Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Marine Occurrence Investigation
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No.283
Final

Thermal oil heater explosion on board the products tanker

Qian Chi

at Brisbane, Queensland

16 January 2011

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

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SAFETY SUMMARY

What happened

On 16 January 2011, while the products tanker *Qian Chi* was at anchor in Moreton Bay, Queensland, the ship's number two oil-fired thermal oil heater exploded. The explosion seriously injured three crew members and severely damaged the thermal oil heater and surrounding equipment and fittings. The injured crew members received only rudimentary first aid on board. Shore-based emergency paramedics attended the ship and the injured crew members were evacuated by helicopter for treatment and recuperation.

What the ATSB found

The ATSB found that, during maintenance, the thermal oil heater burner nozzle had been assembled incorrectly. This was because the crew lacked experience with the equipment and the manufacturer supplied instructions were not clear and detailed. As a result, the nozzle leaked fuel into the furnace throughout the pre-ignition start sequence. The furnace exploded when the burner igniter started.

The ATSB also found that the ship's crew were not aware of the importance of providing immediate and accepted first aid treatment for burn injuries. It was also found that deficiencies in the Brisbane port vessel traffic service procedures and preparedness contributed to delays in providing emergency assistance.

What has been done as a result

The ship's operators have renewed the burner equipment installed in the ship for both oil-fired thermal oil heaters and altered the control system to better suit the fuel being used and the load demands placed on the heaters.

The heater's supplier, Garioni Naval, advised they were updating documentation supplied with their machinery. They had also been in contact with the burner equipment manufacturer and others regarding this incident and equipment design.

Maritime Safety Queensland has undertaken a review of its procedures and practices to take into account the risks associated with ships within port limits but not at a berth and the emergency response required in such situations.

Safety message

Ship's crew should remain vigilant to safety even when conducting repeated or seemingly simple tasks. Personnel need to consult equipment documentation and pay increased care and attention when undertaking unfamiliar tasks. To support that process, equipment documentation needs to be comprehensive and accurate.

Ship's crew should also understand the importance of providing immediate and appropriate first aid to injured persons, especially burn victims. Burn injuries should always be immediately cooled, under clean, cold running water, for at least 10 minutes.

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The cover photograph and Figure 1 have been used with permission of John Wilson.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

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 identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, 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 initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

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, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, 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 in the interests of improved transport safety.

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.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

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

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

1 FACTUAL INFORMATION

1.1 *Qian Chi*

Qian Chi is a crude oil/products tanker (Figure 1) which was built in 2008 by the China Shipping Industry (Jiangsu) shipyard. It has an overall length of 185.0 m, a breadth of 32.0 m and a deadweight of 45,541 tonnes at a summer draught of 12.1 m.

Figure 1: ***Qian Chi***

Qian Chi is of conventional double-hulled construction with 14 cargo tanks (including two slops tanks) and segregated ballast tanks. All of the cargo tanks are situated forward of the accommodation superstructure, seven either side of the ship's centreline. The ship has a cargo carrying capacity of 54,866 m³, at 98% full, including 2,019 m³ in the slops tanks.

Propulsive power is provided by a YMD-MAN B&W 6S50MC-C reversible, two-stroke, diesel engine which delivers 9,000 kW at 127 rpm. The main engine drives a single, four bladed, fixed-pitch propeller which gives the ship a service speed of 14.6 knots[1].

At the time of the incident, *Qian Chi* was managed and operated by the China Shipping Development Company, China. It was owned by Qian Chi Shipping, Hong Kong, registered in Hong Kong and classed with Det Norske Veritas (DNV).

Qian Chi operated with an unmanned machinery space[2] when at sea. This changed to a traditional 4 hours on/8 hours off watchkeeping routine during port cargo operations and whenever otherwise necessary. Watchkeeping was undertaken by the second, third and fourth engineers, with the engineering cadet (cadet) assisting as necessary. When not on watchkeeping duties, the cadet was a day worker.

The ship's crew consisted of 24 Chinese nationals. All the crew were appropriately qualified to sail on board a Hong Kong registered ship in the positions they held.

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

2 A notation indicating that the ship may be operated with the machinery spaces periodically unattended.

The master had 11 years of seagoing experience, all of which was with the China Shipping Development Company. He obtained his Chinese master's certificate of competency in 2007 and joined *Qian Chi* about 2 months before the incident.

The chief mate had 15 years seagoing experience. He obtained his chief mate's certificate in 2002 and had been sailing as chief mate since that time. He joined *Qian Chi* about 3 months before the incident.

The chief engineer obtained his chief engineer's certificate of competency in November 2009. Prior to the incident, he had served on board *Qian Chi* for 10 months. In that time, he progressed from second engineer to chief engineer and had been chief engineer for just over 5 months. This was his first ship as chief engineer.

The third engineer held a third engineer's licence obtained from the Nanjing Marine College (China) in 2009. He had worked with the China Shipping Development Company throughout his seagoing career and joined *Qian Chi* about 4 months before the incident.

The electrical engineer had been at sea since 2006. He held qualifications as an automation and electrical engineer obtained from the China Maritime College in 2006. He had worked with the China Shipping Development Company since commencing his training and had been on board *Qian Chi* for 10 months.

The ship's political officer was on board to assist the ship's master with day-to-day administration and personnel issues. He had served as a political officer on various ships since 2002. Prior to this, he had served as a ship's medical officer until the position was removed from Chinese registered ships. At the time of the incident, he had been on board *Qian Chi* for almost 5 months.

The cadet graduated in 2009 and had recently completed his trainee sea time. He had been at sea for more than 1 year and had been on board the *Qian Chi* for more than 5 months.

1.2 Thermal oil heaters

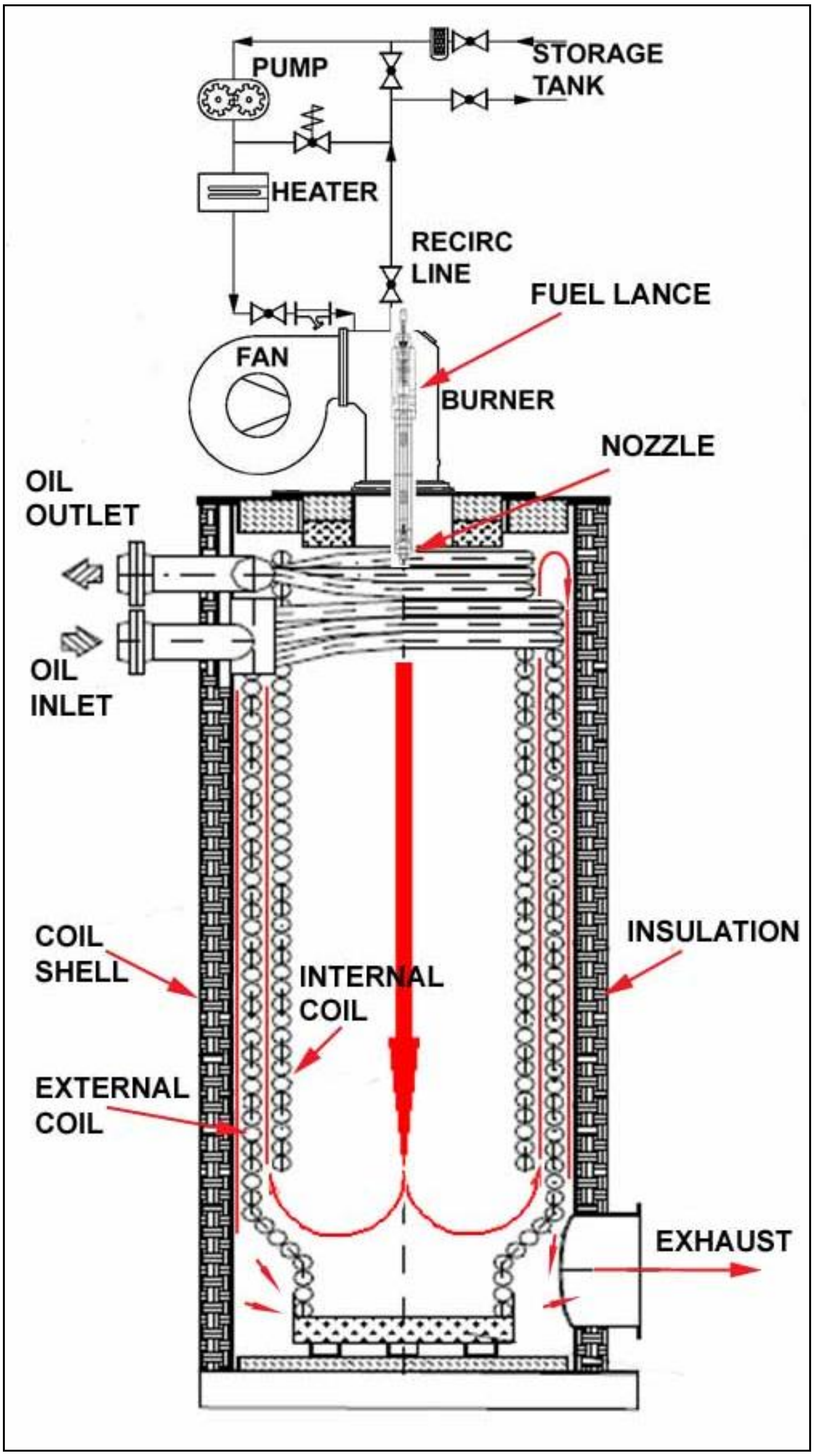
At the time of the incident, *Qian Chi* was equipped with two Garioni Naval TH/V 6000 oil-fired thermal oil heaters which produced a maximum of 6,978 kW (6,000,000 kCal/hr) of heat energy. The ship was also fitted with a Garioni Naval TH-EG 560 exhaust gas waste heat recovery unit (economiser) which utilised waste heat from the main engine exhaust gas to heat the thermal oil.

The heaters and economiser were set to heat the thermal oil to about 175 °C. The hot oil was piped round the engine room in a primary heating circuit which supplied heat for the main engine fuel system and other utilities and also two secondary heat exchangers for cargo tank heating and washing.

At sea, all the ship's heating needs were usually met by running the economiser. At times when insufficient heat was extracted from the main engine exhaust gas, such as under slow steaming conditions, the oil-fired thermal oil heaters were used to assist the economiser. In port, the operation of one oil-fired thermal oil heater was usually sufficient to meet the ship's heating requirements.

The oil-fired thermal oil heaters were approximately 6.2 m tall and had a diameter of 2.5 m. They were located on platform A in the after part of the engine room and spanned two decks, extending up the funnel space (Figure 8). They were of roof-fired vertical design with heating surfaces formed by two concentric coils of thermal oil circulation piping. This created three passes of combustion gas flow over the coils (Figure 2).

Figure 2: Garioni Naval vertical thermal oil heater as fitted in *Qian Chi*



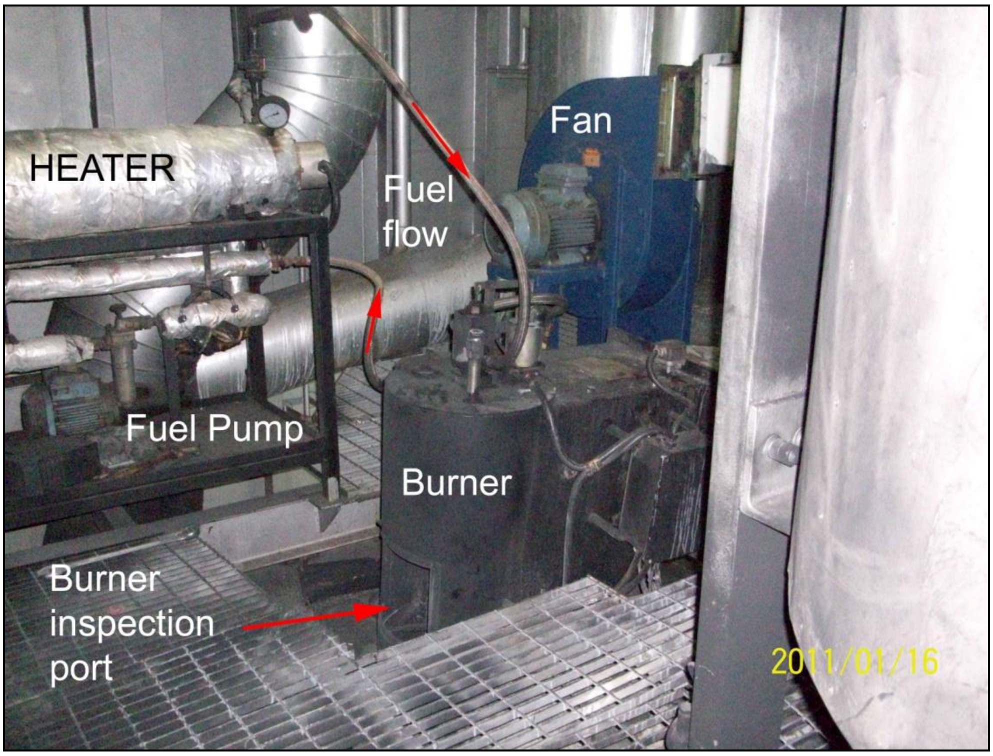
1.2.1 Oil firing system

The thermal oil heaters were fitted with a roof mounted oil firing unit which could be fired using either heavy fuel oil (HFO) or marine gas oil (MGO)[3]. At the time of the incident, they were both fired with MGO.

The firing system consisted of an external forced-draught fan and a fuel treatment unit feeding the roof mounted burner lance, nozzle and combustion head (Figure 3). Fuel from a storage tank was pumped to the inlet of the fuel unit burner pump. This pump then boosted the fuel pressure and circulated it through the electric heater, to the burner lance and nozzle, returning through the regulating valve to the suction side of the pump.

Combustion air was ducted from the fan to the side of the burner unit and flowed, via a modulating damper, down around the oil lance and into the furnace.

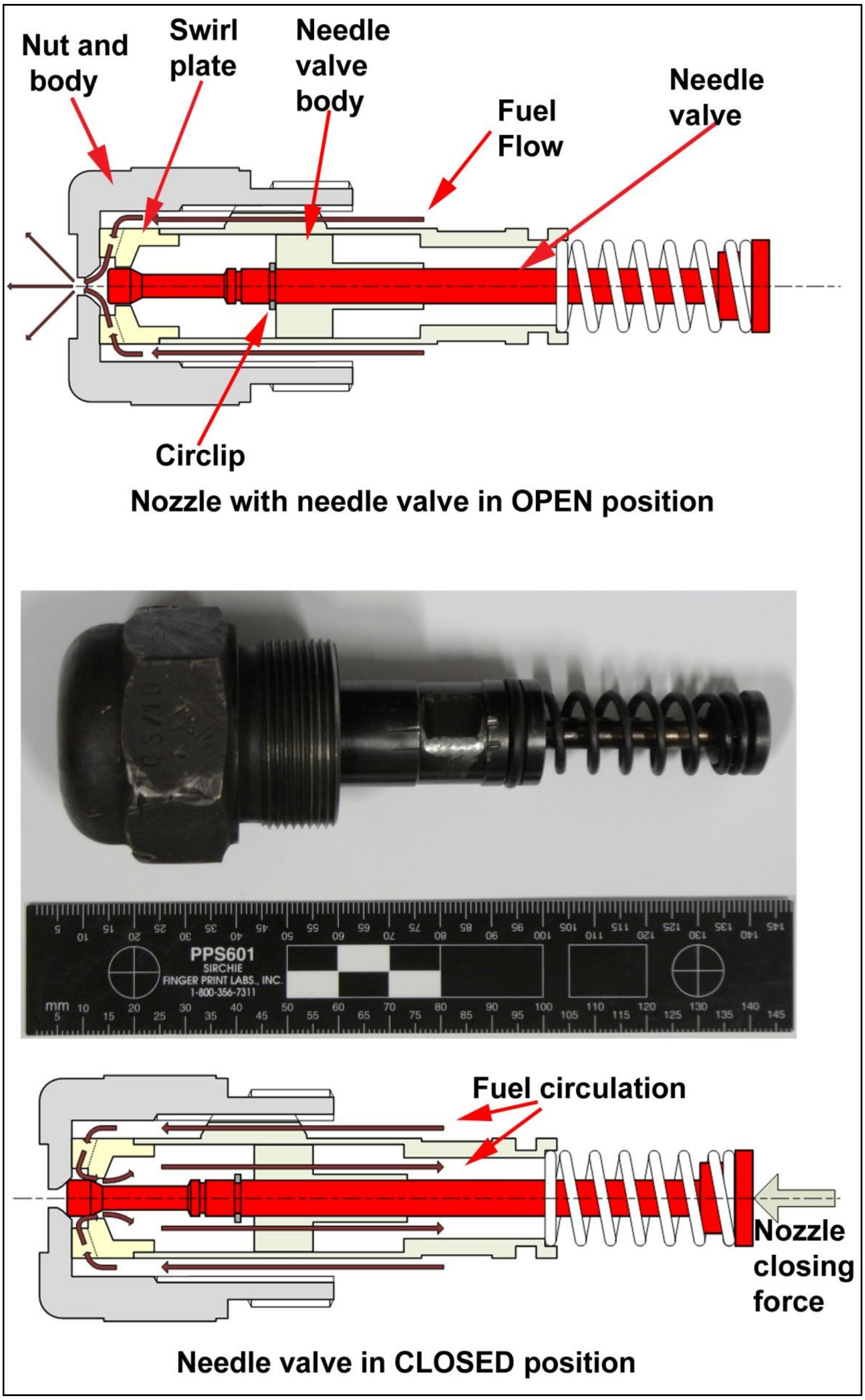
Figure 3: Thermal oil heater top showing burner and fuel supply layout



The thermal oil heater, in automatic mode, cycled on and off as required, controlling around the thermal oil temperature set point of 175 °C. When the circulating thermal oil temperature dropped to 175 °C, the firing unit received a start signal. The start sequence took 4 minutes, during which time the forced-draught fan and burner fuel pump both ran continuously. The fan purged the

3 Marine gas oil refers to a low sulphur, low ash content distillate fuel with a viscosity of 1.5 to 6 centiStokes (cSt) at 40°C which usually requires no heating for combustion. This compares to heavy fuel oils with viscosities ranging from 180 to 700 cSt which can require heating up to 150°C for combustion. MGO is composed of the petroleum fractions of crude oil which are separated in the refinery by boiling the oil to a gas and then condensing into a liquid (‘distilling’).

Figure 4: Burner nozzle showing open and closed positions



furnace with fresh air and the fuel pump circulated fuel through the heater, down to the nozzle and back to the pump suction. During this time, the fuel flow was cycled from minimum to maximum and back, to be at minimum just prior to ignition.

During the start sequence, fuel was prevented from entering the combustion chamber by the needle valve in the spray nozzle (Figure 4). The needle valve was held closed by a solenoid actuated operating rod acting on the top of the needle valve stem (nozzle closing force).

The starting sequence was immediately followed by ignition sparking and the opening of the fuel nozzle. Once a flame was established, the fuel supply was regulated automatically until the thermal oil temperature increased to 175°C. At this point, the firing stopped, the needle valve closed and the fuel supply pump and forced-draught fan stopped. The system then remained in standby mode until the thermal oil cooled sufficiently for the system to again call for heat.

1.3 Port of Brisbane

The city of Brisbane lies on Australia's east coast and is the capital and principal port of Queensland[4]. The city is located in the south-east corner of Queensland and straddles the Brisbane River as it enters Moreton Bay (Figure 5). The port extends on both banks of the river for about 12 miles[5] upstream from the entrance beacons to Hamilton wharves. All berths in the port are located in the Brisbane River or at its mouth.

Brisbane port limits extend from the lower reaches of the Brisbane River, across Moreton Bay and north to Point Cartwright. Ships enter Moreton Bay and the shipping channel southeast of Caloundra Head and proceed through the bay for about 40 miles from the fairway beacon to the river entrance beacons. The Brisbane River entrance is to the north of Fisherman Islands.

The port of Brisbane is Queensland's busiest port and services the rapidly growing areas of south-east Queensland and northern New South Wales. In the financial year 2010/11[6], more than 2,400 ships visited the port, handling 33.1 million tonnes of cargo, including 11.8 million tonnes of oil products and more than 978,800 teu[7].

At present, the port has 29 operating cargo berths including 8 tanker berths. The principal import to the port is crude oil with other cargoes including fertiliser and chemicals, motor vehicles, cement clinker and gypsum. Exports include coal, refined petroleum products, grain, woodchips, mineral sand and beef and dairy products.

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4 *Admiralty Sailing Directions, Australian Pilot Volume III* (NP15), tenth edition, 2005, p129.

5 A nautical mile of 1852 m.

6 2010/2011 figures from PoBC Annual Performance Report, 2011, Key Trade Results <http://www.portbris.com.au/NewsMedia/AnnualPerformanceReport/KeyTradeResults20102011>

7 Twenty-foot Equivalent Unit, a standard shipping container.

Figure 5: Brisbane

1.3.1 Brisbane vessel traffic service

According to Maritime Safety Queensland's (MSQ) port procedures and information for shipping, the Brisbane vessel traffic service (VTS) is 'the principal tool by which the regional harbour master manages the safe and efficient movement of vessel traffic approaching, departing and operating within the pilotage area.' [8]

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8 Port Procedures and Information for Shipping, Port of Brisbane, June 2010, Maritime Services Queensland Transport and Main Roads, Queensland Government, §3.1 p22,

All ships visiting the port of Brisbane are directed to, and provided with, an 'Emergency Information' flier which directs the master to call 'Port Control' by telephone or contact 'Brisbane Harbour' using emergency very high frequency (VHF) channel 16. Both connect the caller to the VTS, located in MSQ's Brisbane port control centre. Hence, in the event of an emergency, VTS is the 'key notification and communications facility that will activate the appropriate response agencies'[9].

Under existing arrangements, MSQ is the lead agency responsible for responding to incidents involving oil/chemical spills, groundings and ship collisions within the limits of the port. MSQ does not have the resources or expertise to respond to other incidents such as medivacs or fires on board ships. The lead agency responsible for responding to other incidents within the port, including those which involve the ambulance and fire and rescue services, is the Queensland Police Service, through the Brisbane Water Police.

The VTS acts as the first contact point for the crew of any ship needing emergency services via the water police. The VTS then coordinates communication and information between the ship and the responding agencies. In this role, VTS provides support and advice as the source of expert information regarding the port, ships and shipping to both the ship involved in the incident and the responding shore agencies.

At the time of the incident, two experienced and qualified VTS operators were on duty. In addition to on the job training and several years of experience, they had completed an IALA approved certificate III in VTS operations[10]. The senior operator on duty had also completed an IALA approved certificate IV in VTS operations for VTS supervisors and had been the port's VTS training officer for several years.

1.4 The incident

During the evening of 10 January 2011, *Qian Chi* arrived off Brisbane, Queensland following a voyage from Port Botany, New South Wales. At 2240[11], a Brisbane harbour pilot boarded the ship and following a master/pilot information exchange, *Qian Chi* began the 5 hour pilotage of Moreton Bay to its berth in the Brisbane River.

By 0500 on 11 January, the ship was all fast alongside the Pacific Terminals wharf (Figure 6). At 0805, cargo operations commenced and discharge of diesel and unleaded petrol continued without incident throughout the morning.

At this time, Brisbane and the surrounding area was receiving heavy rainfall and consequent flooding. The resulting strong current within the Brisbane River led the regional harbour master to close the port to all traffic. All ships in the port were directed to evacuate to Brisbane Roads in Moreton Bay before 2359 that night.

<http://www.msq.qld.gov.au/~/media/2e2a8238-782e-4cb2-802f-1a27c0d30013/pdf_brisbane_ppm_june10.pdf>.

9 Ibid, §12.7.2 p76.

10 IALA Model Course V-103/1, On Vessel Traffic Services Operator Training, Edition 2, December 2009, IALA-AISM, Saint Germain En Laye, France.

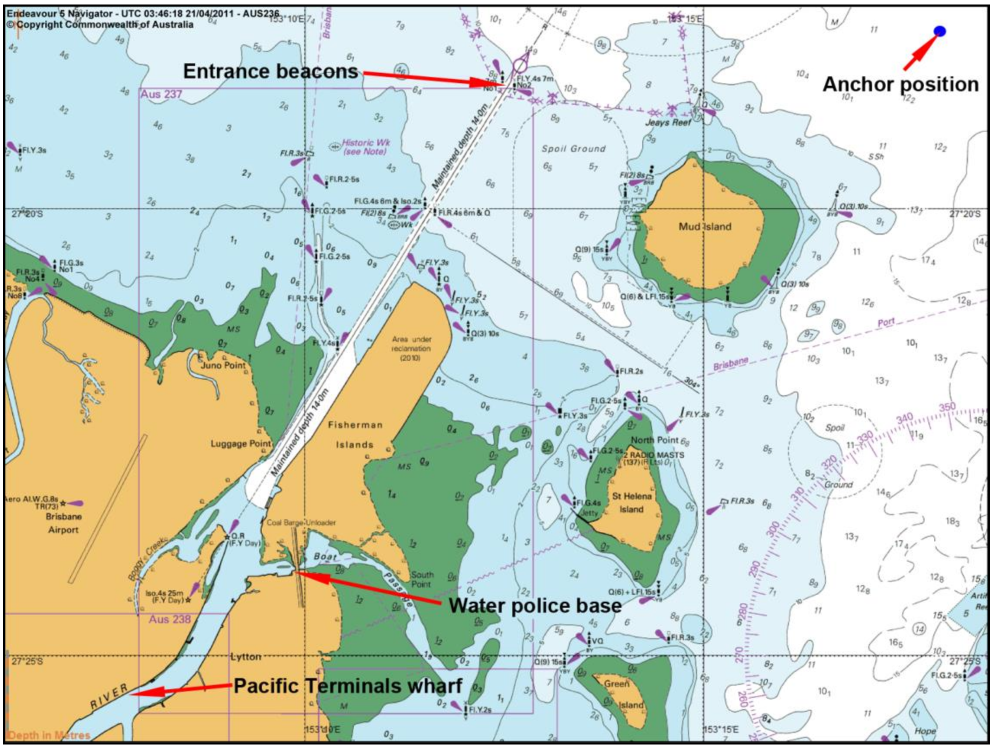
11 All times referred to in this report are local time, Coordinated Universal Time (UTC) + 10 hours.

At about 1200, cargo operations on board *Qian Chi* were stopped. At 1300, a harbour pilot boarded and the ship was moved to an anchorage in Moreton Bay. By 1600, *Qian Chi* was anchored and the pilot had disembarked. The final anchorage position was about 4 miles from the entrance beacons.

Given the weather and the condition of the flooded Brisbane River, it was not known how long the ship would be at anchor. Consequently, the engineering department continued watchkeeping duties and undertook routine and general engine room and machinery maintenance. During the initial days at anchor, all necessary machinery systems, including the thermal oil heaters, were operating normally.

At about 2120 on 14 January, the ship's number two thermal oil heater failed to fire. The unit was stopped and the burner lance removed and the igniter electrodes cleaned. It was then put back into operation and observed to operate correctly through four on-off cycles. It was then left operating overnight.

Figure 6: Section of navigational chart Aus 236 showing *Qian Chi*'s anchor position



The following morning, further ignition failures occurred. The engineers attempted to remedy the situation by cleaning and adjusting the ignition electrodes. However, they had no success and, by mid-afternoon, the decision was taken to leave the unit off for the evening.

During the morning of 16 January, the engineering staff met and discussed the day's work schedule. Effort was again to be directed toward getting the number two thermal oil heater operational. With the exception of the fourth engineer, all engineers were variously engaged in this work. After further checking of the ignition electrodes, the heater ran for about 90 minutes, cycling eight times without incident. However, at 1050, it again failed to ignite. Rather than continue working on the unit, the engineers went to lunch.

At about 1400, the electrician began inspections of the thermal oil heater electrical systems. This included verifying the igniter circuitry and checking and setting the electrode condition and position.

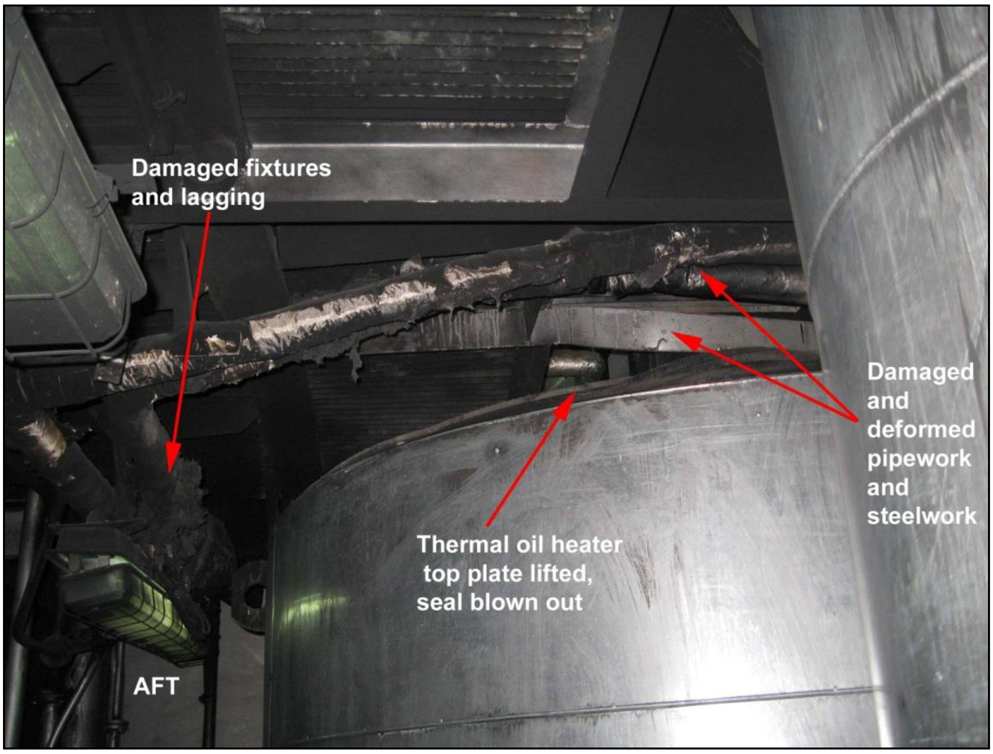
At about this time, the third engineer and the cadet began inspecting and cleaning the burner lance and nozzle. They removed the nozzle from the burner lance and took it to the workshop for further inspection and cleaning. The third engineer dismantled the nozzle and found it to be clean and in good condition. He then reassembled the nozzle. At this time, the chief engineer came into the workshop and confirmed the condition of the nozzle and reaffirmed the conduct of the work. The nozzle was then refitted to the burner lance and the burner reassembled.

By about 1500, the thermal oil heater burner had been reassembled and prepared for operation. The engineers then initiated the burner's automatic start sequence. The third engineer was crouched on the deck grating above the thermal heater to observe the operation of the burner unit, fuel regulator and linkages. From there, he was able to look through the observation port in the burner top while waiting for ignition and firing. The cadet was standing just forward of the burner unit, on the same level as the third engineer, observing the burner fuel pressure gauge. The electrician was a little further away, to port, having just returned to the area to observe ignition.

At the time, everything appeared to be operating as normal, with the forced-draught fan and fuel supply pump running as the heater went through its 4 minute purge cycle. The third engineer observed and confirmed the operation of the fuel regulator as it opened and closed–in the fuel flow as the system sequenced. After some time, the third engineer refocused his attention to the peep hole to observe the ignition.

At about 1512, the burner igniter operated and the thermal oil heater exploded.

Figure 7: Thermal heater top damage – including lifted top plate, bent steel and piping and damage to fixtures and lagging

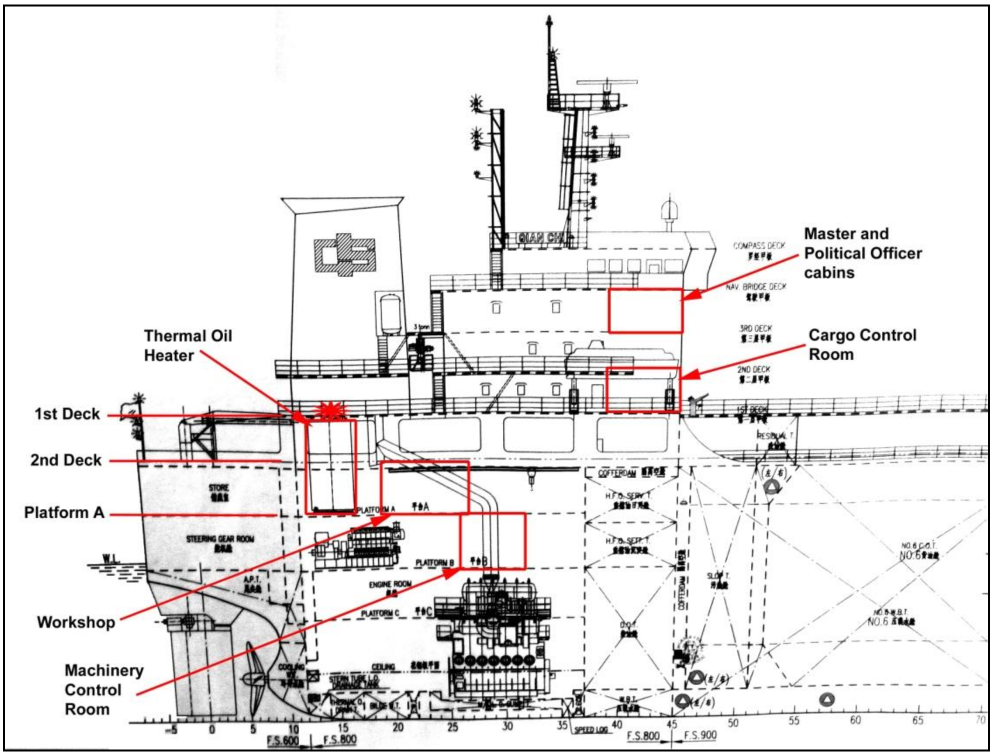


The explosion lifted the thermal oil heater casing top (Figure 7). Several securing bolts were snapped as the force of the explosion was released into the upper engine room, the funnel space and out the open access door onto deck. The burner arrangement was pushed out of alignment and the air duct inspection cover fitted to the burner was torn from its four securing bolts. The deck grating and mounting supports were upset about 300 mm vertically. The ducting from the externally mounted forced-draught fan was torn apart at the canvas flexible joint. Fuel lines running across the top of the thermal heater were deformed, and at least one began to leak from a weakened flange.

The explosion triggered the engine room fire detection system initiating a fire alarm on the fire control panel on the ship's bridge. At the same time, the local fire suppression system automatically activated and doused the area around the top of the thermal oil heater with a fine water mist. This also initiated water mist release alarms in the machinery space adjacent to the oil heaters, in the machinery control room and on the bridge water mist alarm panel, but not throughout the remainder of the ship.

The force of the explosion threw the third engineer to the deck. The flame-front escaping from the thermal heater engulfed the area around the top of the unit and with it, the three crew members. All suffered burns, to varying degrees, over large portions of their bodies. They were blackened all over, their hair and exposed skin was burned and their clothing dry, brittle and coming apart. The third engineer was more seriously injured than the electrician and cadet with severe burns to his arms and hands. However, none of the men were incapacitated and they were able to make good their escape from the area.

Figure 8: *Qian Chi* arrangement showing general location of explosion, workshop, cargo control room, machinery control room and master's cabin



The electrician and the cadet made their way onto the open deck and forward to the accommodation where they met the chief mate, who told them to go to the political officer’s cabin for medical treatment (Figure 8). The third engineer escaped down into the engine room and made his way toward the workshop where he met the chief engineer who had heard the explosion and was making his way aft to investigate. He directed the third engineer to the political officer’s cabin to seek medical assistance.

The chief engineer, along with an oiler, proceeded to the thermal oil heater space. In the vicinity of the heater top, they found smoking debris and liquid. Using a hand-held fire extinguisher, they extinguished a small localised fire. The chief engineer then directed that the fuel supply pump to the thermal oil heaters be stopped.

The explosion was heard throughout the ship’s accommodation. Both the master and the political officer immediately went to the bridge to assess the situation. Upon arrival, they saw that the fire control panel was alarming and that a large quantity of black smoke and soot was coming from the funnel.

The chief mate went to the cargo control room to investigate and secure the cargo system. He saw that everything was in order and then called the bridge and verified that the officer of the watch was aware of the situation and to ensure the general alarm would be sounded to muster all of the crew. He then returned to the deck to muster the crew.

The master called the engine room and was informed that number two thermal oil heater had exploded. At about 1514, he activated the ship’s general alarm to muster all personnel in response to the emergency.

The crew mustered and were organised to inspect and assess the area around the number two thermal oil heater. The chief mate assembled a fire fighting team and they entered the space from the main deck. The chief engineer confirmed that any fires had been extinguished and the fire team was then tasked with securing and monitoring the area. The oiler was tasked with securing the fuel line and any other flanges loosened during the incident and to ensure that there was no further fuel leakage.

Once satisfied with the local conditions and response, the chief engineer went to the bridge to discuss the situation with the master. The chief mate went to the political officer’s cabin to lend assistance to the injured crew members.

The three injured men were seated in the political officer’s cabin. They had their burned clothing removed and all were given pain killers to assist with the pain. Their exposed skin was covered with clean dry cloths and, other than being given water to drink, little other treatment was administered.

At 1539, the master contacted Brisbane VTS by VHF radio, reported the incident and requested medical assistance. The master also contacted the ship’s local agent and the company’s Australian representative, informing them of the incident.

The VTS unsuccessfully attempted to call the Queensland water police for assistance. They then contacted the Queensland Police communications centre and were advised to telephone the emergency ‘000’ number directly.

At 1542, VTS called ‘000’ and were directed to Ambulance emergency at the Queensland Ambulance Service (QAS). VTS informed them of the situation and explained the ship's location. They also explained the need to assemble at the water police base at the port for transport by boat to the ship.

The emergency operator dispatched QAS paramedics immediately. The operator also passed on the emergency information to other agencies. At 1546, the Queensland Fire and Rescue Service (QFRS) were notified of the incident. They responded with two vehicles to the water police base.

At 1548, *Qian Chi*'s master contacted VTS to request a helicopter evacuation of the injured men as they were seriously burned and in great pain. He told VTS that the ship had no helicopter landing area and that the injured men would need to be winched off the ship. At 1550, VTS contacted the water police and requested assistance in organising the helicopter evacuations. During subsequent conversations, it was mentioned that the ship was a products tanker and would 'have gas everywhere; venting'. At 1609, the water police informed VTS that the helicopter option was not available and that they would consider the ship to have a 500 m exclusion zone around it because of its condition.

At about 1600, *Qian Chi*'s chief mate contacted the Shanghai Seamen's Hospital and requested assistance and guidance regarding medical treatment for the three crew members. In addition to gaining urgent shore assistance, he was advised to puncture what blisters he could with a needle to release the accumulating fluid.

At 1610, VTS informed *Qian Chi* that the ship's earlier request for a helicopter evacuation was denied and assistance, in the form of paramedics and fire officers, would be arriving in about 30 minutes by launch. In anticipation of the arrival of the shore medical personnel, the three injured men were moved from the political officer's cabin down to the cargo control room.

By 1610, the QFRS and QAS teams had gathered at the water police base. Two police launches had been organised and, at about 1617, departed. Five QAS personnel were on board the first launch and two QFRS personnel on the second.

When the paramedics arrived at the ship, they made their way to the cargo control room and assessed the condition of the injured men. Pain medication, including morphine, and oxygen were given to all three as needed. The paramedics quickly determined that, given the patients' condition, helicopter evacuation was required as transport by launch would be impractical. At 1652, the request for two helicopters was made.

At 1708, the second police launch arrived at *Qian Chi* and two QFRS fire fighters boarded to assess the ship for possible dangers and risks.

At about 1735, the first helicopter arrived overhead *Qian Chi*. The electrician and cadet were assisted down to the main deck and were winched to the helicopter and transported directly to the Royal Brisbane Hospital.

Soon after, the third engineer was winched on board the second helicopter in a stretcher. This helicopter had a doctor and extensive facilities on board.

By 1811, the helicopters and the fire officers had departed the ship and at 1815, the paramedics departed.

Qian Chi remained at anchor until the morning of 19 January, when it berthed to complete cargo discharge. On 20 January, the ship was moved to another berth so that further inspections and temporary repairs could be carried out.

On 21 January, *Qian Chi* departed Brisbane bound for Daesan, South Korea, where permanent repairs were to be made.

2 ANALYSIS

2.1 Evidence

On 18 January 2011, two investigators from the Australian Transport Safety Bureau (ATSB) attended *Qian Chi* while the ship was at anchor in Moreton Bay, Queensland. The master and directly involved crew members remaining on board were interviewed and they provided accounts of the incident. Photographs of the ship and copies of relevant documents were obtained, including log books, reports, manuals, procedures and certificates. Physical evidence, including the burner nozzle, was inspected on site and collected for further examination.

On 19 January, the investigators again attended the ship after it had berthed in Brisbane. They completed inspections of the ship and finalised evidence collection.

On 3 February, interviews were conducted with personnel from Maritime Safety Queensland (MSQ), Brisbane harbour vessel traffic service (VTS) and the Queensland Ambulance Service (QAS).

The following day, *Qian Chi*'s electrician was interviewed in the Royal Brisbane Hospital. The third engineer and cadet were subsequently interviewed at the Royal Brisbane Hospital on 3 March, after they had recovered sufficiently from their injuries.

On 29 July, two ATSB investigators again visited *Qian Chi* upon its return to Brisbane. The master and chief engineer (second engineer at the time of the incident) were interviewed and apprised of the investigation's progress. The ship was inspected again and further information obtained. Repairs and alterations to the thermal oil heater units were also inspected.

During the investigation, additional information was provided by the Australian Maritime Safety Authority (AMSA), the China Shipping Development Company, Garioni Naval, MSQ, Petrel Shipping, the QAS, the Queensland Fire and Rescue Service (QFRS), the Queensland Police Service and Wilhelmsen Ship Services.

The ATSB limited its safety investigation to initial shipboard and maritime agency response to the incident and did not, therefore, scrutinise the actions or decision making processes followed by the shore-based emergency services and providers.

2.2 The incident

On 16 January 2011, while *Qian Chi* was at anchor in Moreton Bay, the ship's number two oil-fired thermal oil heater exploded, seriously injuring three crew members. The explosion severely damaged the thermal oil heater and surrounding equipment and fittings.

In the days leading up to the explosion, the number two thermal oil heater failed to fire on a number of occasions and the ship's engineers had been working on its burner unit. When the explosion occurred, the engineers were in the process of firing the thermal oil heater after burner maintenance had been completed.

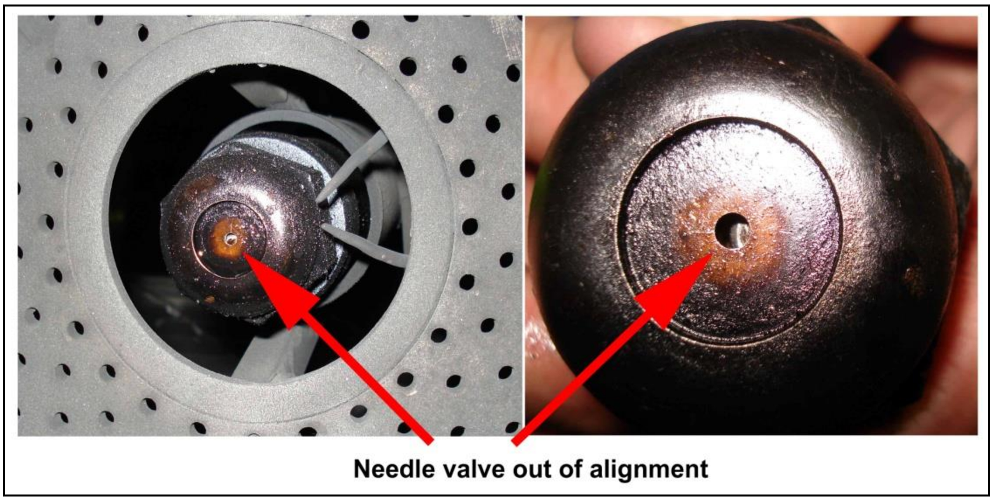
The three crew members were all severely burned. However, they received only rudimentary first aid from the ship's personnel. Later, QAS paramedics attended the ship and the injured crew members were evacuated by helicopter to a hospital for further treatment.

All three men spent several weeks in treatment and recovery within the hospital's intensive care and burns unit prior to being repatriated home.

2.3 The explosion

Following the explosion, the ATSB investigators inspected the thermal oil heater, its burner unit and associated systems. As a result of these inspections, the investigators determined that the fuel nozzle needle valve was not seated centrally in the nozzle housing (Figure 9). In that position, it would not have sealed the nozzle opening during the 4 minute pre-firing sequence immediately before the explosion.

Figure 9: Nozzle showing the misalignment of needle valve



Therefore, throughout the 4 minute pre-firing sequence, fuel would have been spraying from the nozzle into the thermal oil heater furnace while the forced-draught fan was supplying fresh air to the furnace in an attempt to purge it of combustion gases.

The thermal oil heater was not normally isolated from the heating oil circulation system when in standby or not in use. Therefore, the heating coil surface and, consequently, the surrounding furnace temperature were probably just below the thermal oil temperature, in the vicinity of 160 °C. The fuel in use at the time (marine gas oil [MGO]) had a flash point[12] of about 68 °C[13]. Therefore, the leaking fuel would have vaporised almost immediately on entering the furnace. The fuel vapours would have mixed with the air in the furnace and the concentration of this mixture would have continued to increase as more and more fuel flashed off (quickly evaporated) as it sprayed into the furnace.

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12 Flash point is the lowest temperature at which the oil gives off a combustible vapour.

13 Information from *Qian Chi* bunker specification for MGO bunkered and in use at the time.

Eventually, the concentration of the fuel vapour/air mixture would have entered its flammable range[14]. Then, when the burner igniter operated, its spark ignited the fuel vapour/air mixture. The furnace pressure would have rapidly increased, providing enough force to break the thermal oil heater's top cover bolts, lift the top cover and push a flame-front out of the furnace.

2.4 Burner needle valve misalignment

During the pre-firing start sequence, fuel was circulated from the burner fuel pump, to the burner nozzle and back. The nozzle incorporated a needle valve which should have prevented fuel from entering the furnace during the pre-firing start sequence.

During the investigation, the nozzle was removed from the burner lance and inspected. The inspection revealed that the needle valve head was offset within the nozzle orifice and the nozzle spring was compressed about 7 mm more than was measured on a spare nozzle. Upon dismantling, the needle valve stem was found to be bent about 20 mm above the valve head (Figure 10).

Figure 10: Nozzle needle valve with bend

The nozzle was retained by the investigators and examined in detail in the ATSB's technical analysis laboratory. This examination revealed markings consistent with incorrect assembly. These included:

- circular surface impressions in the upper ring of the swirl plate consistent with the diameter and thickness of the lower ring of the needle valve body;
- galling on the valve head, on the opposite side to the direction of bending in the valve stem; and
- witness marks on the tapered inner bore of the swirl plate matching the galling on the valve head. These marks were of the same size as the galling on the valve head and were diametrically opposite the surface impression in the upper ring of the swirl plate.

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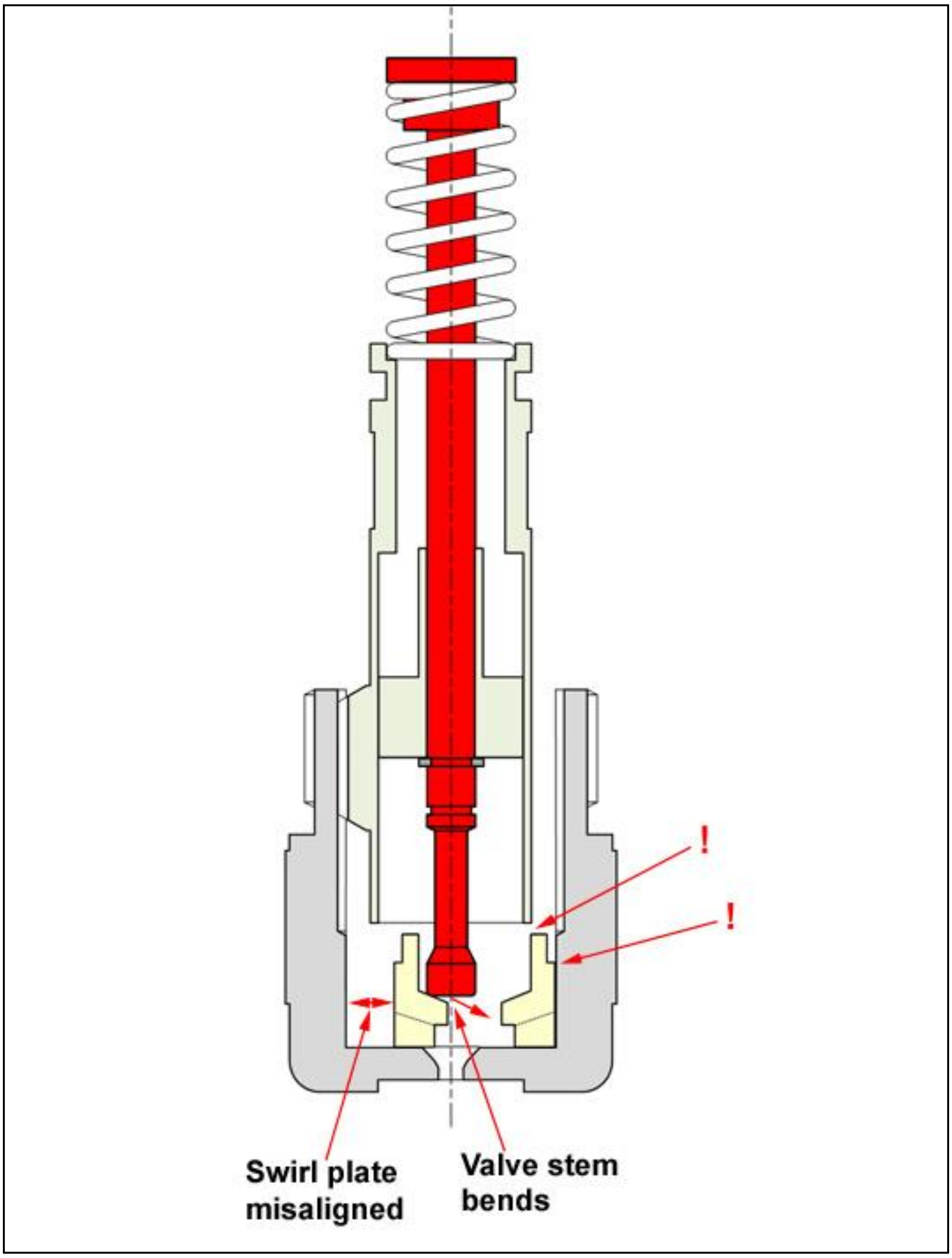
14 Flammable (or explosive) range is the range of hydrocarbon gas or vapour concentration in air that will burn (or explode) if an ignition source is introduced (ISGOTT).

The evidence provided by the on board inspection of the nozzle and the laboratory examination confirmed that the nozzle had not been correctly assembled when it was installed in the thermal oil heater.

When correctly assembled, the swirl plate should have been located centrally in the valve body. However, the swirl plate was 6 mm smaller in diameter than the surrounding internal diameter of the nozzle nut. If assembly of the nozzle was not carried out correctly, this clearance could result in misalignment of the valve stem and the swirl plate (Figure 11).

Figure 11: Burner nozzle showing misalignment of the needle valve head in the swirl plate



It is likely that this is what occurred during the nozzle assembly on the day of the incident. Then, when the nozzle was fitted to the lance, the needle valve head contacted the tapered internal surface of the swirl plate. As the nozzle was tightened into the lance, the closing force on the end of the needle valve overstressed the valve stem bending the head of the needle valve. The misaligned swirl plate and valve body allowed the valve head to jam in the swirl plate orifice. This resulted in the excessive compression of the nozzle spring found when the nozzle was initially inspected.

Because of the misalignment and resulting bend in the valve stem, the nozzle was never able to shut off the flow of fuel. Therefore, during the 4 minute start-up cycle, fuel flowed continuously into the furnace.

2.4.1 Nozzle design

The burner nozzle was originally designed to accommodate various fuels, including heavy fuel oil (HFO). For HFO, the fuel was circulated from the external heater and pump, through the burner lance to the nozzle needle valve, and back again. The fuel flowed down an outer path in the lance and nozzle, through slots in the swirl plate and back up an internal route within the nozzle and lance (Figure 4). Clearances were necessary to allow fuel flow and for dismantling the nozzle components for cleaning and inspection. These clearances resulted in a 6 mm difference between the swirl plate outer diameter and the internal diameter of the nozzle nut and body. This clearance allowed the swirl plate to be free within the nut. However, there was the potential for misalignment with the mating bore in the needle valve body. Unless some control measures to minimise the risk were taken, this potential misalignment could lead to maintenance and assembly errors.

In any hierarchy of risk controls, the first and best control is to eliminate the risk. In this case, this would have included designing the burner nozzle so that it could not have been assembled incorrectly while maintaining the need for fuel flow and maintenance operations. There were a number of engineering design options which could have been employed to positively locate the swirl plate within the nozzle body and ensure correct alignment with the needle valve and body whilst maintaining sufficient flow paths for fuel circulation.

The ATSB was advised by the China Shipping Development Company that repairs conducted on the ship after the explosion included replacing the burner equipment with a new design from a different manufacturer, but sourced and supplied through a Garioni Naval partner company. The installation of the new burner system included components and alterations to the control system which better reflected the operational needs of the thermal oil heater. These changes significantly reduced the possibility of a furnace explosion of the severity experienced in this incident. This new burner unit, however, included a nozzle of substantively the same design as that of the nozzle described in this report, and supporting documentation of a similar standard.

When contacted, Garioni Naval stated that the nozzle described in this report was not the original nozzle supplied, nor one they supplied as a spare. However, they did not provide sufficient evidence to substantiate this and, based on the available evidence, it was concluded that the nozzle involved in the incident was as originally supplied.

In submission, Garioni Naval, also stated that:

> … Garioni Naval is not the original manufacturer of the burner nozzle initially supplied with the burner. The original manufacturer of the equipment is Energy Bruciatori.
>
> After becoming aware of the issue, Garioni Naval contacted Energy Bruciatori, requesting more detailed design data and design drawings of the originally supplied burner nozzle, and enquiring whether Energy Bruciatori had considered if the current design could be enhanced. Energy Bruciatori has declined to provide further details, citing commercial proprietary and intellectual property reasons.

Regardless of who manufactured the burner nozzle, Garioni Naval, as the supplier of the packaged thermal oil heaters, had a responsibility to ensure that an appropriate safety assessment of all components had been undertaken and that comprehensive maintenance documentation was provided to the end users.

2.4.2 Nozzle maintenance and instructions

Another risk control, although not as effective as eliminating the risk, is to provide administrative controls. This includes providing clear and unambiguous warnings and supporting documentation that clearly detail the risks and give instructions on how to avoid the consequences of those risks. For the burner nozzle, this would have resulted in a comprehensive maintenance manual which included drawings and instructions for the nozzle, its construction and maintenance.

Errors when performing unfamiliar but seemingly simple and routine maintenance tasks are a recognised phenomenon within the shipping industry. Schager[15] suggests that completing numerous uneventful and similar tasks can build a false sense of security or a false sense that the situation is under control when it isn't. This can then lead to reduced vigilance or a deficient risk assessment for the task at hand.

In this case, an experienced engineer, completing a familiar task, that is, dismantle and clean, on unfamiliar but seemingly simple equipment and in the company of several other experienced maintenance staff, made a series of simple errors which led to the incorrect assembly and reinstallation of the nozzle in a dangerous condition.

The documentation a ship receives in association with machinery or equipment forms a vital source of guidance and information within a ship's safety management system (SMS). These documents provide the authoritative reference and support for the less prescriptive and less detailed documents and procedures found within a ship's SMS.

In this instance, the instruction manuals supplied with the thermal oil heater and burner provided very limited guidance for the maintenance of the nozzle and lance.

The documents supplied with the thermal heaters included a suite of more than 150 files, contained in multiple volumes. This library of documents included files from various original equipment manufacturers. One manual from this suite of

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15 Schager, B. 2008, *Human Error in the Maritime Industry*, Marine Profile Sweden AB, English translation printed by Halmstad Tryckeri AB, Halmstad, Sweden.

documents titled *Boiler TH-V 6000 Use Instructions*, in its ‘Safety prescription’ section, advised:

> Never try to carry out operations you are not familiar with; always FOLLOW the instructions and, if no instructions are present, contact the GARIONI NAVAL service centre…

This advice was provided in one section of the thermal oil heater manual but was not included in other sections of the same instruction manual referring to troubleshooting or maintenance. This warning was also not included in the *Heavy Oil Industrial Burners Instruction Manual*, the manual which the ship’s engineers would refer to when performing maintenance on the burner.

Apart from this instruction, the documents limited nozzle maintenance advice to cleaning and replacement when worn and there were no suggestions on how to determine wear. Furthermore, the manuals provided no clear drawing of the nozzle, no spare parts breakdown nor any specific maintenance, assembly, disassembly, testing or inspection instructions. Drawings for the components that were mentioned were small and lacked clarity of detail.

Consequently, nozzle maintenance was undertaken on board *Qian Chi* based on the ship’s engineers experience and maintenance practices learnt and taught as part of marine engineering training and time spent on ships.

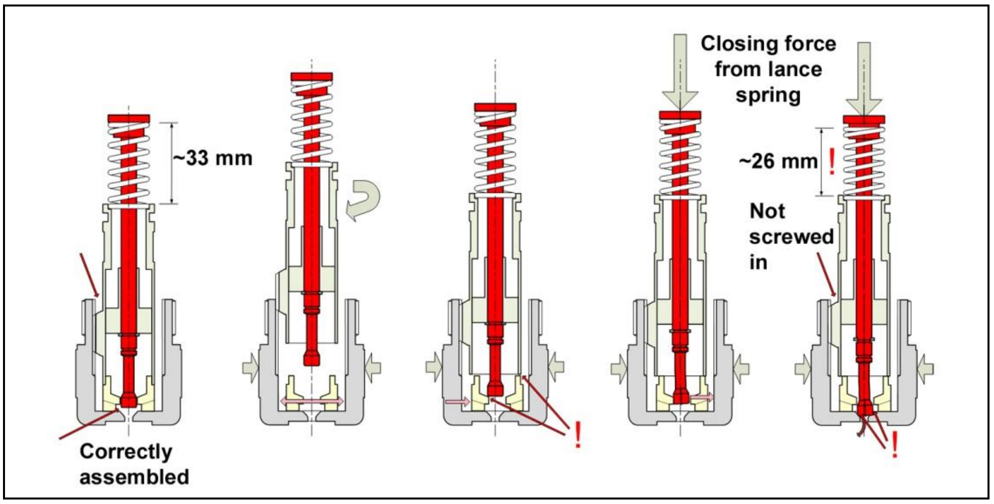
The nozzles were visually inspected regularly but underwent physical dismantling and overhaul only occasionally. At some time prior to the incident, the company had approved a change of fuel from HFO to MGO as the heater burners had ongoing high maintenance requirements when operating on the heavier fuel. The change to MGO had significantly reduced the need for maintenance of the burners and there was little evidence to suggest that the nozzles needed to be removed from the burner lances at regular intervals. As a consequence, the ship’s engineers had limited experience with this maintenance activity. In the 3 years the ship had been in service, no replacement parts for the thermal oil heaters had been ordered by the crew. The redundancy of equipment and this reliability of operation contributed to the engineers’ lack of experience with the equipment and its maintenance.

The previous time the nozzle had been removed and dismantled for the number two thermal oil heater was about 4 months prior to the explosion. This work was performed by the chief engineer, who was still on board at the time of the explosion, but it was not witnessed by any of the other engineers.

The nozzle assembly, when removed from the lance, required mounting in a vice for further dismantling. The unit lent itself to being mounted in a vice across two flats of the nozzle nut with the valve body and spring vertically upwards (Figure 12). This allowed access to the flats machined on the valve body so a spanner could be used to unscrew the body and needle valve assembly from the nozzle nut. At this stage of dismantling, the nozzle would be in three pieces for inspection and cleaning. However, with the nozzle assembly in this orientation, the swirl plate would have sat loosely in the machined bore of the nozzle nut making it possible for it to be misaligned with the valve body as they were tightened together on assembly.

Clear instructions, and perhaps a warning regarding the correct alignment of the components, were required to ensure maintenance staff assembled the unit correctly. Following assembly, the nozzle should then have been inspected, and better still, tested, prior to refitting in the burner. The inspection of the nozzle following reassembly should have included, but not been limited to: sighting the correct location of the needle valve through the nozzle hole, verifying the correct length of the nozzle assembly, checking for freedom of movement as the spring was compressed and, desirably, leak testing.

Figure 12: A method of nozzle assembly leading to valve stem bending and leakage



The burner nozzle needle valve performs a critical task in sealing the fuel flow, and preventing leakage, during the burner pre-ignition sequence. Given the possibility of incorrect assembly this arrangement required some means of verifying correct assembly. The lack of clear maintenance instructions and of a suitable apparatus for leak testing meant that acquired knowledge and experience were the only means available at the time. Therefore, when the nozzle was assembled, insufficient experience and a lack of awareness of the intricacies of the seemingly simple component led to an understandable but incorrect method of assembly. There was then no method or means in place to check that the assembly was correct. Consequently, the needle valve stem was bent, the valve failed to seal and the resulting leak provided the fuel for the explosion.

In submission, Garioni Naval stated that:

> ...adequate instruction and guidance were given during commissioning of the equipment during 2005 …

and that

> … the personnel conducting the maintenance were not authorized by Garioni Naval to conduct such work.

While it may be desirable to have specifically trained personnel or specialist technicians performing maintenance on critical equipment the reality of the shipping industry is such that this is often not possible. Trading ships are mostly at sea with very limited access to resources such as specialist personnel and spare parts. Ship's engineers are required to complete comprehensive and extensive maintenance on often unfamiliar equipment that in other circumstances, for example in shore installations, would be maintained by specialist maintenance personnel trained and experienced on the equipment.

Qian Chi did not enter service until 2008, 3 years after the thermal oil heaters were commissioned. The engineers who may have received training in the heaters at the time of commissioning had long since left the ship and had taken that knowledge with them. Therefore, it was essential that the equipment was supplied with comprehensive operating and maintenance instructions to ensure that the many engineers responsible for operating and maintaining it throughout the ship's life were adequately supported.

2.5 The use of MGO

The thermal oil heaters were designed to run on a variety of fuels. The original intent was to use HFO as the most cost effective alternative. The equipment manufacturer supplied manuals and guidelines in digital format to assist and support the operation of the heaters, with emphasis on the use of HFO.

The burner manual stated that, prior to ignition, the fuel should be circulated until up to temperature 'to allow lance and nozzle heating' and then allow '60 seconds of further prewashing' to clear the furnace of any remaining flammable or exhaust gases. On board *Qian Chi*, this cycle had been set to 4 minutes.

While the manual stated that the pre-ignition cycle should allow time to heat the fuel, it contained no clear instruction on how to operate the burner unit should the fuel be changed to MGO.

Unlike HFO, MGO requires no preheating for use. So, when the fuel was changed, the fuel heater was switched off. However, no other alterations were made to the control and operating systems. Consequently, on 16 January, the fuel pump and fan continued to run for the full 4 minute pre-ignition cycle. Fuel continued to be circulated through the nozzle and, because the nozzle was leaking, fuel was admitted into the furnace.

Had the starting sequence been adjusted to suit MGO, or been operating as the manufacturer's guidelines suggested, the start sequence time would have been decreased to little more than the 1 minute minimum purge time stated in the manual. On 16 January, this would have significantly reduced the fuel pump run time and would have led to less fuel entering the furnace. As a consequence, the likelihood, or severity, of the explosion would have been reduced resulting in less damage to the ship and machinery and probably less severe injuries to the three crew members.

2.6 First aid on board

On the day of the incident, the three crew members burned in the explosion were given first aid on board. Acting on advice from shore based medical support, the injured men were moved to the cool of the ship's accommodation, given pain relieving medication, had some blisters drained, had their burned clothing removed and their burns were covered with clean dry cloths.

While the master's decisions to seek medical advice and arrange for the evacuation of the three crew members were the correct actions to take, the STCW Code[16] states that all seafarers are required to demonstrate a basic understanding of first aid. The ship's master and first mate had both completed the China Maritime Safety

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[16] *Seafarers Training, Certification and Watchkeeping Code*, Section A-VI/4, International Maritime Organisation.

Administration's training and certification in Proficiency in Medical First Aid and for Medical Care On Board as part of their professional seafarer qualifications. Further to this, the ship's political officer was a former ship's medical officer.

The China Shipping Development Company's SMS contained a document titled *SE06 - The Response Measure for Serious Injury Situation*. This document provided assistance on who was responsible and what to do should a serious injury or illness occur on board. The advice given in this document was to consult the *International Medical Guide for Ships*[17] and contact may also be made with the shore-based Shanghai Seamen's Hospital, with which the shipping company had an agreement to provide professional advice to its ships in case of medical emergencies.

The SE06 document also provided advice for methods of assistance in the case of different injuries. For burns injuries the document provided the following advice:

> While burned injury occurred, Cooling the heat burns should be carried out as quickly as possible, and the measures preventing the wound from the infection should be taken [sic]

and

> In the case of large area burn, the patient must be sent to the shore for treatment as soon as possible.

Further, with regard to administering first aid for burns on board a ship, the *International Medical Guide for Ships*[18] states:

> Cool the heat burns as quickly as possible with cold running water (sea or fresh) for at least 10 minutes; OR immerse the burned area in basins of cold water.
>
> If you cannot cool a burn on the spot, take the victim to a place where cooling is possible.
>
> Try to remove clothing gently but do not tear off any clothing that adheres to skin.
>
> Cover the burned areas with dry, non-fluffy dressing larger than the burns, and bandage in place.
>
> After cooling the burn, remove the patient to a warm cabin with a supply of clean water and dressing material.
>
> Encourage the patient to drink oral rehydration solution or hot sweet tea.
>
> If the patient is awaiting evacuation, do nothing further except **keep the patient warm:** take care to prevent blankets from sticking to the burns.
>
> Leave intact blisters alone, unless:
>
>> the fluid in the blisters is bloody or cloudy; OR
>>
>> the blisters are over a joint; OR
>>
>> the patient cannot avoid lying on a blister;
>
> For such blisters, use sterile scissors to remove the entire blister roof:
>
>> do not use a needle to prick blisters.

17 *International Medical Guide for Ships*, 3rd Edition, 2007, World Health Organization

18 Ibid, pg 82

Other texts, available and consulted widely during training and on board ship such as *The Ship Captain's Medical Guide*[19] support this approach.

Therefore, the crew should have been aware that the injured engineers should have had their burns cooled, preferably with water, and should not have had any blisters pierced, contrary to the advice received from ashore.

The actions of the crew on board *Qian Chi*, guided by advice received from the shore hospital, were inconsistent with accepted and published first aid advice for the treatment of burns on board ship. Consequently, the injured crew members suffered more than they might have had they been appropriately treated.

Professional medical assistance was not provided until about 90 minutes after the incident occurred, when the paramedics arrived on board the ship. When interviewed, the attending paramedics stated that there appeared to be little medical equipment in the vicinity of the injured men. They had suffered burns to their faces with the likely expectation of airway damage and resultant breathing difficulties. Had the injured men, the third engineer in particular, been placed on oxygen to assist breathing, any complications from airway damage would have been reduced.

Unfortunately, this is not the first incident in which the ATSB has identified that a ship's crew did not have the required basic understanding of the importance of immediate on board first aid, especially in relation to serious burns[20].

When confronted with serious burns on a scale they had not previously seen, *Qian Chi*'s crew relied upon external advice and followed this advice without question. They did not call upon their own training and on board material to guide them in providing the most appropriate first aid to the burned men. In this situation, they did not comprehend or understand the importance and necessity for immediate first aid that might differ from medical treatment advice provided from afar.

Had the injured men had their burns cooled immediately, in accordance with the recommended treatment for burns, not only might the adverse effects of the burns been reduced but, as stated by attending paramedics, the casualties would have been in appreciably less pain as they waited for professional assistance to arrive.

2.7 Shore response

For incidents, including those requiring medical and/or fire and rescue response, such as occurred on board *Qian Chi*, the arrangement within the port of Brisbane was for the Queensland Police Service (QPS) to be the lead response agency, through the Brisbane Water Police (BWP). Once notified, either directly or through the emergency triple zero (000) telephone number, the BWP co-ordinate the response as required. In this case, this included the provision of transport to and from the ship for Queensland Ambulance Service (QAS) and Queensland Fire and Rescue Service (QFRS) personnel.

In Queensland, for emergency situations, the VTS operators are the first contact point for ships within the port, and provide a communications conduit between the

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19 *The Ship Captain's Medical Guide*, UK Maritime and Coastguard Agency, 22nd edition, 1999, pg 17.

20 For example: ATSB Transport Safety Report, Marine Occurrence Investigation No.258 MO-2008-010 – Auxiliary boiler explosion on board *Saldanha* off Newcastle, 18 November 2008.

ship and emergency response agencies. They also act as a source of expert ship and shipping knowledge for shore-based service providers.

At the time of the explosion on board *Qian Chi*, the Brisbane VTS emergency procedures stated that in the case of a medical emergency the VTS operators were to call the '000' emergency services telephone number, make contact with the QAS and 'Identify your organization and that you are reporting a "Medical Incident at Sea"'. However, when alerted to the unfolding emergency on board *Qian Chi* (about 27 minutes after the explosion), the VTS operator attempted to contact the BWP for assistance as the water police had, for some time, been the accepted response agency for such port incidents.

Due to the widespread flooding in and around Brisbane at that time, the water police were occupied with other matters and did not answer their land line telephone. The call should have automatically forwarded to the duty officer's mobile telephone. However, on this occasion, it did not.

The VTS operator then called the police communications centre and was told to call '000'. The VTS operator subsequently called '000' and made contact with the QAS, who commenced an emergency medical response.

The QAS response was initially confused by the fact that the emergency had occurred on board a ship at anchor in Moreton Bay and that the ship was not accessible by land transport. At one point, the VTS operator received a call from the QAS requesting directions to the water police base. However, the VTS operator was unable to provide the address of the water police base and this information was not available in documentation or procedures to which the operator could easily refer. Eventually, the QAS contacted the BWP directly to determine their location.

About 10 minutes after his initial contact with the VTS operator, *Qian Chi*'s master made further contact and requested a helicopter evacuation for the three injured crew members. The VTS operator passed this request on to the BWP who went about arranging the flights.

A short time later, during a subsequent conversation with the BWP, the VTS operator stated that *Qian Chi* would 'have gas everywhere; venting' and that the ship was a 'gas product carrier'. The VTS operator did this in a bid to be of help and to provide information about the ship which would be relevant to the emergency services when deciding whether to send a helicopter or not. However, this information was not accurate and had not been provided by, or checked with the ship's master. In light of this statement, the BWP cancelled the helicopter evacuation and then placed an exclusion zone around the ship.

It was not until an hour later that the paramedics, by this time on board *Qian Chi*, organised a helicopter medical evacuation.

2.7.1 Emergency preparedness and procedures

Given the size and trade through Brisbane, it is not unexpected that at some time an emergency of some type would occur on a ship not at a berth but within port limits[21], such as at anchor in Moreton Bay. The requirements for attending an incident in such a location are different to those for attending an incident which occurs on a ship berthed within the port. Therefore, it is reasonable to expect that Maritime Safety Queensland (MSQ) reflect the possibility of an emergency in a more inaccessible location within the port in the VTS emergency procedures.

However, the VTS emergency procedures did not differentiate between an emergency on board a ship at a berth in the port and one at anchor in Moreton Bay. As a result, the available guidance material (procedures, guidelines, checklists etc) did not provide the VTS operators with the support they required to fill the role of communications link and knowledge provider between the parties involved in, and responding to, the incident that had occurred on board *Qian Chi*. Consequently, the VTS operators were reliant on experience and memory.

While the guidance material stated that the VTS's first point of contact should be '000', it did not provide the VTS operators with a defined way of helping the '000' operator overcome any uncertainty associated with an incident occurring on a ship at anchor and not accessible by land transport. The material did not include information necessary to the emergency services, like the address of the BWP base, or the duty water police officer's mobile telephone number. Furthermore, it did not include an aid memoir to assist the VTS operators in soliciting necessary information from the ship's master which would be of value to the emergency services when considering their actions.

As it was, the VTS operators were left without guidance and, as a result, when attempting to help by providing shipping relevant knowledge, the information they supplied to the water police when discussing the ship's condition was incorrect.

If the VTS operators had had appropriate guidance material, such as a simple checklist, it probably would have resulted in better managed and more cohesive actions in response to the emergency on board *Qian Chi*.

2.7.2 System improvement

Procedures should be formulated and updated in response to identified needs and analyses of events and risks associated with the task being considered. Through active participation in drills and exercises, both within the organisation and within the broader industrial community, suitable scenarios and analyses can be used to produce procedures, test their effectiveness and make alterations as necessary. In this way, procedures should be tried and tested in preparation for times when they will be most needed, for example, when workload or stress is high such as when the port is unusually busy during a flood situation.

However, despite active involvement in wider port exercises and drills, the specific Brisbane VTS procedures had not been drilled or tested. That is, there had been no testing of the actions to be taken by VTS operators when reacting to an emergency situation within the port. Furthermore, there was no formal schedule for reviewing existing procedures.

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21 In the past 5 years, the ATSB has been notified of and/or investigated at least 10 incidents that occurred within the Port of Brisbane but not at a berth which might have elicited an emergency response from the port authorities.

In submission, MSQ stated that the documents were ‘living documents and constantly reviewed and upgraded based on experience and outcomes from actual or exercised emergencies.’ However, the procedures in place at the time were out of date; they directed the VTS operators to call ‘000’ in an emergency rather than the BWP directly, despite the fact that the water police had been the preferred and accepted lead response agency for some time.

In such a ‘living document’ regime any alterations to the procedures or documents beyond factual changes, such as berth depths, would necessarily have been proposed by persons with a personal interest in improving port operation or made in response to an incident debriefing. That is, changes to the procedures would be reactive rather than proactive.

In general, it has become accepted that all industries and businesses will establish formal and comprehensive business systems to manage safety within their areas of responsibility. An important part of these systems is testing and auditing of plans and procedures to ensure that they are being followed and to allow possible corrective actions and improvements to be carried out.

3 FINDINGS

3.1 Context

On 16 January 2011, while the product tanker *Qian Chi* was at anchor in Moreton Bay, the ship's number two oil-fired thermal oil heater exploded, seriously injuring three crew members. The explosion severely damaged the thermal oil heater and surrounding equipment and fittings.

The three seriously injured crew members received only rudimentary first aid on board. Shore-based emergency paramedics attended the ship and the injured crew members were evacuated by helicopter for treatment and recuperation.

From the evidence available, the following findings are made with respect to the thermal oil heater explosion. They should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing safety factors

- The burner nozzle had been incorrectly assembled after maintenance. As a result, the valve stem was bent and, consequently, the needle valve failed to seal the burner nozzle. This led to fuel leakage through the nozzle and into the heater furnace.
- Throughout the 4 minute pre-ignition cycle, with the fuel pump and forced-draught fan running, the leaking fuel combined with the air to form a combustible atmosphere in the furnace. The explosion occurred at the completion of the pre-ignition cycle when the igniter activated.
- The design of the burner nozzle allowed the nozzle swirl plate and needle valve to be misaligned when being assembled which in turn led to the needle valve stem being damaged during assembly. Furthermore, the maintenance manuals and supporting documentation supplied by Garioni Naval, the thermal oil heater manufacturer, did not provide sufficient guidance to ensure safe and appropriate maintenance of the thermal oil heater burner assembly. *[Significant Safety Issue]*
- The thermal oil heater was firing on marine gas oil, but the pre-ignition cycle time had not been reduced in line with that suggested by the manufacturer. Had the pre-ignition cycle time been reduced, there would have been significantly less fuel in the furnace and the explosion would probably have been less severe.
- *Qian Chi's* crew received first aid advice and provided first aid to the injured crewmembers that was inconsistent with accepted and published first aid advice for the treatment of burns on board ship.
- Initial Brisbane VTS actions when contacting emergency services did not follow existing port procedures. When attempting to provide assistance and appropriate expert advice to the emergency services, VTS actions were hampered by a lack of, and confusion with, relevant information and processes.
- Brisbane port authorities had not put in place sufficient procedures, checklists and/or supporting documents to ensure VTS staff were adequately prepared, trained and practiced to handle a predictable incident such as this. *[Significant Safety Issue]*

3.3 Other key findings

- Ship's crews need to understand the importance of applying immediate first aid to injured persons while seeking further treatment advice. This is particularly relevant for burn injuries; the accepted practice for which is cooling of the injury for an extended period of time, regardless of the extent of the injury.

4 SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Action sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

4.1 Garioni Naval

4.1.1 Burner nozzle assembly and documentation

Significant Safety issue

The design of the burner nozzle allowed the nozzle swirl plate and needle valve to be misaligned when being assembled which in turn led to the needle valve stem being damaged during assembly. Furthermore, the maintenance manuals and supporting documentation supplied by Garioni Naval, the thermal oil heater manufacturer, did not provide sufficient guidance to ensure safe and appropriate maintenance of the thermal oil heater burner assembly.

Response from Garioni Naval

The ATSB has been advised by Garioni Naval that the company has made enquiries and contacted several manufacturers of burner equipment to discuss the incident and burner design. Specifically, Garioni Naval contacted the original manufacturer and supplier of the burner equipment involved in this incident seeking detailed information. However, to date, the design of the burner nozzle has not changed.

The ATSB has also been advised that Garioni Naval is in the process of updating its equipment manuals to highlight the importance of correct burner nozzle assembly and alignment of its component parts.

ATSB assessment of response

The ATSB notes that, to date, the design of the burner nozzle has not been changed, but acknowledges that increased awareness of the risks associated with the maintenance of the burner nozzle should reduce the likelihood of future similar incidents.

4.2 Maritime Safety Queensland

4.2.1 Port of Brisbane preparedness for incidents

Significant Safety issue

Brisbane port authorities had not put in place sufficient procedures, checklists and/or supporting documents to ensure VTS staff were adequately prepared, trained and practiced to handle a predictable incident such as this.

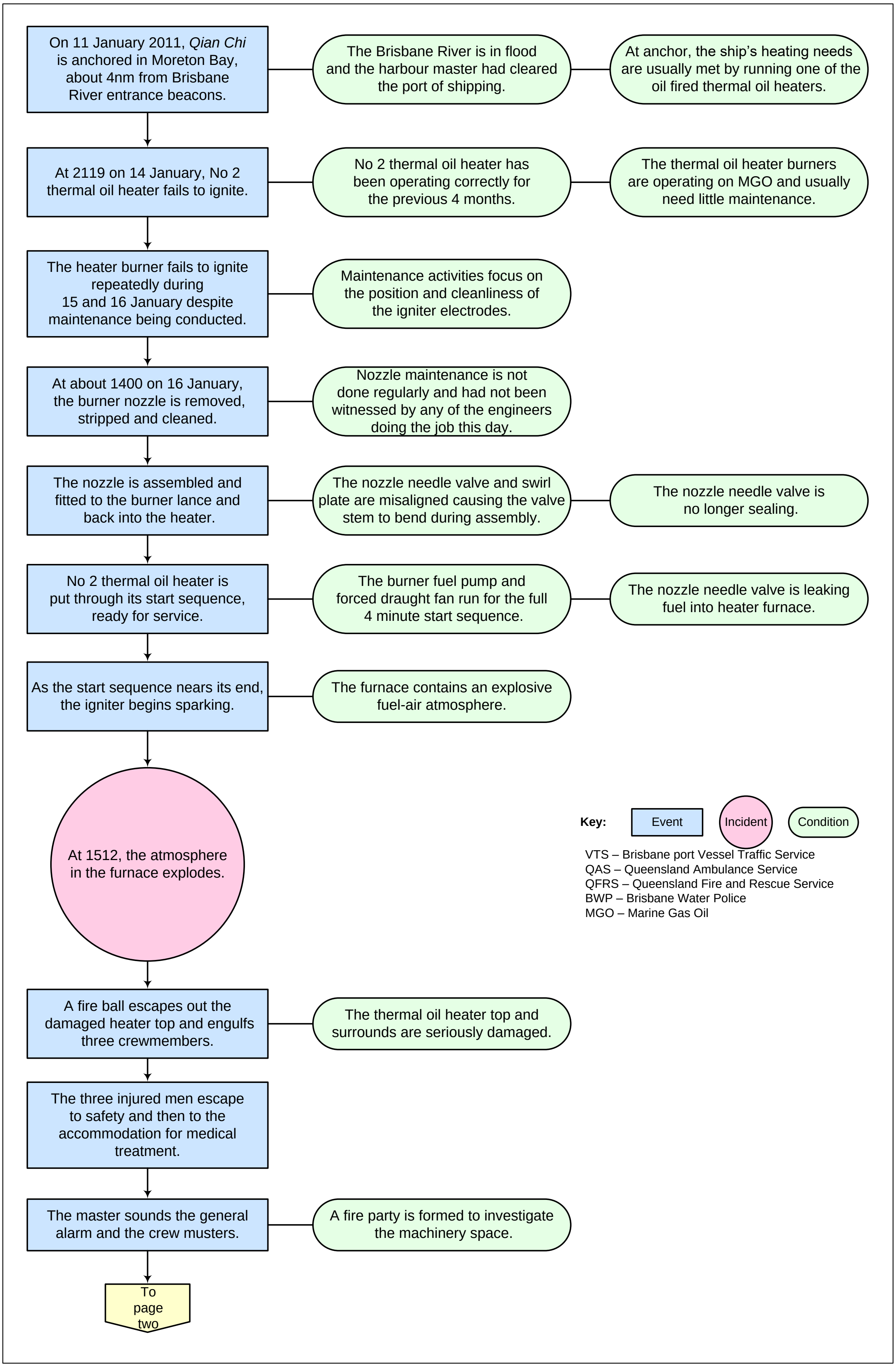
Response from Maritime Safety Queensland

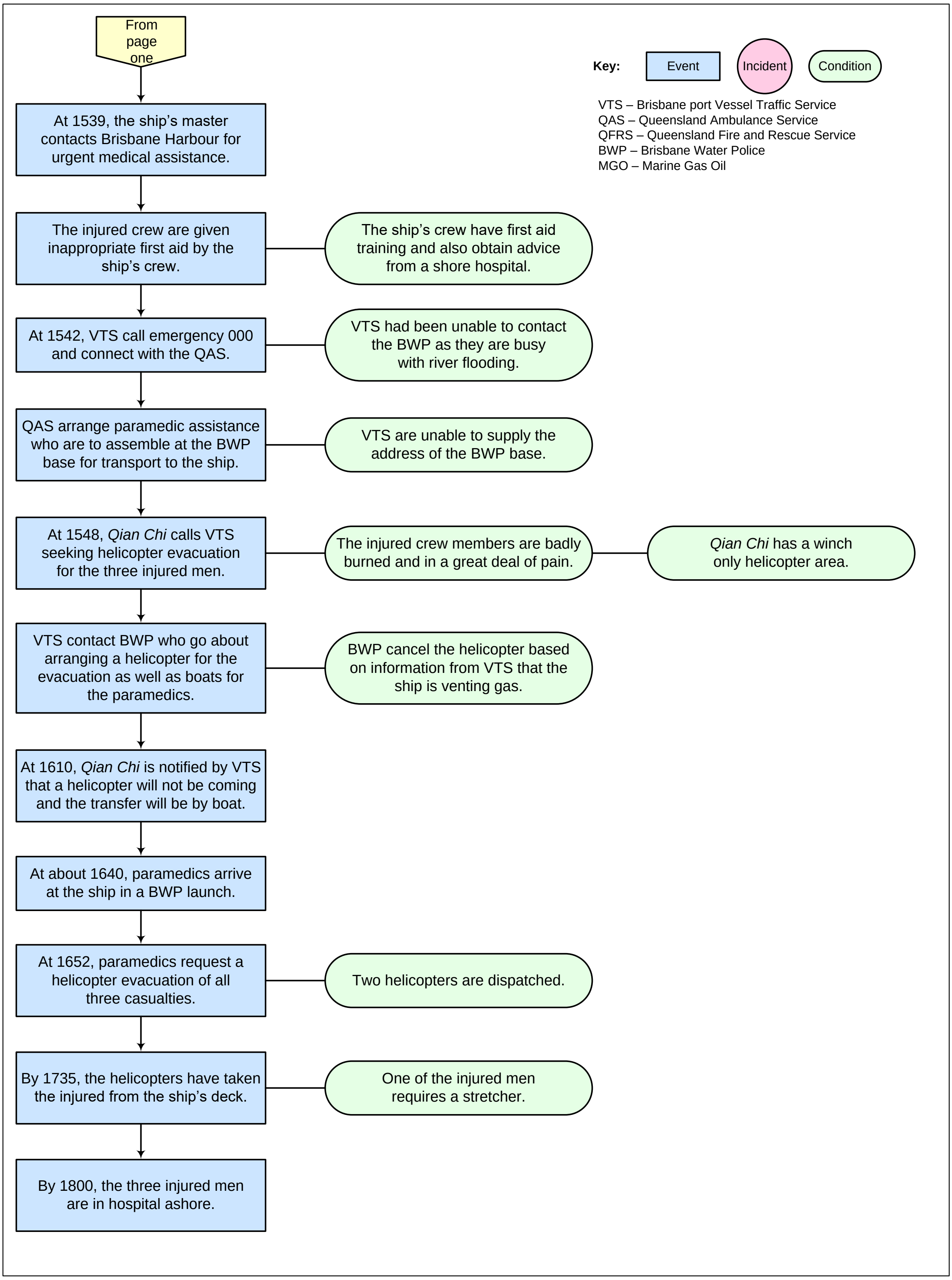
The ATSB has been advised that Maritime Safety Queensland (MSQ) will review and update procedures for its Brisbane and Queensland port network as a result of this and any other marine incident.

ATSB assessment of response

As a result of the MSQ submission, and discussions held with MSQ in relation to this investigation, the ATSB is satisfied that an appropriate review and update of VTS procedures should adequately address this safety issue.

APPENDIX A: EVENTS AND CONDITIONS




From page one
Key:
Event
Incident
Condition
VTS – Brisbane port Vessel Traffic Service
QAS – Queensland Ambulance Service
QFRS – Queensland Fire and Rescue Service
BWP – Brisbane Water Police
MGO – Marine Gas Oil
At 1539, the ship's master contacts Brisbane Harbour for urgent medical assistance.
The injured crew are given inappropriate first aid by the ship's crew.
The ship's crew have first aid training and also obtain advice from a shore hospital.
At 1542, VTS call emergency 000 and connect with the QAS.
VTS had been unable to contact the BWP as they are busy with river flooding.
QAS arrange paramedic assistance who are to assemble at the BWP base for transport to the ship.
VTS are unable to supply the address of the BWP base.
At 1548, *Qian Chi* calls VTS seeking helicopter evacuation for the three injured men.
The injured crew members are badly burned and in a great deal of pain.
Qian Chi has a winch only helicopter area.
VTS contact BWP who go about arranging a helicopter for the evacuation as well as boats for the paramedics.
BWP cancel the helicopter based on information from VTS that the ship is venting gas.
At 1610, *Qian Chi* is notified by VTS that a helicopter will not be coming and the transfer will be by boat.
At about 1640, paramedics arrive at the ship in a BWP launch.
At 1652, paramedics request a helicopter evacuation of all three casualties.
Two helicopters are dispatched.
By 1735, the helicopters have taken the injured from the ship's deck.
One of the injured men requires a stretcher.
By 1800, the three injured men are in hospital ashore.

APPENDIX B: SHIP INFORMATION

Qian Chi

IMO Number	9262417
Call sign	VRDY3
Flag	Hong Kong
Port of Registry	Hong Kong
Classification society	Det Norske Veritas (DNV)
Ship Type	Crude/oil products tanker
Builder	China Shipping Industry (Jiangsu), Jiangdu, China
Year built	2008
Owners	Qian Chi Shipping, Hong Kong
Ship managers	China Shipping Development Company, Shanghai, China
Gross tonnage	30,501
Net tonnage	11,869
Deadweight (summer)	45,541 tonnes
Summer draught	12.10 m
Length overall	184.84 m
Length between perpendiculars	175.79 m
Moulded breadth	32.26 m
Moulded depth	18.923 m
Engine	1 x YMD-MAN B&W 6S50MC-C
Total power	9,000 kW
Speed	14.6 knots
Crew	24

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included:

The master and crew of *Qian Chi*

The China Shipping Development Company Ltd

Garioni Naval

Maritime Safety Queensland, Marine Operations (Brisbane)

The Australian Maritime Safety Authority

The Queensland Ambulance Service

The Queensland Fire and Rescue Service

The Queensland Police Service

Det Norske Veritas

Petrel Shipping Company

Wilhelmsen Ship Services

References

Admiralty Sailing Directions, *Australian Pilot Volume III (NP15)*, tenth edition, 2005.

IALA-AISM, *IALA Model Course V-103/1, On Vessel Traffic Services Operator Training*, Edition 2, 2009, IALA-AISM, viewed 05 July 2011, <http://www.iala-aism.org/chapo/publications/documentspdf/doc_176_eng.pdf>.

IMO, 1995, *Guidelines on the implementation of the International Safety Management (ISM) Code – IMO Assembly Resolution A.788(19) – 1995*, IMO Publishing, London, UK.

International Chamber of Shipping (ICS), Oil Companies International Marine Forum (OCIMF) & International Association of Ports and Harbors (IAPH), 2006, *The International Safety Guide for Oil Tankers and Terminals*, 5th Edition, Witherby Seamanship International, Livingston, UK.

International Chamber of Shipping, 2008, *Guide to Helicopter/Ship Operations*, 4th Edition, Marisec Publications, London, UK, p48.

International Chamber of Shipping (ICS) & International Shipping Federation (ISF), 2010, *Guidelines on the application of the IMO International Safety Management (ISM) Code*, 4th Edition, Marisec Publications, London, UK.

International Maritime Organisation (IMO), 2011, *Seafarers Training, Certification and Watchkeeping Code*, IMO Publishing, London, UK, Section A-VI/4.

Port of Brisbane Corporation, 2010, *PoBC Annual Report 2009/2010*, viewed July 2011 <http://www.portbris.com.au/PortOfBrisbaneAnnualReport2010/Default.aspx>.

Port of Brisbane Corporation, 2011, *Port of Brisbane Port Handbook 2011*, viewed July 2011, < http://www.portbris.com.au/ShippingOperations/PortHandbook>

Port of Brisbane Corporation, 2012, *POBC Annual Performance Report, 2011, Key Trade Results*, viewed August 2012, <http://www.portbris.com.au/NewsMedia/AnnualPerformanceReport/KeyTradeResults20102011>

Schager, B. 2008, *Human Error in the Maritime Industry*, Marine Profile Sweden AB, English translation printed by Halmstad Tryckeri AB, Halmstad, Sweden.

Transport and Main Roads, *Port Procedures and Information for Shipping, Port of Brisbane*, June 2010, Queensland Government, viewed July 2011, <http://www.msq.qld.gov.au/~/media/2e2a8238-782e-4cb2-802f-1a27c0d30013/pdf_brisbane_ppm_june10.pdf>.

UK Maritime and Coastguard Agency, 1999, *The Ship Captain's Medical Guide*, 22nd Edition, TSO (The Stationery Office), Norwich, UK, pg 17.

World Health Organization (WHO), 2007, *International Medical Guide for Ships*, 3rd Edition, WHO Press, Geneva, Switzerland, pg 82.

Submissions

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

A draft of this report was provided to *Qian Chi*'s master, third engineer, electrical engineer and cadet engineer, China Shipping Development Company Tanker Operations Department, the Australian Maritime Safety Authority (AMSA), Maritime Safety Queensland (MSQ), the Brisbane port vessel traffic service officer, Garioni Naval, and the Marine Department of the Hong Kong SAR (MARDEP).

Submissions were received from the China Shipping Development Company, Garioni Naval, MSQ, AMSA, MARDEP and the Brisbane port vessel traffic service officer. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.