183

Departmental investigation into the fire aboard the Australian flag oil tanker *TASMAN* in the port of Melbourne, Victoria on 19 December 1998

MIIU

ATSB
Australian Transport Safety Bureau

Contents

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investigation into into the fire aboard the Australian flag oil tanker *TASMAN* in the port of Melbourne, Victoria on 19 December 1998

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Summary

On 19 December 1998, the Australian flag tanker *Tasman* was alongside at No.28 wharf in the port of Melbourne where it was undergoing some modification work and survey. This included welding work in the aft peak tank.

Shortly after 1100, the duty engineer was in the control room answering alarms which indicated low generator fuel pressure. As he was turning to leave the control room, the fire alarm sounded. At about the same time, those on deck saw thick smoke issuing from the funnel and from openings around the poop deck.

The duty engineer left the control room and tried to enter the generator room with a fire extinguisher. Because of the heat he was forced to withdraw and, realising that the fire was substantial, he made for his fire station.

The 1st engineer, meanwhile, isolated the fuel to nos. 1 and 2 generators then, partly opening the forward door to the generator room, he directed a jet of water from a hose through the door toward the fire, which he could discern was burning mainly in the port aft corner of the space. The heat was such that he was unable to advance past the door.

A report was received that a shore worker was still in the aft peak tank, immediately adjacent to the scene of the fire. The 2nd engineer and an IR, both wearing breathing apparatus, descended the vertical ladder from the poop deck to the steering gear compartment to search for the man. The smoke was intense. Unable to find him in the aft peak tank, they turned their attention to the fire in the generator room. They were unaware that the shore workers had mustered on the wharf and all had now been accounted for. At the aft entrance to the generator room, they found that, although there was still much heat and smoke, the fire appeared to have been extinguished by the hose which had been directed through the forward door.

At the forward door of the generator room, the chief and 1st engineers were continuing to hose down no. 1 generator and the port aft corner of the space. They had, by this time, been able to advance one or two metres into the generator room and, although the space was still very hot, the fire was out.

At 1118, a message was passed to the bridge that the fire was out. At about the same time, the fire brigade arrived alongside the vessel.

At 1200, after an inspection of the engine room, the fire brigade established a control position, isolating the engine room to a single point of access in order to control entry by ship's staff or others. After conducting a number of inspections with a thermal imaging camera and thoroughly ventilating the engine room, the fire brigade finally declared the space safe at 1340.

It was later found that the fire had been started by a fuel pipe on no. 1 generator, the securing screws for which had become loose allowing fuel to spray into the hot-box and leak to the bilge, before igniting on the exhaust pipes. The fire had then spread to the oil in the bilge. The fire caused some damage to no.1 generator, but the most significant damage was that sustained by electric cables in cable trays beneath the deckhead.

Sources of information

Officers and crew of MT *Tasman*

ASP Ship Management

Mobil Oil Australia Ltd

Wärtsilä-NSD Australia Pty Ltd

Australian Transport Safety Bureau, Technical Analysis team

Metropolitan Fire & Emergency Services Board, Melbourne

American Bureau of Shipping

Tasman

The Australian flag products carrier *Tasman* is owned by Probo Pty Ltd of Canberra, managed by ASP Ship Management and is on charter to Mobil Oil Australia Ltd. The ship was built in 1990 by R.O.Brodogradiliste "Uljanik" at Pula, in the former Yugoslavia, and is 182.40 m in length overall, has a beam of 26.82 m and its deadweight is 31,259 tonnes at a summer draught of 10.66 m. It is powered by a five-cylinder MAN-B&W 5L60MCE diesel engine of 6,951 kW driving a single shaft and has a service speed of 15 knots. The ship is classed with the American Bureau of Shipping.

Tasman has three eight-cylinder Wärtsilä VASA R22 main generators. Nos. 1 and 2 generator sets are housed in the same space, the no. 1/2 generator room, on the upper platform aft of, and above, the main engine. No. 3 generator is situated in its own generator room immediately next to, and to starboard of, no. 1/2 generator room.

The ship's engine control room is situated outside the engine room adjacent to the cargo control room, midships, on the 1st poop, deck and faces forward with a view over the main deck.

Tasman has a crew of 19, comprising a master and four mates, four engineers, seven integrated ratings and three catering staff. At the time of the fire, the ship was also carrying two cadets. The main machinery space is classed as an 'unmanned machinery space' (UMS) and the engineer officers maintain a day-work system with one engineer on call in the 'silent hours'. The deck officers maintain a three-watch system both at sea and in port when discharging. The integrated ratings work a rotating roster, which includes either watch keeping or day-work, both on deck and in the engine room.

The fire

On the morning of 19 December 1998, *Tasman* was lying at no. 28 South Wharf in the port of Melbourne. The ship had arrived in Melbourne during the afternoon of 13 December after a 6-hour passage from the Shell oil refinery at Geelong. It was in ballast and had been gas-freed in preparation for a brief layup during which a number of work items were to be undertaken, including the fitting of a new davit for the rescue boat, modifications to the ship's towing gear, tank coatings and surveys. The vessel's draft was 4.4 m forward and 6.8 m aft.

Shortly after 1100, those on deck saw a plume of thick smoke billowing out of various openings around the stern of the vessel. The master made his way into the accommodation and up to the bridge. On his way, having seen the smoke, he shouted to the mate, on his UHF radio, to tell everyone that it was not a drill. The mate, who was making his way aft from the manifold, responded with a suggestion that the fire brigade should be called immediately and then, several times, pressed a manual fire alarm button situated just inside the accommodation access on the starboard side of the upper deck. The fire alarm sounded at approximately 1105.

On the bridge the master found the bridge team, the 3rd mate, the cadet and the chief cook, already mustered. The fire alarm panel indicated that several sensors had been activated. At 1108, the mate, now at his fire station, reported that he and an IR were dressed in fire suits and breathing apparatus (BA), but the 1st engineer was missing from the muster. The master also received a report that the 3rd engineer was missing from his fire station. Very shortly afterwards, however, it was reported that the two missing engineers were fighting the fire from outside the forward end of the generator room.

The 1st engineer had just stepped out of the workshop when he noticed thick black smoke coming from around the generator room door. He ran to the door and, looking through the glass panel in the door, saw a lot of smoke and the orange flickering of flames at the aft end of the space. He grabbed a dry chemical fire extinguisher from outside the switchboard room but, on his return, found that the fire had rapidly gained a hold.

The 2nd engineer (the duty engineer) had been near the air conditioning compressor on the upper platform deck when, at approximately 1104, he heard an engine room alarm. He made his way up to the engine control room, two decks above, where he observed that low fuel pressure alarms were showing for nos.1&2 generators. Immediately after he had acknowledged these, the fire alarm sounded. He headed towards the generator room where he found the 1st and 3rd engineers rigging a fire hose. Going to no. 3 generator room, he grabbed a CO_2 fire extinguisher and then opened the door to no. 1and 2 generator room. Being met by a blast of heat and realising that the fire was substantial, he closed the door again. Leaving the fire extinguisher with the others, he returned to the engine control room. On the way, he met the chief steward and asked him to telephone the fire brigade.

Moments later, in the cross-alleyway, the 2nd engineer met one of the welders who had been working in the aft peak. The welder, who had come up to the accommodation to get a particle of foreign matter removed from his eye, told him that another shore worker was still in the aft peak–the entrance to which was directly adjacent to the scene of the fire. The 2nd engineer and the welder made their way along the starboard side of the main deck and found smoke pouring out of the vertical access hatch to the steering gear. Realising that they could not enter, the 2nd engineer sent the welder ashore and then went to no.1 fire station where he put on a BA set.

The 3rd engineer had been in the inert gas (IG) room adjacent to the engine room, with the ABS surveyor, when he had smelt smoke. As he looked into the engine room the fire alarm sounded. He made his way down into the engine room and, as he reached the forward door to the generator room, the 1st engineer confirmed to him that there was a fire. The 3rd engineer raced over to the hose rack situated outside the main switchboard room and removed the hose and nozzle. Together with the duty IR, he coupled the hose to a fire hydrant then, still holding the nozzle, paid out the hose towards the generator room door. The 1st engineer, meanwhile, isolated the fuel to nos. 1 and 2 generators at the isolating valves situated just outside the door to no. 3 generator room. There was a brief blackout, at approximately 1106, before no. 3 generator, set in the 'stand by' mode, started up automatically and came on line, just before no. 1 shut down.

The 3rd engineer and the IR experienced some considerable difficulty, caused by a tight sealing ring, in connecting the nozzle to the end of the hose. The IR obtained a second hose from the other side of the engine room, but again the same problem was encountered. After some delay, however, the combined efforts of the two men enabled the nozzle to be connected. As there was no fire pump running, the 3rd engineer ran down to the level of the bottom plates and started the port main fire pump at the local panel. Once the hose was pressurised, the 3rd engineer checked the main switchboard space ensuring that all the relevant 220-volt power and lighting circuit breakers for the generator room, were open.

The 1st engineer cooled, then partly opened, the forward door to the generator room and directed a jet of water from the hose through the door toward the fire, which he could discern was burning mainly in the port aft corner of the space. The heat was such that he was unable to advance past the door. As he was doing this, the chief engineer arrived at the generator flat. On the arrival of the chief, the 3rd engineer went up and around to the poop deck. As smoke was pouring out of the vertical access to the chemical store, he lowered one of the hoses, which had been prepared as a safety measure during the welding work, down the hatch in an attempt to cool the bulkheads and the chemical store beneath.

While the above events were taking place, the 2nd engineer had arrived at the mate's fire station and informed him that the fire seemed to be in the generator room. The mate, the 2nd engineer and an IR went aft along the port side with the intention of entering the steering gear compartment from the poop deck. At the poop deck they met the 3rd engineer, who explained the situation to them.

Concerned about the fuel saveall drains and scuppers from the auxiliary boiler flat, which run through the generator room beneath the deckhead, the 3rd engineer then returned to the engine room, through the IG space, and commenced boundary cooling the top of the generator room. When the deck above the generator room was sufficiently wetted, he returned to the forward end of the generator room, having rigged a foam-making branch pipe and foam canister on the boiler flat. At the forward door of the generator room, the chief and 1st engineers were continuing to hose down no.1 generator and the port aft corner of the space. They had, by this time, been able to advance one or two metres into the generator room and, although the space was still very hot, the fire appeared to have been extinguished.

On the bridge, the master made a number of attempts to contact Melbourne Port Control on channel 16 but found the radio traffic very heavy. At 1110, The Water Police took up his call and relayed it to Port Control, requesting the attendance of the emergency services. At the time, the master was still not aware of the extent of the fire or whether there were any injuries.

At 1112, the 2nd engineer and an IR, wearing BA sets, descended to the steering flat from the access hatch on the poop deck to search for the missing shore welder who was believed to have been working in the aft peak tank. Two other crew wearing BA sets stood by at the top of the hatch.

On entering, they found that there was virtually no visibility through the smoke. They could just make out the presence of some flames in the generator room and a glow from the lighting in the aft peak tank, the only two factors which enabled them to orientate themselves. There was a great deal of heat. The 2nd engineer shouted several times through the manhole into the aft peak tank but received no answer. Deciding that he had to search for the missing man, he made a number of attempts to squeeze into the aft peak tank past the temporary plastic air trunking. Once inside, he made his way to where the welders had been working, shouting all the time. Unable to find the missing man, he left the aft peak and they returned to the aft end of the generator room, taking with them one of the temporary floodlights from the area where the welders had been working.

As a lot of black smoke was still billowing from the vertical access hatch, the mate called the bridge asking for all ventilation to be stopped. At 1113, following this request, all ventilation was tripped from the bridge and the 3rd mate started to go around closing down all vent flaps.

At about this time, Melbourne Port Control cleared VHF channel 16 for emergency use and a message was received from the Water Police advising the ship to work on channel 12. Contact was then established between the ship and Port Control, on channel 12, and information was passed to Port Control about the situation on board; that there was a fire in the generator flat, there was no cargo on board and the vessel was inerted.

At 1116, the shore contractors were mustered on the wharf and their foreman shouted to the mate, who was still at the steering gear access hatch on the poop deck, that all had been accounted for. This message was passed to the bridge.

By the time the 2nd engineer and the IR left the aft peak, the fire had been extinguished and, when they reached the aft door to the generator room, the 2nd engineer could see the 1st engineer at the forward end, although there was still much heat and steam in the space. Having pulled the extension lead a bit too far, the floodlight went out and, at the same, time the whistle sounded on his BA set indicating low air pressure. The two men made their way back out, up the ladder to the poop, where they heard that the missing welder had been accounted for.

On instructions from the mate, the 12-4 watch 3rd mate went around to check that all vent flaps were shut. While he was doing this, the mate received a message over the UHF from the 2nd engineer to the effect that there was nobody in the aft peak tank. As they came out, they told the mate that the fire had been extinguished.

At 1118, the chief engineer passed a message to the bridge that the fire was out, but those involved were evacuating the area around the generator room because of continuing thick, black smoke. At about the same time, the fire brigade arrived alongside the vessel, followed by an ambulance two minutes later. The master instructed an IR on the bridge to check the accommodation to ensure that there were no other personnel around, then went down to meet the fire brigade. By this time all of the ship's personnel had been accounted for.

By 1122, boundary cooling, under the control of the 2nd mate, had been established around the poop deck, with two hoses on each side of the upper deck. At this time it was reported to the bridge that the four men who had been fighting the fire from both ends of the generator room were clear of the machinery spaces.

The 2nd engineer changed the air bottle on his BA set, then went back down with one fireman to check that nobody was still in the area and that the fire was out. He made his way around to the forward end of the generator room, via the engine room and, still wearing a BA, relieved the chief and 1st engineers who had been fighting the fire without breathing apparatus.

At 1200, after further inspections of the engine room, the chief fire officer set up a command post on the bridge. At about this time, an altercation arose between the chief engineer and a senior fire officer about who was in charge at the scene. The fire brigade, particularly concerned both about smoke and the possibility of a re-ignition, were unwilling to be dismissed at such an early stage.

A second control position was established at the IG room entrance to the engine room, on the port side of the upper deck, isolating the engine room to a single access in order to control entry by ship's staff or others.

The emergency generator was, by this time, running and at 1205 the emergency fire pump was started. A little later, however, it was found that the emergency generator was running very hot and consequently the fire brigade pressurised the ship's firemain using the international shore connection. At 1245, the ship's emergency fire pump was stopped.

After conducting a number of inspections with a thermal imaging camera and thoroughly ventilating the engine room, using both ship's and fire brigade vent fans, the fire brigade finally declared the space safe at 1340. During one of the inspections, burning insulation was discovered on an electrical cable but this was quickly put out with an extinguisher.

Following the extinction of the fire, an examination was made of the damage to no. 1/2 diesel generator room. It was evident that the most significant damage was to electrical cabling, as cable trays carrying the main power cables from the three generators to the main switchboard run along the deckhead above no. 1 generator. In addition to the power cables, a large number of control, monitoring, alarm and communications cables were also damaged by heat.

Repairs commenced immediately and continued for the following month. After recommissioning all systems to the satisfaction of the class society, and following trials, *Tasman* was returned to service at 1324 on 23 January 1999.

Comment and analysis

No. 1/2 Generator room

No. 1/2 generator room is approximately 8.7 m long (forward to aft) and 6.7 m wide. It is situated between frames 11 and 23 on the upper platform 11.7 m above the baseline. No.1 generator is positioned just to port of the vessel's centre line and all three generator sets are orientated with the alternator (engine drive end) forward.

The space housing nos. 1&2 generators has access through steel, sound insulated, double doors at the forward end (on the port side) and through a single door at the aft end close to the port bulkhead. The forward doors are fitted with a glass sighting panel. The aft door leads to the steering flat and is adjacent to the chemical store at the forward end of the steering flat. Also adjacent to the chemical store is a vertical ladder leading up to a hatch in the poop deck.

Extent of the fire

Examination of the fire scene after the incident showed that the area of most intense heat damage was in the port aft corner of the generator room, consistent with the observations of those involved with firefighting. The point of lowest burn was in the bilge in this port aft corner (fig. 2 & 3) and from here, damage extended up the aft end of, and up the port side of, no. 1 generator.

Flames rising from the bilge up the port bulkhead of the space had melted the perforated aluminium sheet cladding which covers the rockwool insulation. Although the rockwool itself would not burn, indications are that it had acted as a wick, drawing oil, or oily water, up from the bilge. Pools of solidified aluminium were found on the steel deckplates forming the walkway along the port side of the engine. Heat and smoke, trapped beneath the deck plating, had extended across the width of the aft end of the generator room, blistering paintwork on pipes below the plates.

It is usual, in incidents of this type, for even a relatively short-lived fire to produce enough hot gasses, which become trapped against the deckhead, to rapidly cause severe heat damage to electrical cabling in cable trays. It was this effect that had caused the most serious damage, being to power cables, control and monitoring wiring

FIGURE 2
Port aft corner of generator space – bilge fire occured here

FIGURE 3
View of port side of generator space – looking aft to steering flat

and to lighting (fig. 4 & 5). Other significant, although not major, damage caused by the fire was to no.1 generator diesel engine, which subsequently required an overhaul during which it was found that the turbocharger rotor, made of a relatively low melting point alloy, had to be replaced. In addition, most of the instrumentation and wiring for the engine had also to be renewed. Some slight heat damage had been sustained by the rubber foundation mounts.

Before the fire, the door leading aft to the steering flat had been propped open a few centimetres with a block of wood to allow welding cables to be run from the workshop to the port side of the aft peak tank. The partly open door had allowed the passage of heat and smoke into the steering flat, causing the polycarbonate diffusers on light fittings in the steering flat to start to deform. This indicated that the temperature at the deckhead above the steering gear had reached approximately 130ºC.

Origin of the fire

Shortly after the fire, ship's staff examined no. 1 diesel generator and removed the hot box covers from the fuel gallery. It was noticed that, on no. 2 unit, the upper of two Allen screws, was missing from the flange where the fuel suction pipe joins the fuel pump. The missing screw was reportedly found lying on the entablature. The other screw was found to have loosened, allowing the flange to part from the fuel pump body. The O-ring in the joint had broken into three pieces. (figs. 6, 7&8)

During the subsequent MIIU investigation, it appeared that a substantial amount of fuel had flowed from the fuel gallery within the hot box down the port side of the engine and into the bilge, thus providing the main source of fuel for the fire. (figs. 6, 7&8)

The flange which had parted was in line with the space between nos. 1 and 2 cylinder heads. This space connects directly to the port side of the engine, within the covers of which are contained the exhaust manifolds. The bottom of the exhaust box is raised above the level of the top of the engine entablature by approximately 40 mm and it is evident that it was through this gap, between the exhaust box and the top of the entablature, that the leaking fuel oil had escaped down the side of the engine.
(fig. 6,7&8)

The source of ignition of the fire could not be determined with certainty. However, the engine room log shows that, shortly before the fire, the load on no. 1 generator was 650 kW. At this load, the average temperature of the exhaust manifolds is over 400ºC. Data sheets from the Australian Institute of Petroleum give the average auto-ignition temperature of heavy fuel oil, with a specific gravity of between 0.90 and 0.98, as 380ºC. (This figure may vary according to the test procedure used). The specific gravity of heavy fuel oil bunkers carried by *Tasman* varies between 0.96 and 0.98. There is the distinct possibility that fuel spray from the joint passed through the narrow space between the cylinder heads of nos.1 and 2 units and ignited on the exhaust manifold, the temperature of which was above the auto-ignition temperature of the fuel oil.

Considerable fresh residues of fuel oil were observed both on the inside of the exhaust casing at the forward outboard corner and also on the exhaust leading from no.1 unit. (fig. 6,7&8) Neither of these positions, however, are directly in line with the space between nos. 1 & 2 cylinder heads, but it appeared that the spray from the failed joint may have been deflected off the bottom of a bracket which supports the covers of the exhaust hot box. This bracket is in line with the space between the cylinder heads.

Spread of the fire

During the fire fighting operations, the port side of no. 1 diesel generator was subject to intense hosing with high-pressure jets from fire hoses. After the fire had been extinguished, hosing was continued in order to cool down the generator. In the process, most of the evidence of oil flow out of the generator hot box into the bilge was very effectively washed away, rendering difficult an accurate assessment of the mechanism by which the fire spread.

There remained, nevertheless, numerous stripes of scorched and burned paint down the side of the engine crankcase, extending from the top of the engine entablature down to the engine bedplate, along the full length of the engine. There are two possible causes for these burns. The first, and considered the most probable, is that these stripes were caused by burning fuel oil flowing down the side of the crankcase. The other possibility is that the burned paint was caused by radiant heat from the flames which were rising up the bulkhead at the outboard side of the walkway.(fig. 7)

The dark stripes of heavy oil flowing, or dribbling, down the side of the engine would absorb the radiant heat, while the relatively clean, light coloured cream paintwork would reflect much of the heat thus, when the oil had

FIGURE 4
Fire damage to deckhead cables and fittings

FIGURE 5
Fire damage to deckhead cables and fittings

been hosed off, leaving the burned and blistered paint in the form of stripes.

One perplexing effect which was evident, whichever of these two possibilities was correct, is that the burn marks stopped abruptly at the top edge of the engine bedplate, all along the length of the engine. Neither the vertical edge of the bedplate, nor the structure beneath, showed any indication of burned or blistered paint. A possible explanation for this effect is that before the fire, the engine crankcase, and its integral bedplate, was already hot, whereas everything below the engine mounts was cold, effectively insulated from the hot engine by the flexible mounts. The difference in temperature of the steel beneath the paintwork was possibly sufficient to prevent the paint below the engine mounts from blistering and burning.

Although the exact means by which the fire reached the bilge could not be ascertained, it is evident that it did reach, and ignite, the pool of fuel oil which had collected in the bilge at the after end of the space.

During repair work after the fire, it was found that pipework supplying fuel to the composite and auxiliary boilers runs above no.1 generator, over the area where the fire was most intense. Jointing in flanges on this pipework was found to have been burned out. As the inert gas system was running at the time of the fire (for survey), it is likely that leakage of fuel oil from these joints added to the intensity of the fire.

Sequence of events

The engine room alarm logger clock was not synchronised with the ship's time. The fire alarm occurred at approximately 1105 (ship's time) and was recorded on the logger as 08:24:46, i.e. the alarm logger

Time	Channel	Alarm
08:23:54	12107	F.O. Inlet .E.1 Pressure LL=2.991
08:23:54	12307	F.O. Inlet A.E.3 Pressure L=5.533
08:23:55	12207	F.O. Inlet A.E.2 Pressure LL=5.533
08:24:46	12921	Fire Alarm
08:24:52	12108	L.O. Filter A.E.1 DPAH
08:25:03	12106	F.O. Leakage A.E.1FA
08:25:30	12105	A.E.1 Autom. Power failure XA

FIGURE 6
Residue of fuel oil spray within exhaust casing

FIGURE 7
Port side of engine showing stripes of scorched paint

FIGURE 8
Underside of exhaust casing, port side of no. 1 generator

clock was approximately 2 hours 40 minutes behind ship's time.

The print-out taken from the engine room alarm logger records the following sequence of alarms:

These alarms were followed by a succession of high exhaust gas temperature alarms on no. 1 generator, before a generator change over alarm at 08:25:49, and a main switchboard low frequency alarm at 08:26:01 (11.06 real time) – the time of the brief blackout.

The alarm for automation power failure on no. 1 generator at 08:25:30 may indicate that the fire had caused damage to electrical wiring by that time.

In the absence of any conclusive evidence indicating either the source of ignition, or the mechanism of transfer of fire to the bilge, it is considered that the following is the most likely sequence of events leading to the fire:

1. Engine vibration, over a period of time, led to the loosening of the two Allen screws at the fuel pump flange.
2. The flanged joint started to open slightly and fuel under pressure started to dribble into the fuel pump gallery.
3. The top screw loosened until it fell out, the lower screw continued to loosen and the dribble of fuel into the pump gallery became a steady flow.
4. The flow of leaking fuel increased until it exceeded the capacity of the hot box drains, and the level of leaked fuel began to build up to the point where, at the aft end of the engine, it started to overflow across the entablature and down the port side of the engine into the bilge.
5. The level of leaked oil began to back up towards the forward end of the engine, dribbling down the side of the engine, further forward. By this time, the quantity of fuel reaching the port aft corner of the generator room bilge was significant.
6. When the fuel pump flange joint had opened up sufficiently, fuel began to spray around inside the hot box. Failure of the O-ring would have exacerbated this spray. Some of this spray, or oil mist, reached the exhaust manifold where it ignited.
7. Oil, now burning, continued to flow down the side of the engine and began to reach the bilge.

8. The pool of oil fuel, which had already reached the bilge, was ignited.

9. All three generator 'Low fuel oil inlet pressure' alarms were activated at about 1104, probably upon failure of the O-ring. Smoke was seen and the response to the fire by the ship's staff was put in motion.

10. The fire alarm sounded one minute later, at 1105.

11. Sixteen seconds after the fire alarm, the alarm for 'Fuel oil leakage' on no.1 generator activated, the leakage of fuel into the drains at the forward end of the engine having now increased dramatically, finally reaching the alarm unit situated at that (the highest) end of the engine.

In a submission commenting on the draft report, ASP were resolute that the failure of the O-ring was irrelevant to the fire and to the sequence of events. The inspector acknowledges that it was loosening of the screws which caused the fuel oil leakage, thus providing fuel for the fire. The sudden drop in pressure, however, sufficient to bring up all three generator fuel pressure alarms simultaneously, would be consistent with the O-ring failing at this time. The O-ring had hardened and had, at some point failed. Whether or not a considerable spray, as opposed to a dribble, was issuing from the joint before the failure of the O-ring is not considered significant.

There is the possibility that there was already a substantial quantity of oil which had collected in the generator room bilge before the incident. The evidence given to the investigation, however, indicates that the bilge was probably in a satisfactory condition before the fire. The ABS surveyor had been into no. 1/2 generator room in the few days preceding the fire and had been satisfied with the condition of the bilge in that space.

Wärtsilä VASA R22 diesel generators

Tasman's no. 1 generator set is driven by a Wärtsilä VASA 8R22HF-D diesel engine. It is an eight cylinder, four-stroke engine of 220 mm bore and 240 mm stroke, having a power output of 1160 kW at 900 rpm. Diagrams showing the general configuration of this engine type are shown on figure 9. All three generators can run on diesel oil or on heavy fuel oil and, at the time of the fire, no. 1 generator was running on heavy fuel oil. In accordance with the DIN numbering system, the units (cylinders) are numbered from the drive (the forward) end.

FIGURE 9

Wärtsilä VASA R22 – general configuration

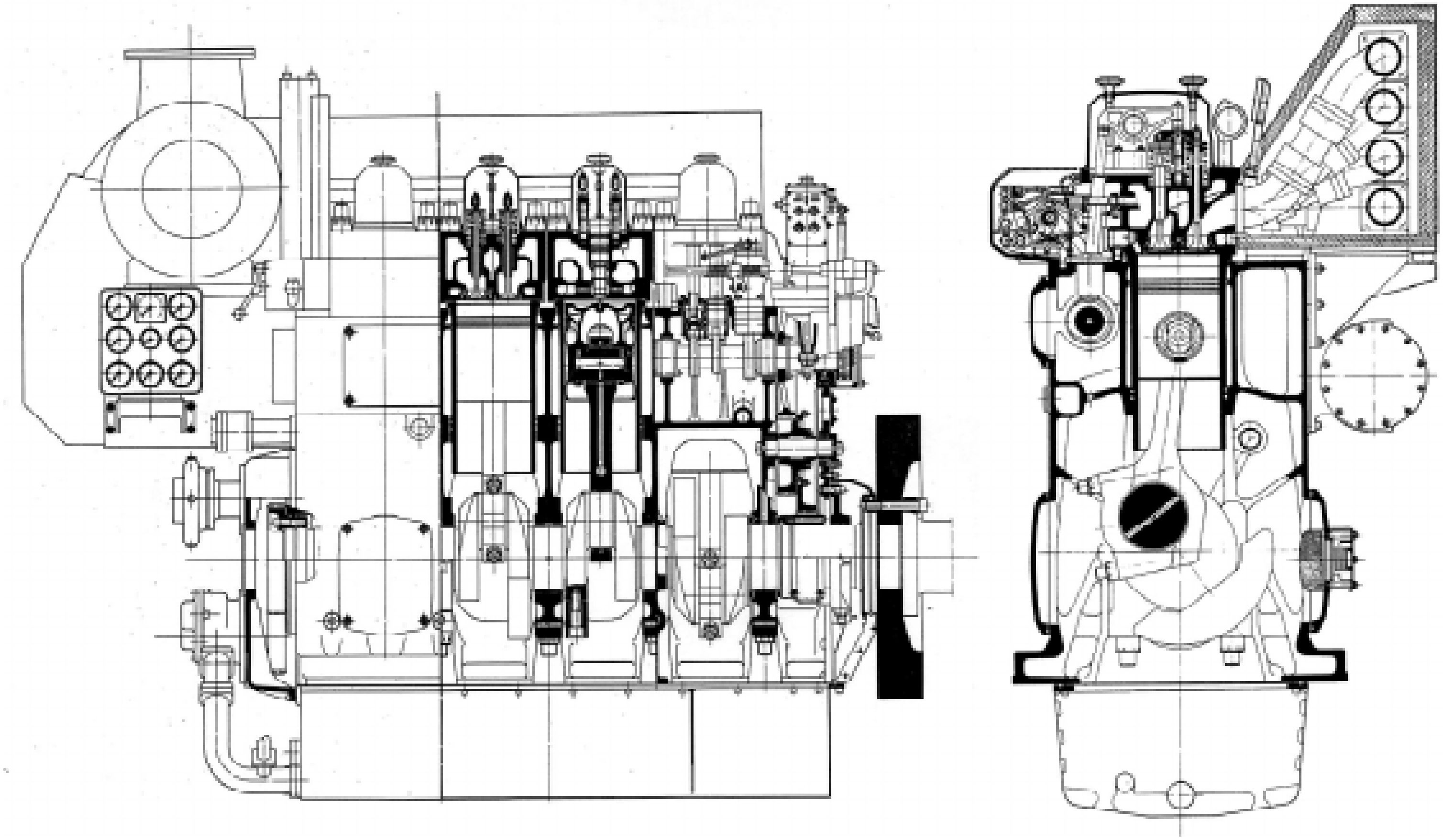
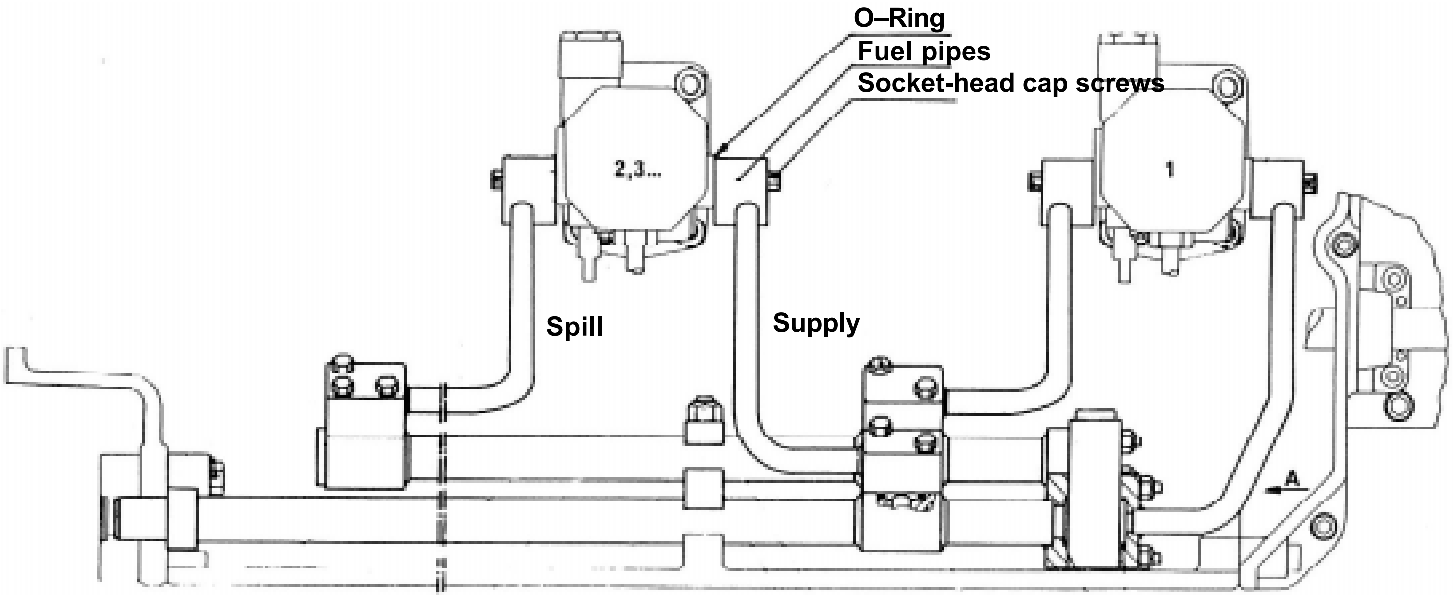


FIGURE 10

Plan of fuel pumps, supply and spill pipework in 'hot box'

Scale: Approx. ¼ full scale



The units have individual ‘L’Orange’ fuel injection pumps. Fuel is supplied to each injection pump via a separate pipe connecting from the fuel supply rail. The end of this pipe is attached to the fuel pump body with a flanged joint, sealed by a 19.2 × 3 mm O-ring, recessed into the flange. (fig. 11). The flange is secured to the pump body by two 8 mm dia. × 45 mm long allen screws. On the opposite side of the fuel pump, the fuel spill port is connected to the spill rail by a similar pipe and flanged joint. A diagram showing the arrangement of the fuel supply and spill pipework is shown as figure 10.

All three generator sets are orientated with the alternator, ie. the engine drive end, forward, and the free end of the engine, with the turbo-charger, aft. With this orientation, the fuel pumps on no.1 generator are on the inboard side and the exhaust manifolds are on the outboard side. The engines are designed such that all the fuel pumps and the associated ‘on engine’ pipework are enclosed within a ‘hot box’ – removable covers over the fuel gallery intended to prevent the escape of oil spray in the case of a fuel leak. On the outboard side, the two exhaust manifolds are enclosed in a separate exhaust casing with removable covers.
(figs. 11&12).

Following this fire aboard *Tasman*, Wärtsilä made available deflector plates which can be fitted so as to screen off the gap between the cylinder heads, thus preventing any possible fuel oil spray from within the hot box from reaching the exhaust manifolds. Since the fire, these were obtained by ASP and fitted to the generator engines on board *Tasman*.

Fuel leakage alarm

The hot box has, at each end, drains which lead down to the fuel oil drain tank. At the forward end, only, there is incorporated into the drain a fuel oil leakage alarm. (fig. 12). The leakage alarm is so designed that small amounts of fuel leakage, which may be considered normal, pass freely to the drain tank down a small pipe, connected to the main drain. However, a substantial quantity of fuel leakage will cause fuel oil to back up in the alarm chamber, thereby activating the leakage alarm.

Vessels such as *Tasman* are invariably trimmed by the stern and, while at Melbourne, *Tasman* was trimmed 2.4 metres by the stern. With this trim and a rate of fuel leakage which exceeds the capacity of the drain at the

aft end, the siting of the fuel leakage alarm at the forward end of the engine results in fuel being able to build up to a theoretical depth of approximately 40 mm at the aft end of the fuel gallery before it reaches the forward drain and the leakage alarm. It is probably for this reason that the alarm for channel 12106 'Fuel oil leakage A.E.1' (no. 1 generator) did not activate until after the fire had already started
(16 seconds after the fire alarm).

It is clear that the siting of the fuel leakage alarm was overlooked when the generator sets were installed and were orientated with the drive end forward. If the leakage alarm had been correctly sited at the aft end of the engine, there is clearly a possibility that the fire may have been avoided.

Allen screws

The two 8 mm × 45 mm allen screws which had secured the fuel suction pipe flange to the pump body were examined. The upper screw, which was reported to have fallen out and later found on the entablature, was stamped 'B109 18' on the side of the head, while the lower screw, which had remained in situ, although loose, was stamped M9 on its upper face. The two screws were subjected to non-destructive hardness tests and, although of different manufacture, returned similar results.

The hardness of both screws, found to be 350 Vickers (or 35 $Rockwell_c$), indicated to the metallurgist at the laboratory of the Australian Transport Safety Bureau that they were of high tensile alloy steel and would have a tensile strength of approximately 1170 MPa.[1] This tensile strength exceeds that required (1000 MPa) to be classed as Grade 10.9.

Microscopic examination showed no indication that the screws had 'bottomed' in their holes. It also showed no indication that the threads had suffered distortion from being over-tightened; in fact, under high magnification, the finish on the flanks of the threads showed little indication of surface interaction, or sliding contact, with the mating thread in the holes. This would indicate that they might not have been tightened sufficiently.

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1 Joint SAE-ASM-ASTM hardness conversions as printed in ASTM E48

Unfortunately , following the fire, the upper screw was sent ashore to contractors by the ship’s staff to see if it could be drilled in order to take locking wire. This action resulted in a regrettable degradation of evidence. The screw was presented for metallurgical examination having been cross-drilled with a 1mm diameter hole through the head and been scored and scuffed on the sides of the head and on the unthreaded portion of the shank, apparently where it had been held and manipulated in a vice. Safety investigations are carried out to ascertain the factors which came together to cause an incident and to help prevent a recurrence. Such investigations rely heavily on evidence remaining undisturbed, as far as is practically possible, until it has been examined.

Tightening torque

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

In any bolted connection, the clamping force between the mating faces is of paramount importance in determining whether the parts will remain joined when subjected to vibration over a prolonged period. The clamping force is a function of the torque applied to the screws upon assembly and is usually referred to as the ‘preload’. The application of an appropriate preload in the shank of the screw is the primary defence against fatigue failure or loosening.

Bolts which fail in use frequently do so in fatigue. Higher preload increases the mean stress in a fastener, and therefore threatens to shorten fatigue life. But higher preload also reduces the load ‘excursions’ seen by the bolt due to the applied cyclic loading. The net effect is that higher preload almost always improves fatigue life. Conversely, screws or bolts which are not sufficiently tightened may have an increased likelihood of failure in fatigue (the load excursions above and below the mean load seen by the fastener, are increased) or they may simply loosen and fall out. Those which are subject to excessive preload i.e. overtorqued on assembly, may be prone to failure in yield when the working load is applied or, when the applied load is below that required for joint

FIGURE 11
Pipe flange, 8 mm allen screw and pieces of O–Ring

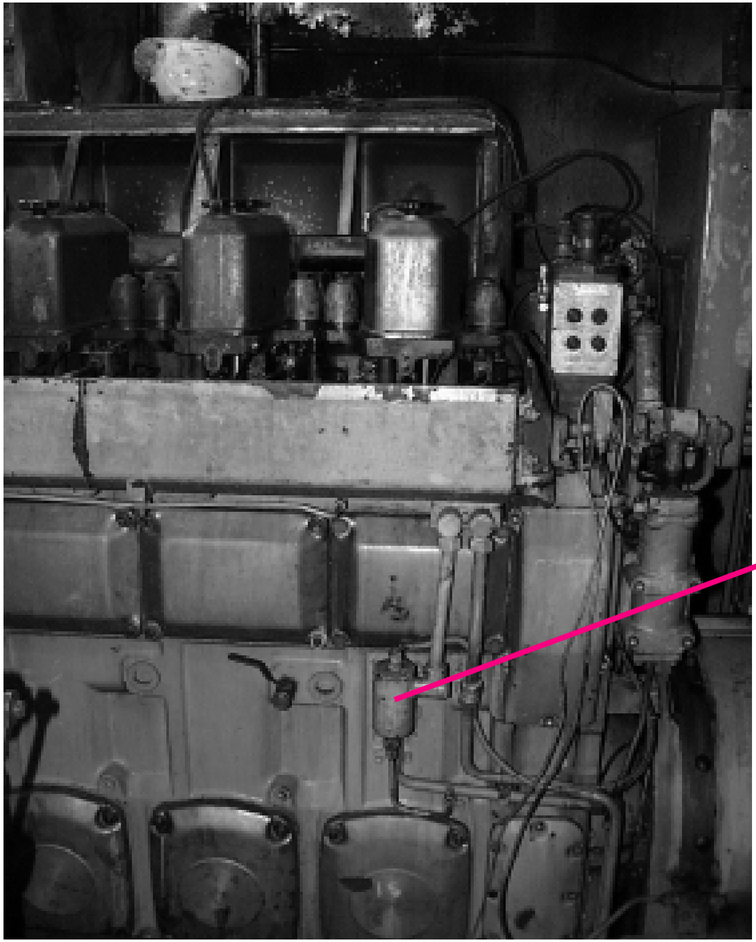

FIGURE 12
For'd end of generator (hot box and exhaust covers removed)

separation, will suffer an increased likelihood of fatigue failure as the increased torque simply increases the mean stress in the fastener to a level above the endurance limit. [2]

The preload is applied by the use of a calibrated torque wrench when tightening the screws on assembly.

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

There are three common grades of steel in use for socket head cap screws, Grades 8.8, 10.9 and 12.9. In each case, the first number before the point is the tensile strength of the material in 100 MPa. The second number is the yield strength (or Set Limit stress) in 10% of the tensile strength. E.g. a Grade 10.9 screw has a tensile strength of 1000 MPa and its yield strength is 9 × 10% × 1000 = 900 MPa.

The parts list which relates to the diagram of the fuel system on the engine, refers to the socket head cap screws securing the fuel suction pipe to the fuel pump body as *'Hexagon socket head screw M8×45 mm DIN 912-10.9'*. The DIN 912 refers to the metric DIN standard no.912 and 10.9 refers to the grade of high tensile steel from which the screw is made. The metallurgical examination mentioned above determined that the screws in question were of the correct grade, ie. 10.9, although neither was from the same manufacturer as the type normally supplied by Wärtsilä.

Page 07-3 of the Wärtsilä maintenance manual carried aboard *Tasman* states that the required torque for tightening the 'injection pipe cap nuts' (item 18) is 50±5 Nm. It was reported to the investigation that this was the figure which was being used by the ship's staff when tightening up the 8 mm screws in question. It is evident, however, that there was some confusion here on the part of the ship's staff, as these are not 'cap' nuts, but 'cap' screws, and the term 'injection pipe' refers to the high pressure pipe joining the fuel pump to the fuel injector, not the low pressure pipe secured by the 8 mm Allen screws. No specific reference to these screws is made in the table of torque figures in the manual.

A generic torque table on the following page gives a figure for M8 screws of 25 Nm, and, although this is the figure recommended for screws of Grade 8.8 material, the engine builders stated that this figure should also be used for screws of grade 10.9.

It appears that the torque figure to which these screws on the generator engines were generally being tightened was too high, although the evidence from microscopic examination, as described earlier, indicated that the two screws which loosened may not have been sufficiently tightened.

In submission, ASP stated that the flanks of the screw threads would not show any evidence of overtightening, had the screws been tightened to 50 Nm instead of the correct torque of 25 Nm. In the case of clean threads, this is correct. If tightened even to the correct torque, however, the thread flanks would be expected to show more evidence of contact with the mating thread than actually existed, with even small particles of dirt leaving significant impressions.

Should these two particular screws have, however, been overtightened along with the others on the engine, this factor would not have contributed to their subsequent loosening.

Why screws of grade 10.9 high tensile steel should be specified in the parts list, with no corresponding appropriate figure being specified for tightening torque, could not be ascertained.

Wärtsilä had issued no service bulletins on the subject over the years, and stated that loosening of the Allen screws in low pressure fuel systems was not a common occurrence. They had, however, experience of them being overtightened.

Loosening of screws

In those fires investigated by the MIIU which have been initiated by joint failures on fuel systems, fatigue failures and vibration loosening of fasteners have occurred in roughly equal numbers. In the case of loosening of screws, it is difficult to tell if screws were insufficiently tightened to start with, or if they have progressively self-loosened.

When screws are initially tightened, stresses are induced in the screw. There will be tensile stress, torsional stress and there may be some bending stress as all the machined faces involved will rarely be exactly parallel. When the tightening is stopped, the screw relaxes to some extent due to localised plastic creep, or metal flow, in the screw threads and joint surfaces. This is known as 'embedment relaxation'.

Embedment relaxation depends on a number of factors most significant of which are the finish on the threads, the sizing of both the thread on the screw and the tapped thread in the hole, the size of the hole, the size of the fillet on the underside of the head of the screw and the finish on mating machined surfaces. Whether the threads are slightly 'out of round' or 'drunken' will also constitute a factor.

Each of the above factors will result in the initial load being taken on one or more very small points of contact which leads to plastic deformation of the metal in those localised areas. Poor finish, poor fits or tolerances can all lead to total relaxation of the stress in the screw and its subsequent loosening. Other factors, such as thermal effects and the tightening of adjacent screws may also offset the preload placed on a particular screw. Screws from one manufacturer, in a particular application, may exhibit a greater propensity for relaxation than those from another.

The loss of preload due to embedment relaxation is typically 10-20%, and may occur in the first few minutes after tightening. For this reason, manufacturer's manuals often state that fasteners should be torqued up twice in succession.

Embedment relaxation is the precursor to self-loosening of screws and self-loosening is frequently caused by vibration. A bolted or screwed assembly is held together by friction forces which exist between the male and female thread surfaces and between the various joint faces. To prevent loosening of fasteners, it is essential to maintain these friction forces at a level higher than the forces which are trying to loosen the screw or nut. The first and most important way to maintain the friction forces is to provide and maintain a high level of preload. It is generally agreed that, discounting the working load and aspects of fatigue, it is necessary to tighten fasteners to the threshold of yield in order to attain maximum vibration resistance.[2]

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[2] 'Fastener tension control – what it is all about.' Smith, S., *Assembly Eng*. Nov. 1976

Commenting on the fact that the screws on the generator fuel pump supply and spill pipes were being generally tightened to 50Nm, instead of the stipulated 25Nm, ASP stated in submission,

> It would appear that the report has not considered the possibility that with over-tensioning there is a higher amount of stored elastic energy in the bolt, and the more stored energy the higher the propensity for the bolt to be unstable. If the assembly is vibrated at a particular frequency and under particular conditions it could allow the bolt to turn to release this stored energy.

There are many theories of how vibration loosening progresses and there is much technical literature on the subject. Although in other aspects they differ, all the theories agree that it is the stored elastic energy in the fastener which *maintains* the friction forces preventing the fastener from loosening hence, as far as vibration is concerned, the more preload the better[3]. The introduction of some form of damping into the design of a bolted joint can, however, also help maintain the friction forces by reducing the magnitude of the vibrational forces trying to overcome the friction.

Engine maintenance

The record, provided to the investigation, of maintenance work carried out on no. 1 generator, indicated that no maintenance or repairs had been carried out on no. 2 fuel pump or its associated pipework since April 1998, when the engine had undergone a 20,000 hour overhaul. At that time, all 8 fuel pumps were removed and sent ashore for overhaul. In fact, since then, the only recorded work in the hot box on the fuel system was the replacement of the fuel spill pipe from no.8 unit fuel pump, which had developed a crack in a weld.

Between the 20,000 hour overhaul commenced on 3 April 1998, at 33,019 running hours, and the fire on 19 December, no. 1 generator had run for a further 2 079 hours.

It was stated categorically during the investigation that, on completion of the 20 000 hour overhaul, all the allen screws were correctly torqued up to the appropriate figure, (i.e. 50±5 Nm which was believed by ship's staff to have been the correct figure). There are, however, a large number of such screws on the fuel supply and spill systems

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2 'Fastener tension control – what it is all about.' Smith, S., *Assembly Eng*. Nov. 1976

3 'An introduction to the design and behaviour of bolted joints' (Ch.16 – Vibration loosening) John H., Bickford. Marcel Dekker Inc.

on the engine and, in the inspector's opinion, it would be quite possible to miss one or two during the final tightening with a torque wrench.

There are no locking arrangements for such screws–indeed it is not common practice to provide locking arrangements for allen screws used in this kind of application. In the table of torque values for specific screws, however, it states that for the driving gear of the lubricating oil, fresh water and salt water pumps (connections with one screw per pump) *'Apply Loctite 242 on the threads'.* This is the only mention in the table of the application of Loctite. The application of Loctite 242 ('Screw lock') would assist in the prevention of screws from working loose if under-torqued, but it would not provide any help in preventing fatigue failure if the screws are either under or over-torqued. The same may be said for any type of locking arrangement.

O-Rings

The O-ring which had failed, at the joint of the suction pipe on no. 2 fuel pump, was found after the incident to be in 3 pieces. It was not clearly established, however, when the two breaks had occurred. ASP suggested in submission that these breaks had occurred after it had been removed from the joint. Compared to a new O-ring it had evidently hardened considerably, either during the 2,079 running hours since the fuel pump had been re-fitted, which the engine builder considered most unlikely in such a relatively short period, or it had been re-used at the time of the 20,000 hour overhaul. The latter possibility was adamantly refuted in a submission from ASP.

Although the engine had run for 2,079 hours since the fuel pump overhaul, fuel at approximately 8 bar and 110°C circulates through the system when the engine is on 'stand by' and this would have been for a total of some 5,800 hours. When the engine is on stand by, however, the joint is not subjected to the substantial vibration and stresses caused by high pressure pulses emanating from the ports of the fuel pump.

Although the condition of the O-ring indicated that it may have been re-used, there was no conclusive evidence either one way or the other. Other O-rings removed during the subsequent overhaul of the engine were also reported to have hardened.

Retrofit of fuel shut-off valves

Other than the requirements for quick-closing valves on fuel oil settling and service tanks, there is no requirement in SOLAS, or class rules, for a separate means of isolating the supply of fuel to a generator room. When *Tasman* was built there were, accordingly, no means provided by which this could be done, at least not without affecting all other running machinery. At the initial stages of this incident, it was evident that the fuel supply to no. 1/2 generator room needed to be rapidly isolated.

Some years earlier, this possibility had been foreseen by one of the ship's previous chief engineers and, at his instigation, a bank of isolating valves for both the fuel supply and spill systems had been retro-fitted outside the doors to the two generator rooms. The fitting of these isolating valves, in the event, proved most fortunate as it enabled the supply of fuel for the fire to be cut off immediately after its discovery.

Firefighting response

The response to the fire by ship's staff was both rapid and effective although, as in all such incidents, one or two shortcomings in organisation and equipment were revealed.

- The first few minutes of any fire are critical. Personnel on the scene or close to a fire are faced with making quick, yet complex, decisions which do not easily lend themselves to a set procedure. An individual is often faced with the dilemma of whether to tackle the fire, which may be getting quite large, or to withdraw and follow a set procedure. Each situation is different and, without hindsight, there is no right or wrong answer. It is a matter of judgement which must be made at the time.

  Within the last two years, the Marine Incident Investigation Unit has investigated eight fires. A feature common to the majority of these was that, over the first few minutes, the first casualty has been communications and control. There has been a lack of clear information reaching the command post and little effective control being exercised at the scene; this is in contrast to the more formal, disciplined routine exercised by fire brigades.

  The most worrying aspect of this is that there is a lack of information relating to the whereabouts and actions of individuals who, on their own initiative, have undertaken a course of action without informing anyone else.

This has sometimes led to people being isolated in areas of high potential risk without anyone being aware of their location. A whole effort to contain a fire can be nullified by the need to search for missing individuals. Such a search is further complicated if the searchers do not know where to look.

This appears to have been the situation in the early stages of this incident when some of the engineers and IRs were dispersed around the machinery spaces. By 1110, some five minutes after the fire alarm had sounded, the master had received relatively little information from the engine room about the situation, the extent of the fire or possible casualties. Any procedure for countering an emergency must have due regard to communications.

- Some considerable difficulty was experienced by the 3rd engineer and the IR in fitting a nozzle to the fire hoses, due to the thickness of the sealing ring. If a problem such as this is found during the routine inspections of fire fighting equipment by ship's staff, it may be prudent to leave the nozzle connected to the hose, ready for use. This will, over time, also compress the sealing ring.

- The 2nd engineer and the IR who descended to the steering flat and thence to the aft peak, looking for the shore welder, took a floodlight from the aft peak tank to use in the very poor visibility at the aft end of the generator room. Of concern is the fact that this was a 220 volt light on an extension lead which, while live, was being dragged through a very wet environment, due to the quantity of firefighting water being used. A very real possibility existed for the two men to suffer electric shock.

- A serious defect was revealed in the vessel's routine organisation, which had no system of recording the coming and going of contractors, or others, from ashore. There was no means of knowing who was on board at any particular time, or where they would be working. After the fire, ASP introduced a sign-in and sign-out system to rectify this problem.

In connection with the last point, it was noted that the mate, at the beginning of the fire, personally asked a number of personnel from ashore to leave the ship but they showed a reluctance to do so. These were people holding responsible positions who would be expected to have understood the mate's obligations and priorities. Some time afterwards he again encountered one of these people, still on board, and had to again ask him, more forcefully, to leave the vessel.

Authority of fire brigade

When the fire brigade inspected the engine room after the fire had been extinguished, there was reportedly an altercation, between the chief engineer and a senior fire officer, over who was in charge. It followed a disagreement centred around the timing of restarting ventilation. The fire brigade were unwilling to be dismissed by the chief engineer before they were certain that the fire scene had been rendered quite safe. The fire officer requested that the master come down to the engine room, but was informed that he was unable to leave the bridge, whereupon the fire officer went to the bridge.

In itself, the incident was relatively insignificant but it does raise an issue about which there appears to be uncertainty in the minds of some ships' officers. The issue is that of the ultimate responsibility for the safety of the vessel and the relative authority of the master and the fire brigade.

In the port of Melbourne the Metropolitan Fire Brigade operates in accordance with the Metropolitan Fire Brigades Act of 1958 no. 6315. Under section 4.(2).(a) of that act, the metropolitan fire district includes the Melbourne port area.

In addition, under section 7, *'Functions of the Board',* it states that:

> (3) The functions of the (Metropolitan Fire and Emergency Services) Board extend to any vessel berthed adjacent to land which by virtue of section 4(2) is part of the metropolitan fire district.

At section 32B 'Action on alarm of fire' it states at (3).(c) that:

> At the scene of an alarm of fire the senior member of the operational staff –
>
> …may, for the purposes of dealing with any alarm of fire cause –
>
> (i) any land, building, structure, vessel or vehicle to be entered upon or into (if necessary by force), taken possession of, shored up, pulled down or otherwise removed;

The Metropolitan Fire Brigades Act clearly defines the authority of the fire brigade under the circumstances prevailing on board *Tasman* on 19 December. The authority of the master, although traditional, is less clearly defined in terms of legislation. However, sections 6 & 278 of the Navigation Act 1912 do imply that ultimate authority rests with the master.

Consideration of this issue reveals a number of anomalies between the various laws of the different states and the law of the Commonwealth. To further pursue these complex legal anomalies is beyond the scope of this investigation. In the opinion of the inspector, however, what is clear is that, whatever anomalies exist, where a trained brigade is involved in fighting a ship fire, the fire brigade should be regarded as the authority on firefighting procedure, yet working in close co-operation with the ship's staff – the situation which prevails in the vast majority of such incidents.

Conclusions

The different factors identified as contributing to the incident should not be read as apportioning blame or liability to any particular organisation or individual. These are:

1. The fire in the generator room was initiated by vibration loosening two Allen screws securing the fuel suction pipe to the no. 2 fuel pump on no. 1 generator.
2. The source of ignition of the fire could not be determined with certainty, but was most probably the exhaust manifold, the temperature of which exceeded the auto-ignition temperature of the fuel oil and which was not sufficiently screened against spray from the engine hot box.
3. The design of the hot box was such that fuel was able to escape and flow to the bilge, where a bilge fire ensued.
4. The situation of the fuel leakage alarm, at the forward end of the engine, combined with the vessel's trim by the stern, rendered the alarm ineffective.
5. Although not conclusive, lack of evidence of interaction on the flanks of the screw threads indicates that the screws may not have been sufficiently tightened during previous assembly of the pipework.

Although not contributing factors, it is further considered that:

1. When tightening up the 8 mm allen screws on the fuel system of the generators, the ship's staff had been using the incorrect torque, namely that specified for the cap nuts on the high pressure injection pipe.
2. There was no routine in place on *Tasman* for recording the coming and going of personnel from ashore, with the consequence that two of the ship's staff carried out an unnecessary search for a shore worker, in a hazardous area adjacent to the fire scene.
3. The response to the fire by the ship's staff was prompt and effective.
4. The retro-fit of isolating valves in the fuel supply and return lines to the generator rooms was a safety measure which proved its worth in this incident.

FIGURE 12
Event and causal factor chart -
Fire aboard MV Tasman 19 December 1998

Submissions

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

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

The master, *M.T. Tasman*

The chief engineer, *M.T.Tasman*

Mobil Oil Australia Ltd

ASP Ship Management

Wärtsilä-NSD Australia Pty Ltd

Metropolitan Fire & Emergency Services Board, Melbourne

1. Submissions received from ASP Ship Management have been considered in the text, or the text has been amended as appropriate. In addition, commenting on the paragraph 'Tightening torque' on page 18, ASP stated :

> Fatigue usually occurs when localised stresses that are cyclically applied are in the order of the yield strength of the material. The cyclic action of the load must also cause localised deformation. If a bolt is under tensioned then the yield strength of the material is never reached. If a bolt is over tensioned it will not experience any cyclic deformation unless the vibrations to which it is subjected are of resonance frequency. An overtightened bolt, even if close to the yield point will be so preloaded that there is no movement between the faces that are clamped and therefore, it will not fatigue.

Having referred the above submission to an expert in engineering failure analysis at the Australian Transport Safety Bureau, the inspector would comment as follows:

‘The above does not consider the most fundamental factor in relation to a component’s ability to withstand fatigue – its ‘endurance limit’. Endurance limit is defined as ‘the completely reversing stress level below which fatigue life will be infinite. There is some such limit for any material and any part. Unfortunately, endurance stress levels are usually only a small fraction of the static yield strength or static ultimate strength of a material or body’.[4]

One source[5] gives the endurance limit of a grade 8 fastener (such as the 8mm 8.8 screws in question) as 0.15 of the material’s proof strength, and it is this factor which is considered in the design of the joint, not yield strength.

To say that if a bolt is under-tensioned, then the yield strength of the material is never reached, is to overlook the effect and magnitude of the applied cyclic loading. The cyclic loading on the 8mm screws securing the suction and spill pipes to the fuel pump is due largely to pressure pulses emanating from the ports in the pump. In some instances this can be in the order of up to 10 times the static load exerted by the nominal working pressure of the LP fuel system (in medium speed engines, at 85% load).[6]

It is not the intention of this report, however, to provide a treatise on the mechanics of fatigue, as the screws which loosened did not fail in fatigue. There is an intent in the text to draw the attention of the maritime industry to the importance of correct torquing of screws or bolts upon assembly, when figures are specified by manufacturers and especially when such fasteners are used in a situation where they are subject to high levels of vibration.

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4 ibid (Ch.17 - Fatigue Failure)

5 ‘Thread forms and torque systems boost reliability of bolted joints’ Product Engineering, Dec. 1977

6 ‘Failures of low pressure fuel systems on ship’ diesel engines’ Research project 401, carried out for the United Kingdom Marine Safety Agency by BMT Edon Liddiard Vince Ltd. 1997

Details of *Tasman*

IMO No.	8810023
Flag	Australia
Classification Society	American Bureau of Shipping
Ship type	Products tanker
Owner	Probo Pty. Canberra, Australia
Operator	ASP Ship Management
Year of build	1990
Builder	R.O.Brodogradiliste, “Uljanik”, Pula
Gross tonnage	20,662
Net tonnage	9,897
Summer deadweight	31,259
Length overall	182.40 m
Breadth extreme	26.82 m
Draught (summer)	10.66 m
Engine	MAN-B&W 5L60MCE
Engine power	6,951 kW
Crew	19 (Australian)