ATSB
Australian Transport Safety Bureau

AUSTRALIAN TRANSPORT SAFETY BUREAU

MARINE SAFETY INVESTIGATION
REPORT 174

Independent investigation into
the ballast tank explosion and subsequent fatalities
on board the Hong Kong registered bulk carrier

Nego Kim

In cooperation with the
Hong Kong Marine Authority

at Dampier WA
on 18 November 2001

COMMONWEALTH DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

Department of Transport and Regional Services
Australian Transport Safety Bureau

Navigation Act 1912
Navigation (Marine Casualty) Regulations
investigation into
the ballast tank explosion and subsequent fatalities
on board the Hong Kong registered bulk carrier
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Investigations into marine casualties occurring within the Commonwealth's jurisdiction are conducted under the provisions of the Navigation (Marine Casualty) Regulations, made pursuant to subsections 425 (1) (ea) and 425 (1AAA) of the *Navigation Act 1912*. The Regulations provide discretionary powers to the Inspector to investigate incidents as defined by the Regulations. Where an investigation is undertaken, the Inspector must submit a report to the Executive Director of the Australian Transport Safety Bureau (ATSB).

It is ATSB policy to publish such reports in full as an educational tool to increase awareness of the causes of marine incidents so as to improve safety at sea and enhance the protection of the marine enviroment.

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View towards port shoulder on *Nego Kim*

Photo: *West Austalian Newspapers Limited*

FIGURE 2:
Ruptured tank on *Nego Kim*

Summary

At about 0200 on Saturday 17 November 2001, the Hong Kong registered bulk carrier *Nego Kim* arrived at the port of Dampier and anchored to await berthing instructions. The ship, which was on a time charter to load a cargo of scrap iron at Fremantle, Adelaide and Dampier, for discharge in Singapore, remained at anchor through Saturday and Sunday. At anchor, the crew continued tasks from the ship's planned maintenance schedule, including the preparation of the interior of no.1 port topside ballast tank for painting.

On Sunday morning the crew performed some routine cleaning tasks. At about 1300, the mate monitored no.1 port topside ballast tank for oxygen content in accordance with safe entry procedures. At about 1430, the eight-man deck crew started work painting the steelwork inside the tank. One man was engaged in painting with an airless spray gun while the other deck crew maintained the paint reservoir, tended a cargo light lowered through the after manhole and assisted the painter as required. An open-ended compressed air hose was led from the forecastle, along the deck and down through this after manhole, while an electrically driven fan was positioned at an angle over the after manhole, which also provided access for the paint hose, light cable and a lanyard.

The mate supervised the initial stages of the task. The paint used was a two-part epoxy mix, thinned as needed using the thinner product supplied by the paint manufacturer. According to the mate, the volume of thinner used was between 30 and 50 percent of the total mixture.

At about 1530 the mate went to the bridge to start his 1600 to 2000 anchor watch, leaving the bosun and deck fitter in charge at the site.

At about 1640 a large explosion ripped through the tank. The tank ruptured and three men were blown down the length of the main deck, killing them all instantly. The explosion also blew four other men over the ship's side. One man, who had been inside the tank, was still alive although severely burned. He was assisted out of the tank, through the ruptured maindeck plating, and later airlifted ashore. Eighteen days later he died in hospital as a result of his burns and other injuries.

A search and rescue operation was initiated, using various surface vessels and aircraft as they became available, in the hope of finding the four men who had been blown overboard. The body of one of the men was recovered from the water at about 1325 the next day, 19 November. The search was continued until last light on 21 November, but none of the other three crew were found.

The report recommends safety actions to improve the ISM documentation carried on ships to include clear instructions for all operations in enclosed spaces and guidance on the conditions under which work in enclosed spaces should be undertaken. Recommended safety actions are also directed to the Dampier Port Authority with regard to an emergency response plan.

Sources of Information

Officers and crew of *Nego Kim*

Western Australia Police Service, Dampier

Disaster Victim Identification Team, Western Australia Police Service

Dampier Port Authority

Hammersley Iron Limited

Woodside Energy Limited

Mermaid Sound Port and Marine Services

Master '*Lady Valisia*'

Chugoku Marine Paints (S) Pte Ltd

Nippon Kaiji Kyokai

AusSAR - Australian Maritime Safety Authority

Defence Science and Technology Organisation

The Coroner, Port Hedland

Western Australian Forensic Science Laboratory

References

DeHaan, J.D. Kirk's *Fire Investigation*, 4th Edition, Prentice Hall, 1997

Dampier Port Authority, Marine Safety Plan, March 2001

Feasibility Study, Dampier Port Authority, Port Control Facility, August 2001

International Safety Guide for Oil Tankers and Terminals, 4th Edition, International Chamber of Shipping 1996

Acknowledgment

Cover photo and fig.1 supplied by *West Australian Newspapers Limited*

Narrative

Nego Kim

At the time of the incident *Nego Kim* was a Hong Kong flag geared bulk carrier owned by Saratoga Shipping Ltd and under the management of Wallem Shipmanagement Ltd, Hong Kong. The ship, which was classed by Nippon Kaiji Kyokai (NK), was built in Hakodate in Japan in 1985 and was originally named *Mashu*. Subsequent names were *Teresa O* (1988) and *Maersk Cypress* (1990) before it was named *Nego Kim* in 1993.

The vessel has a length overall of 167.2 m, a beam of 26 m, a depth of 13.30 m and a summer deadweight of 26591 tonnes at a draught of 9.543 m. The ship was constructed with five holds served by four 30.48 tonne deck cranes and was also assigned a timber loadline. The ship is powered by a single B & W 6L50MCE slow speed diesel engine delivering 5074kW to a single fixed pitch propeller.

The bridge, engine room and accommodation are all situated aft of frame 34. Forward, the collision bulkhead is at frame 201, while the after bulkhead of the raised forecastle is at frame 193. Water ballast can be carried in nos 2 and 4 port and starboard side/bottom tanks and nos 1, 3 and 5 port and starboard combined side/bottom/double bottom tanks. Ballast can also be carried in topside ballast tanks (TBT) nos 1-5 port and starboard.

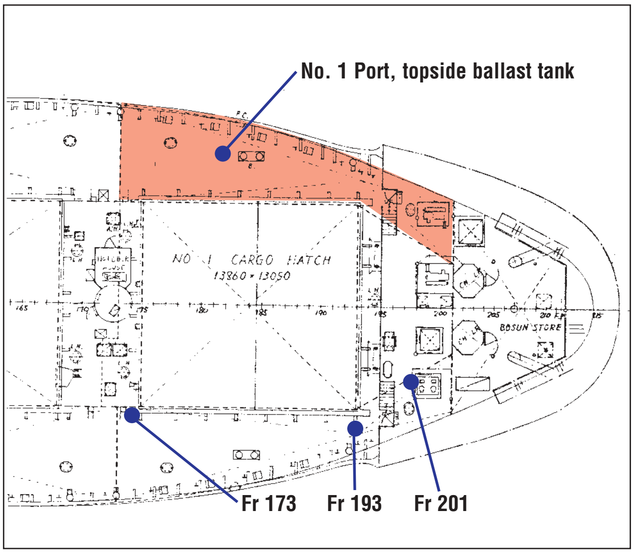
No.1 TBT extends 21.56 m from the collision bulkhead aft to the bulkhead between nos 1 and 2 holds, at frame 173. The tank is 21.56 m in length and is of a triangular cross section having a maximum depth 3.2 m at the after end and 1.9 m at the forward end. No.1 TBT has a capacity of 197.2 m^3. Frame spacing within the tank and hold is 0.77 m. Access to the tank is by two manholes. The forward manhole, between frames 197 and 198, is within the forecastle space. The after manhole is positioned between frames 177 and 178.

The ship's complement consisted of twenty three; the master, mate, second and third mates, chief and three engineers, an electrician, a bosun, four engine room ratings, six deck ratings, a cook, steward and a deck cadet. All were nationals of the Peoples Republic of China.

The incident

At about 0200 on 17 November 2001, *Nego Kim* arrived off the port of Dampier with a little over 17 000 tonnes of scrap steel on board. The

FIGURE 3:
Layout of *Nego Kim* (forward)



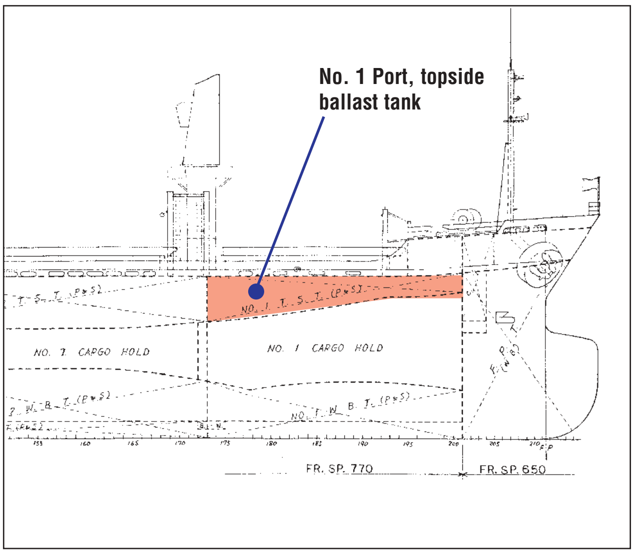
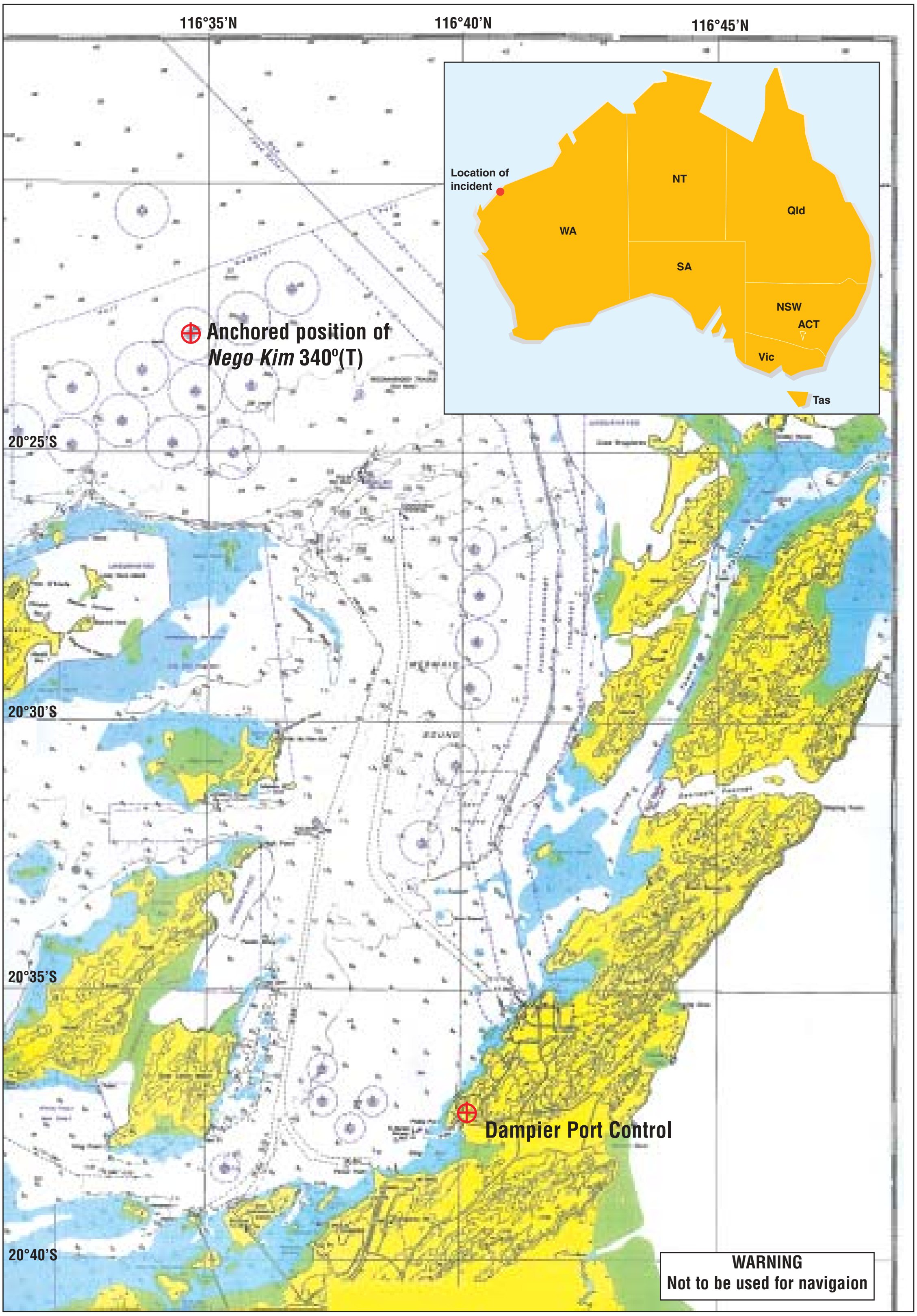


FIGURE 4:
Portion of chart Aus 57 showing anchored position of *Nego Kim* in relation to Dampier Port Control.



vessel was on a time charter, to load part cargoes of scrap steel at the ports of Fremantle, Adelaide and Dampier, for discharge in Indonesia and Singapore. On its arrival, the master made several attempts to contact Dampier Port Control for instructions, unaware that the control tower had ceased 24-hour operation. However, his calls were overheard by the operator in the control centre of Hammersley Iron. The operator told the master that he was not Dampier Port Control. The operator advised the master that the anchorage positions were no longer designated by number and the outer anchorage north-west of the Sea buoy was all now referred to as the 'Western Anchorage'. The master was told to contact his agent for instructions.

The master did not have either the agent's home or mobile telephone number. He anchored *Nego Kim* about one mile within the port limits, in a position 340°(T) by 15.4 miles from Dampier port control tower, previously designated as anchorage A4, to await berthing instructions. The ship remained at anchor through Saturday and Sunday.

Over the previous period of some months the ship's crew had been engaged in progressively painting the topside ballast tanks (TBT) using two different types of paint in alternate tanks. No. 1 port TBT was to be cleaned and painted in accordance with a work order generated from the ship's planned maintenance system, raised on 10 November. The two tank manholes were opened up with work on the tank due to start on 11 November. Preparation of the tank interior included thorough washing with fresh water, removing rust, removing dirt and mud, removing oil and grease and generally preparing the surfaces for painting.

On the morning of Sunday 18 November 2001, the crew performed some routine cleaning of the accommodation. Later the deck crew was to paint the inside of no. 1 port TBT, using epoxy paint applied with an airless paint spray gun. The mate stated that he had instructed the bosun regarding the wearing of safety clothing, that smoking was prohibited and that respirators must be worn inside the tank.

A little before 0800 the mate sampled no. 1 port TBT for oxygen content and found that the space registered 21 percent oxygen. At 0800 he ticked all the boxes on the company checklist, which formed both the checklist and a confined space entry permit. He signed, dated and notated the time of signing at the end of the checklist/permit.

The mate stated that at 1300 he again measured the oxygen level in no.1 port TBT in preparation for painting. The tank was ventilated by means of an open ended, 19 mm, compressed air hose led through the after manhole from a supply at the forecastle space (with its discharge end at or near the actual work site within the tank) and a 300 mm diameter electric fan, which was rigged at an angle above the after manhole and set to blow air into the tank. Illumination of the inside of the tank was by a cargo light, consisting of a 300 watt reflector bulb, a shade and a light metal grill to protect the bulb. The cargo light was suspended through the after manhole by a lanyard held by one of the deck crew or manually directed at the painting site when a second man was in the tank. The paint reservoir and the pneumatic paint pump were positioned on the open deck aft of the after manhole near to the mast house. The paint was mixed adjacent to the paint reservoir and the hose supplying the spray gun was led through the after manhole.

Neither the electric fan nor the light were of an explosion-proof [1] or intrinsically-safe[2] design. Communication with the accommodation/bridge was maintained through a portable VHF radio. The radio, also, was not of an intrinsically safe design.

The deck ratings were reportedly dressed in cotton overalls, wearing safety boots, gloves and safety helmets. A rating in the tank, additionally equipped with a mask over his mouth and nose and a visor, started spray painting. After about five minutes it was found that the spray gun was leaking, so the operation was suspended while the equipment was repaired.

At about 1430 the mate took another sample of the atmosphere in no. 1 port TBT. He made no record of the test, but recalled that the reading was 21 per cent oxygen. The deck crew resumed spray painting inside the tank. The entire deck crew of eight men were involved in this task, either inside or outside, the tank.

The paint used was a two-part epoxy mix, to which the appropriate thinner, supplied by the paint manufacturer, was added. According to the mate, the volume of thinner used was between 30 and 50 percent of the total mixture.

At about 1545, the mate went to the bridge to start his 1600 to 2000 anchor watch, leaving the bosun and deck fitter in charge at the site. He passed the hand-held VHF radio to the deck fitter before leaving for the bridge.

At 1600 the mate took over the anchor watch. The log book entry recorded the wind as being from the west, force 6 (22-27 knots, 10.8-13.8 m/s), the atmospheric pressure as 1010 hPa and the air temperature on the bridge as 26°C.

At about 1640 a large explosion ripped through no.1 topside ballast tank. The explosion blew the tank apart, setting up the main deck by some three metres and blew three men down the length of the main deck killing them instantly. The explosion also blew four other men, apparently standing on the deck above the tank, over the side of the ship into the sea.

A spinning drum of burning thinners was projected aft along the main deck, while a fire fuelled by burning paint and thinners erupted on the deck near the aft end of the tank. Immediately after the explosion, other crew members rushed toward the port shoulder and quickly extinguished the fire using dry powder extinguishers and a fire hose.

After the fire was extinguished they found that one man, who was still in the tank, remained alive although he was severely burned. He was assisted out of the tank through the ruptured maindeck plating. Although initially able to walk a short distance with assistance, he collapsed soon afterwards.

The crew on deck then continued the search for the other crew members from the explosion site. When they realised that more men were missing, they decided to launch the ships lifeboat to search the waters around the ship. Due to the sea conditions at the time, they had considerable difficulty with the launching and eventually, with the arrival of external assistance, this process was aborted. These activities with the lifeboat, however, created some confusion for the aircrew in the first helicopter as they had been informed about ‘people in the water’ and, upon the helicopter’s arrival, saw some of the ship’s crew in the boat.

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1 ***Explosion-proof (‘Flame-proof’)***
Electrical equipment is defined and certified as explosion-(flame-)proof when it is enclosed in a case which is capable of withstanding the explosion within it of a hydrocarbon gas/air mixture or other specified flammable gas mixture. It must also prevent the iginition of such a mixture outside the case either by spark or flame from the internal explosion or as a result of the temperature rise of the case following the internal explosion. The equipment must operate at such an external temperature that a surrounding flammable atmosphere will not be ignited.

2 ***Intrinsically safe***
An electrical circuit or part of a circuit is intrinsically safe if any spark or thermal effect produced normally (ie, by breaking or closing the circuit) or accidently (e.g. by short circuit or earth fault) is incapable, under prescribed test conditions, of igniting a prescribed gas mixture.

The situation was eventually clarified and the sea search continued.

Emergency response

At 1644:45 the master made the first call on channel 11 VHF. He called 'Port Control' very rapidly five times followed by a short silence of three seconds, then

> 'Urgent – Urgent – Nego Kim calling – Nego Kim calling'.

From the first 'Port Control' to the final '*Nego Kim* calling' eight seconds had elapsed. The master made a further four calls over a period of 45 seconds, none of which were prefaced with the urgency group PAN or MAYDAY and none of which were answered by any shore station.

The master broadcast a further four messages alternating between channel 16 and channel 11, calling 'port control' but not providing any information on the nature of the call. At 1646:13, 1 min 28 secs after the initial call, Hamersley Iron Control Centre answered the master's VHF call on channel 16.

The master responded in very rapid English:

> 'Nego Kim master speaking now. Urgent – Urgent, I need your help – Urgent, I need your help. The vessel- vessel exploded – exploded. I need the emergency, emergency, emergency assistance.'

The Hamersley Iron Control Centre centre operator asked the master to slow down and repeat his message. The master slowed down initially but then increased his speed:

> 'Now – now – the crew working in no.1 hatch – now the reason don't know – exploded – exploded. Some injury, high injury I understand may be died. I need the emergency fire – helicopter – emergency assistance fire on our ship - exploded.'

The control centre operator immediately implemented the measures prescribed in Hamersley Iron procedures for 'Helicopter Rescue Support' as they related to a marine emergency. The operator called Helicopters Australia, the police and Hamersley Iron Emergency Response officers. The dampier pilot boat had also picked up the call from *Nego Kim* and responded at 1651. Dampier Police logged their first notification as being at 1650. At 1655 the police put Karratha Hospital on stand-by. At 1658 the Australian Search and Rescue organisation (AusSAR) was alerted and informed that 'local emergency services were dealing with the incident'. AusSAR issued an 'urgency' (XXX) broadcast to all shipping requesting a sharp lookout by all vessels in the area.

While the helicopter was being readied, the master frequently used the VHF to call the Hamersley Iron operator on channel 16, also making some contact with the pilot service on VHF channel 11.

At 1710, the master of a dynamic positioning support vessel employed in the area, *CSO Venturer*, alerted the Dampier Port Authority duty officer to the emergency, on the emergency telephone number. He called the Dampier Port Authority Chief Executive Officer, who went straight to the Port Authority building. This call was followed at 1713 by a call from a Dampier port pilot and at 1714 by the Port Hedland Harbour Master ensuring the Dampier Port Authority were aware of the situation.

At 1712:31, helicopter VH-HRZ with emergency staff on board lifted off from the helipad at Hamersley Iron.

At 1716:59, the master requested the assistance of a boat, reporting that people were in the water and confirming that the fire had been extinguished. This message was received, on VHF channel 11, by the pilot boat which was already on its way to the scene.

At 1719, the police telephoned Woodside Energy Limited (WEL) gate house, which acted as a communications centre, and notified them of the explosion. Suitably trained WEL personnel embarked on the pilot boat *Burrup*

Pilot for *Nego Kim* at about 1800, with trauma kits and resuscitation equipment.

With the information that there were people in the water, the Western Australia Police immediately initiated a search by small surface craft.

The situation facing the police was that of a vessel 15 miles from Dampier, freshening winds to about 30 knots with seas/swell reported as 5 to 6 m at the ship, and nightfall approaching. The distance from the port meant that surface craft would take about an hour to reach the ship. Sunset was at 1832 and civil twilight at 1856.

At 1726:29, Bristow Helicopters informed the Hamersley Iron operator that a large helicopter with winching capacity could be ready in one hour. A further helicopter was available to help in either evacuating crew from the ship or searching. However, preparing that aircraft would also take an hour. Neither of the helicopters available was equipped to undertake the type of operations required during the hours of darkness.

Helicopter HRZ landed on board at 1728:11 and, at 1732:33, confirmed that there were three dead on board and one 'not looking good'. After an initial assessment its engine was stopped to allow the critically injured seaman to be placed aboard the helicopter. The helicopter departed the vessel, at about 1756, for Karratha Hospital.

By 1823 the helicopter had delivered the injured crewman and refuelled. The helicopter returned to search the area. Another helicopter, from *CSO Apache*, joined the search, but the aerial search was suspended at about 1910, as it was growing too dark.

At 1940, with three Dampier Port Authority staff on duty in the Port Authority offices, the Dampier port control tower was offered to the Dampier police as the search and rescue (SAR) communications/co-ordination centre. As the police SAR coordination centre had been established for some hours, and relocation would have taken both time and resources, the offer was declined.

There was some confusion or misunderstanding over the issue of SAR datum buoys. The police, coordinating the search, had discussed the issue of SAR datum buoys with AusSAR at 1740 and, at 1755 shortly after it had left, the Volunteer Coastguard Shark-Cat *Shirley Holland* turned back to collect the buoys. These buoys, however, were stored at the State Emergency Services depot at Karratha and were not immediately available. They were not finally provided to the police until 2133.

Initially, the police search had to rely on small launches. The pilot boat was already on the way and arrived in the area at about 1825 to start the search. At about 1800 the second launch, *Shirley Holland*, again left Dampier, without the datum buoys, and was on site at about 1900. These vessels were joined by a further small launch. At 2000, the offshore support vessel *Lady Valisia*, on charter to Mermaid Sound Port Services joined the search, her master assuming the role of on-scene commander.

The effectiveness of the three small launches was limited by the rough conditions and they were eventually released from the search, returning to port between 2030 and 2100. *Lady Valisia* continued searching and, during the night, was joined by *Mermaid Reunion* (a harbour work launch), and the offshore support vessels *Pacific Maple* and *Pacific Commander*.

Throughout the early stages of the SAR operation, the police had been in frequent contact with AusSAR. At 0142 on 19 November Dampier police formally requested AusSAR to coordinate an air search of a 12 mile square area around *Nego Kim*.

At daybreak on 19 November, the surface search continued. AusSAR coordinated an air search using 2 fixed wing aircraft and 6 helicopters at the request, and under the general direction of, the Western Australia Police.

At 1323 on 19 November, a fixed wing aircraft reported seeing ‘something orange’ in the water. *Pacific Commander* was directed to the position where a body was recovered. *Pacific Commander* then resumed the search. At 1800 the search for the remaining three bodies was suspended overnight and the recovered body of the crew member was returned to Dampier.

The search, including a search of the coastline by boat and on shore, was continued until 1600 on 21 November, but with no result.

The surviving deck crewman, an AB, who had been assisted out of the tank after the explosion, was transferred to Karratha Hospital and later transferred to the special burns unit in Royal Perth Hospital in a critical condition. He subsequently died of his injuries on 4 December, having not regained consciousness.

FIGURE 5:
Area of explosion shown from boat deck

FIGURE 6:
Top of ballast tank viewed from hatch cover

FIGURE 7:
Interior of port topside ballast tank after the explosion

Comment and analysis

Evidence

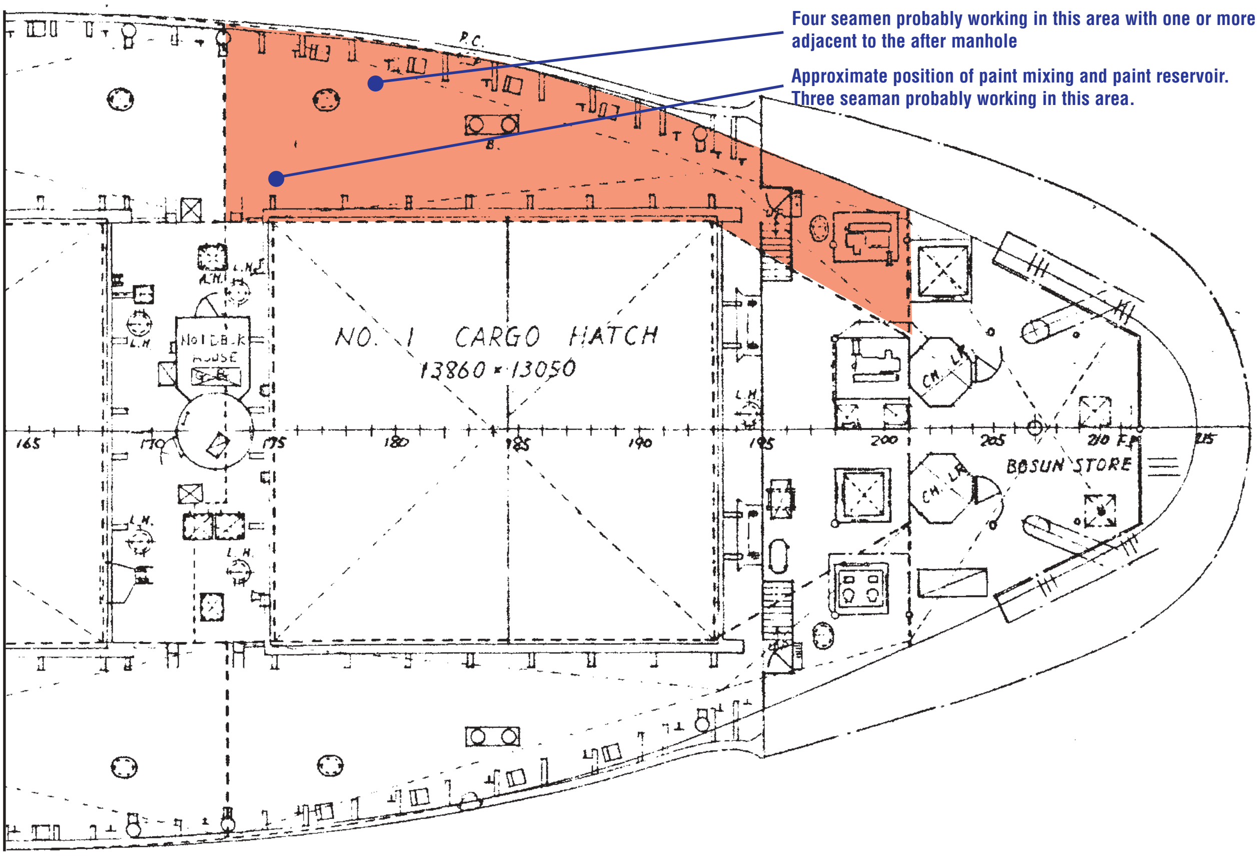
Interviews were conducted with the master and the relevant officers and crew of *Nego Kim*. Interviews were also conducted with the officers of Dampier Port Authority, WA Police, Dampier, Hamersley Iron Limited and the Master of *Lady Valisia*. The ATSB also appointed an investigator with extensive skills in transport medicine, under the provisions of regulation 6(c) of the Navigation (Marine Casualty) Regulations. The medical investigator attended at the post-mortem examination of the five bodies.

Other information was provided by WEL and Dampier Port Authority by letter, telephone and electronic mail.

The ATSB engaged the Defence Science and Technology Organisation (DSTO) to analyse the likely sequence of events which had occurred within no. 1 port TBT and to determine, with the limited amount of factual data available, possible air/vapour ratios within the tank. The calculations by DSTO referred to in this analysis are based on information supplied in the paint's material safety data sheet. This information provides for an application rate of 1.5 lt/min (4 m^2/min) with a maximum wet film thickness of 0.373 mm and for the addition of up to 5 per cent of solvent (thinner), the upper limit for normal painting conditions. The DSTO calculations however, were also carried out for various mixture ratios of added thinner up to the value of 30 per cent, the proportion that was used as stated by the mate. In addition, DSTO investigated the likely effects of exposure by humans to various levels of toxic vapours from constituents in the paint mix.

Information and Material Safety Data Sheets (MSDS) were supplied by the paint manufacturer and taken from Internet sites.

FIGURE 8:
Upper deck of *Nego Kim* - over port topside ballast tank (shown shaded)



The post mortem examination reports on the five recovered bodies were supplied by the Coroner, Port Hedland, together with toxicology reports requested by the ATSB. While the actual cause of death in each case is a matter for the Coroner to determine, the five men died as a consequence of the explosion in no.1 port TBT. It may be surmised that the three seamen who were not found also died as a consequence of the explosion.

The post mortem examination would suggest that the three seamen who were killed on the deck of *Nego Kim* were standing aft of frame 175 over no.2 topside tank. The crewman whose body was recovered from the water had probably been standing between frame 175 and frame 190, over no.1 TBT. The other missing seamen were also probably standing over the area of deck that had violently ruptured.

The explosion and the deaths of the eight crew occurred as a result of a failure of the safety system on board to prevent an unsafe condition (an explosive atmosphere) coming into contact with a hazard (a source of ignition).

Previous painting activity

Extensive painting of the topside tanks had taken place over the preceding months. In at least half the tanks completed, the same paint as was in use on 18 November had been used. The method of application had been the same. There had been no adverse outcome on those occasions and it would appear that only a matter of chance had prevented this incident from occurring earlier.

It is possible that on previous occasions the atmosphere in the tank did not reach the lower explosive level (LEL), or there was no source of ignition, or both. The forward manhole of both no. 1 TBTs was within the enclosed focsle-head. The tank was not uniform in shape, having a very restricted forward area with deep framing and small manholes. The combination of the location of the manhole within the focsle space and the restricted nature of the forward area of the tank may have reduced the number of options for ventilating the tank.

Evidence provided by the mate indicates that substantial amounts of extra thinners were used on this occasion, adding to the already volatile constituents of the paint.

Regardless of whether the painting of no.1 port TBT created conditions different from the conditions in painting the other topside tanks, a number of unsafe conditions had been present during the painting of all the tanks.

The explosion

An explosion is a very rapid oxidation with the evolution of considerable heat, accompanied by a disruptive effect (the result of pressure and confinement).[3] The oxidation takes place at the surface of the fuel source. The ambient air temperature, recorded in the logbook shortly before the explosion was 26° C. The weather conditions recorded in the log were consistent with those at Karratha Automatic Weather Station, where the wind direction was recorded as being 270° (T) at 21 knots, the temperature 28.8°C and the relative humidity 63 per cent.

With the sun on the deck and the ship's side, however, the temperature within the tank would have been significantly greater. When investigators measured the temperature in no.1 starboard TBT some days later, under similar ambient conditions, an internal temperature of 38°C was recorded. It is probable that the temperature in no.1 port TBT at the time of the incident was at least 38°C.

The explosion probably originated within the tank, rather than as a result of an initial explosion on deck spreading to the tank. The crew were mixing paint and adding thinner on the open deck above the after end of the tank. However, as discussed later, there was no

3 Turner, C.F., and McCreery, J.W. *The Chemistry of Fire and Hazardous Materials*, Allyn & Bacon, Boston, 1981, p.92. As quoted in *Kirks Fire Investigation*, p 286.

FIGURE 9:
Port shoulder after the explosion

evidence to indicate that the mixing of the paint was the initiating event. Although an alternative point of ignition cannot be discounted with absolute certainty the probability is that the explosion originated within no. 1 port TBT.

The tank formed an enclosed space of 197.2 m^3, within which an explosive atmosphere could form. The close framing (0.770 m) and web members within the tank provided pockets in which gases that are heavier than air could accumulate and concentrate.

Following the explosion, all the internal surfaces of the tank were covered by a fine, grey powder, the products of combustion.

The fuel source

No.1 port TBT was used as a water ballast tank only. There was no evidence that anything other than water had been carried in the tank. Inspection of the tank by investigators found very little mud or ballast residue, which was consistent with the work order covering the planned maintenance of the tank. A small quantity of water in the tank was probably the result of firefighting immediately after the explosion.

No.1 hold was partially loaded with 2000 tonnes of scrap metal. Examination of the cargo in the hold found no source of possible fuel. Given that the explosion occurred within the ballast tank, the possibility that any fumes from the cargo would have entered no. 1 port TBT was so remote as to be discounted.

The crew were using an epoxy-based paint and using thinner to allow the paint to be applied by an airless spray gun. The two parts of the paint, the epoxy base and the hardener are mixed in fixed proportions and additional thinner applied to aid application. The hazardous chemical constituents of the paint are shown in the table below.

The vapour densities of the chemicals involved were all heavier than air. In theory the fumes would have sunk to the bottom of the tank. There would have been some disturbance of the

Compound [4]	*Flammability Limit per cent by volume in air*	*Flash Point (°C)*	*Vapour Density (Air = 1)*	*Auto-ignition temperature (°C)*
Toluene	1.1 – 7.1	4	3.14	480
Xylene	1.1 – 7.0	27	3.7	527
N-butanol	1.7 – 9.8	29	2.6	345
Isobutanol	1.7 – 10.9	28	2.6	415

4 International Chemical Safety Cards data. Note the values of the critical properties of the chemicals vary marginally from authority to authority.

fumes through the injection of compressed air through the open ended compressed air hose and from the fan above the aft manhole. Also any crew member moving within the tank, particularly in the lower levels would have disturbed the vapours and there would have been some convective mixing due to the temperatures at the time. The proportion of vapour to air that constitutes the flammable range is small. The temperature within the tank was above the flash point of at least three of the compounds, but did not approach their auto-ignition temperatures.

Although the fumes were heavier than air, experiments by the DSTO suggested that the vapours would form an homogeneous mix within the tank, which would persist over time.

As part of the work requested by the Bureau, DSTO was asked to determine whether the paint and paint thinner were the probable explosive medium. The DSTO analysis found that, without any ventilation and using 5 per cent thinner, the concentration of solvent within the tank atmosphere would have reached the LEL (1 per cent) in about 42 minutes. Under the same conditions, using thinner at 30 per cent, the tank atmosphere would have reached a volatile concentration of about 1.4 per cent in twenty minutes. Painting in no. 1 port TBT tank had been under way for about two hours and ten minutes before the explosion occurred.

In the absence of any other credible fuel source the Inspector concludes that fumes from the paint and thinners formed an explosive mixture. Given that the vapour densities of the combustible elements were all heavier than air and considering the effect of the wind on deck, the ignition point was most probably within the tank. Theoretically it was in the bottom half of the tank, though the DSTO findings indicated that this was not necessarily the case.

Tank ventilation

Tank ventilation was provided from two sources, the compressed air hose led through the after manhole (with its open end at or near the actual work site at the after end of the tank) and the electric fan supplying air through the after manhole.

DSTO calculated that the volume of air supplied by the 19 mm compressed airline was about 2.27 m^3/min.

A ship's fan similar to that used on 18 November and in use the next day was rigged at an angle above the manhole. This fan was a 300mm, 400W electric fan of Chinese manufacture and had, on the data plate, a stated air delivery rate of 61 m^3/min. The DSTO report notes that electric fans of this wattage usually rate in the range 30-60 m^3/min. The report comments that a rating of 61 m^3/min is optimistic and it is more likely to be less than 30 m^3/min.

The report calculated that, had the fan delivered air at the rate of 61 m^3/min, the atmosphere inside the tank would not have reached the LEL. With the addition of 5 per cent thinner, the maximum suggested by the paint manufacturer, the concentration of volatile elements would have remained below 0.06 per cent. By adding 30 per cent thinner, a maximum concentration of 0.2 per cent would have been reached.

However, the electric fan was directed at the tank at an angle, severely reducing the flow of air into the tank. At an airflow rate of 40 m^3/min, the tank atmosphere produced by paint mixed with 5 per cent thinner would be maintained at or marginally below 10 per cent of the LEL of toluene.

The fan was set to supply air (blow into) the tank rather than exhaust the atmosphere from within the tank as recommended in the paint manufacturer's instructions. When using a supply fan, a trunking should be used to deliver the supply air to the bottom of the space rather than just to the upper area. Not only was the fan set to supply air to the tank without a trunking, but it was set at an angle to the manhole thus rendering a calculation of the volume of air supplied to the tank highly problematic.

FIGURE 10:
Similar fan rigged on 21 November

The probability is that the actual airflow rate into the tank was far less than 40 m^3/min and the concentration of volatile thinner added was significantly higher than 5 per cent, the maximum volume recommended. The evidence is that, with these combined factors, an explosive atmosphere accumulated within the 2 hours and 10 minutes which elapsed from 1430, when painting was resumed, to the time of the explosion.

Source of ignition

Examination of the scene was unable to identify the source of ignition with any certainty. However five potential sources were present at the scene:

- the electrically driven fan;
- the portable light;
- the hand-held VHF radio;
- cigarettes/lighters/matches;
- an impact from a metallic item dropped into the tank.

The paint manufacturer's MSDS specified that an explosion-proof exhaust ventilation fan should be used. The electrically driven ventilation fan in use was neither explosion-proof nor intrinsically safe. However it was external to the tank and, given the vapour densities involved, it is unlikely that a flame was propagated from outside the tank. The significant breeze blowing across the deck also suggests that it would be unlikely that gas in the explosive range would have accumulated in the vicinity of fan.

The cargo light assembly was suspended within the tank. It consisted of a shade, approximately 350 mm in diameter, a screw fitting housing a 300 watt incandescent reflector bulb and a light steel mesh which protected the bulb. The electrical cable, plugged into a socket in the mast housing, was passed down through the after manhole. The weight of the assembly was taken by a lanyard which also passed through the manhole. The lanyard was held by a crew member positioned above the manhole, to be raised and lowered as required by the person spray painting within the tank.

The light assembly would have been relatively hot, with the main heat source being the bulb itself. The maximum temperature would probably have been around 200°C. The bulb temperature would not have been sufficient to raise the vapours to the auto-ignition temperature of any of the constituent compounds.

There are at least three possible ways in which the light bulb may have initiated the explosion by producing a spark:

- the deterioration of the cement holding the glass globe, particularly with a globe at the limit of its life, could allow vapour to come into contact with the incandescent filament;
- poor connection between the screw cap and the lamp holder fitting, particularly in an atmosphere prone to corrosion which can lead to high resistance or sparking;
- had the light been dropped and the bulb shattered, the incandescent filament would have momentarily provided such an ignition source.

It is not known at what height the light was suspended in the tank at the time of the explosion. However, given that the whole interior of the tank was being painted and that the shade was blown out of the tank by the explosion, the light was probably, but not necessarily, at the upper level of the tank. It is also possible, given the time of the incident, that the crew were withdrawing the equipment from the tank in preparation for completing the day's work as usual at about 1700. Just prior to the time of the explosion, it was probably suspended directly below the manhole.

The VHF hand-held radio in use was not intrinsically safe. As with the fan, however, given the movement of air across the deck and the limited level of vapour on deck, it is unlikely that, if used outside the tank, the radio would have initiated the explosion. If used inside the tank, however, it could have been the source of ignition. No evidence of the radio was found inside the tank. When the mate left the vicinity of no. 1 port TBT at about 1530, he handed the VHF radio to the deck fitter. The probability is that the radio was not used inside the tank and one of the crew lost overboard had the radio with him; possibly the deck fitter, whose body was not recovered.

Direct ignition from a lit cigarette, match or lighter is also a possibility. The mate stated that he gave strict orders that the crew were not to smoke. Investigators did recover a number of cigarettes and cigarette fragments, from the main deck at the scene of the explosion. It appeared that none of the cigarettes recovered, however, had been lit.

The possibility of a falling object cannot be discounted. Metal tools striking steel members within the tank, or a non-ferrous tool embedded with grit, could have generated a spark. However, the only tools or items present in the tank after the explosion were a small pair of pliers and a small tin can both found high (about 1.5 m below the deck, just behind frame 175) in the tank. These were considered unlikely to have generated such a spark as any impact energy at this level would not be very great.

FIGURE 11:
Cargo light assembly

FIGURE 12:
Burnt light shade recovered from deck

The most probable point of ignition was the light assembly, either through a spark in the electrical system, or by being dropped and the bulb breaking, introducing the very hot incandescent filament into a vapour concentration within the flammable range. The latter is supported by the discovery of the light assembly's protective mesh and the light socket at the bottom of the tank, directly below the manhole, while the light shade was recovered from the deck. This indicates that the point of ignition was probably below the shade which was blown out of the tank, possibly through the after manhole or through the ruptured deck plating.

Notwithstanding the source of ignition, there were at least four unsafe conditions present at the scene of the accident, any one of which, given the right circumstances could have been the source of ignition. Neither the fan, nor the light, nor the radio, were intrinsically safe. The crew carried cigarettes on deck and the strong probability is that they would also have carried lighters or matches.

Material Safety Data Sheets (MSDS)

The work order of 10 November 2001 covering the painting of no.1 port TBT, generated under the planned maintenance system, contained instructions on safety, handling chemicals and painting. Chemicals were used in the cleaning process. These chemicals were kept in a mast-house and the ship carried MSDS giving guidance in their use and handling.

The work instruction document, under a section headed 'Handling Chemicals Safety', stated:

> 6. Paints, Cleaning detergents, Acids, Alkalies. Lubricants, Toxic materials and any unknown substances are to be treated as CHEMICALS.

The ship did not carry MSDS for the paints. The paint manufacturer confirmed that MSDS were available for the base and hardener components of the paint. The paint manufacturer stated that MSDS are provided with the first order but, where paint is ordered continuously, a MSDS is not supplied unless specifically requested. The paint manufacturer did not issue a MSDS in respect of the thinner.

In a memorandum to a superintendent of the ship management company, written in August 2001, the then mate requested instructions on the application of both types of paint being used in the maintenance programme. However, the request was not specifically about safety issues and the context seems to suggest that it was more concerned with the issue of application.

Mixing of the hardener with the paint base was conducted by the boatswain on the basis of his previous experience and, according to the mate, on the basis of instructions on the paint containers. No instructions were provided in respect of the addition of the thinner. The mate stated that the thinner was applied to the mix in a proportion of about 30 per cent. The instructions provided to the Inspector by the paint manufacturers contained specific references to the use of thinner.

> 2(e) Most paints do not require adjustment, but under conditions of excessively high or low temperature a small amount of appropriate thinner may be added in order to ease brushing or to bring the paint to a spraying consistency. Do not exceed the amount of thinner specified by the manufacturer.

The paint manufacturer's instructions for mixing epoxy and tar-epoxy paints noted that poor mixing may impair drying property and to ensure a homogeneous mix, mixing should be done by a pneumatic mixing machine or the like.

Mixing on *Nego Kim* was done by hand and the difficulty experienced in achieving a homogeneous consistency could help explain the excessive amount of thinner used. Another reason could have been the high ambient temperature, which would accelerate the chemical reaction in the mix, in a 20 litre drum, to 'go off' (to start hardening) too quickly.

The DSTO analysis by chromatography/mass spectrometry showed that the paint thinner was made up of the following volatile compounds:

Raw material	*Per cent*
Xylenes	68.0
Toluene	23.0
Ketone	6.4
Iso-propanol	2.6

The constituents of the thinner had the same explosive limits, flash point and auto-ignition characteristics as the volatile components making up the base and hardener of the paint.

The manufacturer's MSDS for the hardener specifies 5 per cent by volume as the maximum volume of thinner that should be used. The crew were using at least six times the recommended level of volatile thinner.

The MSDS details the volatile constituents of the paint, the flash point and the explosion limits. The sheets detailed the need to wear protective goggles, a respiratory mask for organic solvent gases, overalls, safety shoes and gloves and also the need to use an explosion-proof ventilation fan set to exhaust. It follows that, if the fan was required to be explosion-proof, any other electrical equipment should also be explosion proof or intrinsically safe.

It might be expected that an experienced mate and boatswain might be aware of the dangers of painting in an enclosed space and take sensible precautions based on that experience. However, the lack of appropriate MSDS for the paint and thinner must be regarded as an important deficiency in the safety system.

Neither the master, nor mate, nor the crew involved comprehended the potential danger of using epoxy-based paints in an enclosed space.

Crew exposure to fumes

The crew working with the paint would have been exposed to the paint and thinner fumes and to some degree could have suffered from their inhalation or absorption through the skin. Samples of blood and brain tissue were taken from those killed by the explosion during the autopsies conducted at Perth on 5 December. Traces of xylene (<0.05 mg/kg to <0.2 mg kg) were detected in the brain tissue of the four bodies and similar traces of toluene were detected in three of the deceased. However, these levels are very low and well below any danger limit. The level of toluene or xylene in the blood suggests that the four men had only casual exposure to the paint fumes, consistent with mixing the paint in the open air or being adjacent to open tins of volatile substances.

The levels of absorption would suggest that the concentrations of volatile compounds on the open deck were minimal. Such concentrations would tend to discount the possibility that the explosion was initiated by a 'flash over' from the open deck.

The DSTO report provides comment on the health effects of the solvents in use, which support standard tests on the subject. Human exposure to high concentrations can contribute to chronic health effects as well as affecting physical co-ordination and mental processes.

The results of the toxicology analyses however, showed that the levels of absorption were not consistent with intoxication or impairment from the effects of the chemicals. Two of the bodies showed some alcohol content, one 0.025 per cent in urine and the other 0.024 per cent in blood. These quantities are consistent with naturally occurring alcohol through putrefaction and do not indicate the consumption of alcohol.

Evidence provided by the mate indicated that the crew were dressed in overalls, safety boots, hard hats and gloves and that the person in the tank wore a respirator. However the evidence provided by the police Disaster Victim Identification Team suggests that the seaman inside the tank, painting at the time of the explosion was wearing only partial appropriate protective clothing. He wore a full face visor with a perspex window (similar to a welders visor), a fabric mask over his mouth and nose and cotton overalls, which offered no protection against absorption of the paint chemicals by inhalation or absorption through the skin. In addition, an open-toed, backless, slip-on, plastic sandal was found inside the tank after the explosion.

In Australia, the maximum permissible exposure to the solvents used is based on 8 hour time-weighted average levels (TWA) and short term exposures limits of 0.5 hour (STEL)[5].

In the following table, 100 parts per million (ppm) equates to 0.01 per cent of atmosphere.

Human Exposure Levels

Chemical	*TWA*	*STEL*
Xylene	80 ppm	150 ppm
Toluene	100 ppm	150 ppm
Methyl Isobutyl Ketone	50 ppm	75 ppm
Isopropyl Alcohol	400 ppm	500 ppm

The DSTO report notes that the human exposure levels are significantly below the 10 per cent LEL of 1000 ppm and comments that to maintain solvent concentrations at a safe level in no.1 port TBT it would require a ventilation rate of 60m^3/min combined with a slow painting rate of 0.7 m^2/min. This calculation was based on thinner being added at 5 per cent.

Autopsy results from the AB who was in the tank, but who died 18 days later, showed no evidence of toluene or xylene and only showed evidence of drugs administered in hospital. His extended period under medication and ventilation, however, would have expelled any evidence of exposure to toxic effects from the paint. It is not known whether this man was the only crew member who was working inside the tank on 18 November.

Given the above information, it is apparent that the crew, particularly any inside the tank, were not appropriately dressed. Conventional overalls and a simple facemask do not offer protection from toxic vapours. Impermeable clothing and a respirator should be worn.

In hot weather, impermeable clothing and other personal protection equipment used for work in toxic atmospheres becomes oppressive if worn for any length of time. Painting in an enclosed space, with the ship at anchor in a tropical port, would invite crew involved to violate safety procedures for their own comfort.

Neither the issue of toxicology, nor the volatility of the chemicals involved, were covered in any instructions carried on board *Nego Kim*.

The International Safety Management Code (ISM Code)

The Safety Management Certificate on board *Nego Kim* was dated 15 May 1998 under the authority of the Hong Kong Special Administrative Region. This certificate was issued by Nippon Kaiji Kyokai based on evidence that the ship had the necessary procedures and documents in place for shipboard operations to comply with the requirements of the ISM Code for a Safety Management System (SMS). The SMS had been audited on board in April 2000.

The Document of Compliance issued by the Hong Kong Director of Marine to the ship management company[6] was dated 30 April 1998. The Document of Compliance had been periodically verified each May since 1998.

The purpose of the Code is to provide an international standard for the safe management and operation of ships and for the prevention of pollution. The Code, as adopted by the International Maritime Organization in Assembly Resolution A.741 (18), provides, inter alia:

- the objectives of the Code are to ensure safety at sea, prevention of human injury or loss of life, and avoidance of damage to the environment, in particular the marine environment, and property;
- safety-management objectives of the company should, inter-alia;

5 National Occupational Health and Safety Commission (NOHSC), Commonwealth of Australia Exposure Standards.

6 The company means the owner of the ship or any other organization or person who assumes responsibility for the ship on behalf of the shipowner. In this case Wallem Shipmanagement Ltd.

  - provide for safe practices in ship operation and a safe working environment;
  - establish safeguards against all identified risks; and
  - continuously improve safety management skills of personnel ashore and aboard ships including preparing for emergencies related to safety and environmental protection;
- the safety management system should ensure;
  - compliance with mandatory rules and regulations; and
  - that applicable codes, guidelines and standards recommended by the Organization, Administrations, classification societies and maritime organizations are taken into account.

The ISM Code requires that the 'company' should:

- establish a safety and environmental protection policy which describes how the objectives will be achieved;
- ensure that the policy is implemented and maintained at all levels of the organization, both shipboard and shore-based;
- establish procedures for the preparation of plans and instructions for key shipboard operations concerning the safety of the ship and the prevention of pollution;
- provide for the reporting of non-conformities, accidents and hazardous situations and that they should be analysed with the objective of improving safety and pollution prevention.

The on-board management

The on-board documentation was in English, while some volumes had been translated into Chinese.

The on-board documentation included instructions relating to the 'Enclosed Space Entry Permit and Checklist' and associated procedures. These are contained in Chapter 7 of the company Safety Manual. There are some minor inconsistencies between the instructions and the checklist that are not material to this incident. However, two specific requirements are particularly relevant:

- 7.8.iv. of the Manual refers to item 5 on the checklist and requires details of the 'Results of atmosphere checks as applicable to type of ship and cargo';
- item 16 asks 'Is all equipment of the approved type?'

There were no instructions for continuous working in an enclosed space.

The mate completed the check for oxygen and ticked the appropriate boxes on the checklist. The permit/checklist also required tests for hydrocarbons and toxic gases under certain circumstances. The ship, not being a tanker and not carrying coal, was viewed as being free of the risk of explosion. As no.1 port TBT had had no cargo and had been entered for washing and cleaning over the preceding days, there was no reason to test it for hydrocarbons. The only hazard that could be anticipated before the start of painting was that of depleted oxygen within the tank's atmosphere. The test for this was carried out.

While the depletion of oxygen is one hazard, in this case there were both the additional issues of the development of a potentially explosive atmosphere and of toxic paint fumes. The dangers of painting in an enclosed space were not recognised by the master, mate, boatswain or the ship's crew, perhaps because 'painting ship' is most often carried out on the open deck in fresh air.

A major deficiency in the management of the painting operation was the lack of proper ventilation. The ventilation was clearly inadequate and showed a lack of understanding for the need to maintain a safe, non-explosive, non-toxic atmosphere within the tank.

The hazards inherent in the paint were detailed in the MSDS and the associated paint manufacturer's instructions. The absence of these documents on board meant that the crew should have treated the paint as a chemical under the company's own safety procedures.

Once the painting had started, no test for hydrocarbon levels was undertaken. Indeed, it could not have been as there was no equipment with which to carry out such tests.

Item 16 of the checklist. 'Is all equipment of approved type' referred to the fan, lighting and radio equipment being of a type approved for working in a potentially gaseous atmosphere. The box was ticked. However, the ship did not carry explosion proof or intrinsically safe fans, radios or lights.

Following the explosion, on the instruction of the Hong Kong Marine Department, Nippon Kaiji Kyokai (as the issuing and auditing organisation) undertook an 'Additional' ISM audit of *Nego Kim*. The auditor concentrated on the documented procedures for enclosed space entry and painting. The auditor reviewed the joining instructions for new ship's crew and the training videos carried on board. He also reviewed the company's procedures and relevant records. The auditor came to the conclusion that the procedures for painting the ballast tanks internally had been complied with to a substantial degree and there were no non-conformities to note. The Inspector raised the issue of 'approved equipment' with the auditor. He explained that this was raised by him at the time. The master and company representative explained the item was taken as 'referring to oil tankers and other ships carrying dangerous cargoes'.

The auditor, however, did make a number of observations. The observations included a recommendation that the company should review the specific issues of spray painting and work in enclosed spaces while using spray paint equipment and chemicals. He also observed that the maintenance and calibration records for the gas detector were 'untraceable'.

Ship maintenance by painting is a major, fundamental and indispensable ship operation. The ISM Code has inter alia, the objective of providing for safe shipboard operations and practices and for the identification of risks. There is a requirement for the procedures, plans and instructions for all key shipboard operations to be documented and to be observed. In this instance, they were not.

The ship management company

The ship managers provided the paint to the ship for maintenance under the *Nego Kim*'s planned maintenance system. It was the ship managers that had ultimate oversight of the ship's maintenance programme and the knowledge of the equipment carried on the ship. The painting of ship structures is a routine and 'key shipboard operation', for which (under the ISM Code) the 'company is required to establish procedures for the preparations of plans and procedures'.

In an e-mail of 10 August 2001 the then chief officer specifically asked for instructions on how to apply the paints supplied.

The paint supplied and the thinner were highly volatile. The MSDS stated this and provided advice on its mixing and application. However, as with the ship personnel, the ship managers did not make the connection between routine painting and the potential hazards associated with using such paint in an enclosed space.

The mate was charged with ensuring that the atmosphere within the tank was safe. He tested for oxygen content before the work started, but he did not check for a hazardous atmosphere. It is likely that he did not connect the paint fumes with a possible explosion. Even if he had, however, the investigators learned that the gas detector had not been on board for some time having been landed in Singapore for repair. The ship managers were aware of this and were conscious of the fact that no gas analyser was carried. In a message to the ship a superintendent instructed:

> Regarding Explosimeter Pls raise Reqn for supply of new unit. Meanwhile keep Multigas detector away from sight as this is required only while loading coal.

The meaning of this instruction is not clear. Neither is the view of the master and the company representative, mentioned above, that such a meter 'was required only for oil tankers and other vessels carrying dangerous cargoes', consistent with this instruction relating to the loading of coal.

The significant point, however, is that there was no equipment on board for testing for an explosive atmosphere.

With regard to personal protective equipment, no recognition was made of the potential toxicity of the paint and the need for impermeable clothing and a proper respirator to protect the painter from the extremely toxic substances.

In short, the ship was not provided with the proper equipment with which to complete the operation safely.

The SMS was deficient in providing procedures to protect the crew as:

- the generation of fumes from epoxy paint is an identifiable risk;
- the requirement for effective ventilation is a basic safety measure; and
- the need for explosion-proof electrical equipment is essential.

Ship management company remedial actions

Immediately following the explosion Wallem Shipmanagement banned all spray painting in enclosed spaces and initiated its own investigation and analysis of the incident. As a result, in February 2002 the Company produced a new and detailed checklist, specifically for painting in enclosed spaces and prohibiting spray painting in enclosed spaces unless the Company's Safety and Insurance Department gave specific permission. In addition the Company issued detailed precautions that had to be followed, when painting in enclosed spaces, covering prevention of explosion and fire and the risks associated with the toxic nature of paint fumes.

Port communications

The effectiveness of communications between *Nego Kim* and Dampier Port is not an issue in the events that lead up to the explosion in no.1 TSBT. It is, however, an issue in the master's call for help, the response to that call and the reasonable expectations of the masters and crews of vessels using the port.

The port is a multi-user port with iron ore and gas exports being the main trade. There is also a significant salt export trade and, in addition, some import and export trade through the public wharf. The port is also a base for offshore support vessels.

Approximately 1700 trading vessels berth at the port of Dampier each year. The Dampier Port Authority 2001 Annual Report notes that for 2000-2001 the total tonnage of exports and imports was 81 452 840 metric tonnes;

> 'The Authority has therefore re-established itself as the largest port in terms of trade tonnage.'

Under the heading 'Principal Activities' nine activities were identified including:

- operate port communications;
- provide emergency response planning.

The Dampier Port Authority (DPA) operates the port under the provisions of the Western Australian Port Authorities Act 1999, with two of the functions being:

- facilitating trade within and throughout the port and planning for future growth and development;
- being responsible for safe and efficient operation of the port.

Under section 114 of the Port Authorities Act 1999, a port authority 'is to have, maintain and implement a marine safety plan for its port.' The plan must be approved by the Minister. Such a plan had been drawn up by the DPA, but the Minister had declined to accept that plan. The plan remained therefore as an unapproved draft.

Section 4.5 of the draft plan makes provision for 'Communications'. This brief section does not deal with an emergency broadcast by a ship. It provides for a 24-hour mobile telephone contact for serious accidents. This seems to be predicated on some person with access to the provisions of the plan being aware of the number. A visiting ship would not necessarily have access to the number before arriving alongside unless it had been specifically provided.

In July 2001 a review was commissioned by the DPA to address the following:

- whether the functions of Port Control can be discontinued;
- in the event that the functions were discontinued, would the Dampier Port Authority still be complying with its legal obligations under the relevant legislation;
- if any of the current functions were viewed to be essential, to document the reasons for this view and to provide recommendations as to options for the Dampier Port Authority for the carrying out of those functions considered essential.

This review concluded, inter alia:

> 'It is therefore recommended that Port Control can be abolished, and in so doing, the safety of marine operations within the Port would not be compromised in an unacceptable way.
>
> However the Marine Safety Plan would need to be addressed to ensure any residual risks are managed by formalising and strengthening communications protocols between operators within the Port.'

The investigation established that the master tried to pass his arrival message through 'Dampier Port Control' and to seek direction on where to anchor his ship. His calls to 'Port Control' were eventually answered by the operator at Hamersley Iron Control Centre. The operator explained that his station was not Dampier Port Control, and the master should contact the ship's appointed agent by telephone.

As an immediate reaction to the explosion, the master's first instinct was to contact 'Port Control' for emergency help. When the Master made the initial call for help, starting at 1644:45, he did not follow the recognised format of a MAYDAY or even a PAN message. The master, obviously under great stress, started his message eight seconds after the call button was depressed. None of his subsequent calls were prefaced with the emergency or urgency prefix.

The effectiveness of the response to the emergency call was due to the initiative of the Hamersley Iron Control Centre operator. It was also fortuitous that the Hamersley Iron Control Centre was manned on this Sunday afternoon. While the room is often operated on a 24-hour basis, this is not necessarily the case on all occasions.

Communication with the master of *Nego Kim* was, and remained, difficult. It is not clear whether he understood that Hamersley Iron Control Centre operator was not port control. He seemed to have been reassured when, at 1648:08, the Port Hedland Control operator replied to a series of radio calls and pleas for assistance, made while the Hamersley Iron Control Centre operator was contacting the helicopter and police.

It is understandable that a foreign master with only basic English should not fully grasp the situation of a port not having a control centre. Dampier is a major port. Indeed, as stated above, the port with the largest tonnage throughput in Australia. In the Inspector's opinion it is hard to imagine a comparable ranking, multi-user port within Australia, or internationally, that would not have some form of 24-hour operations centre.

DPA submitted:

> (This paragraph) ignores the fact that the major users in the Port, being Hammersley Iron/Dampier Salt and Woodside, in fact operate on a 24 hours basis. Consequently these companies have communication procedures and operations centres commensurate with their operations. The companies operate under their respective State Agreement Acts. It is significant that in excess of 99 per cent of vessel visits to the Port are on behalf of the three companies operating under their respective State Agreement Acts. In other words less, than than 1 per cent of vessels visiting the Port utilise the only common-user facility within the port, being Dampier Public Wharf.

The apparent assumption was that, with the closure of the communications tower, trained WEL communications staff at the WEL gatehouse would monitor all channel 16 emergency traffic on their VHF radio. However, the WEL staff understood their responsibility as being that of implementing appropriate operational and communications procedures for the safe shipping movements for the Northwest Shelf Project, particularly during arrival and departures at the Whithnell Bay terminal. While their role within the WEL Emergency Response Plan was understood, the staff were not aware of their role in a more general port emergency. This role had not been explained to them, nor had they been trained in it. Consequently the calls made on Channel 16 by *Nego Kim*'s master at 1644:45, and subsequent radio traffic between the ship and Hamersley Operations Centre, were only monitored, and not recorded, at WEL.

The DPA Board's decision to limit the operation of the Port Control Tower services to office hours was based on a comparison with other ports. The compared ports were either smaller, of much lower traffic volumes, or not in risk areas for tropical cyclones, or in areas were other control towers were in close proximity.

In submission the DPA stated:

> With respect, the ATSB is not aware of the extensive process and considerations that lead to the decision by the board to effect changes in port communications. The DPA Board fully considered the risks and ensured that safe communication procedures were put in place as part of an approved Transition Plan. These 'new' procedures have been in place since September 2001 and have significantly improved safety of vessels moving in the Port. Given that 99 per cent of vessels are visiting the port on behalf of these companies (including Dampier Salt) the most significant consideration by Directors was that the Port continued to operate safely.

In the Inspector's opinion, in closing down the port control tower and removing its communications function, the DPA did not make adequate alternative provision for port communications, particularly in an emergency. The risks and countermeasures were not properly considered. The alternative provisions were not properly formulated or promulgated to other interested parties in the port community.

Response to the emergency

The draft Marine Safety Plan, under 4.4 'Emergency Response' states that 'in light of the Port Authorities Act 1999 and the proposed new regulations the DPA will undertake a comprehensive review and update of the Port's ERP (Emergency Response Plan). Under 4.4.1 'Performance' the draft plan states that:

> 'the DPA will respond to and oversee all emergencies within its area of operations . . .'. Also 'the DPA will provide independent command and control facilities to enable escalation and co-ordination of a response.'

The review of July 2001 did not expressly consider either this issue or an emergency response to a ship. Indeed, it appears that there was an unwritten understanding that WEL would deal with issues or emergencies affecting vessels using its facilities and Hammersley Iron would likewise deal with vessels using its facilities. The question of an emergency affecting a vessel not on charter to either of these companies, or which was to berth at the public wharf, appears to have received no consideration.

Following the closure of the Port Control Tower by Dampier Port Authority in September, the Western Australian Minister for Planning and Infrastructure, whose portfolio includes responsibility for the administration of the Western Australian Port Authorities Act 1999, initiated a review of the Safety Management System at the Port.

A risk management consultant was subsequently commissioned to:

> ' . . . review (audit) the Dampier Port Authority Marine Safety Plan 2001 to ensure it provides an adequate and suitable safety management system of policies, procedures and processes to address the hazards and risks identified, and include an assessment of whether closure of the Port Control Tower allows the Port of Dampier to provide a safe port.'

This review looked at broader issues than those relating to the response to emergency incidents like that involving *Nego Kim*. In terms of this review, the deficiencies in safety related to:

- the lack of a recognised centre for communications and co-ordination, wherever situated;
- the lack of a coherent, up-to-date emergency plan; and
- the decision not to promulgate the plan to those who would implement any such plan.

The port had no approved Marine Safety Plan. The draft Emergency Response Plan in place on the 18 November had been drafted before the draft Marine Safety Plan. Provisions made by the draft Marine Safety Plan were inconsistent with the draft Emergency Response Plan, which was predicated on the DPA control tower being in operation. Organisations such as the police, hospital, the pilotage providers and staff from the port user bodies were not aware of the draft Marine Safety Plan or the implications it had for the Emergency Response Plan.

Search and rescue operations

Although responsible for 'safe and efficient operation of the port', it was not the role of the DPA to manage the emergency response.

Under the policy of the State Emergency Management Advisory Committee (Police, Fire, State Government Department, etc), revised in December 1998, the Western Australia Police are responsible for responding to reports of sudden death and for search and rescue, including marine search and rescue.

The first notification that men had been lost overboard was made at about 1717, some 30 minutes after the explosion. In the circumstances this delay was inevitable. The master did not know that men had been lost overboard until the remaining crew had extinguished the fire and a search of both no.1 TBT and no.1 hold had been completed.

The Hamersley Iron Control Centre operator exercised his initiative in responding to *Nego Kim*. The police assumed the role as Hazard Management Coordinator. No time was lost in deploying the helicopter. The priority was to lift the injured man to hospital. The period of about 22 to 24 minutes between being alerted and lifting off at 1712:31, with three persons on board, was as rapid as could reasonably be expected, consistent with essential pre-flight safety procedures. This helicopter was a Medivac response and not part of the search and rescue, as it was not known initially that anyone was overboard from the ship.

After 1717, the nature of the emergency changed from a medical evacuation to a search for people in the water. The officer in charge of the Dampier Police station continued as the Hazard Management Coordinator. He was qualified in marine search and rescue.

The Australian Search and Rescue Manual notes that the initial stages of a search are often ad hoc. A command structure needs to be created and recognised. There is also an initial need to gather relevant information, which initially can be ambiguous or incomplete. Sea searches are 'dynamic' in that any target is in a moving environment. Although there are SAR programmes that are followed, these are based on certain assumptions as well as tidal and weather information.

The search coordinator must define a search area that is searchable by the resources available and in which the people may reasonably be expected to be found. If the search resources are surface based, such an area is of necessity smaller than one where aviation resources are available. Other factors such as night and day and the availability of appropriate resources are also considerations in such a search operation.

In this case there was no aviation asset with a night search capability and hence any air search was limited to daylight hours. The initial phase of the sea search was conducted by small vessels, with a police officer aboard the vessel *Shirley Holland* appointed as 'on scene commander'.

In particular, the capacity of any survivors in the water to signal for assistance is an important feature of night search and rescue. In this case, it is almost certain that any survivor from the explosion would not have been equipped with lights or flares. They would therefore be very difficult to find in the dark. Until first light, a surface search would be more likely to succeed than an air search.

There were some initial delays in aspects of the SAR operation on 18 November. Probably that of most note was the delay in deploying the SAR datum buoys, which assist in determining the surface movement of the water. In areas of strong tides early deployment of SAR datum buoys is essential so that their movement properly matches the tidal cycle.

The deployment of the SAR datum buoys took 4¼ hours between the notification that men were lost overboard and the delivery of SAR datum buoys to the search coordination centre. The buoys were stored at the State Emergency Services Depot in Karratha, about 20 km from Dampier. By the time the SAR datum buoys were available to the search coordinators the weather had deteriorated to such an extent that *Mermaid Reunion* had to be diverted from the search to collect the buoys for deployment. In the event, because of the delay, the decision was made not to deploy the buoys until the tide was at a similar state to that at the actual time of the explosion. Advice from AusSAR is that this is proper practice to be able to assess the probable movements of targets in the water.

The initial SAR effort was concentrated in the immediate area of the ship itself. This initial searching was conducted using small boats and helicopters. But due to weather and darkness these assets were soon replaced when the larger ships arrived on the scene.

The police provided a continuing surface search grid for use in the SAR operation based on the best information available, including meteorological and tidal data. The search grid was about 6 miles square and was updated and adjusted periodically in accordance with the SAR plan. At first light the air search was commenced over a larger area.

The body recovered at 1325 on 19 October was detected by an aircraft and was about 1.5 miles outside the surface grid, but within the aviation grid. Given the adverse weather conditions and the time lost in deploying the SAR datum buoys, the fact that the body was found outside the surface search area is understandable. It also reflects that the air search area will often be bigger than the surface search area, since the latter is more likely to be constrained by speed of assets and the width they can sweep. The search grid was revised when this information was received and updated for the remainder of the search.

There were also some delays in obtaining boats for the initial search and there were potential assets that were not utilised. Primarily, this is a failure of the port to have an effective emergency response procedure and to communicate that procedure to key organisations and people within the port community.

The surface search involved five offshore supply vessels. *Lady Valisia* was first on the scene and assumed the role of the 'on scene coordinator' at the request of the police. *Lady Valisia* was progressively joined by *Mermaid Reunion*, *Pacific Commander*, *Pacific Commander*, and *Pacifc Bloodhound*. These ships searched until 1900 on 19 November when Dampier Police notified them that they were no longer required. The three smaller harbour launches were deployed throughout the 19 to 21 November as required.

The air search involved 6 helicopters flying 15 search sorties for in excess of 35 hours and two fixed wing planes flying five sorties for just under 15 hours.

Conclusions

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

Based on the evidence available, the following factors are considered to have contributed to the incident:

1. The five dead, and three presumed dead, crew members died as a consequence of an explosion following the ignition of an explosive atmosphere within no.1 TBT tank.

2. The tank contained vapour concentrations, within the explosive range, of the volatile compounds making up the epoxy paint and thinner being used to spray paint the tank.

3. Hand mixing the paint, together with high ambient temperatures, probably contributed to the use of quantities of thinner far in excess of the recommended maximum.

4. The ventilation of the tank was grossly inadequate and allowed the creation of an explosive atmosphere.

5. The electrical equipment in use was not intrinsically safe/explosion proof.

6. The ship management company did not recognise the potential risks associated with the use of epoxy (hydrocarbon based) paint and thinner in an enclosed space.

7. The ship management company did not ensure that adequate instructions in the usage and dangers of the epoxy based paint were provided to the ship and understood by the crew.

8. The ship management company had not supplied the ship with the equipment required to complete the 'key operational task' of painting safely in that explosion-proof fans, radios and lights were not available to the crew, neither was a gas detection meter.

9. There was no adequate perception of the risks involved in using epoxy paints in an enclosed space and those involved did not associate danger with the painting of the interior of the ballast tank.

10. There was no Material Safety Data information held on board relating to the hazardous nature of the paint and the proper method of ventilation.

Additionally:

11. The most probable source of ignition was the momentary exposure of the light globe filament to the explosive atmosphere as a result of the light falling within the tank and the globe breaking. There were, however, other potential sources of ignition.

12. The ambient temperature within no.1 port topside ballast tank was unsuitable for painting with epoxy paint in an enclosed space.

13. The ship management company did not recognise the risks of prolonged exposure to toxic paint fumes and had not supplied proper personal protective equipment and clothing.

14. The objectives of the International Safety Management Code were not met in that procedures did not provide a basis for:

    - preventing injury and loss of life;
    - establishing safeguards against all recognised risks;
    - establishing procedures for the preparation of plans and instructions for

- the key shipboard operation of painting the ship's internal structure.

The Inspector also notes that:

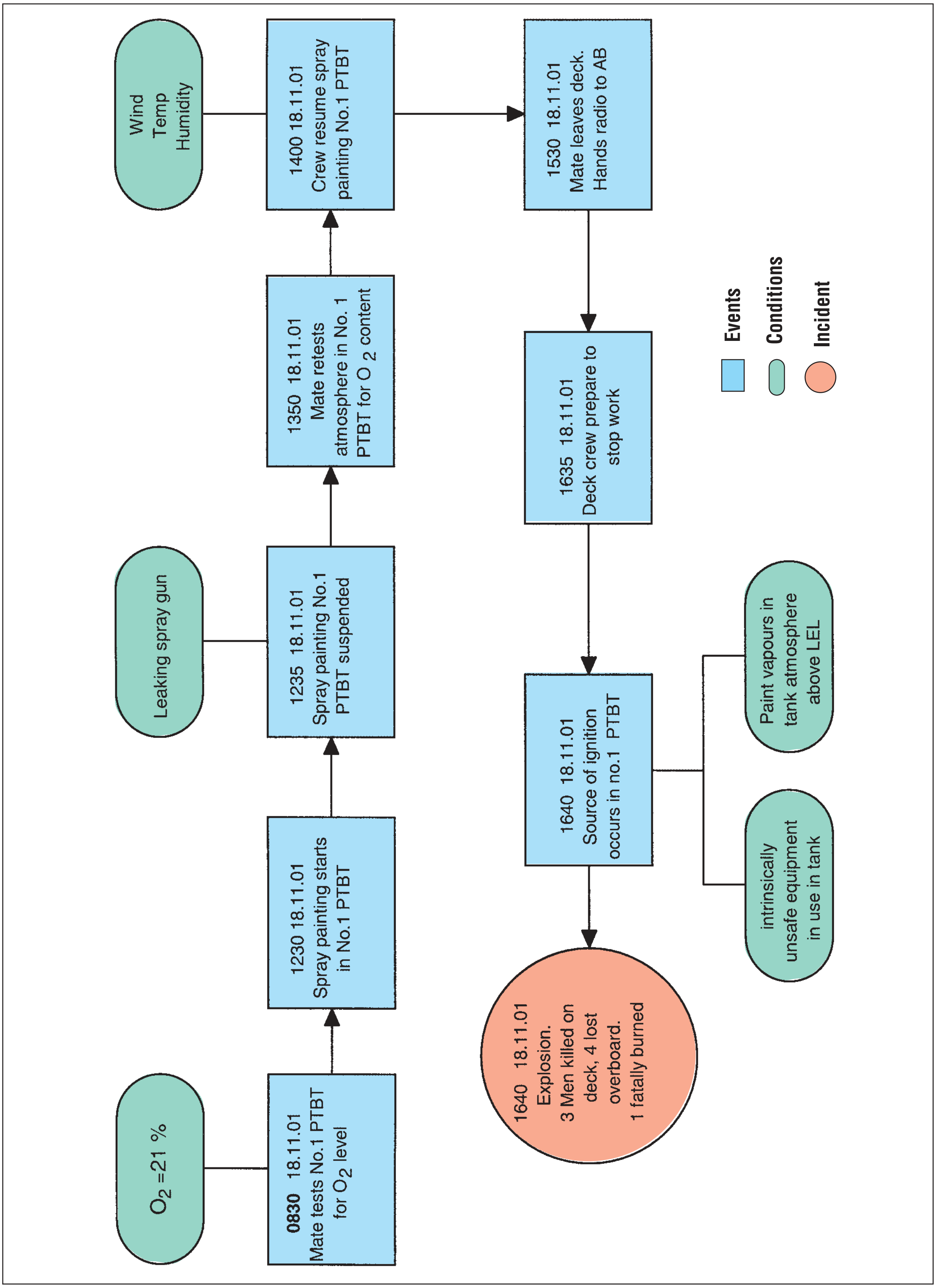
15. The initial prompt response to the emergency was due to the initiative of the operator in Hamersley Iron Control Centre and the police activating their emergency plan.

16. Dampier Port Authority's draft Marine Safety Plan and the draft Emergency Response Plan, were not approved and were deficient in that:

    - the draft Emergency Response Plan did not reflect organisational and procedural changes made as a result of closing the communications tower;

    - the changes brought about by the closing of the communications tower were not sufficiently promulgated or understood by key staff.

FIGURE 13:
***Nego Kim*: Events and causal factors chart 18 November 2001**



Recommendations

In addition to the safety measures already taken, the Inspector recommends that:

1. ISM manuals should include clear instructions for all operations in enclosed spaces, including the hazards of any operation and instructions regarding the wearing of appropriate clothing and protective equipment.
2. ISM manuals should provide guidance on the conditions under which work in enclosed spaces should be undertaken.
3. The Port of Dampier draft Emergency Response Plan should be reviewed to remove ambiguities and to ensure a consistent and appropriate approach to emergency situations within the port, including clear communications.

Submissions

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

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

Wallem Shipmanagement

The Master. *Nego Kim*

The Mate, *Nego Kim*

Dampier Port Authority

Dampier Police

Hammersley Iron Limited

Class NK

Woodside Energy Limited

Transport W.A.

Australian Maritime Safety Authority

Where appropriate the text has been changed to correct the draft or reflect the submission.

Nego Kim

IMO Number	8507535
Flag	Hong Kong
Port of Registry	Hong Kong
Classification Society	Nippon Kaiji Kyokai (NK)
Ship Type	Geared Bulk Carrier
Builder	Usuki Iron Works Ltd Saiki, Japan
Year Built	1985
Owners	Saratoga Shipping Limited
Ship Managers	Wallem Ship Management Ltd, Hong Kong
Gross Tonnage	15 832
Net Tonnage	8 990
Deadweight (summer)	26 591 tonnes
Summer draught	9.543 m
Length overall	167.2 m
Breadth	26 m
Moulded depth	13.30 m
Engine	1 x B & W 6L50MCE
Total power	6 090 BHP (5074 kW)
Crew	23 PRC nationals