Departmental investigation into the damage sustained by the Australian tanker OSCO STAR during tropical cyclone Justin 9 March 1997

Report 113

Australia
Department of Workplace Relations and Small Business

Contents

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Navigation (Marine Casualty) Regulations

investigation into the damage sustained by the Australian tanker

OSCO STAR

during tropical cyclone Justin

9 March 1997

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Summary

On 8 March 1997, the Australian tanker *Osco Star* was in the southern Coral Sea south of Lihou Reefs, on a loaded passage from Geelong to Port Moresby. The vessel had been experiencing east-south-easterly gale force winds since passing Fraser Island on the evening of 6 March.

To the north of Lihou Reef, a tropical depression, moving slowly in a south-westerly direction, had been developing to cyclone status and had been allotted the name “Justin”.

During the early evening of 8 March, *Osco Star* experienced a gradual decrease in the wind to force 2, then the wind backed to the east-north-east and increased in strength, indicating the vessel had passed close eastwards of the cyclone’s centre. By late evening the wind had shifted to the north-north-west, at gale force, and the engine speed was reduced due to the heavy weather.

Towards daybreak on 9 March, the wind increased to storm force. At 0620, an earth fault alarm in the engine control room led to the eventual discovery that seawater had entered the emergency generator room, located on the port side of the poop deck, and was sloshing up underneath the emergency switchboard.

During attempts to rectify electrical faults in the emergency generator room, fuses were removed in the 24 volt rectifier/charger unit, inadvertently stopping all engine room pumps. The main engine, however, continued to run, and only stopped once the fuses had been replaced nearly two minutes later. At about 0841, as the fuses were replaced, there was a complete loss of electrical power.

The main engine was restarted from the emergency manoeuvring position at 0925, but short circuits had damaged the 220 volt section of the emergency switchboard, causing the loss of some engine room instrumentation. Seawater had also caused the failure of the 24 volt rectifier/charger unit. The 24 volt system had switched to battery back-up and the batteries were discharging. By about 1100, the battery voltage had fallen to the point where the contactors in the pumps automation system started to drop out. The main lub oil pump stopped, the stand-by pump failed to start and the engine continued to run until, following some confusion, it was manually stopped by the Chief Engineer.

After carrying out checks on the engine it was restarted but, at 1248, was again stopped for a brief crankcase inspection after loud metallic banging was heard as speed was increased. Nothing was found amiss during the inspection. After again getting under way, there were more noises from the engine and it was noticed, later that afternoon, that the crankshaft had moved about 25 mm forward.

That evening, debris from the crankcase, including paint flakes, white metal, shards of steel and brass shims started to block the lubricating oil strainers which required cleaning at 11 minute intervals.

The ship was nursed to Brisbane where, upon opening up the main engine, it was found that the ahead pads in the thrust bearing had been dislodged and the crankshaft had moved at least 30 mm forward. The engine had suffered extensive damage to the crankshaft, connecting rods, main bearings (which had been carrying the thrust), crossheads and the axial vibration damper. The bedplate had also suffered damage.

Sources of Information

Master, officers and CIR of *Osco Star*

ASP Ship Management

Bureau of Meteorology, Melbourne

ETRS Pty Ltd

Acknowledgement

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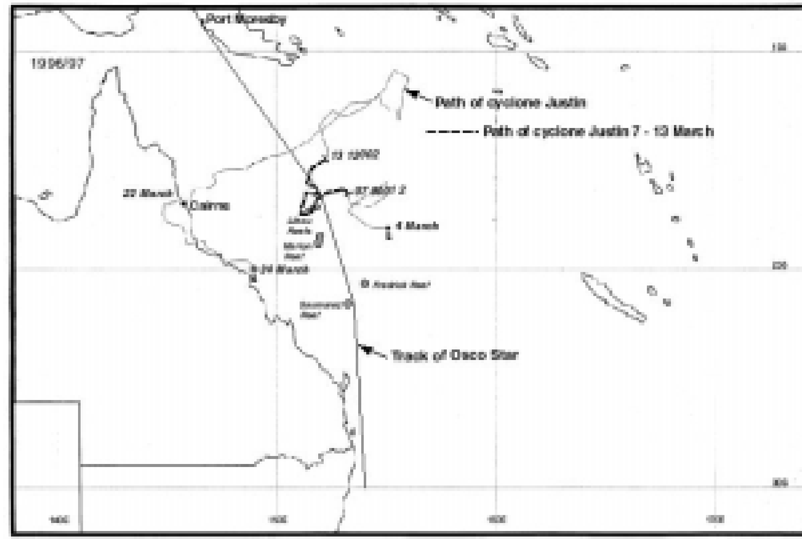
Narrative

Osco Star

Osco Star is a 40,541 tonnes deadweight tanker managed, at the time of the incident, by ASP Ship Management of Melbourne on behalf of Shell Company of Australia, under a long term bareboat charter from the owner, Osco Shipping A/S of Oslo, Norway. The vessel was built at Pula, Croatia in 1989 and has an overall length of 176 m, a beam of 32 m, a moulded depth of 15.1 m and a load summer draught of 11.215 m.



Sketch map of path of cyclone Justin
(adapted from material supplied by the Bureau of Meterology)

The vessel's main propulsion is provided by a slow speed 5 cylinder, single acting, two-stroke, B&W 5L60MC diesel engine producing 6880 kW, driving a single shaft and fixed propeller, giving a service speed of 14 knots. Electrical power is provided by two 1080 kW diesel alternators and one 1000 kW shaft alternator. Emergency electrical power is provided by a single diesel generator set of 80 kW, through the emergency switchboard, both of which are housed in the emergency generator room located in the after port section of the main superstructure on the poop deck, which is at main deck level.

The vessel was manned by an Australian crew; two crews, each of 18, working a "swing" system. Traditional, four on eight off, bridge watches were maintained, while the engine room staff worked daywork, with the engineer officers being on call during the night on a rotational basis.

The voyage

Osco Star sailed from Geelong at 1930 (Eastern Australian Summer Time, GMT + 11 hours) on 2 March 1997 with a cargo of petroleum products for Port Moresby and Darwin. The draught was 10.5 m even keel, providing a freeboard of 4.6 m. The planned route was by way of the east coast to Cape Byron, thence through the Coral Sea, passing between Saumarez and Frederick Reefs, to the east of Lihou Reefs, and on to Port Moresby.

Following his normal procedure, the Master elected to stand the 4 - 8 watch, releasing the Mate for other operational duties.

The voyage progressed well, in fair conditions, and *Osco Star* passed Cape Byron at 0200 on 6 March, at which time the wind was easterly at force 4. Later that morning the wind freshened to force 5 - 6 (20 - 22 knots). During the late afternoon it veered to the east-south-east and during the evening increased to gale strength, force 7 - 8 (32 - 34 knots). By early afternoon, the ship was rolling moderately in a rough sea and heavy south-easterly swell, shipping seas over the main deck on the starboard side.

During the night, clocks were retarded one hour, to make ship's time GMT + 10 hours.

7th March

After taking over the watch from the 3rd Mate at midnight on 6 March, the 2nd Mate, following his usual practice in heavy weather, switched on the maindeck floodlights at 0035 in order to carry out a quick visual inspection of the deck. This visual inspection revealed that the starboard side pilot ladder support brackets had been damaged by the seas breaking over the deck.

At daybreak, the Master brought the ship on to a north-westerly course to put the wind and sea astern, to enable the crew to go out on deck to secure the starboard side pilot ladder, to check around the decks to ensure that everything else was secure and that all ventilators were closed. By 0800, the wind was at full gale strength and the ship was rolling heavily and, at 0825, the main engine revolutions were reduced because of high load on the engine.

The gale force winds, rough seas and heavy swell continued throughout the day, *Osco Star* rolling heavily and shipping heavy seas along the starboard side of the maindeck. At 1130, a cyclone warning was received, advising that at 070001Z[1] , Tropical Cyclone Justin, 986 hPa, was centred at 16.5S 153.2E and was moving slowly to the west with winds of 35 - 45 knots (force 8, 9). The next warning, a storm warning, was received at 1730. This advised that Justin, now 984 hPa, was centred at 16.5S 152.5E and moving slowly west with winds of 35 - 45 knots within 400 miles south of the centre and of 50 knots (storm force 10) near the centre.

The Master assessed the situation. The weather and sea conditions, he considered, were no worse than normally experienced either in the Coral Sea at that time of year, in the Great Australian Bight, or in other oceans. The cyclone was moving to the west and was expected to continue to do so. To haul around to the north-east would put the heavy swell on the starboard beam and cause *Osco Star* to roll even more heavily. He therefore decided to maintain course and speed.

Osco Star passed 18 miles to the east of North East Cay, Saumarez Reef, at 1815 with the ship on a course of 341°, shaped to pass to the east of Lihou Reefs, and making good a speed of 11 knots.

At 2330, the scheduled 6-hourly cyclone message advised that Tropical Cyclone Justin, at 982 hPa, was almost stationary in position 16.5°S 152.5°E and was expected to move slowly westward during Saturday (8th). Winds of 35 - 45 knots (force 8 - 9) were forecast within 400 miles south of the centre, with winds expected to 50 knots (storm force 10) near the centre during Saturday.

The weather experienced by the ship remained steady, with the wind from the east-south-east at force 8, a very rough, easterly sea and a heavy swell. *Osco Star* continued to roll heavily and to ship heavy seas on the main deck.

8th March

The Master was on watch when the next cyclone report was received, at 0530 on 8 March. This advised that at 071800Z, Justin, at 977 hPa, was located at 16.7°S 152°E, was moving west-south-westerly at five knots and that 50 knot winds could be expected within 100 nautical miles of the centre. After referring to the section on cyclone

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[1] Add ten hours for Eastern Standard Time, hence 070001Z is 1001 on 7 March.

avoidance in the Mariners' Handbook and encouraged by the stable weather conditions and the latest movements of Justin, the Master considered deviation from the intended course and a reduction in speed to be unnecessary.

During the late morning the wind shifted to the east and increased slightly, the ship experiencing a pressure drop of 8 hPa (988 to 980) between 0800 and midday. The cyclone message received at 1100 indicated that over the previous six hours, Justin had remained stationary and deepened a further 2 hPa, to 975 hPa. By 1600, the wind had continued its northerly shift to east by north and the barometer had fallen to 975 hPa.

Thereafter the wind started to ease. The 1700 cyclone message advised that at 080600Z Justin, at 975 hPa, was centred at 17.5°S 152.5°E, 30 miles to the south-east of Lihou Reefs and just 30 miles directly ahead of *Osco Star*. By 1800 the wind had dropped away almost completely and the Master made an entry in the deck log book "Ship estimated to be within 40´ from TRS Justin". The wind remained light until shortly after 2000, when it rapidly increased again to gale force from the east-north-east. At 2115, due to a steep confused sea, the Master ordered a reduction in speed to 88 RPM, after which the ship rode more easily.

The Master now felt that *Osco Star*, having passed through, or near to the centre of the cyclone, was now in the "safe", navigable semicircle and that conditions would improve, that the worst was over.

9th March

During the 2nd Mate's early morning watch on 9 March, the wind backed from east-north-east to north and then to north-north-west, but remained reasonably constant at gale force. At 0030, when *Osco Star* was 17 miles to the east of the north-eastern point of Lihou Reefs, course was altered to 324° True, to head the ship towards Port Moresby.

After 0400, the wind continued to back, shifting to the north-west, and increased dramatically, to 50 knots (storm force 10) by 0530, to 60 knots by 0600 and to 70 knots (hurricane force) towards the end of the Master's 4 - 8 watch.

At about 0500, the Chief Engineer, unable to sleep because of the heavy pitching of the vessel, became increasingly aware of the noise of the main engine turbocharger surging. He went to the engine control room, where he met the Duty Engineer (the 2nd Engineer), who had been called out earlier by a high level alarm for the bilge-well beneath the main engine. The 2nd Engineer had already adjusted the main engine speed. The Chief Engineer was also informed that the forecastle bilge alarm had been activated the previous evening, at 2244, but was now (at 0511) normal.

At 0525, alarm 11513, "low insulation resistance 220 v" (earth fault) was activated. The engineers carried out the usual checks and tests, such as successively isolating items of electrical equipment at the main switchboard, to establish the origin of the earth fault. They were at that time, however, unable to determine the location of the earth fault.

With the arrival of daybreak, at around 0530, the Master saw that the forecastle/pumproom door had been sprung open and that the spurling pipe covers had been dislodged.

At 0543, alarm 11512, "low insulation resistance 440 v" was actuated followed, at 0554, by alarm 19602 "failure steering gear system". Investigating the latter alarm, the Chief Engineer discovered water cascading on to the steering motor local electrical panel from a ventilator trunk. Plastic sheeting was placed over the electrical panel and the Master was requested to change over from the running (port) to the stand-by (starboard) steering motor. These actions partially cured the 440 volt earth fault, which thereafter became intermittent.

At 0620, alarm 11514 "fault 24V DC power supply SCR 60" (the rectifier/charger unit for the 24 volt emergency batteries) was activated and the Chief Engineer realised there was a common earthing problem, with everything indicating there must be water in the emergency generator room. However, the weather conditions were extreme and seas were breaking over the poop, so that it was too dangerous to venture out to investigate the problem fully. Because of the cyclone conditions, the Chief Engineer decided to initiate normal sea watches in the engine room.

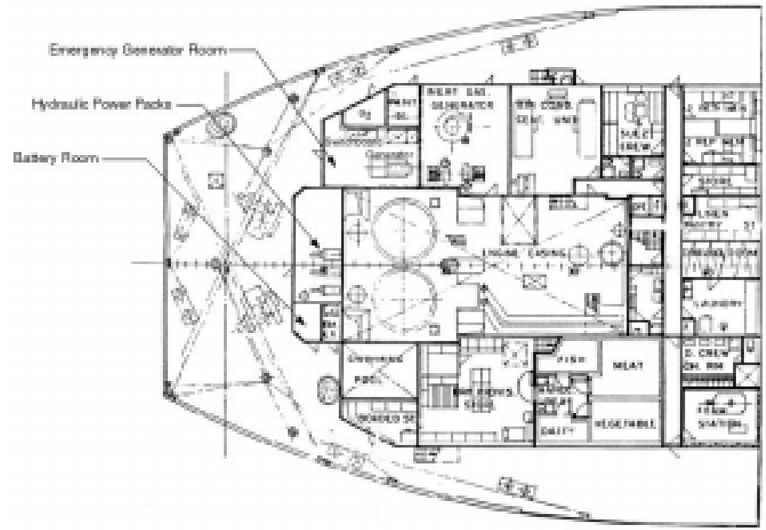
Osco Star was pitching heavily into a very heavy head swell, burying the forecastle and maindeck. At 0630, the Master noticed that electrical cables on the foremast had been torn free and that the cargo valve hydraulic lines on the maindeck had also been torn from their mountings. In the engine room, a heavy sea shipped over the funnel deck caused water to enter through the main engine room hatch and through the ventilation louvres on the forward end of the engine casings.

The Chief Engineer attempted to gain access to the deck and hence to the emergency generator room by the door on the port side of the funnel, but found the funnel deck being swept by the seas. The conditions were such as to arouse his concerns that the lifeboats were about to be carried away.

A succession of various engine room alarms kept the engineers busy until about 0700, when a respite enabled them to take breakfast. At 0810, the visual display unit (VDU) for the Autronica alarm and monitoring system failed. During breakfast, the weather and sea conditions had eased a little and, at about 0830, the 1st and 2nd Engineers were able to gain access to the poopdeck and the emergency generator room. They checked the mushroom ventilators on top of the steering flat but reportedly found them tightly shut. This indicated to them that water must have leaked past when the ventilators had earlier been submerged under seas coming over the deck.

First engine stop

Opening the door of the emergency generator room, they found water sloshing around the deck inside the space; the rolling of the ship was causing the water to splash up, to a height of about 300 mm, underneath the emergency switch board onto the exposed lower terminal strips and also underneath the rectifier/battery charger unit on the starboard side of the space. The emergency switchboard, connected to the main switchboard by the bus-tie circuit breaker, was still live. Short-circuits in the emergency switchboard were causing various "hand/ auto" control indicating lights to flicker and to illuminate with a dull glow.



General arrangement plan of Poop deck area

Assisted by the CIR, the Chief and 1st Engineers set about pumping the water out. While doing this, a possible source of ingress of the water was traced to a small ventilator grille high up on the outboard bulkhead, the storm flap of which was open, having apparently been forced open by the seas breaking on board.

Upon opening the emergency switchboard panel doors, the Chief Engineer found the lower terminal strips to be sparking and smouldering. The ceramic terminals were blackened and there was sparking within the wiring looms. The emergency generator was switched from 'automatic' to 'hand' start, in case it should start automatically, and the terminals were sprayed with contact cleaning fluid in an attempt to dry them. The 24 volt charger/rectifier (SCR 60) cabinet, which had also suffered from an ingress of water, was similarly treated and blown control fuses were changed. Two 80 amp main fuses were also removed and checked. At about 0841, these fuses were replaced and, at that instant, the vessel experienced a blackout. The main engine, which had been running until this moment, stopped. At this time, *Osco Star* was 37 miles to the north of Lihou Reefs.

With the emergency generator in 'hand start' control mode, there was no automatic re-establishment of power and it was necessary to manually restart the ship's two main diesel generators in hand control. No. 2 was started and put on line at 0843, restoring power. No. 1 was started shortly afterwards.

After the ship had blacked out and stopped, the Master telephoned the company's Ship Manager, to advise him of the situation. "Security" messages were broadcast on VHF 16 to warn any other vessels that might be in the area, of the situation.

With power restored, the 3rd Engineer, in the Engine Control Room (ECR), made a number of attempts to restart the main engine, but these were unsuccessful as both bridge and ECR Engine Telegraphs had not been realigned to "Stop" when the blackout had occurred. There were, in addition, problems with the 220 volt supply to the telegraph and to the engine revolution counter. The Chief Engineer, when he arrived in the ECR, was concerned that much of the starting air for the main engine had been used up. He was also concerned that, although power was restored and the Autronica Central Computer system was working and the analogue gauges were indicating, there was no VDU display and alarms were no longer sounding.

At about this time, the Master telephoned the Chief Engineer from the bridge, asking him what was happening and informing him of the close proximity of Lihou Reef. He requested that he restart the main engine as soon as possible. The engineers checked local gauges around the engine room to ascertain that there was lubricating oil, cooling water and fuel oil pressure, then tried an engine start from the local manoeuvring platform at the side of the engine. The attempt again failed as the starting air pressure was down to 16 bar, following the previous attempts.

After the 1st Engineer had isolated all non-essential air outlets from the main air bottles, a further attempt was made and the main engine was restarted at 0925. It was run on manual control and the speed was quickly brought up to about 80 RPM, just above the upper end of the critical revolutions range (65 - 77 RPM). The vessel had experienced very little drift while stopped and its course, 324°(T), was resumed. Intermittent failures of the 220 volt supply were continuing in the ECR and hence there was no reading of main engine speed. The engineers used a hand-held tachometer on the engine and checked the reading by counting and timing the strokes of the main engine exhaust valves.

Second engine stop

At about 1100, the Chief Engineer was still at the main engine local manoeuvring platform. The 1st Engineer was in the control room, where he was monitoring the control room instrumentation as the gauges had been starting to fluctuate intermittently. The 2nd Engineer had just come into the control room when, very shortly afterwards, the 1st Engineer noticed that there was no pressure reading on the main engine lubricating oil gauge. He asked the 2nd Engineer to go down and tell the Chief Engineer to stop the main engine as there was no lub oil pressure. The 2nd Engineer went down to the local control position at the engine side, but the evidence indicates that there was some confusion and, after a short while, he returned to the control room. The engine was still running.

The 1st Engineer then ran out of the control room and down to the bottom of the engine room to check the lub oil pumps, shouting to the Chief Engineer, as he passed the engine local control position, that there was no main engine lub oil pressure. On hearing this, the Chief Engineer stopped the main engine. The 1st Engineer found that no lub oil pump was running, so he started one. He quickly returned to the local control position. The Chief Engineer shouted "what's the oil pressure?" and he reported that the local gauge showed 2 bar pressure. The Chief Engineer then went to the bottom plates level on the starboard side to observe the piston-cooling oil flow through the 'tell-tale' sight glasses. He observed oil flowing through the glasses and the highest oil temperature on the local thermometers was 55°C; within the normal limits.

The engine was still turning over, due to the way still on the vessel, when the Chief Engineer heard a rumble from the forward end of the main engine and observed whiffs of blue smoke coming from the rubber seal around the chain tensioner for the forward moment compensator.

The engineers carried out a number of checks and had a general look around the engine and its ancillary systems. They felt the outside of the crankcase, and checked temperatures and pressures on local thermometers and gauges. During this process, several other pumps were found to have stopped and had to be restarted at the local pump starters. By the time these checks had been carried out, all pumps had needed restarting at their local starters. However, once they were restarted, temperatures and pressures seemed normal and the engineers were unable to observe any further indications of a problem.

At about 1200, following the checks which had just been carried out, the main engine was restarted from the local control position and brought up to approximately 83 RPM. Everything was on manual control, there being continuing concern about the failure of the 24 volt system, the intermittent failures of the 220 volt system and the lack of instrumentation that these problems were causing in the control room.

At noon, *Osco Star* was again in a position 37 miles to the north of Lihou Reefs, but about two miles to the east of the position where the vessel had first stopped, at 0840.

Soon after getting under way again, there was bad vibration and a heavy metallic knocking sound coming from the engine as attempts were being made to increase the engine speed.

Third engine stop

The Chief Engineer advised the Master that it was going to be necessary to carry out an inspection of the crankcase, to which the Master responded by asking him to carry it out as quickly as possible. At 1248, when the engine had been stopped, the turning gear was engaged and, after waiting a half hour for any possible hot-spots to cool down, the engineers opened up the crankcase to carry out a brief inspection. Because of the motion of the vessel in the heavy seas and the fact that the interior of the crankcase was still hot and extremely slippery, they did not enter, but carried out the inspection from the open crankcase doors. They did not see any signs of overheating, such as blueing of steel, and could not see any evidence of white metal in the engine sump. The current drawn by the electric motor of the turning gear was quite normal and the engineers concluded that, judging from what they were able to see, all was well. As there was no apparent problem, the engine was re-started again at 1402, at which time *Osco Star* was 39 miles north of Lihou Reefs and two miles north-east of the noon position.

As soon as *Osco Star* was once more under way, with the wind increasing again after the slight lull of the late morning, the Master altered course to 045° to take the vessel away from the cyclone. By midnight, some 65 miles progress had been made. The Chief Engineer remained at the controls most of the afternoon until, at 1600, the engineers broke into watches, two to a watch, with the 2nd and 3rd Engineers taking over at that time.

At some point during the afternoon, it was noticed that there was axial movement at the main engine flywheel and, at the intermediate shaft plummer block, the shaft could be seen to be moving about 25 mm axially in the bearing. In addition, it was found that the flywheel had moved forward sufficiently far to have contacted, and bent, the pointer for indicating the angular position of no. 1 unit.

During the afternoon, the barometric pressure remained steady at 973 hPa and the wind increased to hurricane strength again. Course was adjusted to 020°, on which heading *Osco Star* was found to ride more easily. The wind remained at hurricane strength until late evening, when it eased to storm force.

Although the Master was sending regular weather reports to the Bureau of Meteorology advising them of the high wind strengths, the storm warnings issued by the Bureau continued to refer to wind strengths of 60 - 65 knots within 100 nautical miles of the cyclone centre.

Deviation to Brisbane

Throughout the day there had been numerous telephone calls between the ship and shore management. In the early stages, it was considered that *Osco Star* could continue to Port Moresby and it was arranged for the "on leave" 2nd Engineer and the Electrical Superintendent to fly to Port Moresby to assist the ship's staff carry out necessary repairs to electrical cables and hydraulic lines on deck. However, by early afternoon the Master and Chief Engineer realised that it would be better to deviate from the voyage and to turn about and head for Brisbane, as soon as the weather and sea conditions permitted. Permission was sought, and obtained, from Shell Australia and contact was made with United Salvage to ascertain whether an ocean-going salvage tug was available, should one be required.

During the day there had been a distress alert for a yacht and *Osco Star* was the nearest vessel to be able to provide assistance. However, because of the problems on board, the ship was released from involvement.

At about 2130 that evening, the engineers on watch called the Chief Engineer to advise him that there were problems with the differential pressure on the main engine lubricating oil filter; it had increased considerably. The main engine speed was reduced to 56 RPM and an inspection made of the lub oil strainers fitted upstream of the main, self-cleaning, filter. The strainers were found to contain substantial numbers of flakes of white metal, paint flakes and sharp shards of steel.

The blocking of the strainers was such that a routine had to be started for swapping over and cleaning the strainers at intervals of about 11 minutes. This interval, however, later increased to about every 20 minutes. Over the following 24 hours, much debris, including paint flakes, white metal and steel shavings, was removed from the strainers. By the end of the following 24 hour period, the amount of debris decreased and it later became necessary to clean the strainers at intervals of only once per watch. The Chief Engineer attempted to run both lubricating oil pumps in parallel in an attempt to flush the debris through to the strainers and, hopefully, to increase the lubrication to the engine, but this was unsuccessful as the oil pressure relief valve kept lifting.

The Chief Engineer was requested by the company to slow down the main engine as much as he could, while maintaining steerage way. Engine speed was reduced to 44 RPM, “dead slow ahead”, and a routine was established where, whenever the vessel lost steerage way, the bridge would ring the engine room and request an increase, as necessary, to bring the ship back on course. Once on course, the revolutions would then be reduced again. The vibration was very bad and whenever the engine speed was increased, there would be heavy metallic knocking coming from the engine - what sounded to the engineers like “piston-slap”. On one occasion, it was not possible to increase the revolutions much as the lubricating oil temperature increased to 70°C, close to the shut-down temperature. In this fashion, the vessel was nursed to Brisbane.

The north-westerly storm force winds continued until the Monday (10th) afternoon, when they eased to gale force. At a telephone link-up between the Master, Chief Engineer, ASP Ship Management and Shell, the Chief Engineer was exhorted to do his best to keep the engine going, under any circumstances. At 1530 on 10 March, the

Master considered that conditions had abated sufficiently to make it safe to turn about and head for Brisbane and course was altered to 160°.

The 220 volt supply, which had been suffering intermittent failures since the previous morning, finally failed completely on 10 March. A jury-rigged supply was provided by running a cable from a spare circuit breaker in the 220 volt section of the main switchboard to the 220 volt automation distribution board at the back of the control room main console, having disconnected the supply from the emergency generator room. This re-established supply to some instrumentation and enabled readings of bearing temperatures, but the VDU of the monitoring system remained inoperative, as the 24V DC to 220V AC inverter was not restored. A temporary solution to this problem was achieved, however, by modifying the system so that when an alarm was activated, a visual indication, as a number, would be provided on the Autronica cabinet and the particular alarm identified by using a photocopy of the list of alarm channels.

As soon as conditions permitted, stock was taken of the damage on the main deck and forecastle. Considerable damage had been done to electrical wiring and to the pipe bridges on the main deck. Most of the hydraulic control lines for cargo valves had been torn from their mountings and were lying in a massive tangle. The emergency fire pump space forward was flooded and eductor pipework and valves in the forecastle had been shattered. Timber racks and gear stowed in the forecastle space had been pulverised. Ladders and railings on the boatdeck had also sustained damage, as had the port lifeboat. A cargo tank pressure/vacuum release valve had been torn off and the walkway around one of the midships foam monitors had been demolished. On the poop deck, the door to the hydraulic machinery room had been forced open by the seas and the space was flooded, causing extensive damage to the hydraulic pump motors.

The tug Austral Salvor was dispatched on Tuesday 11 March and made a rendezvous with *Osco Star* at 1640 on Thursday 13 March, 85 miles north of Frederick Reef. A line was not passed to Austral Salvor, however the tug accompanied *Osco Star* in case of further breakdown.

On Wednesday 12 March, a piece of main engine crosshead shim was found in the lub oil strainers. This indicated that at least one of the crosshead guides had failed. The Chief Engineer contacted the office of ASP in Melbourne and was advised to keep the ship going until such time as it was out of danger, clear of reefs, and the weather had abated.

Osco Star arrived off Caloundra Head at 0600 on 19 March and embarked a Brisbane Pilot. At 0719, Austral Salvor was made fast, to assist the passage through the Moreton Bay channels, and *Osco Star* was brought safely to anchor at 1224.

The cargo was transferred to another vessel, the tanks washed and gas freed and then *Osco Star* was berthed at the Keppel Cairncross shipyard. The main engine was opened up and it was found that the thrust bearing had failed, the thrust pads had been dislodged and the crankshaft had moved approximately 30mm foward, resulting in severe damage to the crankshaft itself, the main bearings, the crossheads, the connecting rods, to the forward axial vibration damper and to other bearings at the forward end of the engine. The bedplate had also suffered heat damage.

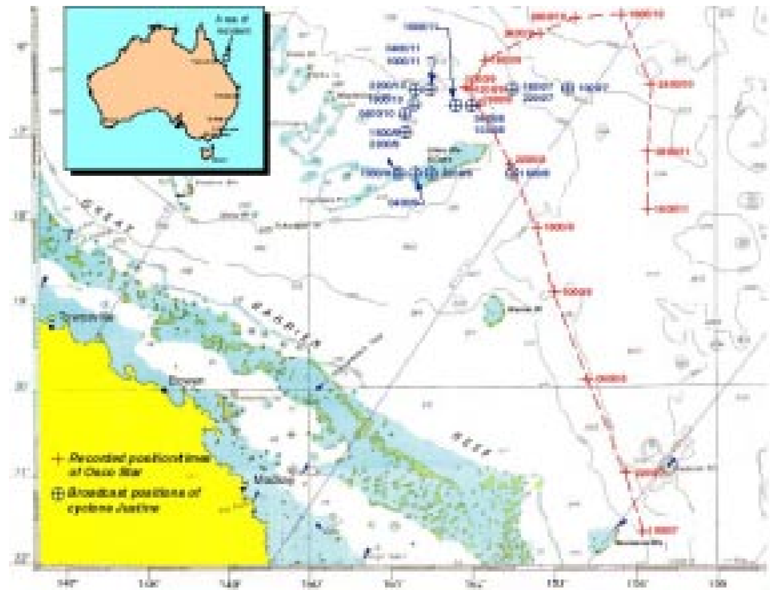
Due to the extent of the damage, *Osco Star* was towed to the Hyundai Shipyard in Ulsan, Korea, to undergo major repairs. The repairs involved the renewal of all of the above engine components with the exception of the bedplate, which was not beyond repair, and four of the connecting rods which were reconditioned.

Comment and Analysis

The weather and sea conditions throughout this incident were extreme and conditions on board difficult.

A sequence of events occurred after *Osco Star* had been caught by the full fury of cyclone Justin, which started with seawater gaining access to the emergency generator room. Following a number of electrical failures, there was a loss of lubricating oil to the main engine, which caused a failure of the thrust bearing and significant damage to the main engine. As the main engine damage was a direct result of the failure of the thrust bearing, it is necessary to examine the events which led to this loss of lubricating oil.

Apart from the damage to the starboard pilot ladder assembly, all of the damage sustained by Osco Star, both on deck and in the engine room, occurred after the vessel had passed through the eye of cyclone Justin.



Portion of chart Aus 4602 showing position/times of Osco Star and broadcast positions of cyclone Justin

Analysis of the movement of cyclone Justin

The first warning to shipping of a developing low was at 1730 (AEST) on 4 March 1997, when *Osco Star* was off the central New South Wales coast. The low continued to develop over the next two days and was named cyclone Justin at 0400 on 7 March, by which time *Osco Star* was already experiencing east-south-easterly gale force winds.

At 1730 on 7 March, when *Osco Star* was passing to the east of Saumarez Reefs, Justin was reported as having been in position 16.5°S 152.5°E at 1600 on 7 March and as moving slowly westward, with winds of 50 knots (storm force) expected to develop near the centre. Justin was, at that time, 325 miles to the north and 34 miles to the east of *Osco Star*'s intended track. In the preceding six hours, Justin had tracked 41 miles due west and, if that movement had been maintained, would have reached a position about 180 miles to the west of *Osco Star*'s track as the vessel cleared Lihou Reefs.

The cyclone warning issued at 2330 on 7 March showed that, instead of maintaining its westerly movement, Justin had remained stationary during the preceding six hours and had deepened by two hPa. Forecast wind strengths, however, remained unchanged. During the same period, *Osco Star* had closed Justin by 64 miles.

The warning at 0530 on 8 March placed Justin 194 miles ahead of *Osco Star*, indicating that Justin had moved west-south-westerly and had deepened by a further 5 hPa. The warning advised that Justin was expected to continue to move west-south-westerly at 5 knots, with 50 knot winds out to 100 miles. If the forecast movement was sustained, Justin would be within 100 miles of *Osco Star* by 1800 that day.

The warning issued at 1100 on 8 March indicated that Justin had again been stationary during the preceding six hours and was moving only very slowly. Justin, with a central pressure of 975 hPa, was now located only 139 miles ahead of *Osco Star*.

The next warning, issued at 1700 on 8 March, indicated that Justin had moved in a south-south-easterly direction and was located only 30 miles directly ahead of *Osco Star*. Between 1800 and 2000 *Osco Star* experienced a lull in the wind as the vessel passed close to the centre.

Justin then moved westward, across Lihou Reefs, and intensified as the forecast storm force winds developed rapidly, increasing to hurricane strength (64 knots and over). After being located over East Diamond Islet at 1000 on 9 March, Justin moved slowly northward during 9 March and 10 March, then turned eastward and became stationary 30 miles to the north of Lihou Reefs, on the evening of 11 March.

The information received by the Master on the evening of 7 March indicated that, if the cyclone movement had been maintained, Justin should have passed well clear. However, the information that Justin had not maintained its movement, but had remained stationary over a 6 hour period, should have indicated that extreme caution was now necessary. Even when movement was resumed, at 5 knots in a west-south-westerly direction, a more southerly direction or even recurvature by Justin was possible. When Justin became stationary for the second time, virtually on *Osco Star*'s intended course line, only considerable evasive action by *Osco Star* could prevent a close encounter with the cyclone and the likelihood of experiencing the predicted severe weather conditions.

Throughout 7 March and the early hours of 8 March, *Osco Star* experienced a steady drop in the barometric pressure, from 1005.5 hPa at 2400 on 6 March to 988 at 0800 on 8 March, with little shift in the east-south-easterly gale force wind. These two factors alone, without the receipt of the cyclone warnings, should have indicated to the Master and deck officers that *Osco Star* and Justin were moving towards each other. The rapid drop in barometric pressure of 8 hPa, between 0800 and 1200 was indication that Justin was then very close.

Tropical Revolving Storms - Cyclones

There is considerable literature available on tropical cyclones and tropical cyclone avoidance and the Master had on board, and referred to, the Mariner's Handbook. An understanding of the theory of the formation of tropical cyclones and their avoidance is also an important part of the meteorological syllabus for mariners' qualifications. Modern satellite imagery provides up-to-date position information and accurate[2] cyclone position warnings are broadcast on a regular basis by the meteorological bureaus, which removes much of the uncertainty for the mariner. However, movement prediction is not an exact science and there is often a degree of uncertainty as to a cyclone's movement, particularly when the cyclone appears disorganised on satellite imagery (more common during the cyclone's weaker phase). Mariners therefore need to keep a careful watch on the barometric pressure and the wind direction.

Generally speaking, but not always (see Attachment), tropical cyclones in the Coral Sea follow the normal tracks of cyclones in the southern hemisphere, south-westerly, recurving to the south-east. However, both latitude and longitude of recurvature can vary considerably, in fact it is not uncommon for recurvature to not occur at all and movement can be contrary to expectations. Also, while stationary, or slow moving, tropical cyclones tend to

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[2] Accuracy depends upon how well defined the eye is in the cloud formation. Median accuracy obtained by the Australian Bureau of Meteorology over the preceding five year period was 20 miles.

intensify more rapidly than when moving quickly, with resultant strong winds also developing rapidly.

Studies of cyclone behaviour have shown that cyclones in the Coral Sea and Gulf of Carpentaria exhibit the most erratic movement of cyclones anywhere in the world. This should always be borne in mind when applying theoretical models for assessing their possible movement and extreme caution is required when one is encountered.

The full wind strength of a cyclone is normally only experienced within about 150 miles of the centre of the cyclone and, therefore, wind conditions outside this area should not be taken as indicative of the winds likely to be experienced nearer to the centre. The winds in the “navigable” semicircle (navigable because in general the cyclone will be moving away from the vessel) are just as fierce as in the “dangerous” semicircle and the seas can be treacherously steep close to the centre, due to opposing seas/swells. To consider the “navigable” semicircle to be the “safe” semicircle is, therefore, wrong.

Vessels should always be steered well clear of tropical cyclones, allowing plenty of room for change in direction and increase in strength and, where a master finds he is in the vicinity of a tropical cyclone, “his first care should be to get as far away as possible from the vortex ...”[3]. Tropical cyclones vary in size and intensity, however, “the matter of vital importance is to avoid passing within 80 nautical miles or so of the centre of the storm; it is preferable to keep outside a radius of 200 nautical miles ...”[4].

Where it is possible to do so and where there is sufficient sea room, vessels should always avoid getting too close to tropical cyclones. Winds of 50 knots are “storm force” strength and the resultant seas, breaking on board, can do considerable damage. Even though a cyclone might only be graded “category 1”[5], wind gusts of up to 67 knots can be experienced.

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3 Meteorology for Mariners (M.O.895)

4 Ibid

5 The usage of the cyclone category system is confined to public warnings for coastal communities and is avoided in the Bureau of Meteorology’s marine warnings. Notwithstanding this, Category 1 equates with mean winds of 34-47 knots (i.e. gales) with <u>gusts</u> up to 67 knots.

Onboard management procedures

The Master appears to have been lulled into a false sense of security in that he considered conditions being experienced to be no worse than conditions frequently experienced in other oceans. Then, having passed close to the centre, during the early evening of 8 June, he considered that *Osco Star* was now in the “safe” semicircle and that conditions would improve as distance from the centre of the cyclone increased.

Although there was some discussion between the Master and officers on the bridge about cyclone Justin, and reference made to the Mariner’s Handbook, there does not appear to have been a proper, full analysis of the developing situation, or a free exchange of views on appropriate action, as might be expected to take place under Bridge Resource Management principles. The 2nd Officer had had command on overseas flag vessels and his experience should have equipped him to provide valuable support to the Master and should have enabled him to discuss the situation openly and freely with him. However, although he had held his own views at the time on what action should be taken, because the Master was happy with the situation, and possibly due to his cultural background and to his own philosophy when sailing as master, he accepted the Master’s decisions.

Routeing

As a result of major public concern regarding pollution of the Great Barrier Reef, most major oil companies now route their vessels through the Coral Sea, rather than through the Inner Route of the GBR.

Not all the Coral Sea area has been surveyed to International Hydrographic Organisation standards. To facilitate the Coral Sea route between Australia’s east coast and the Torres Strait, a 10 km wide track (5.4 miles) has been “swept” for obstructions and possible hazards. The centre line of the route passes 13 miles from the eastern extremity of Lihou Reef.

This incident illustrates that the outer route is subject to its own dangers, particularly in the cyclone season.

Water ingress into the emergency generator room

From the various items of damage sustained by *Osco Star* around the poop deck and boat deck, it is apparent that the vessel was pooped on more than one occasion, with seas breaking not only onto the poop deck, but also onto the boat deck about 7.5 metres above the waterline. At a position midships on the boat deck, a fixed vertical steel ladder at the forward end of the engine casings, just below the funnel, had been torn from its welds and badly twisted indicating the height reached by, and the force of, the seas breaking on the vessel.

Ventilators on top of emergency generator room

The poop deck, which is at the main deck level, but closed off from the main deck by a bulkhead, is enclosed by a solid bulwark. The quantity of water shipped onto the poop deck must have virtually filled the semi-enclosed deck space formed by the accommodation, the forward bulkhead and the solid bulwark. It was of sufficient depth to enter the mushroom ventilators (on the centre line of the poop deck aft) to the steering gear flat, before it was able to drain away. The depth of water constantly trapped on the poop deck delayed the eventual access by the engineers to the emergency generator space.

There are six possible points at which water may have entered the emergency generator room:

- the door from the poop deck at the after end of the emergency generator room;
- next to the door, the engine cooling air intake;
- a ventilation grille above the cooling air intake;
- below the engine cooling air intake, the shore power connection access;

- a small ventilation grille about 2.5 m above the deck level in the port side bulkhead; and
- three vents on the boat deck level.

As there is no internal access, the door at the after end of the emergency generator room, leading from the open poop deck, is the only way into the space. It is secured by only three dogs and is not a proper watertight door (secured by six dogs and double-pin hinges to allow it to be dogged down flat onto the seals).

Poop deck
Poop deck of Osco Star with the open dor to emergency generator room. Engine cooling-air to right of doorway. Small vent flap with broken lug is shown arrowed.

Also in the after bulkhead of the emergency generator room there is a rectangular, louvred opening which is the air inlet for the air-cooling of the diesel engine which drives the emergency generator set. A hinged flap, also secured by two dogs fitted with wing nuts is provided to close off this opening in bad weather. However, the flap has to be open to provide cooling for the generator after an automatic start, otherwise the diesel engine would quickly overheat. This flap would normally be left in the open position in case of an automatic start by the generator set. The lower edge of this louvred opening is approximately 600 mm above the deck.

Connecting this louvred opening to the fan which cools the generator, there is a canvas shroud about 300 mm long. At its underside, the canvas appeared to have been slit with a knife at some time, presumably to allow any water which entered the louvres to drain away instead of sitting in the canvas and being picked up by the fan when the engine ran. The area around this slit was caked with salt, indicating that, at some time either in the past or during the cyclone, water had entered the louvres. It was stated that the flap for the louvres had been closed, however, it could not be ascertained that it had been closed securely and there appears to be some doubt about it still being closed at the time that access was finally gained to the emergency generator room after breakfast on 9 March.

The after bulkhead, close to the door and the louvred air intake, is penetrated by a short length of pipe, approximately 100 mm in diameter and about 200 mm above the deck, provided for passing cables into the emergency switchboard when the vessel is on shore power, such as when in dry-dock. Evidence was given to the investigation that a wooden bung had been fitted in this opening during the procedure of securing for heavy weather. However, other evidence was received indicating that it was not in place shortly after the flooding occurred, when attempts were being made to ascertain the source of ingress of water. The interior of the pipe on the weather deck side of the opening was very rough and gave the appearance of paint having been applied over bubbles of rust. In addition, the paint within the opening at this end of the pipe showed little evidence of having been disturbed by the hammering-in of a wooden bung. Had a wooden bung indeed been fitted, it is unlikely to have seated securely in the rough opening and may well have been displaced by the seas repeatedly breaking over the poop deck.

Interior of SCR60 cabinet
Interior of SCR60 cabinet inemergency room contains transformer/rectifer units for 24 volt DC supplies and charger for emergency batteries. White circular fuses can be seen, centre, two amp fuses on left.

The normal design for such an access for shore cables incorporates a threaded end on the weather-deck side of the pipe and a screwed cap to fit, or a small door, fitted with a rubber seal and properly dogged. In either case, these would be fitted at a much greater height above the deck.

On the port side of the emergency generator room, the dog, with wing nut, securing the hinged storm plate covering the small ventilator grille to the emergency generator room was found to have been sheared off. This may have occurred at the time the vessel was pooped and would have allowed the storm plate to be forced open and admit water into the space in sufficient quantity to cause earthing problems in the emergency switch board. The Mate and the CIR were adamant that this storm plate was properly closed when they had checked around the decks on 7 March. If so, it is probable that something solid (the nearby fire hose box was demolished) struck the wing nut and bolt. Chipped paintwork on a small pipe just forward of the ventilator grille is further evidence of something solid having come into forceful contact with fittings in the area. In addition, the lower lug of the securing bracket on the storm plate was found to be bent inwards. Although this was not recorded in the deck defect book, it is possible that this deformity was not new and, therefore, the storm plate not properly secured. If so, the storm plate may have been sprung open by the force of the seas breaking on board, but that would not account for the dog being sheared off.

The evidence, provided by those interviewed, was that all ventilators were secured. However, in the various contemporary records some items relating to securing the vessel for heavy weather were obviously added at a later time. In addition, the engine room log for the morning of 9 March records “Steering gear vent shut - ingress of water”. This raises the question of whether the poopdeck ventilators were, in fact, closed before the onset of the severest weather and would account for the water “cascading”, as noted in evidence, rather than dripping onto the steering gear electrical panels.

It must also be considered, however, that, on the evidence of the engine room log book concerning the steering gear vents, the three ventilators (one mushroom type, fitted with a fire flap, and two of screw-down type) on the top of the emergency generator room may also not have been closed at the time.

Adjacent to the emergency generator room, and on the centreline of the vessel, is the aft hydraulic machinery room. This has an access door of the same design as that of the emergency generator room, and also leads from the poop deck. After access had been gained to the poop deck on the morning of 9 March, it was found that this door was open and the hydraulic machinery room was flooded to the depth of the door sill. Extensive damage had been caused to the motors which drive the hydraulic pumps. The door to the space had been closed when the poop was secured for heavy weather and had apparently, like the door to the forecastle, been forced open by the seas.

Although reportedly secured for heavy weather, it is evident that *Osco Star* was not, in fact, secured for tropical cyclone conditions. This factor was further compounded by the design of the vessel, in particular that of the bulwark enclosing the poop deck, the absence of an internal access to the emergency generator room, the means for securing doors and flaps and the entry for shore cables.

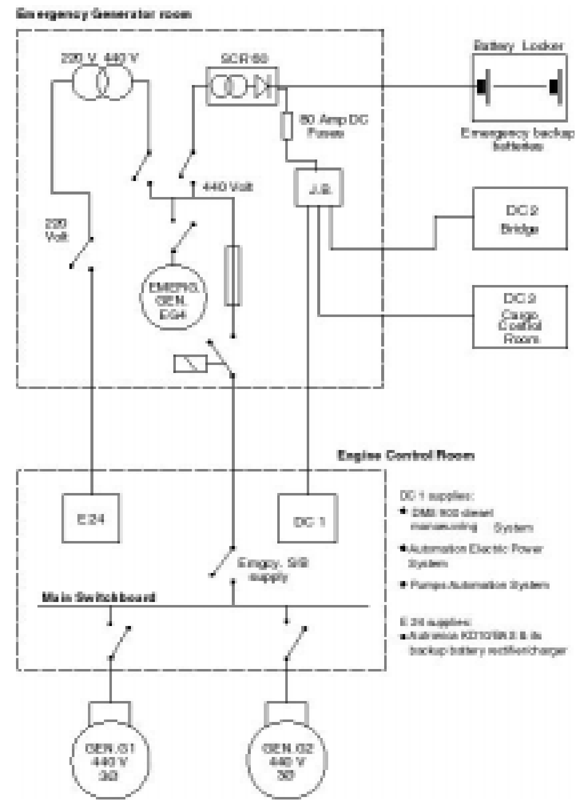
Electrical systems

Osco Star has a shaft generator and two main diesel generators (G1 and G2) which feed the main switchboard in the ECR at 440 volts, 3 phase. It also has an emergency generator (EG4) which feeds the emergency switchboard in the emergency generator room situated near the port quarter on the main deck level. The two switchboards are normally linked by a bus-tie circuit breaker, the emergency switchboard being supplied by the main generators via the main switchboard and the bus-tie breaker.

From the 440 volt sections of the switchboards, power is supplied by transformers to the ship's 220 volt systems. In addition, a 24 volt Automation Rectifier (SCR 60), situated in the emergency generator room and fed from the 440 volt section of the emergency switchboard, supplies 24 volt power to both the ship's 24 volt DC system and to the battery charger for the 24 volt back-up batteries which are located in a separate battery locker on the starboard side of the upper deck.

Failure of the SCR 60 Rectifier/charger unit will cause the 24 volt system to automatically draw its supply from the back-up batteries

(Refer to Annex 1.)



Osco Star - schematic circuit diagram

The Autronica alarm and monitoring system

This system provides constant monitoring of a large array of engine room parameters and provides audible and visual alarms should any of these parameters move outside pre-programmed limits. Instantaneous visual display of the value of any of these paramaters can be obtained on the visual display unit (VDU), in the engine control room, which will also automatically display any alarm which has put the system into alarm mode. Information from this system is printed out on a dot-matrix printer, also in the control room.

The messages displayed on the VDU normally include a ‘status’ code, the code number and description of an ‘alarm event’ and the date and time of that event.

The Autronica system is fed from the 220 volt three phase emergency switchboard via circuit breaker E24 to the automation distribution board E24/1 in the engine control room. One circuit breaker feeds the main system and a second feeds the battery charger for the Autronica’s back-up battery.

A failure of the 220 volt supply will affect the registering, and sounding, of engine room alarms and will also cause a failure of the bridge telegraph.

The Automation Electric Power System APM 101

Called the APM, the system monitors the two diesel generator sets (G1 and G2) at the forward end of the engine room. In addition to controlling automatic start-up sequencing of these units, it will automatically shut them down if they develop faults. This system requires a constant 24 volt supply but, although the loss of 24 volts will not immediately affect it, the design is such that restoration of the supply will cause a shut-down of the generators.

The Pumps Automation System

The Pumps Automation System provides automatic changeover of essential main engine pumps, from the ‘running’ to the ‘stand by’ pump, in the case of a fault in the running pump. It contains racks of relays which enable the pumps to be either automatically or manually switched.

The system requires three supplies:

- A 24 volt DC emergency power supply,provided from distribution board DC1
- Two AC supplies (transformed and rectified to two 12 volt DC supplies) fed from the individual pump motor starters.

All three of the above supplies are required for the system to automatically change over pumps when a drop in pressure is detected or when a running pump stops for any reason, such as overload.

This system will become progressively disabled if the voltage of the 24 volt system falls below a critical level for any reason.

The main engine control system

The main engine of *Osco Star* is controlled by a marine diesel manoeuvring system type DMS 900 manufactured by Søren T Lÿngso of Copenhagen, Denmark. The system facilitates control of main engine speed and reversal, either from the bridge or from the engine control room and consists of:

a) A main control cabinet

b) A main control panel, including the engine telegraph

c) An alarm and slow down cabinet

d) A safety cabinet

All of the above items, situated in the engine control room, are fed from the 24 volt DC distribution board DC1.

A critical part of the system relating to this incident is the ‘Safety solenoid’ which provides the means by which the main engine is instantaneously shut down if the safety system detects a “critical” fault, such as engine overspeed, no lubricating oil pressure, etc.

When a critical fault is detected by the safety system, a 24 volt DC signal is sent, from the safety cabinet in the engine control room, to the safety solenoid valve which, on becoming energised, opens and allows air, at 7 bar pressure from the safety air system, to the top of each of the main engine fuel pumps. Here, the air under pressure operates a piston valve in each fuel pump, which closes off a port thus cutting off the flow of fuel to the fuel valves on each unit.

Without a 24 volt DC supply, this solenoid cannot be energised and hence the system is unable to shut down the main engine.

Design of the safety solenoid actuating system

It may at first sight seem that the design is 'fail-unsafe' rather than 'fail-safe'. A basic principle is that a system should '*fail to safety*' or that a failure in the monitored system should result in *'the least critical of any possible new condition'.*

Safety systems are usually designed with '*normally open'* contacts in the sensor circuit and an abnormal condition of the engine will activate the safety sensor and the contact will close.

A wire-break (which is not an abnormal condition of the engine) will, of course not close the circuit and the safety system will not be activated; the engine will not stop. This principle of '*normally open'* contacts for safety systems is important, because vibration, for example, could cause the contacts to open and cause the engine to stop at a critical moment in terms of navigation. The least critical outcome of this possible new condition is that an alarm only should be activated – the safety system should '*fail to safety'*.

A problem with the design of the systems on Osco Star is that no alarm is provided to indicate a falling voltage of the 24 volt supply – a situation which will disarm the safety system, thereby no longer offering protection for the main engine.

Sequence of events in electrical systems – 9 March 1997

As a result of the flooding of the emergency generator room, instrumentation and control systems fed from the 220 volt side of the emergency switchboard were affected. Also the SCR 60 Rectifier/charger unit which provides a continuous 24 volt supply was rendered inoperative. Electrical circuits, critical for the protection of the main engine and auxilliary machinery, were automatically supplied from the 24 volt emergency battery supply. The failure of the 24 volt DC system affected the Autronica alarm and monitoring system, the automation electric power system, the pumps automation system and the main engine control system.

The print-out from the machinery alarm logger indicates the following:

0525	Alarm 11513	Low insulation resistance 220 volts
0543	Alarm 11512	Low insulation resistance 440 volts

0543	Alarm 19602	Failure of steering gear system
0607	Alarm 19602	Steering gear system normal
0620	Alarm 11514	Fault 24 volt DC power supply SCR 60
0839	Alarm 11108	Power failure to telegraph system

The following were not recorded by the alarm logger but are taken from information provided by the ship's staff:

At 0810 there had been a loss of the video display unit in the engine control room

At 0841 a blackout occurred with complete loss of electrical power

At 0843 the starboard diesel generator was started locally and power was restored.

At 0844 the port diesel generator was started locally

At 0845 the Autronica Central Computer system returned to normal, but there was no video display as the monitor was still defective. Alarms being activated by the Autronica system were not being sounded due to the loss of power from the 220 volt distribution system supplying the signalization (audible alarm) circuits.

It is evident that the first three alarms recorded above were due, at least in part, to the ingress of salt water to the steering gear flat through the mushroom vents as, when action was taken to cover the steering gear control panels with plastic sheeting, the 440 volt earthing problem was partially cured. Both the 440 and the 220 volt problems thereafter remained intermittent.

The fault on the Automation Rectifier (SCR 60) at 0620 would have caused the 24 volt system, at that time, to start to draw its supply from the emergency batteries and they would have commenced discharging, with no facility for recharge being available.

When, at around 0830, access was gained to the emergency generator room, the water under the switchboard was found to be causing several electrical problems including flickering of the “hand/auto” control indicating lights on the switchboard and sparking and smouldering on the lower terminal strips.

Subsequent investigation revealed that an intermittent loss of 220 volt, 3 phase, emergency power had been caused by one of the three phase terminals melting completely and another becoming loose. With the intermittent loss of 220 volt power on the distribution board E24 in the ECR, no audible alarms were able to be annunciated.

Part of the action taken by the ship’s engineers to rectify the problem with the 24 volt system included the removal, for testing, of the main and control fuses in the SCR 60 Automation Rectifier unit. This action, however, appears to have been carried out without any of those involved realising or considering the consequences of their removal. Removing these fuses resulted in the stopping of all pumps by the Pumps Automation System. Stopping of the pumps created various alarm conditions, which, although detected, could not be displayed or sounded due to the loss of the 220 volt supply to the Autronica alarm and monitoring system.

Removal of the fuses, although not immediately affecting running generators, initiates a “critical” alarm (one which would normally cause a shut-down of the machine). Upon replacing the 80 amp fuses, relays which had been “tripped” by removal of the fuses became active, causing the critical alarms to actuate and to shut-down the main generators, resulting in the blackout.

While the fuses were removed, there would have been no 24 volt supply to the safety solenoid valve on the main engine safety system and, even though the running lubricating oil pump had stopped and the ‘stand-by’ pump could not start, the main engine would have continued running, albeit possibly at reduced load due to loss of the fuel booster pump. The ETRS (see Annex 3) report found that a loss of lubricating oil to the thrust bearing, for a period of one minute, would probably have been sufficient to remove most, if not all, of the white metal from the thrust pads.

In all, six fuses were removed and tested, then replaced. Replacement of the fuses would have restored 24 volt power to the main engine safety system and the engine would have automatically stopped as the system would then have detected the lack of lubricating oil pressure.

Drop in battery voltage

The backup batteries for the 24 volt system are rated at 100 ampère-hours at 24 volts and hence, at their full discharge rate of 25 amps, they could be expected to last 4 hours. Tests carried out after the incident revealed that the batteries drop to the critical voltage level (at which contactors in the Pumps Automation System will drop out) after about four hours and forty minutes. However the following conditions would have influenced the load on the batteries and possibly have reduced the battery duration:

- An unusually high number of alarms
- The defective video monitor which overloaded the 24 volt DC to 220 volt AC inverter (both the inverter and the video display unit were later found to be defective).
- Salt water on the Automation Rectifier DC terminals, causing short circuits.

On gaining access to the emergency generator room the engineers had observed that the voltmeter on the front of the Automation Rectifier was indicating that there was voltage present but that the ammeter was indicating 0 amps. They appeared, however, to be unaware of the fact that this was indicating that the batteries had started to supply the 24 volt system and they were unaware of the consequences of the voltage eventually dropping to a critical level.

In spite of attempts by the ship's engineers to rectify the problem, the Automation Rectifier remained inoperative until the ship arrived at Moreton Bay where it was repaired by contractors. It was found that there had been ingress of water at the terminal strip on the 440 volt transformers and there were two broken wires on the 440 volt supply near the emergency switchboard.

The engineers were hampered in their attempts to carry out electrical repairs on that, and subsequent days, by the fact that the majority of electrical drawings available to them on board were only block and system diagrams (to explain the operation of systems) there being few circuit diagrams identifying actual electrical components.

Local control of the main engine

Following the blackout and the loss of the engine telegraph, engine control and some instrumentation in the control room, the Chief Engineer took control of the main engine from the emergency manoeuvring stand at the side of the engine at about 0925.

In this mode of control, the engine safety system provides the following protection for the main engine and, under normal operating circumstances, would stop the engine on any of the following:

- An overspeed signal from the safety tacho-generator
- Lubricating oil pressure low
- Camshaft lub oil pressure low
- Thrust bearing temperature high
- Shaft generator problem
- Emergency stop

Without sufficient voltage on the 24 volt DC system, however, none of the above alarms would have activated the safety solenoid, thereby stopping the main engine. By 1100 that morning, the batteries had been supplying the 24 volt system for four hours and forty minutes and the voltage had fallen to a level below that required to energise the solenoid.

When the engine is controlled from the emergency manoeuvring stand at the side of the engine, the governor is disengaged and the engine speed depends solely on the position of the fuel control lever as set by the watchkeeper. Under these circumstances, and in heavy weather with the ship pitching violently, it is very difficult to control the engine speed, particularly when the propeller is lifted out of the water and the engine is liable to race. On the morning of 9 March, with the engine being controlled in this manner, there was no overspeed protection for the engine. The rotational speeds attained by the engine throughout this period are not known but it is quite possible that the engine did overspeed, although it was stated that there had been no occasion on which this could have occurred.

A later examination of the engine-side control position showed that:

a) There was no local bourdon gauge to indicate main lub oil pressure.

b) The electric pressure sensor for main engine lub oil pressure was fed from the emergency 24 volt DC supply (which, before 1100 was becoming unreliable).

c) The local bourdon gauge which shows camshaft lubricating oil pressure was indicating 6 bar, when there was no pressure present in the system.

d) The thrust lub oil temperature gauge indicated 44°C when the engine was cold and the ambient engine room temperature was approximately 26°C.

With the failure of power supplies to instrumentation and the absence of a bourdon gauge to indicate the main engine lubricating oil pressure, the Chief Engineer at the side of the engine would have had no local indication of the oil pressure. Indication of other main engine parameters at the engine-side control position could, at best, be described as unreliable.

The losses of main engine lubricating oil pressure

It is evident that the engine was run without a supply of lubricating oil for two periods, the first before the blackout at 0841 and the second, before 1100 when it was noticed, in the control room, that there was no oil pressure. The running of the main engine without lub oil during these two periods initiated the failure of the thrust bearing and the ensuing damage to the rest of the engine.

At the time of the blackout at 0841, the main engine had been running at 80 to 85 RPM. The engine room alarm logger printout shows an alarm on channel 11108 “Power failure telegraph system” at 08.39.27. This is the first of a group of alarms recorded at that time, and was reported as having occurred at the time that the 80 amp fuses in the SCR 60 cabinet were removed. 24 V DC power would have been lost, on removal of the fuses, to the DMS 900 diesel manoeuvring system which, along with the Pumps Automation System, was supplied from DC1.

In submission, the ship managers stated that the fuses were removed for only 20 to 30 seconds before being replaced. However, a second group of alarms relating to the DMS 900 system appear on the printout at 08.41.11. Included in this group are:

12001	"Finished with M.E."	Norm.	08.41.11
12002	"M.E. in stop position"	Norm.	08.41.12
12007	"Start blocking indication"	Norm.	08.41.16

These appear to indicate that power was restored to the system at 08.41.11; by inference, the time at which the fuses were most probably replaced.

This being so, it is likely that lubicating oil pressure was lost for 1 min. 44 secs, with the engine running, until it was stopped by the safety system when the fuses were replaced.

Given the difficulties of working in the extreme weather conditions and the wet environment in the emergency generator room, the Inspector considers that 1 minute and 44 seconds is not an unlikely length of time for the two 80 amp fuses to have been removed, tested and replaced.

At 0925, when the engine was again running after the blackout, the Chief Engineer, concerned about the manoeuvrability of the vessel, brought the revolutions up to a similar speed as before (around 80 rpm). It was necessary to bring the revolutions up quickly through the critical range (65-77 RPM)[6] . The engine was running at this speed at around 1100, when it was noticed in the engine control room that there was no lubricating oil pressure on the main engine.

Unknown to the ship's engineers, the falling voltage of the back-up batteries had eventually reached a critical level where the control relay in the Pumps Automation System for the running main engine lubricating oil pump was unable to hold in. As the contactor dropped out, it stopped the running pump.

The battery voltage had also, by that time, dropped to the point where the contactor in the stand-by pump was unable to pull in and start that pump. At the same time, although the main engine safety system may have sent a

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[6] A speed range, usually specified by the engine-builders, within which the engine should not be run due to resonant vibrations being set up in the engine, shafting and propeller.

“shut down” signal to the safety solenoid (the safety system would also have been suffering from the low battery voltage) there was insufficient voltage remaining for the safety solenoid valve to open and hence the engine continued running without lubricating oil until manually stopped by the Chief Engineer.

Tests, carried out when the ship was in Brisbane, showed that the battery voltage has to drop below 3 volts DC for the control contactors to drop out and stop any pump running in the ‘automatic’ mode (the normal running mode). The same tests revealed that the contactors will not pull in below 11 volts DC (to start the stand-by pumps) and the safety solenoid would not operate, to shut down the main engine, below 10.97 volts DC. However, these were ‘bench’ tests and, with the vibration of the running main engine and the movement of the vessel in a cyclone, it could be expected that the contactor would drop out somewhat earlier, before the battery voltage had dropped so low.

When the Chief Engineer was at the engine-side control position and the 2nd Engineer came down from the engine control room shouting that there was no lubricating oil pressure, the Chief Engineer felt that the problem was not an actual loss of lubricating oil, but another problem with power supply to the gauges in the engine control room. He only stopped the engine when the 1st Engineer came down from the control room and, on his way to the lub oil pumps, also shouted to him that there was no lub oil pressure. After restarting the lubricating oil pumps, the 1st Engineer reported that the discharge pressure was 2 bar. The Chief Engineer, having by now stopped the engine, understood this to mean that there was still 2 bar pressure on the system and appears to have been unaware at the time that the 1st Engineer had restarted a pump. The Chief Engineer further convinced himself that the oil pressure had been normal by checking the piston cooling oil sight glasses, on the opposite side of the engine, for oil flow and the oil temperature and found these to be satisfactory.

It was not possible to establish the exact length of time the engine had been running without lub oil on this occasion before the loss of pressure was noticed by the 1st Engineer. To obtain the total time for which the engine was without lubricating oil, this time needs to be added to that taken for the 2nd Engineer to leave the control room, to reach the local control position, to discuss the apparent loss of pressure with the Chief Engineer (during which there appears to have been some confusion), to return to the control room and then for the 1st Engineer to run down to the lubricating oil pumps and to start one in ‘local’ control.

Evidence received indicated that the main engine lubricating oil pump had been the first to stop and, at that time, all other main engine pumps remained running. However, evidence was also received to the effect that some other pumps had also stopped. There were, at that time, already intermittent problems with those gauges which depended on the 24 volt system. What does appear certain, however, is that by the time the engineers were ready to restart the main engine at 1200, all pumps had stopped and had to be restarted in 'local' control, i.e. at the starter near each pump, from where there is no dependence on the relays in the Pumps Automation System.

At 1248, the engine was again stopped to undertake a crankcase inspection but, because of the sea conditions and the hot and slippery nature of the crankcase, an internal inspection could not safely be undertaken. Looking through the crankcase doors, however, no obvious damage could be seen.

It was stated quite categorically by some, in giving evidence to the investigation, that there were only two main engine stops; that following the blackout at about 0841 and then the one at 1100 following loss of lub oil pressure. It was further stated that the crankcase inspection was carried out immediately after the latter, and before the vessel again got under way at about 1200. Evidence received was conflicting and contradictory, but there are two entries in the bridge log book relating to events after the blackout, one recording the stop at 1100 in the handwriting of the 0800 - 1200 watchkeeper, the 3rd Mate, and another recording a planned stop at 1248 for a crankcase inspection, getting under way again at 1402. This latter entry was recorded by the 1200 - 1600 watchkeeper, the 2nd Mate.

There is no written record of times of significant events in the engine room. The 3rd Engineer was directed to maintain a diary, but this record was reported as "lost", following Osco Star's return to Brisbane.

There is little doubt that there were three stops in all, one after the blackout at 0841, one at 1100 following the loss of lubricating oil pressure and a planned stop at 1248 for the crankcase inspection.

Damage to main engine

The loss of lubricating oil to the thrust bearing resulted in damage to the thrust bearing itself and, subsequently, severe damage to the rest of the engine. This damage became evident by the volume of debris collected in the lubricating oil strainers.

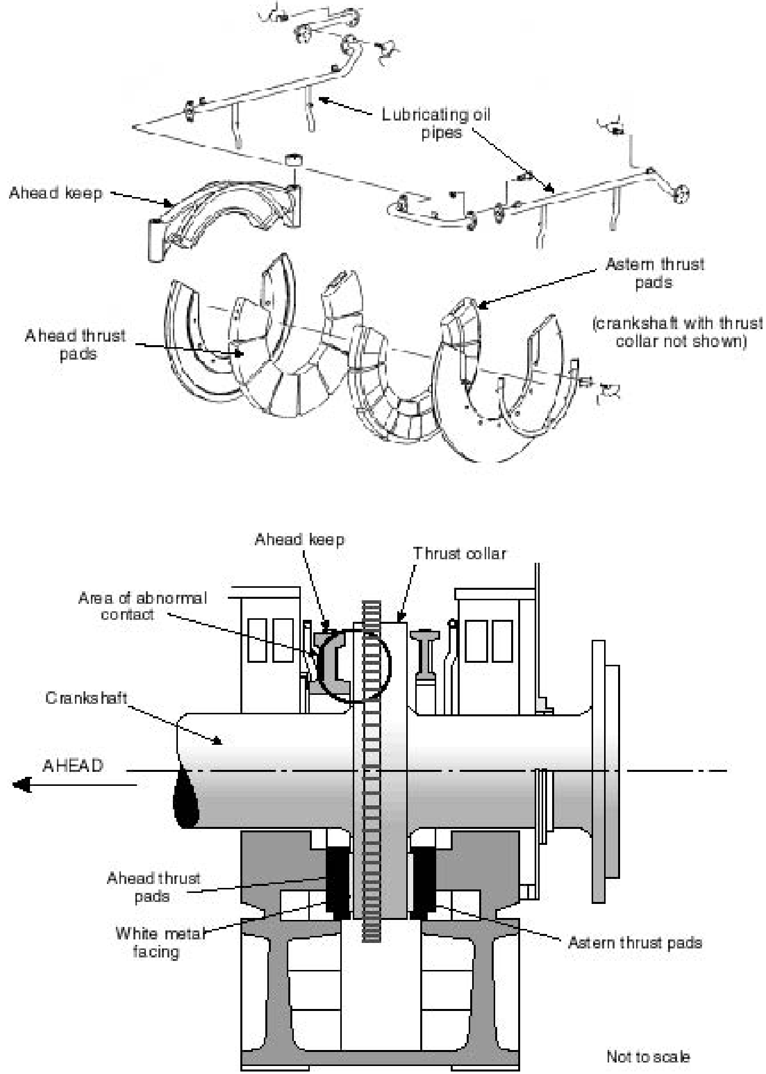
The thrust bearing

The main engine of *Osco Star* is a large, five cylinder, 600 mm bore, slow speed, direct reversing, single-acting two stroke diesel engine with direct drive to a single propeller.

Propeller thrust is borne by an integral thrust bearing, situated at the aftermost part of the engine bedplate, just aft of no. 5 unit. Within the thrust bearing, a collar on the crankshaft transfers the propeller thrust through sets of tilting pads to the ships structure. This type of thrust bearing relies on the formation of a thin film of oil between the appropriate (ahead or astern) set of thrust pads and the thrust collar which forms an integral part of the crankshaft.

In order to maintain an oil film between the thrust collar and the pads, a constant supply of lubricating oil is vital.

(See Annex 2)



Osco Star - thrust bearing block

Main engine damage

A consulting firm specialising in engineering testing and analysis, ETRS, was contracted by ASP Ship Management to investigate the causes of the damage to the main engine which occurred during this incident. Part of their report is reproduced at Annex 3.

The predominant feature of the mechanical damage to the main engine was the severe damage to, and dislodgement of, the ahead thrust bearing pads and their keep.

The failure of the keep and the eventual dislodgement of the thrust pads allowed the crankshaft to move forward at least
30 mm under load, causing extensive damage to all main bearings, crankshaft webs and journals, connecting rods, crossheads and their respective bearings. The axial vibration damper at the forward end of the crankshaft was also damaged by this large forward displacement of the crankshaft. All these components, forward of the thrust bearing, were not designed to resist axial propeller thrust and would have been progressively damaged after the thrust bearing failure had been initiated and while the engine was still running at relatively high engine speed and load. Further, but less severe, damage may have occurred as the ship returned to Brisbane at lower engine speeds and load.

Debris in lubricating oil strainers

By about 2130 on 9 March, a large quantity of debris was being carried from the main engine sump to the lubricating oil strainers by the flow of oil. As the strainers were cleaned, the growing heap of debris removed was collected on a piece of hessian on the engine room floor plates.

Examination of the debris when the vessel arrived in Brisbane showed:

- a large quantity of finely divided particles, including white metal, steel and paint particles
- several large solidified lumps of molten white metal (from the thrust pads)
- pieces of brass shim
- numerous distorted steel nut-locking plates
- one long steel bar from a crosshead guide
- one smaller steel block, also from a crosshead guide
- numerous fragments of fractured bolts or studs, some with nuts in place, all of about 20 mm in diameter

Thrust pad keeper

Ahead thrust pad keeper (Starboard aft face)
Note deep grooves worn by timing chain.

Thrust pads

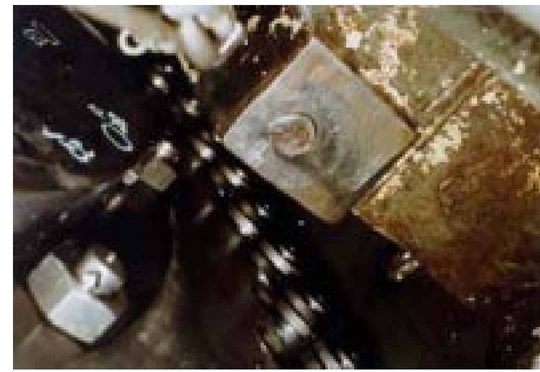
The eight tilting ahead thrust pads from the main engine. An unworn pad (centre) shows pivot axis on back face.

Thrust collar

Fractured lower threaded end of starboard keeper stud in bedplate.
Note timing chain and 'ahead' face of thrust collar.

Thrust pads

Ahead thrust bearing pads nos. 3 &4. Pad no.3 has been worn to a flat taper on the inner edge of its thrust face. Heat discolouration of paint can be seen on the outer periphery.



Main engine debris

Debris recovered from main lubricating oil strainers and crankcase.

Thrust collar

Damage to the 'ahead' face of the thrust collar on the crankshaft.

Analysis by ETRS

Since damage that ensued to the rest of the engine was as a direct result of the forward movement of the crankshaft once the ahead thrust pads had been ejected from the thrust bearing, the ETRS analysis concentrated on the failure of this bearing.

Having been retrieved from the crankcase at Brisbane, the ahead thrust pads were examined by ETRS and compared with pads supplied to the vessel as spares. Damage to the thrust pad keep was also examined and analysed. The results of the analysis are reproduced at Annex 3.

The ETRS report states that any direct metal-to-metal contact between the thrust collar and the pads would have been sufficient to cause surface damage to the soft metal on these pads in a very short time, perhaps as little as one revolution. Once such initial contact had occurred and caused surface damage to the soft metal faces of the ahead thrust pads the effective lubricating oil film between the moving surfaces would have been disturbed and probably lost altogether in the narrow edge of the oil wedge.

Once the soft white metal has been damaged in that ‘thin edge’ region, more rapid and severe surface damage will be promoted and then extend rapidly across the face of the thrust pad. From that time onwards, uniform concentric wear of the thrust pads would have proceeded and accelerated rapidly, even though the normal oil supply was re-established and maintained throughout later periods of engine operation.

Timing of thrust bearing damage

Oil supply to a bearing of this type must be continuous, as there is a centrifugal effect tending to strip the bearing of its oil while the shaft is rotating. The ETRS report concludes that a one minute period of operation under load, without a supply of oil, would probably be sufficient to remove most, if not all, of the white metal from the pads.

According to the analysis by the consultants, damage to the thrust bearing developed in three stages. The first of these was damage to the surface finish of the white metal facings of the tilting pads, the second, the removal of white metal and the third, the wearing of the underlying base metal once the white metal had been worn through.

The ETRS analysis concludes that the main engine stopped at the time of the blackout at 0841, hence it was unlikely that any damage would have been initiated at that time. However, as has been noted, the evidence indicates that, although the engine stopped at the time of the blackout, it was running for a period of nearly two minutes while the fuses were removed and lub oil pumps stopped.

It appears that the first stage of damage may have occurred at this time. If there was any white metal remaining on the pads by 1100 that morning, the second failure of the lubricating oil supply would have contributed to its complete removal and, once that had occurred, the crankshaft would have moved forward by approximately 12 mm. This may have caused the noises at the forward end of the engine, in the vicinity of the axial vibration damper, which were heard by the Chief Engineer as the engine was stopping at 1100. Wear of the base metal of the pads would have progressed rapidly over the next 24 hour period until the 10 mm clearance (in the original assembly) between the thrust collar and the face of the keep was taken up. The load from thrust collar would then have eventually caused the keep securing studs to fail and the thrust pads to be ejected, allowing the crankshaft to move further forward until it had achieved a total displacement of approximately 30 mm.

At 2230 on 9 March an engine room log entry states *"increased engine knocking and vibration"* and engine speed was reduced. This was one hour after white metal had been detected in the main engine lub oil strainers.

A large displacement of the crankshaft was observed within the first 24 hours after the failure of the lubricating oil supply, thus indicating a time frame within which ejection of the thrust pads must have occurred. The exact time cannot be ascertained, but is likely to have been before 1700 on 10 March when the engine log states, in the space for 'Thrust bearing temperature', *"Remote probe failed".*

The ETRS report, at Annex 3, includes information on the theoretical performance analysis of the thrust bearing capacity, based on Engineering Sciences Data Item 83004 – *Calculation methods for steadily loaded, off-set pivot, tilting-pad thrust bearings* (March 1983 issue). In the weather conditions prevailing on the morning of 9 March, however, it is most unlikely that the loading on the bearing was steady. The seas which pooped the vessel on numerous occasions that morning would, in all probability, have caused a slamming load on the propeller which, being transmitted to the thrust bearing, would have contributed to a rapid initiation of white metal failure in the absence of a plentiful supply of lubricating oil.

No records of survey, inspections or maintenance carried out previously on the thrust bearing of Osco Star were available to the investigation.

Risk of crankcase explosion

Chapter II-1, part E, of the International Convention for the Safety of Life at Sea, 1974 and its Protocol of 1978 includes, under Regulation 47:

2. Internal combustion engines of 2,250 kW and above or having cylinders of more than 300 mm bore shall be provided with crankcase oil mist detectors or engine bearing temperature monitors or equivalent devices.

The main engine of *Osco Star* is not fitted with a crankcase oil mist detector but it is fitted with temperature probes at the bearings, connected to the alarm and monitoring system and, as such, complies with the requirement. However, with the failure of the temperature probe on the damaged thrust bearing, the system would not have given warning of conditions conducive to a crankcase explosion in that area. Heat damage to components of the thrust bearing and the bedplate, as seen when the engine was inspected at Brisbane, indicate that such conditions existed, and it may be considered very fortunate that no serious explosion occurred.

Notwithstanding the above, however, it appears that there may have been a minor explosion in the casing for the forward moment compensator chain drive, when the Chief Engineer heard a “rumble” and observed smoke issuing from the seal around the chain tensioner, both of which caused him concern.

As damage progressed to components of the engine forward of the thrust bearing, it is likely that other points could also have provided sources of ignition, such as the contact which occurred between the crank webs and the connecting rods at each revolution. These also would not have been detected by a rise in bearing temperature. Only a crankcase oil mist detector would indicate a hazardous atmosphere within the crankcase which could be ignited by any of these potential sources of ignition.

Personnel

The Master is an experienced seaman, with many years in command and widely experienced in passages through the Coral Sea.

The Mate was on his first voyage as Mate, and on *Osco Star*. In view of this, the Master elected to follow his normal routine of standing the Mate's 4 - 8 watch and allow the Mate to concentrate on his other responsibilities.

The 2nd Mate was also widely experienced and prior to joining ASP in early 1995, he had been in command of overseas flag vessels. He had been 2nd Mate of *Osco Star* since August 1995.

The 3rd Mate had been 3rd Mate since October 1995 when he was appointed to *Osco Star* and had served on the vessel since that time on a regular swing basis.

The Chief Engineer, although he had been many years at sea in tankers, had joined *Osco Star* only 5 weeks before the incident and it was his first voyage on the vessel. He had therefore had comparatively little time to become familiar with the electrical systems and their peculiarities.

It was also the 3rd Engineer's first voyage on *Osco Star*, having joined from "the Roster"[7]. He had been back in the maritime industry for a little over three years after about twenty years ashore. In view of his lack of experience compared with that of the 1st and 2nd Engineers and his short time on the vessel, he was unable to contribute to the efforts of the other engineers in sorting out the various problems and left it to them. He was asked by the Chief Engineer to keep a record of events and log the times of these events but the record was lost, possibly when his overalls became soaked while he was working in the forecastle two days later.

As a consequence of government and industry policies formulated through the Maritime Industry Development Committee and associated tax and financial benefits, Osco Star, in common with most vessels under the Australian flag, carries no Electrician. The sophistication of marine electrical generation, control and monitoring systems has been increasing steadily over the years, but there has been no corresponding review of the skills, or distribution of human resources, required to safely operate such systems. In the opinion of the Inspector, an electrician would have provided the valuable experience necessary to have quickly identified and solved the problems with the 220 volt system and with the 24 volt rectifier/charger unit, thus restoring power to these systems. At the same time, this would have allowed the engineers to devote their attention to the many other problems caused by the cyclone.

Conclusions

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

The following factors are considered to have contributed to *Osco Star* sustaining considerable damage during tropical cyclone Justin:

1. Timely action was not taken to avoid an encounter with the tropical cyclone.
2. A proper appraisal of the possible movement of the cyclone was not made, and no account taken of the steady fall in barometric pressure and lack of wind directional shift, which resulted in *Osco Star* passing close to the centre of the cyclone.
3. There was no full exchange of views, in line with Bridge Resource Management procedures, on the developing situation and the appropriate action to be taken.
4. Reliance was placed upon the wind conditions being experienced beyond the immediate area of effect of the cyclone, rather than on the Bureau of Meteorology's predicted wind strengths.
5. The poop and boat decks were not properly secured against the ingress of water into the steering flat and the emergency generator room, which occurred during the cyclone and which initiated the events which led to electrical, and subsequent mechanical, damage.
6. The design of the bulwark around the poop deck prevented the rapid freeing of water trapped in that area and probably contributed to its ingress into the emergency generator room.
7. The design of the weathertight, rather than watertight, doors and flaps and the poor design of the access to the emergency generator room for electrical shore connections, contributed to water gaining access to those spaces which open onto the poop deck.

8. The design of the ship's 24 volt system and associated alarms was such that the battery voltage was able to drop to a critical point where the engine safety system was disabled, without the ship's engineers becoming aware of the situation.

9. The ship's staff appeared unaware of the fact that;

- Removal of the fuses in the 24 volt rectifier/charger unit would stop all running pumps including that for main engine lubrication.

- The main engine would not stop while the fuses were out.

- After failure of the 24 volt rectifier/charger unit, the system was running on the back-up batteries and they seemed unaware of the consequences of the discharge of these batteries.

10. The loss of voltage from the back-up batteries, as they discharged, caused contactors in the Pumps Automation System to drop out and the running lubricating oil pump for the main engine to stop.

11. The main engine ran without lubricating oil on two occasions, firstly while work was being carried out on the 24 volt rectifier/charger unit and, secondly, after the main lubricating oil pump stopped at about 1100. The first of these occasions probably initiated damage to the white metal of the ahead pads in the thrust bearing.

12. Severe damage to the main engine was caused by the engine continuing to run after the failure of the thrust bearing and the consequent forward displacement of the crankshaft.

13. The lack of a person with the requisite electrical skills, training and experience within the ship's complement contributed to the inability by the ship's engineers to rapidly locate and rectify problems in the 220 volt and 24 volt systems.

It is further considered that:

14. At no stage before the vessel arrived back in Brisbane was the nature, extent or severity of the damage to the main engine determined and, without an oil mist detector, there was considerable risk of a crankcase explosion.

15. The principles of Resource Management are taught in terms of bridge operation. However, application of these principles to the engine room would have assisted in the management and decision-making process relating to machinery operation.

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 was sent to the following:

The Master, Chief Engineer, 2nd Mate, 3rd Mate, Chief I.R. of *"Osco Star"*

ASP Ship Management

Shell Company of Australia

A submission was received only from the Managing Director & Chief Executive of ASP Ship Management. The text of the report has been amended in places where appropriate. The submission is reproduced below:

Page 2 Summary

The reference to "fuses had been replaced about two minutes later" is not correct. The Chief Engineer removed the fuses to check they were not "blown". To remove, check and replace took only 20 to 30 seconds not two minutes. There are several references to "two minutes" throughout the report, which require amending.

Page 8 Paragraph 5 (see also Page 27 Lines 1 & 2)

We question the conclusion that "these actions cured the 440 volt earth fault". We believe that the first three alarms were associated with water ingress into the emergency generator switchboard room. You will have noted that the starter of the Port Steering Gear Motor was subsequently tested by our electrical superintendent, these tests did not reveal any evidence of water ingress at the starter and megger tests *proved there were no earth faults.*

The Port Steering Gear Motor, which was running at the time, is fed from the emergency switchboard and we believe that the water in that space activated the 440V earth alarm. The "curing" of the 440V earth by the use of plastic sheeting was in our opinion a coincidence.

Page 9 First Engine Stop (First line)

"Opening the door of the EMERGENCY generator room.

Page 10 (Second line)

"fluid in"

Page 14 Paragraph three

The "VDU remained inoperative" not "in spite of the re-supply of power" but because the VDU was supplied from the 24VDC to 22VAC inverter which was not restored.

Page 15 Final paragraph

"all of the above engine components" were not renewed. eg. only one connecting rod was renewed, the rest were re-conditioned.

Page 19 Onboard Management Procedures

ASP Ship Management was one of the first companies in Australia to champion the introduction of Bridge Resource Management training. To date, ASP have had more staff attend the courses run by the Marine Consulting Group than any other organisation in Australia. ASP recognises that attendance at such courses is only a first step in achieving what is a cultural shift of attitude and to this end support the current initiative to ensure that the principles taught are being utilised. ASP have a team of Fleet Training Officers who include assesement of the use of the principles of BRM in the regular onboard second – party audit programme. ASP intend that engineer officers participate in future Resource Management programmes of this type.

Page 20 "Water ingress…."

There are <u>six</u> possible points of entry, the one not mentioned is the ventilation grille above the engine cooling air intake.

Page 24 First paragraph

The statement, "A failure of the 220 volt supply will affect…..the VDU display….and the alarm printer" is not correct. The VDU and the printer are supplied from the 24VDC to 220VAC inverter, and are not directly affected by an interruption to the 220 VAC supply.

Page 26 Sequence of events (First paragraph fourth line)

"Electrical circuits, critical for the protection of the main engine and auxiliary machinery, were automatically <u>supplied from</u> the 24 V emergency battery supply.

Page 27 First paragraph

See earlier remarks regarding Page 8 Paragraph 5

Page 27. Second paragraph

There is no "switch " per se, the fault on SRC 60 caused the supply to be automatically provided by the batteries.

Page 27 Paragraph seven

As mentioned previously we believe the fuses were removed only for a period of 20 – 30 seconds.

Page 29 Paragraph four

We consider it extremely unlikely that the engine did not overspeed on any occasion.

Page 30 L.O Pressure (Paragraph two)

The time the fuses were out was only 20-30 seconds.

Details of Osco Star

IMO No.	8617017
Flag	Australian
Classification Society	Det Norske Veritas
Ship type	Tanker
Owner	K/S UL *Osco Star* (Kopenhagen) Denmark
Demise Charterer	Shell Company of Australia Ltd
Managers	ASP Ship Management
Year of build	1989
Builder	R.O. Brodogradiliste " Uljanik" Pula, Croatia
Gross tonnage	22,572
Net tonnage	13,055
Summer deadweight	40,541 tonnes
Length overall	176 m
Beam	32 m
Draught (summer)	11.215 m
Engine	5 cylinder B&W 5L60MC
Engine power	6880kW
Crew	18 (Australian)

Samples of previous cyclone tracks

Code name or number

1	Mar. 23-31 1933
Gertie	Mar. 14-18 1964
Elaine	Mar. 13-19 1967
Dulcie	Mar. 13-17 1967
Glenda	Feb. 18-22 1968

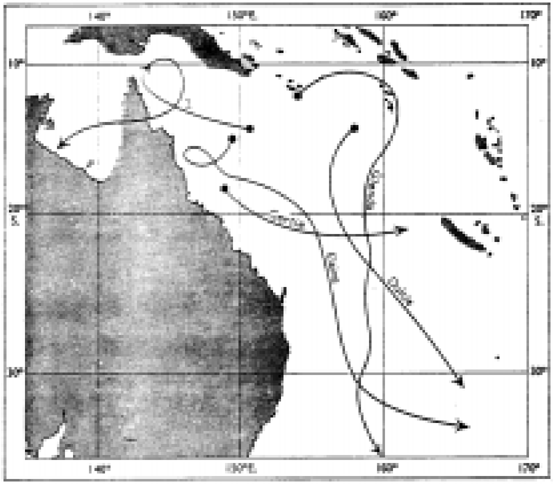


Diagram 5. Tropical Cyclone Tracks. February—March.

Code name or number

VIII	Mar. 23-29 1923
13	Mar. 30-Apr. 6 1962
15	Apr. 20-26 1963
16	May 2-9 1963
Henrietta	Mar. 29-Apr. 10 1963
Douglas Mervin	Mar. 30-Apr. 3 1933

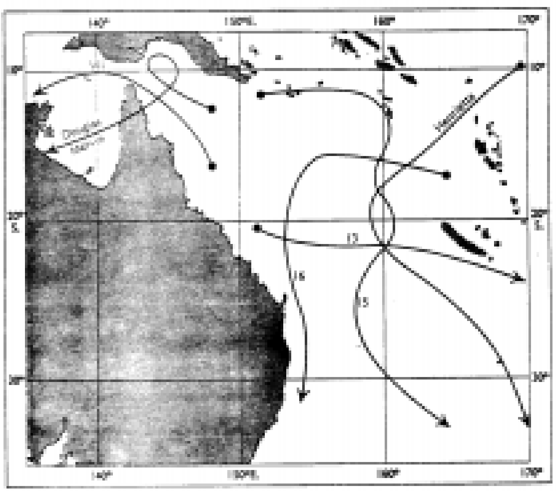
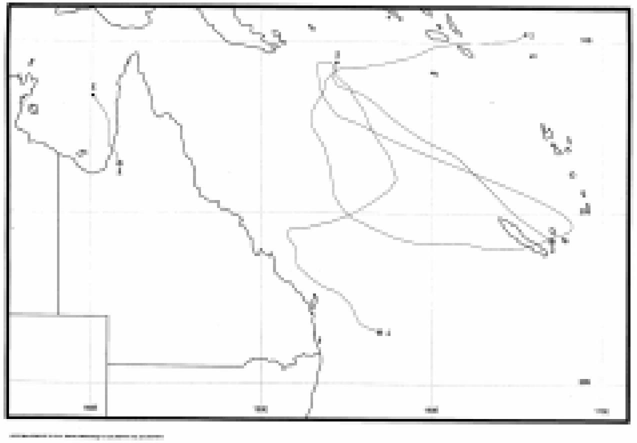
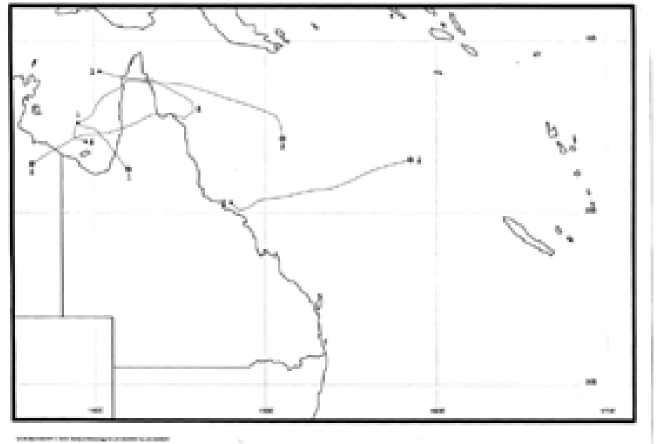


Diagram 16. Tropical Cyclone Tracks. March—May.

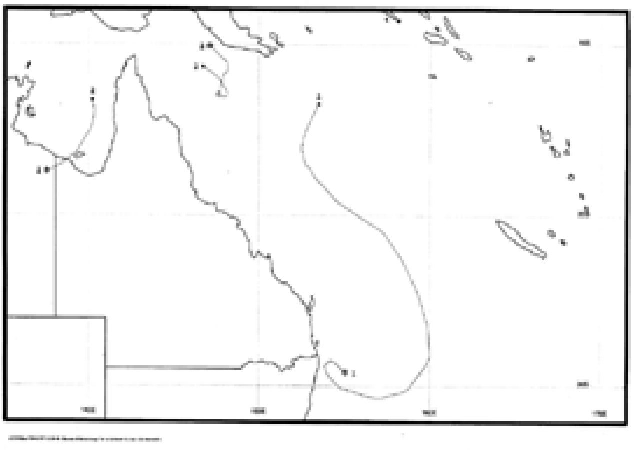
Australian Pilot Volume 111



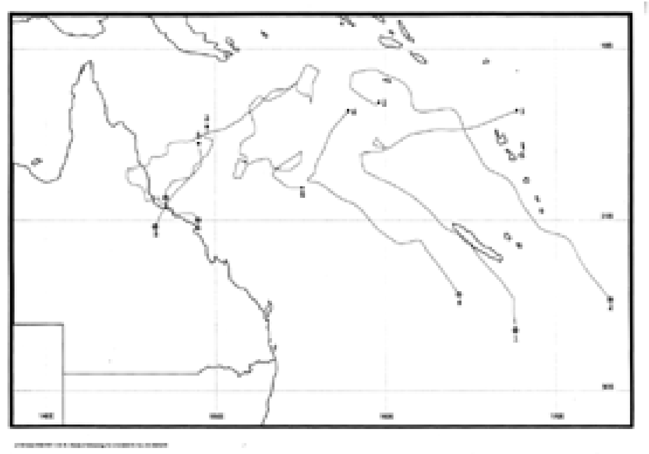
1993/94



1995/96



1994/95



1996/97

Bureau of Meterology

Electrical systems

220 volt

440/220 volt transformers feed a 220 volt bus in the emergency switchboard. The 220 volt bus supplies the vessel's 220 volt systems including a 220 volt distribution board, E24, in the Engine Control Room.

The distribution board E24, situated at the rear of the main machinery control console, supplies 220 volt power to, amongst other things, the following:

- The Autronica alarm cabinet for engine room alarms
- The rectifier for the above alarm system
- The Autronica central alarm printer
- A common engine room signalling (audible alarm) system
- The main engine telegraph system

24 volt DC system

The 440 volt bus in the emergency switchboard supplies power to an Automation Rectifier (SCR 60), also located in the emergency generator room. The output from the Automation Rectifier is connected, via two 80 amp fuses, to a junction box which feeds three distribution boards:

- DC1 in the engine control room
- DC2 on the bridge
- DC3 in the cargo control room

(DC2 and DC3 are not relevant to this incident.)

DC1 is situated at the rear of the main engine control console in the engine control room and supplies 24 volt DC power to, amongst other things:

- The Automation Electric Power system APM 101, which controls the ship's two main diesel generators.
- The emergency power supply to the Pumps Automation System
- The bridge control system for the main engine
- The main engine safety system
- The engine room signalling (audible alarm) system
- The manoeuvring stand signals

The Michell thrust bearing

The thrust bearing of Osco Star is of the Michell type, incorporating two sets of eight tilting pads, one set for ahead thrust and the other for astern thrust. This type of thrust bearing relies on the formation of a thin film of oil between the appropriate (ahead or astern) set of eight thrust pads and a large thrust collar which forms an integral part of the crankshaft.

When running, the faces of the pads and the thrust surface of the collar never come into contact with each other, being kept apart by the automatically generated tapered oil film formed with oil from the engine's main lubricating system. In this type of bearing, there is usually no metallic friction, no wear and renewal of parts is not necessary so long as clean oil is supplied in sufficient volume to carry the load. The pressure formed in the oil film, or wedge of oil, is generated by the rotation of the collar and is not dependant on the actual pressure at which oil is supplied by the system. The pads are so designed that they tilt and float on their own oil film.

As the collar revolves in the flood of oil supplied from the system, the oil adhering to its surface is carried around and lifts the leading edge of each pad to admit the tapered oil film, thus at each pad there is generated a tapered pressure oil film of thickness appropriate to the load, the speed and the viscosity of the oil. For maximum efficiency, the pivot on the rear of the pads is offset from the circumferential width of the pad and this off-set is right-handed or left-handed to suit ahead or astern running.

Extracts from the ETRS Report

Ahead thrust bearing examination

Each of the eight ahead thrust pads carried an identifying mark hard stamped on its outer periphery, thus : 281.1.P; 281.2.P; 281.3.P; …..281.8.P. These pads will be referred to as pad no. 1, no. 2, …..no. 8 respectively.

Pad no. 1 contained three radial holes, drilled and partly tapped to accommodate threaded connectors for three temperature probes. Pad no. 1 would have been the topmost pad on the port side in the assembled thrust bearing. The other seven pads are assumed to have been placed in the bearing in the above numerical sequence, proceeding anti-clockwise as veiwed from astern, looking forward.

Localised, uneven wear was present on different edges of pad nos. 1, 3, 7 and 8, but the remainder of the thrust faces on those pads and the thrust faces of the other four pads (nos. 2, 4, 5, and 6) showed a uniform concentric wear pattern.

Cream coloured paint was present on the four narrow edges of all eight pads. This paint was heat-discoloured adjacent to the rubbing face on each pad and the discolouration was concentrated towards the outer periphery of the assembly.

Thickness of these eight pads had been reduced at their outer periphery by at least 8 mm on the ‘leading’ edge and by about 12 mm on the ‘trailing’ edge. The pattern of the thickness variation is consistent on all eight pads and indicates that those pads had been tilted (as in normal operation) and had been worn flat in that tilted position, producing a ‘wedge-shaped’ pad profile.

This concentric wear reduced the original pad thicknesses of all pads in that bearing by similar amounts, thus allowing the crankshaft to be displaced axially in the forward direction under load by about 12 mm.

The concentric wear on the thrust faces of all eight pads indicates that all eight pads remained in their normal positions while that concentric wear was occurring.

The uneven, localised wear regions on pads No. 1, 3, 7, and 8 could not have occurred while those pads were in position beneath their keeper.

Ahead bearing keeper damage

Aft surfaces

There is clear evidence of almost uniform rotating contact between the crankshaft thrust collar and the curved ribs standing out on the after side of the ahead thrust bearing keeper.

A very deep gouge pattern angled across the starboard side of the aft face of the keeper and had a stepped profile, consistent with one side of the cross section of a large roller chain in the timing mechanism. This pattern indicated that there had been fairly steady contact between the keeper and that timing chain while the chain was moving. Such contact requires the keeper to have been dislodged from its normal position.

Fragments had been fractured from the bottom edges of the keeper on both sides, removing part of each of the stud holes above the mounting faces of the keeper. The removed fragments came from the port side of each stud hole.

Sloping pad contact faces

Burnished witness marks along the forward edges of these two sloping faces were consistent with contact between the 'horseshoe' shaped pad supporting plate and the keeper in their normal relative positions.

Well defined and almost rectangular witness marks along the after edges of both of these sloping contact faces were also consistent with contact between the thrust pads and the keeper while they were in their normal relative positions.

A third witness mark (on the sloping starboard keeper face only) had a similar shape to the last mentioned marks, but was displaced forward by up to 50 mm from it and at an angle of about 10° to it. Several impressions were evident within this mark, which could not have been made if the pad and keeper were in their normal relative positions. This mark may indicate either forward displacement and tilting of one of the thrust pads (relative to the keeper) or rearward displacement and tilting of the keeper (relative to the thrust pad) on the starboard side.

Keeper joint plane

The machined horizontal joint (or seating) face on the starboard side of the keeper shows strong evidence of multiple hammering impacts at different angles against the mating seat face of the bedplate. The corresponding horizontal seating face on the port side shows less evidence of this type of hammering distortion but has one flat region, suggesting one impact against a flat surface.

Keeper stud holes

The upper ends of the stud holes on both sides of the keeper were worn to a short taper. The form of the tapered region on the starboard stud hole generally matches the form of the damaged lower threads at the top end of the fractured starboard stud and indicates that mutual rubbing contact between these components probably generated the taper in that stud hole.

Keeper Stud damage

Starboard stud

The starboard keeper stud had fractured at the top of the lower threaded portion. The fracture had originated by fatigue in two adjacent thread roots at the upper end of the lower threaded section. That fracture was located at about the level of the joint plane between the keeper and bedplate.

Fatigue crack growth had proceeded for about 2 mm radially on one side of the stud and about 5 mm radially on the opposite side before the remaining core of the stud failed catastrophically. From the position of the threaded fragment of this stud that remained in the bedplate, the deeper portion of the fatigue crack appears to have been at the aft side of this stud.

The crests of the lower three threads on the upper threaded section of this fractured stud and the two remaining upper threads on the lower threaded section (just above the fracture plane) were all reduced progressively in height (forming a taper) and polished by moving contact with the stud hole in the keeper.

Port Stud

The port keeper stud (which remained intact in the bedplate) contained a compound bend. Above the bedplate surface the stud was deflected towards the starboard side and about 100 mm above the seating face a reversed bending had occurred to reduce that deflection and bring the upper portion of the stud closer to the vertical.

A broad bruise mark was present on the starboard side of the stud, just above the bedplate and extended for about 70-80 mm up that side of the stud.

Keeper retaining nut damage

The two keeper retaining nuts (one from each of the two keeper studs) were retrieved but the original locations of these two nuts were not identified. The nuts were labelled ‘A’ and ‘B’ for identification.

Nut A

The lower two threads of this nut had been stripped completely, leaving their smeared remains projecting slightly from the base of the nut and the nut had been splayed to a larger diameter at its lower (seating) end. The lower (seating) face of this nut was deformed to a convex profile and numerous small indentations were present in this convex seating face.

Nut B

The thread of this nut is undamaged and the lower side of the nut showed none of the splaying or lower face distortion present on nut A.

The nut had a pair of deep impressions, one on its upper and one on its lower surface. These impressions are located one above the other and were consistent with this nut having been trapped and heavily compressed once only between two metal objects. Partial replicas of the trapping surfaces of these objects remain in these two impressions but the trapping objects were not able to be specifically identified. These objects appear to have extended over the threaded hole in the nut during the trapping and compressing incident.

Although it was reported that this nut was originally found attached to the starboard stud, this is not consistent with the form of the above heavy impressions and the apparent extent of the objects which produced them.

Keeper seat faces on bedplate

On the two machined pads of the bedplate which support the keeper, more hammering impacts damage was evident on the starboard pad than on the port pad.

The smaller of the two fragments of the fractured starboard keeper stud (containing the lower threaded portion of that stud) was retained in the starboard pad on the bedplate.

Thrust bearing design review

Propeller shaft maximum thrust

Maximum thrust produced by the propeller shaft is calculated from the following Measured Mile Data:

Engine power = 6880 kW recorded at a *Measured ship speed = 14.28 knots*

using the established relationship

$$\textbf{Thrust (kN)} = \frac{\textit{Power (kW)}}{\textit{Velocity (m/sec)}}$$

Assuming *1 International nautical mile = 1852 metres*, this formula becomes

$$\textbf{Thrust} = \frac{6880\,kW}{14.28 \text{ knots} \times \dfrac{1852\ metres}{3600\ seconds}}$$

This is equivalent to a thrust load of 95.5 tonnes

Bearing performance analysis

Theoretical performance analysis of the thrust bearing capacity is based on Engineering Sciences Data Item No. 83004, *Calculation methods for steadily loaded, off-set pivot, tilting-pad thrust bearings* (March 1983 Issue) published by Engineering Sciences Data Unit. Using that reference, and the dimensions and data listed in Table 1, Appendix A, the mean pad pressure P_{mean} is calculated from the formula;

$$P_{mean} = \frac{W}{nbL}$$

as 1.88 Mpa

The effect of oil viscosity on oil film thickness was calculated for a thrust bearing temperature of 60°C, which was recorded in the Engine Room Log in the days prior to the bearing damage. Minimum film thickness, *h*, is obtained from equation 6.2 on page 9 of the above reference, viz:

$$h = 0.46\sqrt{\frac{h\ N\ d_m\ b}{P_{mean}}}$$

For SAE 30 grade oil, the corresponding dynamic viscosity, h_g, would be of the order of 0.027 Ns/m^2 so the film thickness would be about 39 µm, without making any allowance for possible misalignment effects or surface roughness.

The following misalignment conditions will affect the required minimum clearance (film thickness):

- unequal pad thickness
- lack of squareness between thrust collar and shaft
- lack of squareness between bearing axis and shaft axis, and
- flatness errors in thrust collar or bearing pads.

The above reference does not give Minumum Acceptable Film Thickness for pad widths greater than 0.16 metre, but extrapolating for this size of pads (b = 0.24 m) suggests the required minimum film thickness would be about 20 µm. On that basis, there appears to be an allowance only 19 µm for misalignment and surface roughness effects. The data relied on in the above calculations is limited to smaller sizes of thrust pads (max b = 160 mm). An assumption is made that the charts in this reference document are relevant to the larger size of pad in this engine and regard the above results as indicative only rather than definitive.