



Departmental investigation
into a fire in the
engine room aboard
the Australian Antarctic
Research and Supply Vessel
AURORA AUSTRALIS
off the coast of West Australia
on 14 January 1999



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Summary

At 0600 on 14 January 1999, the Australian Antarctic research and supply vessel *Aurora Australis* was on passage from Fremantle to the Antarctic, making good a speed of 11.5 knots on a southwesterly heading. After a 'non-critical' engine room alarm at 0614, a fire alarm occurred. The master, who had just relieved the mate on watch, glimpsed flames on an engine room CCTV monitor. The master sounded the general alarm and stopped the main engine. The ship's staff and the expeditioners went to their fire muster stations, while the duty engineer made for the engine control room. He encountered thick smoke as he entered the engine room but was able to reach the control room, from where he shut down all the running fuel pumps and engine room ventilation supply fans.

At 0627, after receiving reports that all vent flaps were shut, all remote fuel shut off valves operated and all fans stopped, the chief engineer discharged the Halon 1301 fixed fire-extinguishing system. The ship's position was 32° 57.7' South, 114° 09.7' East. Seven minutes later, the vessel transmitted a PAN PAN call which, after a number of repeats on different frequencies, was acknowledged by Brisbane Radio.

At 0700, to conserve fuel, the emergency generator was shut down, rendering the vessel 'dead ship'. The master convened a meeting on the bridge to discuss the best method by which to effect a re-entry into the engine room and at 0907, after re-starting the emergency generator, the chief engineer and an IR, backed up by a second team standing by, entered the engine room via the shaft tunnel to assess the situation. They reported that the fire was out then attempted to use a fire hose to cool down the area around the forward end of the starboard main engine, where the fire appeared to have been centred. On pressurising the hose, however, it parted from the coupling. A second hose brought into the engine room also parted from its coupling.

The engine room was vacated while other hoses were tested on deck before another attempt was made to cool down the seat of the fire. It was planned that, because of the heat, teams would enter in 10 minute relays. At 1100 another team entered, cooled the area and checked for hot spots. A bin of smouldering rags was found near the control room and eventually extinguished.

Checking of the engine room for hot spots was continued for the next two hours before the engine room was opened up and venting commenced at 1302. When attempting to start an air compressor, the emergency

generator stopped and it was found that a short circuit appeared to have damaged its automatic voltage regulator. The master, concerned about the vessel's situation, with no electrical power and no starting air for the generators or main engines, called P&O Polar and requested that a tug stand by. Soon afterwards, a tug was despatched from Fremantle.

After fitting a spare AVR, which was found also not to work, the engineers supplied excitation for the generator by tapping off the generator's starting batteries and eventually restored power to the vessel. At 2345, the port main engine was started and *Aurora Australis*, escorted from 0300 by the tug *Wambiri*, proceeded back to Fremantle at 8 knots, arriving alongside at 1305 on the following day (15 January).

Sources of information

The master, officers and crew of *Aurora Australis*

P & O Polar Australia Ltd

P& O Maritime Services Pty Ltd

Wärtsilä-NSD Australia Pty Ltd

Lloyd's Register of Shipping

Tasfire Equipment Pty Ltd

Aurora Australis

Aurora Australis is an Australian flag, purpose-built, oceanographic research and Antarctic supply vessel owned by Antarctic Shipping of Sydney and managed by P&O Polar Australia Pty Ltd., of Hobart, Tasmania. It was built in 1990 by Carrington Slipways in Newcastle, NSW, and is classed with Lloyd's Register as an IceClass 1A Super Icebreaker 100 A1 LMC UMS DP (CM).

The ship has an overall length of 94.91 m, a beam of 20.3 m, a moulded depth of 10.43 m and a maximum draft of 7.862 m. It has a gross tonnage of 6,574, a maximum displacement tonnage of 8,158 and a maximum deadweight of 3,911 tonnes. It is capable of carrying 29 TEU¹.

Propulsive power is provided by two Wärtsilä Vasa 32 engines, one 16 cylinder engine of 5,500 kW (port) and one 12 cylinder engine of 4,500 kW (starboard), in a 'father and son' arrangement. Both engines are coupled, via clutches and flexible couplings, into a single reduction gearbox and drive a single, controllable-pitch, propeller.

Electrical power is generated by two six-cylinder Wärtsilä Vasa 22 generator sets of 944 kW each (nos. 1 & 2) and one four-cylinder set of 608 kW (no.3). The supply is 3 phase, 415 volts, 50 Hz.

The ship is fitted with an athwartships controllable pitch thruster, fitted in a bow tunnel and with two retractable azimuth thruster units aft.

The ship is divided into four main vertical zones. (See general arrangement, page 4) Forward of the collision bulkhead (frame 127) to the stem (frame 143) is the mooring space and forepeak tank. Aft of the collision bulkhead to frame 87 are the cargo hold, stores areas and deep tanks. Between frames 87 and 32 are the machinery space, accommodation and hotel facilities, the helicopter hangars and the navigation bridge and communications centre. The engine casing is four metres wide (two metres each side of the centre line) and extends from the 3rd deck to the funnel between frames 64 and 71. Between frame 32 and the stem are storerooms for scientific equipment, the trawl deck, steering flat and the shaft tunnel.

¹ Twenty-foot equivalent unit containers

The ship is divided horizontally into eight main levels. The upper deck (the freeboard deck), aft of frame 87 and forward of frame 32, consists of accommodation for special personnel (expeditioners) as defined under Marine Orders Part 50, Special Purpose Ships. Above the upper deck are the 1st bridge deck, the 2nd bridge deck, the wheelhouse deck and the wheelhouse deck top (or monkey island). The 1st bridge deck includes a hangar for two helicopters and the open helicopter landing area astern of the hangar. Forward of the hangar and on the 2nd deck is further accommodation, mostly for the officers and ratings.

Below the upper deck are the 2nd deck, 3rd deck and tank top. The 2nd deck is devoted to the galley and mess rooms, a conference room and laboratories. The 3rd deck is at or about the waterline. It includes dry provision stores, refrigerated provisions, hotel facilities and the upper level of the engine room, including the machinery control room (MCR) and engine room workshops. The tank top houses the main engine and main generators. In the engine room, between the tank top and the 3rd deck, is a platform deck.

Aurora Australis is manned by a crew of 24 Australians. The crew comprises a master, three mates, a radio officer or deck communications officer (DCO), four engineers, a chief integrated rating (CIR) and seven integrated ratings (IRs), a chief steward and six hotel staff.

The ship's bridge is equipped with all modern navigational aids and the ship's communications equipment includes radio telegraphy, radio telephony and satellite communications systems, Inmarsat A and Inmarsat C.

The machinery spaces of *Aurora Australis* are classed as 'UMS' – Unmanned Machinery Spaces. The engineers are all on daywork and, at night, one engineer is designated as the duty engineer, with the alarms from the machinery monitoring and alarm system switched through to the appropriate cabin.

The main machinery space is fitted with a fixed Halon 1301 fire-fighting installation. The halon drenching system consists of ten halon bottles situated at various points around the engine room, all of which are designed to be simultaneously discharged upon operation of the halon release panel situated in the bridge. The bottles

discharge into short lengths of fixed pipework fitted with nozzles to evenly distribute the halon gas to all parts of the engine room.

Background

Six months before this incident, on 22 July 1998, *Aurora Australis* experienced a serious engine room fire when in position 65° 29'S 144° 28'E, off the Antarctic ice edge. The vessel was carrying out oceanographic research on its way from Hobart to an Australian Antarctic base when fuel, spraying from a ruptured flexible hose, ignited on the turbochargers of the port (no.1) main engine. The Halon system was discharged and the resulting fire was extinguished, but not before it had caused severe damage to main cable runs in cable trays at the forward end of the engine room and to other electrical and control equipment. (see MIIU report no. 135)

After regaining power on one main engine, *Aurora Australis* arrived back in Hobart on 31 July 1998, where it spent the following three months undergoing repairs.

The voyage

On the following voyage, *Aurora Australis* suffered a controllable pitch propeller failure while in the Antarctic ice and had to return to Fremantle for repairs.

Aurora Australis arrived at the Tenix Shipyard near Fremantle on 27 December 1998 for repairs to the controllable-pitch propeller. The repairs were completed on 11 January 1999.

On 13 January 1999, having taken on expeditioners, stores and bunkers, the ship sailed once more for the Mawson Antarctic base. 'Full away' was rung at 2100. In addition to the ship's complement of 24, there were 16 Antarctic expeditioners on board from Australian National Antarctic Research Expeditions (ANARE).

At 0400 on 14 January, the mate relieved the 2nd mate on watch on the bridge. A fix indicated that the ship's position was 32° 37' South, 114° 30' East; it was making good a speed of 11.5 knots on a south-westerly heading. The weather was cloudy but fine with good visibility. A south-south-westerly wind was blowing at 20 knots and there was a moderate sea on a low south-westerly swell.

At approximately 0600, the master arrived on the bridge and relieved the mate who went below for a shower about five minutes later. At 0614, an engine room alarm sounded on the bridge. The master noted that it was a 'non-critical' alarm, requiring no action on his part, and silenced it. The 2nd engineer, however, who had been the duty engineer that night, responded when the alarm sounded on his cabin alarm panel.

A few moments later another alarm was activated, this time on the fire detection panel. The alarm indicated a fire at zone 21 (engine room lower plates). The master had some difficulty unlocking the panel, but as he eventually opened it, another alarm came up. He decided not to cancel it, but to get the watchkeeping IR to investigate. As he started to dial on the bridge telephone, he glanced at the engine room closed-circuit television monitor and saw flames on one of the screens as the system flicked through the three monitoring cameras. There was, however, no indication of smoke showing on the screen.

The fire

As the master brought the main engine pitch control back to the '0' position, he pressed the general alarm button on the console, holding it in for a few seconds. The time was 0615.

The mate had been below for only a few minutes when he heard a short ring on the ship's fire alarm bells. Knowing that the master was new to the ship, and thinking that an alarm may have come up on the fire panel and that the activated zone may not have been isolated, he dashed back towards the bridge. The chief engineer, the 1st engineer, the 2nd and 3rd mates and an IR were also making their way to the bridge, encountering thick smoke on the way, while the 2nd engineer was on his way down to the engine room.

As the mate opened the door from 'B' deck accommodation into the central stairwell, he also encountered appreciable smoke and realised that there was indeed a fire. On reaching the bridge, he found that the fire detection panel was indicating activated detectors in some eight to ten zones. As the others arrived, the master instructed the chief engineer to close all the engine room fire flaps, while the mate made an announcement over the public address system instructing all passengers and crew to go immediately to their muster stations wearing their lifejackets. The announcement was repeated. The chief engineer, with the assistance of the watchkeeping IR, set about closing the accommodation and engine room vent flaps.

The mate then returned to his cabin, put on his overalls and boots, grabbed a torch and UHF radio and made his way up to the helideck, where all the expeditioners and crew were rapidly mustering under the direction of the 2nd mate. After passing the muster list to the chief steward, the 2nd mate went down the after stairwell to 'D' deck and banged on cabin doors to ensure that all the expeditioners and crew were either out or making their way out, then returned to the helideck.

When the 2nd engineer had reached the forward engine room door on the control room level, he could sense smoke. He opened the door and was met with thick smoke, but he could just make out white light coming from the control room windows. He made for the control room, closing the control room door behind him. He shut down all the running fuel supply and circulating pumps and the supply ventilation fans, isolating them from the main switchboard, then rang the bridge advising the master of the situation. He reported that the engine room was full of smoke, that there was zero visibility and that he had shut down the engine fuel pumps and the engine room supply fans. The master instructed him to get out of the engine room and to go to his muster station. The 2nd left the control room by way of the vertical ladder by the bunker station, so as not to again enter the smoke-filled engine room.

While these events were taking place, the 3rd engineer was trying to reach his muster point, the engine room, via the stairwell. Having the cabin next to the 2nd engineer and having heard the initial engine room alarm, he was concerned about the whereabouts of the 2nd engineer who he knew had gone down below. Before he reached the engine-room door at the bottom of the stairwell, he encountered thick smoke, so he made his way around to the after watertight door on the control room level. On opening that door, he was driven back by more thick smoke. Closing the door again, he decided to try to enter the engine room by way of the shaft tunnel and the lower, after, watertight door and made his way aft to the shaft tunnel via the trawl deck, the catch area, the net store and the after thruster room. Reaching the after watertight door at the forward end of the shaft tunnel, he opened it and again met thick black smoke. When he returned to the deck, he met the mate on the helideck and was able to inform him that both the watertight doors he had tried were closed.

At 0619 a report was received on the bridge that the engine room flaps had all been closed. The emergency generator was started. At about this time, the 2nd engineer, having left the control room via the ladder to the bunker station, arrived on the bridge and advised the chief engineer that the situation in the engine room, in his

opinion, was bad.

At 0621, on the bridge, the chief engineer reported that all flaps were shut then tripped the “Instanta”, or remote fuel shut-off, valves. He also operated all the stops for vent fans and opened the door of the control panel for the Halon fire extinguishing system and turned the keyswitch, automatically stopping remaining fans and other running machinery. The master noted that the indicator panel showed the watertight doors were all closed. The bridge IR went to double-check that all the engine room vent flaps were closed. On stopping the running machinery, the chief engineer heard the emergency generator start up but, after some time, he realised that it had not come onto the emergency switchboard.

From 0621 to 0627, the master’s main concern was to ensure that all the ship’s personnel and expeditioners had been accounted for before the halon was released. He had not, at this stage, received any confirmation that the 2nd engineer had left the engine room. At 0627, however, he received a report by radio that the 2nd engineer was directing expeditioners out of the accommodation by ways other than the central stairwell, which was filling with smoke.

On hearing that the 2nd engineer was accounted for, the master instructed the chief engineer to release the halon. It was 12 minutes after the initial fire alarm. After releasing the halon and hearing the noise of the discharge from the engine room, the chief engineer went to the emergency switchboard and closed the circuit breaker for the emergency generator by hand. The emergency fire pump started automatically.

Meanwhile, on the helideck, the mate was briefing the expeditioners about events as they occurred and assuring them that the situation was under control.

At 0630, the chief engineer became concerned that the door from the accommodation into the engine room, at the bottom of the stairwell, may not have been properly closed and a BA team was sent to check it. They soon reported that it was closed, but that the door was quite hot to the touch. About one minute later, LED indicators on the halon release panel showed that all the halon had been successfully released.

Radio calls

After being awakened by the fire alarm and smelling smoke, the deck communications officer (DCO) had gone straight to the radio office, switched both transmitters to battery power and tested the emergency lighting. He called Perth Radio on 4125 kHz three times, but receiving no reply, so tried transmitting on 6215 kHz, again without response. As the time was just into the radio silence period of 30–33 minutes past the hour, he then tried on 2182 kHz and immediately received a response. At 0632, (2232 GMT), he requested Perth Radio to stand by. The radio room was filling with smoke.

At 0634, the master instructed the DCO to transmit a PAN PAN to all ships giving the ship's position, which was now 32° 57.7'S 114° 09.7'E, and the distance to Fremantle. A report of the fire was also passed to the general manager of P&O Polar and to the Antarctic Division by radiotelephone.

Re-entry

By the time the halon was released, the ship's emergency fire pump had already started automatically and come on line. The mate organised the rigging of fire hoses in the after end of the shaft tunnel, in the area of the forward stores hatch and by the watertight door leading into the engine room on the control room level. The master and the chief engineer decided to wait a minimum of two hours before entering the engine room. Although they received advice from the company to enter about half an hour earlier, they stuck by their initial decision. At 0655, the master briefed the voyage leader on the situation.

At about 0700, the chief engineer went to check the fuel remaining in the tank supplying the emergency generator. It was found to be about half full and the decision was taken to shut down the generator to conserve the remaining fuel. The vessel was now 'dead ship', although the emergency batteries continued to supply the communications equipment.

At 0740, *Aurora Australis* was lying beam-on to the seas and rolling heavily so the mate went forward to check the cargo on the main deck and in the tween decks. Some minutes later he reported to the bridge that all was secure. Shortly afterwards, however, banging was heard from the helicopter hangar and it was found necessary

to re-secure a rock drill and a lifting frame, both of which had broken loose.

Following the release of the halon, a series of 'toolbox' meetings were held to decide on the best course of action. The first of these was at about 0810 to discuss a plan for the initial re-entry into the engine room. The decision was taken to enter by the route down to the after end of the shaft tunnel and along to the aft watertight door. Two fire teams were to enter the shaft tunnel, but only one team was going to enter the engine room, to assess the situation, while the backup team waited by the watertight door.

At 0830, the emergency generator and the emergency fire pump were restarted. The chief engineer isolated all non-essential (at that time) electrical supplies from the emergency switchboard. About ten minutes later, however, when attempting to start the charging compressor for BA bottles in the catch area, it was found that the circuit breaker for the compressor, on the emergency switchboard, would not remain closed.

The 1st and 2nd engineers set about rigging a jury power supply to the compressor, from the steering flat, just as had been done during the previous fire six months earlier.

By 0856, the two BA teams were ready. The first team consisted of the chief engineer and one IR, while the 3rd engineer and the 2nd mate formed the second team. A third team was standing by in the net store. Again, as in the previous fire, the mate found it necessary to station himself in a position in the aft thruster room where he could relay messages to the bridge from the team in the shaft tunnel, there being a 'dead spot' for radio communications aft of the watertight door.

The IR of the first team found it necessary to remove his BA set so he could fit down the vertical access to the shaft tunnel. Once they were in the shaft tunnel, a hose was rigged up to the watertight door. About the same time, a report was received on the bridge, from the 2nd engineer, that the watertight door adjacent to the engine room workshop felt hot to the touch. Shortly afterwards, the 2nd mate and the duty IR rigged a fire hose to that door. Battery-powered emergency lighting was on.

At approximately 0907, with a hose ready and with a BA board maintained by one of the IRs to record times of entry and air pressures, the shaft tunnel door was opened and the first team entered the engine room. As soon as they entered the engine room, they lost radio contact with the mate in the aft thruster room, but they were able

to communicate directly with the bridge. They soon reported that the fire had been extinguished. It appeared to have occurred in the vicinity of the fuel filters at the forward end of no. 2 (starboard) main engine where there was some debris. The team further reported that the engine and deck plates in the area were still very hot.

The team rigged up a fire hose with which to cool the area. The hose was connected to a hydrant at the port side of the lower plates but, when the hydrant was turned on, the hose parted from the end fitting. The chief engineer attempted to locate another hose, descending first to the area of the oily-water separator on the bottom plates level, then climbing back up to the evaporator level. There, he saw that the hose stowed above, and aft of, the starboard main engine had melted in its stowage. Unable to find another undamaged hose, he reported that they would need another hose from the deck.

Upon hearing this, the second fire team, which had been standing by at the watertight door, entered the engine room with a second hose. This was connected to the hydrant then passed to the first team before the second team returned to the watertight door. This time, however, when the hydrant was turned on, the hose blew off the end fitting where it was coupled to the hydrant. After re-entering a second time with yet another hose, the second team was directed by the chief engineer to leave the engine room, as soon as he realised that they had been entering without being instructed to do so and had, in the process, been leaving the aft watertight door open.

At 0927, the chief engineer confirmed to the bridge that the fire was out. Shortly afterwards, the first team also left the engine room, closing the watertight door behind them. Both teams returned to the net store. About this time, the mate decided to move the control position from the catch area, which was cluttered and wet, to the trawl deck workshop where conditions were more suitable.

At 0932, the 1st engineer again shut down the emergency generator to conserve fuel. At 0935, the DCO broadcast a message cancelling the PAN PAN. As he did so, he was informed that he had, throughout the incident, been talking to Brisbane Radio and not Perth, as he had believed.

At 1013, another toolbox meeting was held on the starboard bridge wing to discuss the situation. The master and chief engineer felt that it was still too early to open up the engine room, the rest of the engine room having not yet been assessed for further possible sources of ignition. Teams were reorganised and a plan drawn up to again

enter via the shaft tunnel and to carry in fire hoses with which to cool down the area around the forward end of the starboard engine. They would then check the rest of the engine room for any other hot spots. Because of the heat, it was planned that they would work in 10-minute relays. On account of the problem encountered with the first two hoses used in the engine room, the hoses to be used on this occasion were relatively new, taken from the BA room and from forward, and first pressurised and tested on the trawl deck before being used. Shortly after the toolbox meeting, at about 1022, power had been restored to the BA compressor and the charging of BA bottles commenced.

The team to enter first on this occasion consisted of the 2nd mate and the 3rd engineer, while the backup team consisted of the chief engineer and an IR. At 1100, the first team entered the engine room. They rigged new hoses on the port and starboard sides of the engine room and cooled down the starboard side and forward end of the starboard main engine before being relieved by the second team at 1113. Visibility through the smoke at this time was about three metres. It was reported to the bridge that there was not much steam being generated by the water from the hose, indicating that the area was not as hot as had been thought.

The second team started checking the rest of the engine room for hot spots and discovered a bin of smouldering rags outside the engine control room. The nearest extinguisher, which they could locate, was a dry powder type and this they discharged at the rags, however it was not effective in extinguishing the smouldering fire. By this time, their allocated time was up and they were called out of the engine room, leaving at 1133.

A third toolbox meeting followed from 1133 to 1146 on the starboard bridge wing. The teams were again swapped around and, after two teams had entered carrying water extinguishers obtained from 'D' deck, the smouldering rags were tipped out, spread out and extinguished.

Venting

Further engine room checks were carried out over the next hour before the 2nd engineer, wearing BA, ascended from the engine control room level to the funnel casing on 'B' deck and finally reported that all had been checked

and there was no sign of fire. A last toolbox meeting was held to discuss the venting procedure and venting of the engine room was commenced at 1302. As there was uncertainty, however, of what may have been the situation beneath the bedplate of the starboard main engine, a fire team with a charged hose was stationed near the engine while venting was started.

From 1300 until venting was completed at about 1900, all the ship's staff who were in the engine room continued to wear BA and continued to be monitored. At about 1800, the mate obtained an oxygen analyser from the engine control room and, after calibrating it out on the trawl deck, spent about 25 minutes making his way around all areas of the engine room, reporting satisfactory oxygen levels to the bridge.

During venting, it was found that the breaker to no. 2 engine room vent fan would not close, indicating that the fire had damaged the wiring. It was thus necessary to rely on natural draught for venting.

The chief engineer then drew up plans for restoring power and propulsion. At 1400, however, the emergency diesel generator stopped when an attempt had been made to start a main air compressor. A short circuit had occurred and it was later found that the fire had burned the power cables to the air compressors. In addition there was now a fault on its automatic voltage regulator. A spare AVR was obtained from the spare gear store and fitted, but this too was found to be faulty.

After the starting air bottles were found to be empty, and without the emergency generator, the master was aware that it was not going to be possible to start any of the ship's other machinery. At approximately 1630, concerned about the ship's predicament, he called the company's general manager and requested that a tug should come out from Fremantle and stand by the *Aurora Australis*. He was soon advised that the tug *Wambiri* would be despatched from Fremantle at 1900 on the 14th and should rendezvous with the vessel at about 0500 on the 15th.

Other calls were made to the offices in Hobart and Melbourne for advice on how to get the alternator back into service. Following one of these calls, the 12 volt batteries, usually used for starting the generator, were pressed

² Historically, the terms 'generator' and 'alternator' were used to differentiate between machinery which generated direct current power and alternating current power, respectively. As today nearly all power generation is alternating current, the term generator is usually used to refer to the complete generator set (including the prime mover) and the term alternator is used to refer specifically to the alternator, or electrical end, of the generator set.

into service to bypass the AVR and supply a source of pilot excitation for the alternator². This gave the correct output voltage on no load but, as the load increased, they had to tap off the various cells of the starter batteries to maintain the correct output voltage. This enabled the generator to provide a source of power by which other machinery could be started, particularly an air compressor used to provide starting air for generators and main engines. In spite of charring of the cables, one of the air compressors could be started and was able to run.

Return to Fremantle

By 1720, after a number of stops and starts to arrange the electrical load on the switchboard, the emergency generator was running reasonably well and the engineers set about the process of restoring electrical power to the vessel. At 1721, one of the ship's main generators was started.

A heavy south-westerly swell was running and *Aurora Australis*, lying beam-on to the swell, was periodically rolling up to 30°. Some cargo again broke loose in the helideck area and had to be re-secured.

By 1937, electrical services were restored to much of the ship and the 'not under command' lights were illuminated.

At 2303, no.1 main engine (port) was turned over and was ready to start. A steering motor was started and the steering gear tested. When all proved satisfactory, the port main engine was started. For an unexplained reason, when the engine was started the clutch engaged itself – probably on account of fire damage to control wiring. The engineers, however, decided to leave it engaged and, at 2345, *Aurora Australis* was again under way and making 8 knots, with manual control of the propeller pitch.

At 0300, the tug *Wambiri* was sighted. Although, in the event, it was not required, it escorted *Aurora Australis* back to Fremantle. As the gyro- compasses were inoperative, the ship was steered using the magnetic compass and the GPS. There was no lighting in the engine room, apart from lead lights which had been temporarily rigged. Electrical supplies also had to be jury-rigged to keep various ancillary electric pumps running. Other problems were encountered during the next 12 hours, including overheating of the port main engine, but the vessel was nursed on the passage back to Fremantle, arriving alongside at 1305 on the following day, the 15th January.

Comment and analysis

Origin of the fire

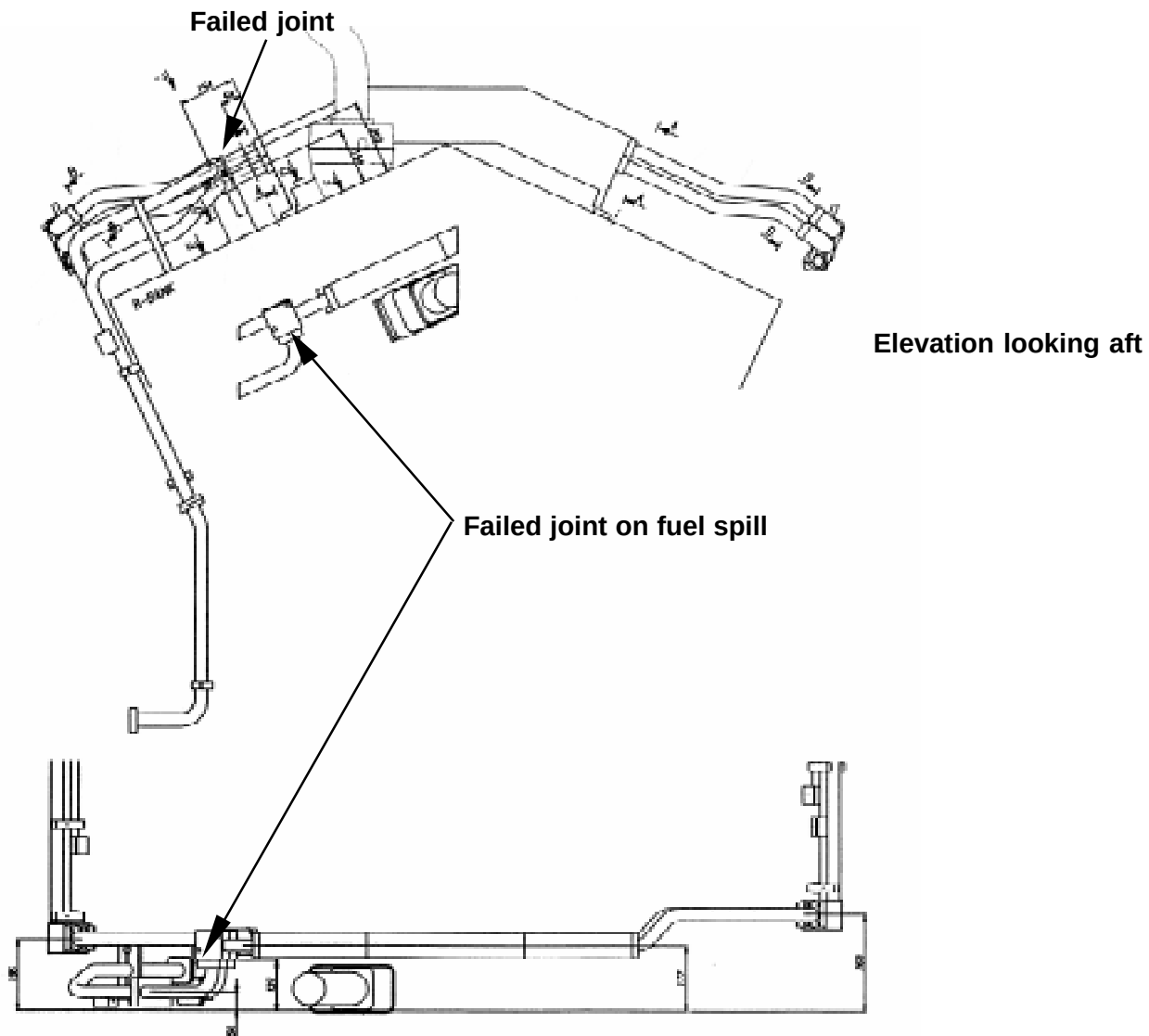
When *Aurora Australis* arrived in Fremantle, an investigation of the fire scene was undertaken. The area around the forward end of the starboard main engine had remained relatively undisturbed since the incident. Initial examination, however, gave no indication of the origin of the fire. It became necessary to pressurise the fuel system for 1 or 2 seconds, whereupon a well atomised spray of fuel, extending for 2-2½ metres issued in a fan shape from the starboard side of the forward end of the engine.

The spray of fuel was then found to have come through a narrow gap at the aft side of a sheet metal cover. The protective cover was secured over two flanged pipe joints where the low pressure (LP) fuel supply and spill pipes join the forward end of the engine. The origin of the spray, however, was still not visible from outside the engine, until the sheet metal cover had been removed. See page 21

When the cover was removed, it revealed a failure of the flanged joint on the fuel return pipe, adjacent to the forward end of B bank, where it branches across the engine to the hot box of A bank. See diagram page 19. Of the four screws securing the flange, the upper two had broken, the left lower screw was quite loose and the fourth had lost its preload. The pipe had sprung and the joint had opened up about 3 mm. During the investigation the engine room staff reported that difficulty had been experienced fitting the LP fuel pipework and this is borne out by the fact that the pipe sprung when the screws failed.

The source of ignition for the spray of leaking fuel could not be positively identified, however the leak occurred at a position immediately below the starboard turbocharger of the engine. The automated engine data logger recorded, at midnight, that the cylinder exhaust temperatures of the starboard engine varied between 423°C and 483°C, while the temperatures of the exhaust gas entering the two turbochargers were 409°C and 408°C. The fuel used by all main and auxiliary engines on *Aurora Australis* is gas oil and the bunkers taken in Fremantle before sailing for the Antarctic were BP Gas Oil G21.

³ AIP data sheet TDS7-1990v



Fuel supply and spill pipework at forward end of VASA 32 engine



Fuel sprayed
from this area

Fire damage around starboard main engine



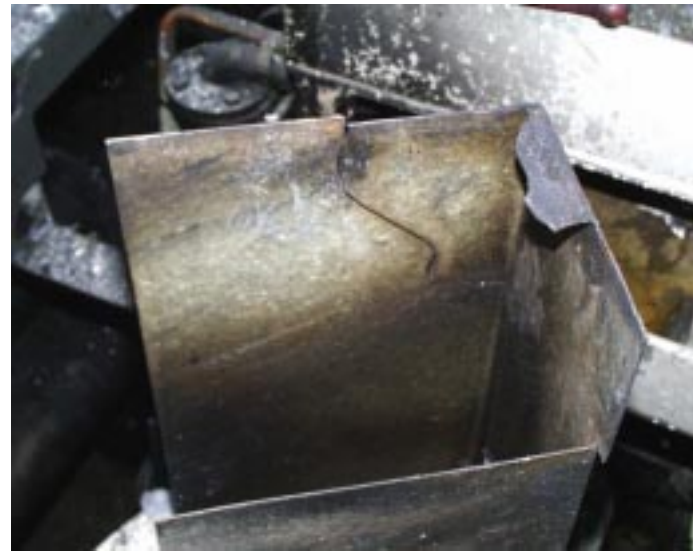
Fire damage around starboard main engine



Damage to electrical cables under deckhead

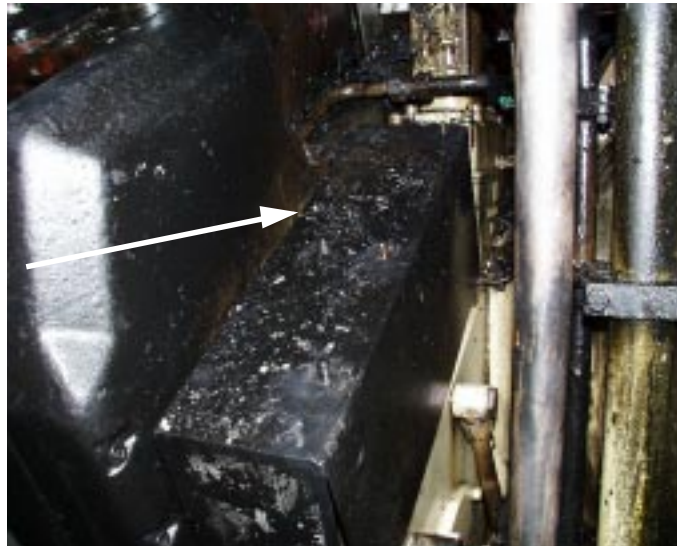


Melted polycarbonate light diffuser



Damaged sheet metal cover in situ over failed joint

Fuel sprayed through gap here



Damaged sheet metal cover removed from engine

The refinery, which supplied the bunkers taken by *Aurora Australis* in Fremantle on 11 January 1999, was unable to supply a figure for the auto-ignition temperature of the fuel in use at the time of the incident. Testing fuels for auto-ignition temperature before dispatch is not a routine procedure. However, an estimate provided by the refinery's laboratory was that it would have been about 350°C. Typically the auto-ignition temperatures for diesel fuels, including gas oils, are in the order of 300°C to 350°C, the higher end being for automotive gas oils.³

With the spray of leaking gas oil in such close proximity to the turbochargers and the exhaust system on the engine, it is likely that these provided the source of ignition, being at a temperature higher than the auto-ignition temperature of the fuel.

Damage

When the master saw flames on the video monitor on the bridge at the beginning of this incident, he noticed that there was little or no smoke. It was found that there was relatively little damage in the immediate vicinity of the fire, and evidence of only a minor bilge fire at the starboard forward corner of the starboard main engine. These factors indicate that the spray of leaking fuel ignited almost immediately it started and that it burned like a boiler burner, well atomised and producing intense heat but little smoke, until the fuel was isolated.

Damage to the starboard main engine was limited mainly to rubber and plastic components such as cooling and vent pipes, some fittings and on-engine wiring.

It is usual, in incidents of this type, for even a relatively short-lived fire to produce enough hot gasses, which rise and become trapped against the deckhead, to rapidly cause severe heat damage to electrical cabling in cable trays. It was this effect that had caused the most serious and extensive damage. The fire damaged power cables, control and monitoring wiring and lighting throughout a large area of the engine room, both under the platform deck and the engine room deckhead. (See photos 20) It is also likely that charring of cable insulation caused most of the smoke which was generated during the incident.

Polycarbonate, from which was made the diffuser of the light fitting in the photograph on page 21, starts to flow at a temperature of approximately 165°C and discolours at approximately 220°C, thus giving an indication of the temperature reached at that point under the starboard side of the platform deck where the fitting was located.

Engine fuel systems

The fire was centred around the forward end of the outboard side of the starboard main engine. The starboard main engine of *Aurora Australis* is a Wärtsilä Vasa 12V32 turbo-charged diesel engine – the designation 12V32 indicating 12 cylinders in V formation, with a cylinder bore of 32 cm. Between the fuel filters and the engine, the fuel system consists of a supply line and a return, or spill, line of similar dimensions.

The main engines are set on rigid mountings. Consequently, at the time the vessel was built the connections to the engine supply and spill systems were originally made by fixed, or rigid, pipework between the filters and the engine.

Since the first voyage of the *Aurora Australis* in 1990, problems had been experienced with this pipework. Vibration caused cracking of the rigid pipework between the filters and the engines. After a number of attempts to resolve this problem, using different types of pipes and flexible hoses, a braided flexible hose was adopted for insertion in engine fuel supply and spill pipework. In July 1998, however, the failure of one of these hoses in the port main engine fuel system led to a serious engine room fire.⁴

During the subsequent repair period, these hoses on both engines were replaced with sheathed flexible hoses, offering some protection should the hose fail. The work of fitting these hoses, together with the modification involving the fitting of pulsation dampers (q.v.), necessitated the removal of the rigid fuel supply and spill pipework where it leads up to, and enters into, the forward end of the engine hot box. This work, carried out in Hobart by shore contractors during the repair period which lasted from 1 August to 29 October 1998, included the breaking of the flanged joint which failed and which was the precursor for the fire.⁴

At the time of the fire, the starboard main engine had run for 256 hours since the above work was completed and the pipes refitted.

⁴ See MIIU report No. 135

The sheet metal cover

Outside the engines, flanged joints on the fuel systems are covered by removable sheet metal covers in accordance with the requirements of SOLAS Reg II-2/A,15.5.1, which states that:

'Where necessary, oil fuel and lubricating oil pipelines shall be screened or otherwise suitably protected to avoid as far as practicable oil spray or oil leakages on to hot surfaces or into machinery air intakes.'

Wärtsilä VASA 32 engines are provided with sheet metal covers which shield the joints on the LP fuel systems outside the hot-boxes. The cover which was in place over the failed joint at the time of the fire, however, was not of Wärtsilä supply, but had been made up by shore contractors some two years earlier, as had the replacement cover adjacent to it. The cover was not a good fit, leaving a gap along the side adjacent to the engine. It was also badly cracked and had most of one end missing, the damage most likely having been caused by work-hardening from vibration. See photos, page 21

Other covers which were in place both on the starboard and the port main engines were well fitting, and showed no gaps such as existed at the aft side of the cover in question. The gap was exactly in line with the flanged joint which it was supposed to be protecting, with the result that the spray of leaking fuel issued directly through the gap.

Engine vibration

Vibration has been a chronic problem aboard *Aurora Australis* and was a significant factor in the decision to fit flexible main engine fuel hoses in the early 1990s. Pulsation dampers (volume chambers, commonly referred to as 'fat pipes') designed to alleviate the vibration caused by fuel pump pressure pulses, were offered by Wärtsilä to P&O Polar in 1993. These, however, were not fitted by P&O until after the fire of July 1998. At a meeting on board the vessel before its departure from Fremantle in January 1999, ship's staff reported that, since the dampers had been fitted, vibration outside the engines had been considerably reduced.

In March 1999, P&O commissioned Ship Technology Unit Pty Ltd, of Sydney, to carry out an investigation into the linear vibration characteristics of the main engines. Trials of each engine, in single engine running, were

undertaken. The investigation found that the vibration levels, measured on the casings and foundations of both engines were surprisingly low - being well below 4 mm/s (RMS) for every measurement undertaken.

The report of the investigation concluded that the vibration component contributing to the series of failures of the fuel system pipework, since the ship entered service, was the result of in-line fluctuations due to pumping forces rather than direct transmission of engine casing vibration.

Wärtsilä Technical Bulletins

On 1 August 1995, Wärtsilä Diesel (as they then were) published a Technical Bulletin entitled '*Safety aspects on and maintenance of fuel supply system of VASA 32*'. The bulletin opened with the following paragraphs:

'During the long lifespan of the VASA 32 engines some incidents with serious fuel leakage in the low pressure fuel supply system have occurred and a few of these leakages have led to a fire. There are different reasons for the fuel leakages and the components involved vary depending on the engine output stage and manufacturing year.

Consequently measures to prevent the leakages, being it modification of design, welding method or maintenance routines, will vary depending on engine output stage and manufacturing year.

Our service network, as well as the engine owners, have been informed about some of the modifications earlier but we have found it necessary to issue a summary of the modifications irrespective of being these new modifications or a few years old'.

The bulletin then goes on to describe a number of modifications to be carried out to the fixed pipework within the engine hot-box, to the fuel pumps and to the fuel supply and spill pipework between 'A' and 'B' cylinder banks. The aim of the modifications, as stated in the service bulletin, was to dampen the pressure pulses and vibration and to strengthen the pipes, welding and screw connections. In particular, flanges on the fuel supply and spill pipework at the forward end of engine were changed from 2-screw to 4-screw flanges and an extra support was provided for the pipework.

In April 1996, the LP fuel pipework between 'A' and 'B' cylinder banks of the starboard main engine had suffered a failure. The welding on a pipe support bracket broke and also the pipe clamp on 'B' bank broke. This was followed by the failure of the screws in what was then a 2-screw flange. The result of this failure was that fuel sprayed around the engine room, but no fire ensued.

P&O in Hobart implemented the modifications to this pipework, recommended in the bulletin, shortly after the April incident, during the vessel's winter layup of 1996. A modification kit, supplied by Wärtsilä, included the pipes with 4-screw flanges, screws and O-rings.

In addition to the instructions for the modifications to pipework contained in the bulletin there were, at section 5, recommendations as follows:

'5. Maintenance of the fuel supply system

In addition to the instructions in the manual we recommend that following inspections are made after every 2000 running hours:

- Remove the hot box covers and look for possible fuel leakages.
- *Check systematically that all screws are in place. If screws have loosened or are opened -replace the O-rings and screws with new ones. Use original parts only!*
- *Check that fuel pipes are not loose from their clamping - this may cause wear and eventually leakage.'*

Because of the number of leaks which had occurred over the years from pipes in the hot-boxes, it had become a routine for the duty engineer on *Aurora Australis* to remove the hot-box covers on his rounds and carry out an inspection on a daily basis.

The screws had been subjected to about 256 running hours and would therefore have not been inspected under any routine recommended in the Wärtsilä bulletin.

Following the previous engine room fire in July 1998, P&O Polar had issued a new company directive stating that the chief engineer had to personally carry out inspections of the new flexible fuel hoses and to make an entry in

the log that he had done so. At about 2100 on 14 January, after 'Full away' had been rung, the chief engineer had checked the flexible hoses situated beneath the level of the deck plates at the starboard forward end of the engine. These are almost vertically below the failed flange. From above the deck plates it is difficult to see the flexible hoses, so he had gone beneath the deck plates, into the bilge, to carry out a thorough check and had seen no sign of leaking fuel which would have been apparent if the flange on the LP fuel system had been leaking at the time.

Failure of the allen screws

Socket head cap screws, or allen screws, are used in large numbers on medium speed diesel engines. A constant problem with such engines is vibration, which has a powerful tendency to seek out and either loosen, or cause the fatigue failure of, any incorrectly tightened screws or bolts. In one year, the MIIU has investigated four engine room fires aboard vessels in Australian ports or waters, which were directly attributable to the failure of flanged joints secured by socket head cap screws. During the same year information was received concerning two other similar failures, but where the incident was observed before a fire ensued.

In any bolted connection, the clamping force between the mating faces is of paramount importance in determining whether the parts will remain joined when subjected to vibration over a prolonged period. Screws or bolts, which are not sufficiently tightened, may loosen and fall out, or they may fail in fatigue. Those which are overtightened are likely to fail in fatigue. The clamping force is a function of the torque applied to the screws upon assembly and is usually referred to as the 'preload'. The application of an appropriate preload in the shank of the screw is the primary defence against fatigue failure or loosening. The preload is applied by the use of a calibrated torque wrench when tightening the screws on assembly.

Engine builders, well aware of the problem, usually specify a figure for the torque to which specific screws on an engine must be tightened and also usually specify, in tabular form, torque figures to which other non-specific, or generic, screws should be tightened. The values vary according to the diameter of the thread, the thread pitch and the material from which the screw was manufactured. The actual preload, however, will vary further depending on such things as the surface finish on the threads, the degree of rusting, any coating on the thread such as cadmium or zinc plating, and whether the thread is dry or lubricated upon assembly.

The screws fitted to the flanged joint, which failed, were 8 mm x 30 mm (M8) socket head cap screws of grade 8.8 high tensile steel. There are three common grades of steel in use for socket head cap screws, Grades 8.8, 10.9 and 12.9. In each case, the first number before the point is the tensile strength of the material in 100 MPa. The second number is the yield strength (or Set Limit stress) in 10% of the tensile strength. e.g. a Grade 8.8 screw has a tensile strength of 800 MPa and its yield strength is $8 \times 10\% \times 800 = 640$ MPa.

The Wärtsilä manual for the main engines of *Aurora Australis* does not provide a torque figure to which these specific screws should be tightened, but the table of torque figures for generic screw tightening is headed:

'We recommend the use of torque measuring tools when tightening other screws and nuts. The following torques apply to screws of the strength class 8.8, when oiled with lubricating oil or treated with Loctite®.'

The table then shows a figure of 25 Nm as the torque applicable to M8 screws.

Following the fire, an attempt was made to measure the residual torque on those screws still in place on both supply and spill pipe flanges. It was found that, because of the bend of the pipes adjacent to the flanges, it was extremely difficult, if not impossible, to apply a common type of torque wrench to three of the eight screws. Of those screws which were still in place after the fire and to which a torque wrench could be applied, one on the top flange and two on the bottom flange, all three started to move at a torque of less than 10 Nm.

There are no locking arrangements for such screws - indeed it is not common practice to provide locking arrangements for allen screws used in this kind of application. Beneath the table of torque values for generic screws, however, there is a note about cleaning the threads before the application of Loctite®. The application of Loctite® 242 ('Screw lock') would assist in the prevention of screws from working loose if under-torqued, but it would not provide any help in preventing fatigue failure if the screws are either under-or over-torqued. The same may be said for any type of locking arrangement.

There is a conflict in the evidence concerning the allen screws and whether over-tightening, (or torquing) the screws may have been a factor in their failure.

In evidence given by the engine builders, it was stated that at least one allen screw, the top right hand screw (looking aft), had been over-tightened. Their evidence was that, as the pipe did not properly align with the mating

flange, the top right hand screw had been over-tightened to pull the pipe into alignment. Their evidence was based on their observation of the screw, the thread of which, adjacent to the head, showed significant distortion and enlargement of the thread pitch by over 0.5 mm.

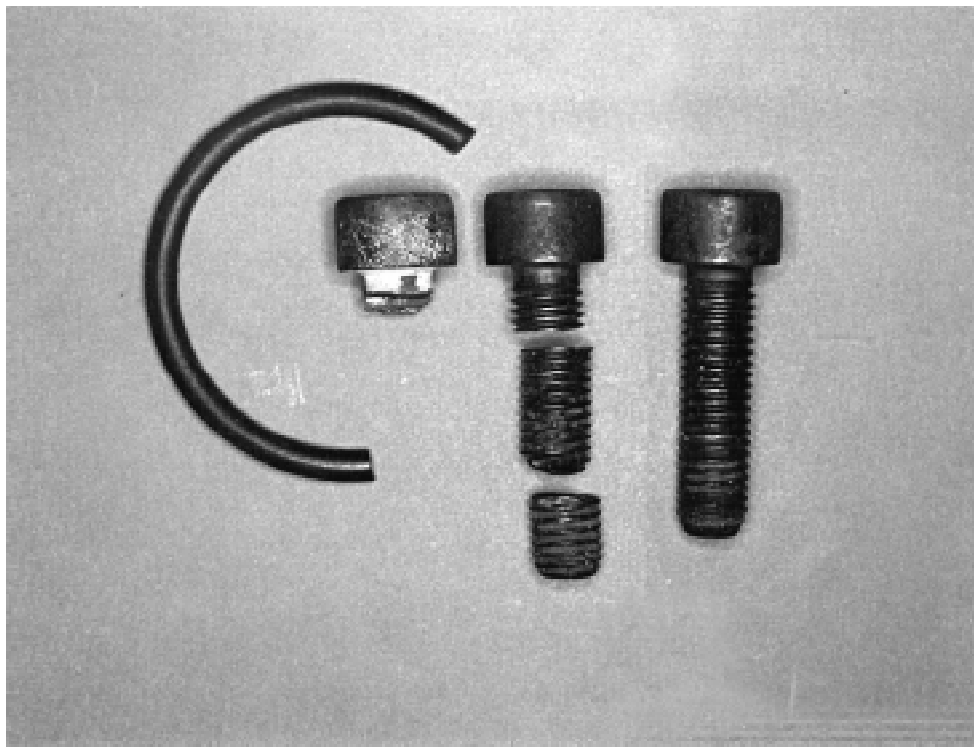
The shipowner supplied two complete screws and parts of two screws from the failed joint for metallurgical examination by ETRS. One screw head was missing. None of the three screw heads, with their small portion of attached thread, showed the reported distortion in the thread. See photos next page.

The report, commissioned by the shipowner, on the examination of the screws which were provided, contained no conclusions but in discussion stated that one screw, which had failed in high-cycle, low-stress, fatigue, had failed first. The other screw had started to fail in fatigue, but when the first had failed, this one had then suffered a fast fracture. The two intact screws from the flange showed no sign of over-tightening or fatigue.

Four screws from the adjacent flange were also examined and an extensive fatigue crack in one of them indicated that that pipework was also subjected to similar cyclic forces to that experienced by the failed flange.

The O-ring was also examined and it was found that, as the rubber was firm with no visible degradation or cracking, it had not contributed to the failure.

The inspector originally requested verbally in January that the screws and the 'O' ring be supplied to the Unit for independent analysis. The initial request was followed up in writing in February. This request was only complied with after a period of five months and then only after some screws had been treated and sectioned by ETRS. The package contained one intact screw, two screw heads and two headless ends. Those screws which were provided, including the four from the adjacent flange, were not labelled or individually identified. Of the four screws from the failed joint, only one was complete. The inspector cannot reconcile the conflicting evidence, presented by ETRS and Wärtsilä, in the absence of the fourth screw.



Screws and O-ring from failed flange joint, as supplied for examination



Fracture surface of one of the failed screws (drilled for removal from tapped hole)

Firefighting

Response

The response to the fire in the engine room was very prompt, very effective, well conducted and well controlled.

Once the Halon had been discharged, the master initiated a series of 'toolbox' meetings on the bridge, a practice he had brought with him from the offshore industry. This maximised the ship's resources, utilising the principles of Bridge Resource Management. The planning and consultation seemed to be appreciated by all those involved.

BA use, which continued over several hours mostly under the direction of the mate, was particularly well monitored and controlled. In the final stages of venting the engine room, extensive measuring of oxygen levels throughout the space was undertaken with an oxygen meter. The ship's staff were well aware that this would tell them when there was sufficient oxygen in the engine room to breathe without BA sets, but that it would not indicate the presence of any toxic gas, such as from the burned PVC insulation on cables.

As in all such investigations into shipping incidents, one or two shortcomings in organisation and equipment were revealed.

Within the last two years, the Marine Incident Investigation Unit has investigated eight fires. A worrying feature common to the majority of these is that, over the first few minutes, there was a lack of information relating to the whereabouts and actions of individuals who, on their own initiative, had undertaken a course of action without informing anyone else. These actions were invariably well-intentioned, but this sometimes led to people being isolated in areas of high potential risk without anyone being aware of their location. Such was the situation of the 3rd engineer in the initial phase of this incident.

Any procedure for countering an emergency must have due regard to communication. A whole effort to contain a fire can be nullified by the need to search for missing individuals. Such a search would be further complicated if the searchers did not know where to look.

Another, related issue, concerns the actions of individuals at the onset of a fire and the siting of muster points. Aboard the majority of ships, in the event of a fire the normal muster position for the chief engineer and, often for

an additional engineer, is in the engine control room. It is also the point of initial response by the duty engineer. Where the engine control room is located in the main machinery space, this requires individuals to enter the main machinery space to gain access to the control room and to the vital controls for machinery, electrical distribution, etc.

A recurring feature of recent main machinery space fires in Australian waters has been the propensity for oil mist and/or superheated gases to explode in a fire-ball. To this must be added the possible danger of toxic fumes. Although quick and decisive action by an engineer in the control room may avert disaster and limit a fire, anybody entering the main machinery space after a fire has developed runs the risk of death or serious injury under such conditions. Such issues are often a case for fine judgement and not subject to hard and fast procedures. However, considering the speed and ferocity with which fires, particularly atomised oil fires, have developed, the inspector believes that in the event of a main machinery space fire, nobody should access the control room alone and without backup. In such an emergency, and where means are provided, access to the control room should be made without entry into the actual main machinery space.

Equipment

Following the fire of July 1998, P&O had carried out extensive upgrading work during the subsequent repair period, to address defects in engine-room safety. The most significant items were:

- flexible fuel hoses were replaced with an approved type fitted with an outer sheath
- the Halon 1301 fixed-fire extinguishing system was fitted with a gas pilot-discharge system
- control wiring for generator shut-downs was renewed with fire-resistant cabling.

In addition, and as extra safety measures:

- closed circuit. TV was fitted so that the unmanned engine room could be monitored from the bridge
- 25 mm rubber 'first aid' hose reels were fitted
- a 'dead-man' alarm system was fitted in the engine room.

In addition, P&O also undertook a number of measures to upgrade the vessel's fire-fighting equipment. The BA sets and firemen's outfits were upgraded, eight new UHF radios were provided and rechargeable torches were fitted in all cabins.

There is no requirement under the SOLAS Convention for ships to be fitted with air compressors suitable for recharging breathing air bottles. This has been an issue in many other ship fires where there has been no capacity to recharge BA bottles. *Aurora Australis* carries an appropriate air compressor. Following problems with its electrical supply during the last fire, it was re-wired so as to be supplied from the emergency switchboard. Some of this wiring, however, ran through the engine room and was damaged in the early stages of this incident. Nevertheless, the engineers quickly repeated the temporary measures taken during the previous fire to supply it with power from the steering flat and, as a consequence, BA bottles were charged as required. In spite of all the BA sets being in use for many hours, there was no shortage of compressed breathing air at any time.

After the last fire it was considered that the engine room fire hoses were rather too long and during the repair period, with AMSA's approval, they were cut down from 14 to 8 metres. However, they were then found during this incident to be too short. It was when being shortened that they were reportedly sent ashore to contractors to have the hoses banded onto the couplings.

The problem of hoses parting from their couplings had been revealed previously when, in a safety equipment survey during the lay-up, 14 hoses had been tested and of these, six had failed when the banding stayed on the outer sleeve while the hoses slid out from underneath. According to the ship's staff, when they had tried banding on board without an outer sleeve, the connections were satisfactory.

The problem of the failed hose connections was referred back to the contractors during the investigation. The contractors confirmed, in submission, that their practice was to fit a sleeve over the hose to prevent the bands from cutting into the hose. However, they stated that they had experienced only one such failure and that was when a hose was pressurised to 2100 kPa. As the hoses which failed during the incident were not sent to the contractors by P&O for examination afterwards, they were unable to comment further. In addition, as some hoses are banded on board and others are sent ashore for banding, there appears to be some doubt about who banded the particular hoses which failed.

The expeditioners and crew mustered quickly on the helideck although, as in the last fire, members of the Antarctic Division had VHF radios whilst the ship's staff were using UHF radios. As a consequence, the expeditioners were, initially, unable to keep themselves informed of what was happening during the firefighting operations until a UHF set was provided. Also as in the last fire, the 'dead spot' in radio communication from the shaft tunnel made it necessary for the mate to station himself in the net store to relay messages to the bridge. Subsequent to the fire of July 1998, the ship's staff had asked for a UHF antenna system to be installed. This request had not been actioned by P&O at the time of this incident, but has since been done.

Drills

On the day of departure from Fremantle, a drill was held to demonstrate the use of equipment, particularly BA sets, extinguishers and the BA compressor. The expeditioners were fully briefed on the use of their lifejackets and on lessons learned from the last fire. On completion, a boat drill was held.

The muster and emergency stations list was posted on notice boards throughout the ship detailing each member's duty in the event of a fire. The master's station was on the bridge with the 3rd mate and the DCO. The mate was to muster at the scene. The 2nd mate was in charge of team 2 and the chief engineer was in charge in the engine room. The 3rd engineer's muster point was in the engine control room with the chief engineer. In general, the ship's crew responded to the emergency in accordance with the procedures laid down.

The policy on *Aurora Australis* was to exercise emergency procedures at least once a week, usually on a Saturday afternoon. The drills required by Marine Orders, Part 29 were practised to the most practical extent possible.

Conclusions

These conclusions identify the different factors contributing to the incident and should not be read as apportioning blame or liability to any particular organisation or individual.

Based on all the evidence available, the following factors are considered to have contributed to the fire:

1. The fire was caused by the failure of a flanged joint on the starboard main engine fuel supply pipework, the resulting spray of diesel fuel igniting on the turbochargers or exhaust pipework.
2. The flanged joint failed after two of the four screws failed in fatigue, and the other two had worked loose.
3. A sheet metal cover, manufactured by local contractors and which left a gap down the side, failed to provide the necessary screening of the failed flanged joint, hence allowing the escaping fuel to reach a source of ignition.
4. In the absence of all the physical evidence, the inspector could not reconcile conflicting evidence, given by the engine-builders and ETRS, on whether or not the 8 mm allen screws had, or had not, been overtightened upon last assembly of the pipework.
5. The design of the pipework adjacent to the failed flanged joint is such that a torque wrench cannot be applied to all the screws in order to tighten them to the correct torque specified in the Wärtsilä manual.
6. Vibration and mis-alignment of the pipework were factors which contributed to the failure of the allen screws.
7. The use of allen screws, having no locking arrangement, in the LP fuel system was a further contributing factor.

It is also considered that:

1. In general, the response to the fire by the ship's crew and the expeditioners on board was measured, effective, and demonstrated initiative.

2. Following an earlier fire on the same vessel, in July 1998, P&O had taken all reasonable measures to reduce the risk of another such engine room fire.
3. The use of allen screws without any locking arrangement is becoming an increasingly common contributing factor in fires caused by failures in the LP fuel systems of medium speed diesel engines.
4. The maritime industry should note the inspector's concern about the practice of individuals entering a fire zone in the engine room in order to reach the engine control room during the early stages of a fire.

Submissions

Under sub-regulation 16(3) of the Navigation (Marine Casualty) Regulations, if a report, or part of a report, relates to a person's affairs to a material extent, the inspector must, if it is reasonable to do so, give that person a copy of the report or the relevant part of the report. Sub-regulation 16(4) provides that such a person may provide written comments or information relating to the report.

The final draft of the report, or relevant parts thereof, was sent to the following:

The master, chief engineer, 3rd engineer of *Aurora Australis*

P & O Maritime Services Pty Ltd

P & O Polar Australia Pty Ltd

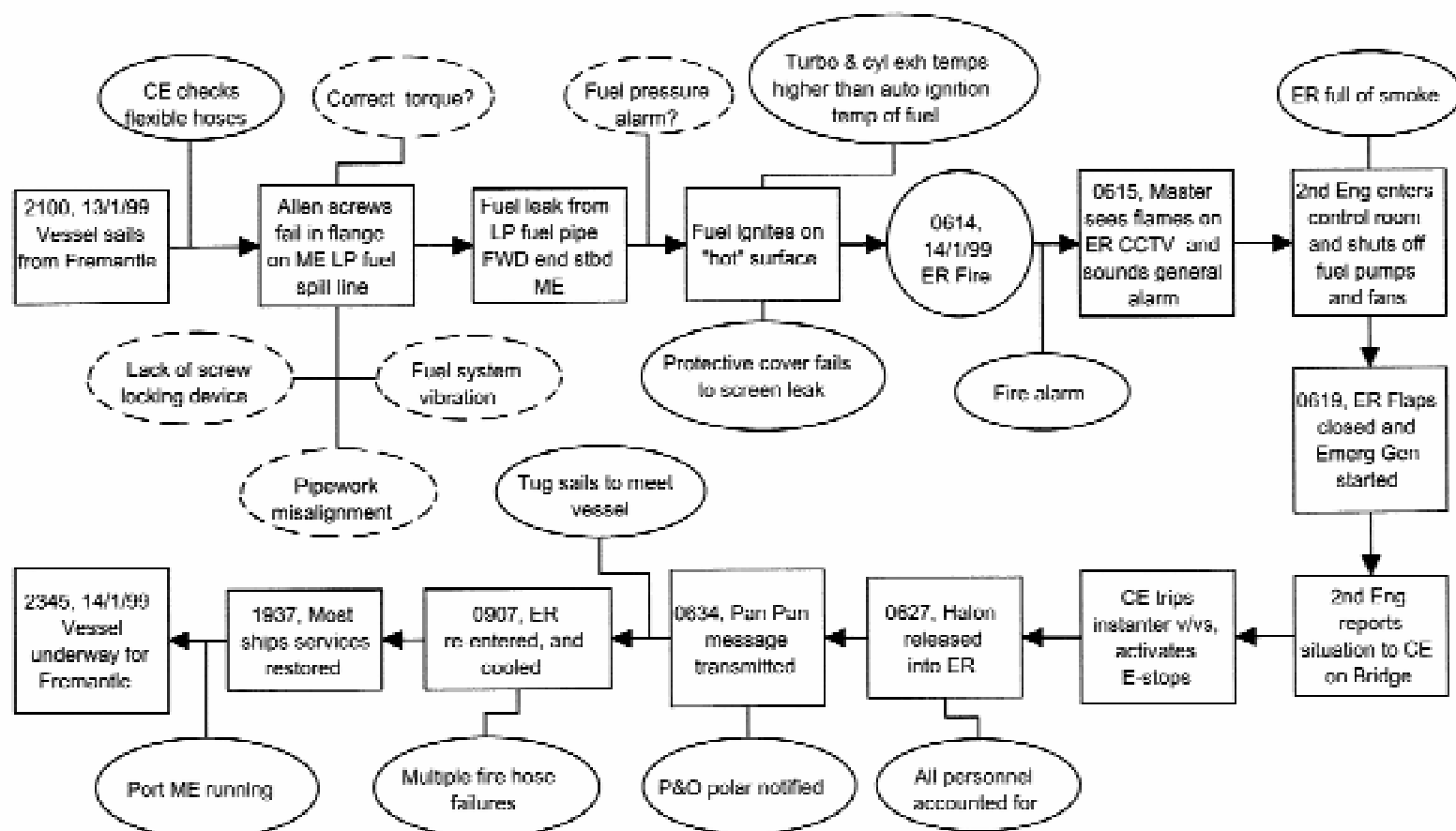
Wärtsilä – NSD Australia Pty Ltd

Australian National Antarctic Research Expeditions

Tasfire Equipment

Submissions were received from P&O Maritime Services, Wärtsilä – NSD and Tasfire Equipment. The text has been modified accordingly.

Events and causal factor chart



Details of *Aurora Australis*

IMO No.	8717283
Flag	Australia
Classification Society	Lloyd's Register of Shipping
Ship type	Research and Antarctic supply vessel (Ice Class)
Owner	Antarctic Shipping Pty Ltd
Operator	P & O Polar Australia Pty Ltd
Year of build	1990
Builder	Carrington Slipways Pty Ltd, Newcastle, NSW
Gross tonnage	6574
Net tonnage	1971
Summer deadweight	3911 tonnes
Length overall	94.91 m
Breadth extreme	20.35 m
Draught (summer)	7.85 m
Engines	2 Wärtsilä VASA 32
Engine power	Port 16 cyl: 5500 kW Starb'd 12 cyl: 4500 kW
Crew	24

Annex 1

LP fuel line pressure pulses

The flanged joint that failed was on the return side of the 'low pressure' fuel system. The 'low pressure' fuel system is a relative term used to differentiate it from the high pressures generated by the injection pump to each cylinder. The low-pressure fuel system has a working pressure of 6 bar (600 kPa) under normal running conditions.

Research has shown that pressure pulses in the supply and spill pipework, produced by the opening and closing of the ports in the engine fuel injection pumps, can reach levels up to ten times the system working pressure. The magnitude of the pulses at any point in the system pipework can only be ascertained by direct measurement with relatively sophisticated equipment, although it can be expected that they would be significantly reduced at points further away from the engine. If cavitation occurs in the system due to its design, pressure 'spikes' in excess of 100 bar can be encountered at points close to the pumps. These pressure pulses are the direct result of spilling fuel at 800 to 1500 bar into the low-pressure pipework. Many fuel systems with mis-matched pipework are in existence, the notation 'low pressure' having lulled shipyards, classification societies, repairers, owners and operators into a false sense of security.⁵

⁵ Marine Safety Agency (United Kingdom) Research Project 401, carried out by BMT Edon Liddiard Vince Ltd., January 1997.