Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Marine Occurrence Investigation No. 238
Final

Independent investigation into the boiler explosions on board the Panamanian registered bulk carrier

Shirane

off Newcastle, New South Wales

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None.

Abstract

On the morning of 2 April 2007, the bulk carrier *Shirane* was off Newcastle, New South Wales.

The ship's third engineer had been assigned the task of replacing the auxiliary boiler burner with a clean spare unit. When he had finished the job, he attempted to fire the burner to check its operation but it failed to ignite. A few moments later, at 1013, while he was removing the burner to inspect it, there was an explosion (flashback) from the boiler furnace.

The third engineer ran into engine control room and, as it was clear to the chief engineer and the first engineer that he had been burned, he was taken to the ship's hospital for first aid treatment.

The master was informed and, shortly after 1015, he telephoned the ship's agent in Newcastle and requested a medical evacuation.

After purging the boiler furnace for about an hour, the chief engineer and the second engineer removed the burner to inspect it. A few moments later, there was another flashback from the boiler furnace. The chief engineer, the second engineer and a fitter were burned by the flashback.

The flashback had also caused a small fire on the deck, which was quickly extinguished. The three men then went to the ship's hospital for first aid treatment.

By 1324, a rescue helicopter had evacuated the second engineer, the third engineer and the fitter from the ship and, at 1729, it returned for the chief engineer.

As a result of the investigation, the boiler manufacturer and the ship's management company have taken a number of safety actions. The ATSB has also issued three safety advisory notices to address the safety issues identified.

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

At 0940[1] on 19 March 2007, the Panamanian registered bulk carrier *Shirane* anchored off Newcastle, New South Wales. The master expected the ship to be at anchor for about a month, while waiting to berth and load a cargo of coal. He intended for the crew to carry on with their normal duties during the period at anchor. He also planned for the ship to complete an occasional short voyage to sea to help reduce the build-up of marine growth on the ship's hull.

At about 0800 on 2 April, the chief engineer instructed the third engineer to exchange the auxiliary boiler burner with a clean spare burner while the ship was completing a planned short voyage to sea.

The third engineer shut down the boiler oil firing unit and then ran the forced draft fan for a few minutes to purge the furnace. He then switched the boiler control select switch to the 'off' position. He removed the burner and replaced it with the clean spare unit. He then attempted to fire the burner to check its operation but, on three successive occasions, it failed to ignite.

He purged the furnace for a few minutes before starting to remove the burner to inspect it. A few moments later, at 1013, while he was leaning over the open oil firing unit, to loosen the burner fuel connections, there was an explosion (flashback) from the boiler furnace. He turned and ran away from the boiler, throwing his face shield to the ground and shaking the smouldering gloves off his hands.

He then ran into the engine control room and, as it was clear to the chief engineer and the first engineer that he had been burned, he was taken to the ship's hospital for first aid treatment.

The master was informed and, shortly after 1015, he telephoned the ship's agent in Newcastle and requested a medical evacuation for the third engineer.

The chief engineer surmised that there must have been some unburnt fuel in the hot furnace that had vaporised and then ignited. After purging the boiler furnace for about an hour, he and the second engineer removed the burner to inspect it.

A few moments later, at 1141, there was another flashback from the boiler furnace. The chief engineer and the second engineer were burned by the flashback. The fitter, who had just walked out of the nearby workshop and was about three metres away from the boiler, was also burned.

The flashback started a small fire on the deck, which was quickly extinguished by the three men. They then went to the ship's hospital for first aid treatment.

At 1305, a rescue helicopter landed on board the ship. Paramedics, from the helicopter, assessed the injuries that the four crew members had sustained. The second engineer, the third engineer and the fitter were evacuated from the ship immediately and, at 1729, the helicopter returned for the chief engineer.

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

As a result of the investigation, the boiler manufacturer and the ship's management company have taken a number of safety actions. The ATSB has also issued three safety advisory notices to address the following safety issues:

- The ship's crew were not aware of similar previous flashbacks involving Osaka OECV2 boilers and they were not aware of all of the hazards associated with servicing the boiler burner.
- The personal protective equipment being used by the crew members while they were servicing the boiler burner did not provide them with adequate protection and, therefore, was not appropriate for the task.
- The injured crew members were not provided with the appropriate first aid treatment for their burn injuries.

1 FACTUAL INFORMATION

1.1 *Shirane*

Shirane is a Panamanian registered bulk carrier (Figure 1) which is operated by Nippon Yusen Kaisha (NYK), Japan, and managed by Taiheiyo Kisen Kaisha, Japan. The ship is owned by Dorado Maritima II and Dorado Maritima, Panama; and classed with the Class NK.

The ship was built in 2000 by Mitsui Engineering and Shipbuilding, Japan. It has an overall length of 229 m, a beam of 36.5 m, a depth of 18.5 m and a deadweight of 77 672 tonnes at its summer draught of 12.82 m.

Shirane is a conventional bulk carrier with five cargo holds located forward of the accommodation superstructure. A helicopter landing area is located on the number three hold hatch covers.

Figure 1: *Shirane* at anchor off Newcastle

Propulsive power is provided by a five cylinder Mitsui B&W 5S60MC, single acting, direct reversing two-stroke diesel engine developing 10 223 kW. The main engine drives a single fixed pitch propeller which gives the ship a service speed of about 14.5 knots[2].

The ship's crew, at the time of the incident, consisted of 20 Filipino and two Chinese nationals. The mates maintained a watchkeeping routine of four hours on, eight hours off at all times. The engineers operated a 24 hour duty roster system. They performed maintenance duties between 0800 and 1700 each day and the engine room was unattended outside of these hours.

The master held a master's certificate of competency which was issued in the Philippines in 1998. He had 26 years of seagoing experience, with the last six years in command. At the time of the incident, he had been on board *Shirane* for about ten months.

The chief engineer had 21 years of seagoing experience. He held a class one certificate of competency which was issued in the Philippines in 2005. He joined *Shirane* on 18 December 2006 for his first assignment as chief engineer.

2 One knot, or one nautical mile per hour equals 1.852 kilometres per hour.

The second engineer held a class two certificate of competency which was issued in the Philippines in 2005. He had 14 years of seagoing experience and, at the time of the incident, had been on board *Shirane* for about 14 months.

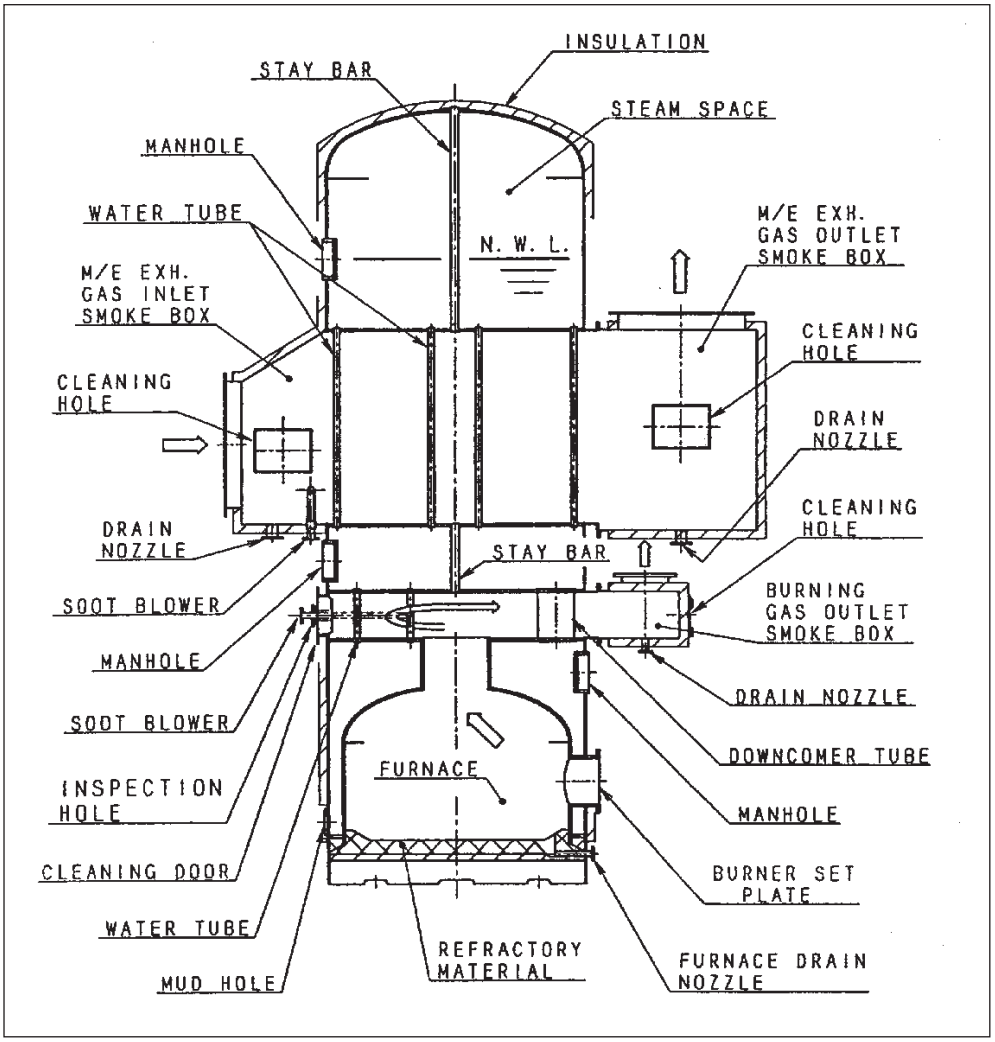
The third engineer had 15 years of seagoing experience and held a class three certificate of competency which was issued in the Philippines. He had also been on board *Shirane* for about 14 months.

Figure 2: *Shirane*'s composite boiler

1.1.1 The boiler

Shirane is fitted with an Osaka Boiler Mfg Company OEVC2-120/120-20 vertical composite boiler (Figures 2 and 3). The boiler has a working pressure of 6.0 bar[3] and uses main engine exhaust gases and/or a packaged oil firing unit to produce steam. Steam is used on board the ship to heat fuel, for treatment before its use in the main and auxiliary engines, and for general heating purposes.

Figure 3: Schematic diagram of boiler



The upper section of the boiler water space houses the economiser part of the boiler (Figure 3). In this section, the main engine exhaust gases are directed over a bank of water tubes. Beneath the economiser section is the smoke box, which has a hot gas inlet from the furnace, another bank of boiler water tubes and an exhaust gas outlet.

The truncated hemispherical steel furnace lies below the smoke box. The furnace chamber has a single oil firing unit opening at one side. When the burner is firing, the flame is directed at the furnace wall opposite the burner opening with the flow of hot gas sweeping the periphery of the cylindrical furnace chamber before rising to the smoke box inlet.

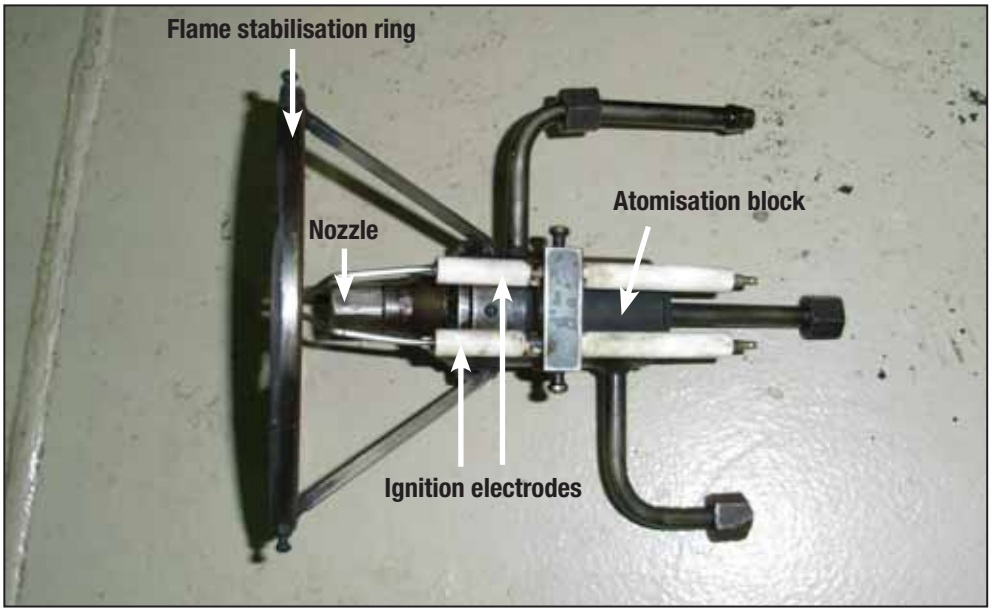
3 1 bar equals 100 KPa or approximately one atmosphere.

The flow paths of the main engine exhaust gases and the boiler furnace exhaust gases are entirely independent.

Many auxiliary boiler designs have a water space around the entire furnace that acts to cool the furnace. However, this is not the case with the Osaka OECV2 boiler. While the top part of the furnace is water cooled, the furnace floor is not. Furthermore, the floor is lined with refractory material which cools relatively slowly after the boiler has been firing.

Figure 4: Volcano VJ-140-1 oil firing unit

Figure 5: Oil firing unit burner



When the ship's main engine is stopped, or is providing insufficient exhaust gas energy to produce enough steam to meet the demand, the boiler is fired using oil. The oil firing unit, a VJ-140-1, was manufactured by the Volcano Company of Japan (Figure 4). The unit comprises a fully automatic pressure jet oil burner, integrated with a single electric motor driving both the forced draft fan and the fuel oil feed pump. Control of combustion air flow is provided by a single, two-position, damper on the forced draft fan's air inlet housing. The oil firing unit may be fired using either diesel or heavy fuel and has an integrated electric heater for use when firing on heavy fuel. The oil firing unit's controls and monitoring system are located in a cabinet which is mounted on a bulkhead adjacent to the boiler.

The burner (Figure 5) is fitted inside the oil firing unit at the boiler furnace opening. The burner consists of an atomiser block, which holds a single fuel nozzle, to which a flame stabilisation ring and a pair of ignition electrodes are attached. The atomiser block has three fuel line connections; one line is led from an electric solenoid valve which supplies the fuel nozzle, and the two other lines allow fuel circulation through the atomiser block. The burner may be removed from the oil firing unit through a maintenance cover at the top of the unit, after the ignition electrode cables and the three fuel pipes have been disconnected.

1.2 The incident

Shirane anchored off the port of Newcastle, New South Wales, at 0940 on 19 March 2007, after a 13 day voyage from Pusan, Korea. The master expected the ship to remain at anchor for about a month, while waiting to berth and load a cargo of coal. His intention was for the crew to carry on with their normal duties during the period at anchor and for the ship to complete an occasional short voyage to sea.

The purpose of the short voyages to sea was to reduce the build-up of marine growth on the ship's hull. The master planned to complete the first of these short voyages on 2 April.

On the morning of 2 April, the engineers met in the engine control room, as normal, and discussed the days work schedule. During the discussion, the chief engineer instructed the third engineer to exchange the boiler burner with a clean spare unit while the ship was completing the short voyage. This would enable the third engineer to complete the task while the boiler steam pressure was maintained by the heat from the main engine exhaust gases.

At 0800, the main engine was tested in preparation for the planned short voyage. The crew then began heaving up the anchor. By 0830, the ship was underway and departing the Newcastle anchorage.

The third engineer prepared his tools and then shut down the boiler oil firing unit. The boiler furnace was automatically purged by the forced draft fan for one minute as part of the automatic shutdown process. The third engineer then purged the furnace for a few minutes more before switching the boiler control select switch to the 'off' position.

He shut the boiler fuel supply valve, opened the maintenance cover, removed the burner and replaced it with the previously cleaned spare. He opened the fuel supply valve and, after confirming that there were no fuel leaks, replaced the maintenance cover.

He then tried to manually ignite the burner to test its operation. He ran the forced draft fan for a few minutes to purge the furnace of vapours before energising the

fuel solenoid and then operating the igniter. However, the burner did not ignite. He de-energised the fuel solenoid, purged the furnace and tried again to manually ignite the burner. However, once again, it did not ignite.

He then placed the boiler control select switch in the 'automatic' position and attempted to ignite the burner for a third time. The oil firing unit went through its normal automatic sequence but it failed to ignite.

The third engineer purged the furnace for a few minutes, before removing the burner to inspect it. He switched the boiler control select switch to the 'off' position and then removed the maintenance cover. He opened the oil heater drain cock and waited while a small amount of fuel drained out. He then disconnected the ignition electrode cables before loosening the three fuel pipe connections. A small amount of fuel drained from the loosened fuel lines but no more than normal.

A few moments later, at 1013, while the third engineer was leaning over the oil firing unit disconnecting the fuel fittings, there was an explosion (flashback) from the boiler furnace. He turned and ran away from the boiler, throwing his face shield to the ground and shaking the smouldering gloves off his hands.

The chief engineer and the first engineer, who were in the engine control room, heard the flashback. Shortly afterwards, the third engineer ran into the control room. He was covered in soot and was yelling and gesturing that his face and hands had been burned. The chief engineer determined that he required first aid treatment so he was taken to the ship's hospital.

The flashback had set off the fire alarms, so the master telephoned the engine control room. The master and the chief engineer discussed what had happened. They decided to keep the ship steaming at dead slow ahead while the chief engineer investigated the cause of the flashback.

The chief engineer was concerned that the heavy fuel temperature would drop below an acceptable level. He thought that the reduced steam output from the boiler, caused by the failure of the oil firing unit and the limited heat available from the main engine exhaust gases at dead slow ahead, would not be enough to maintain the fuel temperature. Therefore, he decided to change the main and auxiliary engines over to diesel oil.

After talking to the chief engineer, the master instructed the second mate, the ship's medical officer, to go to the hospital and treat the third engineer's injuries.

Shortly after 1015, the master telephoned the ship's manager and notified him of the incident. He then telephoned the ship's agent in Newcastle and requested a medical evacuation for the injured third engineer. The agent then arranged for the local rescue helicopter service to carry out the medical evacuation.

When the chief engineer inspected the boiler he noticed white smoke exhausting from the boiler furnace through the oil firing unit maintenance opening. He surmised that there must have been some unburnt fuel in the hot furnace that had vaporised and then ignited. Consequently, he started the forced draft fan in an attempt to purge the furnace of the smoke and any remaining vapours. He also instructed the engine room staff to remain clear of the boiler.

About an hour later, the chief engineer stopped the forced draft fan and, before he and the second engineer started removing the burner, he ensured that they were both wearing gloves and face shields. They shut the fuel oil supply valve, opened the oil heater drain cock and waited for the fuel to drain out. The second engineer disconnected the ignition electrode cables and the burner fuel connections. He then

removed the burner from the oil firing unit and placed it into a bucket. There was a small amount of fuel and carbon build-up inside the oil firing unit, so the second engineer started wiping it out with rags.

A few moments later, at 1141, there was another flashback from the boiler furnace. The chief engineer and the second engineer were burned by the flashback. The fitter, who had just walked out of the nearby workshop and was about three metres away from the boiler, was also burned.

The flashback started a small fire on the deck, which was quickly extinguished by the three men. They then went to the ship's hospital for first aid treatment. On the way, the fitter stopped at the change room for a few minutes and cooled his burns by splashing them with water. When the three men arrived at the ship's hospital, the second mate also applied burn ointment to their injuries.

At 1305, a rescue helicopter landed on board the ship. Paramedics, from the helicopter, assessed the injuries that the four crew members had sustained. They decided to immediately evacuate the second engineer, the third engineer and the fitter. Since the chief engineer's injuries were less severe, and the helicopter was full, they decided to return to the ship and evacuate him later.

At 1324, the rescue helicopter departed from the ship with the three crew members on board. The ship then proceeded towards the Newcastle anchorage. At 1410, the ship's anchor was let go in the anchorage.

At 1729, the rescue helicopter returned to the ship. The paramedics assisted the chief engineer on board and, at 1731, the helicopter departed the ship.

The four crew members were treated in Newcastle at the John Hunter Hospital. The chief engineer was discharged from the hospital and he returned to the ship the next morning. The second engineer and the fitter were discharged from the hospital a day later. They then received some out-patient medical treatment while they were in Sydney awaiting repatriation to the Philippines.

The third engineer, the worst injured of the four men, was transferred to the Royal North Shore Hospital in Sydney, where he received treatment in the burns unit. After being discharged from the hospital he was repatriated to the Philippines.

2 ANALYSIS

2.1 Evidence

On 3 April 2007, two investigators from the Australian Transport Safety Bureau (ATSB) attended *Shirane* while the ship was at anchor off Newcastle. The master and directly involved crew members were interviewed and they provided accounts of the incident. Copies of relevant documents were obtained, including log books, operating manuals, procedures, permits and statutory certificates.

On 4 April, the investigators interviewed the second engineer and the fitter at their hotel in Sydney.

The investigators returned to Sydney when the third engineer had recovered sufficiently and, on 6 April, interviewed him at the Royal North Shore Hospital.

During the course of the investigation information was also obtained from the Osaka Boiler Mfg Company and the Volcano Company.

A technician from the Volcano Company attended *Shirane* while the ship was in Newcastle. He checked that the burner was set correctly and then checked the operation of the forced draft fan, the damper and the igniter. He then fired the boiler, starting and stopping it a number of times. The technician found no faults with the boiler oil firing unit.

2.2 The flashbacks

The third engineer made three attempts to ignite the burner, immediately prior to the first flashback, and on each occasion unburnt heavy fuel oil would have been deposited on the furnace floor and on the furnace wall directly opposite the oil firing unit.

When the oil firing unit was shut down, there was no flow of air through the furnace until the maintenance cover was removed. With the maintenance cover removed, the air flow through the furnace was dependent upon the ambient pressure in the engine room and the natural updraught within the boiler due to the hot uptakes. Consequently, the air flow through the furnace was limited and probably passed directly from the oil firing unit opening to the smoke box inlet, leaving areas adjacent to the furnace walls relatively unswept (Figure 3).

It is likely that the residual heat in the refractory material, and furnace walls, was sufficient to vaporise the lighter fractions of the heavy fuel. The fuel vapours then accumulated in the unswept area of the furnace until the vapour/air ratio reached its flammability range[4] (between 0.9% and 7.0%). It is probable that the vapour was then ignited by the hot refractory or by smouldering fuel/carbon residue on the refractory floor. Once the fuel vapours were ignited, the furnace pressure rapidly increased until the pressure was sufficient to push a flame front out of the furnace through the oil firing unit maintenance opening.

After the first flashback, the chief engineer started the forced draft fan and ran it for about an hour in an attempt to purge the furnace of any remaining vapours.

4 The flammable range includes all concentrations of flammable vapour or gas in air, in which a flash will occur or a flame will travel if the mixture is ignited. There is a minimum concentration of vapour or gas in air below which propagation of flame does not occur on contact with a source of ignition (too lean). There is also a maximum proportion of vapour in air above which propagation of flame does not occur (too rich).

However, the oil firing unit maintenance cover had not been replaced and the majority of the air flow from the forced draft fan probably followed the line of least resistance and was exhausted out of the oil firing unit maintenance opening. While the forced draft fan had been left running for a considerable amount of time, the furnace had still not been effectively purged or cooled.

When the chief engineer stopped the forced draft fan, once again, the limited air flow through the oil firing unit effectively bypassed the unswept, hot, area of the furnace. The evidence suggests that the residual heat in the refractory material, and furnace walls, was still sufficient to vaporise the lighter fractions of the heavy fuel. The fuel vapours then accumulated until the vapour/air mixture was rich enough to be ignited in a similar fashion to the first flashback.

2.3 Hazards associated with servicing the burner

It was not unusual for *Shirane*'s boiler to misfire due to a build-up of carbon on the flame stabilisation ring. Consequently, during periods when the boiler was operating, it was normal practice for the burner to be exchanged with a clean replacement unit every few days.

The ship's crew had identified a number of the hazards associated with servicing the boiler burner and they had implemented some control measures. They had identified the need to wear gloves and eye protection to protect themselves as well as the need to purge the furnace before servicing the burner.

While sufficient purging of the boiler furnace prior to opening the oil firing unit is a basic safety precaution, in some instances, this precaution alone may not be enough to prevent a flashback. If there have been a number of unsuccessful attempts to ignite the burner, as there were on board *Shirane* on 4 April 2007, liquid fuel may still be lying in the furnace even after a lengthy purge. At these times, it is essential to allow the furnace to cool sufficiently before it is opened.

Shirane's boiler was not equipped with a quick method of safely sighting the furnace floor. Therefore, there was no easy way to gauge when it was necessary to allow the furnace to cool before opening the oil firing unit maintenance cover. The only way to sight the furnace floor was to remove the burner and then look down the oil firing unit flame funnel.

Therefore, on each occasion that *Shirane*'s engineers opened the oil firing unit maintenance cover, shortly after a burner misfire, they ran the risk of a boiler flashback similar to those that occurred on 2 April 2007.

2.4 Previous incidents

There have been a number of similar incidents on board ships fitted with the same type of boiler/burner combination as that fitted on board *Shirane*.

On 29 April 2001, the Singapore registered bulk carrier *Alam Mesra* experienced a series of boiler explosions similar to those which occurred on board *Shirane*. After a succession of burner flame failures, the third engineer and an engineer cadet disconnected the burner and removed it from the oil firing unit.

While they were in the workshop, working on the burner assembly, they heard an explosion from the boiler. They went to investigate and, while they were examining the boiler, there was a succession of flashbacks from the boiler furnace. The two

men were burned as a result of the incident. At the time, the flashbacks were attributed to the leakage of fuel from the burner fuel connections into the hot furnace.

On 17 May 2003, the Panamanian registered bulk carrier *Medi Monaco* experienced a series of boiler explosions. After a number of burner flame failures, the third engineer decided to clean the burner. While he was in the process of withdrawing the burner from the oil firing unit, there was a flashback from the boiler furnace. The third engineer suffered severe burns to his face and upper body.

The chief engineer and the second engineer went to the boiler to see what had happened and as they were inspecting the burner, there was a second flashback. Both men sustained burns to their faces.

The ATSB report into the incident on board *Medi Monaco* (ATSB report No.194) recommended that:

> The Osaka Boiler Mfg Company provide a safety bulletin to operators of OEVC2 boilers warning them of the incidents on *Medi Monaco* and *Alam Mesra* and drawing their attention to the correct safety precautions when servicing the fuel burner unit.

As a result of this recommendation, the Osaka Boiler Mfg Company, in consultation with the Volcano Company, developed a safety bulletin and caution plates that were to be fitted to all VJ type burners and their control panels. The companies attempted to distribute the safety bulletin and caution plates to all operators of OECV2 boilers. However, due to changes in the management of *Shirane* neither the safety bulletin nor the caution plates were received on board the ship.

At about 0140 on 10 September 2002, a similar incident also occurred on board *Shirane* while the ship was berthing in Kimitsu, Japan.

The boiler burner had misfired and the third engineer was in the process of removing the burner, to clean it, when there was a flashback from the boiler furnace. It was determined that fuel had leaked from the burner fuel connections and that the fuel ignited in the hot furnace.

While the second and third engineers, on board *Shirane* on 4 April 2007, were vaguely aware that a flashback had occurred either on board *Shirane*, or another ship in the fleet, neither the master nor the chief engineer was aware of any previous incidents. Furthermore, the ship's crew had not received any safety bulletins from the boiler manufacturer, or the ship's management company, that may have highlighted all of the hazards associated with servicing the boiler burner.

The cause of some of the previous flashback incidents had been attributed to the leakage of fuel from the burner fuel connections into the furnace. However, it is possible that the fuel leakage was not the cause of the flashbacks. On each of these occasions fuel would have been deposited in the hot furnace by the misfiring boiler burner. Therefore it is possible that the flashbacks were caused in much the same way as those on board *Shirane* on 2 April 2007.

2.5 Procedures

There were at least four ship-specific procedures on board *Shirane* that were relevant to servicing the boiler burner. The ship's crew had, through these procedures, identified some of the hazards associated with the task. Furthermore, they had outlined control measures to mitigate the identified risks. However, they had not identified all of the hazards associated with carrying out the task and the procedures were inconsistent and ambiguous.

The need for the ship's crew members to wear specific personnel protective equipment when working on the boiler burner had been identified, as had the need to purge the furnace prior to opening the oil firing unit maintenance cover. However, the fact that purging the boiler furnace following a series of burner misfires was not always enough to prevent a flashback had not been identified.

The number of conflicting procedures was also counter productive. The procedures included some inconsistencies and hence may have led to uncertainty in the minds of the crew members as to which procedure should be followed. For example, the procedure titled 'Burner Handling Safety Precautions' advised of the need to purge the furnace for at least one minute following a burner misfire, while the procedure titled 'Precautions and Safety Handling of BJ Burner' stated that the furnace should be purged for at least three minutes following a burner misfire.

Furthermore, not all of the procedures were posted near the boiler and the one that was, titled 'Precautions on Maintenance Service of Composite boiler', made no mention of furnace purging.

Consequently, the ship's crew were not aware that, even after a lengthy purge following a misfire, there may be liquid fuel still lying in the furnace and that, in these circumstances, the furnace should be allowed to cool before opening the oil firing unit maintenance cover.

Despite the fact that a similar incident had occurred on board *Shirane* in the past, all of the hazards associated with servicing the boiler burner had not been identified. Furthermore, a single unambiguous ship-specific procedure that would ensure that the crew members servicing the boiler burner were given appropriate safety guidance had not been implemented.

2.6 Personal protective equipment (PPE)

It was a company requirement for the crew members on board *Shirane* to wear overalls and steel toe-cap work boots when working in the engine room. In addition to this protective clothing, the ship-specific procedures had also outlined the need to wear gloves and eye protection when servicing the boiler burner.

The fitter, who had just walked out of the workshop at the time of the second flashback, was not wearing gloves or eye protection but the engineers working on the oil firing unit were. However, their overalls and gloves had not provided them with adequate protection and, while the face shields protected their eyes from injury they still sustained facial burns.

2.6.1 Overalls

When the third engineer joined *Shirane* he was issued with one pair of white 100% cotton overalls. He used these overalls when attending drills or carrying out work that he thought would not get them too dirty. Consequently, on 2 April 2007, he did

not wear these overalls. Instead, he wore a pair of dark blue synthetic overalls that had been issued to him on board a previous ship.

The third engineer's blue synthetic overalls had a plastic central zipper which was stitched into the overalls using a synthetic thread. Tests carried out by the ATSB indicate that the material that these overalls were made from was a 65/35 blend of polyester and viscose. The tests also showed that this material ignited when exposed to a naked flame for more than two seconds.

When the third engineer's overalls were hit by the flames from the furnace flashback, the cental zipper melted and the overall material ignited (Figure 6). The overalls had provided inadequate protection to the third engineer and, as a result, he sustained burn injuries to his stomach.

Figure 6: The third engineer's polyester/viscose overalls

On 2 April, the chief engineer and the second engineer were both wearing their issued white cotton overalls. While the second engineer's overalls were not severely damaged by the flashback, the chief engineer's overalls were. It is likely that the chief engineer's overalls were exposed to more flame because of the position he was in at the time of the flashback.

The central zipper in the front of the white cotton overalls was plastic and it was stitched into the overalls using a synthetic thread. When the chief engineer's overalls were exposed to the flashback, the zipper, and the thread holding it in place, melted (Figure 7). This allowed the overalls to fall open and resulted in the chief engineer sustaining burns to his stomach.

Neither the synthetic overalls nor the cotton overalls provided the engineers with the protection they needed. Therefore, they were not appropriate for the task.

Figure 7: The chief engineer's 100% cotton overalls

2.6.2 Gloves

The ship-specific procedures outlined the need to wear gloves when servicing the boiler burner but they gave no direction as to what type of gloves should be worn.

The third engineer decided to wear white, elasticised, polyester/cotton gloves. He felt that these gloves protected his fingers from the hot boiler components while affording him the fingertip dexterity he required to work with his hands inside the oil firing unit. However, when he was hit by the flashback the gloves caught fire and his hands were seriously burned.

The second engineer and the chief engineer were also wearing white, elasticised, polyester/cotton gloves when they were working on the boiler. Their hands were also burned as a result of the flashback but the burns were not as serious as those sustained by the third engineer.

Had the ship-specific procedures provided the crew members with appropriate guidance as to what type of gloves should be worn while servicing the boiler burner, some of the injuries that the crew members sustained, as a result of the flashbacks on 2 April 2007, may have been less severe.

2.7 First aid

On 2 April 2007, the fitter stopped in the change room, while on his was to the ship's hospital, to cool his burns by splashing them with water for a few minutes. All of the other casualties went straight to the hospital where the second mate applied burn ointment to their injuries.

The ATSB is also aware of a number of previous instances where butter, honey or burn ointment has been applied to a casualty's burns. However, none of these substances should ever be used as a form of first aid for the treatment for burns.

With reference to the first aid treatment of burns, St John Ambulance, Australia, issues the following warnings and recommendations[5].

Warning

1. Do not apply lotions, ointment or fat to burn.
2. Do not touch the injured area or burst any blisters.
3. Do not remove anything that is sticking to the burn.
4. If the burn is large or deep treat the casualty for shock.

First aid treatment

1. Remove the casualty from danger.
2. Cool the burnt area.
   - Hold burnt area under cold running water for at least 10 minutes.
   - If a chemical burn, run cold water over burnt area for at least 20 minutes.
   - If a bitumen burn, run cold water over burnt area for 30 minutes.
   - If burn is to eyes, flush eyes with water for 20 minutes.
3. Remove any clothing or jewellery from the burnt area (unless it is sticking to the burn).
4. Place a sterile, non-sticking dressing over the burn.
5. Calm the casualty.
6. Seek medical assistance.

Had the injured crew members on board *Shirane* received the recommended first aid treatment, the adverse effects of their burns may have been reduced and they may have recovered quicker.

5 A quick guide to first aid/burns, St John Ambulance, Australia, website - www.stjohn.org.au

3 FINDINGS

3.1 Context

On the morning of 2 April 2007, the third engineer on board *Shirane* replaced the auxiliary boiler burner with a clean spare unit. When he was finished, he tried to check its operation but the burner failed to ignite.

A few moments later, at 1013, while he was attempting to remove the burner to inspect it, there was a flashback from the boiler furnace. The third engineer was burned by the flashback.

After purging the boiler furnace for about an hour, the chief engineer and the second engineer removed the burner to inspect it. A few moments later, there was another flashback from the boiler furnace. The chief engineer, the second engineer and a fitter were burned by the flashback.

From the evidence available, the following findings are made with respect to the boiler flashbacks on board *Shirane* on 2 April 2007. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing safety factors

- The Osaka Boiler Mfg Company had previously attempted to send a safety bulletin and caution plates to all operators of OECV2 boilers, warning them of the hazards associated with servicing the boiler burner and drawing attention to the correct safety precautions to be taken. However, the information had not been supplied to *Shirane*. *[Safety issue]*
- The ship's crew were not aware of any similar previous flashbacks involving Osaka OECV2 boilers and they were not aware of all of the hazards associated with servicing the boiler burner. *[Safety issue]*
- A single unambiguous ship-specific procedure that would ensure that the crew members servicing the boiler burner were given appropriate safety guidance had not been implemented. *[Safety issue]*
- Unburnt heavy fuel was deposited on the furnace floor, and on the furnace wall directly opposite the oil firing unit, on each occasion that the burner misfired.
- The unburnt fuel was probably vaporised when it was heated by the hot surfaces inside the furnace.
- It is likely that the fuel vapours accumulated in areas of the furnace that were not swept by the limited amount of air that was flowing between the oil firing unit maintenance opening and the smoke box inlet.
- The fuel vapours were probably ignited by the hot furnace floor refractory or by smouldering fuel/carbon residue on the furnace floor.
- Running the forced draft fan to purge the furnace after the first flashback was ineffective because the oil firing unit maintenance cover had not been re-fitted.

- The personal protective equipment being used by the crew members while they were servicing the boiler burner did not provide them with adequate protection and, therefore, was not appropriate for the task. *[Safety issue]*
- The injured crew members were not provided with the appropriate first aid treatment for their burn injuries. *[Safety issue]*

4 SAFETY ACTIONS

4.1 Safety action taken by Osaka Boiler Mfg Company

The ATSB has been advised that the following safety actions have been taken by the Osaka Boiler Mfg Company as a result of the boiler flashbacks on board *Shirane* on 2 April 2007.

- The company is in the process of again distributing the safety bulletin and caution plates to all operators of OECV2 boilers. On this occasion they have enlisted the support of classification societies to assist in the development of a more comprehensive and up to date mailing list.

4.2 Safety action taken by Taiheiyo Kisen Kaisha

The ATSB has been advised that the following safety actions have been taken by Taiheiyo Kisen Kaisha as a result of the boiler flashbacks on board *Shirane* on 2 April 2007.

- The Osaka Boiler Mfg Company caution plates have been supplied to *Shirane*. These plates have been fixed to the oil firing unit and the boiler control panel.
- A new work instruction 'Danger of backfire and flashback of auxiliary boiler' has been posted at the boiler control panel.
- *Shirane*'s boiler oil firing unit has been modified in line with the most recent developments in the VJ burner design. The atomiser block has been replaced and a diesel pilot burner has been added. The design of the maintenance cover has been changed and it now includes a limit switch which prevents the oil firing unit from operating when the cover is removed. A push button to test the operation of the igniter has also been added.
- The company has issued new instructions to all ships in its fleet addressing the issue of appropriate first aid treatment for burns.
- The company has reviewed the personal protective equipment supplied to their vessels and has now issued fire retardant overalls, fire proof gloves and face shields with helmets. The company has also issued a work instruction outlining the need to use these items when servicing the boiler oil firing unit.

4.3 ATSB safety advisory notices

MS20070011

The ship's crew were not aware of similar previous flashbacks involving Osaka OECV2 boilers and they were not aware of all of the hazards associated with servicing the boiler burner.

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

MS20070012

The personal protective equipment being used by the crew members while they were servicing the boiler burner did not provide them with adequate protection and, therefore, was not appropriate for the task.

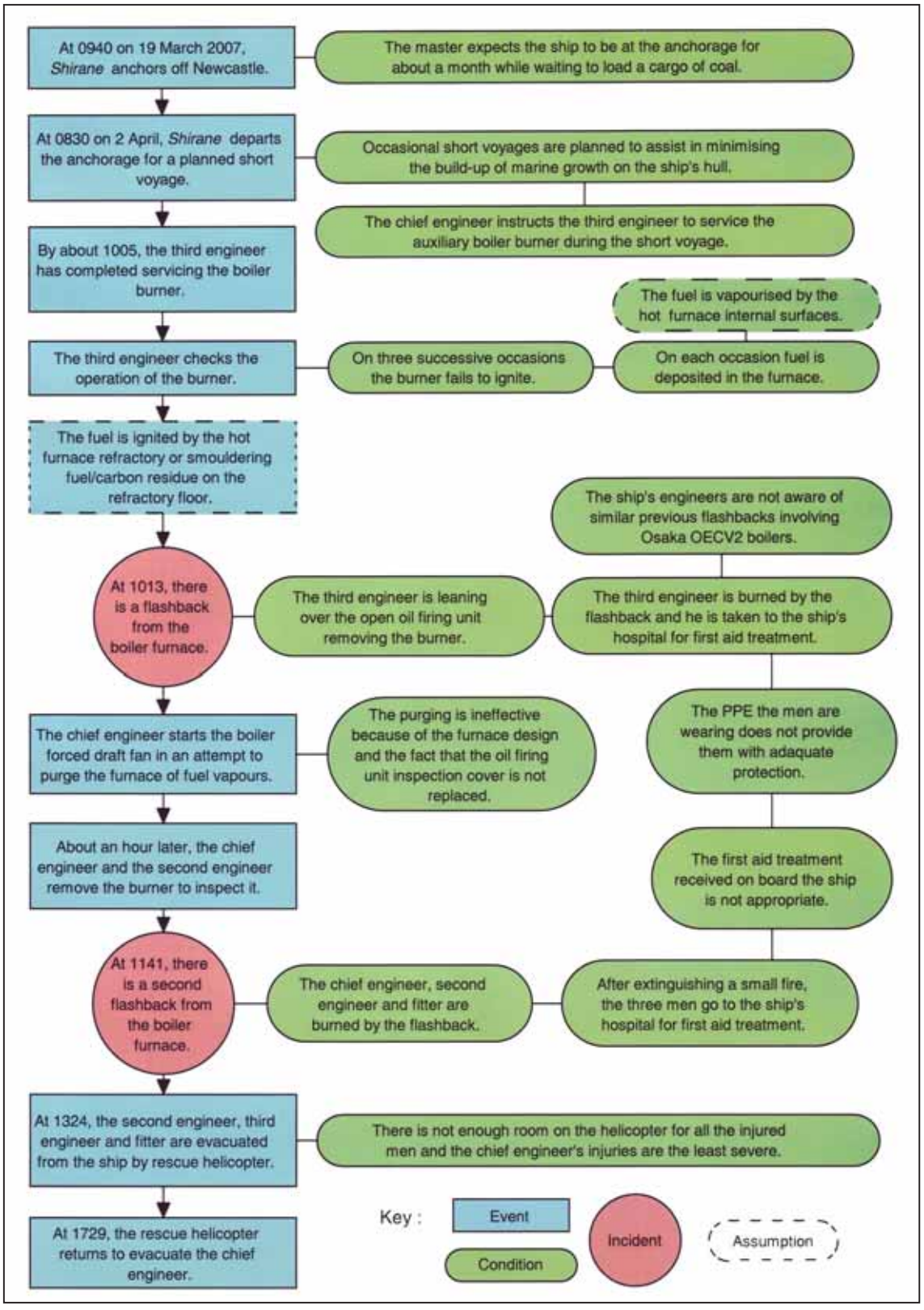
The Australian Transport Safety Bureau advises that ship owners, operators and masters should consider the safety implications of this safety issue and take action where it is considered appropriate

MS20070013

The injured crew members were not provided with the appropriate first aid treatment for their burn injuries.

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

APPENDIX A : EVENTS AND CONDITIONS CHART



APPENDIX B : SHIP INFORMATION

Shirane

IMO Number	9202584
Call sign	H3BL
Flag	Panama
Port of Registry	Panama
Classification society	Class NK
Ship Type	Bulk carrier
Builder	Mitsui Engineering and Shipbuilding, Japan
Year built	2000
Owners	Dorado Maritima II and Dorado Maritima
Ship managers	Taiheiyo Kisen Kaisha
Gross tonnage	43 376
Net tonnage	23 540
Deadweight (summer)	77 672 tonnes
Summer draught	12.82 m
Length overall	229 m
Length between perpendiculars	218 m
Moulded breadth	36.5 m
Moulded depth	18.5 m
Engine	Mitsui B&W 5S60MC
Total power	10 223 kW
Crew	22

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of information

The Master and crew of *Shirane*

The Osaka Boiler Mfg Company

The Volcano Company

References

Tramp Oil and Marine – Residual fuel oil/bunker fuel oil data sheet

Valero Marketing and Supply Company – Residual fuel oil material data sheet

St John Ambulance website – <www.stjohn.org.au>

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the T*ransport 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 the Australian Maritime Safety Authority, the Osaka Boiler Mfg Company, the Volcano Company, Taiheiyo Kisen Kaisha and *Shirane*'s master, chief engineer, second engineer, third engineer and fitter.

Submissions were received from the Osaka Boiler Mfg Company and Taiheiyo Kisen Kaisha. The submissions have been included and/or the text of the report has been amended where appropriate.

APPENDIX D: MEDIA RELEASE

Crew members burned by a series of boiler explosions

The ATSB has found that four crew members who were injured on board the bulk carrier *Shirane* on 2 April 2007 were not aware of similar previous boiler explosions (flashbacks) which could have fore warned them.

The Australian Transport Safety Bureau investigation also found that the ship's crew were not aware of all of the hazards associated with servicing the boiler burner and that the personal protective equipment they were using did not provide them with adequate protection.

On the morning of 2 April 2007, *Shirane* was off Newcastle, New South Wales and the ship's third engineer had been assigned the task of replacing the Osaka OECV2 auxiliary boiler burner with a clean spare unit. When he finished the job, he attempted to fire the burner to check its operation but it failed to ignite. A few moments later, at 1013, while he was removing the burner to inspect it, there was a flashback from the boiler furnace.

The third engineer ran into engine control room and, as it was clear to the chief engineer and the first engineer that he had been burned, he was taken to the ship's hospital for first aid treatment.

The master was informed and, shortly after 1015, he telephoned the ship's agent in Newcastle and requested a medical evacuation.

After purging the boiler furnace for about an hour, the chief engineer and the second engineer removed the burner to inspect it. A few moments later, there was another flashback from the boiler furnace. The chief engineer, the second engineer and the fitter were burned by the second flashback.

The flashback had also caused a small fire on the deck, which was quickly extinguished. The three men then went to the ship's hospital for first aid treatment.

By 1324, a rescue helicopter had evacuated the second engineer, the third engineer and the fitter from the ship and, at 1729, it returned for the chief engineer.

The ATSB report found that the flashbacks were caused by unburnt fuel being deposited in the furnace when the burner misfired. The fuel was then vaporised and ignited by the hot surfaces inside the furnace.

The ATSB is pleased to report safety action already taken by the shipping company and the boiler manufacturer and has also issued three safety advisory notices with the aim of preventing similar occurrences.

Independent investigation into the boiler explosions
on board the Panamanian registered bulk carrier
Shirane off Newcastle, New South Wales, 2 April 2007