



**Departmental investigation
into the the fire
aboard the Australian flag
oil tanker
HELIX
at Brisbane, Queensland on
17 October 1998**



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Navigation Act 1912 Navigation (Marine Casualty) Regulations
investigation into the the fire aboard the Australian flag oil tanker

HELIX

at Brisbane, Queensland on 17 October 1998

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Sources of information

The Master, officers and crew of *Helix*

ASP Ship Management

Frank Mohn A/S

Bureau of Air Safety Investigation, Metallurgy Laboratory

Queensland Fire and Rescue Authority

Shell Australia Ltd.

Summary

In the morning of 17 October 1998, the Australian tanker *Helix* was discharging oil products at the Shell terminal at Pinkenba, on the Brisbane River.

At 0800, three of the ship's crew were in the engine room, starting a daily routine of maintenance. In the cargo control room the Mate was handing over the cargo watch to the 3rd Mate. Shortly after 0800, a fire broke out in the machinery space housing the motors and pumps for the hydraulic power units. A fireball travelled through the ventilation grating where the exhaust trunks penetrated the bulkhead to the main machinery space.

The three personnel in the engine room made their escape, two by way of the door to the steering flat and one by way of the encased escape from the bottom plates of the main machinery space. In the cargo control room, personnel heard a thump and felt a sensation through the deck. Almost simultaneously smoke filled the internal stairwell to the main deck and rolled along the deckhead.

The cargo pumps closed down automatically and the Mate directed crew on deck to close the cargo manifold valves. The fire alarm was sounded and the shore supervisor called the Queensland Fire and Rescue Authority at 0804.

The crew mustered at their fire stations. The ventilation fans and motors were stopped and all remote fuel stops were closed. The smoke cleared very rapidly and the Chief Engineer entered the engine room and laid out a fire hose to the hydraulic machinery space, within which there appeared to be a fire still burning. Two crew, dressed in breathing apparatus, made an entry to the main machinery space from the main deck level. They reached the machinery control room level and then descended to the hydraulic room level. They could see an isolated piece of lagging burning outside the ventilation grille, which was extinguished using a portable extinguisher. On entering the hydraulic machinery space they found a small fire burning in one corner of the "save-all" beneath the hydraulic pump units. This too was extinguished.

The remainder of the lower levels of the engine room were checked and no fire was found. Five units and a command vehicle of the Queensland Fire and Rescue Authority arrived at 0816 and fire officers boarded

the ship. At 0839 the ship was declared safe.

Damage was limited to destroyed light fittings, melted indicator and warning lights and smoke damage. Little damage was sustained to the ship's electrical cabling.

Initial examination indicated that two bolts, securing the hydraulic oil damper/ filter unit to No.3 hydraulic pump had failed, allowing a spray of fuel to come into contact with a source of ignition, most likely the exhaust trunking of the diesel engine driving No.3 hydraulic pump.



Fire damage immediately aft of hydraulic room bulkhead
Small lagging fire occurred on this pipework



Smoke damage around diesel exhaust trunks above hydraulic room

Narrative

The Australian flag tanker *Helix* is owned by Phinda Pty Ltd, managed by ASP Ship Management and is on charter to the Shell Company of Australia. Built in 1997 the ship entered service in August 1997. It is nearly 183 m in length overall, and its deadweight is 46,092 tonnes at a summer draught of 12.518 m. It is powered by a 6-cylinder Sulzer RTA diesel engine of 8,840 kW driving a single shaft and has a service speed of 14.5 knots.

Helix has a crew of 18, a master and three mates, four engineers, seven integrated ratings (IR) and three catering staff. The main machinery space is classed as an “unmanned machinery space” (UMS) and the engineer officers maintain a daywork 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 loading or discharging. The integrated ratings work a rotating roster, which includes watchkeeping and daywork, with deck and engine room duties.

The accommodation block and main machinery space is aft of frame 47. The accommodation block is arranged in six deck levels with the cargo control room on level one, crew accommodation on levels two, three and four and the bridge on level 5. The galley and messes are arranged on the main deck level. Below the main deck, the main machinery space (frames 15 to 47) is divided into four general levels above the tanktops - the lower plates, platform 1, platform 2 and the tween deck.

Helix is a double-hulled tanker designed to carry petroleum products. The cargo tanks, all forward of frame 47, are numbered one to ten and are divided by a central longitudinal bulkhead giving 20 cargo tanks in all. In addition there are two slop tanks which can also be used as parcel tanks. All the cargo and slop tanks are protected by inert gas. The space between the side shell plating and the cargo tanks and the double bottom spaces under the cargo tanks are divided into ballast tanks.

The ship is fitted with a Framo hydraulic cargo pumping system. Each cargo and ballast tank has an independent, hydraulically powered, deepwell pump. A central hydraulic system, manufactured by Frank Mohn A/S of Nesttun, Norway, supplies power to the 24 cargo and ballast pumps. The hose handling crane

and the bow thruster propeller are also powered by this central system.

System hydraulic pressure is provided by five hydraulic pumps located in the hydraulics room. The hydraulics room is at the forward end of the engine room at the second platform level, between frames 41 and 47. Two pumps are electrically driven and three are driven by dedicated diesel engines; all pumps feed a common manifold. There is a screen between the diesel engines or electric motors and their respective hydraulic pumps. The exhaust trunks are well lagged and, from the diesel engines, lead over the top of the screen and penetrate the bulkhead into the main machinery space at the deckhead level through a grille to the engine room. Beneath the hydraulic motors a “save-all” is constructed to retain any leaking oil. The space is illuminated by fluorescent light fittings with tubes protected by polycarbonate covers.

The Fire

Helix berthed starboard side to the Pinkenba oil berth at about 2000 on 16 October 1998 with eleven grades of oil product. Discharge of cargo started with four grades of product being discharged simultaneously, requiring all five hydraulic pumps.

During the evening a problem arose with No.2 port deepwell pump and the Chief Engineer and others were engaged in rigging a spare portable pump until about 0030 on 17 October. Cargo discharge continued throughout the night. Minor operational problems activated UMS alarms and the duty engineer attended to each problem.

Just before 0800 on 17 October, the 1st Engineer entered the main machinery space and went to the control room on the port side at the tween deck level. One of the IRs was already in the main machinery space setting up an impact wrench ready to work on the platform around the engine. A second IR entered the control room and picked up the checklist ready to take the various temperature and other readings for the engine log book. The second IR exited by the forward control room door. At the same time the 1st Engineer remembered that he had left his daily work sheet in the office next to the cargo control room and left the control room by the after door and started up the port ladder to the main deck level.

The 1st Engineer was about half way up the ladder when he heard a sound of some sort of explosion

described as a “whumph”. He looked over the rail and saw a large orange fireball at his level coming towards him. His immediate reaction was to go up the ladder, but after just one step he turned and went down to the tween deck level as fast as he could. The IR making rounds was about half way down the ladder between the tween deck and platform 2 facing aft when he heard a blast, which he described as rather like a large oxy-acetylene torch being lit. He looked around and saw a cloud of orange flame which seemed to be getting bigger and bigger. He could feel radiant heat and smell the hot smoke. Above him he could see the 1st Engineer making for the entrance to the steering flat and followed him. Both men escaped through the steering flat and then by ladder to the open poop deck. By this time other ship’s personnel were beginning to muster at the fire stations on the poop deck.

The IR, engaged in rigging the air hose and scaling machine, estimated he had been in the engine room a matter of 3 or 4 minutes when he smelt smoke, an unusual smell that should not have been there. Within seconds he heard a “whoosh”. The air seemed to explode upwards two levels above where he was standing and he saw a big fire mushroom funnelling up and debris started to fall around him. He knew he could not go upwards within the main machinery space, so went down to the bottom plates and escaped through the vertical escape trunking to the main deck accommodation. As he climbed out of the trunking near the mess room he heard the fire alarms sounding and he told the people there to go to their emergency stations. He then reported to his fire station on the poop.

At 0800, the Chief Engineer was at the after end of the main deck preparing to take a consignment of bulk lubricating oil from a road tanker. A few minutes after 0800 he realised that the cargo pumps were slowing and stopping and everything had gone quiet. At the same time he saw smoke coming from the foam room bulkhead vent on the starboard side of the accommodation block at main deck level. He immediately went to the fire station on the starboard side of the poop deck and, as he did so, he heard the fire alarms.

At 0800 the Mate was handing over to the 3rd Mate who was relatively new to the ship. Four products were being pumped. In 9 P and S tanks there was about one hour to go before the tanks were empty and the Mate suggested that the 3rd Mate reduce the speed of the pump to prevent overspeed or cavitation. As the 3rd Mate adjusted the speed they heard a “thump”, as though water-hammer had occurred in pipe work in the accommodation. The alarm indicating “low return line pressure” on the hydraulic system console

sounded and all hydraulic pumps and motors stopped automatically.

Both officers became aware of smoke along the deckhead and, outside the control room, thick smoke was coming from the internal stairwell to the main deck. They immediately moved to the external starboard door to the open deck as the fire alarms were sounding. The Mate instructed the watch on deck to close the manifold valve and to isolate the inert gas system. The jetty supervisor was close to the ship and the lubricating oil tanker. He called up to those at the manifold asking if “everything was all right.” The IR closing the valves could see smoke coming from the accommodation and he called to the supervisor to call the shore fire brigade.

At about 0800, the Master was in the ship’s office on the starboard side of level 1 deck. He had just joined and was in the company of the outgoing master. They noticed the shutting down of the ventilation. Almost simultaneously they were alerted by the fire alarm and the indication of fire on the alarm repeater panel. The Master entered the alleyway and noticed a haze of smoke, but on opening the central stairwell he found heavy smoke. He left the accommodation by the port entrance onto the weather deck to go to the bridge by the external ladders. On the weather deck the Master met an IR, who informed him that there was a fire in the Framo (hydraulic) room. On the bridge, he found the port door was locked so returned to level 4 deck where he re-entered the accommodation and made his way to the bridge via the central stairwell. The fire alarm panel confirmed a fire in the Framo room and the Master took overall command of the emergency. Using the bridge VHF, he notified all concerned of the fire’s location.

When the fire alarm sounded the crew mustered at their appointed stations. The Mate and Chief Engineer arrived at the fire station at almost the same time. The Mate opened the door of the fire control room but smoke billowed out. They then went to the fire equipment room, a small locker about 2.2 m square at the starboard after end of the deckhouse. Again when they opened the door smoke billowed out. The Mate took a deep breath of clean air and entered to find the breathing apparatus (BA) sets, which were hung on a frame inside the door. He found one but dropped it close to the door. He came out and then went in again and found a second set. Meanwhile the Chief Engineer had reached inside the locker and found the dropped set.

By this time the Chief IR, the IR on deck watch and other crew members had arrived. The Mate and the



Smoke damage at top of engine room

Looking forward towards top of hydraulics room bulkhead



Smoke damage outside hydraulic room

watch IR dressed in the BA sets. The Mate told the IR not to fit the BA regulator, to save air, until they were ready to make an entry. The Mate then re-entered the fire equipment locker and brought out the BA control board and torches.

The smoke was beginning to clear and the 1st Engineer was able to enter the fire station and shut the quick-closing fuel valves while the 2nd Engineer made for his fire station in the engine control room.

When the fire party were kitted up and making their way to the aft deck, with the intention of making an entry through the aft end of the engine room, the Chief Engineer checked the atmosphere in the engine room through the starboard door from the fire station. Lighting was on, although darker than usual due to smoke-blackened diffusers at the main-deck level. Finding that there was no undue heat and the atmosphere was almost clear, he entered and made his way towards the hydraulics room; the area to which the fire appeared to have been confined. As he made his way down the atmosphere cleared completely.

After running out the starboard engine room fire hose to the closed hydraulics room door in preparation for the arrival of the fire party, the Chief Engineer entered the engine control room to start the emergency fire pump and to update the 2nd Engineer on events.

The emergency fire pump failed to start and, when he rang the bridge to inform the Master of this problem, he was told that it had also failed to start when an attempt had been made to start it from the bridge. The 3rd Engineer and an IR were sent to the forecabin to start the pump manually.

When the fire party was ready, the Mate and IR went to the door to the fire control room, fitted the BA regulators and entered. Their entry was timed on the BA board. On the way through the fire control room the Mate operated all the ventilation trips. The two men entered the alleyway outside the main machinery space door. Once there, the IR tested the door with the back of his hand and found that it was not unduly hot. They opened the door carefully and found that it was possible to make an entry. Inside there was, by now, little smoke; it was not thick and they were able to see quite well.

The engine room flaps had not been closed and this had had the effect of enabling the smoke to dissipate as rapidly as it formed.

The Mate had realised that the fire was probably related to the failure of the cargo pumps and any fire was probably in the hydraulics room. The two men descended the two flights of ladders to the hydraulics room level. Outside the hydraulics room, close to the ventilation grille and below the exhaust trunks from the diesels, there was a small fire in some lagging on a pipe leading to the hotwell tank. Using a foam extinguisher they extinguished the fire in the lagging.

They then made an entry into the hydraulics room and found a small fire burning in the inboard after end of the save-all beneath No.3 hydraulic pump. This fire was also extinguished using the foam extinguisher. No other fire was obvious.

The Mate went to check the remainder of the engine room. There seemed to be no other area of fire and all seemed in order. Near the bottom plates he found a hard hat. He reported the state of the main machinery space to the bridge and the finding of the hard hat, requesting a roll call of the ship's crew. All the crew however had already been accounted for. By this time the atmosphere in the engine room was quite clear.

At 0810 the Master received a report that men in BA sets had entered the engine room and, at 0815, a further report that the fire had been extinguished.

A call for assistance from the fire brigade was put through to harbour control over the VHF. The fire brigade arrived alongside at 0816. At about 0820, fire officers from the Queensland Fire and Rescue Service arrived in the engine room. After a thorough inspection of the space, they confirmed the fire was extinguished.

Although the ship suffered significant damage to polycarbonate light diffusers and various other plastic fittings around the machinery space, there was minimal other damage, such as to electric wiring. There was widespread smoke damage. However, the ship was able to resume discharge of its cargo.

Damper body joint face



Pump body joint face



Comment and analysis

Site of the fire

Examination of the fire scene centred on the hydraulic room at the 2nd platform level at the forward end of the engine room. The source of fuel for the fire was found to be hydraulic oil from No.3 hydraulic pump escaping from a joint between the hydraulic pump and the hydraulic oil discharge filter/pulse damper unit. Two socket-head cap bolts securing the top of the filter had failed allowing hydraulic oil to escape.

Framo hydraulic system



Hydraulic pumps (No.3 damper/filter unit removed)

The hydraulic power pack, which supplies pressure to the Framo central hydraulic system, consists of three Rexroth A4V 500 and two A4V hydraulic pumps each of which provides an oil delivery of 824 litres/min. at 258 bar pressure. The pumps and their prime movers are all mounted on a common “skid” base. Two of the pumps, Nos.1 & 2, are driven by 405 kW, 60 Hz, 3 phase, electric motors and the remainder, Nos.3 to 5, are driven by 460 kW Cummins GTA1963 diesel engines. The pumps are connected by flexible hoses to the hydraulic supply and return pipework of the ring main.

On the side of each hydraulic pump, there is attached a combined filter, bypass and pressure pulse damping unit. (See photo). The pulse damper is simply a volume chamber, 495 mm long and approximately 240 mm in diameter, secured to the side of the pump by four 20 mm dia., 200 mm long socket head cap bolts at the

pump's free end. Sealing is effected by means of an O-ring. The bolts are made of grade 12.9 high tensile steel having a tensile strength of 1200 MPa and a set limit stress of 1080 MPa. At the pump's drive end, the pulse damper is secured to the pump body by a right-angled pressed steel bracket and two 20 mm dia. hexagon-head set screws. (See photo top page12).

The oil in use in the hydraulic system is Shell Tellus 46, having a flash point of 267°C, a viscosity of 46 cSt at 40°C, and a minimum auto-ignition temperature of 320°C.

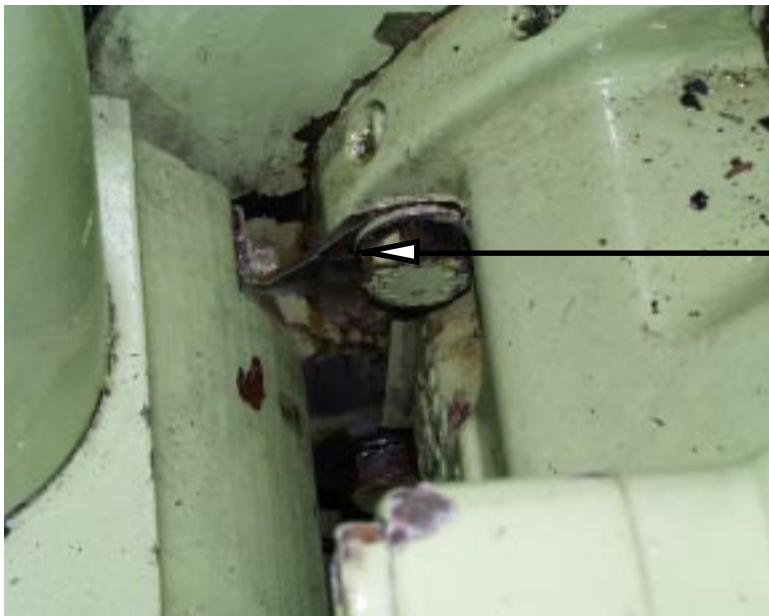
The failure

At the time of the incident, No.3 hydraulic pump was in use for the cargo discharge. Following the fire, it was found that the two upper set bolts, securing the pulse damper unit to the HP outlet flange of the hydraulic pump, had failed approximately 180 mm below the heads of the bolts. The two lower bolts were found slack. The upper eye in the bracket securing the other end of the pulse damper to the pump body had failed (see photo bottom page 12). The effect of these failures was to allow the pulse damper to move relative to the body of the hydraulic pump and for the joint to open up to the point where the O-ring had failed, allowing the escape of hydraulic oil under high pressure.

The supporting bracket, at the pump drive end, for the pulsation damper/filter unit was distorted and cracked across the bolt holes. Significant marking due to vibration was found on the pump flange where the bracket was secured.

It was also noticed during the investigation that these brackets on each of the other diesel-driven pumps i.e. Nos.4 & 5, had cracked in way of the bolt holes where they were connected to the pump body flange. On pump No.4, the lower 20 mm x 55 mm hexagon head screw securing the bracket had failed. The brackets, and their securing screws, on the two pumps driven by electric motors remained intact.

The bolt clearance holes in the attachment flange of the pulsation damper, where it joins the pump body, were found to be worn due to relative movement of the parts. Some fretting marks were evident on the two mating surfaces and the split O-ring was distorted. The thread in one of the holes in the pump body was damaged but the depth of the hole was 32 mm allowing sufficient clearance for the end of the bolt; the



Failure

**Broken
bracket on
No. 3 pump**



Failure

bolts had not “bottomed”.

Metallurgical examination

The failed bolts were submitted to the metallurgical laboratory of the Bureau of Air Safety Investigation for examination and the report is attached at Annex A.

The report on the examination stated that the two failed bolts had fractured as the result of fatigue crack growth. The remaining two (intact) bolts had no obvious indications of crack growth.

It was evident that the fracture of one bolt preceded the fracture of the other. Fatigue in the first bolt which failed was caused by alternating stresses aligned with the axis of the bolt. The indication of number of cycles to failure was roughly consistent with the pump running/pump shutdown cycles during cargo discharges over the life of the ship.

The features of fatigue crack growth in the second bolt were consistent with the application of alternating, rotating, prying loads under the head of the bolt. This type of fatigue crack growth is consistent with an increased ability of the damper assembly to move with respect to the pump housing following the fracture of the first bolt and the bracket which had been supporting the end of the damper at the pump flange.

The fracture of two cap bolts by fatigue indicates that the magnitude of alternating load imposed on the bolts during the operation of the hydraulic pump exceeded the fatigue endurance stress for the bolts.

The primary defence for fatigue in screws/bolts subjected to alternating stresses during operation is the establishment of an appropriate preload in the shank of the bolt during assembly. The most common method of establishing this preload is by applying a specified torque to the bolt head during tightening.

It was notable during the examination of the bearing surfaces of the bolt threads and bolt heads that there was little evidence of interaction with the mating surfaces in the pump housing and damper assembly. This lack of surface interaction (scoring, ploughing) indicates a low assembly torque and consequently low bolt preload.

No anomalies were observed in the thread forms of the fractured bolts which may have increased thread friction, thereby reducing the preload established by the application of the specified torque.

Section 4.10 of the Framo manual for the hydraulic system contains information on the tightening torques for bolts. At 4.10.3 it states *“If no torque is specified in service instruction or on drawing, use tightening torques according to the following table ...”*

The table contains tightening torque for a range of thread sizes and for three different qualities of steel. For M20 threads in 12.9 high tensile steel, the tightening torque specified is 660 Nm, with the threads lubricated. Another table, however, was found in the service instructions from the supplier of the Rexroth hydraulic pumps, Breuninghaus Hydraulik. This table indicated that, for M20 bolts in grade 12.9 steel, the correct tightening torque should have been 590 Nm. This table was also generic, not referring specifically to the bolts in question.

To further confuse this issue, following the incident, information received by ASP Ship Management from Frank Mohn A/S, indicated that the correct torque for the tightening of these bolts is 641 Nm. Whichever of these three figures, 590, 641 or 660 is taken as correct, it would appear that the torque figure to which the bolts should have been tightened during assembly was in the order of 600 Nm.

Maintenance records on the vessel do not indicate that any work had been carried out on No.3 hydraulic pump which would have necessitated the dismantling of the joint in question since the vessel was delivered. Following the fire, the torque to which the relevant set bolts had been tightened on the other hydraulic pumps was checked. All the other bolts started to move at a torque figure of between 220 and 270 Nm; little more than one third of any of those specified.

There was no reason to believe that the bolts on No.3 pump would have been tightened up any more than all the others. This agrees with the evidence from the metallurgical examination of the failed bolts indicating that, on assembly of the hydraulic pump units, insufficient torque had been applied to the bolts.

The fact that screws and brackets had failed at the opposite end of the damper unit (pump drive end) on all of the diesel driven pumps, indicates that vibration from the diesel engines was also a contributing factor in

the initiation of the failure. In addition, the original design of the pulsation damper did not incorporate the HP filter as fitted to the units on board *Helix*. The weight of this filter, attached to the end of the pulsation damper, would impose a considerable additional load on the pressed metal bracket supporting that end of the damper at the pump body flange. With the failure of the supporting bracket, the total load of the combined weight of the pulse damper and the HP filter would have been transferred to the four 20 mm set bolts securing the damper unit to the pump outlet face.

Manufacturers modifications

Following the fire, the manufacturers of the hydraulic system initiated a number of modifications to the design of the support for the pulse damper/HP filter unit. These included :

- an increase in the thickness of the metal of the supporting bracket, from 4 mm to 6mm
- an increase in the contact area around the support bracket bolt hole
- an increase in the length of the 20 mm socket head cap bolts to 210 mm in order to have a thread engagement of 25 mm
- to install 5 mm thick washers underneath their heads
- to specify a torque setting of 640 Nm on the relevant drawing.

In addition, means were being considered by which to optimise the strength of the high pressure flange connection between the pump and the pulse damper.

No.3 pump had attained the most running time, 3231 hours, while the other pumps had similar running hours of between 1700 (No.1 electric) and 2079 (No.4, diesel). Given the failed brackets on the other pumps and the lack of preload on all the relevant bolts of all the pumps, it is evident that other, similar, failures would have occurred in the near future on the diesel-driven pumps.

Prime mover/hydraulic pump separation

The height of the deckhead in the hydraulic machinery space is approximately four metres. The hydraulic pumps were separated from their prime movers by a sheet metal screen which extended the length of the hydraulic power unit and up to a height of approximately 3 metres. Between the top of the screen and the deckhead, pass the four lagged exhaust trunks for the diesel engines. The exhaust trunks pass directly above the hydraulic pumps.

In the “Equipment installation requirements” section of the hydraulics manual, it states at 4.4.2 under the heading “Heat sources”,

*“When hydraulic hoses must be routed near hot, potentially hazardous areas such as exhaust manifolds, heaters etc. fire sleeves that either fit over the hose or are built into the cover should be used. In addition, a **barrier must prevent hydraulic oil from a failed hose from spraying onto any potential ignition source.**”* (Inspector’s emphasis).

Although the topic under which this paragraph appears is referring to flexible hoses, the principle is equally applicable to the risks associated with any leak of hydraulic oil under pressure. Had one of the flexible hoses from the hydraulic pumps failed, instead of the bolts as occurred in this instance, the outcome may have been very similar. The design of the installation was such that there was insufficient separation of the hazardous heat source, the exhaust trunking, from the hydraulic side of the system.

In the report on the fire which was prepared by the suppliers of the hydraulic installation, it is recommended that the screen is rebuilt in such a way that the prime movers and the hydraulic pumps and their pipe connections are separated completely. It is also worth noting that, when the vessel was under construction, an owner’s remark was submitted to the shipyard about the lack of protection of the engines and exhausts from hydraulic oil. This resulted in the addition of 1.5 m to the then existing height of the partition, although this was considered unnecessary by the shipyard at the time.

The fireball

The fire seemed to have been confined to a rolling ball of fire, some minor consequential lagging fires close to the vent grille between the main engine room and the hydraulic room and a pool fire in the save-all beneath the hydraulic pumps.

The 1st Engineer and the IR in the engine room at the time of the fire both described the fire as a relatively slow moving and developing fireball.

The speed with which a flame front progresses through a fuel-air mixture is dependant on the concentration of that mixture and is at its maximum when the concentration is near stoichiometric. At this concentration, the pressure wave produced will also be at its maximum and can be up to 8 bar above atmospheric pressure in ideal conditions.¹ In a lean mixture the flame propagates at a lower speed and produces less heat and lower pressures. All of the fuel is consumed and there is no subsequent flame or fire. A rich mixture also has a lower speed of flame propagation and also results in a less vigorous explosion, although the excess fuel produces smoke or soot and an additional flaming fire. The heat effects and the blackening are usually greater when the mixture is rich, although the blast damage is less.

The circumstances described during the fire in the engine room of *Helix*, together with the physical evidence of blackening indicate that the most of the fire occurred in a rich fuel-air mixture. It is additional evidence indicating that the release of oil spray into the hydraulic space was almost instantaneous and ignition followed almost immediately, as there appears to have been insufficient time for a thorough mixing of the atomised fuel spray and the surrounding air.

Source of ignition

The engine-room alarm print-out indicates the following sequence of events

08:01:58 M1009 Air cond. swbd fail

¹ Harris, R.J. The investigation and control of gas explosions. 1983

08:01:58	M1013	Fire in ER space
08:02:00	ME068	Oil mist in machinery space
08:02:25	M1029	Cargo pump hydr system failure

The time between the fire detection alarm (simultaneous with the shut-down of the air conditioning system) and the alarm for detection of oil mist within the machinery space, from an oil mist detector directly above the hydraulic pumps, was a mere two seconds. This indicates that the fire must have been ignited almost immediately after the beginning of the spray of oil, probably upon the failure of the O-ring. The cargo pump hydraulic system automatically shut down on low return line pressure 27 seconds after the initial alarm.

Although the source of ignition could not be ascertained with any certainty, there were two possibilities. The space on the pump side of the screen contained a considerable amount of electrical equipment, none of which was intrinsically safe. This included several fluorescent light fittings and control equipment, such as pressure switches, etc. There was a relatively high air pressure within the space, from the ventilation, causing a blast of air to flow continuously from the large grille between the hydraulic machinery room and the engine room. Situated immediately outside the grille, and directly in the path of the airflow, was a fluorescent light fitting, one end of which had suffered severe heat damage.

Considering that the light fitting may have been the source of ignition of a cloud of oil mist billowing out of the grille, it was submitted to the electricity supply authority of the Australian Capital Territory for examination. A close examination of the remains of the light fitting however, found no evidence of any pre-existing electrical fault which could have been a source of heat or, hence, ignition. The fitting had been severely burned by an ingress of burning oil, probably after the polycarbonate diffuser had been blown off by a pressure wave following ignition of the vapour cloud.

If the source of ignition was not electrical, the most likely cause was the heat of the exhaust trunking from the diesel engine driving No.3 hydraulic pump. The trunking runs almost directly above the pump, over the screen which partially separates the pumps from their prime-movers. The deckhead above the hydraulic module and particularly the area surrounding the exhaust trunks from the diesels showed the most

significant amount of heat and smoke damage. The exhaust trunking from No.3 diesel is lagged throughout its length and the lagging is covered with cleading. The trunking is supported by pipe-hangers which are attached to lugs welded to the trunking and which protrude through the cleading.

At the time of the fire alarm, the diesel engine driving No.3 hydraulic pump had been running at maximum load. The 3rd Mate was just reducing the speed of the cargo pump, as it had been on high speed for the discharge. Observation of No.2 pump during a subsequent cargo discharge showed that, with the pump on a relatively high load, the exhaust temperature, at the position of the sensor, about two metres back along the trunking towards the engine, was 440°C. The self, or auto, ignition temperature of Shell Tellus 46 hydraulic oil, from the relevant Shell Safety Data Sheet, is 320°C (min.). It is thus evident that, should any spray have found its way onto the suspension lugs which would be conducting heat from the trunking, or even through joints in the cleading, there is a high probability that it could have been ignited from this source.

For ignition of any fuel, sufficient energy has to be transferred to the fuel from the ignition source to exceed the minimum ignition energy of that fuel. For hydrocarbon fuels this is in the order of 0.25 millijoules, but depends on the concentration of the vapour and is at its minimum when the fuel is at its stoichiometric or ideal concentration. In addition, the concentration of the vapour has to be within its flammability range and the duration of the contact between fuel and ignition source has to be of sufficient duration for enough ignition energy to be transferred to the fuel. These conditions could all have been met if an atomised spray of hydraulic oil made contact with a hot surface on the exhaust trunk.

The response to the emergency

The immediate response by the ship's crew, the jetty supervisor and the fire brigade was rapid and effective. The crew mustered promptly and were quickly accounted for, whilst the Mate and IR followed correct BA procedures for entering the engine room and their entry was monitored using a BA control board.

At interview, however, the crew had difficulty in recalling the exact sequence of events. The whole incident had occurred within a short period and there was confusion about who had been where at any particular

time.

Because of the nature of the “fireball”, the amount of material that actually caught fire was small and the fireball itself was of very limited duration. The fire on the lagging and the small save-all fire were dealt with promptly by the Mate and IR.

The smoke cleared very rapidly, as the engine room vent flaps had not been closed. Although it appears that it was safe for the Chief Engineer to enter and he had carefully assessed the situation, he had done so apparently without anyone knowing. While the response may have been appropriate, there was poor communication because of the lack of available UHF radios at the fire scene. It is essential that, whatever the imperative, individuals ensure that they themselves do not become a victim and thereby exacerbate an emergency situation.

The same concern is raised when anyone, such as the 2nd Engineer in this instance, has a fire muster station in an engine control room, and the engine control room is situated within the engine room where the fire has been detected.

The emergency fire pump was later found to have failed to start because of an intermittent electrical fault in the power supply to the starting solenoid. In this instance, however, the fire was out before there was any requirement for the pump.

Conclusions

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

1. The fire was initiated by a combination of two factors: the failure of the bolts securing the pulse damper unit to the hydraulic pump, together with the failure of the supporting brackets connecting the damper to the pump body flange.
2. The failure of the bolts was initiated by fatigue crack growth due to insufficient preload (torque) upon assembly.
3. The failure of the supporting bracket was caused by vibration and inadequate design, once the weight of the HP filter unit had been added to the pulse damper.
4. Ignition of the resulting spray of hydraulic oil was, most probably, caused by oil mist contacting a hot surface on the exhaust trunking of No.3 diesel, the temperature of which was above the auto-ignition temperature of the oil.
5. The design of the installation in the hydraulic machinery room provided insufficient separation, or screening, between the pressurised components of the hydraulic system and the hot surfaces of the prime movers.

It is also considered:

6. The response by the ship's crew was rapid and effective.
7. Evidence from this and other incidents suggests that procedures relating to entry into spaces while fires are burning, or after they are believed to have been extinguished, should be reviewed and appropriate safety measures implemented.
8. The terminal emergency procedures for calling the Queensland Fire and Emergency Services are effective and appropriate.

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 parts of the report, was sent to the following:

The Master,

Chief Engineer, and

ASP Ship Management

Submissions were received from the Chief Engineer and ASP Ship management. The text was amended accordingly.

Details of Helix

IMO No.	9134713
Flag	Australia
Classification Society	Lloyd's Register of Shipping
Vessel type	Products Tanker
Owner	Phida Pty Ltd
Managing Agents	ASP Ship Management
Year of build	1997
Builder	Stocznia Szczecinska S.A.- Szczecin
Gross tonnage	28,810
Net tonnage	10,700
Summer deadweight	46,092 tonnes
Length overall	143 m
Breadth, extreme	182.960 m
Draught (summer)	32.61 m
Engine	Sulzer 6RTA52U
Engine power	8840 kW
Service speed	14.5 knots
Crew	18 (Australian)



ENGINEERING FAILURE ANALYSIS REPORT

HYDRAULIC PUMP JOINT FAILURE MV HELIX



1. INTRODUCTION

During the investigation of a fire aboard an Australian Oil Tanker, MV Helix, two of four cap screws used to attach a pulsation damper and filter/bypass assembly to one of the ship's cargo discharge hydraulic pumps were found fractured. It was considered that oil spraying from the loosened joint provided the immediate source of fuel for the fire. The general arrangement of the hydraulic pumps is shown in figure 1.



Figure 1. View of the cargo discharge hydraulic pumps showing the pulsation damper/filter bypass assembly removed from the pump with the failed joint. The locations of the cap screws used to secure the pulsation damper filter/bypass assemblies are indicated by arrows.

1.1 Component History

At the time of the fire the ship had been in service for 1 year. Six hydraulic pumps are provided for the discharge of liquid cargo. Prior to the engine fire the ship had completed 60 cargo discharge cycles.

2. CAP SCREW FRACTURE ANALYSIS

The damper and filter assembly is attached to the pump housing by four steel cap screws. The nominal diameter of the screws was 20mm. All four screws exhibited the grade marking 12,9. Two of the screws fractured as the result of fatigue crack growth. The remaining two screws were intact with no obvious indications of crack growth. The four cap screws from the hydraulic pump are shown in figure 2.



Figure 2. Cap screws from the failed pulsation damper filter/bypass hydraulic pump joint, as received.

An examination of the features of the two fractured screws indicated that the failure of one screw preceded the other.

Fatigue crack growth in the first screw to fracture was caused by an alternating stress state aligned with the axis of the screw. The plane of crack growth was normal to the axis of the screw. Fatigue cracking initiated in the root of the thread engaged in the pump housing, two thread forms from the joint surface. Following the growth of this initial fatigue crack and the accompanying changes in load transfer further fatigue cracking initiated in the screw from the thread root closest to the joint surface. The growth of multiple cracks resulted in the liberation of the small section of the screw, see figure 3.

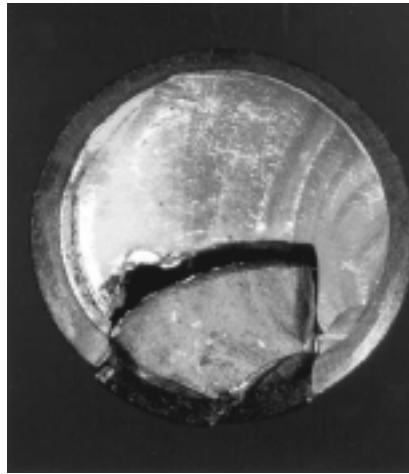
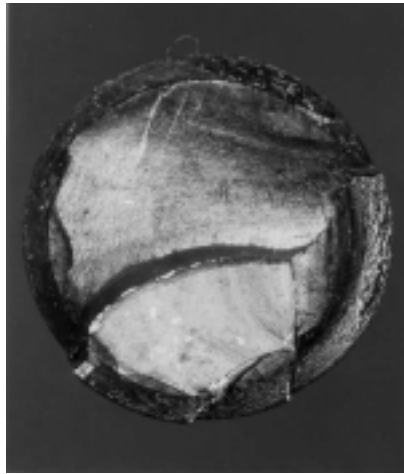


Figure 3. First screw to fracture, showing multiple crack growth. A detailed view of the primary fatigue fracture is shown, bottom right. A detailed view of the secondary crack (liberated section of the screw removed) is shown, bottom left.

No gross material abnormalities or geometric discontinuities were observed to be associated with the initiation of fatigue cracking during a nondestructive inspection of this screw, see figure 4



Figure 4. Detailed view of the site of primary fatigue crack initiation.

The features of fatigue crack growth in the second screw are consistent with the application of alternating, rotating, prying loads under the head of the screw. Fatigue cracking initiated at a number of sites in the root of the first engaged thread. Crack growth extended on planes inclined to the axis of the screw, see figure 5. This type of fatigue crack growth is consistent with a loosening of the bolted joint following the fracture of the first screw.

Wear on the edge of the bearing surface of the cap screw head is consistent with an alternating prying loading condition created after joint loosening.

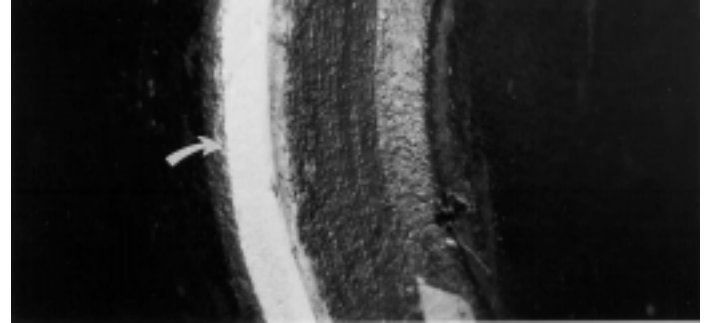


Figure 5. Fatigue fracture, second cap screw. A detailed view of the wear on the edge of the cap screw head is shown at the bottom of the figure.

3.

FAILURE ANALYSIS

The failure of two cap screws in the pulsation damper filter/bypass mechanical joint indicates that the magnitude of the alternating loads imposed on the screws during the operation of the hydraulic pump exceeded the fatigue endurance stress for the screws.

The primary defence against fatigue in screws/bolts subjected to alternating stresses during operation is the establishment of an appropriate preload in the shank of the screw during assembly. The most common method of establishing this preload is by applying a torque to the screw head during tightening. If the magnitude of the alternating load applied to the screws does not exceed the preload in the screws and the stiffness of the screws is less than the joint, then the magnitude of the alternating load experienced by the screws will be small

It was reported that the manufacturer specified a screw tightening torque of 640 Nm. It is not unusual for this value to exceed the torque value specified in the hydraulic pump repair manual for the standard installation of screws of the same size and grade (590 Nm for a M20, 12,9 grade screw).

It was notable during the examination of the bearing surfaces of the threads and screw heads that there was little evidence of interaction with the mating surfaces in the pump housing and damper assembly, see figures 6 and 7. This lack of surface interaction (scoring, ploughing) may indicate a low assembly torque and, consequently, a low preload in the screw.

The breakaway torque of the cap screws installed in the remaining hydraulic pumps was reported to be 250Nm, considerably less than the specified 640Nm. This low value of breakaway torque supports the hypothesis that the preload in the cap screws created during assembly was inadequate

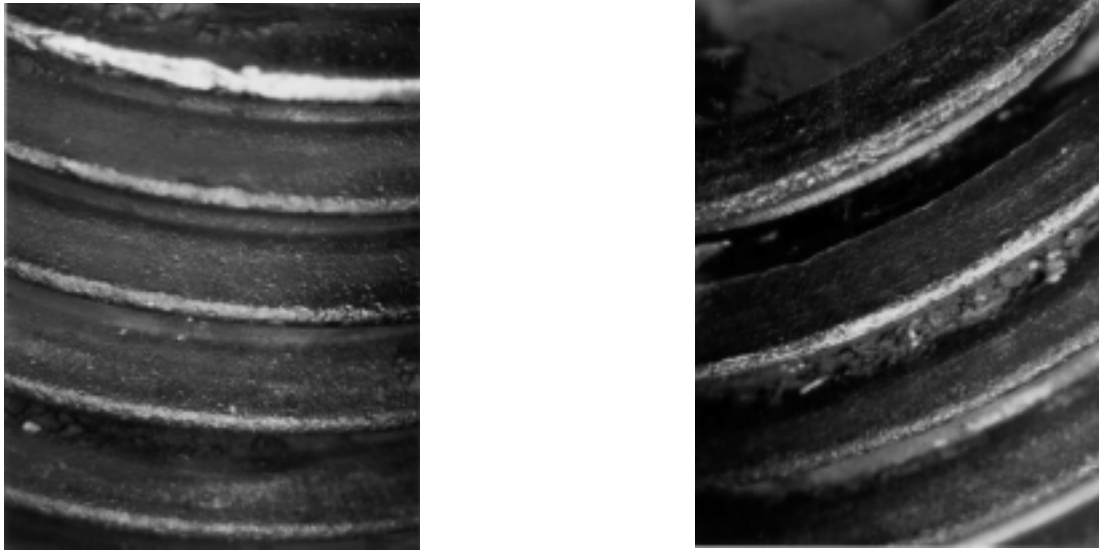


Figure 6. Detailed views of the loaded thread flanks of an intact cap screw from the failed joint (left) and the cap screw that fractured first (right).

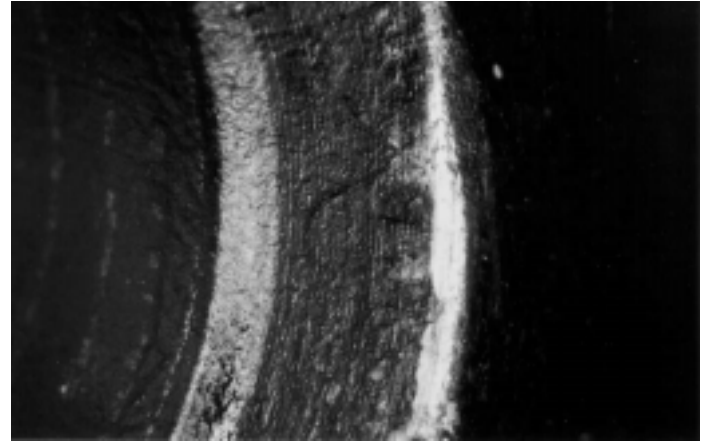
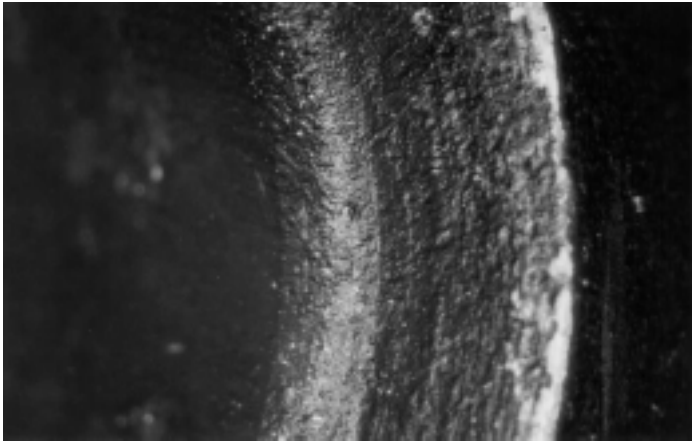


Figure 7. Detailed views showing the bearing surface under the heads of two cap screws from the failed joint.

No anomalies were observed in the thread forms of the fractured screws that may have increased thread friction and, as a consequence, reduced the preload established by the application of the specified assembly torque.

3. CONCLUSIONS

The fractures of two cap screws employed to attach a pulsation damper filter/bypass assembly to a hydraulic pump on the Australian oil tanker, MV Helix, were caused by fatigue.

The available evidence indicates that the significant factor in the fatigue fracture in two cap screws was an inadequate preload in the cap screws. It is likely that the cap screws were not tightened by the application of the specified torque. No evidence of any thread anomalies or defects that may have interfered with the creation of an adequate preload under specified tightening conditions was found.

Dr A. Romeyn

8-2-1999

Air Safety Investigator (Engineering Failure Analysis)