OTSI Office of Transport Safety Investigations

RAIL SAFETY INVESTIGATION REPORT

DERAILMENT OF PACIFIC NATIONAL FREIGHT SERVICES CB76 AND 1WB3

LAPSTONE (CB76) 1 MARCH 2005

WAUCHOPE (1WB3) 7 MARCH 2005

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Office of Transport Safety Investigations
Level 17, 201 Elizabeth Street
Sydney NSW 2000

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Information about OTSI is available on its website or from its offices at:

Level 17, 201 Elizabeth Street
Sydney NSW 2000
Tel: (02) 9322 9200

PO Box A2616
Sydney South NSW 1235

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The Accidents

On 1 March 2005, at approximately 1:55pm, Pacific National (PN) coal service CB76 suffered a screwed journal[1] after a Packaged Unit Bearing (PUB) failed. As a result of this mechanical failure, a wagon derailed but remained upright and attached to CB76. The wagon travelled 4.28km in this state and in the process caused significant track damage between Glenbrook and Lapstone. It also caused ballast to be dislodged from a rail bridge over the Great Western Highway, shattering the windscreen of a car below.

At approximately 11:15am on 7 March 2005, PN's freight service 1WB3 also suffered a screwed journal when a PUB failed. One wagon derailed, approximately 11kms North of Wauchope, but remained upright and attached to 1WB3. As a consequence, approximately 3km of track and a rail bridge were damaged.

Findings

In relation to those matters prescribed by the Terms of Reference as the principal lines of inquiry, OTSI finds as follows:

a. Causation.

i. Both derailments were caused by the failure of Packaged Unit Bearings (PUB).

ii. There was nothing to suggest, in either instance, that the PUBs had been inadequately maintained or that there were problems elsewhere on the bogies. Nor were the wagons overloaded.

iii. Both PUBs were virtually destroyed and there was no conclusive evidence to indicate what initiated their failure.

iv. There were some limited indications to suggest that both bearings might have been penetrated by moisture or some other foreign material. PN suspects that in the case of CB76, this may have occurred while the wagon was being pressure-cleaned. However, this possibility and PN's premise could not be confirmed.

1 The term 'screwed journal' is widely understood throughout the rail industry to describe the failure of a PUB and the subsequent separation from the wheel set of the axle portion upon which the PUB was assembled. If a PUB fails, but it and the remainder of the axle remains intact, the situation is referred to within the rail industry as a 'hot box'.

b. Anticipation and Management of Risk:

i. PN had appropriate policies in place to minimise the likelihood of PUBs failing and continues to refine its policies and practices to further reduce the related risks.

ii. ARTC has installed a Bearing Acoustic Monitor (BAM)[2] at Metford to increase the prospect of deteriorating axle bearings being detected well before they fail. RailCorp has also installed a BAM at Kingswood which, in addition to axle bearings, will also monitor the bearings in the traction motor and gearbox equipment of its electric trains. However, the RailCorp equipment will not be fully functional until mid-2007.

c. Effectiveness of the Emergency Response:

i. The emergency response to both incidents was timely and effective.

d. Other Matters that would enhance the Safety of Rail Operations:

i. ARTC and RailCorp have plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW. The implementation of these plans will contribute to enhancing the safety of rail operations in NSW.

ii. ARTC's plans to enhance the detecting and monitoring systems on its network in NSW are dependent on the outcome of ongoing discussions with rolling stock operators who use its network about how the related project will be funded.

iii. RailCorp's plans to enhance the detecting and monitoring systems on its network in NSW are dependant on the progressive identification of appropriate technologies and the cooperation and collaboration of rolling stock operators who use its network.

Recommendations

In order to enhance the rail safety environment in NSW and minimise the potential for collateral damage from this kind of derailment, it is recommended that:

2 BAMs record the acoustic signature of bearings as they pass the equipment. The data can be compared with recordings taken of the same bearing at another BAM, or at the same BAM at a different point in time, to determine if there has been any significant change in the condition of the bearing.

a. ARTC and RailCorp proceed with their plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW as expeditiously as possible;

b. ARTC and RailCorp provide ITSRR with a copy of their latest plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW, and

c. ITSRR monitors the progress of the implementation of ARTC's and RailCorp's plans.

PART 1 INTRODUCTION

Notification and Response

1.1 At 2:10pm on 1 March 2005, both RailCorp and PN notified the Office of Transport Safety Investigations' (OTSI) Duty Officer that PN's coal service CB76 had derailed at Lapstone in NSW at approximately 1:55pm after having suffered a screwed journal. The Chief Investigator directed PN to formally investigate this matter.

1.2 On 7 March 2005 at 11:45am, the Australian Rail Track Corporation (ARTC) and PN notified OTSI's Duty Officer that PN freight service 1WB3 had derailed near Wauchope in NSW at approximately 11:15am and that it too had suffered a screwed journal. This latter incident occurred on the Defined Interstate Rail Network (DIRN) and OTSI therefore notified the Australian Transport Safety Bureau[3] (ATSB) of the incident, in accordance with established protocols. However ATSB elected not to investigate this incident.

Initiation of Investigation

1.3 Concerned by the occurrence of two derailments involving the same operator within seven days, and seemingly initiated by screwed journals, the Chief Investigator determined that both matters warranted independent investigation in accordance with s67 of the *NSW Rail Safety Act 2002.*

1.4 On 7 and 9 March 2005, the Chief Investigator notified all Directly Involved Parties (DIP) that OTSI was investigating the derailments at Lapstone and Wauchope. Each of the DIPs was requested to nominate an officer to act as the point of contact for all inquiries made by the appointed OTSI Investigator in Charge. The Terms of Reference for the Investigations were provided to the DIPs with this notification. Subsequently, the Chief Investigator determined that these two incidents would be the subject of a single investigation.

[3] The ATSB is a Federal Government Authority with powers under the Federal *Transport Safety Investigation Act 2003* to investigate rail incidents on the Defined Interstate Rail Network.

Interim Factual Statement

1.5 Interim Factual Statements notifying OTSI's investigation and describing the incidents in terms of what had happened were published on the OTSI website on 14 March 2005.

Terms of Reference

1.6 The Chief Investigator established the following Terms of Reference to determine why these two accidents had occurred and what to do to prevent the recurrence of similar incidents:

a. identify the factors, both primary and contributory, which caused the accidents;

b. identify whether the accidents might have been anticipated and assess the effectiveness of the risk management strategies of the respective organisations involved;

c. assess the effectiveness of emergency actions in response to the accidents, and

d. advise on any matters arising from the investigation that would enhance the safety of rail operations.

Methodology

1.7 OTSI utilises the ICAM (Incident Cause Analysis Method) approach in the conduct of its investigations and applies the Reason Model of Active Failures and Latent Conditions to its analysis of causative and contributory factors.

1.8 The underlying feature of the methodology is the Just Culture principle with its focus on safety outcomes rather than the attribution of blame or liability.

Consultation

1.9 On 15 December 2006, a copy of the investigation Draft Report was forwarded to PN, ARTC, RailCorp and ITSRR. The purpose was to provide the DIPs with the opportunity to contribute to the compilation of this Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and providing any commentary that would enhance the structure, substance, integrity and resilience of the Investigation Report. DIPs were requested to submit their comments by 15 January 2007. Submissions were received from PN, ARTC, RailCorp and ITSRR.

1.10 The Chief Investigator considered the representations made by DIPs and where appropriate, reflected their advice in this Final Report. On 18 January 2007, the Chief Investigator informed DIPs which matters from their submissions had been incorporated in this Final Report and where any proposal was not included, the reasons for not doing so.

Investigation Report

1.11 This report describes the derailments which occurred at Lapstone and Wauchope on 1 and 7 March 2005 respectively and explains why they occurred.

PART 2 FACTUAL INFORMATION

Incident Locations

2.1 Lapstone is located approximately 65kms due West of Sydney in the lower Blue Mountains, while Wauchope is located on the Mid-North coast, approximately 455kms from Sydney, as indicated in *Figure 1*.

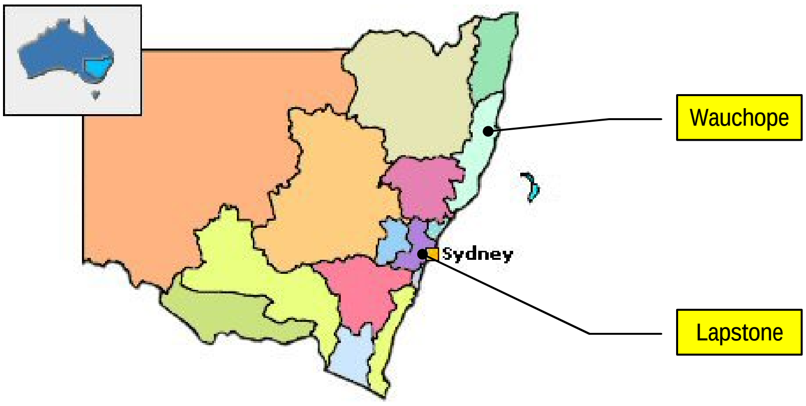

Figure 1 Incident Locations

Derailment of CB76 (Lapstone)

2.2 At approximately 1:55pm on 1 March 2005, PN coal service CB76, which was enroute from Charbon Colliery[4] to Port Kembla, passed through Lapstone Station. As it did so, station staff observed dust and dirt emanating from beneath the wagons. Appreciating that there was some form of problem with CB76, one of the staff immediately contacted the signaller at Penrith, who in turn, placed all signals in the Emu Plains-Lapstone Section to 'Stop' to prevent the possibility of other trains approaching CB76 on adjacent lines. The signals between Springwood and Glenbrook were also placed at 'Stop'. The signaller then contacted the Rail Management Centre in Sydney to advise it of the incident.

2.3 Shortly after CB76 passed through Lapstone, members of an electrical maintenance team working trackside, observed a derailed wagon as the train passed by. A hand-signaller, providing protection to the maintenance team, then attempted, unsuccessfully, to alert the crew of CB76, by waving his arms

[4] Charbon Colliery is located between Wallerawang and Mudgee.

in the air, that one of its wagons had derailed. A member of this team also contacted the signaller at Penrith.

2.4 Immediately before being notified of the incident by station and maintenance staff members, the signaller at Penrith began to note the failure of various signals on the 'Down'[5] main line on his track indication panel. After being contacted by the staff members as described in paragraphs 2.2 and 2.3 above, the signaller immediately contacted the driver of CB76 by radio, instructing him to stop and inspect his train. Upon inspection of CB76, the driver discovered that the 17th wagon (NHVF 35217U), in a consist of 45, had suffered a screwed journal and derailed, but remained upright and attached. Subsequent inspections revealed that the wagon had derailed at kilometrage 66.770, some 4.28km earlier, causing significant track damage, and had dislodged ballast from the rail bridge over the Great Western Highway, shattering the windscreen of a car below.

Derailment of 1WB3 (Wauchope)

2.5 At approximately 11:15am on 7 March 2005, PN freight service 1WB3, conveying steel products from Port Kembla to Brisbane, was brought to a stand at kilometrage 466.000, which is approximately 11km North of Wauchope, after the train lost brake pipe pressure. The assistant driver walked beside the 930m long train in order to establish why brake pressure had been lost and, in the process, found that the 49th wagon (RKDF 20411Q) had suffered a screwed journal and derailed. He also found that the two trailing wagons had parted from the train and come to rest approximately 250m South of the derailed wagon RKDF 20411Q. Subsequent inspections revealed that the 49th wagon had derailed at kilometrage 462.111, some 3.8km earlier.

Injuries and Damage

2.6 There were no injuries as a result of either derailment. However, passenger services were disrupted and there was extensive damage in both instances.

[5] The terms 'Up' and 'Down' are used within the NSW rail industry to describe train movements either towards or away from Sydney respectively.

a. **CB76 (Lapstone).** In addition to the damaged bogie on wagon NHVF 35217U (see *Photo 1)*, 436 concrete sleepers between kilometrage 65.770 and 65.200 and guard rail fastenings between 65.515 and 65.535 required replacement. Extensive repairs were also required to the Lapstone emergency crossover and associated signal equipment. In addition, the ballast formation between kilometrage 65.770 and 61.490 required reshaping to be returned to the required formation.

Photo 1 Damaged Wagon on CB76 (Lapstone)

(Photo provided by Pacific National)

Photo 2 Damaged Wagon on 1WB3 (Wauchope)

(Photo provided by Pacific National)

b. **1WB3 (Wauchope)**. In addition to the damaged bogie on wagon RKDF 20411Q (see *Photo 2*), approximately 3km of track, between kilometrage 462.111 and 465.200, was extensively damaged. The Saltwater Creek rail bridge, located within the area of track that was affected, was also damaged but to a lesser extent.

Emergency Response

2.7 **CB76 (Lapstone)**. Once CB76 had come to a stand, its crew placed audible warning devices to the front and rear of the train to protect it in accordance with RailCorp's *Network Rule NTR 400* and *Network Procedure NPR 720*. At 1:50pm the Rail Management Centre (RMC) in Sydney declared the derailment to be a major incident and instituted Major Incident Management (MIM) procedures. These procedures required the RMC to dispatch response staff to the incident and manage other trains that might be affected by the incident. First response representatives from both PN and RailCorp were on-site by 3:50pm. At 4:50pm, the 'Down' Main line was re-opened after temporary repairs. The 'Up' Main line was re-opened at 10:00pm.

2.8 **1WB3 (Wauchope)**. Upon discovering the derailed wagon, the crew of 1WB3 immediately alerted ARTC's Train Control Centre at Broadmeadow and PN's Operations Centre in Adelaide of their circumstances and then acted to protect their train. PN's emergency response group was subsequently deployed from Newcastle. OTSI investigators arrived at the scene at 7:30pm and subsequently authorised the commencement of the recovery operation. This operation was completed by 10:30pm.

Train Information

2.9 **CB76 (Lapstone).** CB76 consisted of four 82 Class locomotives and 45 loaded coal wagons. The train measured 850m in length and had a trailing load of 4500 tonnes. The derailed wagon, NHVF 35217U, was the 17th wagon in the consist and had a gross weight of 100 tonnes.

2.10 **1WB3 (Wauchope).** 1WB3 consisted of three NR Class locomotives and 51 wagons. The train measured 930m in length and had a trailing load of 3721 tonnes. The derailed wagon, RKDF 20411Q, was the 49th wagon in the consist and had a gross weight of 91.66 tonnes.

Crew Information

2.11 Personnel records reviewed by OTSI confirmed that the crews of CB76 and 1WB3 were appropriately qualified and sufficiently experienced to operate their respective trains.

Track and Train Control Information

2.12 **CB76 (Lapstone).** The rail section between Glenbrook and Emu Plains is electrified, dual line. The line is classified as Class 1 line and is comprised of 53kg rail affixed to concrete sleepers. Train movements through the section are controlled using the Rail Vehicle Detection System (RVDS) operated from RailCorp's Penrith Box. The maximum operating speed for freight trains travelling in the 'Up' direction in the area where the derailment occurred is 60km/hr.

2.13 **1WB3 (Wauchope).** The rail section between Wauchope and Telegraph Point is non-electrified, single line. The line is classified as Class 1 line and is comprised of 53kg rail affixed to concrete sleepers. Train movements through the section are bi-directional and controlled using RVDS under a centralised traffic control (CTC) system from Broadmeadow in Newcastle. The maximum operating speed for freight trains travelling in a Northerly direction in the area of the derailment is 90km/h.

PART 3 ANALYSIS

3.1 Track inspections established that wagon NHVF 35217U, which was part of CB76 (Lapstone), derailed at kilometrage 65.770 on the 'Up' Main line and stopped at 61.490. A like inspection at Wauchope established that wagon RKDF 20411Q, part of 1WB3, derailed at kilometrage 462.111 whilst travelling in the 'Down' direction and stopped at approximately 465.200.

Exclusions

3.2 OTSI inspected the track at both Lapstone and Wauchope and found it to be in good condition in both instances. It also reviewed event recorders and load documentation and established that both CB76 and 1WB3 had been operated and loaded appropriately and were travelling within the specified speed limits at the time of the derailments. Blood alcohol test results obtained from the Police indicated that 'impairment' was not a factor in either instance. Rostering information also indicated that both crews had worked within the industry's fatigue guidelines. Given the presence of two screwed journals, OTSI therefore focused its attention on mechanical and maintenance issues.

What is a 'Screwed Journal' and Why do they Occur?

3.3 The term 'screwed journal' is widely understood throughout the rail industry to describe the failure of a Packaged Unit Bearing (PUB) and the subsequent separation from the wheel set of the axle portion upon which the PUB was assembled. A typical PUB is shown in *Figure 2*.

Figure 2 Exploded View of a Typical PUB

3.4 The PUB is seated over a portion of the axle referred to as the 'journal'. The PUB typically consists of a 'cup' in which two cones of cylindrically-shaped roller bearings run. Outboard the cup, seals are used to retain grease lubricant within the unit. The PUB is pressed onto the end of each axle (i.e., it sits outside the wheel) with a prescribed interference fit and is held in place by an end-cap and cap screws. A bearing adapter casting locates the PUB into the wagon bogie's 'pedestal' or side frame as shown in *Photo 3*.

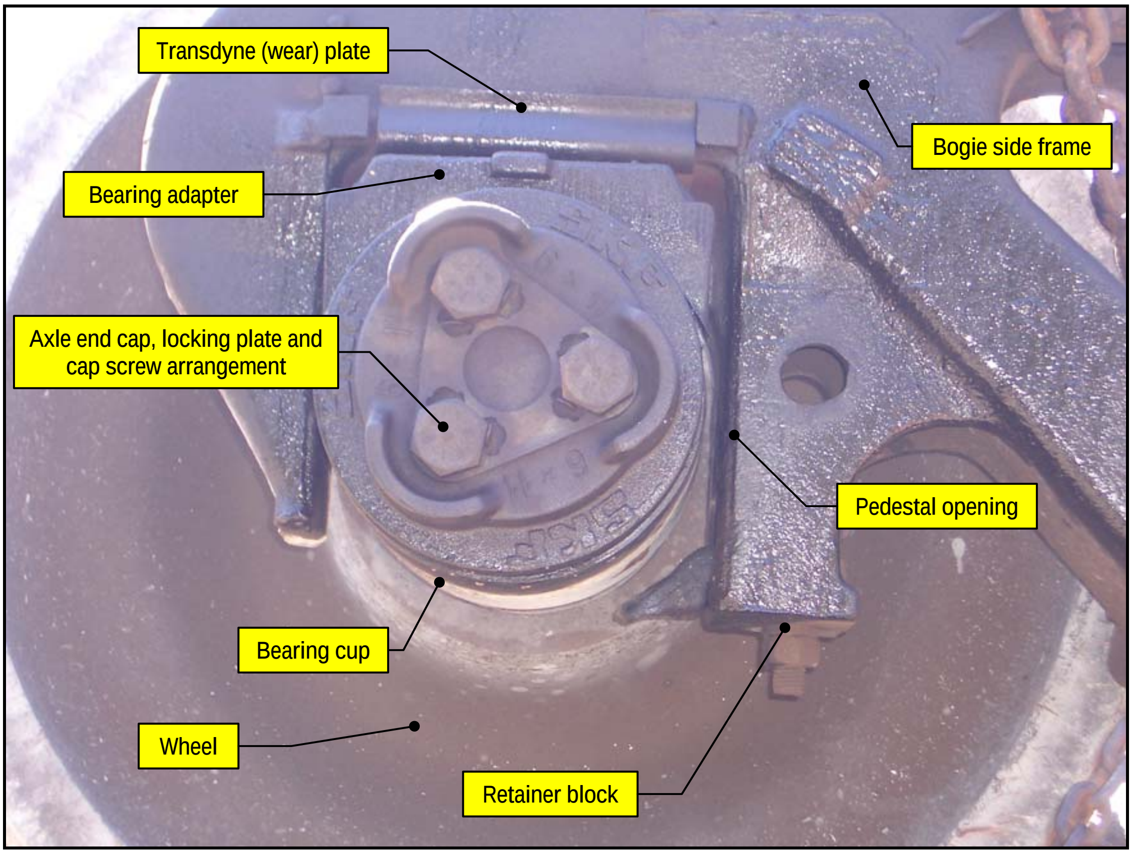

Photo 3 Typical Wheel and Bearing Components

3.5 Screwed journals can be caused by a multitude of factors including poor manufacturing, poor storage, poor handling, poor assembly, poor maintenance, stress imparted through overloading or impact, poor loading, the ingress of foreign material, including water, and/or the poor condition of bogies/axles/wheel sets. In each of these instances, there are many 'sub-factors' that may also come into play. Typically however, some form of defect or stress sets up a condition which causes friction within the PUB to such an extent that it becomes exceedingly hot and the journal is in effect 'turned' or 'lathed' off the axle. The remains indicated in *Photos 4* and *5* are from the journal that failed on 1WB3 (Wauchope), with the red arrow indicating the point at which the axle separated. The tapered effect in *Photo 4* is the consequence of the axle rubbing on the underside of the bogie frame and being 'lathed' as described above.

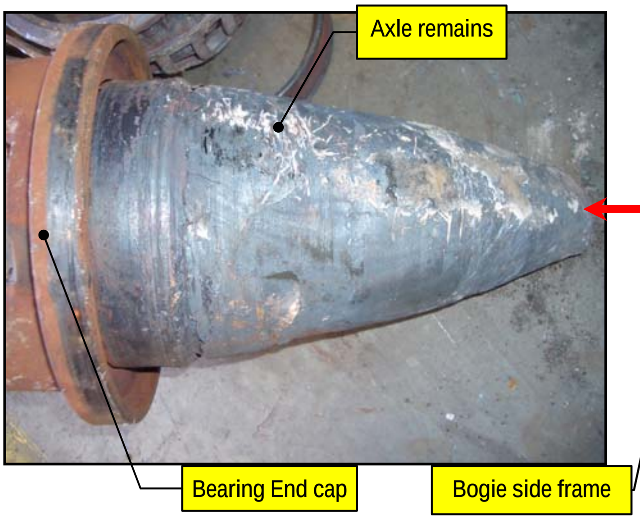

Photo 4 1WB3 (Wauchope) Axle Journal Remains

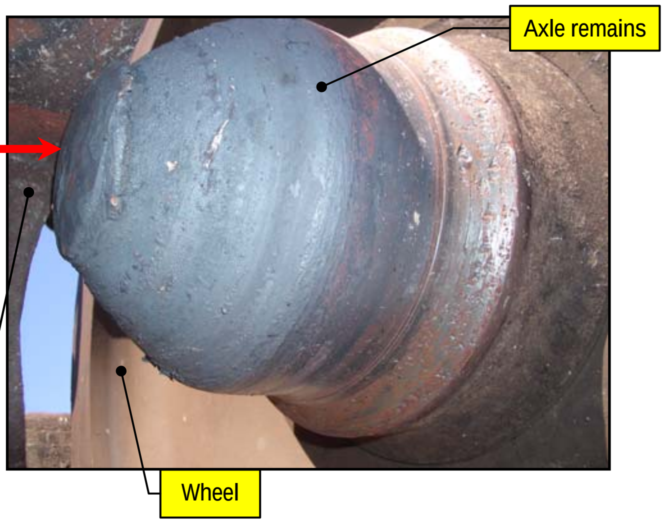

Photo 5 1WB3 (Wauchope) Other Half of Axle Journal Remains

3.6 Such a condition can occur in a relatively short time or distance and results in the derailing of the affected wagon, and sometimes others. If the derailed wagon remains upright and coupled, the axle and/or pedestal will usually impact on every sleeper over which it passes, as illustrated in *Photos 6* and *7*.

Photo 6 Commencement of Sleeper Damage at Wauchope

Photo 7 Commencement of Sleeper Damage at Lapstone

(Photo provided by Pacific National)

Detection of Defective PUBs

3.7 **CB76 (Lapstone).** The PUB that failed (AAR Class E in size and serial numbered 60219) was fitted to the 'leading' wheel set (serial number 831009) on the 'A' end[6] of the wagon. It had been manufactured in Italy, by Svenska Kullager Fabriken (SKF), in 1988.

3.8 **1WB3 (Wauchope).** The PUB that failed (AAR Class E in size and serial numbered 712030) was fitted to the 'trailing' wheel set on the 'A' end bogie on the wagon. The PUB's identification markings were obliterated but some of its components, in particular the cones on the bearing and its 'mate' at the other end of the axle, were manufactured in Italy by Fischers Automatische Gusstahlkugelfabrik (FAG), now known as FAG Kugelfischer, in 1983 and 1985. This suggests that the failed PUB may have been of a similar age.

3.9 Defective PUBs may be detected in service by a number of methods, including:

a. 'roll-by' inspections by the crews of passing trains, outgoing crews after crew changes, and station/terminal/signalling or track staff at shunting terminals or yards who look for obvious signs of defects and who might also, in the process, hear a faulty bearing;

b. the analysis of data from Bearing Acoustic Monitors (BAM) located at Metford (Maitland) and Kingswood (Penrith) to detect bearing 'rumble' or noise,[7] and

c. the activation of heat-sensing equipment, generally referred to as 'hot box' detectors (HBDs), situated at various locations on the NSW rail network, to detect increased bearing temperatures as bogies pass the monitoring equipment.[8]

3.10 Once a warm or hot bearing has been detected by a HBD, the signaller monitoring the equipment alerts the crew to stop the train and inspect the axle

6 The ends of a wagon are designated as the 'A' or 'B' end to assist staff in identifying the location of various components on the wagon.

7 BAMs record bearing data as wagons pass over the monitor. The results of subsequent recordings, either by the same monitor or other monitors at a later point in time, are compared electronically to establish if there has been deterioration in the condition of the bearing. If the bearing falls outside certain parameters, a computerised alert is issued to specialist staff within PN. BAMs are therefore intended to provide an earlier 'line of defence' than a hot box detector.

8 HBDs are less expensive than BAMs but BAMs generally provide earlier warning of an impending problem. Used in conjunction, BAMs and HBDs form two 'layers' of defence against the prospect of failed bearings.

identified by the HBD. Newer HBDs can generate automatic warning messages on train radio systems that alert both signallers and the train crew. Further discussion on the distribution of these detectors is provided at paragraphs 3.25 to 3.27.

3.11 CB76 passed over a HBD at Medlow Bath, approximately 50 kilometres before Lapstone[9], which recorded the temperature of the bearing that was later to fail as being 69°C. While this reading was slightly more elevated than that which is considered normal,[10] it was still below the temperature required to generate an alarm. 1WB3 passed over a similar monitor at Maitland, some 260kms before Wauchope, and the temperature of the bearing that was later to fail was normal.

Bearing Maintenance Regimes and History

3.12 PN's maintenance regime requires that PUBs be serviced every time the wheel set is removed from the bogie for re-profiling (turning) of the wheel tread or when wheels are replaced. Wheel sets under coal wagons are removed on a three year mandatory schedule. However, the wheel sets on other types of wagons carrying lighter loads, such as the wagon that derailed at Wauchope, are removed when wheel tread conditions exceed limits rather than at a specified time interval.

3.13 Once PUBs are removed from the axle, they are sent to specialist bearing maintainers for re-qualification. During re-qualification, each bearing component is cleaned, then inspected for damage and measured for wear before being rebuilt. If a bearing component does not meet the required parameters, it is scrapped and replaced. PUB servicing dates are recorded in a database populated by the organisation performing the servicing. Maintenance documentation indicated that the PUB that failed on CB76 (Lapstone) had last been re-qualified on 18 November 2003, while the PUB that failed on 1WB3 (Wauchope) had last been re-qualified on 6 July 1998. Given that there were no wheel tread defects evident on wagon RKDF 20411Q (Wauchope) and the PUB that failed at Lapstone had been serviced

9 This HBD was of the older type that does not generate automatic warning messages on train radio systems.

10 Normal operating temperatures of PUB's generally do not exceed 50°C. Warm alerts on HBDs are generally set at 90°C. This significant 'margin' is required to ensure that other components that can become heated e.g., brakes, do not trigger the alarm.

within the specified time intervals, neither PUB was considered 'overdue' for re-qualification.

3.14 PN's wagon maintenance procedures also require that any wagon that has been stowed for extended periods must have its wheels inspected and rotated every 100 days to ensure that the rollers on the bearing cones remain lubricated. Wagons stored for longer than 200 days must also have the bearings rumble tested[11] prior to being returned to service. The bearings on wagons stowed for longer than two years must be re-qualified before the wagon re-enters service. Records indicated the following:

a. Wagon NHVF 35217U had not been stowed for in excess of 100 days, and
b. Wagon RKDF 20411Q had been stowed for 39 days in the latter half of 2004 and had travelled approximately 25,000km between the time it was returned to service and the day of the incident.

3.15 The records also revealed that wagons that derailed on CB76 and 1WB3 had undergone detailed inspection and the safety critical items, i.e., brakes, bogies, wheels and couplings had been serviced on 16 February 2005 and 16 July 2004 respectively. There was nothing in the records to indicate that the PUBs were damaged or defective.

3.16 PN employs a Train Management System (TMS) to ensure that only serviceable rolling stock is utilised for its operations. This system, which is essentially a database, informs both its maintenance and operations by alerting PN if a piece of rolling stock requires maintenance. In the event that defects are not remedied or maintenance has not been performed, those personnel marshalling rolling stock will be alerted when they enter consist details into the TMS. This system therefore 'pushes' information, whereas earlier systems required operators to search for such information.

3.17 OTSI noted that routine train safety examinations were conducted prior to and at the departure of CB75[12] from Inner Harbour on 28 February 2005 and 1WB3 from Morandoo (Newcastle) on 6 March 2005. OTSI further noted that

11 Bearings are rotated by trained staff to detect if there is any undue action or noise within its operation.

12 The train number of coal service CB75 became CB76 after it was loaded at Charbon Colliery.

a 'roll by' inspection was also conducted on 1WB3 as it departed Taree, approximately two hours prior to the derailment. These inspections served a limited, but nonetheless useful purpose, and that was to detect obvious defects. The inspecting crew at Taree examined the side of the train on which the PUB later failed but did not detect any faults.

Specialist Examinations of the Failed Bearings

3.18 Determining the exact cause of a screwed journal is complicated by the fact that such events are normally associated with catastrophic mechanical failure. The PUB will often disintegrate and, even when the various components are found, the combined effects of heat, pressure and disintegration may mask or obliterate signs that would otherwise indicate the actual failure mode (see *Photos 8* and *9*).

Photo 8 Damage to Bearing Cup from PUB off 1WB3 (Wauchope)

Photo 9 Damage to Bearing Cone and Rollers from PUB off 1WB3 (Wauchope)

3.19 When a PUB is extensively damaged, specialist engineering and metallurgical examination is generally required to interpret any indications that may remain on the bearing. In the event that very little useful information is gleaned from the failed PUB, the condition of the 'mate' PUB may provide some indication of the condition of the failed PUB.

3.20 Those components of the PUB and the journal recovered from CB76 (Lapstone) were examined independently by two specialist engineers and two metallurgists. The PUB off 1WB3 (Wauchope) was examined by a specialist engineer and a metallurgist. The respective findings arising from these examinations are indicated in *Tables 1* and *2* at the end of this report.

3.21 The specialist examinations of the two PUBs did not establish conclusively why these bearings failed. Two of the four specialists who examined the failed PUB on CB76 noted that one or both of the cups on CB76 had been hit with considerable force at some stage. One specialist further suggested that the impact was a consequence rather than a cause. Another noted that there was evidence that suggested that moisture, or some other foreign material, had penetrated the inner workings of the PUB (See *Photos 10 and 11*).

Photo 10 Brinelling Marks in the Cup from the 'Mate' PUB on CB76 (Lapstone)

Photo 11 Condition of Lubrication in the 'Mate' PUB on 1WB3 (Wauchope)

3.22 A fourth specialist eliminated the possibility that the failure was caused by a loss of interference/contact in/on the axle. OTSI's consideration of the specialist advice was also informed by technical commentary from a specialist within ITSRR. PN believes that the most likely cause of failure was ingress of water whilst the wagon underwent high pressure-cleaning. There were indications that the inner workings of the failed PUB on 1WB3 might also have been penetrated or that there may have been a loss of interference. This latter indication suggests that the inner 'race'[13] on the outer cone, i.e., the left-hand cone depicted in *Figure 2*, which is not intended to rotate, had done so.

[13] The 'race' is ring which is fixed onto the axle upon which the rollers, forming part of the 'cone', rotate.

Remedial actions taken or intended by Pacific National

3.23 Data provided by PN indicates that it suffered an average of 0.88 bearing failures per month in the 2004/2005 financial year. The average number of such failures per month in the previous financial year was 1.5. These figures need to be considered in the following context:

a. PN operates 13,339 wagons with a total of 106,712 PUBs;

b. PN's wagons travelled a total of 29,673,103km in Financial Year 2004/2005 and 32,727,100km in Financial Year 2005/2006, and

c. it is not uncommon for wheel sets on inter-modal vehicles to travel 1,000,000km between reconditioning.

3.24 In response to these incidents, and the risks of bearing failures more generally, PN advised that:

a. it has commenced auditing the work of bearing maintenance contractors and sub-contractors that it utilises with a view to improving the bearing re-qualification process;

b. it has issued instructions to maintenance contractors to ensure PUBs are sealed and protected from the ingress of water and foreign material during wagon cleaning operations, and

c. it is trialling a plastic bearing adapter, which is less rigid, on some of its rolling stock to determine whether such an adapter might ensure a more even distribution of load between the bogie frame and the PUB.

Other Safety Matters

3.25 In addition to PN’s efforts to further improve the management of PUBs, both ARTC and RailCorp are seeking to upgrade detection systems on their respective networks in NSW. These upgrades include the installation of detectors in new locations and the replacement of older HBDs with newer variants which, as previously indicated, provide an alert directly to the train driver. The purpose of these and other types of detectors, such as wheel impact load detectors (WILDs), dragging equipment detectors, hot wheel detectors and BAMs, is to alert drivers and/or operators to the existence of a problem before it results in a major mechanical failure and/or accident[14].

3.26 The most sophisticated of the trackside detection technologies in Australia is the BAM, one of which was recently installed on the 'Up' coal line at Metford by the Australian Rail Track Corporation (ARTC). ARTC has also improved the sensitivity of the WILD at Metford to provide more reliable detection of tread defects which can have a damaging effect on PUBs. OTSI understands that ARTC also plans to install another BAM North of Goulburn and to upgrade existing and/or install other types of detectors in the Hunter Valley and on the Main South and Main West Lines, but this enhancement is dependent on the outcome of ongoing discussion, between ARTC and rolling stock operators who use its network, about how the related project will be funded.

3.27 RailCorp has installed a BAM on the Main West line at Kingswood for trial purposes but this equipment has yet to be fully commissioned[15]. OTSI understands that RailCorp's plans include the installation of 'hunting', or wheel profile, detectors[16], but that RailCorp is still considering what generation of technology it will employ. RailCorp's plans are also dependant on cooperation and collaboration with and/by the rolling stock operators who use its network.

3.28 The recent introduction of BAMs onto the NSW rail network is a very welcome development, and ARTC's and RailCorp's plans to employ other new technologies is encouraging, from both a safety and reliability perspective. OTSI appreciates that the continued introduction of such technologies requires significant cooperation and collaboration between the infrastructure "owner" and rolling stock operators, but that given the significant benefits that

[14] Other types of detectors used on the NSW network also include weight and load height detectors, embankment slip and rock-fall detectors and rainfall and temperature monitors. Some detectors, such as the height and load detectors warn of an immediate problem. Others, such as a BAM or WILD, are in effect condition monitoring devices whose outputs are intended to be monitored over time by operators.

[15] RailCorp's BAM at Kingswood has an additional function; it will also monitor the condition of bearings within the traction motors and gearboxes which power its electric trains. However, these trains have side 'skirts' which can shield bearings from being 'read'. This requires the sensors on the BAM to be repositioned to overcome the interference caused by the skirts. This process is scheduled to be completed in June 2007.

[16] Hunting detectors are intended to identify wheels that are not tracking properly.

such technologies can contribute to the safety and efficiency of rail operations, it is important that all parties commit to the timely realisation of the expansion and enhancement plans.

3.29 OTSI believes that ITSRR is the appropriate agency to monitor and encourage the progress of ARTC's and RailCorp's related plans.

PART 4 FINDINGS

4.1 In relation to those matters prescribed by the Terms of Reference as the principal lines of inquiry, OTSI finds as follows:

a. Causation:

i. Both derailments were caused by the failure of Packaged Unit Bearings (PUB).

ii. There was nothing to suggest, in either instance, that the PUBs had been inadequately maintained or that there were problems elsewhere on the bogies. Nor were the wagons overloaded.

iii. Both PUBs were virtually destroyed and there was no conclusive evidence to indicate what initiated their failure.

iv. There were some limited indications to suggest that both bearings might have been penetrated by moisture or some other foreign material. PN suspects that in the case of CB76, this may have occurred while the wagon was being pressure-cleaned. However, this possibility and premise could not be confirmed.

b. Anticipation and Management of Risk:

i. PN had appropriate policies in place to minimise the likelihood of PUBs failing and continues to refine its policies and practices to further reduce the related risks.

ii. ARTC has installed a Bearing Acoustic Monitor (BAM) at Metford to increase the prospect of deteriorating axle bearings being detected well before they fail. RailCorp has also installed a BAM at Kingswood which, in addition to axle bearings, will also monitor the bearings in the traction motor and gearbox equipment of its electric trains. However, the RailCorp equipment will not be fully functional until mid-2007.

c. Effectiveness of the Emergency Response:

i. The emergency response to both incidents was timely and effective.

d. Other Matters that would Enhance the Safety of Rail Operations:

i. ARTC and RailCorp have plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW. The implementation of these plans will contribute to enhancing the safety of rail operations in NSW.

ii. ARTC's plans to enhance the detecting and monitoring systems on its network in NSW are dependent on the outcome of ongoing discussions with rolling stock operators who use its network about how the related project will be funded.

iii. RailCorp's plans to enhance the detecting and monitoring systems on its network in NSW are dependant on the progressive identification of appropriate technologies, and the cooperation and collaboration of rolling stock operators who use its network.

PART 5 RECOMMENDATIONS

5.1 In order to enhance the rail safety environment in NSW and minimise the potential for collateral damage from this kind of derailment, it is recommended that:

a. ARTC and RailCorp proceed with their plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW as expeditiously as possible;

b. ARTC and RailCorp provide ITSRR with a copy of their latest plans to expand and upgrade the range of monitoring and detection systems throughout the rail network in NSW, and

c. ITSRR monitors the progress of the implementation of ARTC's and RailCorp's plans.

PART 6 APPENDIX

Table 1 – Bearing Examination Results from CB76 (Lapstone)

Specialist 1	
• The journal for the 'mate' bearing was within specifications. • The only evidence of pitting on the failed bearing was laterally across the raceways. • The cones on the 'mate' bearing were found to be 11µm oversized and 10µm of fretting was found on the back face of the inboard cone. • Outboard cup raceway on the 'mate' bearing was broken due to brinelling. Brinelling marks were also found on the outboard cone raceways of this bearing. • Two rollers on the outer cone on the 'mate' bearing were found to be broken in half and the cage was bent. • 17.04 ounces of grease were found in the 'mate' bearing.	<u>Conclusion</u> • There was little evidence available from/in the failed bearing. Evidence taken from the 'mate' bearing suggests a severe overload and impact to the bearing, but most of this was probably due to the derailment. • *The cause of the failure could not be determined.*
Specialist 2	
• The remnants of the failed PUB was in a burnt condition and fractured and appeared to have been hit with a very high impact to either or both sides of the cup. • The raceways of the failed PUB appeared to be in good condition. • The 'mate' PUB was in good condition except for a few marks on the raceways. There was, however, indication of slight wear on the outboard-end of the end seal wear-ring and some fretting on the backing ring.	<u>Conclusion</u> There was no evidence to suggest that a failure occurred within the PUB. *The package unit cup on the failed bearing was hit with very high impact and this created a fracture which, over time, progressed into an end-to-end fracture*. The inside diameter of the cup on the failed bearing increased and resulted in the rollers skewing under the cage, overheating, loss of lubrication and eventually the failure of the PUB.

<table>
<tr><th colspan="2">Specialist 3</th></tr>
<tr><td>

- The failed PUB was extensively damaged and many component parts were missing.
- The failed PUB had collapsed and the outer ring had welded to the inner rings. The external surface of the outer ring was indented by the adaptor in the overheated zone.
- The collar, locking plate and cap bolts on the failed PUB were intact and undamaged. The collar was corroded and light corrosion was also evident on the edge of the axle mounting face.
- There was no evidence of a loss of interference.
- The exterior of one seal case on the failed PUB was heavily corroded but there was only light corrosion internally. The other seal case was only lightly corroded. The absence of significant internal corrosion indicates that the grease had been able to absorb any ingress of foreign material or moisture. The corrosion was indicative of the seal being dislodged from the PUB or a rubber insert having failed.
- The outside seal wear-ring on the failed PUB was heavily deformed; the other intact, but overheated and swaged at the outer edge. The wear was most likely the result of, rather than the cause of, the derailment.
- Only one half of one roller was recovered and this was fractured at the beginning of the edge of the recess in the roller end & had progressed through the roller in a single event. This roller was unlikely to have contributed to the failure.

</td><td>

<u>Conclusion</u>

The pattern of damage to the PUB outer ring suggested it had failed as a result of a bearing seizure, but the cause of the seizure was not apparent. *Possible contributing factors were seal failure, ingress of moisture or foreign material, and/or split rollers.* There was no evidence to suggest a loss of interference/contact of the inner rings.

</td></tr>
<tr><th colspan="2">Specialist 4</th></tr>
<tr><td>

- The surface of the raceways on the failed PUB was obliterated by scoring, indentation and smearing which also obliterated any signs of surface failure.
- There was no circumferential scoring to the raceways of either of the inners. The possibility that the failure was a consequence of the inner races spinning on the axle was discounted.
- The cup on the ‘mate’ bearing exhibited non-cleavage type fractures cause by impact and in the same area there were four transverse roller indentations on the raceway. Otherwise the raceway surfaces were in good condition. The inner race corresponding to the fracture in the cup also had roller bearing indentations.

</td><td>

<u>Conclusion</u>

The failed bearing did not spin on the axle. The failure occurred in the rolling contact interface of the bearing. All evidence of the exact cause of failure, be it raceway surface degradation, lubrication failure or contamination, or a failure occurring in the cup or inner races, was obliterated.

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Table 2 – Bearing Examination Results from 1WB3 (Wauchope)

<table>
<tr><th colspan="2">Specialist 2</th></tr>
<tr><td>The extent of the damage made it very difficult to assess the failure mode
The inboard cone was in better condition that the outboard cone on the failed PUB.
There was .05mm and .02mm of fretting on the inboard and outboard cones respectively on the ‘mate’ bearing. Both cones had oversized bores.
Both cup raceways were broken on the ‘mate’ bearing and there was spall on the outer surface of the outboard cone – inside this, there was a 20mm diameter electric-like burn.
The grease found within the mate bearing had low viscosity.</td><td><u>Conclusion</u>
It is possible that this failure was the consequence of contamination of the lubricating grease, an electrical arc from welding, or that a high impact force on the PUB damaged the cones or seals, subsequently creating the conditions that led to the collapse of the PUB.</td></tr>
<tr><th colspan="2">Specialist 4</th></tr>
<tr><td>There were no manufacturer’s markings left intact on the failed PUB.
Remnants of the outside inner race on the failed PUB were fused onto the axle.
The outside diameter of the cup on the failed PUB was heavily deformed and gouged from dragging along the track. The indications on the cup were not consistent with the raceways having failed.
The raceways on the failed PUB had black surface oxide from overheating, rust and molten metal splatters.
One raceway on the failed PUB had no scoring or spalling or other signs that would have indicated a surface failure; the other had minor scoring, hard particle indentations and small pattern spall-like indications. The partly scored area indicates that the inner turned a little on the axle rather than spinning and causing the failure. Had the inner spun, there would have been more significant indications of scoring, erosion and burning.
There were minor indentations on the failed PUB but no scoring or other indication of failure on that part of the raceway that was recovered. However, that part of the inside of the diameter surface that was not obliterated had some scoring.
The ‘mate’ bearing had fractures at both ends of the cups and they were established as being progressive ductile tears. The raceway had hard particle indentations but no surface failure features. The fracture occurred due to excessive angular movement and stress when the PUB at the other end of the axle failed.</td><td><u>Conclusion</u>
The failure was not the consequence of failure within the rolling interfaces of the failed bearing. The indications suggest that the outside inner race spun on the axle causing frictional heating. It was not possible to determine why the outside inner race may have started to spin, but the possibilities include :
Insufficient interference/contact between the axle and the inner race at the time the axle box was installed; this in turn may have resulted from a mismatched axle and bearings or damage to the axle/race due to faulty installation, and
Increased diameter of the inner race due to long term metal structural changes.
Exacerbation of either of the above conditions caused by excessive running temperatures that were not high enough to induce a rolling contact interface failure, but which could have reduced the interface/contact through thermal expansion of the race.</td></tr>
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