for Transport tasked The Coastguard Agency to examine Recommendation 85. An Emergency Towing Study Team was commissioned and a Final Report was prepared for The Coastguard Agency in May 1995. Extracts from the report are in Section 1.17.3 and Annex 3.

1.22.3 Coastguard internal guidance

The following are extracts from the Coastguard's internal guidance with respect to emergency towing arrangements and the use of powers of intervention:

> *"Choice of Tugs. It should be noted that most harbour tugs are unsuitable for emergency offshore towing, particularly in bad weather. Their use must therefore be seen as a first-aid measure hopefully to control the situation before the arrival of a more suitable vessel,"* and

"Optimum Arrangements. The optimum arrangement to control a large vessel is to secure the services of a tug with a bollard pull of 80 tons and above, observing that to control a fully laden VLCC in heavy weather will require one or more tugs each capable of exerting a bollard pull of 90-150 tons."

1.22.4 CAST Agreement

The Maritime and Coastguard Agency has recently concluded an agreement with the British Tugowners' Association (BTA) concerning tug-hire arrangements in an emergency. The Coastguard Agreement on Salvage and Towage (CAST Agreement) applies to those members of BTA who might be able to provide a harbour or port tug, at short notice, to assist in emergency towing operations. On 19 November 1997, no such agreement existed in respect of tugs based in the Shetland Islands.

1.22.5 Emergency Towing Vessel (ETV) Cover

On 19 November 1997, Coastguard chartered ETVs were based in "Dover", "Hebrides" and "South West Approaches" with contracts to supply cover for the winter period only. New contracts have since been awarded to supply similar cover in the same areas.

The "Hebrides" based ETV, at anchor 220 miles away in Staffin Bay, Isle of Skye, was too far away to be of assistance to *Green Lily*.

1.23 STANDARDS OF TRAINING, CERTIFICATION AND WATCHKEEPING FOR SEAFARERS, 1978, AS AMENDED IN 1995 (STCW) CONVENTION

1.23.1 From 1 February 1997 the STCW Convention required minimum basic safety training and instruction for all seafarers. These requirements relate to competence and knowledge to achieve effective human relationships on board, an understanding of orders and an ability to communicate effectively. Masters and mates on vessels of 500 gt or more must be competent to organise and manage the crew. They should have knowledge of personnel management, organisation and training on board ship.

From 1 January 1999, amendments to the Convention require additional standards of competence in crisis management and human behaviour for masters, chief mates, chief engineer officers, second engineer officers and any person responsible for the safety of passengers in an emergency situation on passenger ships. These standards relate to effective leadership skills and an ability to identify excessive personal stress which can adversely affect human behaviour in an emergency situation. The relevant officers and crew must have an ability to establish and maintain effective communications and control during the emergency. These requirements do not apply to cargo ships.

Relevant details of the requirements are noted in Annex 4.

1.23.2 None of the above requirements were in force prior to 1 February 1997. The transitional provisions of the STCW Convention are such that certificates of competency, held prior to entry into force of the above requirements, remain valid for service after their entry into force.


Emergency Towing Study Final Report May 1995 — Operating Areas
SHETLAND ISLANDS
FAIR ISLE
ORKNEY ISLANDS
HEBRIDES
NORTH CHANNEL
FORTH & TYNE
NORTH SEA
HUMBER
DOVER
W & N WALES
SW APPROACHES
IRISH SEA
CELTIC SEA
ENGLISH CHANNEL
CHANNEL ISLANDS
NORTHERN IRELAND
REPUBLIC OF IRELAND
SCOTLAND
ENGLAND
WALES
FRANCE

SECTION 2
Analysis

The purpose of the analysis is to determine the contributory causes and circumstances of the accident as a basis for making recommendations to prevent similar accidents occurring in the future.

2.1 SEAWORTHINESS

2.1.1 The certification issued in respect of *Green Lily* was valid at the time she sailed from Lerwick and the vessel was manned in accordance with her Safe Manning Certificate. At the time of departure from Lerwick there were no known deficiencies nor evidence to suggest the vessel was unseaworthy.

The senior officers were appropriately qualified and experienced.

The master received no external pressure to sail. He was aware that the vessel would be heading into adverse weather and that progress would be slow. He was also aware that adverse weather was forecast for several days ahead, and that if he chose not to sail, the vessel would be significantly delayed. When sufficiently clear of the land, he intended to turn the vessel on to a more southerly heading to reduce the adverse effect of the wind on the vessel's speed.

In deciding to sail on 18 November, the master was optimistic that the prevailing and predicted weather conditions outside Lerwick would not unduly hinder the vessel's progress. He should have considered the worst predicted conditions and their effect. Although at least one officer was concerned about the master's decision to sail, no one openly questioned him.

After clearing Bressay, the vessel was effectively hove to in south-east force 9 winds. The master recognised that the weather conditions were worse than he had expected and that progress would be much slower than he had hoped. He had the opportunity of returning to Lerwick but chose not to do so, in the hope that the weather would improve. Having decided to sail, his decision not to return to harbour was possibly influenced by his not wishing to be seen as having failed to consider the worst predicted conditions.

The reluctance of anyone on board to question the master's decision to sail from Lerwick, and his decision not to turn back after realising he had failed to consider the worst predicted weather conditions, suggests an autocratic style of management. A less authoritarian style might have encouraged greater discussion of the issues and would have enabled decision-making shortcomings to be identified at the outset.

2.1.2 Although there was no evidence to suggest *Green Lily* was unseaworthy prior to the accident, the master would have demonstrated better seamanship had he not sailed on 18 November. Having sailed, his decision not to return led to the vessel and her crew being subjected unnecessarily to the stress of the weather.

2.2 SEA SUCTION PIPE FAILURE

2.2.1 The fracturing of the pipeline between the main sea water cross-over line and the sea suction valve on the general service pump was sudden and catastrophic. Although the size of the hole has been estimated as "fist size" (about 100mm in diameter), it has not been possible to identify the exact position, shape or type of fracture. It is known that the pipe material was galvanised mild steel with a nominal diameter of 100mm, but its age, condition, and date when last inspected, could not be established with any certainty.

Based on the following assumptions the accepted "life" of galvanised steel pipes and fittings is in the order of 5-10 years:

a. the design water flow speed of 3m/sec is generally maintained;

b. the galvanising is of the correct thickness;

c. the coating contains sufficient zinc.

This "life" can also be affected by:

d. impingement attack, (sharp bends, poor weld finishes, misalignment of flanges etc, giving rise to local turbulence, high water speeds, and corrosion due to the removal of the protective oxides coating);

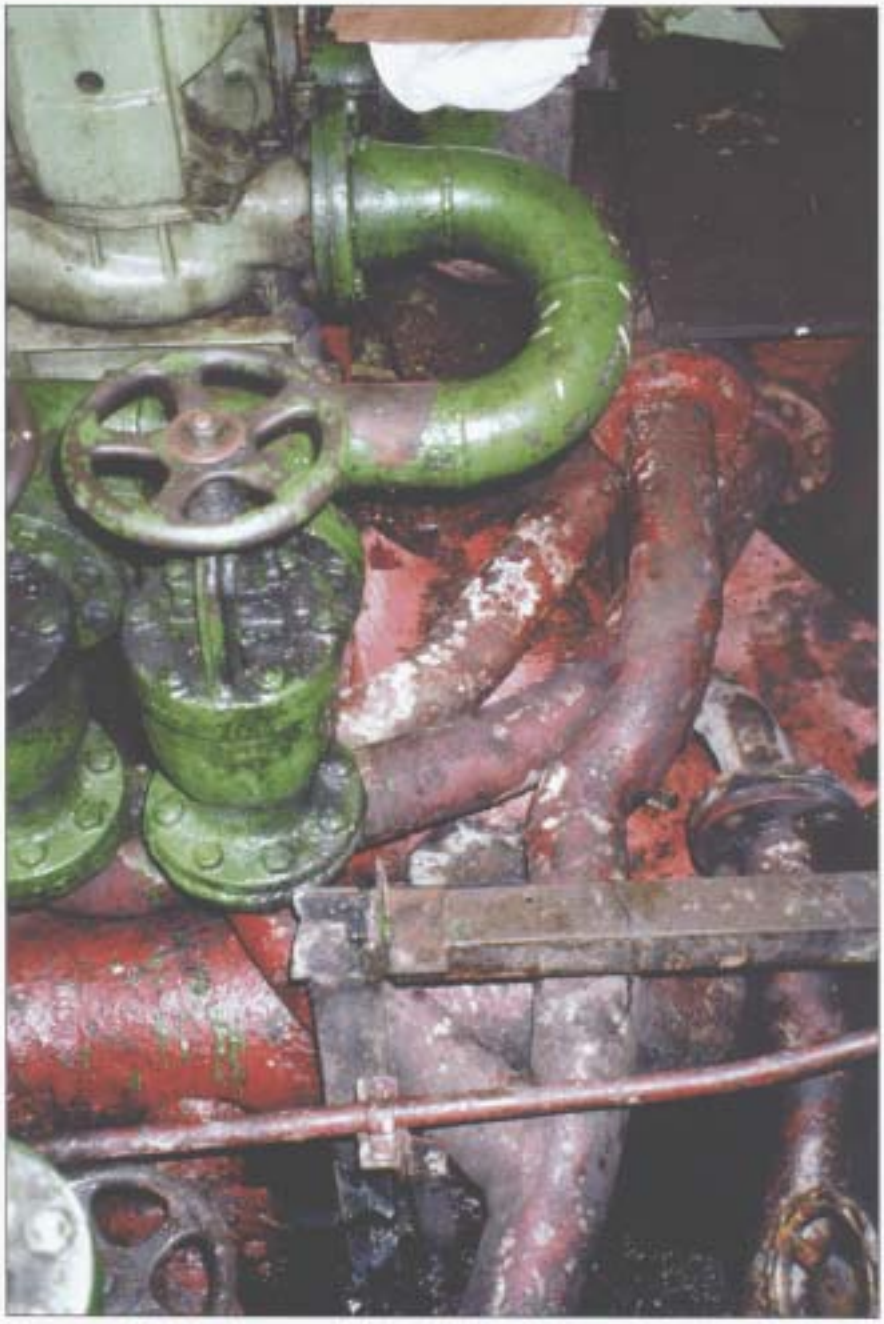
e. cavitation erosion, (the collapse of entrained air bubbles causing mechanical damage to the protective coating);

f. deposit attack, (corrosion occurring beneath the deposit and/or impingement attack due to local turbulence and high water speeds).

Additional considerations are the care with which the pipe was installed (ie not fitted under tensile or compressive forces), mechanical damage suffered during vessel operation, and whether there have been long periods during which the pipe has been unused in a damp or partially filled condition. All these factors affect the length of time a galvanised steel pipe will retain its integrity and strength.

2.2.2 A study of the "as fitted" drawings together with a visit to a sister vessel, *Green Tulip*, by an MAIB inspector, confirmed that the fractured pipe consisted of one "L" shaped section, about 1.5m in length, flanged at each end. It ran vertically downwards from the pump valve to the tank top where it passed forward beneath two other pipes to join the main sea water cross-over line. Access to this pipe was very restricted and a full examination of the condition would be difficult without removal of other pipes.

Although the shape and position of this pipe section was not unusual, it did present two potential high risk areas of weakness. One was the outside curve of the 90° bend, which, from an erosion/corrosion point of view is the weakest point, and the other was condensation/water etc dropping down from pipes and floor plates above. Both these points of attack tend to result in local thinning of the pipe material giving rise to pin hole weeping. Once this situation has developed or is close to developing, any sudden shock loading due to rapid changes of draught or heavy vibration due to pitching, can lead to sudden failure. If the thinning area has developed over a relatively wide area, then failure can result in an immediate large hole.



View of General Service Pump on sister vessel MV *GREEN TULIP* showing configuration of pipework below floorplates. The sea water inlet pipe to the G.S. Pump passed below these pipes.

2.2.3 At the time of the fracture Green Lily was making way in heavy weather and had been doing so for some 18 hours. During this time she was virtually hove to. Under these conditions, heavy rolling combined with severe pitching occurred giving rise to shock loading and heavy vibrations at the aft end of the vessel.

Apart from confirming that the pipe had fractured beneath the floor plates, none of the crew knew its precise location. The size was estimated as being about 100mm in diameter and the likelihood is that it occurred on, or adjacent to, the 90° bend.

The fracture of the sea water suction pipe was due to probable corrosive/erosive thinning of the pipe wall followed by severe shock loading and eventual failure brought on by the vessel's movement in the high sea state.

2.3 INITIAL ENGINE FAILURE

2.3.1 The stopping of the main engine 20 hours into the voyage was sudden and unexpected. There is no reason to suggest the crew stopped it deliberately and, since sailing, the engine had run continuously without any reported malfunction. Temperatures and pressures had been normal. By noon on 18 November engine speed was reduced from 750 to 710 rpm because of the high sea state. These revolutions were maintained until about 0600 on 19 November when, following the flooding incident, the chief engineer requested a further reduction. This reduction limited the effect of the engine flywheel picking up floodwater and splashing the engine. A few minutes later the main engine stopped.

It cannot be established with absolute certainty why the engine stopped, but it was probably due to one of the following reasons:

a. failure of the fuel supply;

b. automatic shut down by the engine governor; or

c. operation of the mechanical over-speed trip.

Each of these is examined in greater detail.

2.3.2 Fuel oil system

There is no evidence to indicate that failure of the fuel supply to the main engine was the cause of the initial stopping of the engine.

On sailing from Lerwick, *Green Lily* had 230 tonne of IFO and 93.5 tonne of GO aboard, sufficient for the projected passage to the next bunkering port. The quantity of fuel carried in the heavy fuel oil tank was therefore sufficient to prevent either fuel starvation or air locks due to the violent motion of the vessel. The possibility of restrictions within the fuel oil system is also discounted. Additional support for the view that fuel oil system failure did not occur is provided by evidence that the engine could be started manually by holding the fuel lever over after the original shut down.

2.3.3 The engine governor

The governor's prime function is to regulate the engine speed and to effect automatic shut down of the engine in response to high cooling water temperature or low lub oil pressure. Shut down is actuated within the governor by operation of the electric solenoid, either automatically or by manual operation of a stop button.

Prior to shut down, the engine flywheel was picking up a large amount of water that was splashing onto the engine control stand and adjacent equipment including a nearby electrical terminal box. This terminal box linked most of the engine speed controls, including the governor control and alarm sensors, to the control system. The box was not waterproof and the electrical connections inside could have become wet. It is probable that they shorted out to disable the control and alarm circuits, and cut off the electrical supply to the governor solenoid.

The failure of the electrical supply would disable the governor solenoid. Because the governor solenoid required this electrical supply to operate, the governor would not have caused the main engine to stop.

2.3.4 Operation of the mechanical over-speed trip

When the mechanical over-speed trip operates, the fuel control is moved to zero and the engine stops. Manual resetting of the trip is necessary to restart the engine.

Due to the severity of the weather and the resulting strain on the vessel and her machinery, the master reduced the engine speed within 3 hours of sailing. Despite further deterioration in the weather, no further engine speed reduction was made. This change in sea state led to greater ship movements and pitching. Under these conditions the risk of engine over-speed occurring due to the propeller racing had increased. Trying conditions in the engine room, combined with the continual change in engine speed, often leads to a lowering of awareness. Given the state of emergency that existed in the engine room at that time, over-speed could have occurred without the engineers being immediately aware of it.

2.3.5 The probability is that the mechanical over-speed trip operated and stopped the engine while the engineering crew were fully occupied trying to stem the flooding.

2.4 FAILURE OF MAIN ENGINE TO RESTART

2.4.1 In addition to opening the starting air supply, the normal procedure to start the main engine requires the starting of the independent electrically driven lub oil pump. This pump primes the main engine lub oil system causing a pressure operated relay to activate the electric solenoid of the air start system. Failure to start the pump prevents the auto-start system from operating.

After the main engine stopped, the chief, second and electrical engineers, attempted to restart it a number of times without success. The initial attempt to use the electric start system produced no response. The relay of the air start solenoid was then manually operated to admit air to the air start system. With the fuel regulator rack moved and held in the run position, the engine started. As soon as the manual operation of the fuel rack stopped, however, the engine stopped.

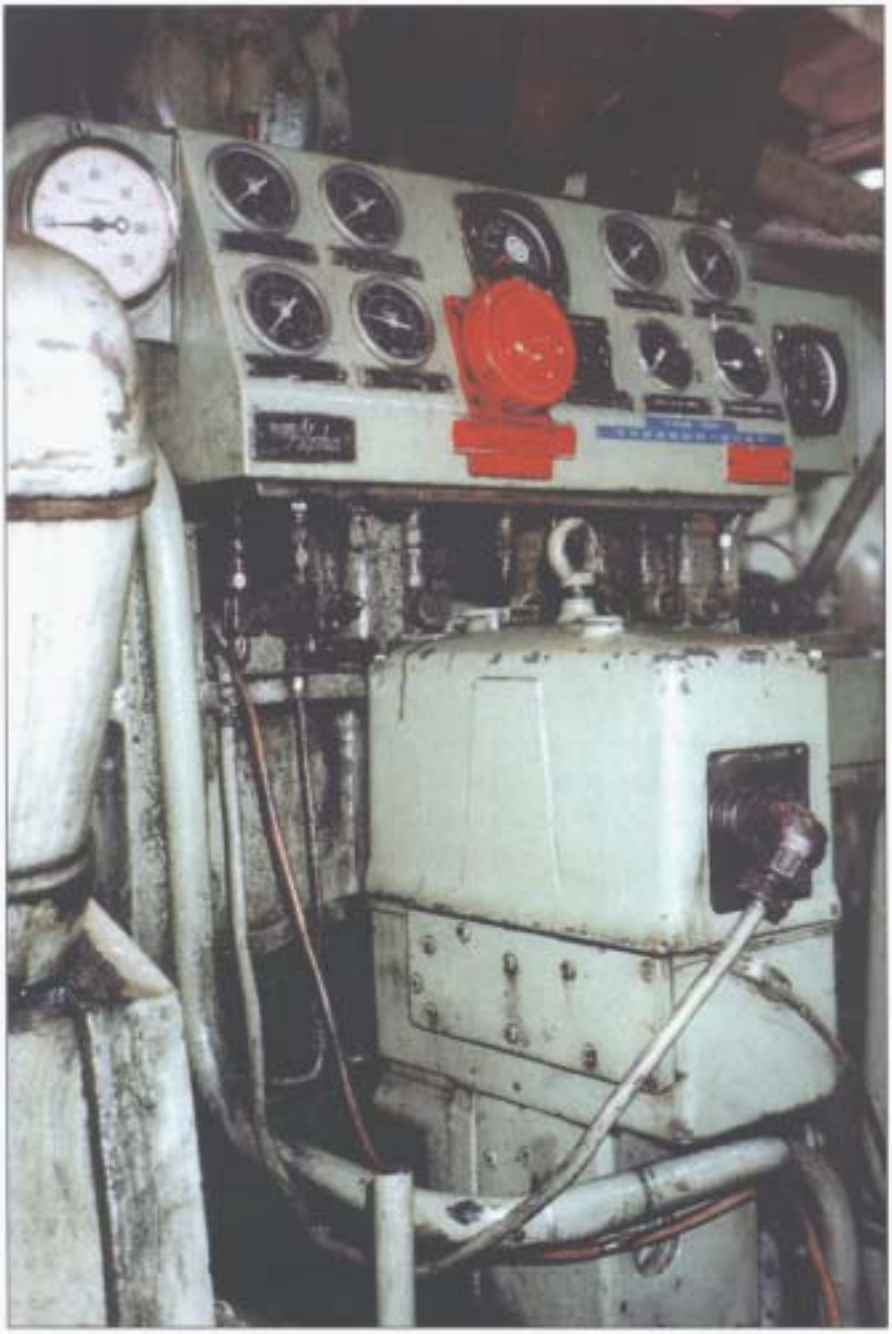
2.4.2 Failure of the electric start system suggests that either:

a. the circuit was locked out by the low lub oil pressure switch; or

b. the electric system itself had failed.

With the electric motor of the stand-by lub oil pressure pump positioned on the starboard side close to the fractured sea water pipe, failure could have occurred due to water ingress. The chief engineer has stated that he started the stand-by lub oil pressure pump before attempting to restart the main engine. This statement is accepted, since, with the lub oil pressure gauge immediately adjacent to the engine start switch, any lack of pressure should be readily noticeable. The possibility of lub oil pressure failure as a cause of engine restart failure is therefore rejected.

With the electric air start not working, the electrician, by manually holding the starting solenoid over, by-passed the safety system allowing starting air to be admitted to the air start system. Once the engine was turning over, the engine driven lub oil pump pressurised the system and caused the lub oil pressure relay to move into the run position.



View of Main Engine control point showing Governor and Electric Starting Control (red rotary switch). This control point is at the Port Aft end of the Main Engine.

As stated earlier, the electrically operated stop system fitted in the governor is of the "energise to operate" type. Any electrical circuit failure, either within the governor housing itself or in the supply wiring outside, would cause the electrical shut down system to fail. Without a 24V supply, the stop solenoid could not operate and the engine would continue to run. If the engine was in a stop condition at the time of electrical failure, the solenoid would become free and a spring beneath the ball valve would operate and reset the valve. Under this condition, the governor would revert to normal hydraulic control on the engine but without any electrically operated safety devices. Failure of an electrical circuit to the governor, therefore, would not prevent the engine from restarting.

2.4.3 It has already been established that the reason why the main engine stopped was probably due to operation of the mechanical over-speed trip. The reason that the engine could not

be restarted could have been due to either the over-speed trip not being reset or being reset incorrectly.

The reset for the over-speed trip was positioned on the starboard side forward of the main engine and was not easily accessed. To reset, the locking pin, facing inboard, had to be pulled out, ie towards the engine or inboard. This action, if carried out from the side of the engine, had to be done by feel, as access for sighting was restricted. If the reset was carried out from the forward end of the engine, sighting would have been possible but again with restricted access. Under normal conditions, resetting was not easy. Under the conditions of flooding and adverse weather experienced during this incident, failure to reset correctly, and not be aware of it, was a real possibility.

Even with the mechanical over-speed trip locked in, it was possible for the regulating shaft to be manually forced a short way against the compressed air stop valves and/or springs, allowing limited fuel to reach the pumps and causing the engine to fire. Once the shaft was released, the regulating shaft would return to the "no fuel" position, stopping the main engine.

2.5 THE RESPONSE OF THE ENGINEERING STAFF

2.5.1 Engine room flooding

The fracture of the sea suction pipe and the consequent inflow of water into the engine room was both sudden and unexpected. It occurred some two hours after the second engineer had come on watch.

The events which followed involved, primarily, two experienced and qualified senior engineer officers; the chief and second engineers.

The chief engineer had joined the vessel 11 days before the incident and might have had limited knowledge of the sea water cooling and ballast systems.

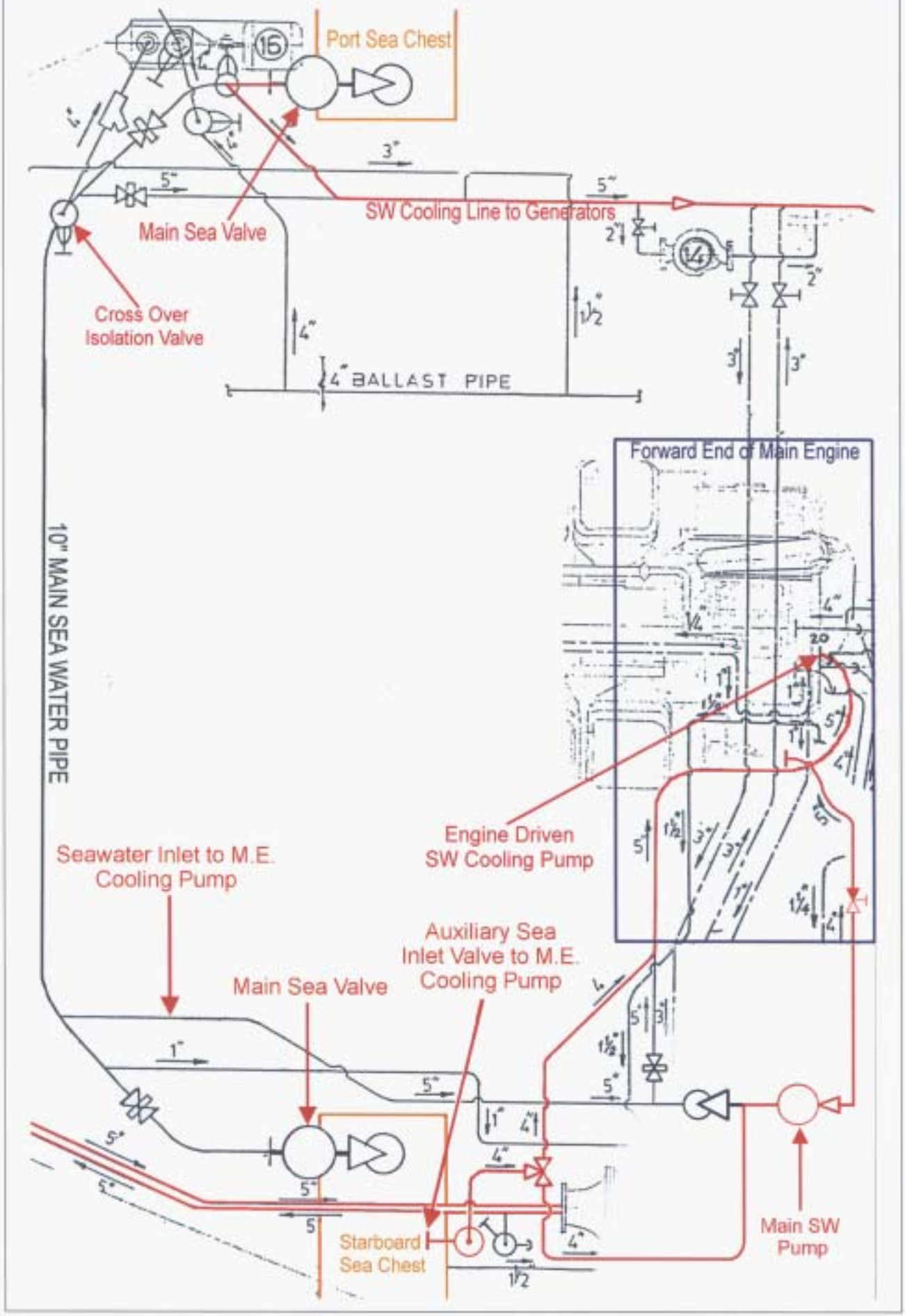
The second engineer joined the vessel in June 1997 and had stood-by during her dry docking in Gdynia when the sea water and ballast systems had been surveyed, maintained and sections renewed. He should have had detailed knowledge of the systems.

The working environment on the morning of 19 November was unpleasant; the weather conditions were severe and the vessel was pitching heavily.

The second engineer identified the general source of the leak as the fire and general service pump piping but could not locate the precise position. A valuable period of about 15 minutes was lost trying to stop the leak by shutting various valves around the pump. Only when it became apparent that the water level was continuing to rise did he call the chief engineer.

On his arrival in the engine room, the chief engineer should have appreciated the urgent need to shut the main sea valves as soon as he had established where, and in what pipe, the fracture had occurred. His immediate action in instructing the fitter to try and plug the hole using wooden plugs was an inadequate response to a critical situation. The hole was already 100mm in diameter and the pipe in an obviously weakened condition.

MV *GREEN LILY* Sea Water Cooling System



The engineers' decision to solve the problem by trying to stop the leak at the pipe itself was flawed. It is possible they thought that closing the main sea water valves would lead to a loss of propulsion power. An alternative cooling water supply to the main engine and generators was available but not used.

According to the machinery drawing of the vessel, a 100mm diameter auxiliary sea water cooling line came directly off the starboard sea chest to supply the main engine driven sea water pump. A similar 75mm diameter direct line from the port sea chest supplied the generators. The main engine would continue to operate therefore, even with the two main sea water inlet valves shut.

Following flooding, over half an hour elapsed before the main sea valves were closed. The chief engineer was very slow to react effectively to the situation and, given his relatively short time on board, it is possible he needed time to think things through before taking the appropriate action.

If both chief and second engineers had had a better understanding of the sea water system, the flooding could have been stopped much earlier. The problem created by water spray from the main engine flywheel would have been reduced, allowing an accurate diagnosis to be made of why the main engine stopped.

2.5.2 Main engine stoppage

At 0610, some 40 minutes after the flooding had started, the main engine stopped.

Confronted with a new problem, the chief and second engineers, assisted by the electrical engineer, attempted to restart the engine.

The electrical engineer joined the vessel in August 1997 and was an experienced electrical and engineer watchkeeper, familiar with the engine room layout and the electrical circuitry.

Between them, the three officers manually operated the air start system and managed to get the engine running by holding the fuel rack lever in the run position. Once released, the lever moved back to zero and the engine stopped. The process was repeated a number of times.

The problem they faced was an engine that would start but not run. To overcome the problem they required a good system knowledge leading to an accurate diagnosis. These factors are examined.

System knowledge and problem diagnosis
Having managed to restart the engine by holding the fuel rack lever in the run position and seeing it move back to zero, the chief, second and electrical engineers do not appear to have considered what was causing this mechanical action. They should have realised that failure of the low voltage electrical system disables the alarm and shut down function, but does not cause the engine fuel rack to lock out. The fuel rack lever could only be moved to, and held in, the stop position by applying compressed air to the stop cylinders. For that to happen, the over-speed trip needed to operate. By resetting the trip, the stop cylinders would vent, and the fuel rack would return to normal operation.

Although the lack of system knowledge and effective systematic diagnosis of events contributed to the failure of the engineers to restart the engine, their performance would also have been affected by the following:

a. the weather and flooding which resulted in poor working conditions in the engine room;

b. their belief that the main engine failure was due to the effect of flooding on the electrical supply to the engine controls;

c. their optimism that a tow would be available well before the anticipated time of grounding, so that use of the main engine would be unnecessary; and

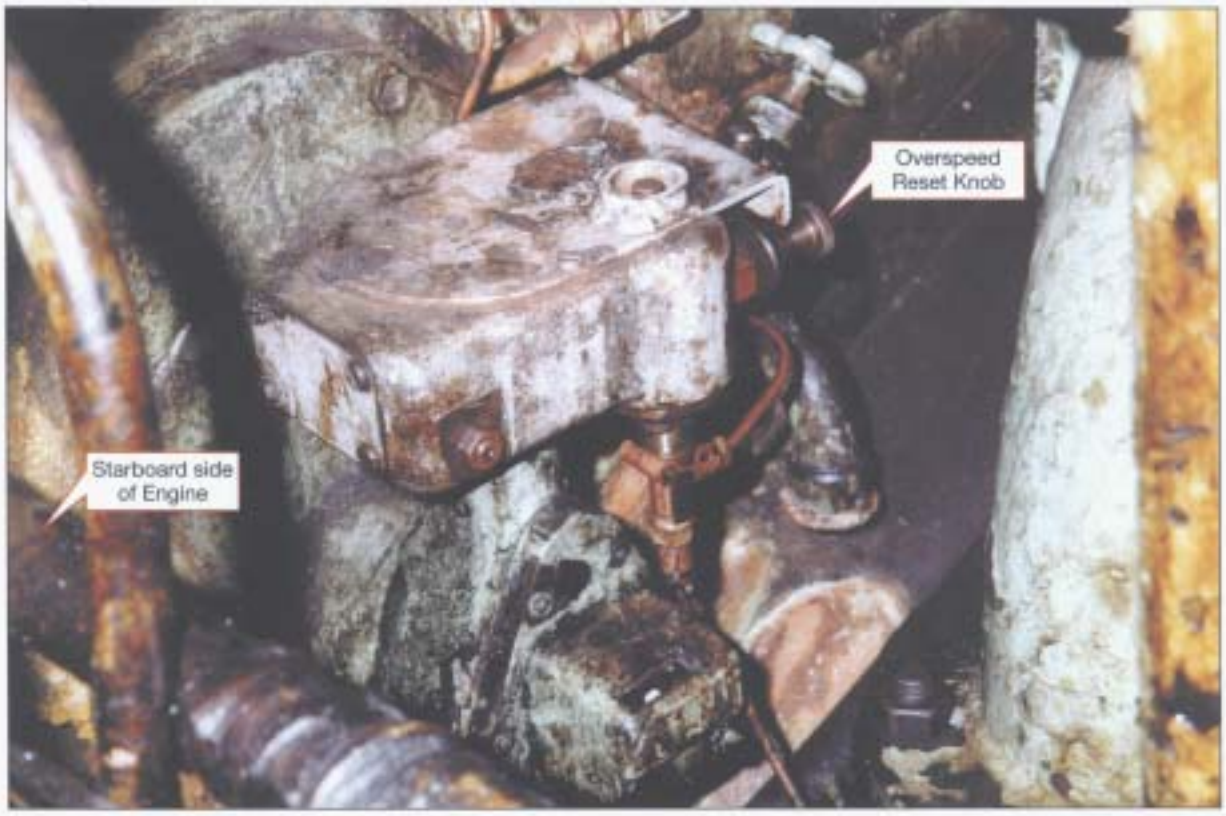
d. the stress and anxiety caused by the emergency situation.

The over-speed trip

Failure to restart the main engine was due to the mechanical over-speed trip not being reset. The reason the engineers did not recognise this may have been influenced by the position of the reset mechanism.

They would have been more aware of the possibility that the over-speed trip had not been reset had the mechanism been easily accessible, and readily identified from the engine control position.

Better siting and identification of the over-speed trip, along with better knowledge of the main engine control system and better diagnostic skills, would probably have enabled the engineers to restart the main engine.



View of Main Engine Mechanical Overspeed Trip fitted at end of Camshaft, Starboard side forward. The Reset Knob faces into the centre of the 'V' Engine and away from the Engine side. Access for operation is difficult from the Engine side. Feel only, no sight. Access from Forward is easier although at arm's reach.

2.6 FACTORS AFFECTING THE TOW AND EVACUATION OF *GREEN LILY*

During the period when attempts to salvage *Green Lily* were being made and preparations were underway to evacuate the crew, notable delays arose. There are several possible reasons.

2.6.1 Actions of key personnel

Failure to communicate and exchange certain essential information
In an emergency it is important that everyone involved has an accurate appreciation of the situation. To achieve this, effective communication is necessary. There were shortcomings in this incident.

The recorded communications to and from *Green Lily* indicate they were conducted in a calm manner. Despite this, there seems to have been a lack of appreciation on board of the impending risk of grounding and the increasingly difficult, and diminishing options for a safe evacuation. The master was advised by Shetland Coastguard on a number of occasions to prepare for the possible failure of securing a tow. Had the gravity of the emerging dangers been recognised earlier, attention should have been given to the evacuation of the crew.

One reason why the master did not take action to evacuate earlier is because he remained optimistic that a tow would be successful. On the other hand, he was unaware that the masters of *Tystie* and *Gargano* had reservations about their ability to secure and carry out a tow. At no time did the master of *Tystie* express his concerns to either Shetland Coastguard or to *Green Lily*. The master of *Gargano*, who had similar reservations because of the light towing gear, did not tell Coastguard of these until he was actually paying out the tow wire. Had *Green Lily*'s master been aware of these reservations, he would have been in a better position to make an informed assessment of the situation and would probably have considered an earlier evacuation.

Use of the heavy wire pendants on board *Gargano* would have been a viable option in connecting a tow since power was still available forward on board *Green Lily*. The master of *Gargano* made no attempt to confirm whether *Green Lily* had power forward and assumed that none would be available when *Gargano* arrived on scene. Although it would have delayed his departure from Lerwick, preparation of the additional wire towing pendants would have provided the master of *Gargano* with a choice of gear for use once on scene. On the other hand, the additional time needed to prepare the towing pendants before departure might have prevented *Gargano* arriving on scene in time to be of any assistance to *Green Lily*.

Despite clear instruction from *Gargano* to *Green Lily* to pass a messenger, they failed to do so. It is possible that the instruction passed from the master to the second officer was either unclear or misunderstood.

The urgency of the situation increased when the towline with *Gargano* parted. This prompted Shetland Coastguard to task the Coastguard helicopter and Lerwick RNLI lifeboat to be in a position to at least evacuate non-essential crew.

The master of *Tystie* offered to put a towline on board. Whilst attempting to connect it, *Green Lily* was lying with the weather on her starboard beam. The resultant motion was such that the helicopter pilot declared it was unsafe to lower the winchman and that it would be necessary for *Green Lily* to be swung head to wind before he could start an evacuation. This

either required *Tystie* to connect the tow and turn *Green Lily* into the wind, or for the anchors to be let go and allow the weather, or *Maersk Champion*, to make the turn.

The lifeboat, meanwhile, stood by *Green Lily* for about 35 minutes waiting for an opportunity to commence evacuation from her lee side. During this period, the lifeboat coxswain considered that *Green Lily* was rolling and pitching too heavily to start evacuation. It was only after the starboard anchor was let go, causing *Green Lily*'s head to turn marginally into the wind, that the coxswain considered it possible to approach her port side. Prior to this, nobody requested the lifeboat to start evacuation, nor was any information passed by the coxswain detailing the lifeboat's limited potential for evacuating personnel in the prevailing circumstances. Rather than let go the anchor to enable the crew to be evacuated via the waiting lifeboat, all the effort was focused on trying to connect the tow in an evolution that had limited prospects of success. As a result, valuable time was lost and the vessel's drift towards the shore continued.

It is possible the master assumed that the lifeboat was reluctant to start evacuation for the same reason as the helicopter. However, he would not necessarily have appreciated that the lifeboat might have difficulty in functioning alongside after *Green Lily* had been turned fully into the wind.

Everyone was hopeful that *Tystie*'s efforts to secure the tow would be successful. At the same time however, the time available to evacuate personnel successfully progressively diminished. The need for everyone, and most especially those on board *Green Lily*, to be aware of the reducing time and options available to evacuate the vessel was seriously underestimated. This required a comprehensive exchange of information that could have been achieved had there been more effective communications and better understanding of the difficulties among everyone involved.

On-scene Command and Control
Generally, the different limiting operational parameters of Coastguard helicopter LC and the lifeboat in the circumstances were not fully recognised. Had the Coastguard appointed an On-Scene Commander (OSC), a better appreciation of the situation might have been possible. In the event nobody appreciated that valuable evacuation time was being lost by the lifeboat not being put to use when it was potentially able to offer assistance.

A tow remained a viable option until the anchor cable parted. So long as the towing option remained, *Green Lily*'s master was probably reluctant to release more than a limited number of his crew so that he had sufficient numbers on board to connect the tow. He did not know how *Maersk Champion* intended connecting the tow until just before she arrived.

In an emergency situation the chance of a successful outcome is dependent on effective teamwork, involving a sound plan of action and objectives that are clearly communicated among all parties. Individuals must understand their roles and responsibilities. There were several instances where lack of effective teamwork contributed to the accumulated delay.

2.6.2 Towing vessel availability

Although an ETV was based in "Hebrides", she was too far away to be of assistance.

In the prevailing circumstances and, in the absence of a CAST Agreement in respect of tugs based in the Shetland Islands, there was no guarantee of the immediate availability of any harbour tugs.

Had the revised procedure for updating the register of tugs in port been in place at the time of this incident, it would have had no effect on the outcome.

Shetland Coastguard acted in accordance with the MCA's internal guidance with regard to its selection of appropriate towing vessels from those available. In accordance with the guidance, the most appropriate vessel for the task was *Maersk Champion* but because she had to discharge her cargo first, she was not immediately available. Lerwick Harbour Trust and the relevant quay operators in Lerwick responded effectively to the need for the cargo to be offloaded.

Shetland Coastguard did not initially consider *Gargano* as she was registered as a supply vessel and they understood she was undergoing repair. It was recognised later that she should have been capable of securing a successful tow and was tasked accordingly.

Although the least capable of the three available towing vessels, the harbour tug *Tystie* was retained to assist if required. *Maersk Champion* had sailed and she was tasked to secure a tow should *Gargano* be unsuccessful.

The prevailing weather conditions were such that most vessels normally engaged in offshore work were in port. While in port, no vessel has an obligation to respond to a distress call. It was therefore fortuitous that *Gargano*, *Tystie* and *Maersk Champion* were in a position to help and declared themselves available to render assistance. Their problem was that, in their different ways, none were immediately available to provide the degree of assistance required in the circumstances and in the time available.

It is ironic that during adverse weather, when the risk of a vessel drifting onto a lee shore and requiring assistance is high, those most able to provide such assistance are themselves likely to be sheltering in port.

It is possible that had ETV cover been based in "Fair Isle" as recommended by the Emergency Towing Study Team in 1995, appropriate assistance would have been rendered to *Green Lily*.

However, it is also possible that *Gargano*, *Tystie* or *Maersk Champion*, all of which were available albeit not immediately, might have prevented *Green Lily* from grounding had it not been for a number of circumstantial factors which are discussed in the next section, Towing vessel capability. These factors prohibited each of the tugs effecting a successful tow.

The decision by Shetland Coastguard to release *Sidsel Knutsen*, prior to *Gargano*'s tow clearing the lee shore, was premature. There was still a risk of the tow failing, thus having to effect a tow by another means.

2.6.3 Towing vessel capability

Gargano and *Tystie* might have effected a successful tow had the circumstances been slightly different.

Tystie's tow might have been successful had she made the connection in a weather lee. Other contributing factors to her inability to effect a tow were the failure of the towline cow hitch connection and the fault with her winch control.

The use of the polypropylene hawser by *Gargano* was initially successful. However, when *Green Lily* failed to follow in *Gargano*'s wake, the hawser was not strong enough to withstand the additional loading.

Gargano's chances of success in securing a tow were affected by the working conditions in the open. She had a relatively low freeboard, an exposed aft deck and, given the appalling conditions that day, a tendency to ship water easily. One of the crew was injured while working on deck and the risks facing other deckhands were judged to be high. This sea state limitation was a factor in assessing her effectiveness.

Given the high sea state an effective towing capability could best be provided by a vessel with a high bollard pull, good manoeuvrability, an experienced crew and a deck area where people could work safely. The vessel best placed to fulfil these requirements was *Maersk Champion*.

Two factors reduced her effectiveness. She was not immediately available and had to offload her cargo before being in a position to provide assistance. Secondly, she was not equipped with a range of towing gear suitable for towing a small general cargo vessel such as *Green Lily*. There is every prospect that in a future emergency other towing vessels, seemingly suitable on first inspection, may be restricted in what they can provide at short notice.

But for the failure of *Green Lily*'s anchor cable, it is possible that the tow could have been successful. However, the cable was designed as a means to anchor the vessel rather than for towing in an emergency during adverse weather conditions.

2.6.4 Emergency towing vessels

Following the decision not to implement the recommendation of the Emergency Towing Study Team to position an ETV in "Fair Isle", no such vessel was available to assist in this incident. It is impossible to make a judgment as to whether a "Fair Isle" ETV would have made any difference on this occasion. Had one been, say, at anchor in Scapa Flow and sailed immediately the first "Pan Pan" message was transmitted, it is unlikely she would have reached the casualty in sufficient time to prevent her from grounding.

What must be assumed however, is that a "Fair Isle" ETV would have been suitably equipped, and available at short notice to render the degree of assistance so badly needed by *Green Lily* on 19 November. Whatever the merits of the existing arrangements for providing emergency towage cover in the waters around the Northern Isles, the conclusion of this investigation shows that despite the dedicated and often brave efforts of the masters and crews of three vessels capable of towing, each had some reason for not meeting the salvage need on the day.

The lack of an ETV did not necessarily affect the outcome of this accident, but the MAIB believes the incident introduces the need to look, once again, at the original decision not to position an ETV in "Fair Isle". In the MAIB's opinion this incident has exposed flaws in the existing arrangements for the provision of emergency towing in this area.

2.6.5 Other issues

From the moment *Green Lily* lost power, the combined wind and sea conditions caused her to drift towards the land.

The commitment by everyone involved to secure a successful tow and rescue *Green Lily*'s crew was commendable.

The master of *Green Lily* allowed himself to remain optimistic of a successful outcome throughout. While accepting this as a natural reaction to his predicament, he should have planned for the worst scenario.

- His interpretation of the weather forecast prior to sailing was conservative.
- He based his drift calculations on the slowest rate and allowed himself to think he had more time than he had.
- He placed an unjustifiable reliance on the ability of the tugs to secure a tow.
- No contingency planning for the worst case scenario was carried out.

The Shipboard Contingency Plan provided little practical guidance for how to handle an engine failure. Building on the lessons learned from this incident, such plans should embrace topics such as:

- An assessment of the potential dangers and any time factor restrictions.
- Navigation and calculation of drift rates.
- Breakdown diagnostics and/or damage assessment.
- Anchoring preparations.
- Weather forecasts.
- Crew evacuation plans.
- Recording of events.
- Manning requirements.
- Communications and liaison with outside authorities (including potential media interest). Content of basic information to be passed ashore including nature of cargo, amount of fuel carried, number of people on board and their state, availability of auxiliary power. Hazardous or dangerous goods carried.
- Content of alerting message to owners and follow up action.
- Towing arrangements and any relevant information to be passed to any towing vessel. (LOF).
- Medical requirements.
- Outside information to be sought including details of rescue units and their operating parameters.
- Provision of safety and/or survival equipment.

2.6.6 Bridge and engine room resource management

A number of MAIB investigations have shown that one of the most important factors in the chain of events is the lack of any training in crisis management. In most cases, all officers involved, both deck and engine, held internationally recognised certificates of competency and were experienced in their particular jobs.

Many of the accidents investigated showed that while coping adequately with standard emergency procedures and situations, cohesion failed when non-standard emergency situations occurred, leading to rising levels of personal stress.

During these periods of high stress levels, engineer officers often show a lack of diagnostic skills, while deck officers fail to operate as an effective bridge team.

Both these findings were reflected in the *Green Lily* investigation.

Bridge and engine room simulators are used to familiarise officers with standard emergency situations and procedures, but only rarely as a means to train officers in crisis management. Clarity of thinking under pressure, coupled with the ability to make the best use of team skills and knowledge, can be developed and analysed using simulator technique. This variable approach to crisis management allows staged levels of stress to be introduced to sea staff, so that good on-board team management can be developed in parallel with individual departmental skills.

The use of bridge and engine room simulators as part of the training of ships' officers to cope with non-standard emergency situations, such as that which occurred on board *Green Lily*, shows officers how important it is to learn how to operate under pressure. Such training should form part of the core curriculum for both deck and engineer officers.

IMO, through the STCW Code, clarifies standards of competence required of ships' officers, but provides little guidance on bridge and engine room resource management and diagnostic skills. Furthermore, these skills are not required to be tested for the issue of certificates of competency.

Certain UK shipping companies use simulators to create non-standard emergency situations with increasing levels of applied stress. The aim is to develop and assess senior shipboard teamwork, and promotability. Canada, India and the USA use simulation to assess competence.

The findings of the *Green Lily* investigation suggest that serious consideration should now be given by flag states to the introduction of proactive crisis management training using simulation within the standards of competence required of ships' officers.

The standard of competence required is a matter for flag state administrations, but MAIB believes that the use of simulation to raise the standard of team management and diagnostic skills while under stress, is an increasingly important factor in maintaining high levels of safety at sea.

SECTION 3
Conclusions

These conclusions identify the cause and factors contributing to the incident and should not be taken as apportioning either blame or liability.

3.1 CAUSE OF THE GROUNDING

The cause of the grounding was the lack of propulsion and failure to restart the main engine in time to prevent the vessel drifting ashore in severe weather conditions.

The cause of the loss of the helicopter winchman is covered in the AAIB Bulletin No: 4/98 in Annex 5.

3.2 CONTRIBUTORY CAUSES

1. It was imprudent of the master to sail on 18 November 1997 in view of the prevailing and predicted weather conditions. [2.1.2]

2. The prevailing wind and sea conditions caused *Green Lily* to drift towards the land. [1.8, 2.6.5]

3. Failure to restart the main engine was probably due to the mechanical over-speed trip either not being reset or being incorrectly reset. [2.4.3]

4. The polypropylene hawser was unable to withstand the loading experienced during the towing operation, particularly when *Green Lily* moved off line on to the starboard quarter of *Gargano*. [2.6.3]

5. *Tystie* failed to effect a tow due to the absence of a weather lee, a failure of the towline cow hitch connection and a fault in her winch control mechanism. [2.6.3]

6. The failure of *Maersk Champion*'s attempt to tow *Green Lily* clear was unsuccessful due to the anchor cable being unable to withstand the excessive loading experienced in the prevailing circumstances. [2.6.3]

7. The physical location of the mechanical over-speed locking pin on *Green Lily* was not easily visible or accessed. [2.4.3, 2.5.2]

8. The flooding of the engine room was the result of a fracture in the sea suction pipe to the fire and general service pump, which deviated attention from the cause of the engine stopping. [1.14.1, 2.5]

9. The fracture of the sea suction pipe was due to probable corrosive/erosive thinning of the pipe wall followed by severe shock loading and eventual failure brought on by the vessel's movement in the high sea state. [2.2.3]

10. The second engineer failed to take appropriate immediate action. [2.5.1]

11. The chief engineer was very slow to react effectively to the situation. [2.5.1]

12. The chief engineer's and second engineer's lack of system knowledge and effective systematic diagnosis of events contributed to their failure to restart the engine. [2.5.1]

13. The chief engineer's and second engineer's performance would have been affected by the following:

    - the weather and flooding, which resulted in poor working conditions in the engine room;

    - their belief that the main engine failure was due to the effect of flooding on the electrical supply to the engine controls;

    - their optimism that a tow would be available well before the anticipated time of grounding, so that use of the main engine would be unnecessary; and

    - the stress and anxiety caused by the emergency situation. [2.5.2]

14. The master of *Green Lily* failed to make contingency plans at each stage of the incident and, instead, remained over-optimistic of a successful conclusion. [2.6.5]

15. An autocratic management style on board *Green Lily* resulted in decision-making shortcomings not being identified. [2.1.1]

16. The Shipboard Contingency Plan provided little practical guidance on how to handle an engine failure. [2.6.5]

3.3 OTHER FINDINGS

1. There were no known deficiencies in *Green Lily* nor was there any evidence to suggest she was unseaworthy when she departed Lerwick on 18 November 1997. [2.1]

2. *Green Lily* was adequately manned and the senior officers were appropriately qualified and experienced. [2.1]

3. In the absence of an immediately available dedicated ETV or CAST Agreement in respect of local harbour tugs, it was fortuitous that *Gargano*, *Tystie* and *Maersk Champion* were in the vicinity and declared themselves available to render assistance. [2.6.2]

4. Although *Maersk Champion* was identified as the most suitable towing vessel available, she was unable to render immediate assistance due to her deck cargo.[1.17.3, 2.6.2]

5. It is possible that *Gargano*, *Tystie* or *Maersk Champion* might have prevented *Green Lily* from grounding, had it not been for a number of circumstantial factors. [2.6.2]

6. Lerwick Harbour Trust and the relevant quay operators in Lerwick responded effectively to the need for *Maersk Champion*'s deck cargo to be discharged. [2.6.2]

7. *Green Lily* was not equipped with an insurance wire and her anchor cable was not designed for use as a means for towing the vessel in an emergency during adverse weather. [1.6.3, 2.6.3]

8. *Maersk Champion* effectively used her grapnel to connect a towline to the anchor cable of *Green Lily*. [1.18.5]

9. Stronger wire pendants were available for use on board *Gargano*. However, the additional time needed to prepare them before departure from Lerwick might have prevented *Gargano* arriving on scene in time to be of any assistance to *Green Lily*. [2.6.1]

10. The polypropylene hawser used to effect the tow by *Gargano* was initially successful. [2.6.3]

11. The decision by Shetland Coastguard to release *Sidsel Knutsen*, prior to *Gargano*'s tow clearing the lee shore, was premature. [2.6.2]

12. It is possible that the evacuation of *Green Lily* would have commenced at an earlier stage following failure of the towline with *Gargano* had *Tystie* not offered to put a towline on board. [2.6.1]

13. In opting to continue solely to try to save the vessel, rather than simultaneously to start to evacuate the crew of *Green Lily*, valuable time was lost in an effort to secure a tow, the success of which was in doubt. [2.6.1]

14. Generally, the different limiting operational parameters of the Coastguard helicopter and the lifeboat in the prevailing circumstances were not fully recognised. The reduced time available to evacuate *Green Lily*, should the tow with *Tystie* fail, required a comprehensive exchange of information, that could have been achieved had there been more effective communications and better understanding of the difficulties among everyone involved. [2.6.1]

15. The master of *Green Lily* would have been in a position to make a more informed assessment of the need to evacuate the vessel had he been informed of the reservations held by the masters of both *Gargano* and *Tystie*, with respect to effecting a successful tow. [2.6.1]

16. A lack of effective communications on board *Green Lily* resulted in delays when connecting each of the towlines, when anchoring and when preparing to abandon ship. [2.6.1]

17. The commitment of everyone involved to secure a successful tow and, subsequently, to evacuate *Green Lily* was commendable. [2.6.5]

18. An appointed OSC might have more readily appreciated that valuable time was being lost by the lifeboat not being put to use at a time when it was potentially able to offer assistance. [2.6.1]

19. *Green Lily* had undergone an extensive dry dock, repair and maintenance period in May/June 1997 during which time the sea water cooling and ballast system was inspected and renewed as necessary. [1.7.1, 2.5.1]

20. Emergency cooling of the main engine was possible via the starboard sea chest. [2.5.1]

21. It is probable that electrical failure within the main engine control and instrument systems occurred prior to the initial stopping of the main engine. [2.3.3]

22. It is possible that had ETV cover been based in "Fair Isle", in accordance with the Emergency Towing Study Team's 1995 recommendations, appropriate assistance would have been rendered to *Green Lily*. [2.6.2]

SECTION 4

Recommendations

4.1 **The Director of Logistics and Maritime Transport of the Department of the Environment, Transport and the Regions** is recommended to:

1. Review previous decisions not to provide the recommended ETV cover in "Fair Isle" and re-examine the need for emergency towing cover in the area.

4.2. **The Maritime and Coastguard Agency is** recommended to:

1. Commission a research study into how bridge and engine room simulators can best be used for bridge and engine room resource management training that includes escalating emergencies and increasing levels of stress. The results should be used to develop effective training for handling emergencies at sea.

2. Introduce simulator training for handling escalating emergencies within the UK certificate requirements for senior officers and, through the IMO, promote similar training internationally.

4.3 **The Maritime and Coastguard Agency** in consultation with **RNLI, MoD and CAA** is recommended to:

3. Produce guidelines for exchanging relevant information and intentions between key on-scene personnel during an emergency.

4.4 **The International Chamber of Shipping** is recommended to:

1. Promote the use of bridge and engine room resource management simulator training, including escalating emergencies and increasing levels of stress, for senior deck and engineer officers.

4.5 **Green Management A/S, Minde, Norway** is recommended to:

1. Provide bridge and engine room resource management simulator training, including escalating emergencies and increasing levels of applied stress, for senior deck and engineer officers employed on their ships.

2. Review its Shipboard Contingency Plan to take account of the lessons learnt from this accident.

Glossary of Terms

Catenary	–	Natural curve formed by weight of hanging chain
Class	–	Classification Society
Cow Hitch	–	Type of rope connection
Exclusion zone	–	Area over which no flights are permitted
Grapnel	–	An instrument with several flukes or claws for seizing or lifting
Hard Eye	–	Eye in rope with steel thimble/shaper
Hi-Line	–	Weighted guideline
Insurance Wire	–	Dedicated towing wire
Lee Shore	–	Shore on the side of vessel that is sheltered from the weather
"Mayday Relay"	–	Relay distress signal
Messenger	–	Small rope attached to large wire or hawser
Panama Fairlead	–	Type of fitting allowing smooth passage of rope or hawser
"Pan Pan"	–	Urgency signal
Pendant	–	Short length of rope attached to a towline
Proactive	–	The act of varying conditions before establishing a process or situation
Propeller Pitch	–	Angle of propeller blade
Riding turn	–	Turn of a rope that rides over or across another turn or turns
Shackle	–	A metal coupling link closed by bolt, or a length of chain cable measuring 15 fathoms
Simulator	–	Full size model of bridge or engine control station capable of imitating various conditions of a process or situation for training purposes
Soft Eye	–	Eye in rope without steel thimble/shaper
Steelite Rope	–	Trade name for a particular type of rope
Supermix	–	Trade name for a particular type of rope

ANNEX 1

Particulars of Tugs:

GARGANO

Certificate of Registry Particulars of Vessel:

Port of Registry	:	London
Type	:	Supply Vessel
gt	:	1,392
Length	:	61.14m
Breadth	:	13.00m
Depth	:	6.30m
Maximum Draught	:	5.512m
Propulsion	:	2 × B&W ALPHA each developing 4,240 hp at 775 rpm driving CP Propellers in fixed nozzles
Bow Thruster	:	1 × TORNADO tunnel thruster producing approximately 5 tonne thrust
Bollard Pull	:	100 tons
Manager	:	Gulf Offshore Ltd

TYSTIE

Port of Registry	:	Lerwick
Type	:	Tug
gt	:	797
Length Overall	:	38.37m
Breadth	:	13.92m
Maximum Draught	:	3.53m (aft)
Propulsion	:	2 × Voith Schneider Units
Main Engines	:	2 × Caterpillar each developing 2,150 kW at 1,000 rpm
Bollard Pull	:	56 tonne
Owner	:	Shetland Towage Ltd

MAERSK CHAMPION

Port of Registry	:	Ringkobing, Denmark
Type	:	Anchor Handling Tug/Supply Vessel
gt	:	2,887
Length Overall	:	69.30m
Breadth	:	17.61m
Depth	:	9.02m
Maximum Draught	:	6.105m
Propulsion	:	2 × Controllable Pitch Propellers
Main Engines	:	4 × 3,600 bhp B&W ALPHA
Bow Thruster	:	1 × 1200 bhp BRUNVOLL producing about 13.5 tonne thrust
Aft Thrusters	:	2 × 1200 bhp BRUNVOLL, each producing about 13.5 tonne thrust
Bollard Pull	:	170 tonne
Manager	:	The Maersk Company Limited

ANNEX 2

The following is a log of events with respect to making *Maersk Champion* available for salvage work:

0735: Lerwick Harbour Port Control called *Maersk Champion* on VHF radio and requested the master to contact Shetland Coastguard.

0739: The master of *Maersk Champion* advised Shetland Coastguard of the need to discharge his deck cargo which would take between 2 and 3 hours after securing the vessel alongside a quay.

0820: Shetland Coastguard requested the owner of *Maersk Champion* to advise on the vessel's availability.

0833: It was confirmed that *Maersk Champion* would be unable to discharge her deck cargo at Holmsgarth Quay.

0855: The owner of *Maersk Champion* was advised that the vessel would be able to discharge her deck cargo at Green Head Base but would need to discharge ballast first in order to lighten her draught.

0900: The master of *Maersk Champion* was advised that the vessel had been released by the charterer and that her deck cargo could be discharged at Green Head Base. *Maersk Champion* immediately started to discharge ballast.

0904: Shetland Coastguard was advised that *Maersk Champion* could be alongside at 1030 and ready to sail at 1200.

0915: It was confirmed that the shore crane intended for use at Green Head Base was inoperative.

0935: A request was received by Lerwick Harbour Trust for a crane to be supplied to Green Head Base.

1000: *Maersk Champion* proceeded towards Green Head Base.

1025: *Maersk Champion* arrived alongside Green Head Base and awaited the arrival of a shore crane.

1055: *Maersk Champion* commenced discharging her deck cargo.

1215: *Maersk Champion* completed discharging her deck cargo and was now rigging her towing wire and grapnel.

1305: *Maersk Champion* completed rigging her towing wire and grapnel and departed Lerwick.

ANNEX 3

Extracts from Emergency Towing Study Final Report May 1995 – The Coastguard Agency

"4.54 *A draft specification of the type of vessel that the Study Team consider would meet the criteria required for a capable and versatile ETV follows ...*"

"4.63 *Vessel to be in class with major Classification Society such as Lloyds, ABS, DNV or Germanischer Lloyd. Vessel to be Noble Denton approved for unrestricted world-wide towing.*"

"Towage/Anchor Handling Equipment (Minimum)

4.67 *Towing Drum 250 tonnes pull*
350 tonnes holding power
Capacity for 1200 metres of 64mm wire
Anchor Handling Drum – Pull and capacities as above
Storage Reels – 2 × 1200 metres × 64mm wire capacity
Spare Tow wire storage reel
Closed top towing pins
Mechanical Stopper (Shark's jaw, Karm fork or Triplex)
Stern roller – Minimum diameter of 2.5 metres and minimum length of 3.5 metres. Minimum SWL of 300 tonnes
Tow wire – 1200 metres × 64mm diameter
Spare tow wire (as above)
Work wire – 200 metres × 56mm diameter
Towing Pendants 2 × 35m × 62mm diameter (Hard Eyes)
2 × 35m × 62mm diameter (Soft eye – hard eye)
Stretcher – 2 × 26m × 96mm diameter (8 Plait)
Selection of lightweight towing gear suitable for towage of small vessels
Shackles 4 × 110 tonnes SWL
4 × 85 tonnes SWL
4 × 55 tonnes SWL
Chafe chain – 10m × 76mm dia studlink chain (Open link at each end)
BEL 109 grapnel – SWL 100 Tons (or equivalent)
BEL 101 J Hook – SWL 100 Tons (or equivalent)"

"Bollard Pull (Continuous)

4.69 *100 tons (Minimum) for DOVER*
125 tons (Minimum) for SW APPROACHES, NORTH CHANNEL, HEBRIDES, and FAIR ISLE"

"We recommend

11.17 *That ETV cover should be provided throughout the year in the Primary Danger Areas of DOVER, HEBRIDES and the SOUTH WEST APPROACHES; and for the winter only (1 October – 31 March) in the Secondary Danger Areas of FAIR ISLE and NORTH CHANNEL.*"

ANNEX 4

Extracts from Standards of Training, Certification and Watchkeeping for Seafarers Code (STCW Code)

Section A-VI/1 of the STCW Code sets out mandatory minimum requirements and basic safety training and instruction for all seafarers. Such training is required to cover personal safety and social responsibilities to the extent set out in Table A-VI/1-4 of the Code, which includes the following:

> *"Competence: Understand orders and be understood in relation to shipboard duties.*
>
> *Knowledge, understanding and proficiency: Ability to understand orders and to communicate with others in relation to shipboard duties."*
>
> *"Competence: Contribute to effective human relationships on board ship.*
>
> *Knowledge, understanding and proficiency: Importance of maintaining good human and working relationships aboard ship. Social responsibilities; employment conditions; individual rights and obligations; dangers of drug and alcohol abuse."*

Section A-II/2 of the Code sets out mandatory minimum requirements for certification of masters and chief mates on vessels of 500 gt or more. The competencies required to be demonstrated are set out in Table A-II/1 of the Code and include the following:

> *"Competence: Organize and manage the crew.*
>
> *Knowledge, understanding and proficiency: A knowledge of personnel management, organization and training on board ship. A knowledge of related international maritime conventions and recommendations, and national legislation."*

Amendments to the STCW Convention which are due to enter force on 1 January 1999 introduce minimum standards of competence in crisis management and human behaviour for masters, chief mates, chief engineer officers, second engineer officers and any person having responsibility for the safety of passengers in emergency situations on passenger ships. The minimum standards are set out in Table A-V/2 of the Code and include the following:

> *"Competence: Control response to emergencies.*
>
> *Knowledge, understanding and proficiency: Ability to make an initial assessment and provide an effective response to emergency situations in accordance with established emergency procedures.*
>
> *Leadership skills: Ability to lead and direct others in emergency situations, including the need:*
> *.1 to set an example during emergency situations*
> *.2 to focus decision making, given the need to act quickly in an emergency*
> *.3 to motivate, encourage and reassure passengers and other personnel*

Stress handling: Ability to identify the development of symptoms of excessive personal stress and those of other members of the ship's emergency team. Understanding that stress generated by emergency situations can affect the performance of individuals and their ability to act on instructions and follow procedures."

"Competence: Control passengers and other personnel during emergency situations.

Knowledge, understanding and proficiency: Human behaviour and responses: Ability to control passengers and other personnel in emergency situations, including:

.1 awareness of the general reaction patterns of passengers and other personnel in emergency situations, including the possibility that:
.1.1 generally it takes some time before people accept the fact that there is an emergency situation
.1.2 some people may panic and not behave with a normal level of rationality, that their ability to comprehend may be impaired and they may not be as responsive to instructions as in non-emergency situations
.2 awareness that passengers and other personnel may, inter alia:
.2.1 start looking for relatives, friends and/or their belongings as a first reaction when something goes wrong
.2.2 seek safety in their cabins or in other places on board where they think that they can escape danger
.2.3 tend to move to the upper side when the ship is listing
.3 appreciation of the possible problem of panic resulting from separating families."

"Competence: Establish and maintain effective communications.

Knowledge, understanding and proficiency: Ability to establish and maintain effective communications, including:
.1 the importance of clear and concise instructions and reports
.2 the need to encourage an exchange of information with, and feedback from, passengers and other personnel.
Ability to provide relevant information to passengers and other personnel during an emergency, to keep them appraised of the overall situation and to communicate any action required of them, taking into account:
.1 the language or languages appropriate to the principal nationalities of passengers and other personnel carried on the particular route
.2 the possible need to communicate during an emergency by some other means such as by demonstration, or by hand signals or calling attention to the location of instructions, muster stations, life-saving devices or evacuation routes, when oral communication is impractical
.3 the language in which emergency announcements may be broadcast during an emergency drill to convey critical guidance to passengers and to facilitate crew members in assisting passengers."

ANNEX 5

AAIB Bulletin No: 4/98

REF: EW/C97/11/4 CATEGORY: 2.1

Aircraft Type and Registration:	Sikorsky S61N, G-BCLC
No & Type of Engines:	2 General Electric CT58-140-2 turboshaft engines
Year of Manufacture:	1974
Date & Time (UTC):	19 November 1997 at 1456 hrs
Location:	Bressay, Shetland Islands
Type of Flight:	Search and Rescue
Persons on Board:	Crew – 4 (including the winchman on the vessel) Passengers – 10
Injuries:	Crew – 1 fatal; Passengers – None
Nature of Damage:	Winch cable partially severed; winch jammed
Commander's Licence:	Airline Transport Pilots Licence
Commander's Age:	49 years
Commander's Flying Experience:	5,800 hours (of which 2,800 were on type)
Information Source:	AAIB Field Investigation

History of flight

At 0836 hrs the Search and Rescue (SAR) crew at Sumburgh were brought to a standby because the Motor Vessel (MV) Green Lily had suffered an engine failure and was drifting. Her position was 10 nm south east of Bard Head, the southernmost point of Bressay, one of the Shetland Islands. She had a crew of fifteen. By 1218 hrs, the vessel was under tow to Dales Voe; the SAR standby was to remain until the vessel arrived at Dales Voe. At 1239 hrs, the tow broke and at 1258 hrs the SAR crew, in helicopter 'LC', were scrambled to a position 2.7 nm south east of Bard Head; the helicopter was airborne at 1309 hrs and on scene at 1319 hrs. The Marine Accident Investigation Branch are carrying out an Inspector's Inquiry into the accident and consequently this Bulletin will be confined to the events which are directly related to the SAR helicopter and the loss of the winchman. The sequence of events was determined, in the main, from crew reports and replay of the Combined Voice and Flight Data Recorder (CVFDR).

When the helicopter arrived on scene, the MV Green Lily was lying with her starboard beam to the wind and swell. The surface wind was estimated as 150°/50 to 70 kt, the sea state 8 and the visibility 5,000 metres. The tug Tystie was in attendance and the Maersk Champion and the Lerwick Lifeboat were proceeding to the scene. It was decided to winch off two injured crewmen as soon as possible. It proved difficult to select a suitable winching area as the smooth deck surfaces were overhung by cranes and cables. The preferred area was the forward part of the aft raised hatch cover and, based on this, a dummy approach was made. The ship's master was briefed on the Heaving-in line (Hi-line) transfer method. The commander positioned 'LC' on the ship's leeward side and the Hi-line was lowered.

The deck crew took the Hi-line and moved to the well between the raised hatch and the bridge structure, a less than ideal position from the helicopter crew's viewpoint. However, the ship was now only about 1.5 nm from the shore and the rolling motion had worsened to the extent that the commander decided to abort the rescue attempt until one of the tugs could stabilise the ship by hauling its head into wind.

The Tystie eventually managed to get a line to the MV Green Lily but the tow parted before it had any effect on the ship's orientation. The master was then advised to slip the ship's anchors; after some time, the starboard anchor lowered but the port did not. The ship's head was now about 45° off the wind and the Lerwick Lifeboat came alongside, on the port, and managed to take off five crewmen. The Maersk Champion managed to grapple the MV Green Lily's anchor and started to turn the vessel before the lifeboat had to abandon the attempt. Although the ship was now very close to the shore the situation appeared to be more stable and the helicopter commander decided to start winching operations.

At about 1441 hrs, the helicopter was manoeuvred into the winching position and the Hi-line was lowered. The winchman was lowered onto the deck with two strops to recover the ten remaining crewmen, two at a time. At about 1443 hrs, it was reported on the radio that the anchor cable had parted and the Green Lily started to drift stern first towards the coast. The situation now became more critical and winching started at 1444 hrs. Large and rapidly varying flight control positions were recorded as the commander maintained the helicopter's position; the radio height varied between 40 and 90 feet and, as the groundspeed was zero, the values recorded as airspeed gave an indication of wind speed. This was of the order of 35 kt with several gusts exceeding 50 kt.

As the third lift was taking place, the master was told to go onto the deck immediately to be winched off. The fourth lift had started, leaving the master, one crewman and the winchman still on board. The master reported at 1450 hrs that the vessel was aground. The ship was now rolling violently and the commander reported that, to maintain hovering references, the helicopter was about 30° out of wind and holding about 10° of left bank. He was having difficulty keeping clear of the vessels superstructure. It was decided to get the winchman to 'hook on' with the last two crewmen; winching three people at a time is within the capability of the equipment but would only be used in an emergency situation such as was deemed to exist at the time. The winch operator recalled seeing all three people on the deck engulfed by a large wave as he prepared to lift them off; as the ship rolled back he winched the last two crewmen off. The winchman was not in radio contact with the helicopter and despite the winch operator's hand signals, he had not attached himself to the hook.

Once the last two crewmen had been pulled into the cabin, the hook was immediately sent down to the winchman. At 1456 hrs the ship was rolling violently and huge waves were breaking over the deck. At this time, as the cable was being winched out, the winch operator became aware that the Hi-line appeared to have become snagged in the ship's superstructure. Thirty seconds later, while still trying to release the Hi-line, the winch operator noticed that the winchman was no longer on the deck. Five seconds later the helicopter momentarily rolled 8° to the right and, to avoid further endangering it and its occupants, the winch operator decided to activate the cable shear system. The noise of the cartridge firing was audible to the crew and was recorded on the CVFDR. The winch operator advised the commander that the cable had not sheared and that the Hi-line was still attached. There can be no doubt that the winchman had already been washed overboard when the cable shear system was operated. Fortunately the Hi-line became

unsnagged and was now clear of the ship's structure. The winch operator managed to raise the hook to about two feet of the winch mechanism. He could now see that the top end of the Hi-line had wound itself round the hook, effectively bypassing the weak link. He was able to cut the line free using the bolt-cropper provided as part of the back-up equipment. At about 1458 hrs, the commander advised Shetland Coastguard that they had lost the winchman overboard.

The winchman had been swept overboard and was dashed repeatedly against the side of the ship. He was last seen in the sea with his lifejacket inflated. His helmet was missing, he was covered with oil and there appeared to be no sign of life. The winch was no longer usable so there was no way the helicopter crew could attempt a rescue and the location and conditions were such that it was not possible for the lifeboat to approach. Even if the helicopter winch had still been available a rescue would not have been feasible. The commander decided to take the survivors to hospital and then to return to Sumburgh where a replacement winch could be fitted.

The ten crewmen who had been rescued from the MV Green Lily were flown to the Gilbert Bain Hospital at Clickimin and were disembarked at 1505 hrs. The helicopter was then flown to Sumburgh where it landed at 1523 hrs. The back-up aircraft with a serviceable winch took off again at 1550 hrs, with a replacement crew, to continue the search for the winchman.

Flight Recorders

The CVFDR was removed from the aircraft and replayed at Farnborough. The recorder had retained data from the whole flight and the last 61 minutes of crew audio. Throughout the operation the crew of the aircraft were in radio communication with all vessels taking part and with Shetland Coastguard. The winch operator was connected via the aircraft's intercom to the crew and his speech was also recorded on the CVFDR. The quality of the recording was excellent.

Failure of the cable cutting mechanism

The Lucas Air Equipment Hoist, part no 76378-100, includes a cable cutting device (*see Appendix A*), which is operated by an electrically fired squib. The winch cable passes down through a vertical hole in the cylindrical shearing knife holder. The fixed anvil is situated on one side of the cable and on the other side there is the chisel (or guillotine), the cutting edge of which should be horizontal and at right angles to the cable. A drilling in the chisel blade is aligned with a horizontal drilling in the shearing knife holder and a shearing pin is force fitted. This not only keeps the chisel back from the cable but should also ensure its correct alignment. When the squib is fired the pin is sheared, the chisel is driven forward against the anvil and the cable is cut. There are two gas exhaust holes in the shearing knife holder. These are slightly larger than the shearing pin drillings but are in the same vertical plane and at right angles to them, ie they are in the same alignment as the cable.

The cable cutting mechanism was dismantled at the company's facility at Aberdeen. The following observations were made:

1. The squib had fired correctly.

2. The chisel had sheared the retaining pin and had impacted the anvil. A groove had been cut into the anvil by the chisel.

3. The cable had been partially sheared along its vertical axis.

The drilling in the chisel blade had been aligned with the gas exhaust holes rather than with the horizontal drilling in the shearing knife holder and a shearing pin had been fitted through the gas exhaust holes; the blade was aligned with the cable axis and did not sever the cable when operated.

An across the fleet inspection revealed one other case where the mechanism had been assembled in exactly the same way. In another case the shearing pin had been fitted through the correct drilling in the shearing knife holder but had passed in front of the chisel rather than through the drilling in it; the blade was again aligned with the cable axis and would not have severed the cable if operated.

The hoist is an on condition maintenance item and is returned to the Aberdeen workshop at approximately 18 month intervals for replacement of part of the clutch/brake assembly. The opportunity is taken to clean and inspect the cable cutting mechanism; there is no formal servicing requirement for this item. The helicopter company's Quality Assurance department carried out an immediate and comprehensive audit of the system and identified the following shortcomings:

1. The layout of the maintenance manual, with text and related illustrations widely separated, made it difficult to use. An unofficial rearrangement of the manual pages to aid clarity was evident in one copy examined.

2. It was physically possible to assemble the guillotine and retaining pin in three different ways:

    a. With the retaining pin inserted into the correct set of body holes and through the guillotine.

    b. With the retaining pin inserted into the incorrect set of body holes and through the guillotine.

    c. With the retaining pin inserted into the correct set of body holes and with the guillotine trapped between it and the end plug.

3. The maintenance manual did not include any specific instruction on the orientation of the guillotine blade or on the correct set of holes to use for pin insertion.

4. The company hoist worksheets did not include any specific instruction on the orientation of the guillotine blade or on the correct set of holes to use for pin insertion.

5. Contrary to the impression given in the maintenance manual, the guillotine retaining pin was a loose fit and required care to ensure that it remained in place during subsequent stages of assembly. Should it fall out, the concentration required to replace it may have reduced the attention given to correct positioning of the guillotine.

6. The company hoist worksheets did not require a verification of correct guillotine blade orientation after assembly.

As a consequence of this several pertinent recommendations were made by the Quality Assurance Department. These included the acceptance and introduction of a locally designed tool for setting the position of the guillotine prior to inserting the retaining pin, and a duplicate inspection to confirm the correct installation.

The helicopter company also issued a Temporary Manual Revision (TMR) dated 3 December 1997 which contained the following caution:

'Ensure that shearing pin is fitted horizontally and correctly located in the chisel: ie at right angles to the hoist and not through the exhaust gas holes.'

It has been agreed to include this caution in the next revision of the maintenance manual. However, it is recommended that the manufacturer of the winch reviews the design and/or assembly, including the use of tooling, of the mechanism to ensure that it is physically not possible to assemble the guillotine incorrectly and, in the interim, issues more comprehensive guidance in the form of a procedure which may alleviate the problem.

Hi-line transfer

The Hi-line is a 150 foot nylon line with a karabiner on each end. There is a 150 lb 'weak link' between the line and the karabiner, which is attached to the winch hook. Weighted bags (10 lb each) are attached to the karabiner at the other end; the number of bags attached depends on the wind strength. The Hi-line used was manufactured by the operator.

The Hi-line can be used whenever lack of visual reference or obstacle clearance between the helicopter and the vessel, is such that undue workload is placed on the crew to execute the transfer. The appropriate weights are attached to the lower end of the Hi-line, the top end is attached to the winch hook and it is then lowered from the cabin door. The line is hand lowered until the weights land in the transfer area. Once the Hi-line is safely in hand on the deck, the helicopter is manoeuvred into the transfer position, normally to the left of the vessel. From a low hover, at about deck height, the winchman is winched out. As he is lowered the helicopter climbs to a higher hover and the winch cable is run out to keep the winchman's height above the surface (about 20 to 30 feet) and his position relative to the vessel, constant. Once sufficient height has been attained, the deck party will haul in the Hi-line to bring the winchman towards the vessel. This procedure is reversed to effect the transfer from vessel to helicopter. It is important that the deck crew maintain control of the Hi-line at all times and particularly that they do not secure it to, or allow it to become entangled with, any part of the vessel's structure.

On this occasion the Hi-line had wrapped around the winch hook, effectively bypassing the weak link. Had the lower end of the line not fortuitously become unsnagged after the cable cutting mechanism had failed, the helicopter and its occupants would have been put in an extremely hazardous position. It is therefore recommended that the helicopter operator gives urgent consideration to a review of the design of the Hi-line to minimise the risk of it becoming entangled with the winch hook and rendering the weak link ineffective.

Communications

In the conditions prevailing, the winch operator was unable to communicate effectively with the winchman on the deck. Had he been able to, the winchman would undoubtedly have been transferred with the last two survivors, and would not have lost his life.

It is therefore recommended that the operator, in conjunction with HM Coastguard and the CAA, urgently address the feasibility of radio communication between the winchman and the helicopter, and that the CAA should require the operator to address the communication between the winchman and the operator within the operations Manual.

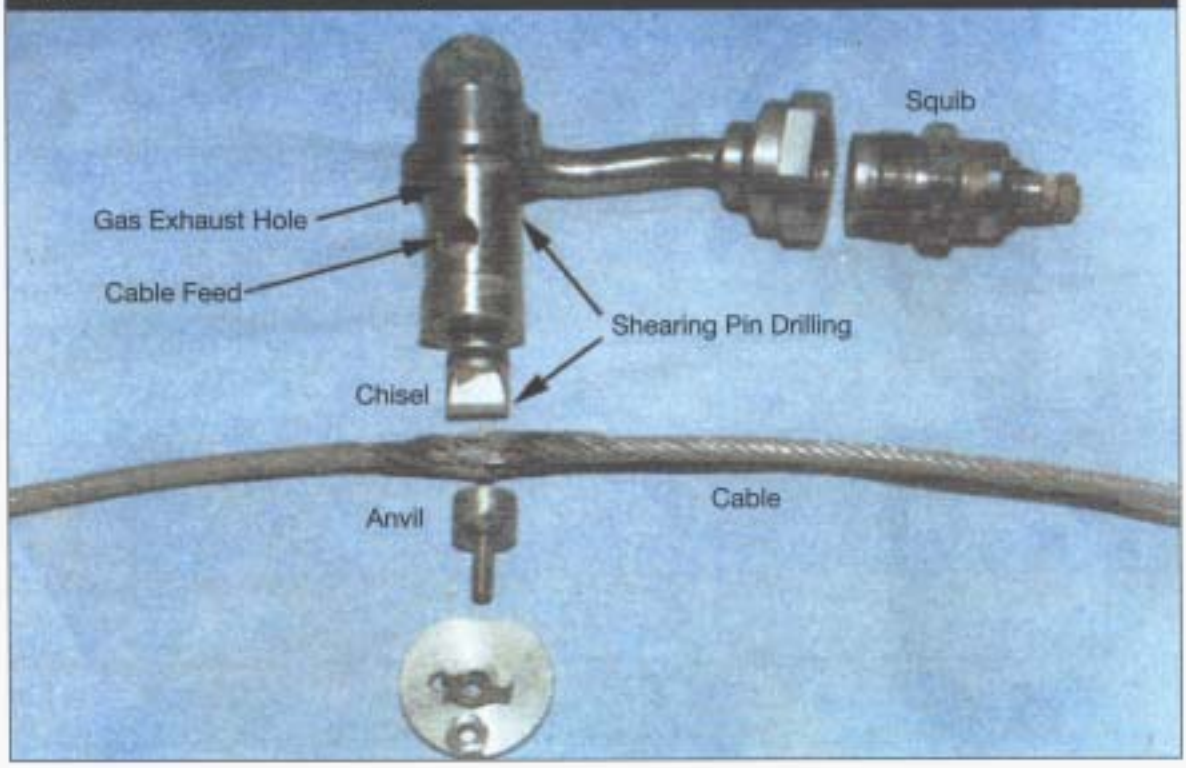
Safety recommendations

Recommendation 98-28
It is recommended that the manufacturer of the winch reviews the design and/or assembly, including the use of tooling, of the mechanism to ensure that it is physically not possible to assemble the guillotine incorrectly and, in the interim, issues more comprehensive guidance in the form of a procedure which may alleviate the problem.

Recommendation 98-29
It is recommended that the helicopter operator gives urgent consideration to a review of the design of the Hi-line to minimise the risk of it becoming entangled with the winch hook and rendering the weak link ineffective.

Recommendation 98-30
It is recommended that the operator, in conjunction with HM Coastguard and the CAA, urgently address the feasibility of radio communication between the winchman, and the helicopter and that the CAA should require the operator to address the communication between the winchman and the operator within the operations Manual.

Appendix A: **Hoist cable cutting mechanism**



APPENDIX

Alternative Text

Regulations 9(4) and 9(6) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 1994 provide that any person whose reputation is likely to be adversely affected by the Report shall have the opportunity to comment on that part of the Report before it is submitted to the Secretary of State. If, following representations, there are passages in the Report which remain in issue and are critical of the person, alternative text can be provided by the person for the part which is in issue. Such alternative text must be included with the Report as an appendix.

A number of persons, companies and organisations have exercised their rights in this respect. The alternative texts, which have been incorporated into the relevant numbered paragraphs from the Report, are given following, together with the person, company or organisation who provided the text.

Berrymans Lace Mawer representing Captain Robinson, master of AHTS *Gargano*

Page 15, 1.3.5 – paragraph 3

"Although "Gargano" had not been informed that the situation was an emergency or that "Maersk Champion's" departure would be delayed she reported at 0911 that she would get underway with a jury rigged towing gear ready for use."

Page 33, 1.17.1 – paragraph 4

"and because the eyes on the pennants were too small to go over a ship's bitts and it was highly unlikely "Green Lily" would have a shackle large enough for the job; there was no means of making them fast."

Page 33, 1.17.1 – paragraph 5

"Once the polypropylene towing pennant was included in the towing rig, it rendered the double nylon pennant superfluous; also to have rigged the nylon pennant would have delayed departure critically."

Page 33, 1.17.1 – paragraph 9

"The master was aware, having monitored all VHF channel 16 traffic with "Green Lily" that she had power on the forecastle."

Page 53, 2.6.1 – paragraph 3

"The master of "Gargano" had similar reservations because as he had reported to Shetland prior to his departure at 0911 he was obliged to use a jury rigged towing connection. All those involved knew the difficulties the atrocious weather would impose in attempting the connection and the tow and which were exacerbated when "Green Lily's" crew mistakenly made the messenger fast. The weather precluded any certainty of success regardless of towing gear used."

Page 53, 2.6.1 – paragraph 4

"Although "Gargano" was equipped with heavy wire towing pennants these were designed exclusively for use with Smit towing brackets and were wholly unsuitable for this application; recent experience proved the soft eye was too small to go over ships bitts and the wire was too stiff to have been turned up around the bits so there would have been no means of making it fast. The master of "Gargano" had monitored all VHF channel 16 traffic to and from "Green Lily" since 0911 hrs and knew the casualty had power on the forecastle. However this made no difference to the options available for use as towing gear. If "Gargano" had prepared the wire towing pennants it would have delayed her departure from Lerwick so that she might have been too late arriving at the casualty."

Page 61, 3.3 – paragraph 9

"Although there were stronger wire pennants aboard "Gargano" they were wholly inappropriate for use in this application as there would have been no means of making them fast aboard "Green Lily". In addition, the time needed to prepare them before departure from Lerwick might have prevented "Gargano" arriving on scene in time to have been of any assistance to "Green Lily"."

Holmes Hardingham Walser Johnston Winter, representing Laurence Johnson, master of *Tystie*

Page 35, 1.17.2 – paragraph 4

"From the outset, the master believed he had little chance of successfully securing a tow to "*Green Lily*" but was prepared to give whatever assistance he could."

"The master of the "Tystie" believed that, provided he could get there on time, he stood a good chance of assisting the casualty. His concern was one of time, not one of the ability of the tug. He did not envisage any difficulty in securing his towing gear as the tug, having Voith-Schneider propulsion, had excellent station holding capabilities. His belief was borne out by events which can be seen on the video taken by the rescue services with the "Tystie" holding station within 50 feet of the casualty for some 20 minutes with a heaving line and messenger on board the casualty. If the crew of the casualty had been able and willing to take the connection it could have been made within minutes."

Page 35, 1.17.2 – paragraph 8

"The difficulties experienced in connecting the tow were compounded by the decreasing availability of sea room. Once it had reduced to about 1 mile, the "*Tystie's*" master was reluctant to manoeuvre inshore of "*Green Lily*"."

"It would have served no purpose whatsoever for the "Tystie" to have moved inshore of the "Green Lily". Her position at this stage was such that she could only be towed out to sea and into the weather. The possibility of towing her down wind had been lost a number of hours earlier."

Page 53, 2.6.1 – paragraph 3

"One reason why the master did not take action to evacuate earlier ... He would have been in a better position to make an informed assessment of the situation and would probably have considered an early evacuation."

"One reason why the master did not take action to evacuate earlier is because he remained optimistic that a tow would be successful. Given the prevailing weather conditions he had no

reason whatsoever to be optimistic about a tow being successful and the fact that three tugs tried and failed bears this out. Using the rate of drift from 0644 hours onwards it is perfectly possible to calculate that the vessel would have grounded at around 1445 hours. The master of the "Green Lily" had the information necessary to make an informed assessment of the need to evacuate the vessel and he should have considered an earlier evacuation."

Page 61, 3.3 – paragraph 14

"Generally, the different limiting operation parameters ... better understanding of the difficulties among everyone involved."

"In the circumstances the master of the "Green Lily" had no reason whatsoever to expect a successful tow. The prevailing weather conditions and the proximity of the "Green Lily" to the shore were such that he should have considered an earlier evacuation."

Page 61, 3.3 – paragraph 15

"The master of the "*Green Lily*" would have been in the position to make a more informed assessment of the need to evacuate the vessel had he been informed of the reservations held by the masters of both "*Gargano*" and "*Tystie*" with respect to effecting a successful tow."

"Within minutes of arriving at the casualty at 1340 hours the "Tystie" had a heaving line on board and was holding position within 50 feet of the casualty's bow. From 1340 hours until the towline parted at 1410 hours the master of the "Tystie's" concentration was fully occupied in a close quarter situation in very difficult conditions. He was simply not in the position to become involved in a review or discussion on the options available to the "Green Lily". The urgency of the situation was suitably expressed on several occasions, particularly by the Lifeboat and the Coastguard. The master of the "Tystie" himself expressed concern to the master of the casualty whilst waiting for the casualty's crew to take the towing connection on board."