Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Marine Occurrence Investigation No. 256
MO-2008-008
Final

Independent investigation into the grounding of the Isle of Man registered bulk carrier

Iron King

at Port Hedland, Western Australia

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Abstract

At 2142 on 31 July 2008, the fully laden cape-sized bulk carrier *Iron King* departed from its berth in Port Hedland, Western Australia, with a harbour pilot on board.

Iron King made its way through the harbour and while the assisting tugs had been let go by 2217, just before the ship reached Hunt Point, they continued to escort it. Shortly afterwards, at 2219 and again at 2221¼, the ship's rudder failed to respond to port helm orders as the pilot attempted to steady the ship's heading on the Spoil Lead.

The master switched the steering control switch between the two follow-up control systems and informed the pilot that steering control had been restored. The ship was still turning to starboard, so the pilot ordered full ahead and hard-to-port in an attempt to keep the ship in the channel and thus avoid grounding. He also directed the tugs to make fast to the ship as soon as possible. However, the tugs were unable to provide much assistance and by 2225, the ship had collided with Beacon 44 and grounded.

The ship remained aground until the next high tide, when it was successfully refloated.

The investigation found that the steering gear failed to respond to the helm orders because a leaking actuator relief valve was limiting the steering system hydraulic pressure. It was also found that; it was normal practice for assisting tugs to be let go before departing ships reached Hunt Point; the pilot directed the tugs to make fast to the ship again, but they were unable to do so before it grounded; the master was not aware of the appropriate emergency steering system change-over procedure; and the pilot had not been provided with training in the implementation of a suite of 'risk analysed' responses to predictable emergency scenarios in a simulated environment.

A number of safety actions have already been taken by relevant parties to address these safety issues. In addition, the Australian Transport Safety Bureau has issued one Safety Advisory Notice.

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

When the ATSB issues a safety recommendation, the person, organisation or agency must provide a written response within 90 days. That response must indicate whether the person, organisation or agency accepts 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.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

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

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

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

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

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

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

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

EXECUTIVE SUMMARY

At 2142[1] on 31 July 2008, the fully laden cape-sized[2] bulk carrier *Iron King* departed from its berth in Port Hedland with a harbour pilot on board.

The ship made its way through the port and by 2217, the last of the four assisting tugs had been let go. Shortly afterwards, at 2219 and again at 2221¼, the rudder failed to respond to the pilot's port helm orders.

The master switched the steering selector between the two main control systems and, when he informed the pilot that steering control had been restored, the pilot ordered full ahead and hard-to-port in an attempt to avoid grounding. The pilot directed the tugs to make fast again. However, the tugs were unable to do so in the available time and by 2225, the ship had run over Beacon 44 and grounded.

The pilot reported the grounding to harbour control and confirmed that soundings of the ship's tanks indicated that its hull had not been breached. Attempts were made to re-float the ship but it did not move.

By 2254, another pilot had boarded the ship and four more tugs were in attendance. However, the ship remained aground. At 0021 on 1 August, the main engine was stopped and the pilots ceased their attempts to refloat the ship.

The ship was ballasted by the stern and plans were put in place to refloat it on the next high tide, which was predicted to peak at 1047 that morning.

At 0910, an attempt was made to re-float the ship but it did not move. At 0951, another attempt was made and on this occasion, the ship moved astern.

When *Iron King* was in the centre of the channel, the pilot came ahead on the engine and commenced the passage out of the port. At about 1007, and then again at about 1010, the rudder stuck at starboard 20°. On both occasions, the pilot stopped the main engine and used the tugs to control the ship's heading. He then continued the transit without the use of starboard rudder.

The transit continued without incident and at 1406, the pilot advised harbour control that the ship had exited the channel at Beacon C1 (the end of the channel) and anchored in the outer anchorage.

The investigation found that on two occasions shortly before the ship grounded, *Iron King*'s rudder failed to respond to helm orders because the steering system hydraulic pressure was limited by a leaking actuator relief valve whenever the rudder moved to port.

The investigation also found that; it was normal practice for assisting tugs to be let go before departing ships reached Hunt Point; the master was not aware of the appropriate emergency steering system change-over procedure; and that the pilot had not been provided with training in the implementation of a suite of 'risk analysed' responses to reasonably foreseeable emergency scenarios in a simulated environment.

1 All times referred to in this report are local time, Coordinated Universal Time (UTC) + 9 hours.

2 Dimensions larger than that allowable for transit of the Panama Canal.

A number of safety actions have already been taken by relevant parties to address these safety issues. In addition, the Australian Transport Safety Bureau has issued one Safety Advisory Notice.

1 FACTUAL INFORMATION

1.1 *Iron King*

Iron King is a conventional cape-sized bulk carrier (Figure 1). At the time of the incident, it was owned by Frontier Maritime, Cayman Islands, managed by Enterprises Shipping and Trading, Greece, registered in the Isle of Man and classed with Bureau Veritas (BV).

The ship was built in 1996 by Hyundai Heavy Industries, and has nine cargo holds located forward of the accommodation superstructure. It has an overall length of 280.1 m, a beam of 45.0 m, a depth of 23.8 m and a deadweight of 161,167 tonnes at its summer draught of 17.519 m.

Figure 1: *Iron King* at anchor off Port Hedland

Propulsive power is provided by a six-cylinder Hyundai Sulzer 6RTA72U, single acting, direct reversing, two-stroke diesel engine delivering 15,215 kW at 88 rpm. The main engine drives a single, fixed pitch, right hand turning propeller which gives the ship a service speed of about 14 knots.

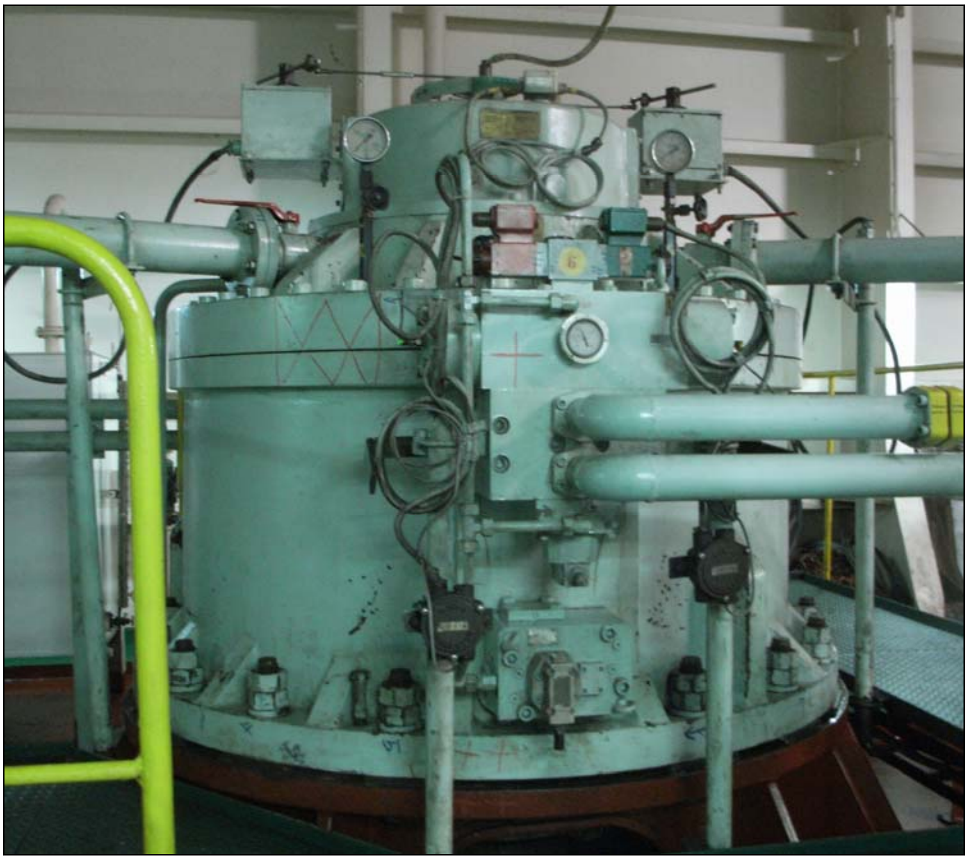
At the time of the incident, *Iron King* had a crew of one Polish and 21 Ukrainian nationals. The master held a certificate of competency as master that was first issued in Poland in 1995. He had 29 years of seagoing experience, with the last 10 years in command. He had been employed by Enterprises Shipping and Trading since May 2001 and had been master of *Iron King* for about 5 months. He was completing his second assignment on the ship and had been to Port Hedland several times in the past.

The pilot on board *Iron King* for the ship's departure from Port Hedland on 31 July 2008, held an Australian master's certificate of competency. He started his pilotage career in 2006 when he joined Port Hedland Pilots and he had completed about 560 pilotages in the port. During these voyages, he had either acted as an observing trainee pilot, a pilot under the supervision of a senior pilot, or as a solo pilot. At the time of the incident, he was licensed to pilot ships up to 165,000 deadweight tonnes and was the sole pilot on board *Iron King*. He had piloted many different types of ships, including bulk carriers similar to *Iron King*.

1.1.1 Steering gear

Iron King is fitted with a Porsgrunn hydraulically operated rotary vane steering gear (Figure 2). The rotary vane unit (actuator) consists of a rotor, mounted directly on the upper section of the rudder stock, which is enclosed in a circular housing (stator) that is secured to the ship's structure (Figure 3). A set of nitrile rubber seals provide an oil seal between the rotor and stator.

Figure 2: Rotary vane steering gear assembly



For redundancy purposes, the steering gear has two identical and independent hydraulic and control systems (Figure 4). The various hydraulic control and pressure relief valves are mounted on the outside of the steering gear housing, one set on the forward end and the other set on the aft end. The two hydraulic units, each incorporating an electric motor, pump and hydraulic oil tank, are mounted separately.

At sea, generally, the ship's steering is controlled by one hydraulic unit/control system and the other is placed in stand-by mode. During pilotage, both systems are normally run, providing faster steering response and increased system reliability.

Operation of the rotary vane unit

When hydraulic fluid is supplied under pressure, via the directional control valve(s), to chambers A1 and A2 (the chambers are common due to internal drillings in the actuator) and the directional valve(s) allow chambers B1 and B2 to drain, the rotor, and hence the rudder, moves in a clockwise direction, turning the ship to port (Figures 3 and 4). Similarly, when hydraulic fluid is supplied under pressure to chambers B1 and B2 and chambers A1 and A2 are allowed to drain, the rudder moves in an anti-clockwise direction, turning the ship to starboard.

Figure 3: Conceptual diagram of a rotary vane unit

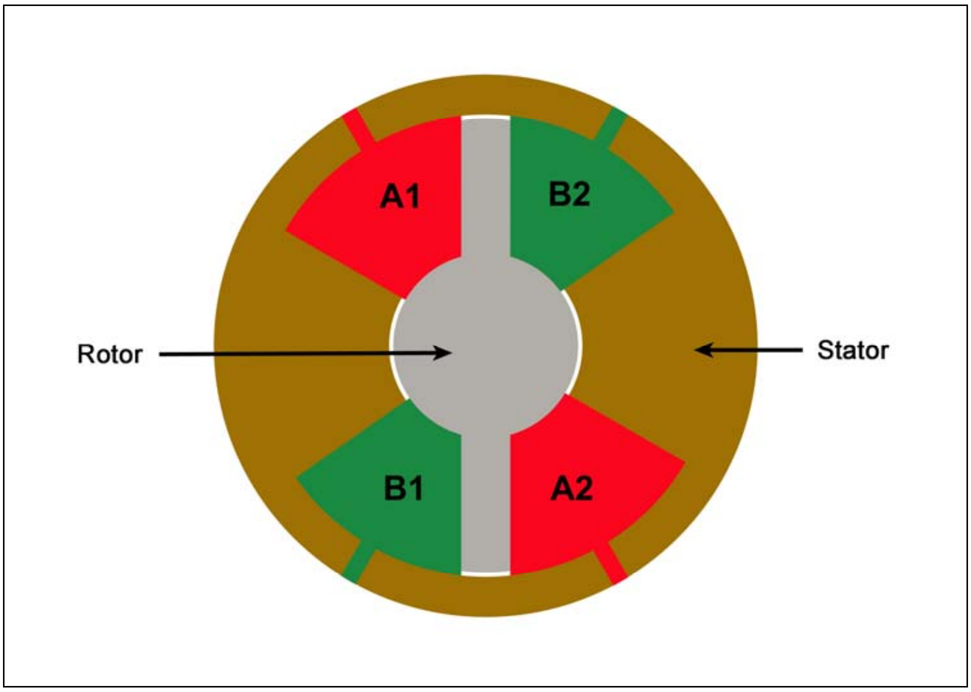
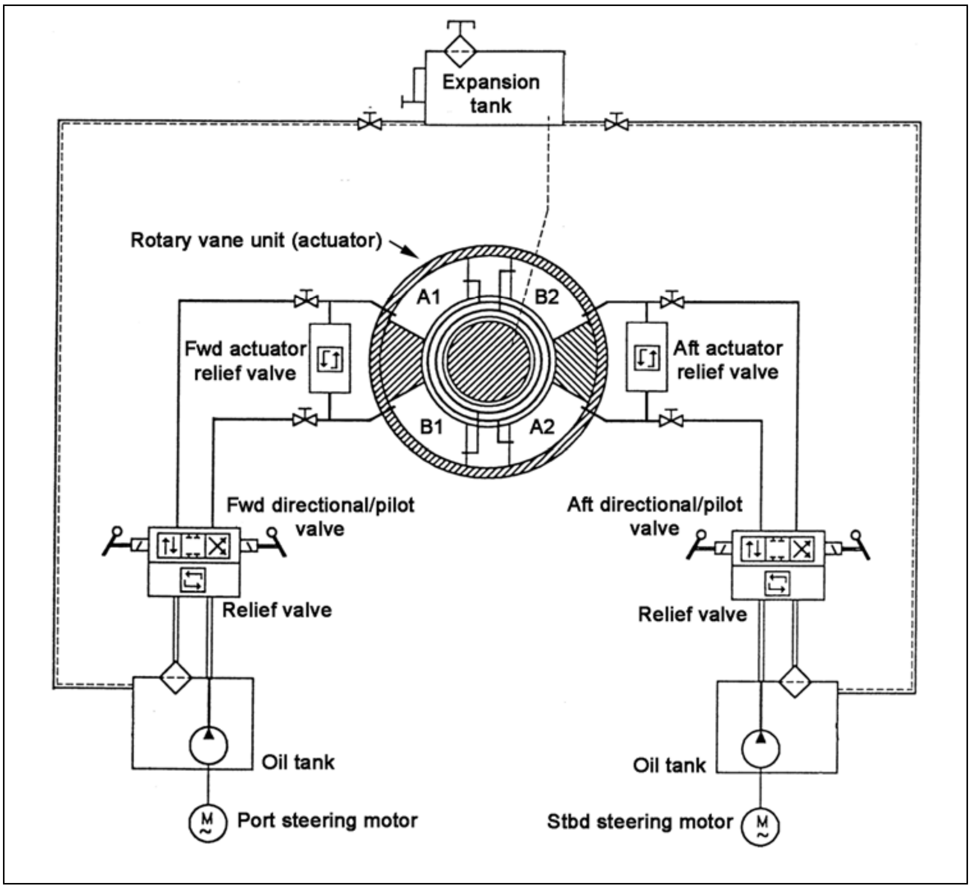


Figure 4: Schematic diagram of the hydraulic control system



While the rotary vane unit operates similarly whether one or two hydraulic pumps are operating, running two pumps increases the flow of hydraulic fluid which increases the speed with which the rudder responds.

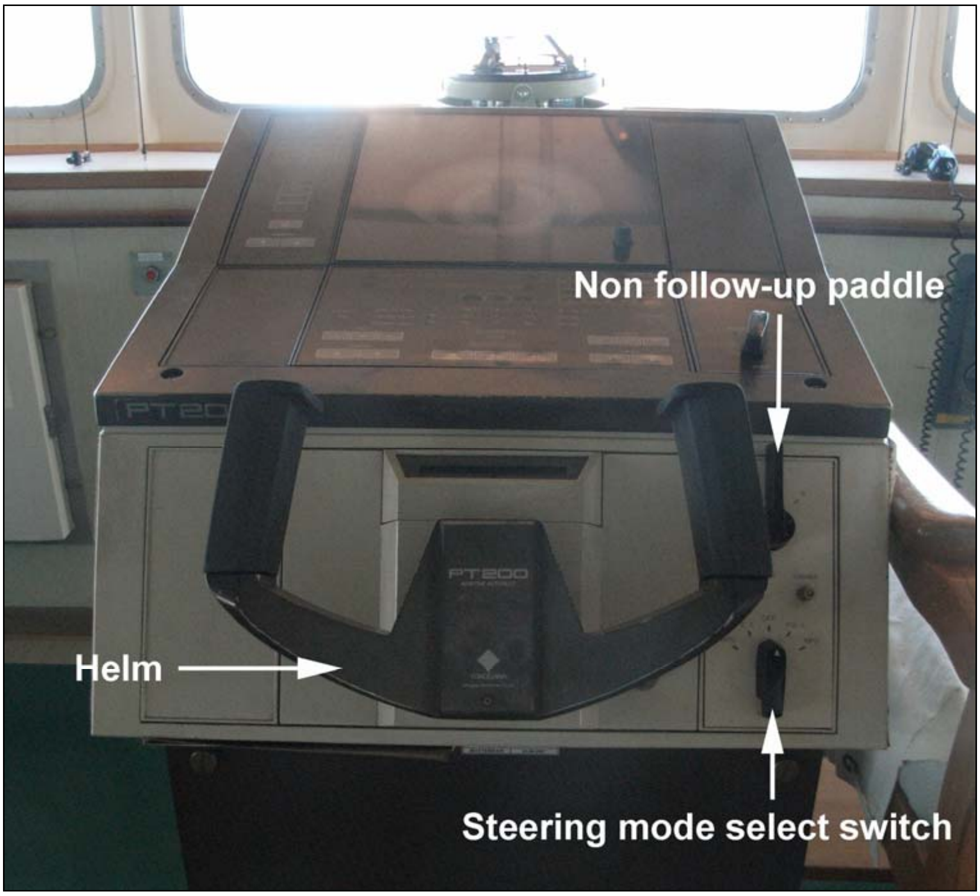
When steering is controlled from the bridge, each of the directional control valves is operated by a solenoid pilot valve. In emergency situations, the steering can be operated from the steering flat by manually operating the pilot valves.

The hydraulic system is also provided with a pair of pump relief valves, which limit the pressure supplied to the actuator, and a pair of actuator relief valves, which protect the actuator from over-pressurisation.

Steering electronic control

Remote control of the hydraulic system solenoid valves is provided by a pair of independent and interchangeable electronic control systems. Hence, if the control system in use fails, the operator, generally the officer of the watch on the bridge, can change over to the standby system. Furthermore, each control system incorporates independent and interchangeable follow-up and non follow-up control modes.

Figure 5: Yokogawa PT200 steering control stand



When either control system follow-up steering mode is selected (Figure 5), the operator controls the ship’s steering by turning the control stand mounted steering wheel (helm) to a desired rudder position (e.g. port 20°). The follow-up control system constantly compares the electronic input signal from the helm with the signal received from a position transmitter mounted on the rudder stock. If the signals are not the same (i.e. the rudder stock is in a different position to the helm), the control system applies an output signal that energises the relevant solenoids on the pilot valves. As a result, the rudder moves in the desired direction. When the 'desired' helm signal matches the output from the rudder stock position transmitter, the solenoids are de-energised and the rudder stops moving and remains in the desired position (e.g. port 20°).

When non follow-up steering mode is selected, the operator controls the ship's steering by manipulating a paddle lever. This system operates the solenoid valves directly, independent of the feedback signal from the rudder position transmitter. When the lever is moved to port, the control system energises the relevant solenoids and the rudder moves to port. When the rudder reaches the desired position (e.g. port 20°), the operator releases the lever which returns to its central position, the solenoid valves are de-energised and the rudder stops moving. Similarly, when the lever is moved to starboard, the control system energises the relevant solenoids and the rudder moves to starboard.

1.2 Port Hedland

Port Hedland (Figure 6) is one of Australia's largest bulk cargo ports. It is located on the northwest coast of Western Australia and services the mineral rich eastern Pilbara region. The port's major export commodity is iron ore. In the financial year ending on 30 June 2008, over 125 million tonnes of iron ore was loaded at the port.

Figure 6: Aerial photograph of Port Hedland harbour

The port has two iron ore loading berths at Nelson Point, two at Finucane Island, two at Anderson Point and a number of general cargo wharves. Management of the port is carried out by the Port Hedland Port Authority, a statutory authority established under the Western Australia *Port Authority Act 1999*. The authority has a charter to operate along commercial lines and its primary purpose is to facilitate trade through the port.

The Port Hedland Port Authority defines the port as:

> …all that piece of water within a radius of 10 miles[3] of Hunt Point Beacon (Beacon 47). This area is shown on chart AUS53 as the "Port Limit". To seaward of the port limit is the pilotage area, which extends out to sea a distance of 20 miles from Hunt Point[4].

The entrance to the harbour is bounded on the north-western side by Hunt Point, at the eastern side of Finucane Island, and on the south-eastern side by Airey Point, a low inconspicuous point, 3.5 miles west of Cooke Point.

The mean spring tidal range at Port Hedland is about 5.9 m while the mean neap tidal range is about 1.4 m. Hence, the channel is dredged to varying depths in order to make maximum use of the tidal range. The controlling depth between the Port Hedland channel approach (Beacon C1) and the swing basin, is 14.3 m, off Hunt Point.

A computer based dynamic under keel clearance program is used to determine each ship's maximum permitted departure draught. The program takes into account a number of factors, including channel depths, height of tide, sea state, ship speed, squat, minimum required under keel clearance and passage time from the berth to Beacon C1.

Pilotage within the port limits is compulsory for all ships of 150 gross tonnes or more, except for Australian Defence Force vessels, Australian fishing vessels of less than 35 m and vessels under the command of a master holding a valid pilotage exemption certificate. Pilotage is also compulsory for all departing ships of 150,000 deadweight tonnes or more within the extended pilotage area (10 miles beyond the port limit). Pilotage services in the port are provided by a private company, Port Hedland Pilots.

Towage services in Port Hedland are provided by Teekay Shipping. At the time of *Iron King*'s grounding, there were nine ASD tugs[5], ranging in power from 50 to 63 tonnes rated bollard pull[6], stationed in the port.

1.3 The incident

On 17 February 2008, a new master joined *Iron King* while the ship's cargo of iron ore was being discharged in Caofeidian, China. During the handover of command, the two masters discussed many matters of ship's business but their major concern was associated with the malfunction in the ship's steering gear on arrival at its last port of call. The rudder had stuck for a few seconds before responding as required. The incoming master was told that the ship's managers had been informed and that they were arranging for a service technician to attend the ship as soon as possible.

On 19 February, *Iron King* departed Caofeidian bound for Port Walcott, Western Australia, where the ship would load iron ore for export to the Japanese ports of Kimitsu and Tobata.

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3 A nautical mile of 1852 m.

4 http://www.phpa.com.au/

5 Azimuth Stern Drive tug – A multi-purpose tug, with azimuthing propellers aft.

6 The pulling power of a tug, expressed in tonnes.

The voyage was completed without incident and, on 2 April, *Iron King* arrived in Tobata where a service technician attended the vessel to check the operation of the steering gear. He found that there was a great deal of wear in the rotary vane unit's bearings and seals. As a result of the wear, the system was not building up the hydraulic pressure required to function correctly and the rudder was taking too long to move from hard-over to hard-over. The technician fitted new seals to the rotary vane unit, which improved the steering gear's performance. However, he advised the master, and the ship's managers, that the steering gear needed a complete overhaul.

Iron King continued to trade while the ship's managers arranged to dry dock the ship so that the steering gear could be overhauled. The ship's scheduled dry docking was due in January 2009, so it was decided to bring forward all of the scheduled maintenance items and complete them while the steering gear was being overhauled.

On 12 May, *Iron King* entered a dockyard in Zhoushan, China. The steering gear rotary vane unit was removed from the ship and taken ashore to a machine shop for overhaul. The unit was stripped of all its components and each part was either replaced or reconditioned to within specification. The unit was then refitted to the ship and tested.

On 13 July, *Iron King* departed Zhoushan, bound for Port Hedland. On 22 July, the ship arrived off Port Hedland and anchored. The voyage had been completed without incident and the crew had experienced no problems with the steering.

On 29 July, a Port Hedland pilot boarded *Iron King* for the transit from the anchorage to Anderson Point berth number one. By 1048, the ship was all fast, port side to the berth. Once again, there had been no problems with the ship's steering.

Cargo loading started soon after the ship berthed. The cargo plan indicated that the loading would be completed on the evening of 30 July. However, there were some loading delays and it was decided that the ship would be moved to Anderson Point berth number two when loading was completed. This would free the iron ore loader for the next ship. *Iron King* would then be readied to sail on the next high tide.

At 1100 on 31 July, the third mate tested the ship's navigation equipment in readiness for the move to Anderson Point berth number two. As part of this process, the operation of the steering was tested. The steering gear operated correctly and the third mate completed the bridge departure checklist, noting that there were no problems with the navigation equipment.

In the meantime, there had been further delays with the loading and the master was informed that *Iron King* would remain at Anderson Point berth number one. Loading would continue until 2100 and the ship would then be readied for a 2130 departure. The master informed the crew that the ship's sailing time had been postponed.

At 2030, the third mate returned to the bridge to test the navigation equipment prior to the ship's departure. He completed a second bridge departure checklist, again noting that there were no problems with the equipment.

At 2115, a Port Hedland pilot boarded the ship. The pilot and the master discussed the plan for letting go and the transit to sea. The master gave the pilot a copy of the ship's pilot card and confirmed that the ship's draughts were 16.52 m forward and 17.46 m aft. The two men discussed the tides and the fact that the next high tide was predicted to peak at a height of 5.4 m at 2248. The pilot informed the master that the port's dynamic under keel clearance program had calculated that the ship needed to depart the berth by 2149 to ensure that the minimum required under keel clearance would be maintained throughout the outbound passage. He also confirmed that all the ship's equipment, including the steering gear, had been tested and was in good working order.

By 2134, four harbour tugs were in place for *Iron King*'s departure. One tug was made fast on the ship's starboard shoulder, one was pushing up on the starboard shoulder, one was made fast on the starboard quarter and one was made fast through the ship's centre lead aft.

By 2142, *Iron King*'s mooring lines had been let go and the ship started to clear the wharf (Figure 7). The pilot began manoeuvring the ship towards the centre of the channel and the tug that had been pushing up on the starboard shoulder moved around to the port side of the ship and was made fast to the port shoulder. In the process of getting the ship into the centre of the channel, the pilot used the rudder as far over as 20° in either direction.

The pilot moved from the bridge wing to the centre of the bridge, immediately in front of the helmsman, and the master positioned himself to the right of the helmsman. The only other bridge team member, the chief mate, was operating the engine telegraph and recording details in the bell book.

Once the ship was in the centre of the channel and moving ahead, the pilot requested the two forward tugs and the tug on the ship's starboard quarter, to lay alongside the ship with no weight on their lines. He also asked the tug positioned at the ship's centre lead aft to 'trail behind' with no weight on its line.

By 2209½, the ship was on a heading[7] of 352° and the pilot ordered slow ahead on the engine and hard-to-starboard on the helm as he commenced the turn round Mangrove Point. At 2212, he ordered half ahead on the engine and at 2213 he eased the helm to starboard 20°. The ship was now turning to starboard and moving ahead at a speed of about 3 knots.

Between 2214 and 2216, the pilot ordered midships on the helm, followed by port 20° and midships again, as he slowed the ship's rate of turn to starboard. It was now on a heading of 042°. The pilot then directed the tugs to be let go and requested that they continue to escort the ship.

At 2216½, the pilot ordered the helmsman to steady the ship on a heading of 041°. At 2217, he ordered full ahead on the engine and directed the aft tug to push up on the ship's stern to assist it in building up speed.

At 2218½, the pilot ordered starboard 20°. Then, at 2219, he ordered midships but when the helmsman moved the helm to the midships position, the rudder did not respond. The ship continued to turn to starboard so the pilot ordered port 20°. He then ordered port 20° again, before ordering hard-to-port.

By 2219½, when the rudder began to respond to the port helm, the ship's speed had increased to 5 knots. At 2220, the pilot ordered port 20°, followed by midships, starboard 10° and then starboard 20° as he continued to steady the ship's heading.

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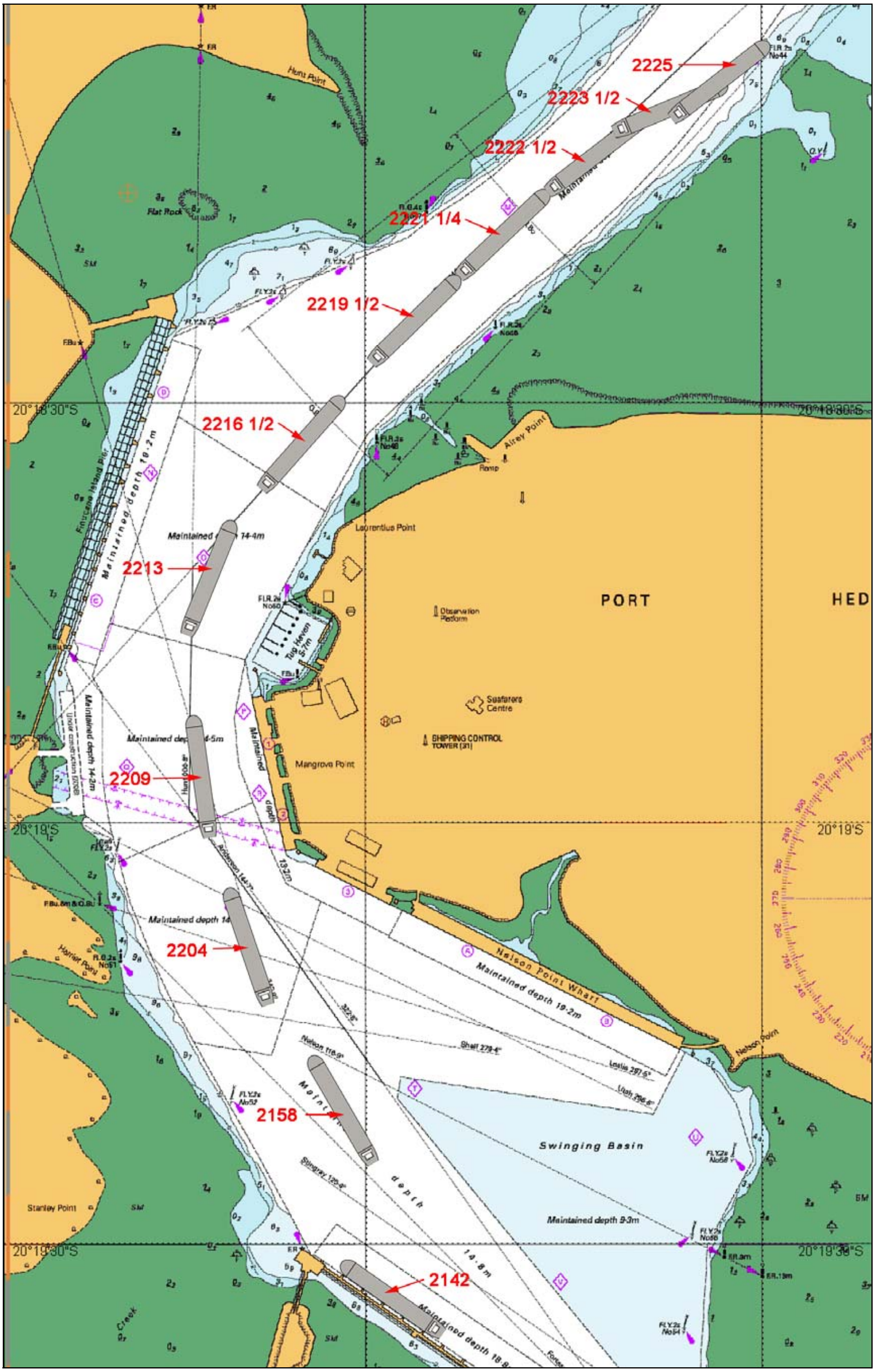
7 All ship's headings in this report are in degrees by gyro compass with negligible error.

Figure 7: Section of navigational chart Aus 54 showing *Iron King*'s track displayed by a series of scale images of the ship



At 2221¼, the pilot ordered midships. However, when the helmsman moved the helm to the midships position, the rudder again failed to respond. The rudder then began slowly moving to starboard. The helmsman moved the helm to port, hoping that doing so would make the rudder respond and the master switched the steering stand selector switch between the two follow-up steering systems, in an attempt to get the steering to respond.

The pilot noticed that the rudder had not responded and, at 2221½, he said, in a quiet voice, 'stuck again'. The master then suggested to the pilot that he should stop the engine. In response, the pilot ordered dead slow ahead before directing the tugs to make fast. The ship was now on a heading of 045° and turning to starboard.

At 2222½, the rudder began to respond to the port helm and the pilot asked 'is the rudder working', to which, the master replied 'yes'. The pilot then ordered hard-to-port and full ahead on the engine. He also directed the aft tug to assist the ship to turn by pushing up on its port quarter. The ship was now on a heading of 058° and its speed was about 7 knots.

At 2223½, when the pilot realised that the ship was probably going to ground, the ship's heading was 067° and its speed was still about 7 knots. He ordered the engine stopped, before ordering midships and then full astern on the engine. Soon afterwards, he stated 'think we've got the beacon'.

By 2224½, the main engine had started in the astern direction and built up to half astern (50 rpm) but the ship was still moving ahead at a speed of about 6 knots.

By 2225, the ship had run over Beacon 44 (Figure 7) and grounded in position 20°18.15'S 118°34.9'E on a heading of 052°.

At 2225½, the pilot reported to harbour control that he had lost steering control near Beacon 44 and that he was currently trying to recover. The harbour control officer called the harbour master, who closed the port to other shipping, and then initiated the port's emergency plan.

The pilot asked the master to check the ship's watertight integrity, so the crew sounded the ship's ballast, fuel oil and lube oil tanks. The soundings indicated that the ship's hull had not been breached.

At 2229½, the pilot ordered emergency full astern on the engine and by 2231, tugs had been made fast to the ship's port and starboard shoulders. By 2236, tugs had also been made fast to the ship's port and starboard quarters.

By 2239, two more tugs had arrived on the scene and been made fast to the ship. A second pilot then boarded the ship via helicopter.

At 2243, the second pilot arrived on the bridge and the two pilots discussed the situation. They then tried refloating the ship with all six tugs pulling astern.

By 2254, eight tugs were in attendance and the pilots tried using various combinations of tugs and engine thrust to free the ship. While the ship's stern was moving as a result of the propeller's transverse thrust, the forward part of the ship remained firmly aground.

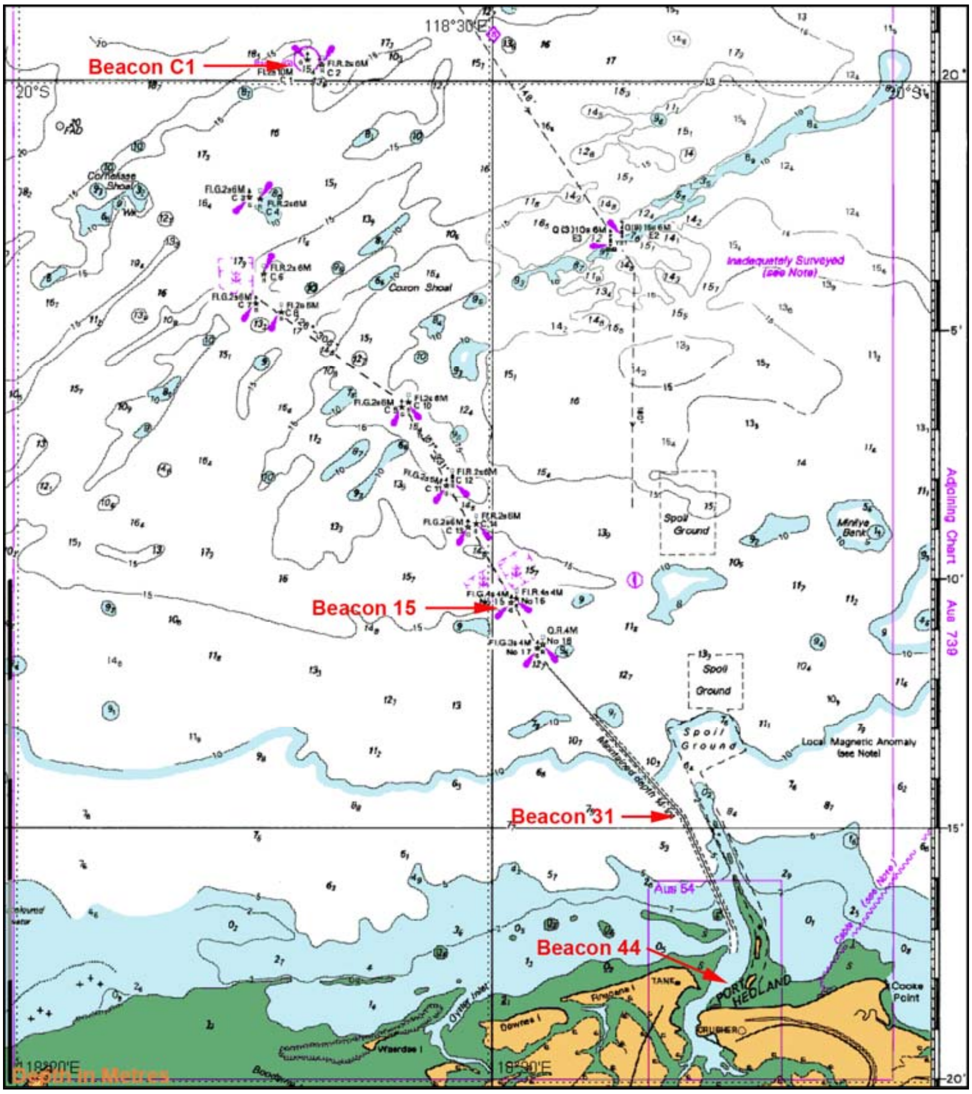
The tide was now ebbing and by 2319, *Iron King*'s forward draught had reduced by 1.5 m, to 14 m. For the next hour, the pilots tried various combinations of tugs and propeller thrust but the ship did not move.

At 0021 on 1 August, when the pilots stopped the engine and ceased their attempts to refloat the ship, its draughts were 14.6 m port forward, 14.2 m starboard forward, 17 m port midships, 16 m starboard midships, 18.4 m port aft and 18.1 m starboard aft. The ship's position had not changed significantly and it had settled on a heading of 069°.

At 0144, the original pilot left the ship and the pilot who remained on board continued to monitor the situation.

The port authority's oil spill response team formulated a plan to contain the spread of any pollution that may result from *Iron King*'s grounding. The tug crews were providing regular updates of the ship's draughts and they were monitoring the water for signs of pollution. The port's oil spill equipment was readied for deployment and assistance, in the form of oil spill personnel and equipment, was provided by the Dampier Port Authority. The Western Australia Department for Planning and Infrastructure was also notified to ensure that the state wide oil spill response resources would be available if needed.

Figure 8: Section of navigational chart Aus 740



The port authority and the pilots began planning how they were going to refloat the ship. A number of options were canvassed and it was decided that since the next high tide, at 1047 in the morning, was predicted to be 6.2 m, almost a metre higher than the tide on which the ship grounded, they would attempt to refloat the ship on that tide, with the assistance of the port's tugs. If they were successful, they planned to take the ship out of the harbour, under its own power and with the assistance of the tugs, and then anchor it in the anchorage beyond Beacon C1 (Figure 8). As a contingency, they considered that if the ship had insufficient under keel clearance to complete the transit of the channel, they could take it as far as the escape area nearby Beacon 15.

The ship's general arrangement and tank capacity plans were ferried to the port authority offices. These plans were used when considering the possibilities for re-ballasting the ship and to confirm the location of the fuel and lube oils stored onboard. The heavy fuel oil bunkers were not of a major concern because they were stored in the ship's number six wing tanks. However, 12,000 L of diesel oil was stored in side tanks and 48,000 L of lubricating oil was stored in a centre tank.

In an attempt to trim the ship slightly by the stern, *Iron King*'s master was asked to determine whether the ship's number five wing tanks and the aft peak tank could be filled with ballast water without further stressing the ship. The master confirmed that this could be done and shortly afterwards the chief mate began ballasting the tanks.

By 0450, low tide of 2.1 m had been reached and the tide began to flood.

At about 0530, preparations were made to relieve the pilot who was still on board *Iron King*. Prior to boarding the ship, the next relieving pilot met with the harbour master and the other pilots to discuss the plans for re-floating the ship. He then prepared tide tables, passage plans and other documents he needed to take on board the ship. At about 0610, he boarded the ship and at about 0630, when the two pilots had completed their handover, the relieved pilot departed the ship.

At 0743, the pilot requested dynamic under keel clearance calculations for the ship with the revised draughts, due to the re-ballasting, and a speed of 6 knots. The calculations showed that the ship's transit needed to commence no later than 0930 for it to reach the end of the channel with sufficient under keel clearance.

At about 0800, the operation of the ship's equipment, including the main engine and the steering gear, was checked. All the equipment, including the steering gear, functioned satisfactorily.

The ship was listing about 2° to port but it began to right itself on the flooding tide. A lines boat crew was reading the ship's draught marks and this information was regularly forwarded to the pilot and harbour control.

At 0830, two more pilots boarded the ship. The three pilots discussed their plan and agreed to start trying to free the ship at 0910. At that time, the height of tide would be about 5.4 m, the same as when the ship grounded. The lead pilot would have the conduct of the ship and control the main engine and the tugs, one pilot would be monitoring his actions and the third pilot would be in charge of communications with harbour control.

The tugs were recalled and made fast to the ship. At 0910, the ship's main engine was run at dead slow astern and the tugs were instructed to start building up thrust. The main engine speed was progressively run up to full astern and while the ship 'wiggled a little', it did not move. At 0930, the pilot stopped the main engine and eased off on the tugs.

At 0951, the main engine was again started at dead slow astern and the pilot again ordered the tugs to build up to full thrust. The main engine speed was slowly increased and by 0954, it was running at full astern. The ship then started to move astern. At 0955, the pilot stopped the main engine. He then used the tugs to manoeuvre the ship into the channel (Figure 9).

At 0957, the pilot came ahead on the main engine and the ship began its transit of the channel. There was no sign of any pollution and the pilot asked the master to sound all the tanks again; and to start de-ballasting number five wing tanks and the aft peak. The tank soundings again indicated that the ship's hull had not been breached.

Figure 9: Tugs assisting *Iron King* from its grounded position

At 1002, harbour control told the pilot to proceed to the Beacon 15 escape area and to bring the ship's speed up to 6 knots as soon as possible. Shortly afterwards, the pilot ordered full ahead on the engine.

At about 1007, and then again at about 1010, the rudder stuck at starboard 20° and then drifted to starboard as port helm was applied. On both occasions, the pilot stopped the main engine and used the tugs to correct the ship's heading. He then decided to continue the transit without the use of starboard rudder. He used the rudder to turn the ship to port and the tugs to turn the ship to starboard.

The pilot advised harbour control that the ship's crew were de-ballasting number five wing tanks and the aft peak and that the tanks would be empty by the time the ship reached Beacon 12, giving the ship a maximum draught of 17.35 m at that time. He then requested revised dynamic under keel clearance calculations based on this information.

The calculations showed that the ship would have sufficient under keel clearance to complete the transit of the channel, so the pilot was informed that he had permission to proceed to the outer anchorage. The transit continued without incident and at 1406, the pilot advised harbour control that the ship had exited the channel at Beacon C1 and was at anchor in position 19°54.6'S 118°25.8'E.

Earlier in the day, *Iron King* had been detained by the Australian Maritime Safety Authority (AMSA) pending verification of the ship's seaworthiness. As a result, an underwater survey of the ship's hull was conducted by divers under the supervision of a classification society (BV) surveyor while the ship was at anchor.

The divers' inspection confirmed that the grounding damage was confined to the bow area and consisted of major indentation of the shell plating to a maximum depth of about 300 mm forward of the collision bulkhead. Aft of the collision bulkhead, there was an indentation of about 100 mm in depth, over a 10 m length. The divers found no damage to either the propeller or the rudder.

While the underwater survey was being carried out, and over the following days, technicians worked on finding and rectifying the fault in the ship's steering gear.

At 1430 on 12 August, AMSA lifted its detention order after BV had verified *Iron King*'s seaworthiness. At 1730, the ship departed the anchorage bound for Qingdao, China, where its cargo was discharged. It then sailed to Zhoushan, where permanent repairs were completed.

2 ANALYSIS

2.1 Evidence

On 3 August 2008, investigators from the Australian Transport Safety Bureau (ATSB) attended *Iron King* while the ship was at anchor off Port Hedland. The master and directly involved crew members were interviewed and they provided accounts of the incident. Photographs of the ship and copies of relevant documents were obtained, including log books, charts, reports, manuals, procedures and statutory certificates. The investigators also removed a hard drive from the ship's voyage data recorder (VDR) which contained information backed-up for the time of the incident.

On 4 August, the investigators interviewed the harbour master, the pilot on board *Iron King* at the time of the grounding and the pilots involved in the refloating of the ship. Copies of relevant information were also obtained, including procedures, reports, Automatic Identification System (AIS) data, photographs and port video and audio recordings.

During the course of the investigation further information was supplied by the Port Hedland Port Authority, Aker Solutions, Bureau Veritas (BV), Skipper Technology and Teekay Shipping.

2.2 The grounding

At 2142 on 31 July 2008, 7 minutes before *Iron King*'s tidal window closed, the ship departed its berth at Anderson Pont. The outbound transit of the Port Hedland channel then progressed normally until, on two occasions, the ship's rudder failed to respond to the pilot's port helm orders.

The master's attempts to regain steering control were ineffective but the steering did begin to respond, so the pilot ordered hard-to-port and full ahead on the main engine in attempt to keep the ship in the channel. However, it became apparent to the pilot that the ship was going to ground, so he ordered the engine stopped, the helm to midships and then full astern on the engine.

As soon as steering control was lost, the pilot had directed the tugs escorting the ship to make fast. However, they were unable to do so in time to assist the pilot in his attempts to keep *Iron King* in the channel and at 2225 the ship grounded in the vicinity of Beacon 44.

2.3 Steering gear malfunction

On two occasions, just prior to *Iron King*'s grounding in Port Hedland on 31 July, the ship's rudder had stuck in the starboard 20° position. The rudder also stuck in the same position on two subsequent occasions during the ship's transit out of the port after it had been re-floated on 1 August.

2.3.1 Technician inspections

Initial testing of the steering gear, carried out on 3 August by a manufacturer's technician, indicated that the hydraulic system was operating correctly. As a result, the technician concluded that the fault probably lay in the steering gear electronic control system.

An electronics technician was then contracted to trace the fault in the steering gear control system. He discovered that a poor contact in one of the control system relays could result in the rudder sticking in one position, as it had done just prior to the grounding. The control system relays were replaced and the ship was taken to sea so that the steering gear could be tested under full load conditions. However, when the rudder was put over to starboard, it would not return to port.

Iron King returned to the anchorage and a second manufacturer's technician was asked to attend the ship.

The technician tested the two hydraulic pump units and found that they were both providing the design pressure of 75 bar[8]. He then checked the rotary vane unit (actuator) pressure and discovered that the actuator pressure was 75 bar when the rudder was turning to starboard, but only 20 bar when it was turning to port. He determined that the aft actuator relief valve (one of two valves controlling oil pressure within the actuator) was draining oil from the actuator whenever the rudder was turning to port. As a result, the actuator pressure was being limited to 20 bar, a pressure that was insufficient to provide the torque required to turn the rudder to port when it was under load.

The aft actuator relief valve was removed and the technician found that it was sticking. He overhauled the valve, re-set it and then refitted it to the steering gear housing. On 12 August, the ship was again taken to sea for a steering gear trial. On this occasion the steering gear operated correctly.

2.3.2 Forces acting on a rudder

The forces acting on a rudder are dependent on its size and form, but they do not remain constant. The forces increase as the applied rudder angle increases. They also increase with the square of the velocity of water flow over the rudder's surface. For a centre line mounted rudder behind a single propeller, the following formula can be used to calculate the forces acting on the rudder[9]:

$$Q = 18 \times AV^2\Theta$$

Q = Load (N)
A = Area of rudder (m^2)
V = Velocity of water flow (m/sec)
Θ = Rudder angle (degrees)

Steering gears are designed so that they will provide sufficient torque to overcome the forces acting on a ship's rudder under all operational conditions. In the case of a rotary vane steering gear, like *Iron King*'s, the torque developed by the steering gear is proportional to the hydraulic pressure applied to the actuator chambers.

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8 1 bar equals 100 KPa or approximately one atmosphere.

9 *Ships and Naval Architecture*, R. Munro-Smith, Chameleon Press, 1981, pg 269.

While *Iron King*'s steering gear was only developing 20 bar of pressure when it was turning to port, the effect of this low pressure did not become evident until the ship's speed started to build up after the pilot ordered full ahead, at 2217, and the rudder was moved to the starboard 20° position, at 2218½. It was then, at 2219, when the pilot ordered midships that the forces acting on the rudder were greater than that that could be overcome by the steering gear that was operating at reduced pressure.

The third mate had tested the steering gear before the ship's departure from Port Hedland and he experienced no problems with its operation. Similarly, when the steering gear was tested after the grounding, it appeared to function normally. It is likely that on each of these occasions, the steering gear was operating at only 20 bar pressure when the rudder was moving to port. However, since the ship was not in motion, the load on the rudder was relatively low and the steering gear appeared to operate normally.

2.3.3 Previous steering gear repairs

On 13 February 2008, *Iron King*'s master notified the ship's operator that he had experienced a steering gear malfunction during the ship's port arrival. The operator then acted promptly to address the issue. They arranged for a service technician to attend the ship on 2 April, to carry out repairs, and by 12 May, the ship had entered dry dock for a complete steering gear overhaul.

The operation of the steering gear was tested at the completion of the dry dock and it operated satisfactorily. The ship then sailed from Zhoushan to Port Hedland without incident.

It is possible that the aft actuator relief valve fault existed before *Iron King* was dry docked for repairs and it was not rectified at that time, or that the fault arose as a result of debris left in the hydraulic system following the overhaul, which then lodged in the valve.

However, on 31 July, when the crew prepared *Iron King* for the departure from Port Hedland, they had no reason to suspect that there was a problem within the steering gear hydraulic system that may cause the ship's steering to malfunction during the transit out of the port.

2.4 Shipboard response to the steering malfunction

Since the leaking actuator relief valve could not be isolated from the actuator by any remote means, it would not have been possible for the ship's crew to do anything that would have restored full steering control during *Iron King*'s transit out of Port Hedland on 31 July 2008.

However, at the time, the master was not aware of what the problem was. Therefore, he should have followed the appropriate procedure instead of repeatedly switching the steering stand selector switch between the two follow-up control systems.

The master did not try the non follow-up (NFU) control system and he did not stop either of the hydraulic pumps. His actions indicate that he probably did not have a thorough understanding of the ship's steering control system and that he was not aware of the correct procedure to be followed in the circumstances.

With reference to steering gear testing, drills and shipboard familiarity with the equipment, Chapter V, Regulation 19-2 of the International Convention for the Safety of Life at Sea, 1974 (SOLAS) states:

(a) Within 12 h before departure, the ship's steering gear shall be checked and tested by the ship's crew. The test procedure shall include, where applicable, the operation of the following:

(i) the main steering gear;
(ii) the auxiliary steering gear;
(iii) the remote steering gear control systems;
(iv) the steering positions located on the navigation bridge;
(v) the emergency power supply;
(vi) the rudder angle indicators in relation to the actual position of the rudder;
(vii) the remote steering gear control system power failure alarms;
(viii) the steering gear power unit failure alarms; and
(ix) automatic isolating arrangements and other automatic equipment.

(b) The checks and tests shall include:

(i) the full movement of the rudder according to the required capabilities of the steering gear;
(ii) a visual inspection of the steering gear and its connecting linkage; and
(iii) the operation of the means of communication between the navigation bridge and steering gear compartment.

(c) (i) Simple operating instructions with a block diagram showing the change-over procedures for remote steering gear control systems and steering gear power units shall be permanently displayed on the navigation bridge and in the steering gear compartment.

(ii) All ships' officers concerned with the operation or maintenance of steering gear shall be familiar with the operation of the steering systems fitted on the ship and with the procedures for changing from one system to another.

(d) In addition to the routine checks and tests prescribed in paragraphs (a) and (b), emergency steering drills shall take place at least once every three months in order to practise emergency steering procedures. These drills shall include direct control from within the steering gear compartment, the communications procedure with the navigation bridge and, where applicable, the operation of alternative power supplies.

Iron King's safety management system (SMS) procedures stated that the operation of the ship's steering should be checked prior to each port departure and that emergency steering drills should be carried out every 3 months as required by SOLAS.

Steering system operating instructions and a block diagram showing the change-over procedures for remote control were also displayed on the ship's bridge. This procedure was a simple three-step process, similar to that found on board most ships. Its aim was to systematically eliminate the areas where a fault was likely to exist, the follow-up electrical control system and the two hydraulic systems. The procedure to be followed when two steering pumps were running (as was the case on 31 July) was:

2.2.1 SWITCH OVER TO NFU STEERING MODE.

2.2.2 STOP PUMP NO.1. CONTROL THE RUDDER MOVEMENT ON THE RUDDER INDICATOR. IF NONE GO TO 2.2.3.

2.2.3 START PUMP NO.1 AGAIN AND STOP PUMP NO.2. CONTROL THE RUDDER MOVEMENT ON THE RUDDER INDICATOR.

Had *Iron King*'s master been aware of the ship's emergency steering change-over procedures and adequately exercised their operation, it is likely that his automatic reaction would have been to follow them when the ship's rudder failed to respond to helm orders on 31 July.

While the ship's SMS procedures stated that emergency steering drills should be carried out, they did not detail how this task should be performed. As a result, it is possible that the master and the ship's officers were not appropriately drilled in the emergency steering control changeover procedure.

The ship's SMS procedures also stated that steering gear tests should be conducted prior to the ship departing port, but did not detail how this task should be carried out. As a result, the third mate, the deck officer responsible for testing the operation of the ship's steering gear prior to the ship's departure from port, had never tested non follow-up control during the pre-departure steering gear tests. Furthermore, he demonstrated at interview that he did not know what non follow-up steering control was, or how it worked.

It is likely that the master, like the third mate, did not have a thorough understanding of the ship's steering control systems and thus, was not aware of the appropriate procedure to follow when faced with a situation where the rudder did not respond to helm orders.

The reaction to an emergency situation like the one on the evening of 31 July should, as far as practicable, be a considered, tested and trained response. This is one of the main reasons why it is important that appropriate steering gear tests and emergency steering gear drills are regularly conducted. Hence, it is the responsibility of the ship's operator, through its SMS, to ensure that steering gear tests and emergency steering gear drills are properly carried out. The SMS should ensure that the master and every officer who may be in charge of a bridge watch, has a complete understanding of the steering system and is aware of, and has practiced, emergency procedures like steering control change-over.

2.5 The pilot's actions

Traditionally, a pilot is engaged by the ship owner as a specialist advisor and ship handler. The pilot advises the master on the conduct of the ship in waters in which the pilot has local knowledge of tides, conditions, channels and port operations. The master maintains overall command and responsibility for the ship, while the pilot has navigational control of the ship.

However, pilots, pilot associations, port authorities and government authorities increasingly see the role of pilotage as a port function; its principal purposes being safety and the reduction, to the greatest extent possible, of the structural, environmental and financial risks associated with ships navigating within the port and its limits. These expectations should not only counsel how a pilot thinks while navigating a ship, but how they are trained and accredited.

At 2219 on 31 July 2008, when *Iron King*'s rudder stuck for the first time, the pilot's only actions were to order the application of more helm. At this point in time, the ship was making headway at about 5 knots on a heading of 043° and Beacon 44 was 5° to starboard and 4½ cables[10] ahead. Shortly afterwards, the rudder began to respond to the helm.

It was not until 2222½, after the rudder had stuck for a second time that the pilot directed the tugs to make fast to the ship. The ship was now making headway at about 7 knots on a heading of 058° and it had closed to within 1½ cables of Beacon 44.

Had the pilot acted at 2219, and used the tugs to assist the ship, it is possible that he may have been able to maintain its position in the channel. At the very least, he may have been able to use a combination of tugs and astern thrust from the ship's main engine to slow the ship, thus reducing the impact, and the resultant damage to the ship, when it grounded. Reducing damage to the ship would have lessened the likelihood of pollution. It is also possible that this action may have resulted in the ship being refloated shortly after the grounding, alleviating the need to close the port to other ships.

In submission, Port Hedland Pilots stated:

> It is the opinion of Port Hedland Pilots that whoever had been the pilot, grounding could not have been avoided in this instance. Subsequent simulation of the incident showed that, even with a tug fast aft, grounding would have occurred. A lower velocity and finer angle of impact was achieved if the main engine was stopped and put astern, immediately the rudder jammed over. The reactive decision to do this would have been a very difficult one for the pilot, without full knowledge of the extent and history of *Iron King*'s steering failures; as was the case.

While it is possible, with the benefit of hindsight, to discuss what the pilot should, or should not have done, he had to evaluate the situation, consider the options available to him, formulate a plan and implement it, all within a matter of seconds. If the modern risk mitigating strategies now considered necessary by most port authorities are to be as effective as possible, pilots should not be left in a position

10 One cable equals one tenth of a nautical mile or 185.2 m.

where they are expected to make this type of on-the-spot decision. The risks associated with pilotage within the port need to be identified and analysed and pilots need to be appropriately trained and equipped with the knowledge and experience to mitigate these risks.

The pilot assigned to *Iron King* for the ship's departure from Port Hedland on 31 July 2008 was licensed to pilot ships of up to 165,000 deadweight tonnes. He was 18 months through a 2-year training program that, when finished, would provide him with a licence to pilot any size of ship operating in the port. Prior to the incident, he had completed a total of 560 transits of the port, but he had never experienced a steering failure. These transits were completed either as a training pilot under the guidance of a senior pilot, as a supervised pilot with the assistance of a mentor (senior pilot) or as a solo pilot.

As part of his initial training, he had completed a manned model ship handling course at the Australian Ship Handling Centre (Port Ash). He had also been involved with the port authority's simulation exercises for various berths in the port. The simulations were carried out at either the Broome or Fremantle ship simulators; and while they did simulate emergencies, such as the loss of propulsion, the exercises were focused on future use of berths, not pilot training.

During the pilot's training and mentoring, the senior pilots had often put questions to him while he was piloting, such as; what would you do if you lost the engine now? He and the mentoring pilot would then discuss the scenario and the possible options at hand.

While emergency response scenarios were an integral part of the pilot's training, he had not completed dedicated simulator training for such events at the time of the incident. This training was normally undertaken towards the end of the pilot training process.

The pilot had received what has traditionally been considered appropriate and effective pilot training. While this method has, over time, proven to be effective, it does not necessarily equip the pilot with all the knowledge and skills that may be needed in the event of an emergency.

In other safety critical industries like aviation, there has long been acceptance that there is a need to analyse operational risks, formulate appropriate responses to mitigate the risks and to train for these eventualities. This is often achieved through the use of a simulator. In a simulator, participants can experience various emergency situations first hand. This training includes tutorage in appropriate responses to defined operational situations and provides the participant with a set of learnt rules on which to fall back on in 'real life' situations.

It may be argued that the handling characteristics of ships vary (due in part to differences in hull form, draughts, rudder size, direction of propeller rotation, etc) and that a single answer to all situations is not practical. However, there is little doubt that providing a pilot with experience in implementing a suite of 'risk analysed' responses to reasonably foreseeable emergency scenarios in a simulated environment, will better equip the pilot for dealing with similar emergency situations in a real life context.

With reference to simulator training, the International Maritime Organization (IMO) resolution A.960 '*Recommendations on training and certification and operational procedures for maritime pilots other than deep sea pilots*' states that initial pilotage training and refresher training for licensed pilots should include simulation exercises; exercises, which may include radar training and emergency ship handling procedures.

In human performance terms, simulator training enables an individual to formulate and practice pre-packaged responses or solutions to both normal and unusual situations without the risk of adverse consequences. Individual performance improves with practice in recognising and then implementing a pre-thought-out solution (or procedure). The cognitive response to an aberration in a normally skill-based task becomes a rule-based response when a practiced solution is implemented when the task does not go to plan, rather than a potentially error prone untried knowledge-based solution. With reference to the various levels of human cognitive performance, James Reason[11] states:

- At the skill-based level, we carry out routine, highly-practised tasks in a largely automatic fashion with occasional conscious checks on progress. This is what people are very good at most of the time.
- We switch to the rule-based level when we notice a need to modify our largely pre-programmed behaviour because we have to take account of some change in the situation. This problem is likely to be one that we have encountered before, or have been trained to deal with, or which is covered by the procedures...
- The knowledge-based level is something we come to very reluctantly. Only when we have repeatedly failed to find some pre-existing solution do we resort to the slow and effortful business of thinking things through on the spot. Given time and a forgiving environment to indulge in trial-and-error learning, we often come up with good solutions. But people are not usually at their best in an emergency, though there are some notable exceptions. Quite often, our understanding of the problem is patchy, inaccurate or both...

In a marine pilotage context, the analysis and management of operational risks should be carried out using the combined knowledge and experience of the port authority, the pilotage company and, where necessary, other relevant expertise. The best responses based on rigorous analysis of the risks should then form the basis of an evolving training and accreditation program. This program should not only provide pilots with regular 'hands on' experience at dealing with emergency situations in a simulated environment, but should also equip them with a suite of practiced 'best responses' to identified operational risks.

Prior to 31 July 2008, the Port Hedland Pilots had not appropriately analysed the operational risks in the port, formulated appropriate responses to mitigate the risks, and trained their pilots for these eventualities. Had *Iron King*'s pilot received such training, he may have experienced a steering gear failure, albeit in a simulated environment, and had practice in implementing a risk analysed response to this reasonably foreseeable emergency scenario.

11 *Managing the Risks of Organizational Accidents*, James Reason, Ashgate, 1997, p 68-70.

2.6 Use of tugs

At 2142 on 31 July 2008, four harbour tugs assisted *Iron King* in un-berthing at Anderson Point. The ship then made its way through the harbour with all four tugs made fast. At about 2216, as the ship approached Hunt Point, the pilot ordered the tugs to let go. By 2217, they had all been cast off from the ship. The pilot then ordered the tug that had been positioned at the centre lead aft to push up on the ship's transom.

Shortly afterwards, at 2219, *Iron King*'s rudder stuck at starboard 20°. The rudder did eventually respond to the helm order but it stuck again in the same position at 2221¼. Once again the rudder did eventually respond to the pilot's port helm orders, but it was too late to prevent the ship from grounding.

The pilot ordered the tugs to make fast to the ship again, but they were unable to do so before it grounded. The tugs did provide some assistance to the ship, the aft tug pushed on the port quarter to assist the ship's turn to port, but without lines made fast to the ship, they were unable to assist in slowing it.

The action of letting go the tugs as a departing ship approached Hunt Point was consistent with routine pilotage operations in the port. Usually, the tugs would then escort the ship until it reached Beacons 30/31 (Figure 8), as was the plan for *Iron King*'s departure. The forward two tugs would stand off the ship and hold station on each side, while the aft tugs would generally trail behind the ship. Once at Beacons 30/31, the tugs would wait for the next incoming ship and escort it into the port.

With reference to the use of unsecured tugs to escort a ship, Captain Henk Hensen, the author of 'Tug Use in Port, - A Practical Guide' states:

> Securing tugs can take several minutes. This has consequences for tug response time, the time between the moment failure happens and the moment tugs are effective. Several very costly minutes may be lost.

The pilots generally considered that by the time a departing ship had reached Hunt Point, it had passed the highest risk area in the port. Also, once past this point, the ship, and the tugs assisting it, are exposed to the swell and wind. The collective experience of the pilots has shown that if the tugs remain alongside the ship, they will pound against its side, damaging both the ship and the tug, in particular, the tug's fendering. Furthermore, as the ship starts to build up speed, the tugs become less effective in their usual positions and it becomes increasingly difficult for the tow lines to be let go.

However in this instance, it would have been possible for the aft tug, with its tow line secured through *Iron King*'s centre lead aft, to remain in position without damaging itself or the ship. A tug in this position could have provided an effective and quick braking and/or steering force for the ship. A stern tug can provide an effective steering force for a ship underway because as the ship's headway increases, its pivot point moves forward, and the tug acts on a lever of increasing length. There is little doubt that the availability of such a quick and effective aid would have been of assistance to the pilot as he attempted to prevent *Iron King* from grounding after the ship's steering gear malfunctioned.

2.7 Shore-side emergency response

The port authority’s response to the incident was prompt, effective and consistent with its emergency plan. Within minutes of *Iron King* grounding, the pilot had informed harbour control of the incident and the harbour master, the duty pilot and the towage company had all been notified of the grounding. All parties then worked together in a coordinated response to the situation.

The port’s oil spill equipment was readied for deployment and assistance, in the form of oil spill personnel and equipment, was requested from the Dampier Port Authority. This assistance arrived on site at about 1000 on 1 August. The Western Australia Department for Planning and Infrastructure was also notified to ensure that the state wide oil spill response resources would be available if needed.

Throughout the night of 31 July, the harbour master, port authority staff and the pilots worked together to formulate a plan for the re-floating of the ship. A plan that was ultimately successful.

The response by those involved in the coordination of the aftermath of *Iron King*’s grounding was timely and well managed. Their response ensured that the risks, particularly the potential pollution of the sea by oil, were appropriately addressed.

In submission, the Port Hedland Port Authority stated that:

> As a part of our wash up and in preparation for a major oil spill exercise in September 2008 we reviewed our capability to manage the potential spill particularly if the HFO had been stored in the side tanks rather than the diesel. Our analysis revealed that if a moderate quantity of HFO had escaped despite our preparations the equipment to hand would not have proved suitable to protect the Port from a potentially catastrophic environmental outcome. To mitigate this risk the Port has put out a tender for first strike response equipment. The Port is also developing a first strike response plan that will enable us to protect the Port environment more effectively should such an incident ever occur again.

3 FINDINGS

3.1 Context

At 2142 on 31 July 2008, the fully laden cape-sized bulk carrier *Iron King* departed from its berth in Port Hedland with a harbour pilot on board.

The ship made its way through the port and, by 2217, the last of the four assisting tugs had been let go. Shortly afterwards, at 2219 and again at 2221¼, the ship's rudder failed to respond to the pilot's port helm commands.

The master immediately started switching the steering control stand selector switch between the two main control systems. When he informed the pilot that steering control had been restored, the pilot ordered full ahead and hard-to-port in an attempt to avoid grounding. The pilot also directed the tugs to make fast to the ship.

However, the tugs were unable to make fast, and by 2225 the ship had collided with Beacon 44 and grounded.

From the evidence available, the following findings are made with respect to the grounding of *Iron King* at Port Hedland on 31 July 2008 and should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing safety factors

- On two occasions during *Iron King*'s outbound transit of the Port Hedland channel on 31 July 2008, the ship's rudder failed to respond to the pilot's port helm orders because, whenever the rudder moved to port, the steering system hydraulic pressure was limited by a leaking actuator relief valve.
- *Iron King*'s pilot followed the normal pilotage procedure for the port when he let go the last of the four assisting tugs just before the ship reached Hunt Point.
- Although the assistance of tugs may be required by the pilots of outbound ships after they had passed Hunt Point, it was normal practice for the tugs to be let go before ships reached Hunt Point. *[Safety issue]*
- When *Iron King*'s rudder failed to respond to helm orders for a second time, the pilot directed the escorting tugs to make fast to the ship, but they were unable to do so before it grounded.
- At 2225 on 31 July, *Iron King* grounded in the vicinity of Beacon 44 despite the actions of the harbour pilot.
- The pilot had received what has traditionally been considered to be appropriate pilot training. However, as part of its risk management strategy, the pilotage company had not developed a suite of 'risk analysed' best responses to reasonably foreseeable emergency scenarios and provided the pilot with experience in implementing these responses in a simulated environment. *[Safety issue]*

3.3 Other safety factors

- *Iron King*'s safety management system did not include procedures that adequately ensured that the ship's master and crew were aware of, and drilled in, the emergency steering system change over procedure to be followed in the event of steering control loss. *[Safety issue]*

3.4 Other key findings

- The response by those involved in the coordination of the aftermath of *Iron King*'s grounding was timely and well managed. Their response ensured that the risks, particularly the potential pollution of the sea by oil, were appropriately addressed.

4 SAFETY ACTIONS

The safety issues identified during this investigation are listed in the Findings and Safety Actions 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 Port Hedland Port Authority

4.1.1 Pilotage procedures

Safety issue

Although the assistance of tugs may be required by the pilots of outbound ships after they had passed Hunt Point, it was normal practice for the tugs to be let go before ships reached Hunt Point.

Action taken by Port Hedland Port Authority MO-2008-008-NSA-034

The Port Hedland Port Authority has advised the ATSB that since the *Iron King* incident, pilots departing the port have kept the tug aft fast beyond Hunt Point until around the bend and into the channel straights between Beacons 36 and 38. Port and starboard shoulder tugs are now kept fast for as long as conditions permit safe tug operations. At present the port has limited this to a recommendation to pilots rather than mandated due to the fact that there are many occasions where keeping the tugs fast presents a risk to the tugs and crews as great as, or greater than, the risk being mitigated.

In August 2008, the port authority commissioned a simulation of the *Iron King* incident on the Pivot Maritime/Broome TAFE simulator. With the participation of senior pilots and the utilisation of VTS data, we were able to accurately simulate the incident. This simulation was used over two one week sessions to firstly evaluate the use of tugs to mitigate the original outcome and to develop standard emergency response practices that would lead to a more acceptable outcome.

This simulation work was expanded to evaluate the learnings on larger ships in different scenarios and locations throughout the port. To date, six of the pilots have spent time on the simulator undertaking emergency response training, including the *Iron King* simulation. The remaining pilots will complete the training this calendar year.

This work has highlighted the fact that in emergency situations in the more extreme operating parameters, even when made fast, the benefit of the current 65 tonne tugs becomes marginal.

With larger ships and increased multiple movements, escort towage is considered a viable mitigating strategy against such incidents as *Iron King*'s grounding. The port authority has commissioned a full towage review utilising external consultants and a final report is expected to be completed in late 2009. It is anticipated that tugs more suited to open water operations and dedicated active escort tugs will be among the report's recommendations.

ATSB assessment of response

The Australian Transport Safety Bureau acknowledges the actions taken by the Port Hedland Port Authority to address this safety issue.

4.2 Port Hedland Pilots

4.2.1 Pilotage procedures

Safety issue

Although the assistance of tugs may be required by the pilots of outbound ships after they had passed Hunt Point, it was normal practice for the tugs to be let go before ships reached Hunt Point.

Action taken by Port Hedland Pilots MO-2008-008-NSA-035

The ATSB has been advised by Port Hedland Pilots that it is now standard practice to keep the stern tug fast until the vessel has made the Goldsworthy Leads in the vicinity of Beacons 36/37. Trials are also being undertaken whereby tugs that are fast on the shoulders transiting the harbour are retained fast towards Beacons 36/37, depending on weather conditions and tug/vessel interaction. Where conditions make it unsafe for these tugs to remain fast, they are kept in the immediate vicinity ready to make fast if necessary.

ATSB assessment of response

The Australian Transport Safety Bureau acknowledges the actions taken by the Port Hedland Pilots to address this safety issue.

4.2.2 Pilotage risk analysis and training

Safety issue

The pilot had received what has traditionally been considered to be appropriate pilot training. However, as part of its risk management strategy, the pilotage company had not developed a suite of 'risk analysed' best responses to reasonably foreseeable emergency scenarios and provided the pilot with experience in implementing these responses in a simulated environment.

Action taken by Port Hedland Pilots MO-2008-008-NSA-036

Port Hedland Pilots have advised the ATSB that they are now in the process of, and will continue, reviewing 'risk analysed' best responses to foreseeable emergency scenarios in conjunction with the Port Hedland Port Authority. The importance of emergency procedure simulations is also recognised and will now be undertaken by trainee pilots in three phases; prior to the granting of an initial tonnage licence; prior to the granting of a cape size tonnage licence; and prior to the granting of an unrestricted licence. Unrestricted pilots will also undergo refresher simulations every 2 years.

ATSB assessment of response

The Australian Transport Safety Bureau acknowledges the actions taken by the Port Hedland Pilots to address this safety issue.

4.3 Enterprises Shipping and Trading

4.3.1 Awarness of emergency procedures

Safety issue

Iron King's safety management system did not include procedures that adequately ensured that the ship's master and crew were aware of, and drilled in, the emergency steering system change over procedure to be followed in the event of steering control loss.

Action taken by Enterprises Shipping and Trading MO-2008-008-NSA-037

Enterprises Shipping and Trading has advised the ATSB that the company has revised its safety management system with regards to steering drills. It now states that 'the master must ensure that during steering drills relevant personnel are familiar with the manufacturer's instruction manual and their responsibilities.' Ship's masters have also been instructed to ensure that instruction tables, in line with the manufacturer's manual, are posted in the steering gear room and on the bridge.

The company has also implemented a system whereby suitably trained ship's masters visit the company's ships as 'training officers'. Their role is to carryout internal audits and to train the crews in accordance with specific company guidelines. The training officers will also be required to focus on emergency steering drills and to provide the company with a written report covering their activities.

ATSB assessment of response

The Australian Transport Safety Bureau acknowledges the actions taken by the company to address this safety issue.

4.4 Owners, operators and masters

4.4.1 Awarness of emergency procedures

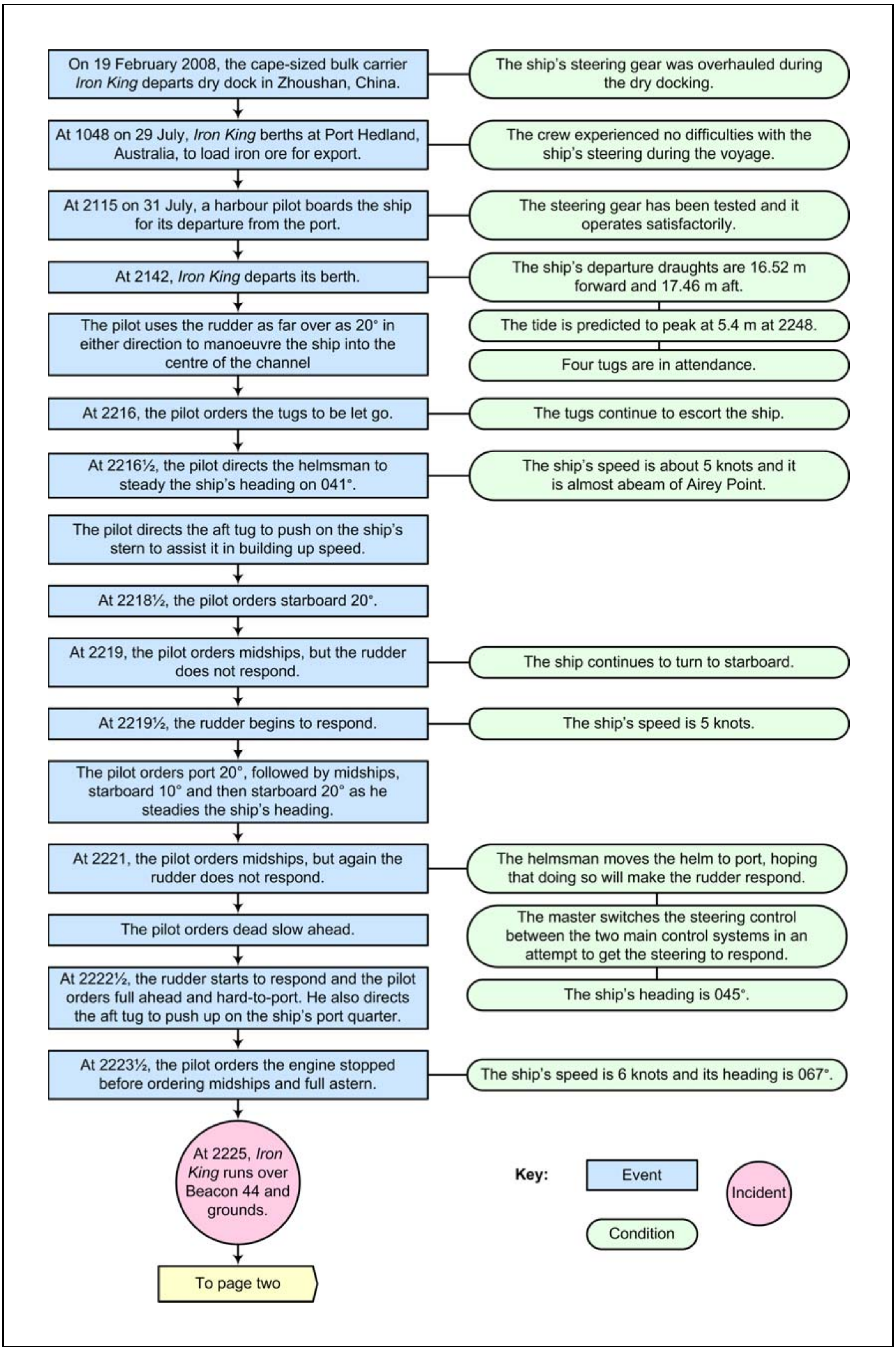
Safety issue

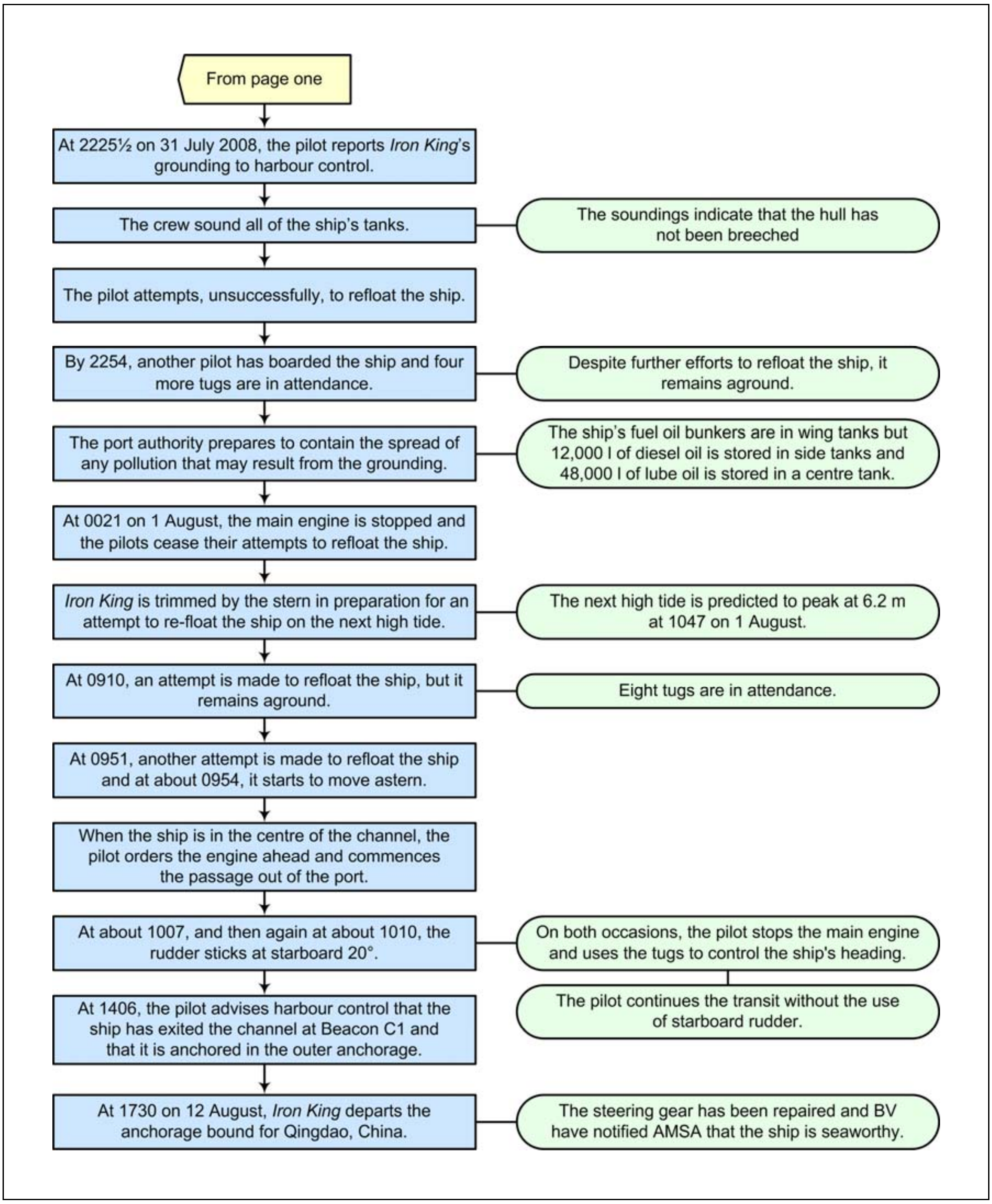
Iron King's safety management system did not include procedures that adequately ensured that the ship's master and crew were aware of, and drilled in, the emergency steering system change over procedure to be followed in the event of steering control loss.

ATSB safety advisory notice MO-2008-008-SAN-025

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

APPENDIX A: EVENTS AND CONDITIONS




From page one
At 2225½ on 31 July 2008, the pilot reports *Iron King*'s grounding to harbour control.
The crew sound all of the ship's tanks.
The soundings indicate that the hull has not been breeched
The pilot attempts, unsuccessfully, to refloat the ship.
By 2254, another pilot has boarded the ship and four more tugs are in attendance.
Despite further efforts to refloat the ship, it remains aground.
The port authority prepares to contain the spread of any pollution that may result from the grounding.
The ship's fuel oil bunkers are in wing tanks but 12,000 l of diesel oil is stored in side tanks and 48,000 l of lube oil is stored in a centre tank.
At 0021 on 1 August, the main engine is stopped and the pilots cease their attempts to refloat the ship.
Iron King is trimmed by the stern in preparation for an attempt to re-float the ship on the next high tide.
The next high tide is predicted to peak at 6.2 m at 1047 on 1 August.
At 0910, an attempt is made to refloat the ship, but it remains aground.
Eight tugs are in attendance.
At 0951, another attempt is made to refloat the ship and at about 0954, it starts to move astern.
When the ship is in the centre of the channel, the pilot orders the engine ahead and commences the passage out of the port.
At about 1007, and then again at about 1010, the rudder sticks at starboard 20°.
On both occasions, the pilot stops the main engine and uses the tugs to control the ship's heading.
The pilot continues the transit without the use of starboard rudder.
At 1406, the pilot advises harbour control that the ship has exited the channel at Beacon C1 and that it is anchored in the outer anchorage.
At 1730 on 12 August, *Iron King* departs the anchorage bound for Qingdao, China.
The steering gear has been repaired and BV have notified AMSA that the ship is seaworthy.

APPENDIX B: SHIP INFORMATION

Iron King

IMO Number	9108300
Call sign	MVLA7
Flag	Isle of Man
Port of Registry	Douglas
Classification society	Bureau Veritas (BV)
Ship Type	Bulk carrier
Builder	Hyundai Heavy Industries, Korea
Year built	1996
Owners	Frontier Maritime
Ship managers	Enterprises Shipping & Trading
Gross tonnage	81,155
Net tonnage	52,207
Deadweight (summer)	161,167 tonnes
Summer draught	17.519 m
Length overall	280.09 m
Length between perpendiculars	270.0 m
Moulded breadth	45.0 m
Moulded depth	23.8 m
Engine	Hyundai Sulzer 6RTA72U
Total power	15,220 kW
Crew	22

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of information

Iron King's master and crew

Port Hedland Pilots

Port Hedland Port Authority

Bureau Veritas (BV)

Aker Solutions

Skipper Technology

Teekay Shipping

References

Managing the Risks of Organizational Accidents, James Reason, Ashgate, 1997

Ships and Naval Architecture, R. Munro-Smith, Chameleon Press, 1981

SOLAS, Consolidated Edition 2001, the International Maritime Organization

Tug Use in Port – A Practical Guide, Captain Henk Hensen, the Nautical Institute

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 the Australian Maritime Safety Authority, the Isle of Man Ship Registry, the Port Hedland Port Authority, the Port Hedland Pilots, Aker Solutions, Enterprises Shipping and Trading, *Iron King*'s master and the pilot that was on board the ship at the time of the grounding.

Submissions were received from the Australian Maritime Safety Authority, the Isle of Man Ship Registry, the Port Hedland Port Authority, the Port Hedland Pilots, Aker Solutions, Enterprises Shipping and Trading and the pilot that was on board *Iron King* at the time of the grounding. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Independent investigation into the grounding of the Isle of Man registered bulk carrier *Iron King* at Port Hedland, Western Australia, on 31 July 2008.