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- safety data recording, analysis and research
- fostering safety awareness, knowledge and action.

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Engine room fire on board the container ship *Maersk Duffield* in Moreton Bay, Queensland 10 December 2009

Abstract

On 10 December 2009, during *Maersk Duffield*'s transit into Brisbane, Queensland, the ship's number four diesel generator (4DG) suffered a catastrophic failure, disabling the generator and starting a fire. The engine room was evacuated and the ship's fixed carbon dioxide (CO₂) fire extinguishing system was operated. After the fire was extinguished, the crew were able to restart most of the ship's equipment and it berthed the following morning.

The ATSB investigation found that it is possible that one or more of the connecting rod palm nuts or counterweight nuts had not been sufficiently tightened during recent overhauls and that the resultant failure of one of the retaining studs was the initiator of the catastrophic engine failure.

FACTUAL INFORMATION

Maersk Duffield

Maersk Duffield (IMO No. 9227340) is a 4,112 TEU¹ cellular container ship (Figure 1) which was built in 2002 by Samsung Heavy Industries, Korea. It is 281.0 m long with a beam of 32.3 m and it has a deadweight of 53,370 tonnes at its summer draught of 12.525 m.

The ship is powered by a HSD Sulzer 9RTA96 two-stroke, single acting diesel engine that delivers 51,390 kW at 102 rpm. The main engine drives a single, fixed pitch propeller which gives the ship a service speed of about 24 knots².

At the time of the incident, *Maersk Duffield* was registered in Liberia and classed with Germanischer Lloyd (GL). It was owned by KG MS Santa Rosanna Offen Reederei, managed by Reederei Claus – Peter Offen, both of Germany, and chartered by Maersk Line, Denmark.

Figure 1: *Maersk Duffield*



- 1 Twenty-foot Equivalent Unit, a standard shipping container. The nominal size of a ship in TEU refers to the number of standard containers that it can carry.
- 2 One knot, or one nautical mile per hour equals 1.852 km/hr.

The ship had a crew of 25 which included the master and three mates, three engineers, two electricians, three oilers, a trainee engineer and a fitter.

The master had 16 years of seagoing experience. He held a Polish master's certificate of competency, issued in 2003. He had sailed with the company since April 2006 and this was his fourth contract as master. He had rejoined *Maersk Duffield* on 31 October 2009 for his second contract on board the ship.

The chief engineer started his apprenticeship in 1983. He held a German chief engineer's certificate of competency, issued in 1996 and he had been a chief engineer since 2001. He had been with the ship's manager for 7 years and on board *Maersk Duffield* for 2 ½ months.

Generators

Maersk Duffield's electrical power is provided by five main generating sets connected to a main switchboard. The main generators are located in the generator room which is located within the ship's engine room. For port arrivals and departures, two generators are normally used to supply power to the normal systems and a third generator is run for the bow-thruster.

Power for essential emergency services is provided through the emergency switchboard. The emergency switch board is normally connected to the main switchboard but in the event that no power is available from the main switchboard, the ship has one emergency generator to provide power to the emergency switchboard. The emergency switchboard and emergency generator are located outside the engine room.

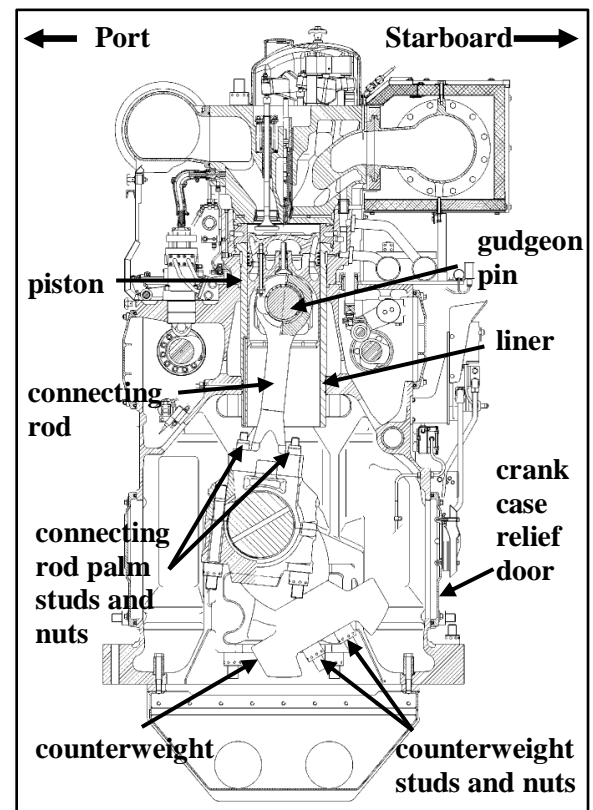
Four of the main generators, including 4DG, are driven by STX MAN/B&W 7L 32/40 seven cylinder, single acting, four stroke, turbo charged, trunk-piston engines. These engines have a bore of 320 mm and a stroke of 400 mm and they each deliver 3,600 kW at 720 rpm.

The ship's fifth main generator is driven by an STX MAN/B&W 6L 32/40 four stroke diesel engine that delivers 2,748 kW at 720 rpm.

Each of 4DG's seven cylinder assemblies consists of a piston, a connecting rod and a gudgeon pin that joins the connecting rod to the piston (Figure 2). Each piston runs inside a water-cooled,

replaceable steel cylinder liner. Each connecting rod is bolted onto a bottom end bearing at a palm face using studs and nuts. Each of the crankshaft webs has a counterweight³ attached to it with studs and nuts.

Figure 2: Generator engine cross section



The incident

At 1030⁴ on 10 December 2009, a Brisbane pilot boarded *Maersk Duffield* at the pilot boarding ground after the ship's voyage from Singapore. The master and pilot conducted their information exchange and the pilot took the conduct of the ship. At 1055, the ship entered Moreton Bay.

The ship's electrical power was being supplied by the number one diesel generator (1DG) and 4DG. At about 1305, the chief engineer started the number three diesel generator (3DG) to supply additional power for the ship's bow thruster.

At about 1312, the trainee engineer, who was cleaning in the generator room, noticed an

³ Machined steel blocks that act as balance weights to reduce vibration in the engine.

⁴ All times referred to in this report are local time, Coordinated Universal Time (UTC) + 10 hours.

unusual smell and heard a knocking noise. He went to investigate and found that oil was leaking from the number five cylinder crankcase relief door on 4DG. He immediately went to find the oiler who was working outside the generator room.

The oiler came to inspect the leak and both men then went to the control room to report what they had seen to the chief engineer. The chief engineer inspected the leak and decided to immediately shut down the generator. He went back to the control room and started the number two diesel generator (2DG) and synchronised it with the main switchboard. Once 2DG was connected to the main switchboard, he transferred the load from 4DG. When 4DG had been unloaded and disconnected from the main switchboard, he switched it to manual and pressed the stop button.

Figure 3: Damaged crankcase on 4DG

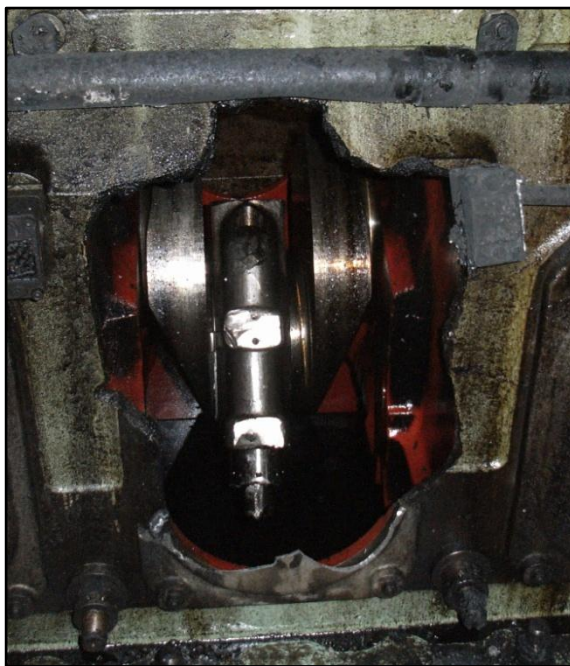


Figure 4: Connecting rod from 4DG



However, before 4DG had stopped, an explosion occurred and the number five cylinder forward counterweight, piston and connecting rod were

ejected from the engine (Figures 3 and 4), shattering the crankcase relief door.

The oil vapour escaping from the engine immediately ignited, resulting in a small fireball and at 1320, the ship's fire alarms sounded.

The heavy debris that had been ejected from 4DG struck 3DG, which was still running, and broke a crankcase door (Figure 5). The fractured door allowed more oil and vapour to be released, adding fuel to the fire.

Figure 5: Crankcase door on 3DG



Following the explosion, the chief engineer left the control room to investigate. From outside the control room door, he could see flames in the generator room. He returned immediately to the control room and telephoned the master and told him that there was a fire in the generator room.

The second engineer and the third engineer tried unsuccessfully to enter the generator room and extinguish the fire using portable extinguishers. They then left the engine room with the trainee and the oilers.

Following the chief engineer's telephone call, the master informed the pilot of the fire, sounded the ship's general alarm and made an announcement to the crew using the public address system.

At this time, *Maersk Duffield* was outside the Moreton Bay shipping channels and approaching an anchored gas tanker. The pilot immediately ordered hard to port to turn the ship around (Figure 6) and set it on a heading of about 040°(T). He then reported the fire to the Brisbane Vessel Traffic Service (VTS) and requested tug assistance for the ship.

At 1325, the chief engineer telephoned the bridge again, informing the master that the fixed CO₂ fire extinguishing system would need to be used because the fire was large.

At 1328, the chief engineer went to the emergency generator room, started the ship's emergency generator and connected it to the emergency switchboard. He then ran up to the bridge and asked the master for permission to activate the CO₂ system. The master told him to prepare the system but to wait until all of the crew were accounted for.

The chief engineer returned to the fire control station. The second engineer went with the chief engineer and the third engineer was instructed to close the engine room ventilation dampers from their local controls.

The third engineer closed all the dampers. However, while he was climbing up to shut the incinerator room vent, he inhaled some of the smoke that was billowing from it.

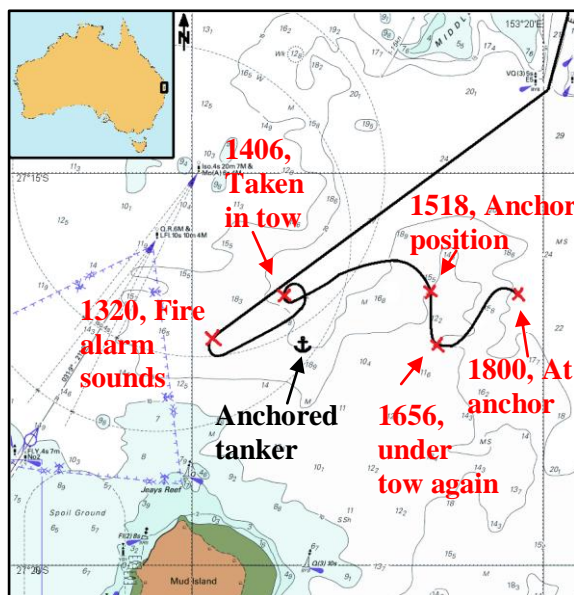
and, except for emergency services, the ship blacked out.

At about 1332, the chief mate informed the master that all of the crew had been accounted for and the master gave the chief engineer permission to release the CO₂. At 1335, the chief engineer released the CO₂ into the engine room.

At about 1335, the master was informed that a police launch was bringing fire fighters to the ship. He ordered the crew to prepare a pilot ladder on the starboard side and for the boatswain to standby the port anchor. He then asked the pilot when the ship would drop anchor. He was told that the ship was still making headway and that, since the anchor could not be retrieved once it was let go, it was better to wait.

The chief engineer was eager to enter the engine room to ensure that the fire had been extinguished. However, the master told him that there were fire fighters en route to the ship so he should wait until they arrived.

Figure 6: Section of chart Aus 236 showing *Maersk Duffield's* track.



At about 1356, the chief mate reported to the master that the third engineer was having difficulty breathing and showing signs of smoke inhalation. The third engineer was taken to the bridge and treated with oxygen.

At 1403, the pilot contacted Brisbane VTS, on behalf of the master, and reported the medical problem and requested a helicopter evacuation (medivac) for the third engineer.

At 1406, the tug *Wilga* was made fast forward and, following the pilot's instructions; it started pulling the ship away from the anchored tanker (Figure 6). At about 1427, the tug *Newstead* arrived and it began pushing on *Maersk Duffield's* stern.

The crew began making preparations for the medivac. They cleared the forecandle and laid out fire fighting equipment. At 1446, the helicopter arrived and two paramedics were winched down onto the ship's deck.

Meanwhile, the pilot informed Brisbane VTS of his actions and they offered him assistance from the Queensland Fire and Rescue Service.

At 1329, the chief engineer activated the emergency stops for all of the engine room ventilation fans and oil pumps before operating the remote quick closing valves for all of the fuel and oil tank discharge valves in the engine room. At 1330, the main engine and generators stopped

At about 1500, the police launch arrived alongside and the fire fighters climbed the pilot ladder. The chief engineer explained the situation to them and they asked if there was any more CO₂ on board. There were nearly 100 cylinders that had not been used and the fire fighters asked for them to be released into the engine room.

At 1505, the chief engineer requested permission from the master to release the remaining CO₂. Permission was granted and it was released at about 1515.

The third engineer was taken to the forecastle and at 1515, he and the paramedics were winched on board the helicopter. The helicopter then departed towards Brisbane.

At 1518, the ship's port anchor was let go in position 27°16.5'S 153°18.4' E, and 6 shackles⁵ of cable was payed out.

At 1600, the fire fighters donned breathing apparatus (BA) units before opening the door to the generator room and using thermal imaging equipment to determine if the fire had been extinguished. The fire was no longer burning so at 1610, they decided to start ventilating the engine room.

At 1616, the pilot and master realised that the ship had begun to drag its anchor and it was drifting towards the tanker. The tugs were ordered to return and tow the ship clear. At 1627, two more shackles of anchor cable were also payed out.

At about 1656, the tugs were made fast astern. The anchor could not be recovered so the tugs began to tow the ship clear stern first with its anchor still down. At 1711, *Newstead's* line parted but *Wilga* continued to tow the ship clear.

At 1735, the BA equipped firemen re-entered the engine room. They saw some smouldering rags which they extinguished with a fire hose. The CO₂ levels in the engine room were still very high and the generator room was very hot. They asked the ship's crew to open all the engine room doors and ventilation dampers in order to speed up the ventilation of the engine room.

At 1800, towing ceased in position 27°16.34' S, 153°19.8' E (Figure 6) and the ship was brought up at anchor.

At 1825, the atmosphere was tested for oxygen content before the chief engineer and the firemen re-entered the engine room. The engineers then began restarting the ship's equipment.

At 1856, 1DG was started and electrical power was restored. The engineers began restarting the ship's equipment. The fire had damaged some cabling and equipment in the generator room and some systems needed to be bypassed.

At 1940, another pilot boarded the ship to relieve the original pilot, who had been on board the ship for about 9 hours.

At 2012, the chief engineer informed the master that the ship was ready to sail under its own power. However, it remained at anchor over night with a tug in attendance.

At 0755 on 11 December, Brisbane VTS informed the master that the ship could get underway and proceed to its berth. The main engine was tested and the anchor was heaved in.

At 0924, *Maersk Duffield* entered the Brisbane River and by 1036, the ship was all fast alongside number 1 berth at Fisherman Islands.

ANALYSIS

On 11 December 2009, two investigators from the Australian Transport Safety Bureau (ATSB) attended *Maersk Duffield* in Brisbane. The master and relevant crew members were interviewed and they provided their accounts of the incident. Photographs were taken on board the ship and copies of relevant documents were obtained, including log book entries, maintenance records, procedures and statutory certificates. A copy of the voyage data recorder (VDR) data was also downloaded.

The fire

An examination of the fire scene between 3DG and 4DG indicated that the fire was intense, localised and had been short in duration. The evidence indicated that the fire was initiated by the catastrophic failure of 4DG's number five cylinder.

Generator failure

At about 1320 on 10 December, the number five piston, connecting rod and the forward counterweight were ejected from *Maersk Duffield's* 4DG.

The piston skirt had shattered and was found outside the crankcase, indicating that the piston

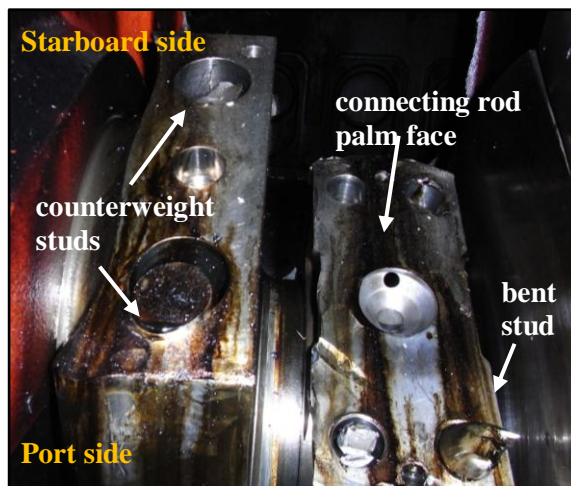
⁵ One shackle equals 90 feet or 27.43 m.

and connecting rod were complete when they were ejected from the engine.

The connecting rod had separated from the bottom end bearing after all four of the palm studs had failed. Both of the forward counterweight's retaining studs had also failed (Figure 7).

Two scenarios for the failure were considered possible; the initial failure of one or more of the connecting rod palm studs or the initial failure of one of the counterweight studs. From the evidence that was examined by the ATSB, it could not be determined which of the two failure scenarios had occurred.

Figure 7: Number five cylinder crankcase



Connecting rod palm stud failure

The first scenario considered possible by the ATSB was that the connecting rod palm studs may have failed first, thus allowing the connecting rod to move off the palm face and strike the counterweight.

One of the port side palm stud ends showed signs of necking ⁶ and a degree of bending (Figure 7). These details indicate that it had been the last stud on the palm face to have failed. For the failure of that stud to have occurred last, the starboard side studs had to fail first.

It is possible that one or more of the starboard side studs had failed through fatigue cracking due to the action of joint movement and the associated bending loads as the nut progressively

loosened during the engine's operation. The relative movement of the palm faces could also account for the metallic knocking sound that was heard by the trainee engineer immediately before the failure.

An overhaul had recently been completed on 4DG. According to the ship's planned maintenance system (PMS), all of the pistons had been removed, serviced and reinserted into the engine at 18,638 running hours, 48 running hours before the engine failure. All the connecting rod palm nuts were also re-tensioned at this time.

While it could not be confirmed, it is possible that one or more of the connecting rod palm nuts had not been sufficiently tightened during this recent overhaul. Therefore, it is possible that an insufficiently tightened nut could have been the initiator of a fatigue related connecting rod palm stud failure.

The failure of the connecting rod palm studs would have allowed the connecting rod to disconnect from the palm face and the piston to drop into the crankcase. The piston in the crank case would have interfered with the swing of the counterweight as the crankshaft rotated, leading to the subsequent failure of the counterweight studs.

Counterweight stud failure

The second scenario considered possible by the ATSB was fatigue cracking of one of the counterweight studs. The failure of this stud would have allowed the counterweight to move into the path of the connecting rod. It would have then been struck by the connecting rod, shearing the other counterweight stud and the connecting rod palm studs.

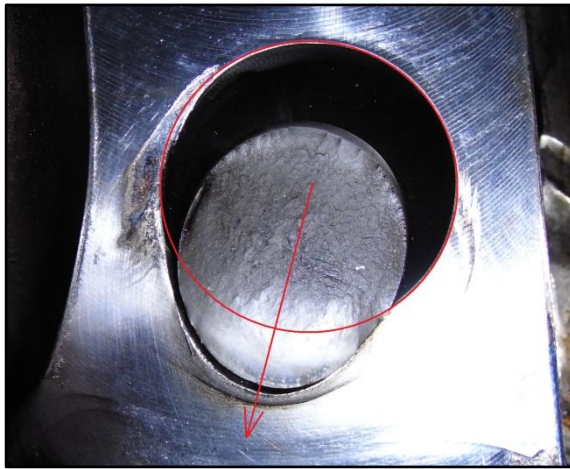
An inspection of the forward, port side, counterweight stud fracture surface revealed that it failed transversely in a flat manner (Figure 8). The stud hole was distorted from its original shape, which indicated that the stud fracture was related to a high degree of shear loading in the direction indicated in the diagram.

A detailed examination of the starboard side counterweight stud (Figure 7) was not possible in situ. However, the fracture surfaces were angular in nature and the hole through which the stud passed was not distorted. This indicates that it

⁶ A decrease in cross-sectional area.

had not been subjected to the same shear forces as the adjacent stud. It is possible that the failure of this stud may have allowed the counterweight to shift and contact the connecting rod. This would have impeded the connecting rod's free movement and resulted in the failure of the other counter weight stud and the connecting rod palm studs.

Figure 8: Sheared counterweight stud showing shear force direction and associated crank deformation



Two of the connecting rod palm studs that were found outside the crankcase showed signs of necking and elongation adjacent to the fracture face (Figure 9). This suggests that the studs may have failed suddenly through tensile overstress, which is consistent with the counterweight impeding the movement of the connecting rod.

Figure 9: Failed connecting rod palm stud



An examination of the one of the machined faces in the counterweight surface where the retaining nuts sat revealed a series of circular indentations (Figure 10). The counterweight had been severely affected by the fire and it is possible that the marks had been formed through plastic

deformation⁷. However, the shape of the indentations suggested that they may have been created by relative movement between the counterweight and the nut during the operation of the engine. This suggests that at least one of the nuts may not have been sufficiently tight.

Figure 10: Counterweight circular indentation



According to the ship's PMS, 4DG counterweight nuts were re-tensioned on 5 March 2009, at 16,937 running hours, 1,713 running hours before the engine failed.

The manufacturer's maintenance manual stated that the counterweight nut tension should be checked every 6,000 hours. However, according to the PMS, the counterweight nuts were re-tensioned every 8,000 hours. While there is a discrepancy between the intervals listed in the PMS and the maintenance manual, the failure occurred well within the recommended maintenance interval for re-tensioning and the difference in maintenance interval did not contribute to the failure.

Use of the ship's fixed CO₂ installation

After the fire alarm sounded at 1320, the chief engineer decided that the fire was too large to safely extinguish using hoses or extinguishers and that the fixed CO₂ fire extinguishing system should be used. The CO₂ was released into the engine room at about 1335; 15 minutes after the fire had started.

The decision to use the fixed system was prudent and the prompt use of the ship's fire dampers, remote valves and emergency stops almost

⁷ The deformation that occurs in a material when it is subjected to forces in excess of its elastic limit.

certainly reduced the severity of the damage to the generator room.

Engine room re-entry

A fire site is not significantly cooled by the release of CO₂. Therefore, there is a risk of re-ignition if a compartment is entered too quickly after the release of the CO₂. Sufficient time must be allowed for any material heated during a fire to cool to a temperature below its auto-ignition temperature⁸.

Maersk Duffield's generator room was accessed by the Queensland Fire and Rescue Service and they were able to assess the state of the fire using thermal imaging equipment without entering the generator room.

Therefore, engine room re-entry and ventilation did not occur until after it had been determined that the fire was extinguished and that it was safe to do so. This did not occur until almost 3 hours after the fire had started.

FINDINGS

Context

From the evidence available, the following findings are made with respect to the engine room fire on board the container ship *Maersk Duffield* and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The fire was initiated by the catastrophic failure of the number four diesel generator's number five cylinder.

Other safety factors

- It is possible that one or more of the connecting rod palm nuts or counterweight nuts had not been sufficiently tightened during recent overhauls and that the resultant failure of one of the retaining studs was the initiator to the catastrophic engine failure.

Other key findings

- The decision to use the ship's fixed CO₂ fire extinguishing system was prudent and the prompt use of the ship's fire dampers, remote valves and emergency stops almost certainly reduced the severity of the damage to the generator room.
- Engine room re-entry and ventilation did not occur until after it had been determined that the fire was extinguished and that it was safe to do so. This occurred almost 3 hours after the fire had started.

SOURCES AND SUBMISSIONS

Sources of Information

Brisbane Marine Pilots

Maersk Duffield's master and crew

MAN Diesel & Turbo Australia

Reederei Claus – Peter Offen

References

MAN B&W 6629–5, B2, Working Instructions for the L 32/40 CD engine.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the Australian Maritime Safety Authority (AMSA), Liberia Maritime Safety, MAN Diesel & Turbo Australia, the Queensland Fire and Rescue Service (QFRS), the Brisbane pilot, Reederei Claus – Peter Offen and *Maersk Duffield*'s master and chief engineer.

Submissions were received from AMSA, MAN Diesel & Turbo Australia, QFRS, the Brisbane pilot, Reederei Claus – Peter Offen and *Maersk Duffield*'s chief engineer. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

⁸ The lowest temperature at which the material will ignite due to heat, without the introduction of a flame.