Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Marine Occurrence Investigation No. 234
Final

Independent investigation into the engine room fire on board the French Antarctic supply ship

L'Astrolabe

in the Southern Ocean, south of Hobart, Tasmania

11 November 2006

Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Marine Occurrence Investigation
No. 234
Final

Independent investigation into the engine room fire on board the French Antarctic supply ship

L'Astrolabe

in the Southern Ocean, south of Hobart, Tasmania
11 November 2006

Published by:	Australian Transport Safety Bureau
Postal address:	PO Box 967, Civic Square ACT 2608
Office location:	15 Mort Street, Canberra City, Australian Capital Territory
Telephone:	1800 621 372; from overseas + 61 2 6274 6440
	Accident and incident notification: 1800 011 034 (24 hours)
Facsimile:	02 6247 3117; from overseas + 61 2 6247 3117
E-mail:	atsbinfo@atsb.gov.au
Internet:	www.atsb.gov.au

ISBN and formal report title: see 'Document retrieval information' on page v.

CONTENTS

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication Date	No. of pages	ISBN	ISSN
234	June 2007	40	978-1-921164-90-3	1447-087X

Publication Title

Independent investigation into the engine room fire on board the French Antarctic supply ship *L'Astrolabe* in the Southern Ocean, south of Hobart, Tasmania on 11 November 2006.

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference number

Jun2007/DOTARS 50280

Abstract

At about 0530 on 11 November 2006, a fire started in the engine room on board the Antarctic supply ship *L'Astrolabe*. The fire was fed by a spray of diesel fuel from a leak that had developed in the starboard main engine fuel system.

The ship's crew closed the remotely operated, fuel system quick closing valves, which shut down all of the main and auxiliary engines, isolated all ventilation to the engine room and then operated the engine room's fixed fire extinguishing system.

By 0620, the fire had been extinguished and the crew worked to restart the ship's main and auxiliary engines. By about 1200, *L'Astrolabe* had resumed its passage to Hobart using its port main engine and, by 1030 on 12 November, the starboard main engine was also back in service.

The ATSB's investigation found that the fire was caused by a leak of diesel fuel, probably in the form of a spray, from a temporary blanking arrangement on the starboard main engine. The fuel ignited when it came into contact with the hot surfaces of the starboard main engine.

The report identifies a number of safety issues and issued one recommendation and three safety advisory notices.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, risk controls and organisational influences.

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety issues can broadly be classified in terms of their level of risk as follows:

- **Critical safety issue**: associated with an intolerable level of risk.
- **Significant safety issue**: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.
- **Minor safety issue**: associated with a broadly acceptable level of risk.

EXECUTIVE SUMMARY

On 5 November 2006, the Antarctic supply ship *L'Astrolabe* sailed from the French Antarctic base at Dumont d'Urville, bound for Hobart, Tasmania. The ship was carrying 12 crew and 13 passengers. Two helicopters, containerised and other cargo was stowed inside the garage and there were drums of aviation fuel in one of the cargo holds.

On 7 November, the engineers discovered that the starboard main engine's main fuel pump was leaking. In order to run the engine, they fitted blanks to the main fuel pump's supply pipe and the fuel pipe between the engine's fuel rail and the main pump before running a stand-by, electrically driven, pump to supply fuel to the engine.

At about 0530[1] on 11 November, while the ship was still 320 nautical miles south of Hobart, a fire started in the engine room. The fire was fed by a spray of diesel fuel from a leak in the starboard main engine fuel system that had been ignited by contact with the hot surfaces on the engine.

The ship's crew closed the fuel system remotely operated quick closing valves, which shut down all of the main and auxiliary engines, isolated all ventilation to the engine room and then operated the engine room's fixed fire extinguishing system.

By 0620, the fire was declared extinguished and at 0700 the crew re-entered the engine room to try to restart the ship's engines. The engineers fabricated a new control system for the ship's main engine governors and, by about 1200, *L'Astrolabe* had resumed its passage to Hobart using its port main engine. By 1030 on 12 November, the starboard main engine was also back in service.

The report identifies the following safety issues and makes one recommendation and three safety advisory notices:

1. The absence of a discharge valve on the main fuel pump required blanks to be fitted into the fuel system so that the engine could be run using the stand-by pump, while keeping the main pump depressurised.
2. The fitting of gasket discs in an open ended cap to blank off a fuel pipe was ineffective for the task because the discs probably became loose due to the effect of pressure pulses within the fuel pipe, allowing fuel to spray into the engine room where it was ignited on the hot surfaces of the engine.
3. Leaving doors open between the engine room and the fire control station exposed the ship to the risk that its fire control systems could be rendered inoperable by an engine room fire.
4. The ship's procedures for re-entry into the engine room after the operation of the FM-200 fire extinguishing system did not adequately consider the time required to cool the fire scene and did not provide the master with adequate guidance about when to safely re-enter the engine room, therefore, exposing the ship to the potential risk of re-ignition.
5. The practice of re-opening the fuel service tank quick closing valve after the fire, without first isolating individual fuel circuits, exposed the ship to the risk of another fuel leak and possible re-ignition.

---

1 All times referred to in this report are local time, Coordinated Universal Time (UTC) + 11 hours.

1 FACTUAL INFORMATION

1.1 *L'Astrolabe*

L'Astrolabe is an Antarctic supply ship that supports the French Antarctic Base at Dumont d'Urville, approximately 1450 miles[2] south of Hobart. Between December and March every year, *L'Astrolabe* undertakes about five return voyages between Hobart and Antarctica.

The ship was built as the offshore supply vessel *Fort Resolution* in 1986 by Ferguson - Ailsa Shipbuilders in Glasgow, Scotland. It was converted for its current role, and renamed *L'Astrolabe*, in 1988. The conversion included the addition of accommodation for 50 passengers and an enclosed cargo space above the engine room, known on board as the 'garage'. Above the garage is a helicopter platform that is used for helicopter operations while the ship is in the Antarctic.

Figure 1: ***L'Astrolabe***

L'Astrolabe is owned and managed by Bourbon Offshore Surf in Marseille, France and is on a long-term charter to the Institut Polaire Francais. The ship is registered in France and is classed with Bureau Veritas (BV) as a ✠1.3/3 Ice-Class I Super Special Service Polar[3] ship.

The ship has an overall length of 65.36 m, a beam of 13.06 m, a moulded depth of 5.36 m and, at its summer draught of 4.782 m, has a deadweight of 949 tonnes.

Propulsive power is provided by two Mirrlees Blackstone 8MB275 non-reversing, four stroke, medium speed diesel engines, each producing a maximum of 2300 kW. Each engine drives a single propeller shaft, and a controllable pitch propeller (CPP), through a reduction gearbox. Together they give the ship a service speed of 12 knots[4].

2 A nautical mile of 1852 m.

3 Class notations indicating that the ship is classed for navigation in extreme ice conditions and the 'Special service' notation is assigned to ships which are not covered by other specific notations.

4 A knot is one nautical mile per hour.

Helicopters and cargo, often in the form of containers and pallets, can be carried in the garage. At the time of the incident, there were two helicopters and several pallets of aviation fuel stored in the garage.

Immediately forward of the engine room are the bulk cargo pods that were originally installed when the ship was built. The pods have been converted to fuel storage tanks for carrying fuel to the Antarctic base and, at the time of the incident, contained about 150 cubic metres of diesel fuel.

Immediately aft of the engine room, below the garage deck, are three cargo holds which are used to store 205 litre drums of aviation fuel. At the time of the incident, the starboard hold contained 45 drums of aviation fuel and the other two holds were empty.

At the time of the incident, the ship had a complement of 12 crew members and 13 passengers. The crew had all rejoined the ship in October 2006 for the start of the Antarctic resupply season. The master, both mates, both engineers, and the chief cook were French nationals. The remaining crew were Ukrainian nationals.

All of the ship's officers had been trained in France and held appropriate French certificates of competency. The master and two mates maintained a standard 'four hours on, eight hours off' watchkeeping routine. The engineers worked a twenty-four hour duty roster with the engine room unmanned outside daylight working hours. Each able seaman (AB) worked a 'four hours on, eight hours off' watch routine and conducted hourly inspections of the ship, including the engine room, during their bridge watch.

L'Astrolabe's master began his seagoing career in 1975 and, in 2000, he gained his foreign-going master's certificate. He had been master of the ship since October 2004.

The chief mate had been at sea since 1993. He held a French dual certificate as both a master and a chief engineer. He first joined *L'Astrolabe* in December 2004 and sailed on board the ship as second engineer from then until the end of January 2005. The next season, he sailed as chief mate from October 2005 until the end of January 2006.

The chief engineer first went to sea in 1982. He qualified as a chief engineer in 1996 and had been the chief engineer on board *L'Astrolabe* since 2002.

The second engineer held a dual certificate and had been at sea since 1999. At the time of the incident, he was starting his second season on board *L'Astrolabe*. He had sailed on board the ship as second mate during the previous season.

1.2 Main engine fuel system

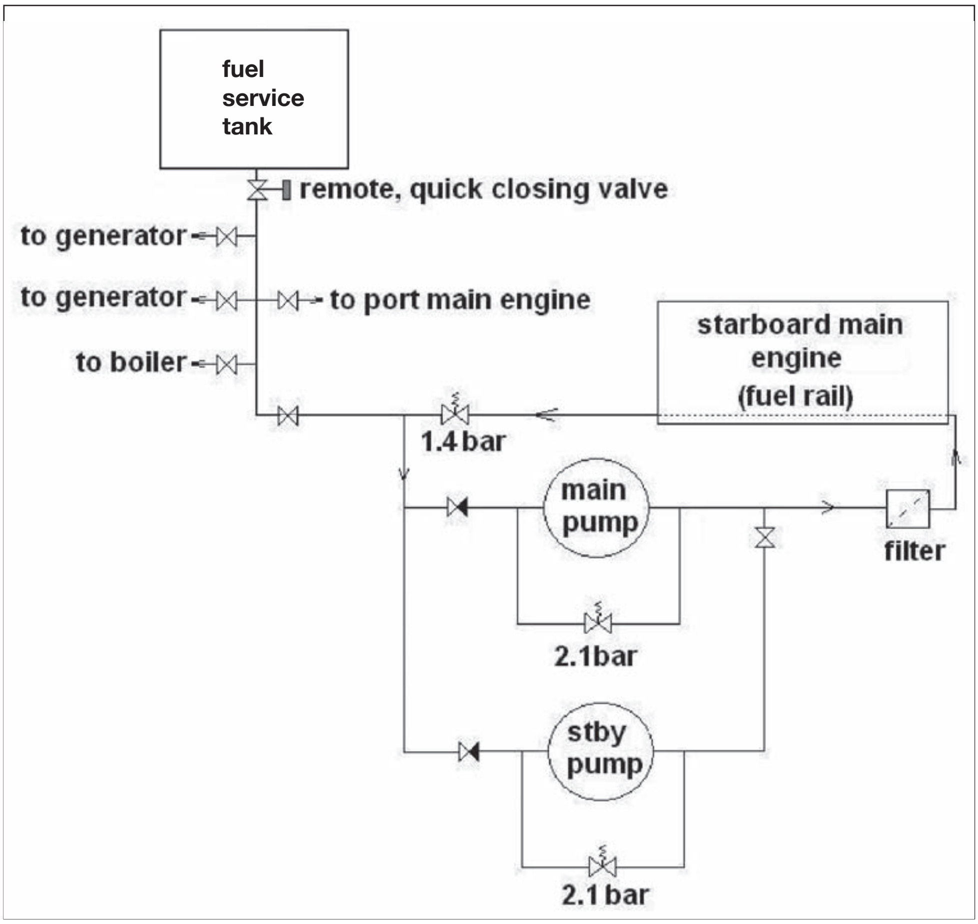
The main and auxiliary engines on board *L'Astrolabe* use marine diesel oil for fuel. Fuel is stored in storage tanks and transferred to a service tank for use in the engines.

Each main engine is fitted with an engine driven main fuel pump. If this pump fails, an electrically driven standby pump can be used to supply fuel to the engine's fuel rail (Figure 2).

The fuel rail pressure is normally maintained at 1.4 bar[5] by a pressure regulating valve. Each pump has a pressure relief valve, set at 2.1 bar, to protect it from over-pressurisation.

5 1 bar = 100 kPa (approximately one atmosphere).

Figure 2: Fuel system schematic drawing



There is no discharge valve fitted after the main pump. Therefore, if the standby pump is operated, the main pump's screw down non-return inlet valve prevents the flow of fuel back through the main pump but the main fuel pump's body remains pressurised. If there is a need to remove the main pump and run the engine on the standby pump, a blank needs to be fitted on the main pump's discharge side.

1.3 Fire control systems

A Minerva Marine fire detection system, with an indicator panel installed on the bridge, is used to monitor *L'Astrolabe*'s engine room for fires. The engine room is fitted with one infra-red flame detector and ten ionization type combustion products (smoke) detectors.

When built, the ship's engine room was fitted with a Halon fixed fire extinguishing system. Halon has been identified as an ozone depleting substance under the Montreal Protocol (1989) and was replaced on board *L'Astrolabe* with FM-200 in 2003.

FM-200 is a trade name for heptafluoro-propane, a colourless and odourless halocarbon gas. FM-200 does not damage electrical or electronic equipment and it has a low toxicity. FM-200 extinguishes a fire by absorbing heat from the flame and this causes the gas to decompose. The decomposition of FM-200 also disrupts the chemical reactions occurring within the combustion process. FM-200, in concentrations as low as 8.6% by volume in air, is effective at extinguishing fuel fires. FM-200 has a high heat capacity but a low thermal conductivity and, thus, does not effectively cool areas affected by a fire; thereby increasing the danger of re-ignition if the space is ventilated too soon after the gas has been released.

The FM-200 system on board *L'Astrolabe* is a single use system that has four cylinders of FM-200 located in different locations within the engine room. The cylinders are fitted with pneumatically operated release valves fed by pressure from pilot gas bottles. The pilot bottles are located within the FM-200 release cabinet. The FM-200 release cabinet, together with the quick closing valve panel and the engine room fan and pump emergency stop panel, is located in the workshop space adjacent to the main engine room entrance.

The cargo hold bulkhead aft of the engine room and the control room bulkheads have an A60[6] fire rating. The deck separating the garage from the engine room and cargo holds also has an A60 rating.

The cargo holds are all fitted with a water sprinkler system that is supplied from a dedicated pump, temperature sensors and two separate smoke detection loops.

The emergency fire pump is located in the bow thruster machinery room. It is driven by its own small diesel engine.

The FM-200 system was serviced on 5 October 2006 in preparation for the annual safety equipment survey on 17 October. The fire dampers, emergency fire pump and quick closing valves were also inspected and tested during this survey.

1.4 The incident

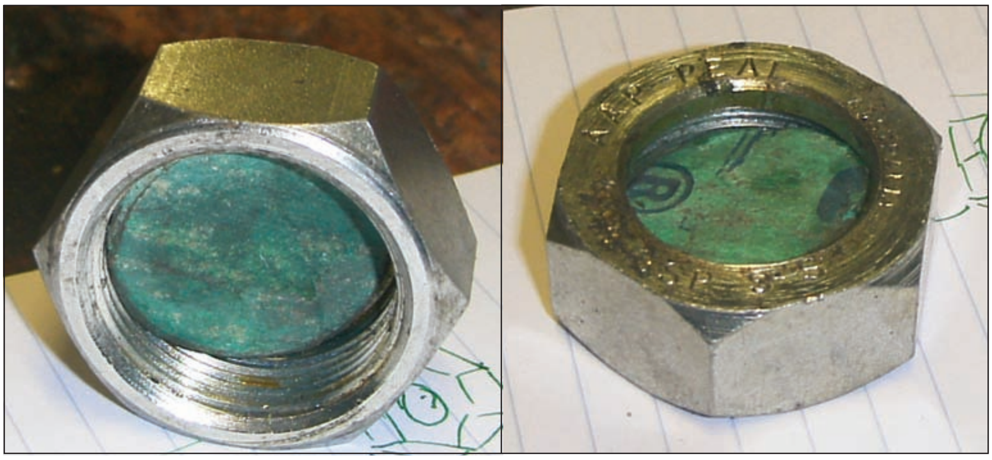
At about 1500 on 5 November, *L'Astrolabe* sailed from the French Antarctic base, Dumont d'Urville, bound for Hobart, Tasmania.

At 1600 on 7 November, as the ship was clearing the ice, the engineers noticed that the main fuel supply pump on the starboard main engine was leaking fuel from the shaft seal. The engine was stopped and the main pump was removed from the engine to replace the seal.

After the pump had been disassembled, the engineers discovered that the pump's shaft bearing had also failed. There were no spare pump shaft bearings on board the ship so the engineers decided to run the engine using the electrically driven standby pump. They refitted the main pump, to close the opening in the engine's drive casing, and removed the main pump's drive coupling to prevent it from revolving. The engineers then removed the short fuel pipe sections adjacent to the pump before the fuel supply pipe and the fuel rail connection to the main pump were blanked off.

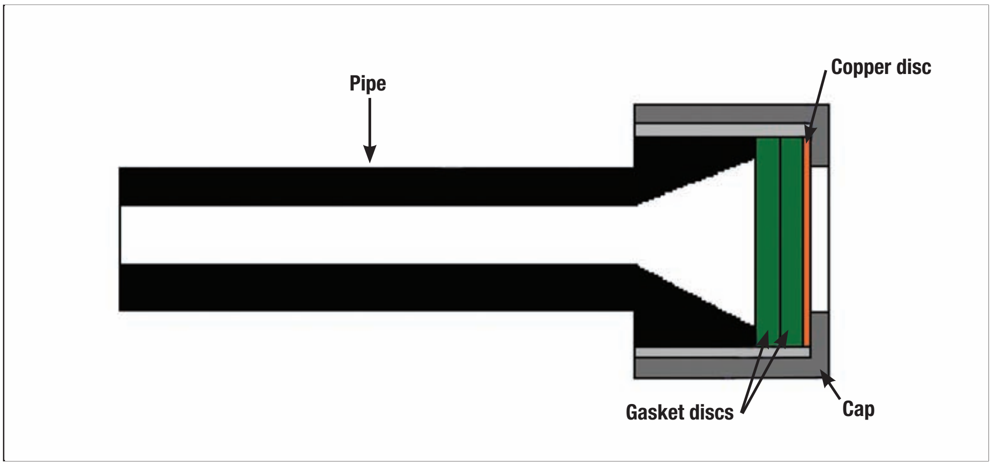
6 A60 surfaces must prevent the passage of smoke, heat and flame for a minimum of 60 minutes.

Figure 3: Similar blanking materials



Each pipe was blanked off using two discs of flexible gasket material, backed by a copper disc, held against the pipe end by an open ended, threaded pipe union fitting (Figures 3 and 4). At 2100, the starboard main engine was re-started. There were no leaks from the blank so the engine was clutched in and returned to service.

Figure 4: Drawing of blanking arrangement



At about 0255 on 11 November, during a routine inspection, the AB on watch noticed a small fuel leak from the starboard main engine number seven fuel injector return pipe. The chief engineer was called and he stopped the engine to repair the leak. At 0300, the engine was restarted and there were no fuel leaks visible on the engine.

The AB conducted his normal ship rounds at 0400 and again at about 0455. He noticed nothing abnormal in the engine room during either of these inspections.

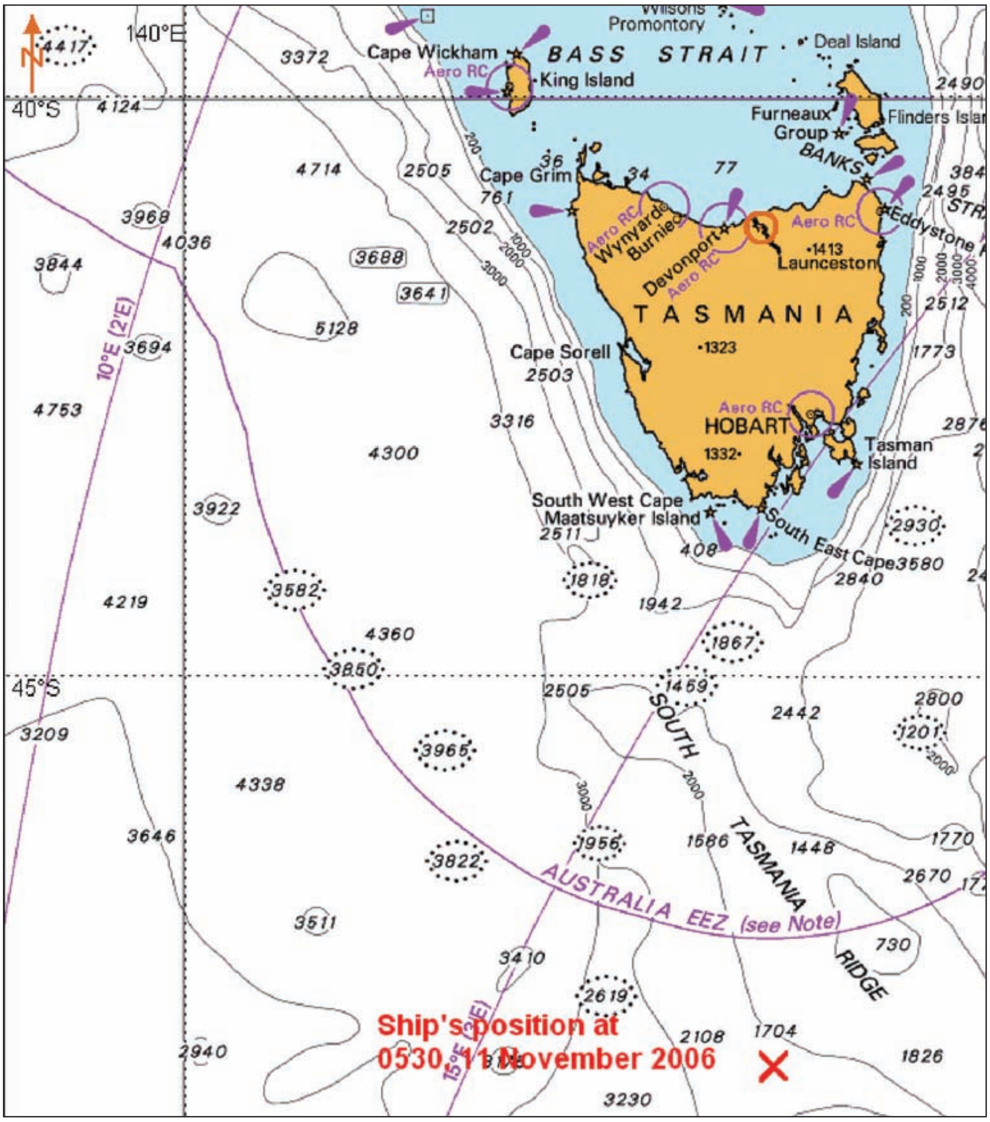
At 0530, when the ship was still about 320 miles from Hobart (Figure 5), the fire alarm sounded, indicating that an engine room fire detector had activated. The chief mate, who was on watch, instructed the AB to go to the engine room and investigate the reason for the fire alarm.

The AB entered the engine room, through an open door, and advanced until he was adjacent to the port side of the engine control room. He could see smoke covering the engine room deckhead. As he moved towards the centreline of the ship, he saw bright flames between the two main engines. Using his hand held radio he immediately reported to the chief mate that there was a fire in the engine room. He realised that the fire was too intense to be extinguished with a portable fire extinguisher so he left the engine room, shutting the door behind him. After leaving the engine room, he went to his muster station.

By this time, the fire alarm bells were ringing throughout the ship. The chief mate left the bridge and went down to the next deck where he opened cabin doors and shouted that there was a fire in the engine room. When the master and chief engineer were awake, the chief mate went to start shutting off the engine room ventilation.

After being woken by the chief mate, the master went to the bridge. As he arrived on the bridge, he looked through the rear bridge windows and saw clouds of thick black smoke billowing from the funnel vents behind the bridge. He decided that the best response to the fire would be to operate the engine room fixed FM-200 fire extinguishing system as quickly as possible.

Figure 5: Section of chart Aus 4074, showing ship's position when the fire occurred



The chief engineer arrived at his muster station in the engineer's workshop and, noticing that the engine room door had become hot to touch, realised that there was a serious engine room fire. He immediately started operating the remotely operated, fuel and oil system quick closing valves. The second engineer began donning a fireman's outfit at the muster station.

By 0540, all of the ventilation and fuel had been shut down in the engine room and the chief engineer and chief mate discharged the FM-200 fixed fire extinguishing system into the engine room on the master's order.

After the FM-200 was released, the chief mate and chief engineer went forward to start the emergency fire pump so that the crew could provide a spray of water onto the garage deck. The deck had not become hot when they started applying the water.

At 0600, the master decided that the chief mate and second engineer should enter the engine room, wearing their fireman's outfits and breathing apparatus, to see if the fire had been extinguished. The two men entered the engine room through the port side door carrying torches and a handheld radio. The visibility within the engine room was about one metre. The men walked carefully around the engine room looking for any signs that the fire might still be burning. They did not see any flames or feel any areas that were hotter than the rest of the engine room. They determined that the fire had been extinguished and left the engine room at about 0620.

At 0700, the chief mate and second engineer re-entered the engine room to recommission the engine room machinery. There was no sign of fire so they opened the quick closing valve for the diesel fuel service tank and tried to start the emergency air compressor.

They found that the small diesel engine driving the emergency air compressor would not run because of the smoke in the engine room so they opened some of the vent flaps to start ventilating the engine room.

At 0735, the emergency air compressor was started but the air pressure in the air receivers did not increase. On investigation, it was found that the plastic bowls on the service air moisture drain traps had melted in the fire, allowing the air to escape. After the service air system was isolated, the air pressure began to rise.

By 0930, there was sufficient air pressure in one air reservoir to start a generator. Most of the circuit breakers were opened at the switchboard before number two generator was started and connected to it. By 0940, power was restored to the parts of the ship that had not been affected by the fire.

At 1020, the master informed the Australian Maritime Safety Authority (AMSA) and the ship's manager of the fire and that the situation was under control.

Once power was restored, the engineers began an inspection of the engine room. The electrical cables and light fittings above the main engines had been severely damaged so some emergency lighting was rigged to make it safer to work in the area.

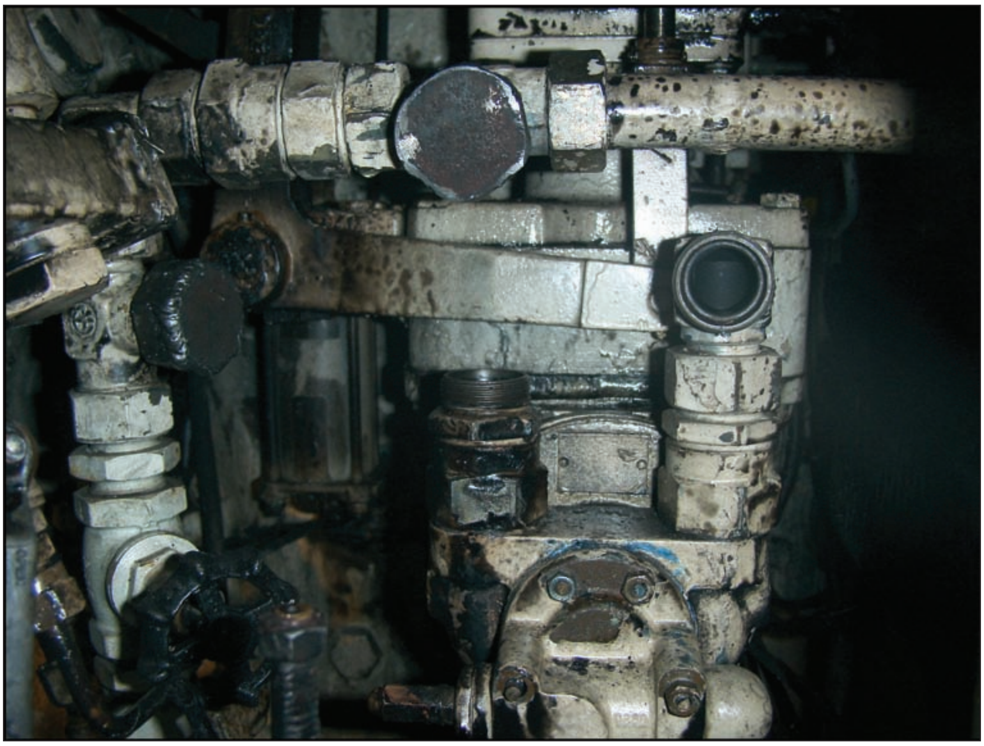
The port main engine appeared to be undamaged so the chief engineer made preparations to start it. The control cables from the control room to the engine had been destroyed in the fire, including the cables for an air regulator that supplied the speed setting air for the engine's governor. The chief engineer assembled a manual air pressure regulator from spare air fittings to supply the governor speed setting air.

At about 1200 the port main engine was started and inspected. After some adjustments were made to the new governor speed setting arrangement, the engine was clutched in. At 1310, control of the propeller was transferred to the bridge and the ship resumed its passage to Hobart.

The engineers inspected the starboard main engine. There appeared to be no mechanical damage to the engine. However, the engine had the same damage to its control wiring and its governor control air system as the port engine. There was also damaged insulation on the wiring for the electrically driven pre-lubrication pump. The blanking discs were also found to be missing from the blanked discharge pipe near the main fuel pump.

The chief engineer fabricated new blanking caps for the fuel pipes (Figure 6) and also another governor speed setting regulator. The pre-lubricating pump could be run, despite the damaged wiring, so the engineers used it to lubricate the engine.

Figure 6: Welded blanking caps



At 1700, the starboard main engine was started and control of the propeller was transferred to the bridge. At 1730, the engineers stopped the engine again because a hydraulic pipe on the reduction gearbox was leaking. The broken pipe was repaired and the engine re-started but, due to another leak, it was stopped again.

With the ship sailing towards Hobart on one engine, the engineers decided to rest overnight and continue recommissioning the starboard engine in the morning.

On 12 November, the engineers replenished the oil lost from the starboard gearbox and repaired the leak. The engine was restarted at 1030 and control of the propeller was passed to the bridge at 1100 with the engine running at 80% load.

At 2100, *L'Astrolabe* arrived in Storm Bay, near Hobart, and reduced its speed in order to berth at first light the following morning. At 0730 on 13 November, *L'Astrolabe* was securely berthed at number three Macquarie Wharf, Hobart.

2 ANALYSIS

2.1 Evidence

On 13 November 2006, two investigators from the Australian Transport Safety Bureau (ATSB) boarded *L'Astrolabe* in Hobart. The master, chief mate, second mate, the AB on watch, chief engineer and second engineer were interviewed and relevant documents and records were obtained. The evidence included copies of log books, equipment manuals and drawings, emergency procedures and checklists, standing orders and various procedures. The investigators also examined and photographed the engine room, particularly the seat of the fire, to identify the source of the fuel and the possible sources of ignition.

2.1.1 Fire scene examination

An examination of the fire scene revealed that the area that was affected by heat extended along the deck head to about 3 m aft of the electrical starter panels between the engines and forward to the control room bulkhead. The direction of travel of the heat was from the seat of the fire and forward towards the funnels (Figure 7), as directed by the ventilation within the engine room. The worst damage was limited to the inboard side of the starboard engine, the electrical panels adjacent to it and the deck head above this area.

Figure 7: Fire damage and spray path diagram

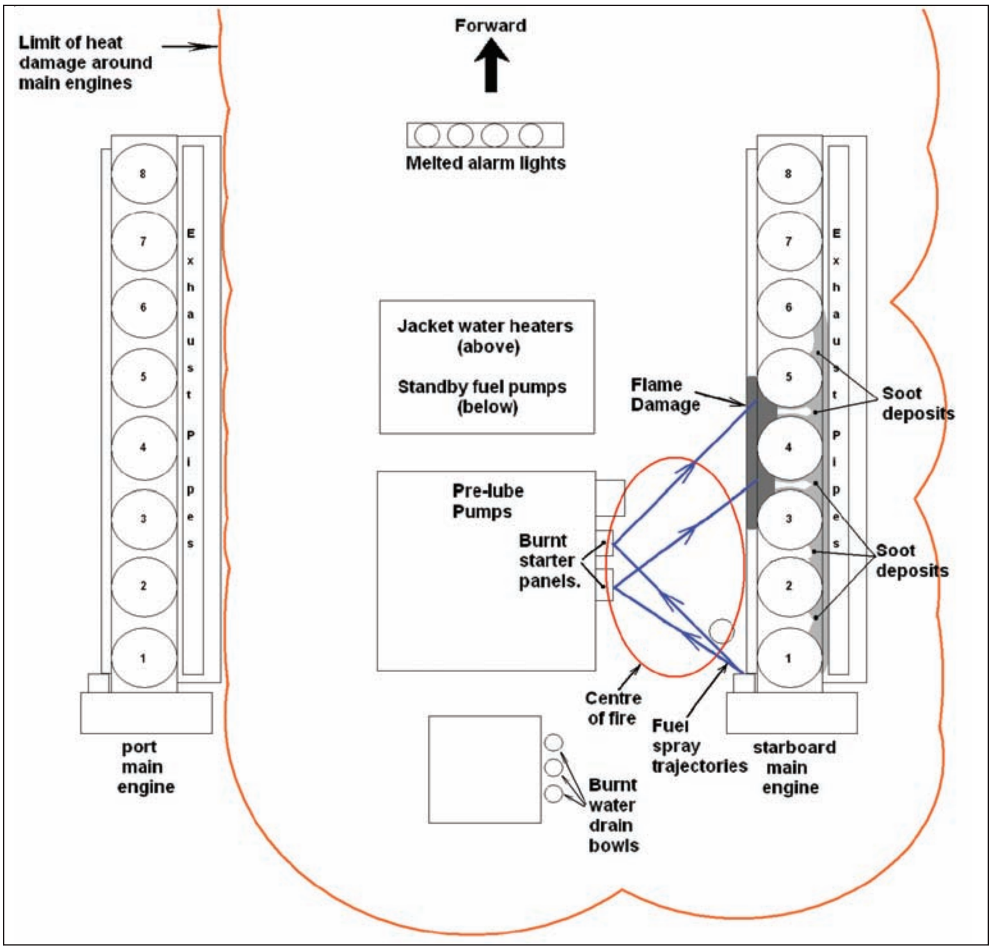
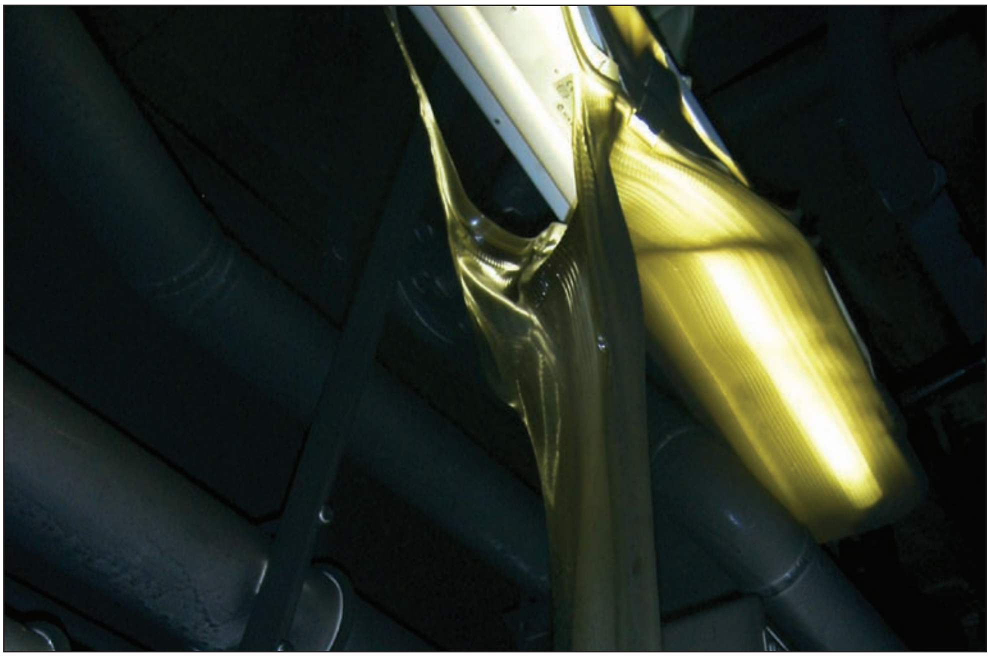


Figure 8: Melted light diffuser



All of the fluorescent lights in the heat affected area were either damaged or destroyed. The fluorescent light fitting mounted forward of the starboard main engine, and about one metre below the deck head, had melted (Figure 8). This indicated that the temperature reached in this area was in excess of 240°C, the melting point of the polycarbonate diffuser.

Figure 9: Melted alarm lights

A bank of alarm lights mounted about 1.5 m below the deck head forward of the engines was also damaged (Figures 7 and 9). The lower degree of heat damage to the covers indicates that these lights were exposed to less heat.

There was no flame or heat damage to the port main engine or to the port side of the jacket water heaters or pre-lubricating pumps located on the centreline between the two main engines.

These observations indicated that the fire was intense but localised and was centred near the starboard main engine fuel pump (Figure 7).

2.2 Source of the fuel

After the fire, an inspection by the engineers revealed that the blanking cap that they had fitted to the starboard main engine fuel pump discharge pipe was loose and the blanking discs were missing. The blank fitted to the supply pipe appeared to be intact. The main flame damaged area was directly in line with the end of the pipe at the missing blank (Figure 7). This indicated that, at some time before the fire started, fuel had probably sprayed from the pipe where the blank was fitted.

Pressure pulses occur in diesel engine low pressure fuel pipes as the fuel injection pump for each cylinder operates. Each pump contains a plunger, driven by the camshaft, which forces the fuel into the high pressure injection pipe as the pump plunger scroll moves upwards and covers the fill and spill ports. At the end of injection, the plunger scroll uncovers the spill port, allowing fuel at high pressure to spill back into the low pressure fuel rail which causes a pressure wave or pulse in the rail. Medium speed engines running on marine diesel fuel can have short duration pressure pulses of up to 41 bar[7] in the low pressure fuel system, regardless of the action of pressure regulating valves or pressure relief valves.

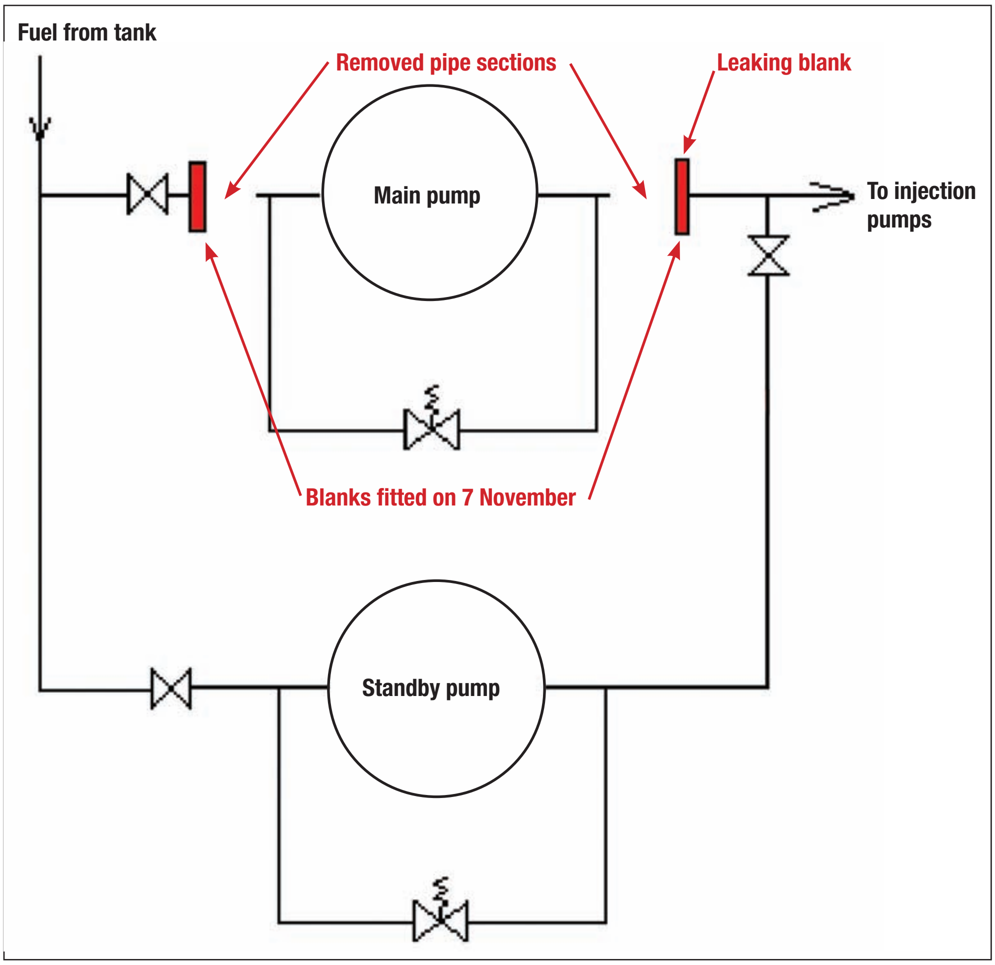
In the case of the blank fitted to the main fuel pump discharge line by *L'Astrolabe*'s engineers, as the pressure pulses occurred within the fuel rail, the gasket and the thin copper discs fitted between the pipe taper and the open ended cap (Figure 4) would have flexed like a diaphragm. The flexing of the discs would have allowed them to deform and become progressively looser within the cap. Ultimately, it is probable that the discs became loose enough to allow a fuel leak to develop.

The fuel leaking past the discs would probably have been in the form of a fine spray which was directed away from the engine and towards the electrical starter panels and pumps located between the engines. The spray was then probably deflected off the electrical panels and back towards the starboard main engine (Figure 7).

On 7 November, the engineers needed to stop fuel leaking from the damaged shaft seal of the main fuel pump. They fitted blanks to the supply and discharge pipes (Figure 10) so that they could run the engine using the stand by pump and stop the main pump from becoming pressurised. If a valve had been fitted in the main fuel pump's discharge pipe, the blanks would not have been necessary. The act of closing the isolating valves would have prevented the pump's body from becoming pressurised while running the stand-by pump and the integrity of the fuel system would have remained intact.

7 Galpin R. and Davies M., Failures of Low Pressure Fuel Systems on Ships' Diesel Engines, BMT Edon Liddiard Vince Ltd, England, 1997.

Figure 10: Section of fuel system schematic showing location of blanks



By using a set of gasket and copper discs held against a tapered pipe by an open ended cap, the engineers fabricated a blank, on 7 November, for the fuel rail on the starboard main engine that was unsuitable for the task because of the pressure pulses within the fuel system. The failure of the blanking arrangement resulted in the fuel leak which ultimately led to the fire.

2.3 The ignition source

After a thorough examination of the fire scene, the ATSB investigators determined that there were four possible ignition sources; the port main engine exhaust pipes, the electrical starter panels in line with the fuel spray, the starboard main engine exhaust pipes and the starboard main engine indicator cocks[8].

Further examination revealed that the port main engine exhaust pipes were too far from the spraying fuel, the path to them was blocked by the starter panels, pumps and frames and there was no evidence of flame impingement or soot on the heat-shield or exhaust pipes of this engine.

The electrical starter panels for the jacket water heaters were in line with the spray of leaking fuel (Figure 7) but these panels had rubber seals on the panel's covers. Furthermore, power to the starter panels was isolated by pulling out the circuit

8 A valve connected directly to the combustion chamber that can be used to mount an instrument or pressure gauge to monitor combustion within the engine.

breakers (Figure 11) so it is extremely unlikely that ignition could have occurred inside the panel. The outside of the starter panels and the wiring inside the panels was burnt by the heat from the burning spray of fuel that impinged on them but there was no evidence of burnt fuel inside the panels. This indicates that the starter panels almost certainly did not provide the ignition source for the fire.

Figure 11: Jacket water heater starter panel

An analysis of the likely fuel trajectory shows that the spray of fuel had probably deflected off the starter panels and been directed back towards the starboard main engine cylinder heads (Figures 7 and 12). The indicator cocks are located on the inboard side of the engine and parts of the exhaust pipes are also in line with the deflected fuel spray.

A detailed inspection of the starboard main engine revealed a layer of fine soot between the cylinder heads and inside the heat shield around the exhaust pipes between number two and number six cylinders. There were also signs of flame impingement between number three and number five cylinders on the inboard side of the engine (Figure 12).

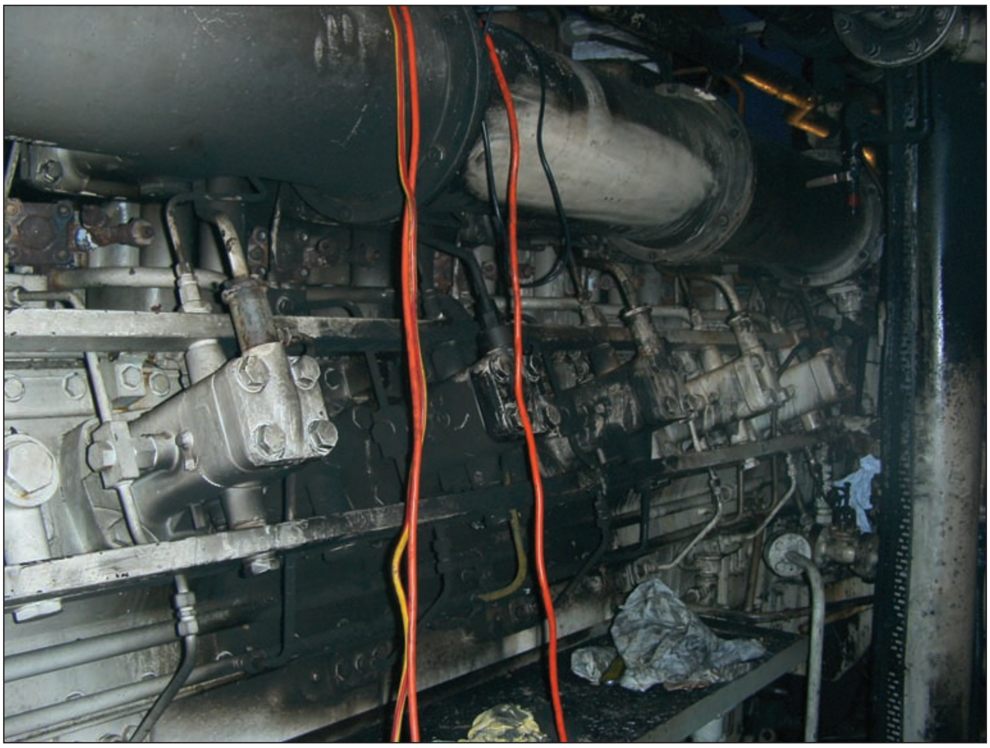
The engine exhaust temperatures, and hence the exhaust pipe temperatures, had been recorded at between 320°C and 400°C with the engine running at its normal load, well in excess of 260°C, the auto ignition temperature[9] of diesel fuel.

The indicator cocks were also hot, although normally cooler than the exhaust pipe due to the cooling effect of the cylinder's cooling water jacket, and were also in line with the deflected fuel spray. Temperatures in excess of 260°C have been recorded on indicator cock bodies[10]. The area surrounding the number four indicator cock was also blackened and covered with soot (Figure 12).

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

10 Hot Surfaces in Engine Rooms, Paper Series No. 2000-P025, November 2000, Det Norske Veritas.

Figure 12: Flame damage on starboard engine



The evidence suggests that the fuel spray from the leaking pipe probably ignited on contact with the hot starboard main engine exhaust pipes or indicator cocks.

2.4 Shipboard emergency response

Once the fire alarm had sounded and the master had gone to the bridge, he realised that the fire could not be fought locally so he quickly made the decision to use the FM-200 fixed fire extinguishing system.

The ventilation and quick closing valves were shut off and the FM-200 fire extinguishing gas was released into the engine room about ten minutes after the fire alarm had sounded.

Shutting the fuel quick closing valves effectively starved the fire of the fuel that was feeding it. Closing all of the engine room ventilation dampers and funnel flaps smothered the fire and allowed the FM-200 to quickly build up to its effective concentration without any of the gas being drawn out of the engine room by the escaping smoke and heat, effectively extinguishing the fire and limiting the extent of damage that occurred.

Instructions for releasing the FM-200 are included in the ship's emergency procedures. These procedures include a guideline for re-entering the engine room after the release of the FM-200 which reads:

> Wait a minimum of 10 minutes before inspecting the area, the time needed for complete extinguishing of the fire.

At 0600, 20 minutes after releasing the FM-200, the master decided to have the engine room inspected to ensure that the fire had been extinguished. His decision was based on the information that was included in the shipboard FM-200 procedure and the fact that the deck in the garage was not hot.

After the FM-200 had been released, the garage deck was sprayed with water to keep it cool, thus protecting the pallets of fuel from the heat of the fire. The cooling water, and the fact that the deck was insulated and rated as A60, would have slowed the rate of heating of the deck. As such, the temperature of the deck would not have given the master a good indication of the state of the fire.

While the master's actions proved to be correct in this instance, there is always a considerable risk of re-ignition if a compartment is entered too quickly after the release of an extinguishing agent. Sufficient time needs to be taken to allow the temperature of any material heated during the fire to cool to a temperature below its auto-ignition temperature so that re-ignition cannot occur when fresh air is introduced.

FM-200 has a limited effect on cooling surfaces heated by a fire because it does not readily conduct heat away from heated surfaces. The waiting time required for re-entry will depend on the size, location and intensity of the fire as well as the thermal inertia[11] of the materials heated by the fire. To be sure, a waiting time exceeding the time suggested in the procedures would have been safer. It would probably have been more prudent for the master to wait for longer than 20 minutes before re-entering the engine room, thus allowing further cooling of the fire scene.

At 0700, the quick closing valve for the fuel service tank (Figure 2) was opened so that an electrical generator could be started. None of the already open fuel system valves were closed to ensure that fuel could not leak from pipes that may have been damaged by the fire before the quick closing valve was opened. This unnecessarily exposed the ship to the risk of another fuel leak and possible fire. It would have been prudent to isolate all fuel systems except for the one required for the generator before opening the fuel system quick closing valve.

The engine room was separated from the accommodation by fire doors at the forward end of the workshop, where the quick-closing valve panel and FM-200 release cabinet are located. The doors separating the engine room from the air conditioning unit room and the air conditioning unit room from the workshop area were kept open, as a matter of practice, while the ship was at sea. A larger fire, or a fire closer to the engine room door, would probably have rendered the workshop inaccessible which, in turn, would have left the fire extinguishing systems inoperable.

SOLAS[12] requires that the controls for stopping ventilation fans and oil pumps, and for the quick closing valves shall be located outside the space that they serve where they will not be cut off in the event of a fire in the space that they serve. By leaving the engine room and air conditioning unit room doors open, the ship's crew effectively circumvented the intent of the SOLAS regulation and exposed the ship to unnecessary risk.

The decision to re-enter the engine room at 0600 and the decision to open the fuel service tank without first isolating individual fuel circuits exposed the ship to the risk of re-ignition. Furthermore, leaving the engine room door open while the ship was at sea exposed the ship to the risk that its fire fighting equipment may have become inoperable due to the fire.

---

11 The term used to describe the response of a material to the heat energy impacting on it. A material with high thermal inertia will retain heat for longer than a material with a low thermal inertia.

12 The International Convention for the Safety of Life at Sea, 1974, as amended, Chapter II-2, Regulation 11.

3 FINDINGS

3.1 Context

During *L'Astrolabe*'s voyage from Antarctica to Hobart, Australia, an engine room fire occurred on 11 November 2006 when a blanking arrangement on the starboard main engine fuel system began to leak, allowing fuel to spray into the engine room and ignite. The fire was extinguished using the ship's fixed FM-200 fire extinguishing system and the ship's engineers were able to restart the ship's main engines to complete the passage to Hobart.

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

3.2 Contributing safety factors

1. The absence of a discharge valve on the main fuel pump necessitated the fitting of blanks in the fuel system so that the engine could be run using the stand-by pump while keeping the main pump depressurised. *[Safety issue]*
2. The fitting of gasket discs in an open ended cap to blank off a fuel pipe was ineffective for the task because the discs probably became looser due to the effect of pressure pulses within the fuel pipe, allowing fuel to spray into the engine room where it was ignited on the hot surfaces of the engine. *[Safety issue]*

3.3 Other safety factors

1. The ship's procedures for re-entry into the engine room after the operation of the FM-200 fire extinguishing system did not adequately consider the time required to cool the fire scene and did not provide the master with adequate guidance about when to safely re-enter the engine room, therefore, exposing the ship to the potential risk of re-ignition. *[Safety issue]*
2. The practice of re-opening the fuel service tank quick closing valve after the fire, without first isolating individual fuel circuits, exposed the ship to the risk of another fuel leak and possible re-ignition. *[Safety issue]*
3. Leaving fire doors open between the engine room and the fire control station exposed the ship to the risk that its fire control systems could be rendered inoperable by an engine room fire. *[Safety issue]*

3.4 Other key findings

1. The quick decision by the master and crew, and the prompt use of the engine room fixed FM200 fire extinguishing system, controlled and extinguished the fire quickly and prevented it from spreading.

4 SAFETY ACTIONS

4.1 ATSB recommendations

MR20070022

The ship's procedures for re-entry into the engine room after the operation of the FM-200 fire extinguishing system did not adequately consider the time required to cool the fire scene and did not provide the master with adequate guidance about when to safely re-enter the engine room, therefore, exposing the ship to the potential risk of re-ignition.

The practice of re-opening the fuel service tank quick closing valve after the fire, without first isolating individual fuel circuits, exposed the ship to the risk of another fuel leak and possible re-ignition.

The Australian Transport Safety Bureau recommends that Bourbon Offshore Surf takes action to address these safety issues.

4.2 ATSB safety advisory notices

MS20070002

The absence of a discharge valve on the main fuel pump necessitated the fitting of blanks in the fuel system so that the engine could be run using the stand-by pump, while keeping the main pump depressurised.

The Australian Transport Safety Bureau advises that the owners and operators of ships should consider the safety implications of this safety issue and take action when considered appropriate.

MS20070003

The fitting of gasket discs in an open ended cap to blank off a fuel pipe was ineffective for the task because the discs probably became looser due to the effect of pressure pulses within the fuel pipe, allowing fuel to spray into the engine room where it was ignited on the hot surfaces of the engine.

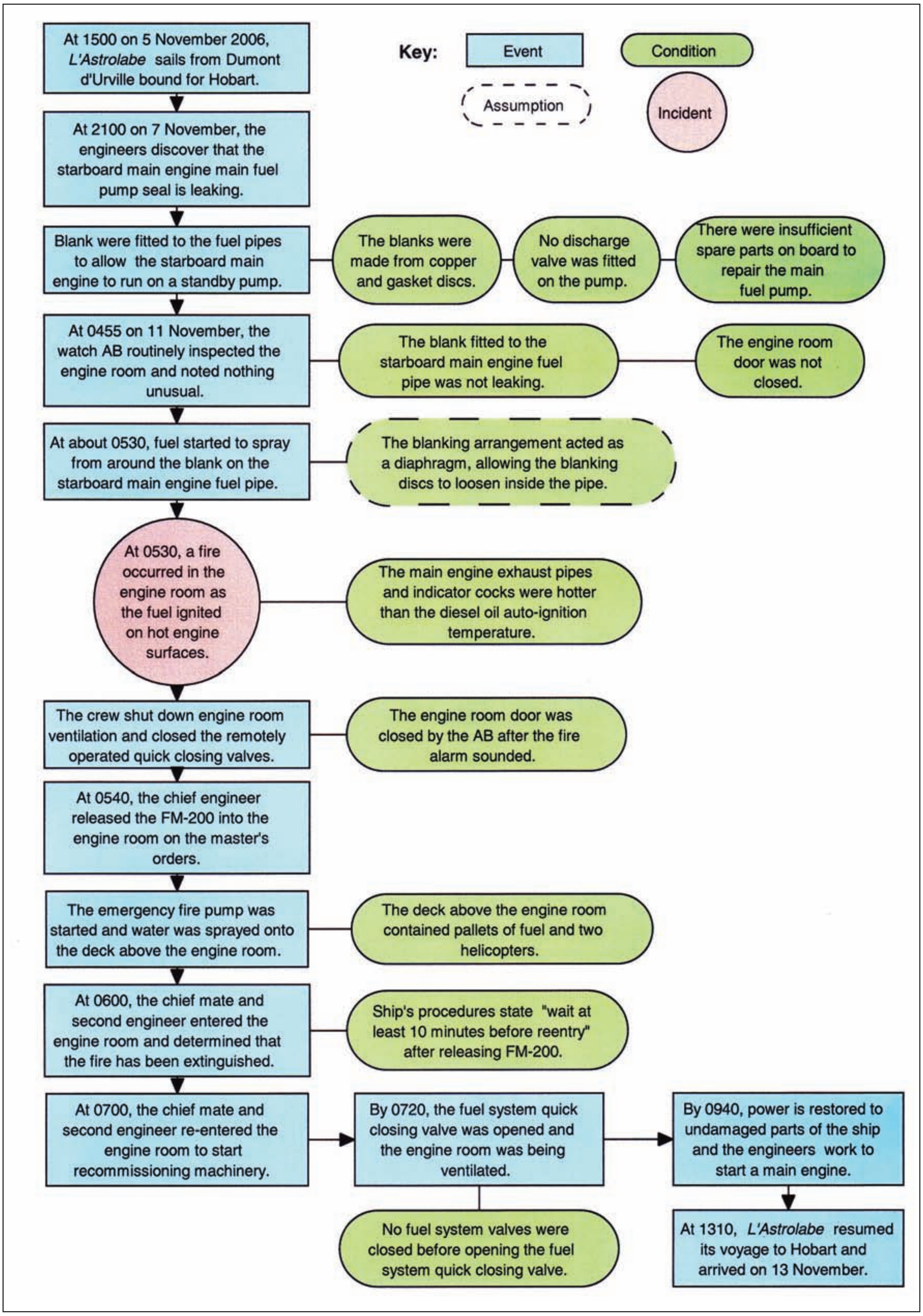
The Australian Transport Safety Bureau advises that the owners and operators of ships should consider the safety implications of this safety issue and take action when considered appropriate.

MS20070004

Leaving fire doors open between the engine room and the fire control station exposed the ship to the risk that its fire control systems could be rendered inoperable by an engine room fire.

The Australian Transport Safety Bureau advises that the owners, operators and masters of ships should consider the safety implications of this safety issue and take action when considered appropriate.

5 APPENDIX A: EVENTS AND CONDITIONS



6 APPENDIX B: SHIP INFORMATION

L'Astrolabe

IMO Number	8418198
Previous name	Fort Resolution (1986)
Call sign	FHZI
Flag	France
Port of Registry	Port aux Francais
Classification society	Bureau Veritas (BV)
Ship Type	Multipurpose offshore vessel
Builder	Ferguson Ailsa, Glasgow, Scotland
Year built	1986
Owners/Managers	Bourbon Offshore Surf, Marseilles, France
Ship charterer	Institut Polaire Francais
Gross tonnage	1371
Net tonnage	525
Deadweight (summer)	949 tonnes
Summer draught	4.782 m
Length overall	65.36 m
Length between perpendiculars	58.32 m
Moulded breadth	12.80 m
Moulded depth	5.36 m
Engine	2 x Mirrlees 8MB275 diesel (each of 2300 kW)
Total power	4600 kW
Crew	12 (French and Ukrainian)

7 APPENDIX C: SOURCES AND SUBMISSIONS

7.1 Sources of information

The master and crew of *L'Astrolabe*

The Australian Maritime Safety Authority (AMSA)

DuPont Fluoroproducts

Chemtura Corporation

7.2 References

Galpin R. and Davies M., Failures of Low Pressure Fuel Systems on Ships' Diesel Engines, BMT Edon Liddiard Vince Ltd, England, 1997

Hot Surfaces in Engine Rooms, Paper Series No. 2000-P025, November 2000, Det Norske Veritas.

The International Convention for the Safety of Life at Sea, 1974, as amended.

7.3 Submissions

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

The final draft of this report was sent to Bourbon-SURF, the French Marine Accident Investigation Office and the master, chief mate, chief engineer and second engineer and the AB on board *L'Astrolabe*.

Submissions were received from *L'Astrolabe*'s chief mate and the French Marine Accident Investigation Office. The submissions have been included and/or the text of the report was amended where appropriate.

8 APPENDIX D: MEDIA RELEASE

Antarctic ship fire the result of fuel leak

The Australian Transport Safety Bureau (ATSB) has found that an engine room fire that occurred on board the Antarctic resupply ship *L'Astrolabe*, on 11 November 2006, was the result of a fuel leak on the starboard main engine.

On 5 November 2006, the Antarctic supply ship *L'Astrolabe* sailed from the French Antarctic base at Dumont d'Urville, bound for Hobart, Tasmania. On 7 November, the engineers discovered that the starboard main engine's main fuel pump was leaking. They blanked off the main fuel pump and ran the engine using another fuel pump.

At about 0530 on 11 November, while the ship was still about 320 nautical miles south of Hobart, a fire started in the engine room when the blank that had been fitted to the starboard main engine's fuel pipe worked loose, allowing fuel to spray out of the pipe. The leaking fuel ignited when it came into contact with the hot surfaces of the engine.

The ship's crew remotely operated the fuel system quick closing valves, which shut down all of the ship's engines. They then isolated all ventilation to the engine room before activating the engine room's fixed fire extinguishing system.

By 0620, the fire had been extinguished and the crew re-entered the engine room to restart the ship's engines. By about 1200, *L'Astrolabe* had resumed its passage to Hobart on its port main engine. The starboard main engine was back in service on 12 November.

The investigation found that the blank fitted to the engine's fuel pipe was ineffective for the task.

The report also concludes that the practices and procedures used for re-entering engine room after the fire may have been risky.

The ATSB has issued one recommendation and three safety advisory notices with the aim of preventing further incidents of this type.

Independent investigation into the engine room fire on board the French Antarctic supply ship *L'Astrolabe* in the Southern Ocean, south of Hobart, Tasmania on 11 November 2006.