



Australian Government

Australian Transport Safety Bureau



ATSB TRANSPORT SAFETY INVESTIGATION REPORT  
Rail Occurrence Investigation Report 2006002  
Final

Derailment of  
**XPT Passenger Train ST22**

Harden, New South Wales

9 February 2006



**Australian Government**

---

**Australian Transport Safety Bureau**

**ATSB TRANSPORT SAFETY INVESTIGATION REPORT**

Rail Safety Investigation Report

2006/002

Final

**Derailment of XPT Passenger Train ST22**  
**Harden, New South Wales**  
**9 February 2006**

Published by: Australian Transport Safety Bureau  
Postal address: PO Box 967, Civic Square ACT 2608  
Office location: 15 Mort Street, Canberra City, Australian Capital Territory  
Telephone: 1800 621 372; from overseas + 61 2 6274 6440  
Accident and incident notification: 1800 011 034 (24 hours)  
Facsimile: 02 6247 3117; from overseas + 61 2 6247 3117  
E-mail: [atsbinfo@atsb.gov.au](mailto:atsbinfo@atsb.gov.au)  
Internet: [www.atsb.gov.au](http://www.atsb.gov.au)

© Australian Government 2007.

This work is copyright. In the interests of enhancing the value of the information contained in this publication you may copy, download, display, print, reproduce and distribute this material in unaltered form (retaining this notice). However, copyright in the material obtained from non-Commonwealth agencies, private individuals or organisations, belongs to those agencies, individuals or organisations. Where you want to use their material you will need to contact them directly.

Subject to the provisions of the Copyright Act 1968, you must not make any other use of the material in this publication unless you have the permission of the Australian Transport Safety Bureau.

Please direct requests for further information or authorisation to:

Commonwealth Copyright Administration Copyright Law Branch  
Attorney-General's Department Robert Garran Offices  
National Circuit  
BARTON ACT 2600  
[www.ag.gov.au/cca](http://www.ag.gov.au/cca)

ISBN and formal report title: see 'Document retrieval information' on page v.

---

# CONTENTS

---

<b>DOCUMENT RETRIEVAL INFORMATION .....</b>	<b>v</b>
<b>THE AUSTRALIAN TRANSPORT SAFETY BUREAU .....</b>	<b>vii</b>
<b>TERMINOLOGY USED IN ATSB INVESTIGATION REPORTS .....</b>	<b>viii</b>
<b>EXECUTIVE SUMMARY .....</b>	<b>ix</b>
<b>1 FACTUAL INFORMATION .....</b>	<b>1</b>
1.1 Introduction .....	1
1.1.1 Location .....	1
1.1.2 Train information.....	1
1.1.3 Crew of train (ST22).....	1
1.1.4 XPT power cars .....	2
1.1.5 XPT bogies .....	2
1.1.6 PLA bogie axles.....	3
1.1.7 Train crew account.....	4
1.1.8 Post accident response .....	5
1.1.9 Loss and damage.....	7
1.2 Safety action following the derailment.....	7
<b>2 ANALYSIS .....</b>	<b>9</b>
2.1 Rollingstock examination .....	9
2.2 Track geometry .....	13
2.3 Wheel Impact Load Detector.....	13
2.4 Examination of cracked axles .....	14
2.4.1 Design.....	14
2.4.2 Manufacture .....	15
2.4.3 Axle stress analysis.....	17
2.4.4 Axle failure analysis .....	18
2.4.5 Summary of axle failure analysis.....	22
2.5 Maintenance, testing and inspection.....	23
2.5.1 Wheelset overhaul.....	23
2.5.2 Axle crack testing .....	25
2.5.3 Crack growth rate and previous MPIs .....	28
2.5.4 Axle painting .....	30
2.5.5 Summary of maintenance, testing and inspection.....	30
2.6 High Speed Train (United Kingdom) comparison.....	31

2.6.1	In service testing of HST wheelsets.....	31
2.6.2	Overhaul of HST wheelsets .....	31
2.6.3	Defect limits for HST axles .....	31
2.7	History of cracked XPT/HST power car axles .....	32
2.7.1	Australia.....	32
2.7.2	United Kingdom .....	32
<b>3</b>	<b>FINDINGS.....</b>	<b>35</b>
3.1	Contributing Factors .....	35
3.2	Other Safety Factors .....	35
3.3	Other Key Findings.....	36
<b>4</b>	<b>SAFETY ACTIONS .....</b>	<b>37</b>
4.1	Safety actions already taken .....	37
4.1.1	RailCorp.....	37
4.1.2	Independent Transport Safety and Reliability Regulator (NSW) .....	37
4.2	Recommended safety actions .....	38
4.2.1	Recommendations to RailCorp.....	38
4.3	Safety advisory notices .....	38
4.3.1	Safety advisory notice to all rail vehicle operators in Australia.....	38
<b>5</b>	<b>APPENDIXES .....</b>	<b>39</b>
5.1	Table of axle examination findings .....	39
5.2	ATSB test results .....	40
5.2.1	Mechanical property data.....	40
5.2.2	Chemical analysis .....	40
5.2.3	Crack dimensions.....	41
5.3	UK and Australian differences .....	42
5.4	Summary of rejection criteria for HST and XPT axles.....	44
5.5	Submissions .....	46
5.6	References .....	47
5.7	Media release .....	48

---

## DOCUMENT RETRIEVAL INFORMATION

---

Report No.	Publication date	No. of pages	ISBN
2006/002	June 2007	60	978-1-921165-03-0

---

### Publication title

Derailment of XPT Passenger Train ST22, Harden New South Wales, 9 February 2006

---

### Prepared by

Australian Transport Safety Bureau  
PO Box 967, Civic Square ACT 2608 Australia  
[www.atsb.gov.au](http://www.atsb.gov.au)

### Reference No.

June2007/DOTARS50299

---

### Acknowledgements

The identified images used in this report are reproduced with the permission of those organisations and/or individuals.

Other than for the purposes of copying this publication for public use, the map information from the map section may not be extracted, translated, or reduced to any electronic medium or machine readable form for incorporation into a derived product, in whole or part, without prior written consent of those organisations and/or individuals.

---

### Abstract

On Thursday 9 February 2006 at about 0351 an XPT passenger train travelling from Melbourne to Sydney derailed near Harden in New South Wales. An inspection by the driver found one wheel on the trailing bogie of the leading power car had derailed. During recovery operations the axle of the derailed wheel was found to have completely sheared with a crack in the radius relief area between the gear and wheel seats.

The ATSB's investigation concluded that impacts from track ballast from unknown location(s) had led to the formation of the cracks in the axles. The investigation also concluded that routine testing of the axles carried out by the operator's maintenance contractor, using magnetic particle inspection (MPI), was ineffective and resulted in the fatigue cracks going undetected for a considerable period of time.

A number of safety actions have been undertaken by RailCorp and the Independent Transport Safety and Reliability Regulator of New South Wales which include measures aimed at the early detection and prevention of axle fatigue cracks in XPT and other diesel fleet rail vehicles to limit the risk of further axle failures. Additionally, the Australian Transport Safety Bureau has issued a safety advisory notice to all rail vehicle operators in Australia that they should consider the risks associated with axle failures as a result of fatigue cracks initiated by ballast strikes and review their maintenance practices accordingly.

---



---

# THE AUSTRALIAN TRANSPORT SAFETY BUREAU

---

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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

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

## **Purpose of safety investigations**

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

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

## **Developing safety action**

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

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



---

## TERMINOLOGY USED IN ATSB INVESTIGATION REPORTS

---

**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

---

On Thursday 9 February 2006 at about 0351<sup>1</sup> an XPT passenger train travelling from Melbourne to Sydney derailed near Harden in New South Wales. An inspection by the driver found one wheel on the trailing wheelset of the trailing bogie of the leading power car had derailed. During recovery operations the axle of the derailed wheel was found to have completely sheared with a crack in the radius relief area between the gear and wheel seats. The point of drop off was determined to be at approximately the 390.325 km point from Sydney Central station. The train travelled a further 4.2 km before coming to rest at the 386.100 km point.

The ATSB's investigation of the derailment concluded that train ST22 had derailed as a result of the axle completely fracturing. The axle had fractured as a result of the initiation and propagation of a fatigue crack. Once the crack had grown to critical size, the axle was unable to withstand further operational stresses, which resulted in the overload of the remaining net section of the axle. Once the axle had fractured the wheelset became unstable on the rail and eventually derailed one wheel.

Subsequent inspections by the train's operator, RailCorp, led to the discovery of thirteen other XPT power car axles which had surface defects with the potential to initiate similar fatigue cracks in critically stressed areas. The ATSB's examination of five of the axles, which exhibited fatigue cracks, revealed a crystalline material, consistent with track ballast, embedded in the surface defects which had initiated each crack. It was probable that impacts from track ballast from unknown location(s) had led to the formation of the cracks in the axles.

Although a definitive rate for the propagation of the fatigue cracks could not be established, the propagation of the cracks was determined to be consistent with a low stress and high cycle mechanism. Given that it was likely that the cracks propagated over a relatively long period, an effective maintenance regime should have detected the cracks before they reached the point where they led to total axle failure.

The investigation also found that routine testing of the axles carried out by the operator's maintenance contractor, using magnetic particle inspection (MPI), was ineffective and resulted in the fatigue cracks going undetected for a considerable period of time.

A number of safety actions have been undertaken by RailCorp and the Independent Transport Safety and Reliability Regulator of New South Wales which include measures aimed at the early detection and prevention of axle fatigue cracks in XPT and other diesel fleet rail vehicles to limit the risk of further axle failures.

Additionally, the Australian Transport Safety Bureau has issued a safety advisory notice to all rail vehicle operators in Australia that they should consider the risks associated with axle failures as a result of fatigue cracks initiated by ballast strikes and review their maintenance practices accordingly.

---

<sup>1</sup> The 24-hour clock is used in this report to describe the local time of day, Eastern Daylight-saving Time (EDT), as particular events occurred, 0351 is 3.51am.



---

# 1

## FACTUAL INFORMATION

---

### 1.1 Introduction

At about 0351<sup>2</sup> on Thursday 9 February 2006 XPT passenger train ST22 travelling from Melbourne to Sydney derailed while approaching Harden railway station (NSW) for a scheduled stop. An inspection of the leading power car by the driver found that one wheel on the trailing wheelset of the trailing bogie had derailed. During recovery operations a further inspection revealed that the axle of the derailed wheel had completely fractured.

#### 1.1.1 Location

The derailment occurred on the main southern railway corridor linking Melbourne and Sydney, between Demondrille and Harden (approximately 390 track kilometres from Sydney Central station).

The track at Harden is standard gauge (1435mm) 53kg/m rail fastened to timber and steel sleepers (4 to 1 ratio) by dog spikes and spring fasteners supported by a bed of ballast. This section of the Defined Interstate Rail Network (DIRN) is managed and maintained by the Australian Rail Track Corporation (ARTC).

#### 1.1.2 Train information

Train ST22 was owned and operated by RailCorp, a NSW government organisation. It consisted of XP2001 (leading power car), XFH2112, XF2208, XBR2150, XL2230, XAM2180 & XP2018 (trailing power car). The train length was 155.6 metres with a total mass of 224 tonnes.

The XPT was introduced into service in 1982 and operates between Melbourne, Sydney and Brisbane. The design of the XPT vehicles used in Australia is based on the UK HST (High Speed Train) and the bogies and wheelsets are similar in both trains. While the HST operates at speeds up to 200km/h, the XPT has a maximum permitted speed of 160 km/h depending on track condition and posted speed limits.

#### 1.1.3 Crew of train (ST22)

The driver of train ST22 was a RailCorp (CountryLink<sup>3</sup>) employee based at the Junee depot. The driver had experience in locomotive overhaul before he started to drive trains in 1984. The driver drove freight and passenger trains before taking a role as an electric train driver inspector based at Sydney Central in 1996. In February 2000, the driver moved to the Junee depot where he began driving XPT passenger trains.

---

2 The 24-hour clock is used in this report to describe the local time of day, Eastern Daylight-saving Time (EDT), as particular events occurred.

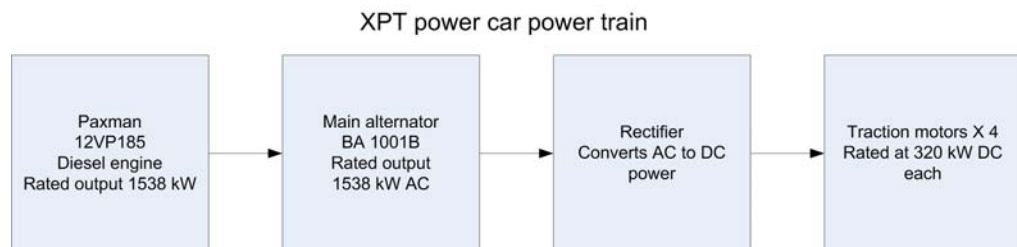
3 CountryLink is part of the government-owned Rail Corporation New South Wales.

The passenger service supervisor (PSS) was a RailCorp (CountryLink) employee based in Sydney who joined the railway industry in 1998 as a passenger service attendant (PSA). The PSS has overall responsibility for service delivery to passengers and supervision of the other passenger service attendants. In addition, the PSS undertakes certain safeworking duties under the direction of the driver.

#### 1.1.4 XPT power cars

XPT power cars have a diesel engine driving an alternator which in turn provides power to four direct current traction motors, one for each axle, via a rectifier. Since 2000, RailCorp have upgraded the original Paxman Valenta engines rated at 1477 kW to Paxman 12VP185 engines rated at 1538 kW. The new 12VP185 engines weigh about 690 kg more and have improved fuel efficiency, reliability, serviceability and driveability characteristics compared with the original Valenta.

**Figure 1: XPT Power car power train diagram**

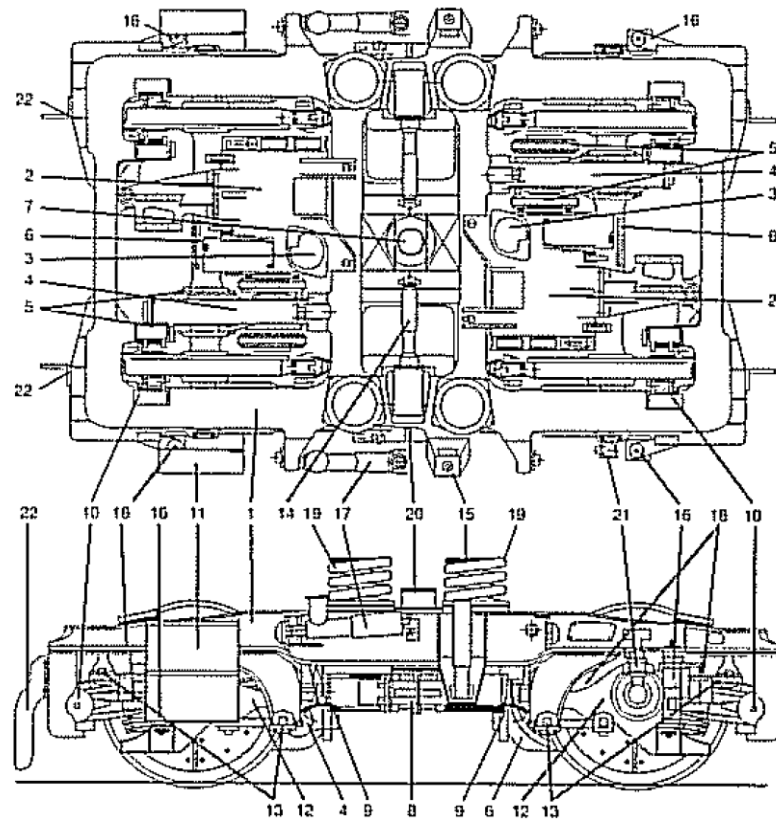


#### 1.1.5 XPT bogies

Each XPT power car has two 'PLA' bogies. Each PLA bogie has two wheelsets, and two traction motors. The traction motors, which are mounted on the bogie frame, drive reduction gearboxes mounted on each axle via a flexible drive link, otherwise known as a kidney link (because of the shape of the flexible links). The flexible drive allows a certain amount of movement between the bogie mounted traction motor and axle mounted gearbox assembly.

The PLA bogie's axle suspension consists of primary, vertical, lateral and yaw dampers with primary and secondary springs to control bogie stability.

**Figure 2: XPT power car bogie diagram**



**Key**

1.	Bogie frame	12.	Axle box
2.	Traction motor and support arm	13.	Alsthorn links
3.	Traction motor cooling air duct	14.	Lateral damper
4.	Gear box and reaction link	15.	Vertical damper
5.	Flexible drive links	16.	Primary damper
6.	Wheel set	17.	Yaw damper
7.	Bogie centre and traction pads	18.	Primary springs
8.	Tread brake assembly	19.	Secondary springs
9.	Parking brake release handles	20.	Bump stops
10.	Brake cylinder (BC) and calliper assembly	21.	Hasler transmitter
11.	Steps	22.	Guard irons

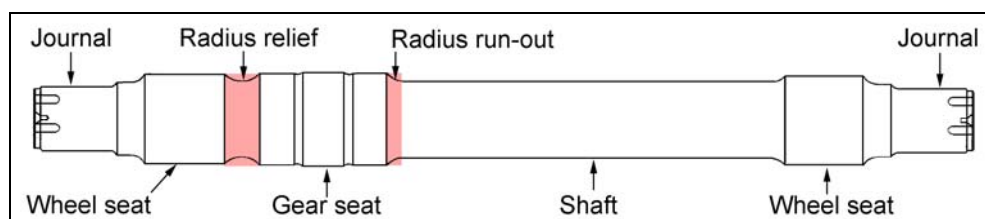
### 1.1.6

#### **PLA bogie axles**

The XPT engineering specifications identify each axle to be a forged and machined item manufactured from manganese-molybdenum alloy steel to the BS 970 605 - M30 specification. The axle length is 2220 mm and the diameter at the radius relief and run-out locations is 180 mm. A bare axle shaft weighs 474 kg. The wheels, gear, and bearings are pressed onto the axle shaft.

The bogie that derailed was numbered PLA 3B with leading axle number 961624 (no defects) and trailing axle 931679 that completely fractured.

**Figure 3: Schematic of an XPT power car axle**



Note: Crack indications found in shaded areas.

The radius relief and run-out areas are designed to prevent critical stress concentrations from loads experienced during operation.

**Figure 4: Axles on wooden storage racks**



### 1.1.7 Train crew account

At 1955 hours on Wednesday 8 February, XPT passenger train ST22 departed from Melbourne on time its final destination was Sydney. Train ST22 travelled through Victoria before crossing the border into NSW and stopping at Albury station. After a shift change for the PSS, the train departed from Albury station, at approximately 2315, to continue the journey to Sydney.

The train arrived at Junee about two hours later where a shift change occurred for the driver. During the handover between drivers the outgoing driver commented on rough riding of the power car through some locations in Victoria, the incoming driver noted this in the power car log book. Train ST22 departed from Junee at 0128, 26 minutes behind schedule. The train lost more time between Bethungra and

Cootamundra due to five signals not functioning and it arrived at Cootamundra at 0307, 81 minutes late.

Train ST22 departed Cootamundra at 0311, passed Jindalee at 0314, and accelerated up Morrisons Hill. While accelerating the driver noticed the wheelslip indicator light illuminating intermittently and the traction motor current meter fluctuating, the frequency of the indications reduced when the train reached track speed. After negotiating a 70km/h curve at the top of Morrisons Hill, train ST22 accelerated. The driver again noticed the wheelslip indicator light illuminating intermittently and the traction motor current meter fluctuating in a similar fashion as before, as well as a muffled clunking noise. The driver called the PSS forward into car 'G', behind the power car, to listen for unusual noises. Train ST22 coasted towards Wallendbeen with no further indications or clunking noises. While accelerating up hill towards Nubba, the driver could feel the power car traction alternating between slipping and gripping, and noted that the effect diminished with a reduction in throttle setting.

Train ST22 coasted through Nubba building speed on the downhill grade before braking for an 85km/h speed restriction at Demondrille Creek and then climbing up hill and passing Demondrille signal box. On the downhill grade towards Harden the driver called the XPT maintenance centre at Sydenham for mechanical support whilst in mobile phone range. During this discussion both the driver and supervisor at the XPT maintenance centre hypothesised what the cause of the symptoms might be. One hypothesis was that the flexible drive link between the traction motor and gearbox had failed causing the unusual symptoms. The driver decided that the best place to inspect the train was at Harden station platform.

Shortly after passing Currawong Creek, the PSS reported to the driver that ballast could be heard splashing up under the train. The driver, who was already slowing the train for a temporary 40km/h speed restriction ahead, immediately stopped the train before the points and crossings at Harden. The time was 0351. The driver exited the train and inspected the left hand side in the direction of travel, finding nothing. He then climbed through the leading door of car 'G' and spoke with the PSS about the ballast noise and a hot metal smell emanating from the right hand side of the train. The driver climbed down and found that one wheel of the trailing axle on the trailing bogie had derailed. The driver informed train control, Harden signal box, and the CountryLink operations supervisor of the situation. Other rail traffic was diverted around the derailed train on an adjacent railway line, the down main line.

### **1.1.8 Post accident response**

At about 0700 hours an emergency breakdown crew arrived to re-rail the derailed wheel. During the re-railing process a further inspection revealed that the axle had completely fractured, shown in Figure 5.



**Figure 5: Axle number 931679 completely fractured in-situ**



Re-railing was stopped pending further investigation. During this time, the passengers remained on board the train until about 0720 when they were transferred to buses to continue their journey by road. Both staff and passengers commented that the transfer went extremely well, both efficiently and in a safe manner. The RailCorp (CountryLink) staff worked cohesively with the assistance of two off-duty railway staff volunteers and the emergency break down crew. Hazards were highlighted with staff members and volunteers positioned to help passengers. An emergency evacuation ladder was set up on the leading end of carriage 'G'. While the ladder had never been used before and did not contain an instruction manual, after initial set up it worked effectively.

**Figure 6: The evacuation of train ST22**



(Copyright ARTC ©)

### **1.1.9 Loss and damage**

An examination of the track determined that the point of derailment was at the 390.325 km point<sup>4</sup> and the derailed wheel had skidded along the gauge face side of the track for approximately 4.2 km before coming to a stop at the 386.100 km mark near the Harden railway station platform. There was only minor damage to track fastenings over this area however, the derailed wheel on train ST22 was severely damaged.

## **1.2 Safety action following the derailment**

As a result of the derailment, RailCorp temporarily suspended all XPT train services pending an engineering examination of power car axles. The initial examination found eight axles that had surface defects of varying size in the radius relief region, similar to the failed axle on train ST22.

RailCorp, in consultation with the Independent Transport Safety and Reliability Regulator (ITSRR) of New South Wales, also initiated 20 day Non Destructive Testing (NDT) inspection cycles when the XPT fleet returned to service. Subsequent examinations found a further four axles with surface defects of varying sizes in the radius relief area, and one axle with a surface defect in the radius run-out area next to the gear seat.

---

<sup>4</sup> Distance from a zero/reference km mark near Sydney Central station.

**Table 1: Summary of XPT power car axles with surface defects**

<b>Axle number</b>	<b>Year of manufacture</b>	<b>Power car number</b>	<b>Bogie number</b>	<b>Last Inspection</b>	<b>Km travelled from last inspection</b>
931679	1993	2001	3B	WS 11/05	88329
95516	1995	Spare UGRFS	~	OH 10/05	0
881733	1988	2004	5B	WS 09/05	135315
87989	1987	2008	26A	OH 04/05	280901
86827	1986	2012	17B	OH 04/05	331942
91778	1991	2014	9B	WS 07/05	208633
85597	1985	2015	18A	WS 05/05	281454
021737	2002	2016	41B	OH 10/05	105921
881725	1988	2016	33B	OH 10/05	105921
89630	1989	2013	32A	W/S 12/05	37700
91774	1991	2013	34A	W/S 12/05	37700
951533	1995	2003	12A	WS 24/7/05	265200
89621	1989	2003	36B	WS 24/7/05	265200
91777	1991	2007	2A	OH 11/05	156684

Note: WS = replacement of bearings and wheels only,  
OH = complete overhaul including gearbox, bearings, and wheels.

A selection of five axles exhibiting cracks which appeared to emanate from the surface defects were taken to the ATSB Technical Analysis Laboratory for more intensive examination. To assist the investigation an independent railway engineering organisation, Interfleet Technology Pty Ltd, was engaged to inspect the train running gear components to determine what factors, if any, contributed to the derailment.

Train ST22 derailed due to the complete fracture of axle number 931679. Examination of the axles on other XPT power cars identified a further twelve axles that had surface defects of varying size in the radius relief region, and one axle with a surface defect in the radius run-out area next to the gear seat all with the potential to lead to fatigue cracks.

This indicated that the failure of the axle on train ST22 may not be an isolated aberrant event and that there may have been a serious systemic problem occurring during the use of power car axles throughout the whole XPT fleet. As a result the investigation focused on the potential causes and mechanisms for crack initiation and propagation including:

- wheel impact load detector data
- axle compliance to design standards
- stress analysis of XPT power car axles
- identifying the possible crack initiators
- maintenance, test and inspection processes
- history of cracked XPT/HST power car axles.

## 2.1 Rollingstock examination

An examination of the components from the derailed bogie and other identified wheelsets (including wheels, wheel profiles, axles, bearings, bogies, suspensions, and braking systems) was conducted at the United Group Rail Fleet Services (UGRFS) facility at Chullora in Sydney. ATSB investigators inspected the derailed bogie (PLA 3B) and the failed axle (wheelset 931679). ATSB investigators also witnessed the testing and measurement of bogie PLA 3B and wheelset 931679 by UGRFS personnel.

### ***Bogie and Axles***

From a visual inspection of the bogie PLA 3B the following points were noted in regard to damage:

- Axle number 931679 had wear marks on the axle probably from contact with the traction motor after the axle failed, as shown in Figure 7. The fracture was orientated perpendicularly to the shaft axis. A considerable portion of each fracture surface had been scored from heavy rotating contact. A small portion of the original fracture still remained and showed evidence of rapid crack progression. Extensive discoloration of these fracture surfaces was indicative of a high level of frictional heating, as shown in Figure 8.
- The gear side wheel on axle 931679 had major damage.
- The traction link arrangement on axle 931679 had damage to the bolt heads from being struck after the axle had failed.
- Axle 931679 had completely fractured between the gearbox and the wheelseat on the axle.

**Figure 7: Axle number 931679**



**Figure 8: Fracture surface of axle number 931679**



Appendix 5.1 tabulates the results of inspections on bogie PLA 3B and axles quarantined as a result of this investigation.

All wheelsets inspected complied with dimensional tolerances for wheel runout, back to back and wheel wobble as defined in the RailCorp documentation TRS 0141-01 'Disassembly/Assembly of Locomotive and Rolling Stock Wheelsets' (dated 16 August 1991).



## ***Bearings***

From a visual external inspection and hand rotation of the bearings, the following points were noted:

- All bearings fitted to the inspected axles were manufactured by Timken
- Grease had leaked from the package bearings on all bearings inspected that had operated in service, this was considered normal
- There was some discolouration of the grease possibly due to water ingress on some of the bearings
- Rust and signs of water ingress were noted on bearing number 532482 fitted to axle number 881733 (see Figure 9)
- Bearing number 251374 on axle number 931679 exhibited internal damage when rotated by hand. This was probably as a result of the axle failure and subsequent derailment.

**Figure 9: Axle 881733 showing signs of water ingress**



The bearings were sent to an independent non destructive testing company for further examination. The following observations were made:

- The internal roller and raceway surfaces of all bearings were noted as being in good condition
- The cup outside diameters for all bearings exhibited varying degrees of fretting wear and corrosion
- All bearings had been through a refurbishment program since their original purchase. They had been marked with Bearing Engineering Services (BES) serial numbers.

The non destructive testing company concluded by stating:

Taking into account their age and service history, all inspected bearings were considered to be in good condition. No areas of concern were identified.

## **Gearbox**

A visual inspection of the gearboxes highlighted the following points:

- Minor leakage on gearbox C65 fitted to axle number 87989
- Oil in gearbox C17 (axle number 931679) showed signs of discolouration with a minor amount of metal particles on the magnetic drain plug
- Dismantling of gearbox C17 showed no apparent internal defects that would have contributed to the failure of the axle.

A sample of oil from gearbox C17 on failed wheelset 931679 was removed and sent for analysis. Test results for viscosity, density and flash point align with the characteristics of BP Transgear 80W-140 oil, which is the designated lubricant. Contaminants identified in the oil include iron oxide, cellulose and inorganic silicates, though only in trace amounts and would have not contributed to the failure of the axle. When the oil drain plug was removed from the gearbox a quantity of metal particles were attached to the magnet plug, which is considered to be normal, shown in Figure 10. There appeared to be no visual major damage to the teeth or bearings after dismantling the gearbox.

**Figure 10: Oil drain plug from gearbox C17**



A sample of new gearbox oil supplied by RailCorp was taken for analysis. The analysis indicated that the sample provided by RailCorp was not BP Transgear 80W-140. It is not known where the new oil sample was collected or whether it was contaminated with oil of inferior characteristics. A second sample of new oil was analysed and the results indicated that the oil was consistent with BP Transgear 80W-140.

## 2.2 Track geometry

Track maintenance and inspection records between Harden and Cootamundra for six months prior to the derailment were reviewed by the investigation team. The track was inspected and maintained in accordance with the ARTC's standards. Additionally, the track between Demondrille and Harden was inspected. The ballast formation was consistent with the ARTC standard. No track defects were found that could have contributed to a rapid and catastrophic failure of the XPT power car axle.

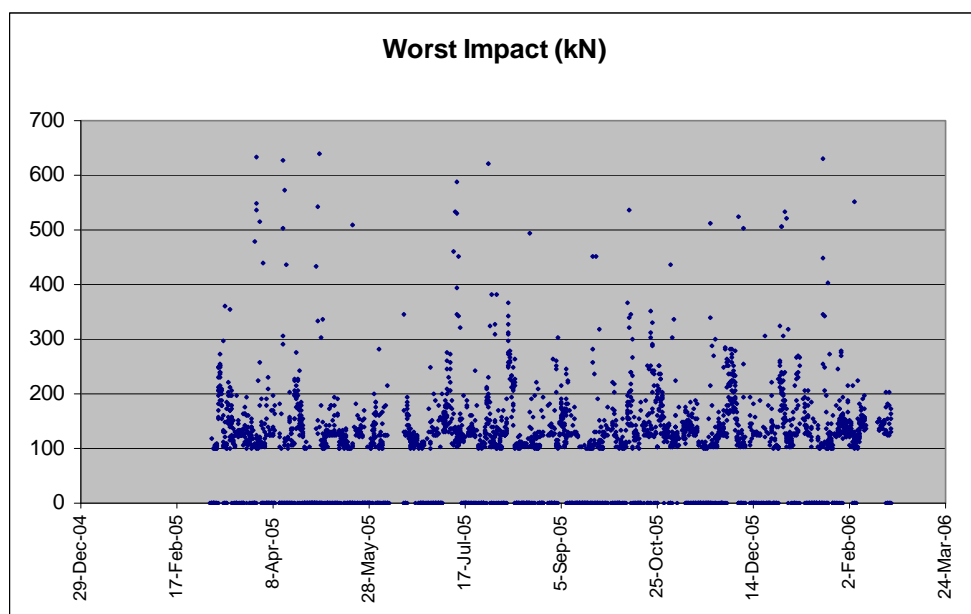
## 2.3 Wheel Impact Load Detector

The ARTC's Wheel Impact Load Detector (WILD) system, developed by Teknis Electronics Pty Ltd, uses a hybrid sensor array consisting of accelerometers and load cells that measure wheel impact and mass respectively, as each axle traverses the array. This information is stored in a database for further analysis. The investigation team analysed the records to determine if there was a correlation between cracked axles and the severity of impacts.

A WILD is located at Moss Vale on the main south rail corridor between Sydney and Melbourne, and monitors passing trains in both directions. All passing wheels are recorded and matched to each rail vehicle via an electronic identification system. Each wheel that passes the WILD is categorised and recorded according to the severity of the impact measured. High level impacts are commonly caused by flat spots, spalling, and skidding of wheels.

The information recorded at Moss Vale between March 2005 and February 2006 was examined by the investigation team. The records contained about 13,250 wheel passes of XPT vehicles, including about 3,630 wheel passes of XPT power cars. Figure 11 shows an overview of WILD records for XPT power cars passing Moss Vale.

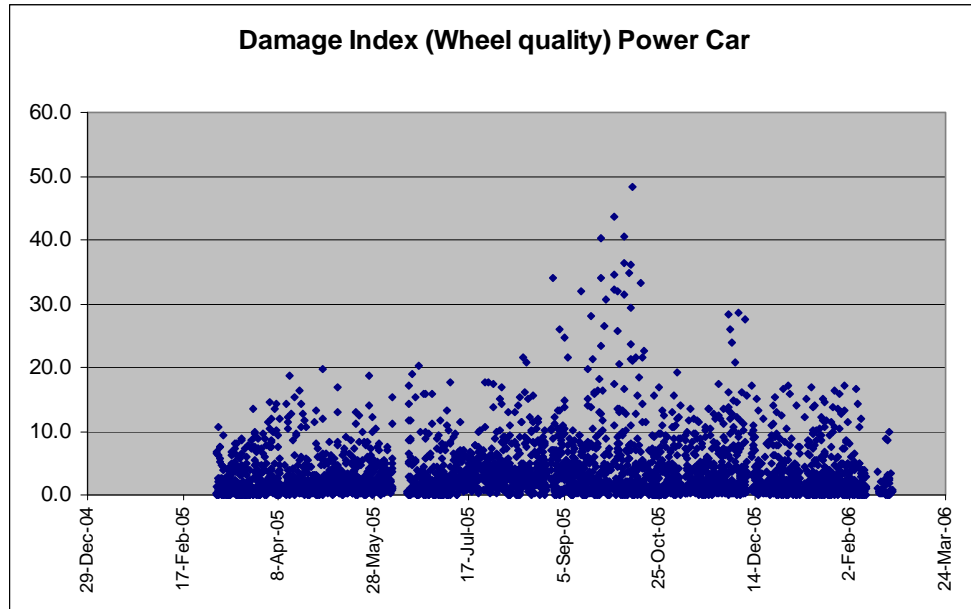
**Figure 11: Overview of XPT power car WILD records**





Each passing wheel impact is measured in units of kilo Newtons (kN). To help with data usability and clarity ARTC apply a mathematical formula to the WILD kN reading to form a numeric scale called a damage index or wheel quality figure. Figure 12 shows the damage index for XPT power car wheels at the same location for the same period.

**Figure 12: Damage index of XPT power car wheels**



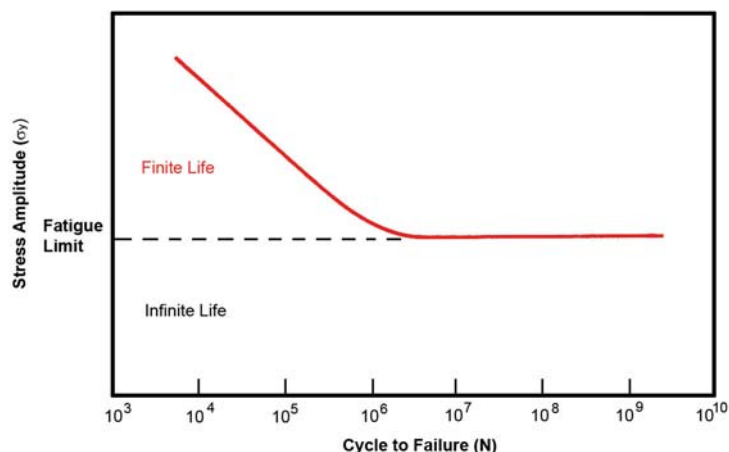
An examination of the WILD data revealed a cluster of relatively high damage index readings between September and October 2005. These readings, along with the measurements (kN) for each XPT power car wheel, were compared with XPT power cars known to have cracked axles. No correlation was found between high level readings for WILD data and damage index and the cracked axles. Although some cracked axles registered high WILD readings, a large number of serviceable axles also registered high readings.

## 2.4 Examination of cracked axles

### 2.4.1 Design

XPT power car drive axles are critical components designed to have an infinite fatigue life. The design for infinite life is addressed by limiting the stresses to which the axles are subjected during their normal service through the use of appropriate material and section thicknesses. Prediction and design for infinite fatigue life can be achieved by ensuring that the nominal stress level within the component does not exceed the fatigue limit for that material. If localised stresses rise to a level above the fatigue limit a reduction in service life occurs due to the initiation of fatigue cracking. The fatigue limit is the nominal cyclic stress level to which a component may operate under for an infinite service life, see Figure 13.

**Figure 13: Fatigue limit**



Four axles were tested for compliance with RailCorp’s manufacturing and design standard, TRS0148.00 ‘High Strength Low Alloy Steel Axles’ (dated 16 February 1995). The document stipulates the minimum strength and alloy composition limits required for the manufacture of forged and heat treated high speed rolling stock axles.

## 2.4.2 Manufacture

### *Tensile and Izod impact testing*

Tensile<sup>5</sup> and Izod<sup>6</sup> impact specimens were prepared from the remnant material from each axle listed in Table 2 and then tested by an external laboratory<sup>7</sup> in accordance with the instructions detailed in TRS0148.00.

One tensile specimen per axle was machined to form and then loaded in uniaxial tension until complete failure occurred. The proof (yield) and tensile strengths of the material were recorded along with percentage elongation. Results of the testing indicated that the steel comprising each axle closely met, or exceeded, the limits specified by RailCorp in TRS0148.00 specification.

Three Izod specimens per axle were machined and tested using the specified test method. The fracture energies recorded by all specimens from each axle met, or exceeded, the material specification for this alloy type.

Appendix 5.2 provides a summary of the axle material properties for each axle compared with the values required in the RailCorp document TRS0148.00.

<sup>5</sup> Tensile test: A method of determining the strength of a material when subjected uniaxial tensile loading.

<sup>6</sup> Izod impact test: A type of test used to determine the impact strength or fracture toughness of a material.

<sup>7</sup> Metlabs Pty Ltd Mechanical Testing Report Number VMT 17542, 17 May 2006.

### ***Chemical testing***

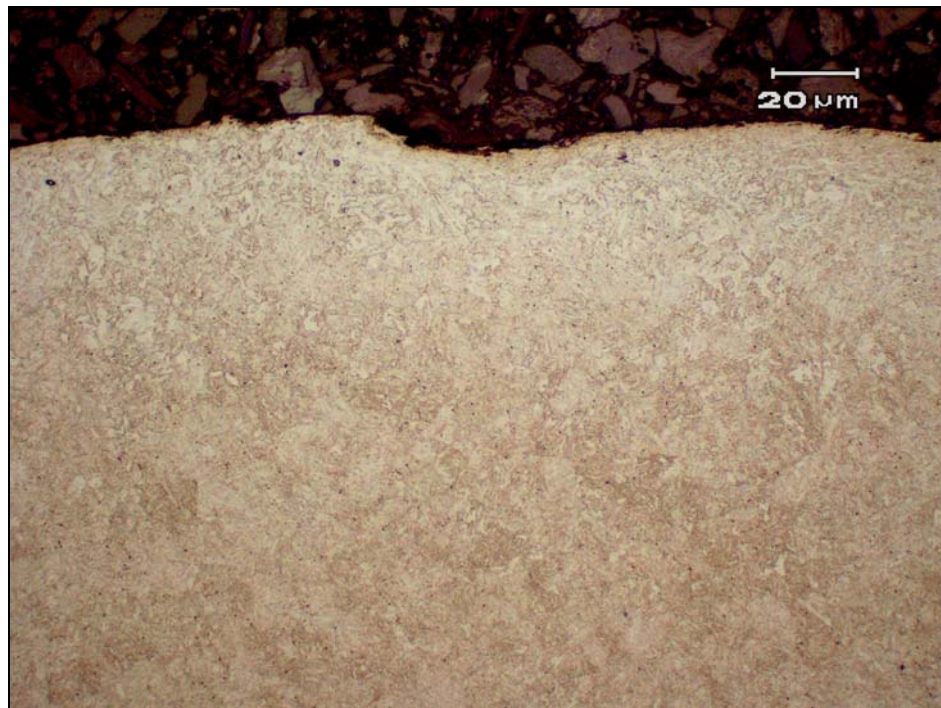
Quantitative chemical analysis of the steel used to manufacture the XPT axles listed in Table 2 was performed by Spectrometer Services Pty Ltd<sup>8</sup>. The results of the analysis indicated that each axle had been manufactured using low-carbon steel with major alloying additions of manganese and molybdenum, see Appendix 5.2.2. The chemical composition of each axle was within the limits specified in TRS0148.00.

### ***Metallography***

In order to examine the microstructure of the material used in the manufacture of XPT axles listed in Table 2, sections of steel both perpendicular and horizontal close to the plane of the fatigue crack were removed and prepared using metallographic techniques. The examination revealed the microstructure of each axle to be mainly comprised of tempered martensite, shown in Figure 14. The microstructure was considered typical for an alloy that had undergone quench and tempering heat treatment.

Some decarburisation of the steel was observed to penetrate approximately 0.1 - 0.2 mm from the surface of each axle. The depth of decarburisation was considered slight and had probably been produced from exposure to a mild oxidising atmosphere during manufacture. Otherwise, the steel comprising each steel section was considered homogenous and clean with no evidence of any sub-surface material defects or inclusions that could have contributed to the axle failures.

**Figure 14: Metallographic section of steel from an XPT axle showing a tempered martensite microstructure**



Note: Etched using 1% Nital.

---

<sup>8</sup> Spectrometer Services Pty. Ltd. Report Reference Number 06/630, 3 March 2006.

### ***Hardness testing***

Hardness measurements of the defective XPT axles listed in Table 2 were performed using a Vickers<sup>9</sup> diamond pyramid indenter and a 30 kg indentation mass. The core hardness values of the axles were found to range between 209 HV and 243 HV, which is typical for low carbon manganese steel of this type and within the required specification. A slight decrease in the hardness levels associated with the slight decarburisation was measured at the surface. See Appendix 5.2 for the results.

### ***Summary of axle compliance with design and manufacturing standards***

Each axle listed in Table 2 that was further examined by the ATSB Technical Analysis Laboratory was found to comply with all aspects of the operator's manufacturing and design standard, TRS 0148.00 'High Strength Low Alloy Steel Axles'.

Mechanical testing confirmed that the tensile and impact strength of each axle<sup>10</sup>, met or exceeded, the requirements in the relevant material specification. Quantitative chemical analysis revealed that each axle was of the correct type and grade, having been manufactured from a low-carbon steel equivalent to the BS 970 605 M30 specification. Metallography of each axle revealed a quenched and tempered martensite microstructure, which was typical for a component of this type and intended use. No anomalies or internal defects were found that could have contributed to the initiation or propagation of fatigue cracking within each axle.

## **2.4.3 Axle stress analysis**

As part of their investigation RailCorp commissioned a strain gauge survey in order to quantify the stresses that might be experienced in an XPT bogie drive axle during service. A finite element model was used to analyse the results of the survey so the effect of axle torque, and vertical and lateral accelerations, on the stress distribution within the axle could be assessed.

The highest stress levels were recorded when the axle was subjected to vertical accelerations<sup>11</sup>. A graphical representation of the calculated axle stresses when exposed to such accelerations is shown in Figure 15. The model indicated that the highest stress levels within the axle were developed in the relief radius between the gear and wheel seat. Moderate stresses were calculated to exist in the radius run-out region when exposed to the same vertical loading. While vertical accelerations were assessed as contributing to the highest proportion of stresses in the axle, rotational acceleration and drive torque were also found to concentrate stresses in the radius relief and run-out as well.

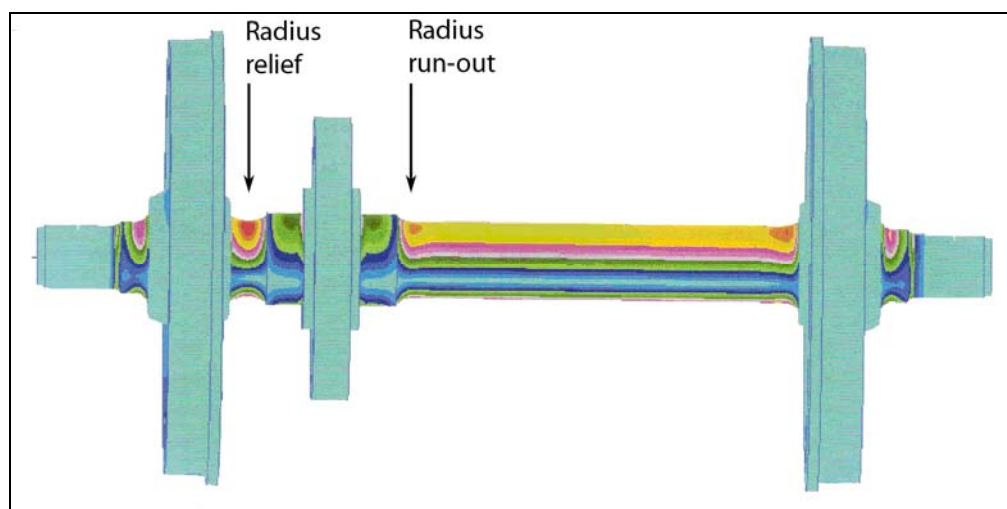
---

9 Vickers Hardness: A standard method for measuring the hardness of a material using a diamond shaped indenter and an applied load.

10 Axle number 91774 measured a tensile stress nine points below the standard of 620 MPa, but it had the second highest proof stress measurement of 454 MPa.

11 Significant vertical accelerations are mainly the result of sudden variations in track geometry.

**Figure 15: Finite element model of an XPT power car axle**



Note: Shows the stress distribution when exposed to 1g vertical loading. The stress gradient decreases in magnitude from red (highest), to blue (lowest).

The report concluded that the most vulnerable area to fatigue cracking was the radius relief between the gear drive and bogie wheel.

#### 2.4.4 Axle failure analysis

The five axles selected by the ATSB for further examination at its Technical Analysis Laboratory in Canberra (shown in Table 2) were tested with a view to determining:

- their failure mode, and
- any significant factors that may have contributed to the cracking in each axle.

**Table 2: XPT axles retained for further ATSB examination**

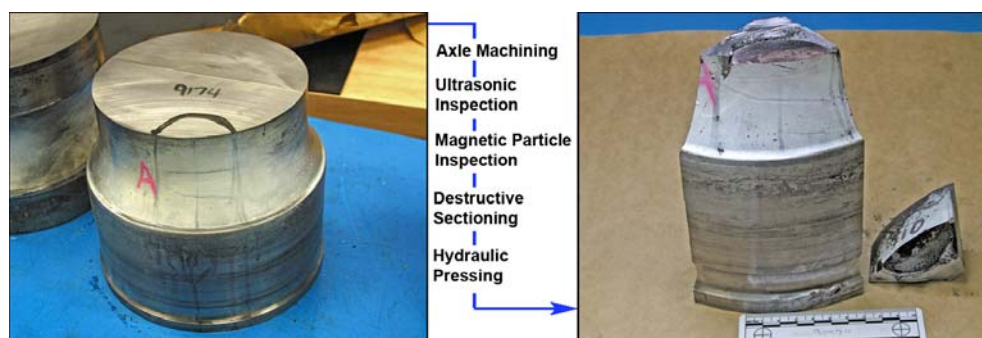
Axle Number	Crack Location	Condition
91774	Radius run-out	Cracked
021737	Radius relief	Cracked
881725	Radius relief	Cracked
87989	Radius relief	Cracked
931679	Radius relief	Fractured

Note: Refer to Figure 3 on page 4 for a schematic of an XPT power car axle.

#### ***Examination methods***

Upon receipt of the XPT axles, each item was photographed and then the size of the surface cracks was established using Magnetic Particle Inspection (MPI) and ultrasonic inspection techniques. Once the cracks were mapped, each axle segment was sectioned and hydraulically pressed in order to expose the crack surfaces, see Figure 16.

**Figure 16: The work process used to open the crack is also shown**



Assessment of the crack surfaces was performed using a binocular microscope and again at much higher magnification using a scanning electron microscope (SEM). Analysis of the axle material was carried out during the examination, including determination of tensile and impact strength, material microstructure, chemistry, and relative hardness.

### ***Fracture surface examination***

#### ***Axle 931679***

Initial laboratory examination of the broken drive axle 931679 from the XPT ST22 confirmed the damaged condition of the fracture surfaces whereby most features of significance had been erased post-failure, caused by hard rotating contact between the fracture faces (shown in Figure 8 on page 10).

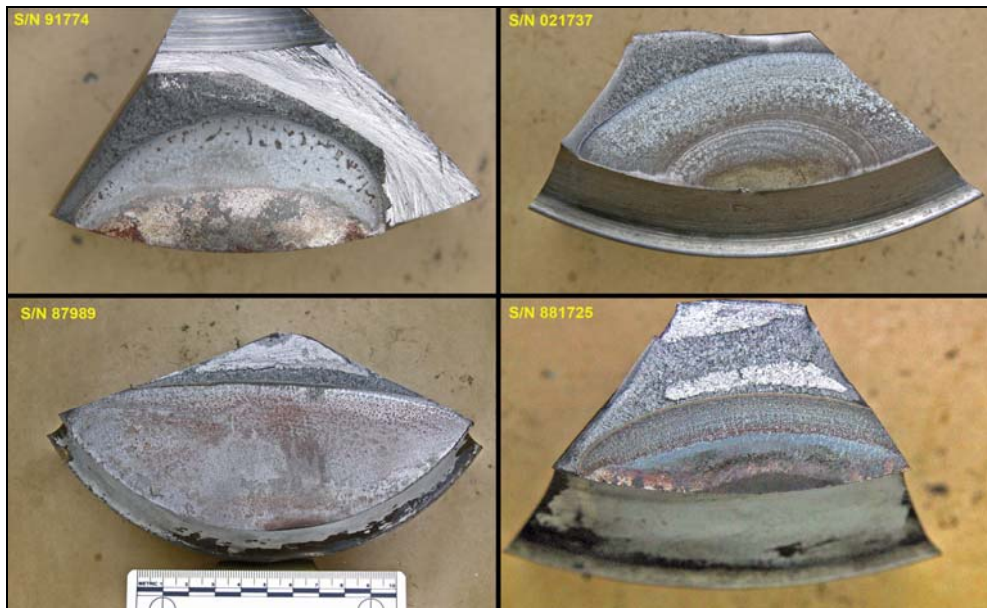
Despite the extensive damage, a small portion of the original fracture remained intact. This area was discoloured from frictional heating and showed evidence of rapid crack progression. No evidence could be found of the fracture origin, nor could the critical crack depth be established, due to the post-failure surface damage. It was noted that the plane of fracture was nearly perpendicular to the axle axis.

#### ***Other axles***

Destructive sectioning and examination of the four other XPT axles revealed that fatigue cracking had developed within each axle. Beach marks clearly defined the progression of each fatigue crack. The cracks had propagated from the radius relief and run-out areas and grown transversely into a semi-elliptical shape. A general accumulation of corrosion and fretting products was observed on each of the crack surfaces, which was consistent with the cracks growing over a substantial period of time. Figure 17 shows a composite view of the axle fatigue crack surfaces.



**Figure 17: Composite view showing the axle fatigue crack surfaces**

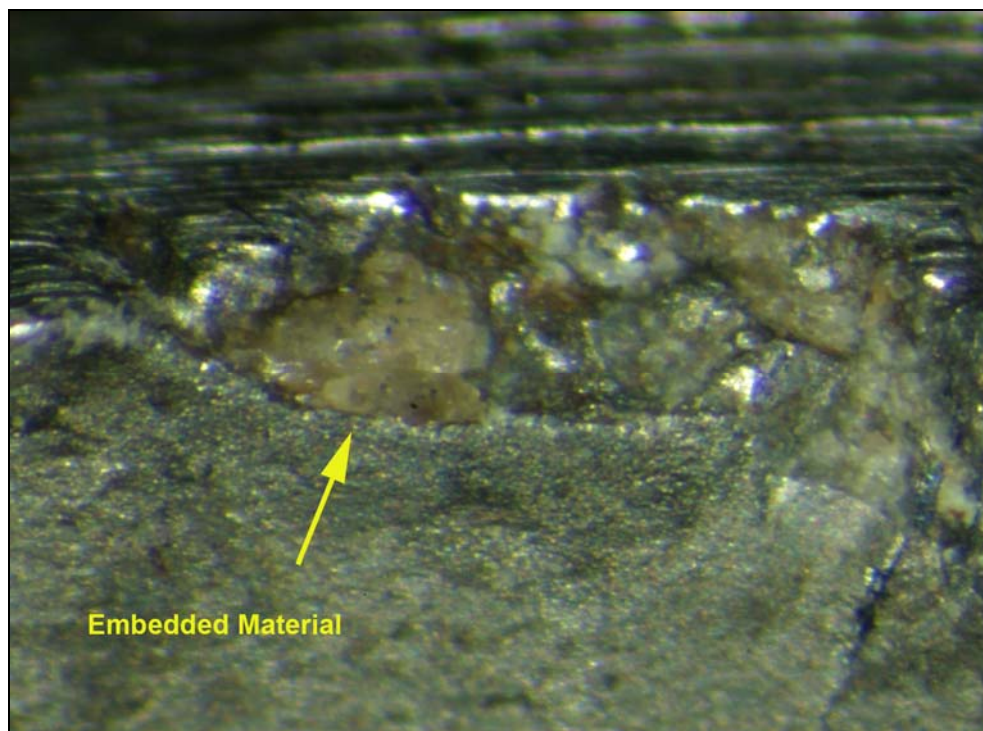


Of particular note during the examination was the presence of irregular surface damage at each crack origin. The general shape of each indentation suggested that they had been mechanically produced. No evidence was observed in or around the indentations to indicate they had been produced by corrosive processes. Low power optical examination revealed that a crystalline material was still embedded within all of the indentations, see Figure 18 and Figure 19.

**Figure 18: Indentation damage (circled) on XPT axle 021737**



**Figure 19: Close-up of embedded material (arrowed) within the indentation damage from XPT axle 021737**



Measurements revealed the defects ranged in depth between 0.1 mm and 0.9 mm. See Appendix 5.2.3 for fatigue crack and initiating defect measurements.

The general size and depth of the indentation damage on each axle was quite small. Although the surface damage was relatively minor, it was present in areas where the service stresses were concentrated and the axle was vulnerable to fatigue. Even though the damage was minor, the evidence indicates that these flaws were sufficient to increase the localised stress intensity above the designed fatigue limit, resulting in a reduction in fatigue life.

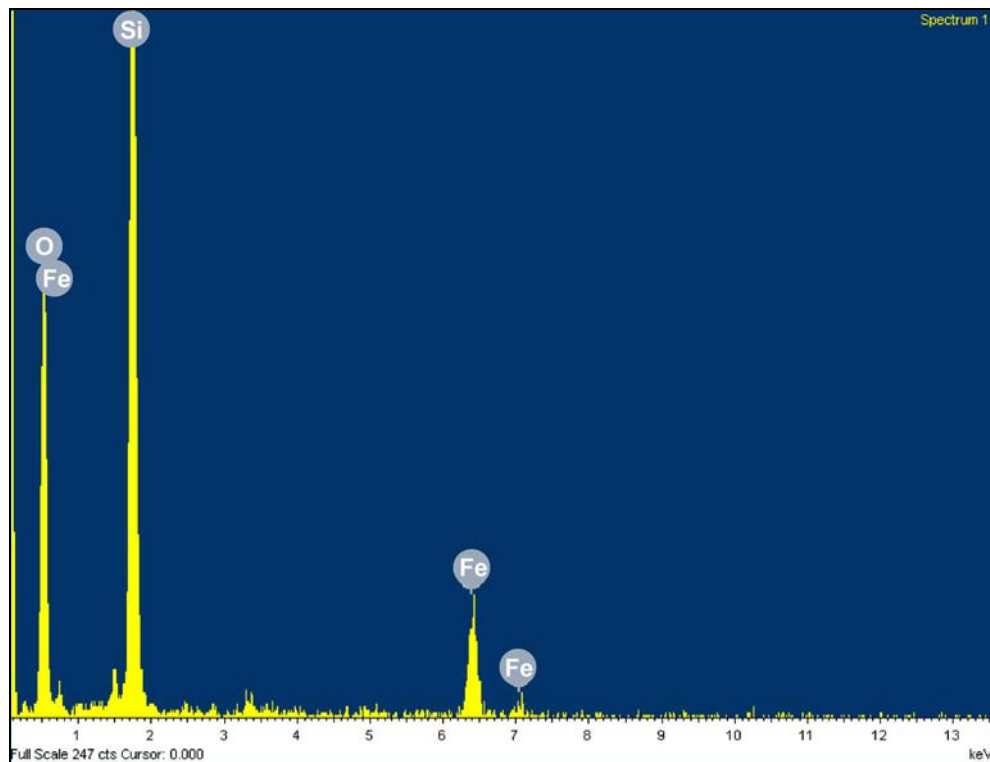
### ***Surface indentation analysis***

In order to identify the foreign crystalline material embedded in each of the axle indentations, semi-quantitative chemical analysis was performed using the energy dispersive spectrometer (EDS) attachment on the SEM.

The analysis revealed the composition of the embedded material to be largely silicon (Si) and oxygen (O). See Figure 20 for a representative EDS chemical spectrum. The chemistry of the embedded material was consistent with a rock or mineral aggregate, such as the type used in track ballast.



Figure 20: EDS chemical spectra of the embedded crystalline material



Note: Si = Silicon, Fe = Iron, O = Oxygen.

## 2.4.5 Summary of axle failure analysis

### ***Harden axle failure XPT ST22***

The drive axle 931679 from XPT ST22, fractured due to the initiation and propagation of a fatigue crack. Despite the loss of most fracture surface details, the transverse orientation of the crack plane through the axle and the presence of crack progression marks was evidence to indicate that a fatigue crack had been the primary failure mechanism. Once the crack had grown to a critical size, the axle was unable to withstand further operational stresses, resulting in overload of the remaining net section causing wheelset instability and eventual derailment. A defect at the crack origin could not be identified due to the post-failure contact damage on the fracture surfaces.

### ***Cracking in other XPT axles***

Failure of axle 931679 from XPT ST22 as the result of a fatigue crack was further supported by the discovery of other XPT drive axles with cracks in the same location. When four of these axles were examined, it was confirmed that in each case that fatigue cracks had propagated from the relief region. Three cracks were located in the radius relief area next to the gear seat, and one crack was located in the radius run-out area. A range of fatigue crack depths were found with a maximum depth measuring 58.3 mm.

The transverse plane and elliptical shape of each crack indicated that in each case loads from rotational bending were driving the fatigue cracking. The general feature

of each crack was indicative that they were propagating under high-cycle, low-stress conditions.

The origin of each fatigue crack was coincident with a mechanically produced indentation within the relief radius surface of each axle. In each example the damage was relatively small, measuring between 0.1 mm and 0.9 mm in depth. The crystalline material embedded in the indentations was consistent in chemistry with that of a rock aggregate, which indicated that a track ballast strike had probably caused the damage. Ballast strike may occur when the track ballast level is too high or when ballast is thrown up during the passage of the train, generally by dragging equipment. Given the shape of the indentations and the embedded nature of the crystalline material within the surface indentations, it was considered very unlikely that another object may have impacted on the axle and forced any coating of ballast dust into the indentation (Figure 19).

## **2.5 Maintenance, testing and inspection**

The XPT fleet is maintained by RailCorp in the maintenance centre at Sydenham using a planned maintenance and condition monitoring program. A trip inspection is carried out each time a train arrives at the Sydenham maintenance depot with more comprehensive inspections and maintenance carried out every 90 days. There are 10 different maintenance levels, which include running and trip inspections and eight different 90-day maintenance levels designated A–H. The maintenance regime is largely based on manufacturer’s recommendations and is modified when condition monitoring dictates the need to focus more effort on specific items.

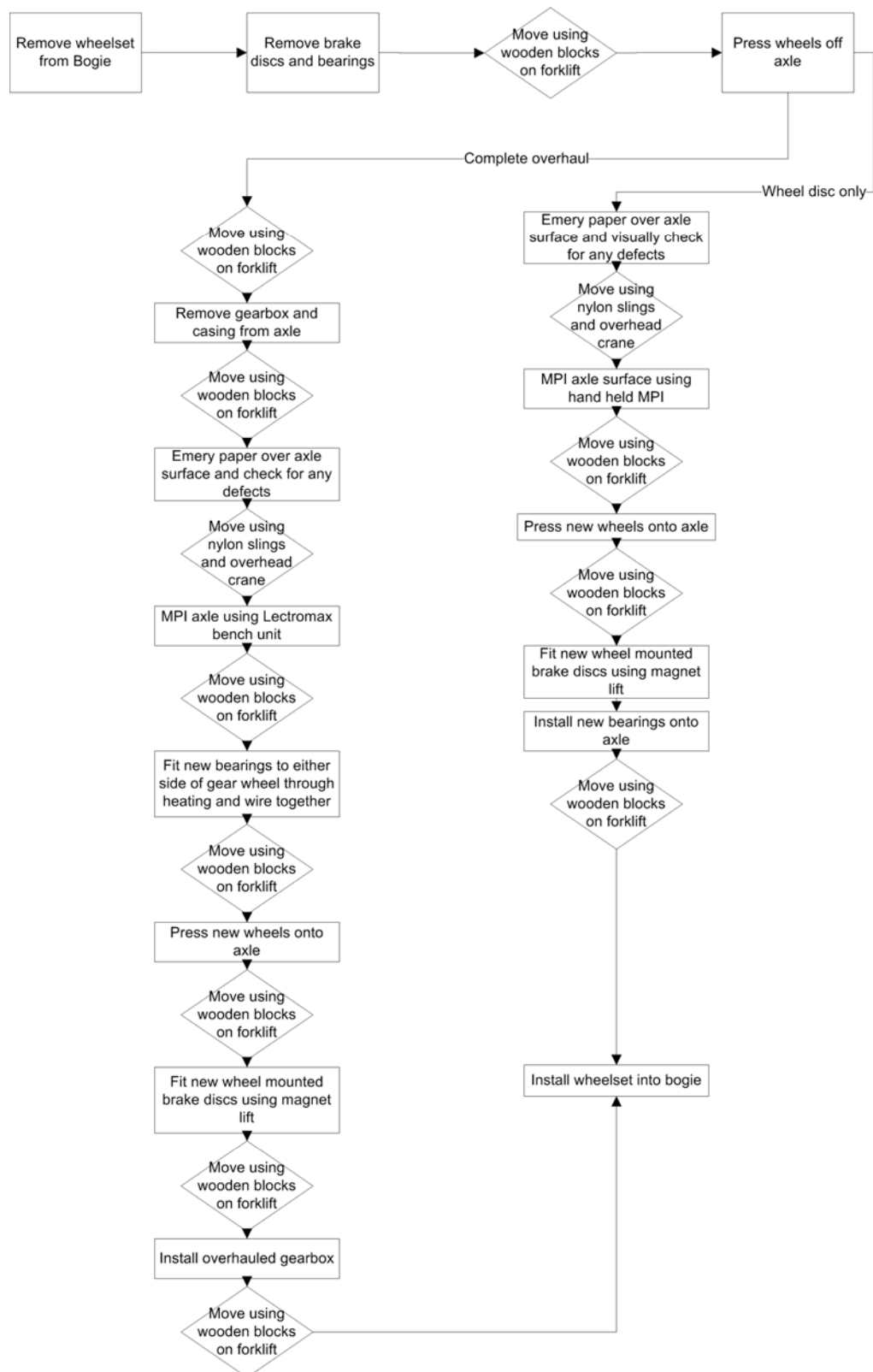
Maintenance scheduling and recording is facilitated by a computer based maintenance program. Regular inspections and maintenance tasks are performed using standardised and documented procedures. Each inspection or maintenance task is divided into a number of trade specific parts and an inspection sheet is issued for each different trade (mechanical, electrical, car and wagon examiners, plumbers, car builders and trimmers). The inspection sheets provide specific instructions on how to perform the maintenance and include a checklist, which must be completed and signed off by the tradesperson performing the maintenance. After a maintenance task is completed, the entries on the inspection sheets are entered into the computerised maintenance program.

Maintenance records showed that the consist of train ST22, including power car XP2001, underwent regular inspection. The periodic inspections included power car bogie components such as the axle, gearbox, and wheels. No abnormal damage was noted.

### **2.5.1 Wheelset overhaul**

Power car wheelsets are overhauled as part of a bogie exchange program where the complete bogie is removed from the XPT power car at the Sydenham maintenance centre and sent to the Chullora facility for disassembly and overhaul, shown in Figure 21.

**Figure 21: Wheelset overhaul process**



No parts of the process were identified that could have contributed to mechanical damage to the radius relief and run-out areas. No major change to the process has occurred in the past 3 years, the last major change being the implementation of a magnet lift to install the wheel mounted brake discs (approximately 2001).

Previously, this was performed by manual lifting which may have been a source of damage to the axle if the disc was rested or dropped there. The current method supports the disc utilising a crane and it is supported until the bolts are installed minimising the risk of dropping the discs.

All XPT power car wheelsets since the XPT was introduced have been overhauled at the Chullora facility. During this time the operator of the site has changed from State Rail Authority (SRA) to Alstom and then to the current operator United Goninan Rail Fleet Services (UGRFS). All components of the XPT wheelsets are overhauled at Chullora apart from the axle bearings. The axle bearings are currently sent out to Bearing Engineering Services for re-qualification and overhaul, though a lifespan limit of 10 years is placed on them.

Wheelsets are currently overhauled at the following intervals:

- 400,000 km – Overhaul includes replacement of the wheel discs and overhaul of the axle bearings and brake discs.
- 800,000 km – Overhaul as per 400,000 km plus gearbox overhaul.

Table 3 contains a summary of the maintenance history of the five axles examined in detail by the ATSB. The table shows the previous two axle maintenance cycles, their date and the type of service.

**Table 3: Summary of maintenance history**

Axle Number	Kilometres Travelled #	Year of Manufacturer	Last Service	Service Type	Previous Service	Service Type
91774	37700	1991	01/2006	WS	03/2005	OH
021737	105921	2002	10/2005	OH	12/2003	WS
881725	105921	1988	10/2005	OH	12/2003	WS
87989	280901	1987	04/2005	OH	10/2003	WS
931679	88329	1993	11/2005	WS	04/2005	OH

Note: # = Kilometres travelled since last service

WS = replacement of bearings and wheels only,

OH = complete overhaul including gearbox, bearings, and wheels.

## 2.5.2 Axle crack testing

Prior to the derailment, RailCorp's policies for testing rollingstock axles including those for the XPT fleet, were set out in document TRS 0165.01 'Non Destructive Testing of Axles' (dated 16 February 1995). The document contained the various requirements and procedures to be used for axle inspections both in service and during overhauls. The Chullora workshops were equipped with a range of crack detection equipment to carry out Ultrasonic Axle Testing (UAT) and Magnetic Particle Inspections (MPI) of axles during overhauls. TRS 0165.01 contained detailed guidance and on how and when to conduct these tests and acceptance/rejection criteria for the axles being tested.

### *In service testing of axles*

With respect to in service testing of axles, TRS 0165.01 states:

2.0.6. For Axles with Road Wheels Fitted & <3 Years Since Last Inspection:

The exposed portions of the axle shall have a visual inspection. No MPI or ultrasonic testing is required unless the operator considers there is a need for additional testing.

The effect of these requirements is that the only in service testing of axles was a visual inspection, neither UAT nor MPI were required if it had been less than three years since the previous wheelset inspection (during overhaul). In theory this meant that prior to the derailment, an XPT wheelset may have run for up to six years without receiving anything more than a visual inspection. However, in practice, the short service life of XPT wheels meant that the wheelsets were overhauled well before in service testing was required. (Based on the maintenance history of the five axles examined by the ATSB in Table 3, the maximum time between services was 22 months.)

### ***Testing during axle overhauls***

The XPT axles were subjected to various crack tests during overhaul depending on the type of service. For a wheelset overhaul, (replacement of wheels and bearings where the gearbox remained mounted on the axle), the exposed portions of the axle were visually inspected followed by a MPI inspection of the axle barrel, wheelseats and the bearing journal and abutments. In this instance a MPI was performed using hand-held equipment as it was not possible to fit the axle into the workshop's Lecromax MPI bench with the gearbox mounted on the axle.

**Figure 22: Lectromax MPI bench with axle in-situ**



For a full axle overhaul where the gearbox was removed from the axle (where the gearwheel remained mounted, Figure 22) MPI was conducted using the Lecromax bench. The requirement stated in TRS 0165.01 was:

2.0.4. For Axles with Gear Mounted:

The exposed portions of the axle shall have a visual inspection followed by a magnetic particle inspection (MPI) of the axle barrel (including suspension journals where applicable), road wheelseats and the bearing journal/abutments. There is no need for ultrasonic testing of the wheelseat.

It is unclear whether or not a crack in the radius relief or run-out areas adjacent to the gear wheel seat would have been detected during these MPIs as there was no requirement to focus on these areas during the inspection. In addition, the proximity of the gear wheel may have made indications of any crack more difficult to detect.

Where the gearwheel was found to be damaged during past overhauls it was removed from the axle and in this instance the crack test requirements of TRS 0165.01 were:

2.0.3. For Used and Reworked Axles Without Wheels, Gear or Bearings:

The entire axle shall have a visual inspection followed by a magnetic particle inspection (MPI) of the axle barrel (including suspension journals where applicable), gear seat, road wheelseats and the bearing journal/abutments. There is no need for ultrasonic testing of the wheelseat.

TRS0165.01 does not specifically refer to the testing of the radius relief and run-out areas on the axle although these areas would normally be subjected to a MPI at the same time as the adjacent gear wheel seat.

With respect to the gearwheel seats TRS0165.01 had a clause 2.0.8, which stated; 'As there is no history of cracking at gear wheel seats, this area does not require ultrasonic inspection.' This indicates that as there had been no history of problems in the past, surveillance of radius relief and run-out areas was probably less than ideal. These areas had probably only been subjected to a targeted MPI during previous overhauls when the gear wheel was removed. There was no correlation in records between the removal of the gear wheel and cracked axles.

The only requirements to conduct UAT specified in TRS0165.01 was for new axles or for axles with road wheels and bearings fitted which had run more than three years since the previous inspection. In the case of XPT axles, where the time between overhauls was less than three years and wheels were routinely removed, there was no UAT performed on axles during any overhaul. It is of note, however, that following the derailment of ST22 due to failure of axle 931679, RailCorp (in conjunction with ITSRR) conducted ultrasonic examinations of all XPT power car axles on cycles of not more than 20 days.

### ***Axle defect limits***

RailCorp document TRS0165.01 stipulates that axles containing cracks are to be rejected. The document also states:

3.1.2 Fine longitudinal discontinuities variously termed hairlines, stringers or fine seams are not considered injurious if they meet the following conditions:-

- Must not extend into fillets and must not have any sharp edges.
- Must not be over 12mm long individually.
- Total sum length of such imperfections 6mm to 12 mm long must not exceed 38mm in any 300mm of axle length.
- Within any 75mm length there may not be more than two such imperfections 6mm to 12mm long in line with each other.

In addition to the requirements contained in TRS0165.01, the document refers to another RailCorp document TRS 0141-01 'Disassembly/Assembly of Locomotive and Rolling Stock Wheelsets' (dated 16 August 1991). This document specifies additional defect limits and permits reclamation of axles with nicks, gouges or deep scratches up to 3 mm deep. The documentation specifies that defect indications must not extend into transition radii (radius relief and run-out areas) and must not have sharp edges. Axles with visible defects in these areas would be condemned. There are no defect limits specified for the wheel, gear wheel seats or bearing journal areas of XPT axles, nor are there any limitations on cumulative defect indications aside from those quoted in TRS0165.01.

Document TRS-0141-01 does not place any restriction on which sections of the axle can be reclaimed, nor does it specify any blending<sup>12</sup> requirement apart from a general comment that it should be blended smoothly.

### 2.5.3 Crack growth rate and previous MPIs

Overhaul documents for the wheelsets identified with cracks were provided dating back to 2001. A review of these records showed that for all quarantined wheelsets the MPI had been performed as required and signed off. A separate log of MPIs was also provided that recorded every wheelset that had been inspected since June 2003 and who had performed the inspection. All of the quarantined wheelsets were identified as being inspected at the times where they had previously been overhauled at Chullora. These records also indicated instances where axles had been condemned due to indications of a crack or fault identified during the MPI process. The fact that these axles were later found to have fatigue cracks suggests that the previous MPI's were inadequate.

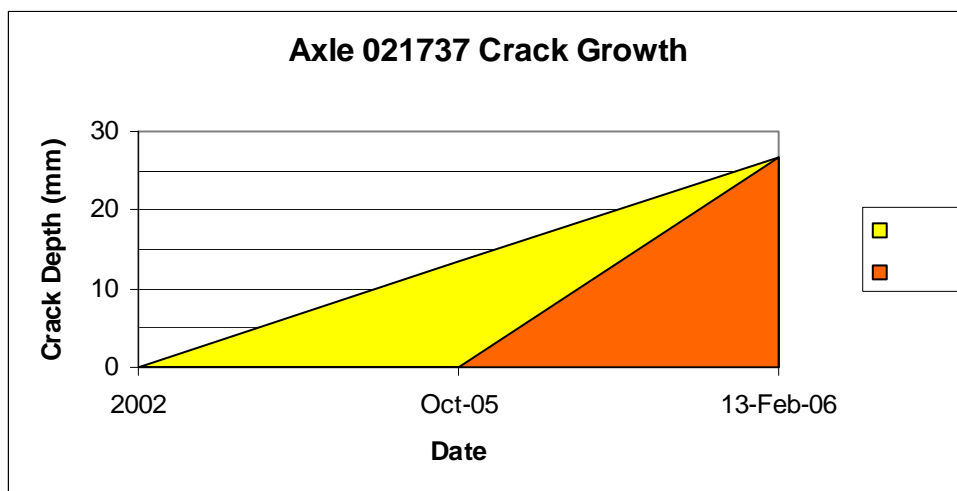
RailCorp's maintenance records showed that the fractured axle, 931679, had last been inspected in November 2005. At this time the axle inspection included the replacement of the bearings and wheels. During this inspection a MPI was conducted using the handheld equipment. The axle had subsequently accumulated an additional 88,329 km of normal service prior to its failure on 9 February 2006. Given the short period of time in service, it is considered unlikely that a crack had initiated in the period following the previous inspection and then developed to full failure under normal operating conditions. This means that a crack would probably have been present when the axle underwent the MPI in November 2005.

As an example of minimum crack growth rate axle 021737 was chosen, because it was the youngest axle, to graphically represent a growth rate, shown in Figure 23.

---

<sup>12</sup> Blending is used to describe the action of removing an axle defect with a grinder or similar.

**Figure 23: Axle 021737 Crack Growth Rate**



The date of manufacture (DOM) and date of the last overhaul (OH) are two datum points used for calculating a fatigue crack growth rate. The yellow area in Figure 23 represents a crack growth rate based on a fatigue crack initiating and propagating, from the time of manufacture (DOM) in 2002 until the date of detection. The orange area represents a crack growth rate based on a fatigue crack initiating and propagating, from the time of the last overhaul (OH) until the date of detection. The only reliable datum point is considered to be the DOM. In this example the minimum crack growth rate would be from the DOM, the maximum based on a fatigue crack initiating and propagating rapidly immediately before detection.

Given the characteristics of each fracture surface examined, the cracks had been propagating in each axle for a considerable time period. It is more likely that the actual crack growth rate in each axle is within the yellow area. Exactly how long the cracks had been propagating in each axle could not be accurately determined but the cracks were very likely to have been present during the previous inspections.

#### **Lectromax MPI Bench**

The Lectromax MPI test bench (shown in Figure 22), used to inspect axles during overhaul, was audited for compliance with Australian Standard AS1171 (Non-destructive testing - Magnetic particle testing of ferromagnetic products, components and structures) and the applicable RailCorp standards. The audit concluded that:

- The machine was in fair condition
- The calibration standardisation certification was overdue
- The fluid was contaminated and not suitable for MPI operation due to insufficient volume of magnetic particles in suspension
- Record keeping was not sufficient
- The volume of magnetic particles in wet suspension was not measured or recorded before machine use
- MPI operators are trained to the RailCorp standard TRS1426.01 Magnetic Particle Inspection & Dye Penetrate Inspection.



An examination of RailCorp documentation identified that no process existed to check that the magnetic particle suspension fluid complied with the Australian Standard AS1171. Similarly, an examination of UGRFS work practices identified that there were no regular inspections or processes to ensure that the MPI equipment was calibrated and 'fit for purpose'.

It is likely that the deficient condition of the Lectromax MPI bench contributed to the failure to detect fatigue cracking in XPT power car axles for a considerable period of time.

#### **2.5.4 Axle painting**

RailCorp document DSS 5196.01 'Wheel Set Overhaul Maintenance Specification for PLA Bogies' (dated 31 January 2001) states that axles are to be painted between wheel seats. However, no examined or observed XPT power cars axles were painted. It is not known why this painting had not occurred in the past but RailCorp issued an instruction to UGRFS on 19 July 2006 that axles must be painted to comply with DSS5196.01.

It is not known if painting the axles would have reduced the likelihood of fatigue cracking as a result of ballast strikes or indeed if paint would have either highlighted the presence of, or concealed, the visual evidence of any cracking.

#### **2.5.5 Summary of maintenance, testing and inspection**

- No part of the overhaul process were identified that could have contributed to mechanical damage to the radius relief and run-out areas.
- The short service life of the XPT wheelsets meant that in-service MPI and UAT testing was not required.
- MPI testing during wheelset overhaul was conducted using hand held equipment every 400,000 km.
- MPI testing during wheelset overhaul was conducted using bench equipment at every 800,000 km.
- No ultrasonic axle testing was performed as part of the overhaul process.
- Although a definitive rate for the propagation of the fatigue cracks could not be established, the propagation of the cracks was determined to be consistent with a low stress and high cycle mechanism. Given that it was likely that the cracks propagated over a relatively long period, an effective maintenance regime should have detected the cracks before they reached to point where they led to total axle failure.
- MPI testing of XPT axles after the Harden derailment found cracks in the radius relief and runout areas. It is likely that MPIs conducted during previous axle overhauls did not detect the earlier stages of these cracks.
- The condition of the Lectromax MPI bench was deficient in that the certification was out of date, the magnetic particle fluid was not suitable for operation, and there were no regular inspections.
- The axles when inspected were not painted as required by document DSS 5196.01 nor did they show signs of paint from previous overhauls.

## **2.6 High Speed Train (United Kingdom) comparison**

The bogies and wheelsets used on the XPT power cars are similar to those fitted to the High Speed Train (HST) in service in the United Kingdom. Since the introduction of the HST into service in the mid-1970s, HST wheelsets have occasionally suffered from fatigue cracking and the lessons learned have led to improvements in the HST wheelset maintenance and overhaul regime. It should be noted that the XPT operates in a different environment to that of the HST in that there is a greater percentage of curves, tighter curves, steeper gradients, and more significant transitions. Appendix 5.6 lists the documentation for the UK and Australian maintenance procedures. A table documenting the differences between the two processes is shown in Appendix 5.3. Where relevant, the differences are summarised in the following sections.

### **2.6.1 In service testing of HST wheelsets**

There are currently three main operators of HSTs in the UK, each with its own maintenance documentation. However, all three operators use a similar in-service testing for power car wheelsets. The axles are ultrasonically crack tested at approximately 120,000 mile (193,121 kilometres) intervals (or about every 30 weeks) in accordance with Technical Procedure TL/NP0211<sup>13</sup>. The maximum interval between in-service UAT on the HST power car wheelsets is 12 months.

In service MPI is not carried out.

### **2.6.2 Overhaul of HST wheelsets**

HST power car wheelsets are overhauled every 500,000 miles (approximately 800,000 km) or two years, at which time both MPI and UAT are carried out.

In the UK, maintenance procedures require that UAT is carried out after the wheelset has been overhauled ie. once it has been completely built up. This is to ensure that any damage caused by the assembly process (e.g. a damaged wheelseat) is identified before the wheelset enters service. However, overhaulers often choose to UAT the bare axle as well to avoid assembling a wheelset that has a cracked axle. All axles are painted in accordance with UK requirements CR/CP0102.

### **2.6.3 Defect limits for HST axles**

UK documentation only permit reclamation of HST axles when the defect has a maximum damage depth of 1 mm. Documentation specifies that there shall be no defect indications that are >5 mm in length and/or 0.25 mm deep in transition radii (radius relief and run-out areas) or the adjacent 10 mm wide zone, and may not be closer than 25 mm to each other. Defect limits (length, depth and proximity) are also specified for the wheel, gear wheel seats or bearing journal areas of HST axles and no more than 10 defect indications are permitted in any axle.

---

<sup>13</sup> Technical Procedure TL/NP0211 Ultrasonic Axle Testing Procedure Chart Number 22 Part 4 for testing of HST Power car Axles – Testing at Wheelset Overhaul.

Where the damage is no more than 1 mm deep, reclamation may only be carried out on the main parallel portion of the axle. Damage in other sections of the axle cannot be repaired. UK documentation also requires that the damaged area be blended in over a length of at least 60 mm with strict requirements for the direction and surface finish of the blending.

A table at Appendix 5.4 is a comparison of the UK and Australian defect limit requirements.

## **2.7 History of cracked XPT/HST power car axles**

### **2.7.1 Australia**

Statistics provided by RailCorp indicate that in the period from 2000 until 17 February 2006, 490 axles had been overhauled. Of these overhauled axles 29 were scrapped for various reasons including one axle for failing non-destructive testing and one for failing inspection. No other details were provided.

### **2.7.2 United Kingdom**

During a scheduled vehicle examination on 26 Jan 1992, a crack was found in a HST power car wheelset. The defect was found by a routine in-service ultrasonic axle test that was carried out every 10-12 months. The crack was situated in the radius relief between the gearwheel seat and the seat of the adjacent road wheel, about 500 mm from the axle end. The crack was found to be 21mm deep and 70mm long at the surface. A small cavity, about 0.5mm x 1.0mm was visible at the approximate mid-point of the crack.

The subsequent metallurgical examination of the axle determined that the crack was due to fatigue that had propagated from the small cavity. The metallurgist determined that the crack had probably grown from a size that had been undetectable at the previous UAT which had been carried out during the wheelset's previous overhaul on 21 March 1991. In the space of 10 months, the crack had grown from an undetectable size to 21mm deep.

The metallurgist determined that the small cavity was probably the result of a mechanical indentation or the remains of one left after its attempted removal using emery paper.

Hardness tests and chemical analysis showed that the axle met the British Rail requirements for steel for that application.

The metallurgist recommended that the risk of indentation damage to HST power car wheelsets could be reduced by ensuring that the bearing end plates are not allowed to fall on to the axle when they are released from the gear boxes. The bearing end plates could be wired to prevent this. A second recommendation was that an approved procedure be developed to enable any axles with surface scores or indents on critical radii to be rectified to an acceptable standard and the surface finish restored.

In parallel to the metallurgist's report, a second review was carried out to determine the effectiveness of the ultrasonic tests on HST power car axles. The review showed

that the UAT according to the procedures in place was unable to find a defect of up to 3mm deep in the area between the road wheel seat and the gearwheel seat.

It was therefore reasonable to conclude that the crack in the HST axle had initiated from an indentation that was less than or equal to 3mm in depth and propagated to a 21mm deep crack in the space of 10 months.

As a result of this finding, MPI of HST power car axles was implemented at wheelset overhaul. In addition, an approved procedure was developed for the reclamation of damaged HST axles such that the surface finish is restored to an acceptable condition.



---

## 3

## FINDINGS

---

From the evidence available, the following findings are made with respect to the derailment of train ST22 at Harden, New South Wales on 9 February 2006.

These findings identify the different factors that contributed to the occurrence and should not be read as apportioning blame or liability to any particular individual or organisation.

### 3.1 Contributing Factors

These findings identify the various events and conditions that increased safety risk and contributed to the occurrence.

1. Train ST22 derailed as a result of axle 931679 completely fracturing. The axle fractured due to the initiation and propagation of a fatigue crack. Once the crack had grown to critical size, the axle was unable to sustain further operational stresses, resulting in overload of the remaining net section which caused a complete fracture. The complete fracture caused the wheelset to become unstable on the rail and eventually derail.
2. The radius relief and run-out areas, adjacent to the gear wheel seat, are two of the most highly stressed areas of XPT axles.
3. The initiator for the fatigue cracks in each of the axles examined by the ATSB was likely to be an embedded particle as a result of a track ballast strike.
4. It is likely that the fatigue crack had been present and not detected during the previous wheelset overhaul(s).
5. RailCorp's non-destructive testing practices for XPT axles prior to the derailment, specifically the magnetic particle inspections, were ineffective in detecting cracks in the radius relief and run-out areas of the axle.
6. The deficient condition of the Lectromax magnetic particle inspection bench probably contributed to the failure to detect fatigue cracks for a considerable period of time.

### 3.2 Other Safety Factors

These findings identify other events and conditions that increased the safety risk.

1. The radius relief and run-out on XPT power car axles are the most vulnerable areas to fatigue cracking.
2. All rollingstock axles are exposed to a risk of failure as a result of fatigue cracking initiated by ballast strike without appropriate detection and intervention strategies.

### 3.3 Other Key Findings

These are findings that are not defined as safety factors or may be positive events and conditions that reduced the risks associated with the occurrence.

1. Train evacuation went very well, apart from the emergency ladder having no instructions.
2. All inspected wheel bearings were considered to be in good condition.
3. Gearbox C17 showed no apparent internal defects that would have contributed to the axle failure.
4. Power car XP2001 underwent regular in-service inspections.
5. No part of the overhaul process were identified that could have contributed to mechanical damage to the radius relief and run-out areas.
6. Mechanical testing by the ATSB confirmed that each axle met or exceeded RailCorp TRS0148 High Strength Low Alloy Steel Axles standard dated 16 February 1995 (results attached).
7. Quantitative chemical analysis confirmed that each axle tested by the ATSB was the correct type and grade for low carbon steel, equivalent to BS-970-605-M30 specification (results attached).
8. Metallography confirmed a quenched and tempered martensite microstructure with no internal defects or anomalies (see attached photo).
9. There was no correlation between Wheel Impact Load Detector data and cracked XPT power car axles.
10. The fatigue crack growth rate for each axle could not be accurately determined, however the propagation of the cracks was determined to be consistent with a low stress and high cycle mechanism.
11. The UK standards for HST power car axles are more prescriptive than RailCorp standards.
12. XPT axles were not being painted before 19 July 2006.



---

## 4

## SAFETY ACTIONS

---

As a result of its investigation, the ATSB makes the following recommendations with the intention of enhancing future rail/road safety. Rather than provide prescriptive solutions, ATSB recommendations are designed to highlight safety issues that need to be considered. Recommendations are directed to those agencies that should be best placed to action the safety enhancements intended by the recommendations, and are not necessarily reflective of deficiencies within those agencies.

### 4.1 Safety actions already taken

#### 4.1.1 RailCorp

RailCorp has undertaken a number of safety actions since the derailment, they are:

- A program using ultrasonic axle testing (UAT) to check all XPT power car PLA axles began on 9 February 2006 (the day of the derailment)
- The XPT fleet was withdrawn from service as soon as the UAT testing discovered a cracked PLA axle
- The XPT fleet remained out of service until all the XPT PLA axles had been subject to UAT
- Scheduled UAT routine inspection for the PLA axles was instigated
- The XPT fleet returned into service in stages as the PLA axles with detected surface defects were replaced
- RailCorp also used UAT to check the entire diesel fleet, including all XPT trailer car axles and all Explorer, Endeavour and 620 Class power and trailer axles and no cracks were found
- A prototype axle protector to fit on the PLA axle radius relief area between the wheel and the gearbox has been designed and installed to all axles on XPT power car XP2010, bogies PLA 32A and PLA 34A
- A review of drawings, standards (RailCorp and external parties) and work procedures for XPT rollingstock has been undertaken
- Extra evacuation ladders have been fitted to XPT buffet cars and instructions on use of the ladders are located on the ladders, aide memoires regarding evacuation procedures have been added to Driver's logbook, Buffet log book and Passenger Service Supervisors (PSS) workstations and all staff have been trained in evacuation procedures.

#### 4.1.2 Independent Transport Safety and Reliability Regulator (NSW)

The Independent Transport Safety and Reliability Regulator of New South Wales (ITSRR) notified the rail regulators in Queensland and Victoria when it became aware of the XPT axle issue. The ITSRR placed four conditions on RailCorp to supplement the assurance already provided by the operator that the risk of axle failure in the XPT and other diesel fleet rail vehicles was being managed.

The ITSRR also conducted inspections of the company undertaking the axle inspections which resulted in the maintainer revisiting some technical issues regarding non-destructive testing.

The ITSRR considered the safety actions undertaken by the operator were both appropriate and adequate (immediate suspension of services, increased maintenance and inspection regimes imposed). The ITSRR has continued to liaise with the operator regarding the risk mitigation strategies implemented regarding this matter.

## **4.2 Recommended safety actions**

### **4.2.1 Recommendations to RailCorp**

#### **RR20070022**

The Australian Transport Safety Bureau recommends that RailCorp review its maintenance procedures with respect to XPT axles with a view to eliminating, or mitigating to the maximum extent practicable, the risk of a fatigue crack initiating and propagating to point of causing an axle failure.

## **4.3 Safety advisory notices**

### **4.3.1 Safety advisory notice to all rail vehicle operators in Australia**

The Australian Transport Safety Bureau advises all rail vehicle operators in Australia that they should consider the risks associated with axle failures as a result of fatigue cracks initiated by ballast strikes and review their maintenance practices accordingly.

## 5

## APPENDIXES

## 5.1

## Table of axle examination findings

Notes	Wheel Serial No. Gear Side	Bearing No. Gear Side	Grease	Rumble	Wheel Serial No. Non Gear Side	Bearing No. Non Gear Side	Grease	Rumble	Gearbox No.	Gearbox Condition	Wheel Runout Non Gear Side (mm)	Wheel Runout Gear Side (mm)	Wheel Wobble Non Gear (mm)	Wheel Wobble Gear (mm)	Back To Back (mm)	Comment
	85597	45110	250929	Leakage	OK	451109	350415	Leakage	OK	Unknown	0.2	0.08	0.28	0.28	1359.1	Bogey P1A 11B
	86827	451109	532459	Leakage	OK	447041	423170	Leakage	OK	C90	0.1	0.15	0.23	0.13	1357.8	Bogey P1A 17B Axle 2
	87989	410623	100749	Leakage	OK	410626	350155	Leakage	OK	C85	0.1	0.1	0.1	0.15	1358.2	Bogey P1A 26A Axle 2
	881725	447043	100923	Leakage	OK	433704	532482	Discoloured grease	OK	C95	0.13	0.2	0.36	0.18	1357.9	
	881733	433687	301016	Water ingress	OK	433688	433479	Leakage	OK	C1	0.13	0.2	0.33	0.23	1359.6	
	91778	451118	250429	Leakage	OK	447029	250039	Leakage	OK	C95	0.15	0.36	0.15	0.23	1357.3	Bogey P1A 1B axle 1
	931679	460432	251374	Leakage	Very high	460401	250952	Leakage	OK	C17 analysed	NA	NA	NA	NA	1357.5	Bogey P1A 1B axle 1
	95516	541925	532163	Overhauled	OK	541914	251106	Overhauled	OK	No gearbox fitted	0.25	0.05	0.25	0.25	1358.7 1357.8	Overhauled new wheels
	96169	NR	NR	Overhauled	OK	NR	NR	Overhauled	OK	NA	0.23	0.23	0.13	0.18	NR	Overhauled new wheels. Control wheelset
	961624	460422	350413	Leakage	OK	460405	350410	Leakage	OK	Unknown	0.25	0.15	0.2	0.18	1358.3 1358.6 1359	Bogey P1A 3B Axle 2 Control wheelset
	21737	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Wheels and bearings removed prior to arrival

1. Measurement of wheel runout, back to back and wheel wobble was performed on 21737 at United Group Rail Chulora.
2. Measurement of wheel wobble and runout was performed using a calibrated dial indicator supplied by United Group Rail Chulora.
3. Measurement of wheel wobble was performed on 95516 and 96169 at United Group Rail Chulora.
4. Measurement of wheel wobble was taken on the flat section of the wheel back.
5. Allowable tolerance for wheel back to back dimensions is 1357.3 - 1359.7 mm (TFRS 0141 dated 16/8/1991).
6. Runout of the each axle was checked independently before measurement of wheel runout and this equated to a maximum of 0.05mm.
7. Measurement of wheel back to back dimensions was performed using a dial indicator, calliper and vernier calliper.
8. The measurement of wheel back to back dimensions was performed using a dial indicator, calliper and vernier calliper.
9. Axle numbers 96169 and 961624 are both control wheelsets used to compare against the axles with defects.

NA - Not Applicable due to component required not being fitted  
NR - Not Recorded as information not critical

## 5.2 ATSB test results

### 5.2.1 Mechanical property data

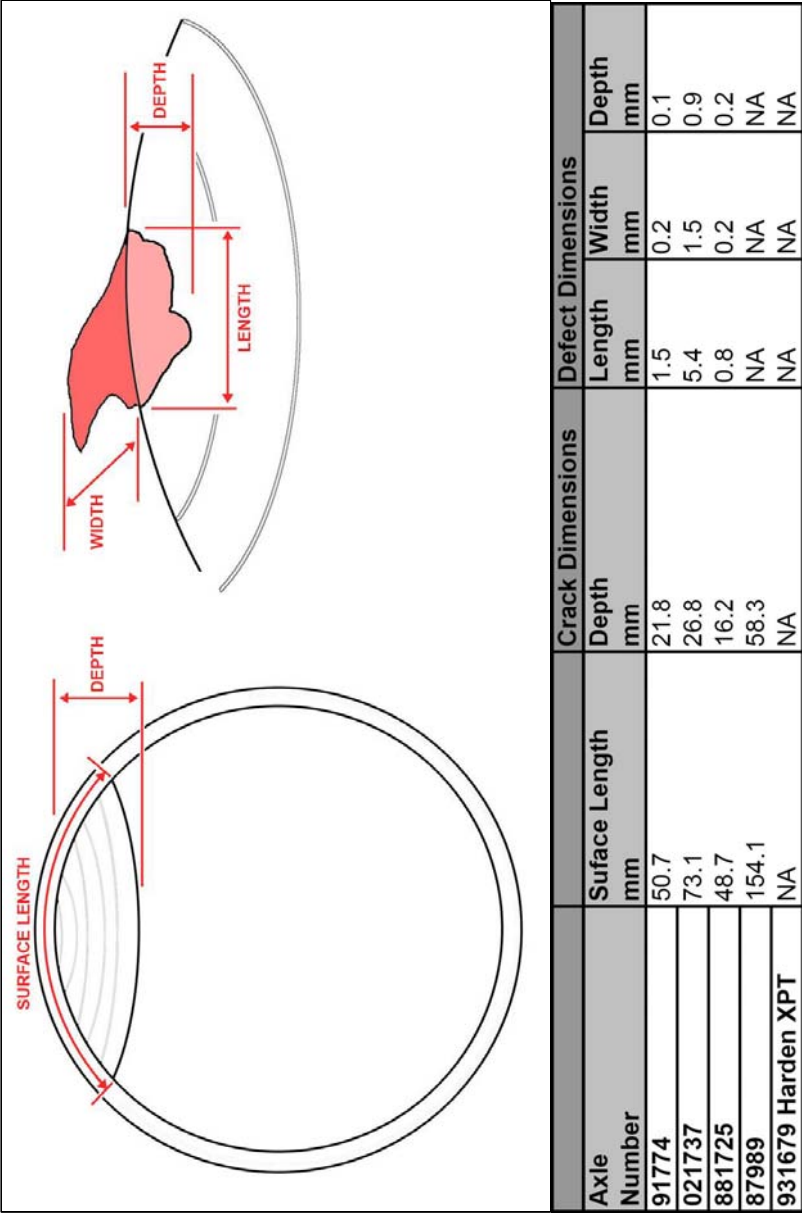
	Proof Stress (MPa)	Tensile Stress (Mpa)	Elongation (% Area)	Core Hardness (HV)	Surface Hardness (HV)	Impact Test (Joules) Min
Axle Standard TRS 0148.00	430 Min	620 Min	19 Min	NA	NA	54
91774	454	611	24	219±5	201±2	120
021737	526	693	24	222±5	214±2	100
881725	522	689	25	238±8	213±4	79
87989	458	620	26	209±2	209±2	93
931679 (XPT Harden)	594	758	19	243±4	236±4	70

### 5.2.2 Chemical analysis

	C	Mn	Mo	Si	S	P	Ni	Cr	Cu	Nb	V	Ti	Al	B
<b>Axle Specification BS 970 605 M30</b>	0.26-0.34	1.30-1.70	0.22-0.32	0.10-0.35	0.050 (max)	0.040 (max)	-	-	-	-	-	-	-	-
<b>91774</b>	0.29	1.50	0.30	0.27	0.021	0.011	0.10	0.06	0.17	0.02	< 0.01	< 0.01	< 0.005	< 0.0005
<b>021737</b>	0.30	1.50	0.29	0.27	0.021	0.014	0.08	0.11	0.20	0.02	< 0.01	< 0.01	< 0.005	< 0.0005
<b>881725</b>	0.32	1.40	0.25	0.23	0.022	0.025	0.11	0.19	0.23	0.03	< 0.01	< 0.01	< 0.005	< 0.0005
<b>87989</b>	0.31	1.50	0.29	0.30	0.021	0.017	0.07	0.10	0.07	0.02	< 0.01	< 0.01	< 0.005	< 0.0005
<b>931679 (XPT Harden)</b>	0.29	1.60	0.28	0.24	0.021	0.027	0.11	0.16	0.21	0.02	< 0.01	< 0.01	< 0.005	< 0.0005

Note: All values are shown by weight percentage.

5.2.3 Crack dimensions



### 5.3

### UK and Australian differences

Subject	UK Practice –CR/CI0546 and subsidiary documents	Australian Practice – document ref. TRS0165.01
MPI Testing periodicity at overhaul	At wheelset overhaul which equates to every 2 years or 500,000 miles.	No specific mileage or time period is given. Compliance with clause 2.0.3 would ensure that MPI is carried out when the wheels are replaced. If the gearwheel is in situ, MPI is carried out but without the gearwheel seat (clause 2.0.4). Note, the gearwheel is not generally removed unless damaged.  MPI is carried out using handheld equipment every 400,000km and is carried out every 800,000km using bench MPI equipment.
UAT periodicity at overhaul	At wheelset overhaul which equates to every 2 years or 500,000 miles.  In the UK, the wheelset specification requires UAT to be carried out after the wheelset has been overhauled i.e. once it has been completely built up. This is to ensure that any damage caused by the assembly process (e.g. a torn wheelseat) is identified before the wheelset enters service. However, overhaulers often choose to UAT the bare axle as well so as to avoid assembling a wheelset that has a cracked axle.	The requirement for UAT at wheelset overhaul is unclear. Clause 2.0.3 states that ultrasonic testing of the wheelseat is not needed but makes no mention of any other UAT requirement. No UAT is undertaken at overhaul of XPT wheelsets as wheels are always removed.
Areas of the axle to be subject to MPI at overhaul	All accessible parts of the wheelset. Removal of components beyond those required by the overhaul procedure is not required. In accordance with GM/RT2451.	Axle barrel, road wheelseats and bearing journal/abutments are subject to MPI at 400,000km. At 800,000km, gearbox is removed which enables axle barrel, road wheelseats and bearing journal/abutments to be subject to MPI.
UAT test requirements at overhaul.	Far-end, near-end and surface wave scans in accordance with TL/NP0212.	The requirement for UAT at wheelset overhaul is unclear. Clause 2.0.3 states that ultrasonic testing of the wheelseat is not needed but makes no mention of any other UAT requirement. No UAT is undertaken at overhaul.
MPI Testing intervals - dimensional	In stages of not more than 300mm along the axle and repeat twice after 120° rotation. (Source GM/RT2451 and TL/NP0318).	Not precisely specified in TRS0165.01, which uses wording like 'entire axle' and 'exposed portions'.
MPI A/C electromagnet lift test	To be assessed daily or before use. Lifting power to be equivalent to at least 4.5kg for a spacing of 300mm or less.	Not specified in TRS0165.01

MPI Measurement of magnetic field direction and strength.	Checked at beginning of the working shift and randomly 3 or 4 times during the shift using a flux field indicator (Burmah Castrol foil indicator)	Not specified in TRS0165.01
MPI Operator's qualification	<p>Operators shall be certificated in accordance with EN473 or be holders of certificates in MPI issued by an ASNT Level 3 MPI certificate holder within a written practice following the guidelines shown within SNT-TC-1A.</p> <p>PCN Level 2 Operators are qualified to perform the test and interpret the results. PCN Level 1 Operators must be supervised. (PCN is a subsidiary of the British Institute of NDT).</p> <p>(Source GM/RT2451).</p>	No specific qualification.
MPI Functional Test of Magnetic Ink	A daily check (or prior to starting work) to prove the correct functioning of the magnetic ink (in accordance with BS6072).	No specific requirements except for a statement that the fluorescent particle media shall comply with AS2085.



## 5.4 Summary of rejection criteria for HST and XPT axles

Axle detail	Max surface texture (µm)	Axial scoring, grooves etc.	Indentations	Corrosion	Fretting	Heating, arcing damage	Dimensions	External radii
Axle end, including machining centre	3.2	N.A.	None which hinder UAT	No surface corrosion or pitting	N.A.	Axles shall be free of weld spatter, electric arc damage and signs of overheating (bluing).	Flatness and run out not to exceed 0.08mm	N.A.
Roller bearing journal	1.2 (0.8 or if rolled 0.4)	None that causes suspect UT defects or loss of oil injection pressure.	No greater than 1mm deep. Blended.	No surface corrosion or pitting	N.A.		Parallel and cylindrical to within 0.05mm. (0.02mm)	N.A.
Wheel seat	1.6 (0.8)	None that causes suspect UT defects or loss of oil injection pressure.	No greater than 1mm deep. Blended.	No surface corrosion or pitting	No fretting damage giving a finish coarser than 3.2µm		Parallel to within 0.05mm and cylindrical to within 0.03mm. (0.05mm)	Generally 0.5 mm
Traction motor suspension or final drive roller bearing seat	1.6	None that causes suspect UT defects or loss of oil injection pressure.	No greater than 1mm deep. Blended.	No surface corrosion or pitting	No fretting damage giving a finish coarser than 3.2µm		Parallel and cylindrical to within 0.05mm.	0.5 mm
Stress relief grooves	0.8	Nil	Nil	No surface corrosion or pitting	N.A.		N.A.	N.A.
Journal shoulder	0.8	N.A.	No greater than 1mm deep. Blended.	No surface corrosion or pitting	No fretting damage giving a finish coarser than 3.2µm		N.A.	N.A.
Transition radii	0.8	N.A.	Nil	No surface corrosion or pitting	N.A.		N.A.	N.A.

Axle detail	Max surface texture (µm)	Axial scoring, grooves etc.	Indentations	Corrosion	Fretting	Heating, arcing damage	Dimensions	External radii
Parts of axle other than the above	3.2	N.A.	No greater than 1mm deep. Blended. <b>(3mm deep)</b>	No surface corrosion or pitting	N.A.		N.A.	N.A.

Note: Bold red text denotes a difference between Australian and United Kingdom requirements.

## 5.5

### Submissions

Section 26, Division 2, and Part 4 of the Transport Safety Investigation Act 2003, requires that the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate, for the purposes of:

- a) Allowing the person to make submissions to the Executive Director about the draft: or
- b) Giving the person advance notice of the likely form of the published report.

The final draft of this report was provided for comment to the following directly involved parties:

- a) RailCorp of New South Wales
- b) The Australian Rail Track Corporation
- c) The Independent Transport Safety and Reliability Regulator of New South Wales
- d) The New South Wales Office of Transport Safety Investigation
- e) The driver of train ST22, and
- f) The passenger service supervisor.

RailCorp, the Australian Rail Track Corporation, the Independent Transport Safety and Reliability Regulator of New South Wales, and the New South Wales Office of Transport Safety Investigation have made a number of comments and observations on the draft report issued to directly involved parties. Comments and observations have been incorporated into the report where they are supported by valid evidence and agreed to by the investigation team.

## 5.6

## References

### ***RailCorp internal standards***

TRS 1524.00 *Allowable Bearing Journal Defects*, 27 February 1995.

DSS 5193.00 *Gearbox Overhaul Maintenance Specification For PLA Bogies*, 3 February 1999.

TRS 1004 *Axle Journals – Electro Chemical Metal Deposition (ECMD)*, 11 June 1991.

TRS 1516.00 *Installation of Metric SP Type Package Unit Bearings*, 27 February 1995.

TRS 0165.01 *Non Destructive Testing of Axles*, 16 February 1995.

DSS 5196.01 *Wheel Set Overhaul Maintenance Specification For PLA Bogies*, 31 January 2001.

TRS 0141-01 *Disassembly/Assembly of Locomotive and Rolling Stock Wheelsets*, 16 August 1991.

EIDSS 5204 *Axle Bearings Overhaul Maintenance Specification for PLA Bogies*, 23 November 2004.

TRS 1513.00 *Allowable Defects and Rework Criteria for Bearings to be Requalified*, 27 February 1995.

TRS 0148.00 *High Strength Low Alloy Steel Axles*, 16 February 1995.

### ***United Kingdom standards***

Technical Procedure, TL/NP0211 *Ultrasonic Axle Testing Procedure*, Chart Number 22, Part 4, for *testing of H.S.T Power car Axles – Testing at Wheelset Overhaul*.

MT 300 *Requirements for Handling, Storage and Transportation of Wheelsets*.

GM/RT 2451 *Magnetic Particle Inspection*.

CR/CI0546 *Component Overhaul Instruction for BP10 bogies* (the bogies fitted to HST power cars).

IB/TS 0648 *Data for Wheelset Overhaul and Repair*.

WOSS 612/10 *Wheelset Overhaul procedures*.

CR/PE0102 *Repainting of Rail Vehicles* (includes the requirements for painting of axles).

TL/NP0318 *Magnetic Particle Inspection of Axles at Wheelset Overhaul and Repair*.

Technical Procedure, VT/TP1038 *Reclamation of Damaged Axles on HST Power Cars*.

## 5.7

### Media release

#### ***Fatigue crack in XPT axle leads to derailment.***

An ATSB investigation has found that fatigue cracking in an XPT axle led to a minor derailment of an XPT passenger service from Melbourne to Sydney on 9 February 2006 at Harden.

The Australian Transport Safety Bureau investigation into the derailment concluded that train ST22 derailed as a result of the axle completely fracturing and eventually derailing one wheel.

Subsequent examinations by RailCorp, the train operator, led to the discovery of thirteen other XPT power car axles with surface defects, or cracks initiated by surface defects, in highly stressed areas.

The ATSB's examination of five of the axles revealed a crystalline material, consistent with track ballast, embedded in each fatigue crack at its origin. It was probable that impacts from track ballast from unknown location(s) had led to the formation of the cracks in the axles.

The investigation also found that routine testing of the axles carried out by the operator's maintenance contractor was ineffective and resulted in the fatigue cracks going undetected for a considerable period of time.

Both RailCorp and the New South Wales rail regulator have initiated safety actions to reduce the risk of fatigue cracks leading to similar axle failures.

The ATSB has issued a safety advisory notice to all rail vehicle operators in Australia to consider their maintenance and inspection regimes to detect possible fatigue cracks.

Copies of the report can be downloaded from the ATSB's internet site at [www.atsb.gov.au](http://www.atsb.gov.au), or obtained from the ATSB by telephoning (02) 6274 6478 or 1800 020 616.

Deraillment of XPT Passenger Train ST22 Harden, New South Wales  
9 February 2006