Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Rail Occurrence Investigation 2006/001

Final

Derailment of Freight Train 3AB6

Yerong Creek, New South Wales

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Abstract

At about 1721 on Wednesday 4 January 2006, the 41st wagon of Pacific National freight train 3AB6 derailed at a track misalignment at Yerong Creek, New South Wales. Eight wagons following the 41st wagon then derailed. There were no injuries. The track sustained significant damage and was closed for 48 hours.

The investigation found that the most likely cause of the derailment was a track misalignment which was caused by a combination of several factors any one of which may not have resulted in the derailment in its own right.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. 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

Occurrence: accident or incident.

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

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

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

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

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

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

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

EXECUTIVE SUMMARY

At about 1721 on 4 January 2006, Pacific National freight train 3AB6 derailed while travelling at 111 km/h at Yerong Creek station in New South Wales. At the time the weather was fine, warm to hot and dry.

Freight train 3AB6 consisted of 49 wagons being hauled by three locomotives, was 1408 m long and weighed 1796 tonnes. The train was travelling from Adelaide to Brisbane via Tottenham Loop (Melbourne). The train crew consisted of a driver trainer, a driver and a co-driver.

The investigation determined that the trailing left-hand wheel of the leading bogie of the 41st wagon had probably derailed at the 564.477 km mark[1]. The train then separated at the 41st wagon with the locomotives and first 40 wagons continuing for 857 m after the derailment before stopping. The derailment sequence behind the 41st wagon escalated until eight of the nine wagons in the rear portion of the train were partially or fully derailed. The last wagon did not derail.

All of the derailed wagons were damaged to varying degrees and it was anticipated that two of the five-pack[2] wagons would be written off. Containers and goods therein also sustained damage, some to the extent of total loss. About 500 m of the main line and 200 m of the adjacent crossing loop were extensively damaged. There was also damage to other installations within the rail corridor. The track was closed for 48 hours as a result of the derailment.

The first two wagons to derail were examined in detail, including an independent specialist examination and a metallurgical examination. The specialist examination revealed that, apart from a broken compression rod[3] on the 41st wagon, no mechanical defects were found that could have caused the derailment. The examination of the broken compression rod revealed that it had probably failed after the wagon had derailed, as a consequence of forces arising during the derailment sequence.

An examination of the track maintenance history and the relevant standards revealed no exceedence or non-compliances that could alone have resulted in the derailment.

The investigation determined that a number of factors contributed to the derailment of freight train 3AB6 at Yerong Creek, any one of which may not have resulted in a derailment in its own right. It was found that the most probable[4] cause of the derailment was a track misalignment due to a combination of:

- thermally induced forces within the rails;

1 Km mark – distance by rail from Sydney's Central Station.

2 Five-pack wagons are a 'single' wagon made up of five permanently coupled wagons.

3 A component of the bogie brake gear. See Figure 8.

4 The term 'probable' means equal to or greater than 75% probability that the event happened as described. There is no evidence of a compelling nature (such as a video of the event) that conclusively excludes other, far less likely, possible derailment scenarios.

- a modified track structure and altered rail neutral temperature[5] as a result of recent track work; and
- the level of dynamic force resulting from the speed of train 3AB6.

The investigation also found that steel sleepers in the vicinity of the misalignment were not installed to the pattern specified in the appropriate standard.

Safety action recommended, as a result of this investigation, relates to the need to develop a strategy capable of monitoring and managing localised stresses that occur in continuous welded rail.

The Australian Rail Track Corporation has indicated that they will be resleepering the Melbourne to Sydney corridor with concrete sleepers. This program will result in the removal of all steel sleepers from the Melbourne to Sydney main line.

5 The temperature of the rail when it is in neither compression nor tension.

1 FACTUAL INFORMATION

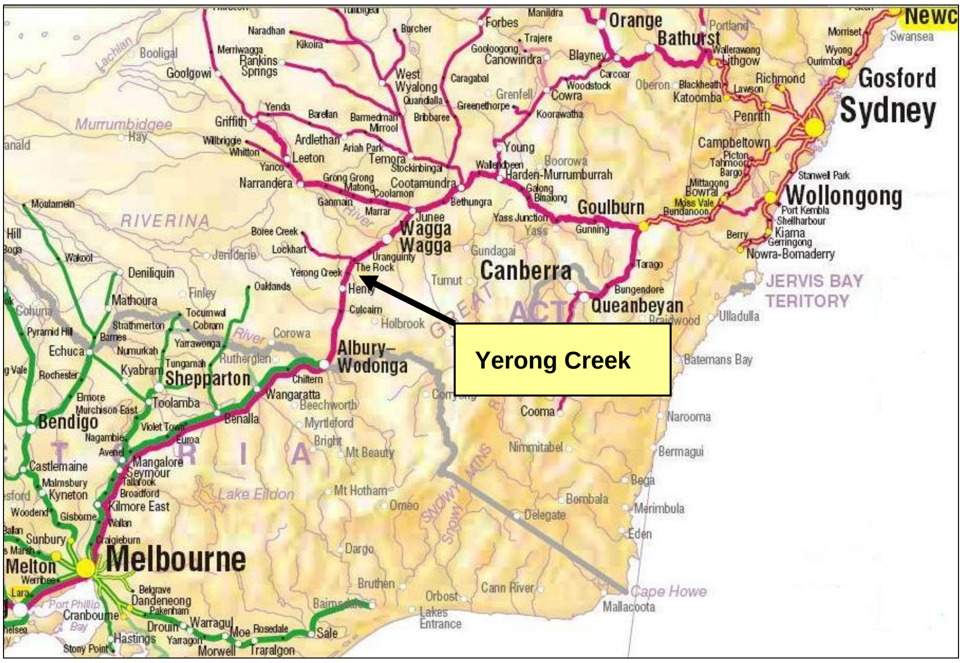
1.1 Overview

At about 1721[6] on Wednesday 4 January 2006, the 41st wagon of train 3AB6 derailed while travelling through Yerong Creek station yard at 111 km/h. Eight wagons behind the 41st wagon progressively derailed as the derailment sequence continued. There was considerable damage to the main line and crossing loop and this resulted in the closure of the rail line between Melbourne and Sydney for 48 hours.

1.1.1 Location

Yerong Creek station is located on the Melbourne to Sydney rail corridor between Albury and Wagga Wagga, 565 km by rail from Sydney. The township of Yerong Creek (population 145) is situated predominantly to the west of the station, with the Olympic Highway (the main route between Wagga Wagga and Albury) running parallel to the track to the east of the station.

Figure 1: Location of Yerong Creek (Railways of Australia).



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The main line between Sydney and Melbourne in this part of NSW consists of single track, with crossing loops such as Yerong Creek at regular intervals. The Yerong Creek station yard layout consists of the main line, a crossing loop (1664 m long) and sidings that serve grain silos (see Figure 2). The main line is straight for several kilometres either side of Yerong Creek station and through the station yard. A train travelling in a northerly direction encounters a falling grade of between 1:87

6 Times referenced to Junee Train Control times; Australian Eastern Summer Time.

and 1:194 for almost four kilometres until the turnout at the southern end of the station yard. The downgrade then eases to 1:684 within the station yard until the bridge over the Yerong Creek watercourse. The grade is then level for about 650 m before gradually rising between 1:721 and 1:81 for several kilometres beyond the turnout at the northern end of the station yard.

The main line is designated as ‘class one’ track and consists of 53 kg/m continuous welded rail fixed by Pandrol fastenings to plated timber and steel sleepers on a formation bed of crushed hard rock ballast. The maximum speed on the main line is 115 km/h for freight trains and 160 km/h for XPT passenger trains.

The safeworking system on this section of the Defined Interstate Rail Network (DIRN) is Rail Vehicle Detection (RVD) with rail movements managed by controllers at Junee. The Melbourne to Sydney rail line is leased to the Australian Rail Track Corporation (ARTC)[7].

1.1.2 Track information

The track at Yerong Creek underwent partial sleeper replacement with steel sleepers in mid 2002 as part of a program of sleeper replacement between Junee and Albury. This was the second partial replacement using steel sleepers on the line.

A partial replacement of sleepers using new timber sleepers with resilient fastenings took place between Junee and Gerogery from 4 October to 17 December 2005. The installation of the sleepers started at Junee and continued southwards. Track tamping machines corrected track geometry after the new sleepers were installed. The derailment site underwent partial sleeper replacement as part of this program on 9 November 2005. The new timber sleepers were installed on a pattern of 1 in 4 with extra sleepers installed to break up any ‘clumping’ of steel sleepers that may have existed from previous resleepering programs. A temporary speed restriction associated with the resleepering work at the site of the derailment was lifted on 29 November 2005.

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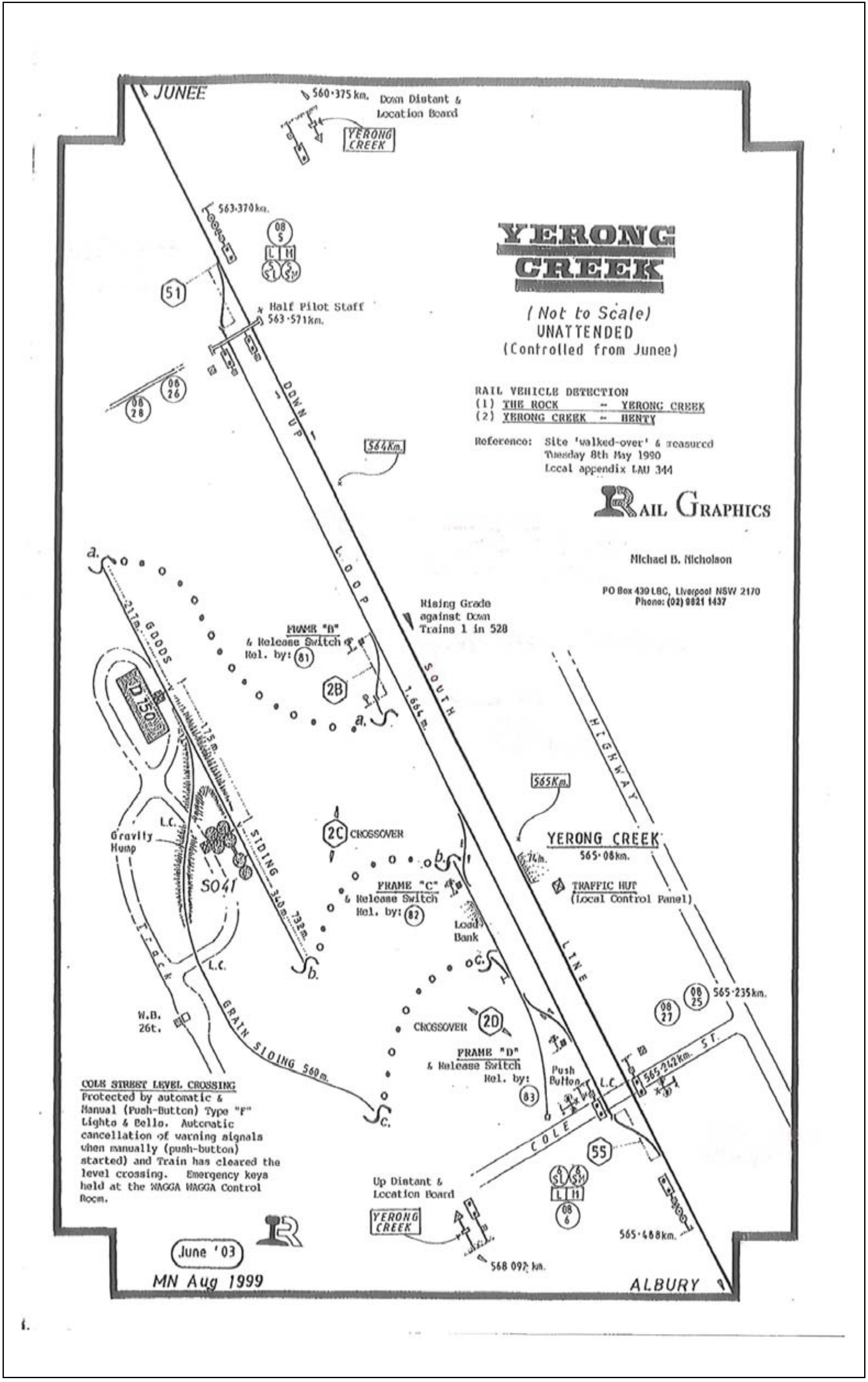
7 ARTC – has been responsible for access to, and management of, the Melbourne to Sydney (Macarthur) rail corridor since September 2004.

Figure 2: Yerong Creek Yard Diagram



1.1.3 Train information

Train 3AB6 consisted of three NR class locomotives hauling 49 wagons for a total length of 1408 m and a gross weight of 1796 tonnes. The train consisted of three locomotives followed by one empty wagon, then twelve loaded wagons, 26 empty wagons and finally nine loaded wagons. The maximum allowable speed of the train in NSW was 115 km/h.

Rear portion of train

The rear portion of the train (which derailed with the exception of the last wagon) consisted of four 'conventional' single platform wagons followed by five, five-pack[8] wagons. This portion of the train was 460.9 m long and weighed 600.42 t. The wagon numbers and individual gross weights of the rear portion of the train were:

- RQSY 34448 loaded two containers 52.41 t
- RQSY 34367 loaded three containers 36.58 t
- RQSY 34455 loaded two containers 59.68 t
- RQSY 34344 loaded two containers 34.84 t (middle container slot empty)
- RRAY 7201 loaded two containers middle and last platforms 69.70 t
- RRAY 7242 loaded three containers first three platforms 72.34 t
- RRGY 7118 loaded three containers first and last platforms 95.10 t
- RRAY 7189 loaded two containers first and third platform 65.85 t, and
- RRYY 23 loaded three containers first, fourth and fifth platforms 113.92 t.

1.1.4 Crew of locomotive (3AB6)

The train was crewed by a Melbourne based driver trainer, driver and a co-driver. The driver trainer was assessing the driver's knowledge of safety-critical competencies in accordance with a routine assessment that is conducted once every two years. The driver trainer and the driver both had extensive experience on freight trains and the Melbourne to Junee rail corridor. The co-driver was still learning the route. All three were appropriately qualified and medically fit in accordance with the required standards. After the derailment the train crew were breath tested by the police and returned negative results.

Pacific National Pty Ltd was the operator of train 3AB6. Pacific National is the largest accredited and privately owned rail operator in Australia.

1.1.5 Train crew account

The train crew signed on at Melbourne at 1015 on Wednesday 4 January 2006. They were rostered to work train 3AB6 (which had originated in Adelaide) to Junee, book off, and return to Melbourne on train 4BM2 the next day. For the driver

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8 Five-pack wagons are a single wagon made up of five permanently coupled platforms.

and co-driver it was their first shift after two days off duty. The driver trainer had finished duty at 1957 the previous evening.

The train crew departed from the Melbourne Locomotive Provisioning Centre (LPC) at 1100 with their three fully provisioned locomotives. At Tottenham Loop the locomotives were coupled to the rear of the recently arrived train 3AB6. The incoming locomotives were then uncoupled and the train became outbound, effectively reversing the train consist. The required brake tests were conducted and the train departed for Junee at 1138.

A routine journey was then experienced until Yerong Creek, although all three train crew felt that the train did not ‘run’ well. This meant that power had to be used to maintain speed in some locations where momentum running would normally suffice. The train crew attributed this to wind resistance caused by the train being loaded in blocks at either end with 26 empty container wagons in between.

At 1455, train 3AB6 was routed into the loop at Chiltern[9] to cross a south-bound freight train. The crew of the south-bound train reported that 3AB6 (stationary) was complete. At 1618, an XPT was waiting at the passenger platform at Albury[10] as 3AB6 passed. The XPT driver also reported that 3AB6 was complete and all looked in order.

The driver was at the controls of 3AB6 as the train approached Yerong Creek station. The driver trainer was seated immediately behind him in the trainer’s seat and the co-driver was seated on the right-hand side. The weather in the area was reported as fine, warm to hot and dry. (The recorded maximum temperatures[11] that day at Wagga Wagga and Lockhart[12] were 33.5°C and 34° respectively.)

At the top of the grade before Yerong Creek the train’s speed was 95 km/h and the locomotives were in notch one, the lowest power setting. A train running well will normally gain speed and pass through Yerong Creek at about 110 km/h without power. In this instance though, some power had to be applied to maintain speed. The driver applied full power for the rising grade ahead as the lead locomotive was passing through Yerong Creek station yard.

One of the train crew thought that there was some rough riding as the lead locomotive passed the wheat silos although the other two crew members felt that the ride, while a little rough, was as expected.

Shortly after the application of full power at 1720:50, a slight ‘tug’ was felt. Within three to five seconds the driver noted that the brake pipe air pressure was falling. He immediately placed the train brake handle in the service zone and did not allow the independent (locomotive) brake pressure to exceed 200 kPa until the locomotive was stationary. This action was intended to keep the train stretched[13] during the stop. The train crew could see a cloud of dust at the rear of the train rising to the

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9 Chiltern – about 116 km from Yerong Creek.

10 Albury – about 83 km from Yerong Creek.

11 Unless otherwise stated, reference to temperature in this report refers to ambient air temperature.

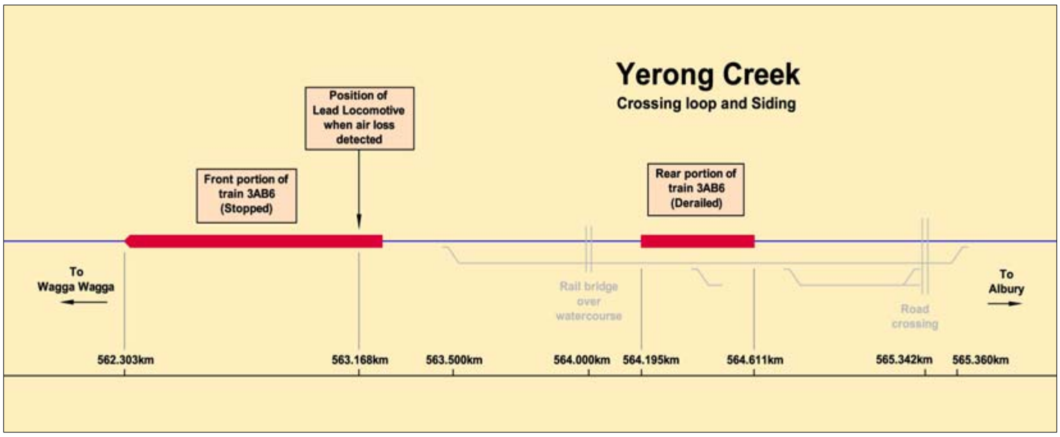
12 Wagga Wagga and Lockhart are 45 km and 51 km respectively from Yerong Creek.

13 A stretched train has its couplings in tension. This reduces the risk of a concertina effect where derailed wagons have been known to overtake and strike an efficiently braking locomotive.

height of the wheat silos as the train was decelerating, and for some time after the locomotives had stopped. The driver advised train control of the occurrence, while the other crew members exited the locomotive to secure the front portion of the train and then inspect the accident site.

The crew found that the train had separated at the coupling between the 40^{th} and 41^{st} wagons and that the eight wagons following the 40^{th} had derailed. The forward portion of the train consisting of the three locomotives and the first 40 wagons had come to a stand with the front of the lead locomotive at 562.303 km and the rear of the 40^{th} wagon at 563.168 km. The rear derailed portion of the train occupied the rail corridor between 564.195 km and 564.611 km.

Figure 3: Overview of train location



1.1.6 Post occurrence response

The area train controller at the Southern Rail Management Centre at Junee was informed of the derailment by the crew of train 3AB6 at about 1724 (time as recorded by ARTC train control). The area train controller contacted the NSW Police service and the local emergency services, and placed blocking facilities on the sections either side of Yerong Creek to protect the derailment site from other rail movements.

Police, NSW fire brigade, ambulance and SES resources arrived promptly on site. The local Salvation Army arrived with support facilities (water, food, shelter, and clean areas) to assist.

The train manifest indicated that train 3AB6 was carrying one litre of hypochlorite solution and 44 tonnes of acid filled batteries. These consignments were classified as dangerous goods. Shortly after the arrival of the Hazmat officers from the Wagga Wagga fire brigade, confusion arose over the location of the dangerous goods. The train manifest showed them as being located in the derailed portion of the train. They were actually located in the front portion of the train.

This caused an escalation in the emergency response and the closure of the adjacent Olympic Highway for a short time. The train control communication network failed soon after the derailment due to damage caused by bushfires in the Junee area. As a consequence, mobile phones in a patchy reception area were the primary means of communication. This added to the delay in confirming to the emergency services the actual location of the dangerous goods.

1.1.7 Loss and damage

Rollingstock and containers

The undamaged leading portion of train 3AB6 departed Yerong Creek at 0314 on 5 January 2006 after being inspected. All of the derailed wagons and bogies sustained damage to varying extent and it was anticipated that two of the five, five-pack wagons would be written off. Containers and goods therein were also damaged, some to the extent of total loss.

Rail infrastructure

About 500 m of main line and about 200 m of the loop were extensively damaged by the derailment. Several poles supporting aerial communication lines adjacent to the rail corridor were knocked down and signal rodding associated with the silo loading road was damaged. The crossing loop was re-opened at 1804 on 6 January 2006 and the main line at 1746 on 15 January 2006.

Figure 4: View of accident scene towards Sydney

2 ANALYSIS

Following a derailment of a freight train at Yerong Creek on Wednesday 4 January 2006, the ATSB initiated an investigation under the *Transport Safety Investigation Act 2003* (TSI Act). The section of line over which the derailment occurred is part of the DIRN and is an essential corridor for the running of interstate rail traffic.

ATSB investigators arrived on site at approximately 2300 on 4 January 2006. Evidence was gathered from various sources, including: the NSW Police, the ARTC, Pacific National, and the NSW State Emergency Service (SES). Evidence included train control graphs, train control voice and data logs, locomotive data logs, organisational rules and procedures, network rules and procedures, technical documents, site drawings, maintenance records, and train crew records. The investigation team also examined and photographed the accident site.

2.1 Sequence of events analysis

2.1.1 Rollingstock on-site observations

Wagon RQSY 34448, the 41st wagon in the train consist, was the first to derail. The leading bogie (RYCD 26426) of this wagon derailed all wheels; the trailing bogie remained on the rails. All wheels of the following seven wagons were derailed. The last wagon, five-pack RRYY 23, did not derail.

Despite the derailment forces, the first four ‘conventional’ single platform wagons remained parallel to and close to the main line, although the adjacent loop track was fouled. However, the two leading five-pack wagons (RRAY 7201 and RRAY 7242) concertinaed longitudinally to the extent that the northern end of the grain loading road on the left-hand[14] side of the main line and the vehicular access gravel road on the right-hand side of the main line were fouled. The next two five-pack wagons also showed some longitudinal movement, but not to the same extent. Of the 20 containers loaded in the second portion of the train, five were completely detached. These five were from the two leading five-pack wagons.

14 When the words ‘left-hand’ and ‘right-hand’ are used in this report, it is relevant to the direction of travel of train 3AB6.

Figure 5: First derailed wagon

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Figure 6: Concertinaed five pack wagons

Copyright ARTC ©

A fractured brake compression rod and three missing eye bolts on the first bogie to derail (RYCD 26426) were the only abnormal mechanical defects identified by the initial site inspection of the derailed rollingstock (Figures 7 and 8). The fractured compression rod, which normally sits between the 'live' and 'dead' brake levers beneath the bogie (see Figure 8), was protruding rearwards (see Figure 7).

The brake compression rod is mounted under the bogie frame and is a component of the mechanical rigging and linkages provided to evenly distribute braking forces between the front and rear bogie axles.

Figure 7: Broken compression rod, bogie RYCD 26426, rearwards of installed position

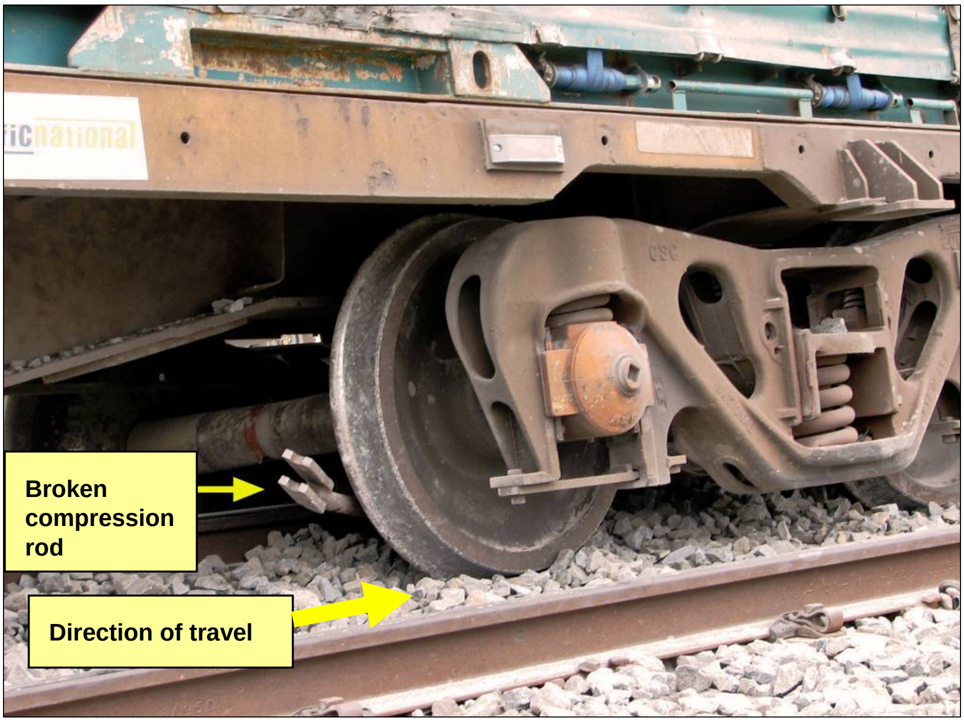
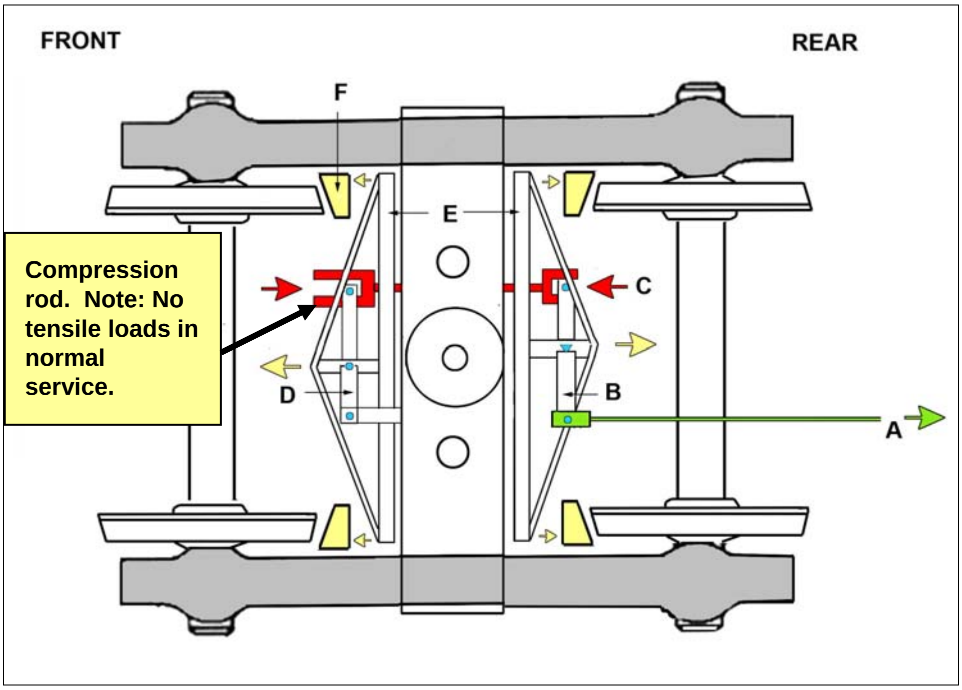


Figure 8: Schematic of mechanical rigging and linkages. (A) long rod, (B) live lever, (C) compression rod, (D) dead lever, (E) brake beam, (F) brake blocks



2.1.2 Site observations

Markings observed by the ATSB investigators on the rail and sleepers indicated that a wheel had mounted the 'up'[15] rail at the 564.484 km mark and derailed to the six foot[16] (left) side of the rail seven metres further along at the 564.477 km mark. These markings were consistent with a derailment on a developing misalignment; where a combination of marginal track geometry and in-train forces results in wheels derailing. For example, differences in individual wheel loads due to minor uneven distribution of the wagon load, as they pass the developing misalignment can derail a wheel or wheels.

About 12 m after the point of derailment a sleeper with multiple flange markings on the four foot[17] and six foot sides of the Up rail was found. This indicated that many wheels derailed at or shortly before this point.

After the first wheels derailed to the six foot side of the Up rail, the corresponding right-hand wheels on those axles derailed to the inside of the 'Down'[18] rail, damaging sleepers in the four foot. As the derailment sequence escalated, fastenings were dislodged and sleepers were broken. The track structure was weakened to the

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15 The 'up' rail in New South Wales is the left hand rail when standing on the track between the rails facing the direction that trains would travel if heading to Central Station, Sydney.

16 The 'six foot' is the area between two tracks in multiple lines, so called because it was historically approximately six feet between the rails.

17 The 'four foot' is the area between the two rails of a track, so called because the distance between the rails is four feet eight and a half inches – colloquially abbreviated.

18 The 'down' rail in New South Wales is the right hand rail when standing on the track between the rails facing the direction that trains would travel if heading to Central Station, Sydney.

point where the rail gauge could not be maintained and this resulted in all of the following wheels derailing, causing further damage to the track and rolling stock.

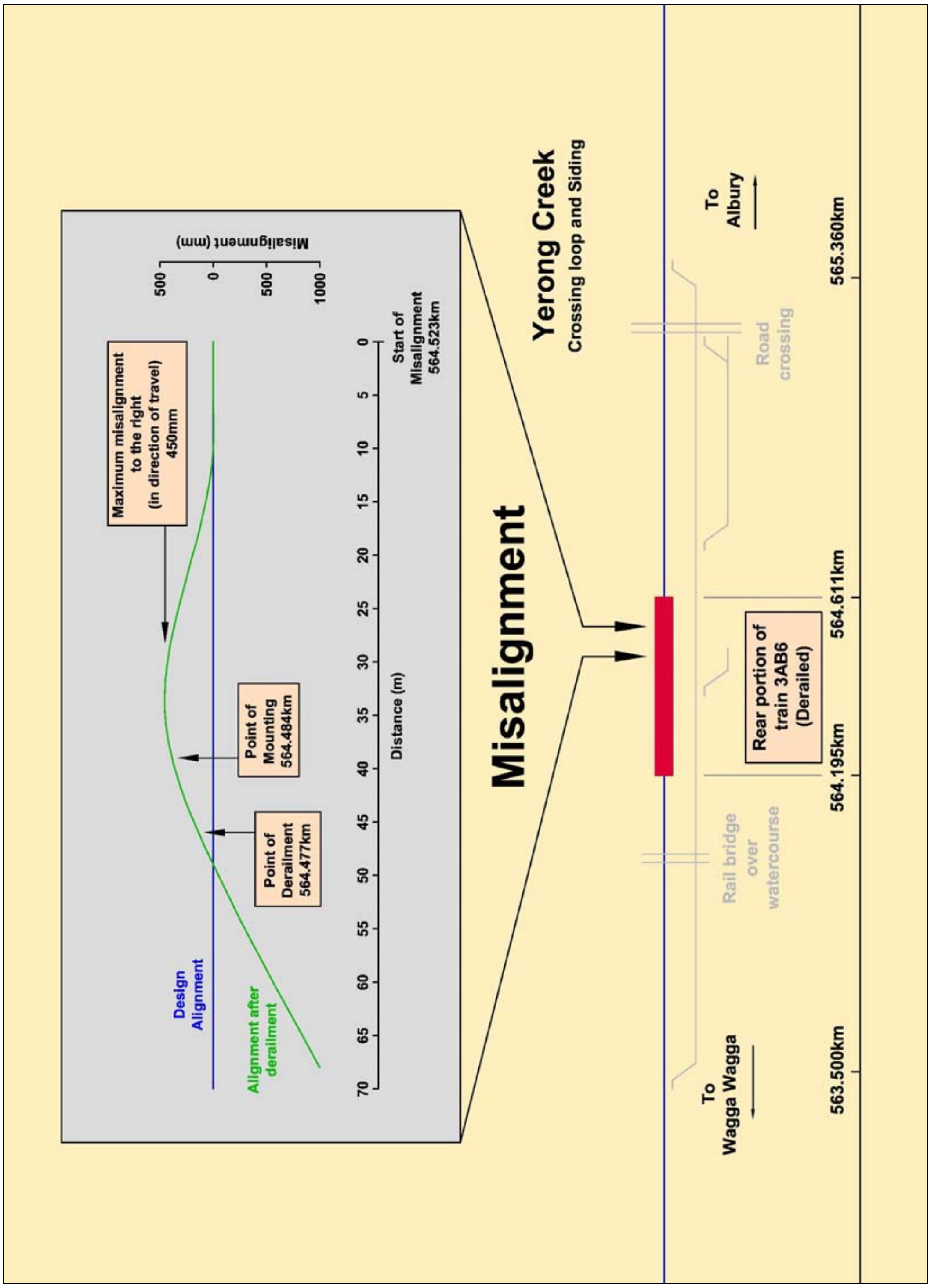
The main line was found to be misaligned for about 40 m before the point of mount. The southern 20 m of the misalignment had a maximum displacement of 30 mm to the Up side. The misalignment extended over at least 68 m and had a maximum lateral displacement of 450 mm to the Down side about four metres before the point of mount. To the north of the point of derailment the track was badly damaged and displaced by train wreckage.

Several sleepers to the north of the point of mount were dislodged from the rail as the track moved laterally, causing the sleepers to be 'left behind' (see Figure 11).

Consideration was given to the hypothesis that these sleepers indicated that the wagons had derailed prior to the track misaligning. The location of these sleepers to the north of the initial point of mount, and the loss of track integrity due to spreading of the rails several metres past this point, indicates that this evidence is likely to be the consequence of derailment forces displacing the track and providing impact loads to dislodge or break sleepers and fastenings. The sleepers that had been left behind by the dislodged rail were on the misalignment curve at the northern extremity, not on the straight track alignment. No other mechanism of derailment could be found that satisfactorily explained the observed post derailment track position and condition.

Figure 9 depicts the location of the Up rail at the derailment site and reflects the centreline alignment of the track up until the point where gauge spreading starts to occur due to derailment damage, just after the initial point of derailment.

Figure 9: Schematic of Yerong Creek and misalignment



Measurements refer to Up rail alignment.

Figure 10: Location of initial point of derailment, looking towards Melbourne

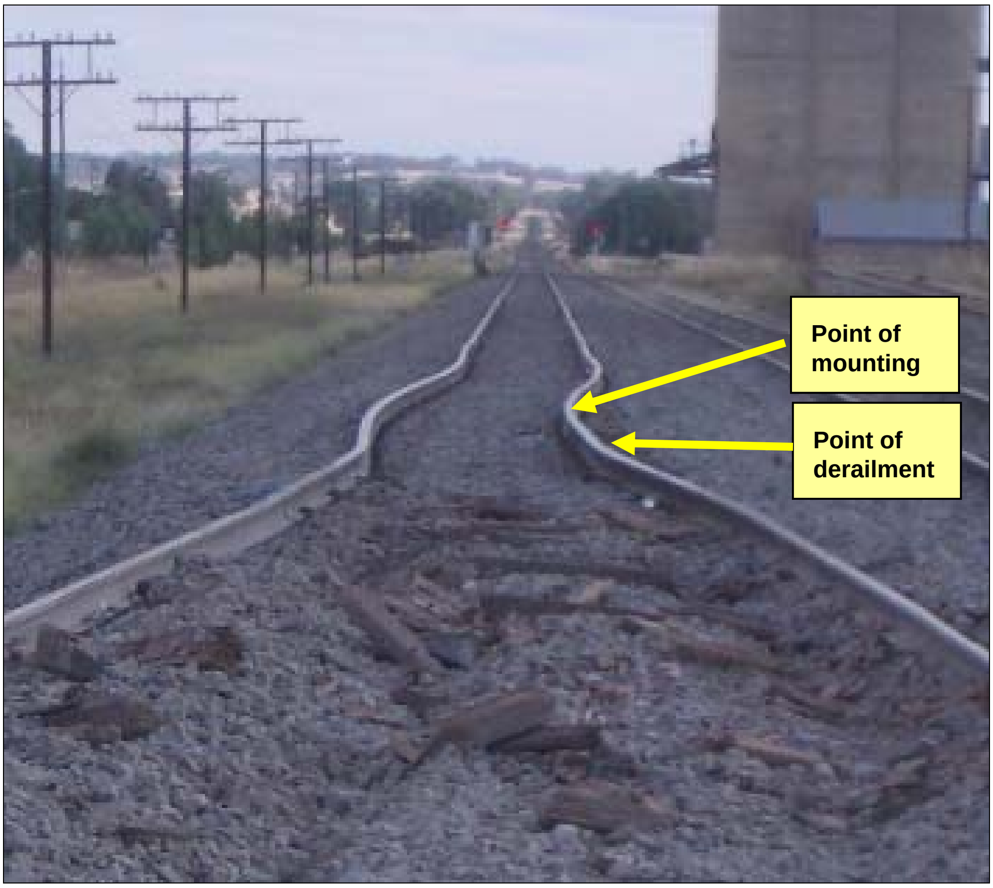


Figure 11: Vicinity of Down rail point of derailment, after removal of last wagon

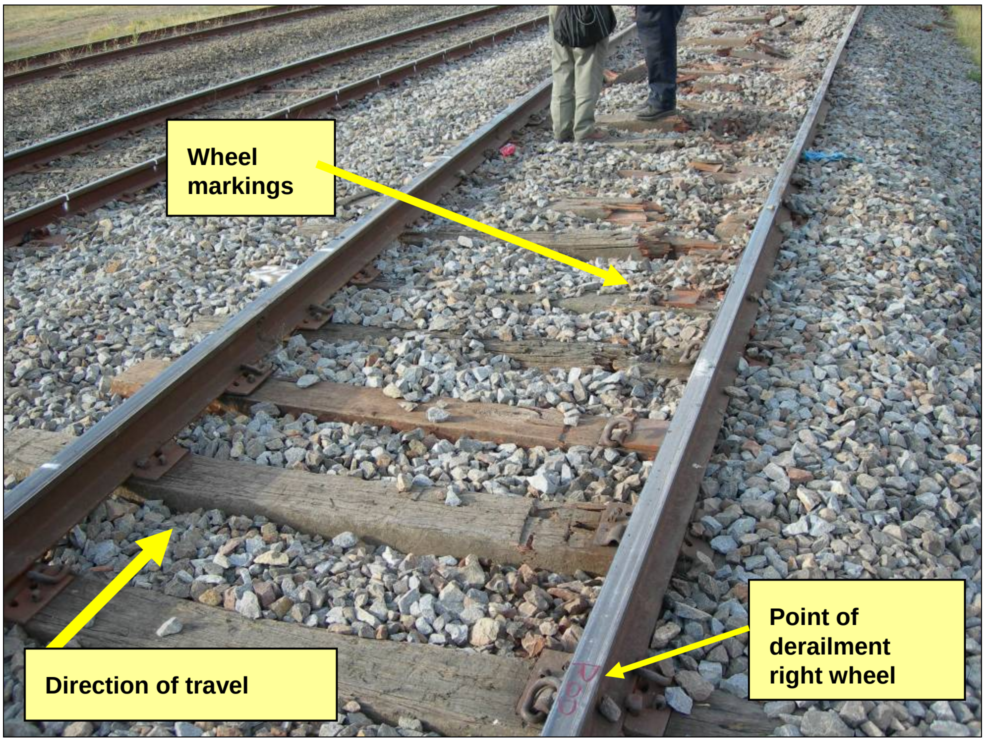


Figure 12: Misaligned track under last wagon of the derailed portion RRYY 23

No damage or markings were found on the crossing loop turnouts or main line before the first indications of the track misalignment. There were two shallow markings on the 'hot mix' bitumen surface of the level crossing located at the southern end of the Yerong Creek station yard. These markings were on the inside of the Down rail, the first being in the flange groove and the second about 180 mm to the inside of the flange groove. There were two light impact marks at a high point on the northern edge of the asphalt in the four foot of the level crossing. It was determined that these markings on the level crossing were relatively minor and typical of 'dragging gear' on a passing train and were not related to the derailment.

Several light oblique intermittent marks were discovered on the running face of the Down rail between the level crossing and the derailment site. They could not be matched to any part of the derailment process.

No evidence of substantial load shift or load imbalance that could have materially contributed to wagon instability was found. Broken load straps and minor load shifts in the leading derailed wagons were probably a consequence of derailment forces. Missing load straps were considered and determined as surplus to load securing requirements.

2.1.3 Locomotive data logger

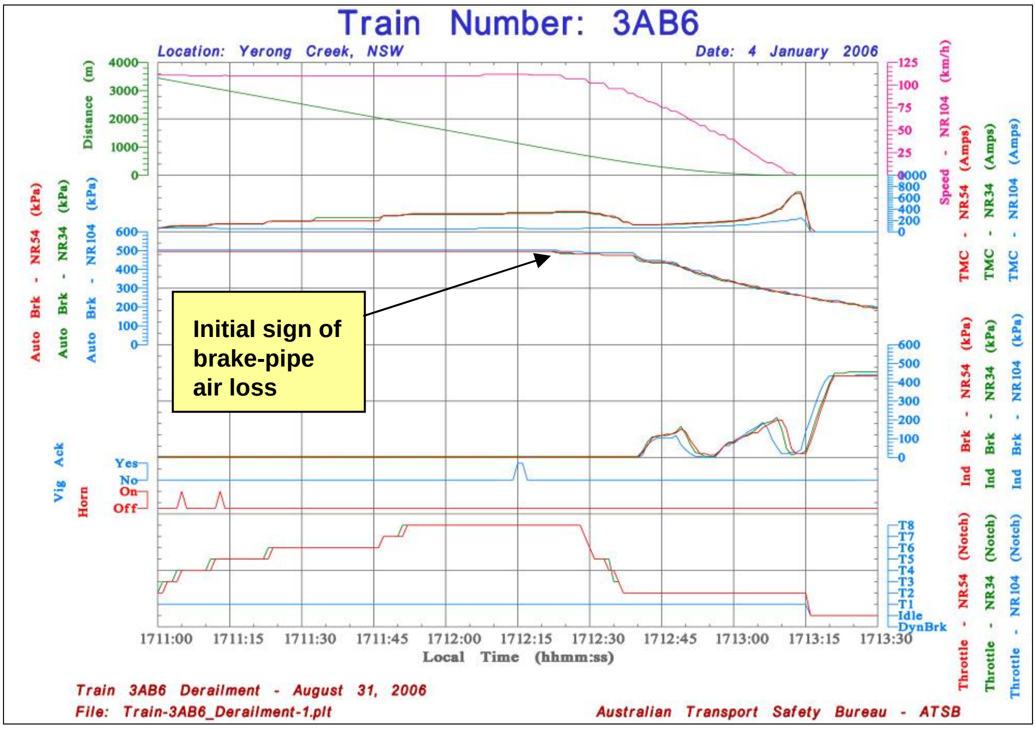
The locomotive event recorders indicate that the locomotives were powered up approaching and passing through Yerong Creek, probably as a result of the 'windage' of wagons loaded with containers interspersed with empty wagons. As a result, the train would have been consistently 'stretched' as it passed through Yerong Creek, with no 'bunching' effects. This in addition to the fact that the derailment initiated at a loaded wagon, effectively rules out the possibility that the derailment was caused by ‘bunching’ of the train consist.

At 1721:12[19] (train speed 112 km/h) the front bogie of wagon RQSY34448M passed the point of mount (564.484 kilometres). A loss of brake-pipe air was registered by the locomotive event recorders at 1721:24 while the train was travelling at 111 km/h[20]. The automatic brake pressure indicates that the rear portion of the train separated from the front portion of the train between 1721:17 (the previous pressure recording) and 1721:24.

The leading end of the rear portion of the train (last nine wagons) stopped at 564.195 km, a distance of 289 m from the point of mount. The trailing end of the rear portion stopped at 564.611 km. The rear portion of the train came to a stop wholly within the Yerong Creek station yard limits.

At 1722:14 the leading end of the front portion of the train stopped at 562.303 km. The whole of the front portion of the train was now outside the Yerong Creek station yard limits.

Figure 13: Locomotive data reproduction



2.1.4 Summary of site findings and sequence of events analysis

A thorough examination of the derailment site by the ATSB investigators revealed evidence of two conditions that warranted analysis as possible derailment initiators:

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19 Correlated time on the data logger graph is as recorded by the event recorders of the three locomotives, using NR104 as the standard time. This time has then been adjusted by nine minutes to correlate to the reference time as recorded by Junee Train Control, and is Australian Eastern Summer Time.

20 Correlated speed as recorded by the event recorders of the three locomotives.

- Failure of the brake compression rod on the first derailed bogie.
- Misalignment of the track.

The compression rod on the first derailed bogie was found to be broken and had rotated through 180 degrees so that it was protruding from the rear of the bogie. The pins connecting the compression rod to the live and dead levers were still in situ. If the compression rod had broken prior to the derailment, it is possible that it may have rotated underneath the rear right hand wheel of the bogie and lifted the flange of that wheel clear of the running face of the rail thus causing it to derail.

A track misalignment was also found at the derailment site. Sleeper markings indicate multiple wheel derailments due to wheel climb occurred at the misalignment. Two basic mechanisms of track misalignment are lateral response to the vehicle load on the rail, and lateral response to the thermal load within the rail. The two mechanisms often occur together. Another common mechanism of misalignment is geotechnical movement; however, there was no evidence of such movement at Yerong Creek.

In order to determine the reason for the misalignment and the mode of failure of the compression rod, it was necessary to analyse the rollingstock that derailed and the track and infrastructure in the vicinity of the derailment.

2.2 Rollingstock

2.2.1 Independent examination

The ATSB engaged the services of a specialist to conduct an examination of the two leading RQSY wagons that were derailed. These wagons were the leading two of the nine wagons of the rear (derailed) portion of the train. The examination required the specialist to report on any element of the rollingstock that could be determined as a contributing factor in the derailment and encompassed wagon body and bogie and wheel examination[21].

Of particular interest was the first wagon to derail, wagon RQSY 34448 and its bogies RCYD 26426 and RCYD 26427.

RQSY 34448

The examination found that there was no noticeable twist to the underframe of this wagon that could have contributed to wheel unloading. The constant contact side bearers showed signs of having been ‘heavily worked’ and both centre plates showed signs of wear. The ‘footprint’ between the king and queen castings[22] appeared to be small. The draft gear was in good condition and showed no signs of damage. The load of the wagon was observed to have suffered minor displacement consistent with derailment forces.

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21 RQSY 34344 and RQSY 34455 each had one bogie and wheelset unavailable for examination.

22 Also described as the centre plate and centre bowl of the mating bogies.

Bogies RCYD 26426 and RCYD 26427

There was some doubt as to the effectiveness of the snubbing devices on both bogies although they did not show signs of being overactive. The constant contact side-bearer pads showed signs of being 'heavily worked' and there appeared to be excessive clearance between spring guides and the springs. It also appeared that the secondary springs had been solid[23] at some point. There was clear evidence of the centre bowl rim maintenance welding beads fouling the centre plate of the wagon, although the degree of fouling would have had only a marginal influence on the tracking of the bogies. All of the horn cheek wear surfaces were in good condition and showed minimal wear. All gibs were found to have minimal wear and all wheel profiles were well within the acceptable operating limits.

The only mechanical defect found involved the compression rod on leading bogie RCYD 26426. The forward facing clevis of this compression rod was fractured between the brake pin holes. Both brake pins and cotter pins were still in place. The clevis showed a clean break and the part of the clevis still attached to the compression rod showed signs of having skidded along a rail. The long rod itself showed no signs of major surface damage.

The specialist engaged by the ATSB recommended that the compression rod and clevis arm be further examined to determine the actual mode of failure.

2.2.2 Examination of compression rod

Initial inspection

The ATSB took possession of the compression rod in order to conduct a detailed failure analysis at the ATSB facilities in Canberra. Before removal from bogie RCYD 26426, an initial examination was conducted at the Pacific National maintenance terminal at South Dynon, Melbourne.

Bogies of this type are normally fitted with two safety loops underneath the bogie frame which are designed to catch the compression rod should it become disconnected at either end through a pin falling out, or suffer a fatigue failure, during service. The safety loops are held in place by four eye bolts. Examination of the bogie revealed that only a single eye bolt from one of the safety loops remained intact and still fastened to the underside of the bogie frame. No evidence was found of the other three eye bolts normally used in the safety loop assembly.

The examination also revealed that the compression rod had broken cleanly through the forward facing clevis. A significant bend in the rod was observed approximately 500 mm from the pin hole of the rear clevis. Close examination of the bend at the inner radius revealed a surface depression associated with a series of minor gouges from sliding-type contact present on the rod surface. The damage was observed to extend for approximately 50 mm.

The shaft was examined around its circumference at the bend location. No further damage of this type, including symmetrical gouging, deep indentations, or sandwiching impressions, was observed. However, a random array of scratches and minor indents coupled with freshly accumulated corrosion product was observed,

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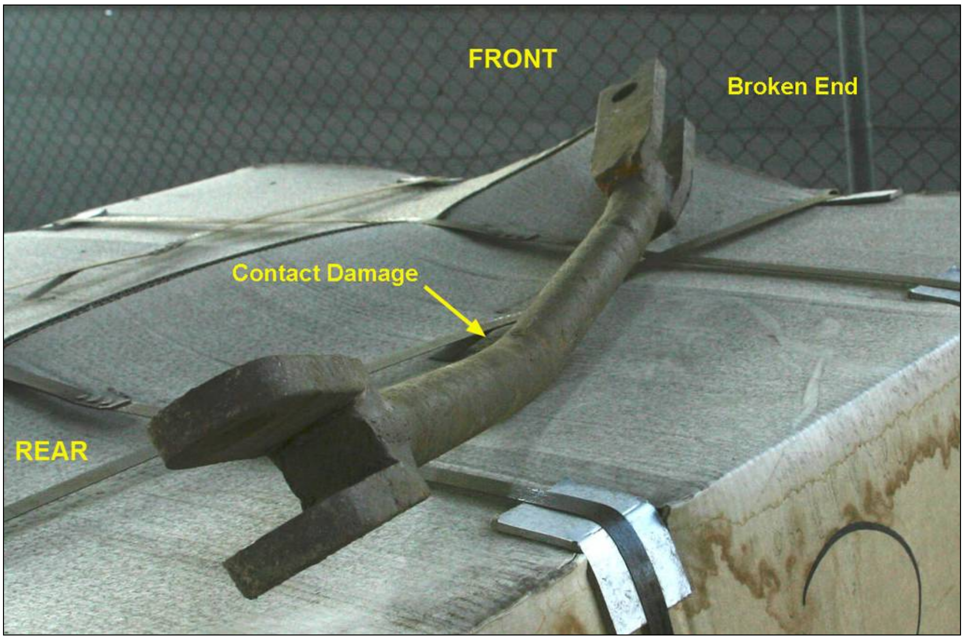
23 Springs that are fully compressed and act as a 'solid' piece of steel rather than as a spring.

which indicated that the lower surfaces at this location had been scored and damaged by ballast shot[24]. The arms of the rear clevis were intact but had been bent outward by approximately 10mm.

During the examination, the rear clevis of the compression rod was re-pinned to the lower connector of the live lever. The front of the rod where it had broken was rotated to the right so that it made contact with the right wheel from the rear wheel set. It was noted that when disconnected at the front, the natural inclination of the rod was to fall downward and to the right. When the rod was rotated in such a manner so that it contacted the right rear wheel, it was revealed that the impact marks and bending coincided with the point of wheel contact.

Figure 14: Rear end of the compression rod showing an obvious bend



Examination of the rear right bogie wheel revealed a general accumulation of fresh corrosion product and a quantity of mechanical damage present on the tread and flange surfaces. There were no markings to indicate where the wheel had passed over the compression rod.

The examination also revealed clear and well defined scoring on one of the fractured clevis arms and one edge of the arm had been chamfered from impact damage. The general appearance of the surface damage indicated that at some time the clevis arm had made significant heavy contact with another metallic object or solid surface.

The fracture surfaces associated with the broken clevis were also examined and were found to be lightly rusted, but otherwise relatively undamaged. The only notable damage was a slight flattening of the corner features on one of the clevis fractures. The flattening was consistent with the fracture being struck by or striking an object sometime during the derailment.

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24 During service a component surface may become damaged when impacted by track-side ballast. The damage produced is called ‘ballast shot’ and is categorised by many small indentations and minor surface irregularities.

Figure 15: End view of the fractured surfaces of the compression rod

Metallurgical examination, Canberra

The fractured compression rod, the mating clevis arms and retaining pin were subsequently examined at the ATSB technical analysis facilities in Canberra. The broken clevis ends were examined optically using a binocular microscope and at higher magnification using the scanning electron microscope (SEM). Material characterisation including metallography, quantitative chemical analysis, metal hardness and stress analysis were performed on the broken component.

No evidence of any pre-existing defects or prior cracking was found during physical examination of the failed clevis. The brittle-cleavage nature of the fracture was indicative that the component had been instantly or rapidly loaded to a degree sufficient to overcome the inherent strength of the item. The features also indicate that the rod clevis broke in a rapid brittle manner from predominantly tensile loads.

Metallographic sectioning and analysis of the broken clevis determined that it had been manufactured from semi-killed low-carbon steel. The core hardness properties were well above the published nominal values for that material. Elevated surface hardness measurements indicated that the clevis ends had been case-carburised. In contrast, the rod was relatively ductile, which indicated that only the clevis end had been given that type of hardening heat treatment. This basic difference in mechanical properties indicates why the rod section had bent rather than fractured in a brittle manner.

It was noted that the clevis heat treatment had produced a microstructure comprised primarily of bainite. Such a structure is not considered ideal for engineering applications as it produces a steel with low ductility and low fracture toughness.

Despite the likely inherent brittleness of the clevis and thus the questionable suitability of its use in an engineering application, the overall section thickness of the compression rod was considered sufficient to manage any loads that might have been produced during normal operation.

Calculations indicated that approximately 2064 kN (210 t) of static tensile load would have been required to overload the clevis in a controlled tensile manner. See Appendix A for the ATSB Laboratory Examination Report.

2.2.3 Wagon maintenance history

The maintenance history of all wagons on train 3AB6 for the 12 months prior to the derailment was examined, with particular attention to the history of wagon RQSY34448, the first wagon to derail.

According to the records, work was performed on RQSY34448 on 24/2/2005, 25/5/2005, 13/6/2005, 2/8/2005, 20/10/2005, 30/12/2005 and 2/1/2006. The work of 30/12/2005 and 2/1/2006 was minor, consisting of the replacement of a single draft yoke pin and the replacement of an identification tag, respectively. The work of 20/10/2005 was far more extensive, including a thorough examination of the vehicle. This examination is in the form of a checklist, and specifically requires an examination of 'safety loops and rigging height'. If any item on the checklist is non-compliant, the vehicle is not to be released back into service until repairs are completed.

The evidence is that all brake gear including the safety loops was checked and found to be satisfactory 10 weeks prior to the derailment.

2.2.4 Summary of rollingstock

With the exception of the fractured compression rod on the leading bogie of RQSY 34448, no mechanical defects were found in the two RQSY wagons and components that would have caused the wagons to derail on straight track.

The investigation could not determine whether the three missing eye bolts (and consequently, the safety loops) had either been detached from the bogie before the derailment, or been dislodged during the derailment sequence. It was noted that the loops are normally in reasonably close proximity to the track ballast and sleepers (but clear of the rail head). Therefore, if they had been fitted to the bogie, it is almost certain that they would have ripped from their mounts as the bogie ploughed into the track ballast outside the sleeper shoulder during the derailment.

The investigation determined that the bending and scoring damage to the compression rod had been caused by the trailing right wheel of the bogie passing over the rod. Of particular note was the absence of any related compression or indentation damage to the underside of the rod at that location. Such damage would be expected if the rod had become trapped between the wheel and the rail head. The only observable damage to the underside of the rod was the small surface indentations and scoring that were typical of repeated ballast impact (ballast shot). Analysis indicated that the bend geometry of the rod was probably a random product of the derailment sequence.

No evidence was found to suggest that the observed machining damage and metal loss present on one of the broken clevis arms had contributed to the failure. The physical evidence suggested that this damage occurred after the initial component failure at some point during the derailment sequence, when one section of the clevis had been forced against the running face of the Up rail. This had probably kept RQSY 34448 running parallel to the main line while derailed.

It is noted that the design of the bogie brake rigging would have only allowed compression loads to be imparted to the compression rod during normal service. This is an important consideration given that the failure mode of the component was from brittle fracture due to rapidly applied tensile loads. From this evidence it is considered very unlikely that the fracture occurred from loads experienced during normal operations.

The physical evidence and nature of the clevis failure indicated that the component was not exposed to static tensile loading, but in fact to a rapidly applied shock-type load. The analysis of the forward clevis from the compression rod of bogie RYCD 26426 revealed that it had broken in a manner consistent with exposure to forces experienced during the derailment.

It was therefore concluded that the failure of the compression rod was probably the result of the derailment and thus did not initiate it.

2.3 Track

2.3.1 Track structure

The track in the vicinity of the derailment was a mix of timber and steel sleepers, the break up of which was calculated as 92 per cent timber and 8 per cent steel. Of the timber sleepers 24 per cent were new, 63 per cent were regarded in fair to good condition and 5 per cent in poor condition. Steel sleepers were interspersed at intervals ranging from one in 8 to one in 30, were in good condition and the pods[25] were adequately packed with ballast.

The rail profile was good and based on visual observation of grinding scallop marks it appeared to have been ground within the last three years. There were no records available from ARTC of this rail grinding. The rail fastenings on the timber and steel sleepers were in good condition.

The ballast was clean and met standards regarding height around the sleepers and width of shoulder. There was no evidence of pumping or fouling of the ballast and the formation outside the ballast profile was dry and firm. The cess area[26] was well drained in the vicinity of the track misalignment.

There was no indication of rail creep or longitudinal rail or sleeper movement. There is no practical non-destructive test available to measure rail compressive stresses in situ.

Track geometry parameters as measured on site on the day following the derailment were all within standard limits. There was some variation in the horizontal alignment of the track immediately before the major misalignment. It is noted that these variations increased progressively approaching the major misalignment. Some

25 The pod of a steel sleeper is the area within the top and sides of the sleeper.

26 The cess area is the area to the field sides of the track.

minor gauge variants were found and a few clips and plate fastenings had not been installed.

2.3.2 Monitoring/defects

ARTC track monitoring standards TEP01, TEP03, TEP04, TEP05, TEP06, TEP07 and TEP14 require track recording car, walking, track patrol and 'front of train' inspections at designated intervals. An examination of the maintenance history for the track in the area of the derailment indicated that these requirements had been met. Of note was that:

- On 4 January 2006 (the day of the derailment) a 'front of train' inspection was conducted by track personnel on the northbound XPT passenger train. This train passed through Yerong Creek at 1258; no problems were identified either visually or with respect to the ride/handling of the XPT power car.
- After the 'front of train' inspection on 4 January 2006, a southbound loaded steel train and an XPT passenger train passed through Yerong Creek at 1320 and 1508 respectively. No reports of rough riding or other problems were submitted by the train crews.

As of 4 January 2006, there were no outstanding work orders raised for defects for the section of track at Yerong Creek. In addition, track maintenance records indicate that since 1992 there have been no incidents of track misalignment at Yerong Creek.

It is noted though, that the day after the derailment a 50 mm track misalignment was found about two km south of the point of derailment at Yerong Creek, at the 566.500 km mark.

2.3.3 Steel sleepers

Steel sleepers were introduced in 1997 as a partial timber sleeper replacement program on the main line between Albury and Junee, in effect randomly interspersed between the existing hardwood timber sleepers. Over time, some areas experienced consequent track geometry problems.

In response to a derailment that was caused by a track misalignment at Rocky Ponds in November 2002, the NSW Office of Transport Safety Investigations (OTSI) conducted an investigation into steel sleeper introduction on class one main line track in NSW between 1996 and 2004[27].

With respect to track geometry, the OTSI investigation found that the installation and maintenance practices for steel sleepers on the main line were deficient in regard to tamping and ballasting requirements. The investigation noted that steel sleepers tended to settle further under equivalent ballast and tamping conditions before supporting the same load as timber sleepers and that this difference in the degree of settlement is important if steel sleepers are interspersed with timber sleepers.

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27 OTSI file reference 02619, 31/08/2005.

Following the OTSI investigation, the ARTC has reissued the Rail Infrastructure Corporation's (RIC)[28] sleeper usage and installation standard. This ARTC standard (TCS10) highlights the desirability of installing steel sleepers in a constant pattern and that this pattern on class one tangent track should be one in four or, if the timber sleepers are in good condition, one in six. Variances of one steel sleeper are allowed, but only if the majority of the pattern is maintained.

The ARTC has undertaken a program to identify and conduct remedial action where steel sleepers have not been installed in accordance with the standard. It has also indicated an intention to remove all steel sleepers from class one track. In this regard, 8000 steel sleepers (6.4 per cent) had been replaced with new timber sleepers over the 75.5 kilometres between Albury and The Rock.

2.3.4 Track work

As part of the ARTC response to the problem identified with the steel sleepers, 18.5 km of the main line (from 563.500 km to 582.000 km) was partially re-sleepered with hardwood timber sleepers from 9 to 25 November 2005. The work started from near the northern end of the loop turnout at Yerong Creek (at the 563.500 km mark) and progressed to the south, including the derailment site. This work created a pattern of one in four new timber sleepers, with additional sleepers installed to break up any 'clumps' of steel sleepers. However, the remaining steel sleepers were not located in a regular pattern following this work and as such did not comply with the standard for a steel/timber sleeper mix.

A Temporary Speed Restriction (TSR) of 80 km/h was applied and progressively extended as work progressed over the 17 day period. On 25 November 2005 the track at Yerong Creek station between the 563.500 and 565.300 km marks was tamped[29]. However, the TSR of 80 km/h remained until 29 November 2005 by which time tamping had been undertaken to the 582.000 km mark. The TSR for the entire work section was then lifted. ARTC Standards TMP11 to TMP17 require that 100,000 tonnes of rail traffic must pass over a work area before the resumption of full speed running. In this instance, over 500,000 tonnes of traffic had passed over the track at Yerong Creek station before the TSR was lifted.

2.3.5 Speed restrictions

The high temperatures experienced on some summer days in inland Australia cause high thermal stresses in continuous welded rail. The rail then becomes susceptible to misalignment as the lateral component of the compressive stress forces acts in opposition to the lateral restraining forces in the track structure. Dynamic forces from passing trains add to the destabilising forces. To reduce these forces, train speed is restricted on hot days, as the dynamic force exerted by a train on the track is proportional to the square of its speed.

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28 Rail Infrastructure Corporation – NSW rail organisation January 2001 to present.

29 Track tamping – a process whereby ballast is compacted around and under the sleepers and alignment of rail is restored.

At Yerong Creek station, a WOLO[30] restriction imposes a speed limit of 80 km/h where the permitted speed of a freight train is greater than 90 km/h. For 115 km/h rated track this represents a reduction in train dynamic forces of over 50 per cent.

Prior to January 2005 WOLO speed restrictions were applied by a two tiered process. Before 15 November each year a WOLO restriction was applied when the Bureau of Meteorology (BoM) forecast that the maximum temperature would exceed 35°C. After 15 November each year a WOLO restriction was applied when the BoM forecast that the maximum temperature would exceed 38°C.

In January 2005, the ARTC amended the forecast temperature threshold at which a WOLO restriction is applied to 35°C, regardless of the date. Shortly after January 2005 this threshold was further amended on the Albury to Junee corridor by ARTC south regional (infrastructure) management to 32°C. This local amendment was as a result of an assessment of the overall track condition, consideration of likely risks, and likely temperature variations on this corridor. WOLO restrictions were applied on this basis between Albury and Junee on 27 and 28 December 2005 and 30 December 2005 to 1 January 2006.

On the day of the derailment, the maximum temperature forecast was 31 degrees; however, the actual maximum was 33.5°C. By 1730 the temperature at Wagga Wagga was still 31.5 degrees. At 1826 the driver of 3AB6 obtained an air temperature reading of 35°C from the Diagnostic Information Display (DID) panel of lead locomotive NR 104.[31]

Due to the forecast temperature not being greater than 32°C, no WOLO speed restriction had been issued. Had the restriction been in place, the dynamic forces exerted on the track by the passage of train 3AB6 would have been reduced by 47 per cent. The track would have been much less likely to have misaligned with such a reduced dynamic loading.

2.3.6 Track stability

Temperature induced stresses

ARTC Standards TMP11, TMP12, TMP13, TMP14 and TMP17 pertain to the conduct of track work that involves a disturbance of track stability during the summer months. These standards place restrictions on some track work that might cause the track to become laterally unstable when temperature thresholds are exceeded. For example:

- Re-sleepering of the track usually involves minor track lifting that breaks the bonding established between remaining sleepers and compacted ballast, and places smooth new sleepers, which have no bond developed with the ballast, into the track.

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30 WOLO – telegraph code for speed restrictions imposed on trains due to hot weather, in accordance with ARTC standard TMP06.

31 The accuracy and reliability of this data is not known, and it was not used for analysis purposes in this report.

- Tamping of the track breaks the bond between the sleepers and the compacted ballast as well as loosening the ballast bed.

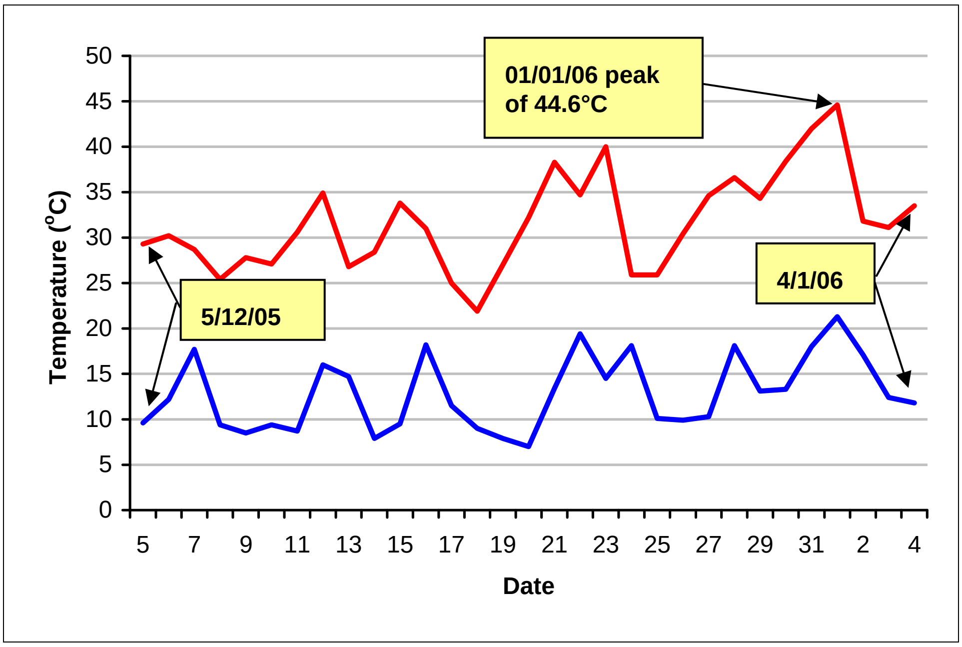
Of note is that an additional instruction pertaining to the maintenance of welded track on the main south line was issued for the period 1 November 2005 to 31 March 2006. A key element of this instruction was that, subject to various other restrictions, no work was to be undertaken if the ambient air temperature exceeded 35°C.

The resleepering work between the 563.500 kilometre mark and 582.000 kilometre mark was carried out during daylight hours between 9 November and 25 November 2005. During the period, the temperatures recorded by the BoM at Wagga Wagga peaked at 32.4°C on 9 November (the first day) and exceeded 30.0°C (31.1°C) on only one other occasion. On the day the ballast was tamped in the main line at Yerong Creek station (25 November 2005), a maximum temperature of 29.1°C was recorded at Wagga Wagga. The tamping work was performed in a southerly direction and was finished by 1150.

Between 29 November (when the TSR was lifted) and 30 December 2005, the maximum temperatures at Wagga Wagga ranged from 21°C to 42°C. The mean maximum temperature for December 2005 was 30.7°C. A total of 30 mm of rain fell during this period, of which 25 mm fell on 3 December 2005.

During the four days prior to the derailment (including 4 January 2006) there were some significant temperature variations. A maximum temperature of 44.6°C was recorded at Wagga Wagga on Sunday 1 January 2006 (the temperature reached 47°C at Lockhart on that day); and a minimum of 11.8°C was recorded early on the day of the derailment. This is a variation of nearly 33°C within three days.

Figure 16: Maximum and minimum temperatures from 5th December 2005 to 4th January 2006, recorded at Wagga Wagga



Rail creep

The propensity for rail creep[32] to occur when sections of rail are welded together is known to be influenced by rail temperature, the braking actions of trains, the direction of the bulk of traffic tonnage, the manner in which the rail is secured to the sleepers and the overall stability of the track.

On a gradient, rail will usually creep downhill, regardless of the direction of travel of a given rail movement. Rail creep can lead to rail ‘bunching’, where the creeping rail meets an unmoving area of rail, leading to large longitudinal compression forces. Rail bunching is most likely to occur at the bottom of hills and places where the infrastructure is ‘anchored’ by fixed points such as level crossings or turnouts. Left undetected or unchecked, the longitudinal compression forces of rail bunching can convert to lateral forces which can cause track misalignment.

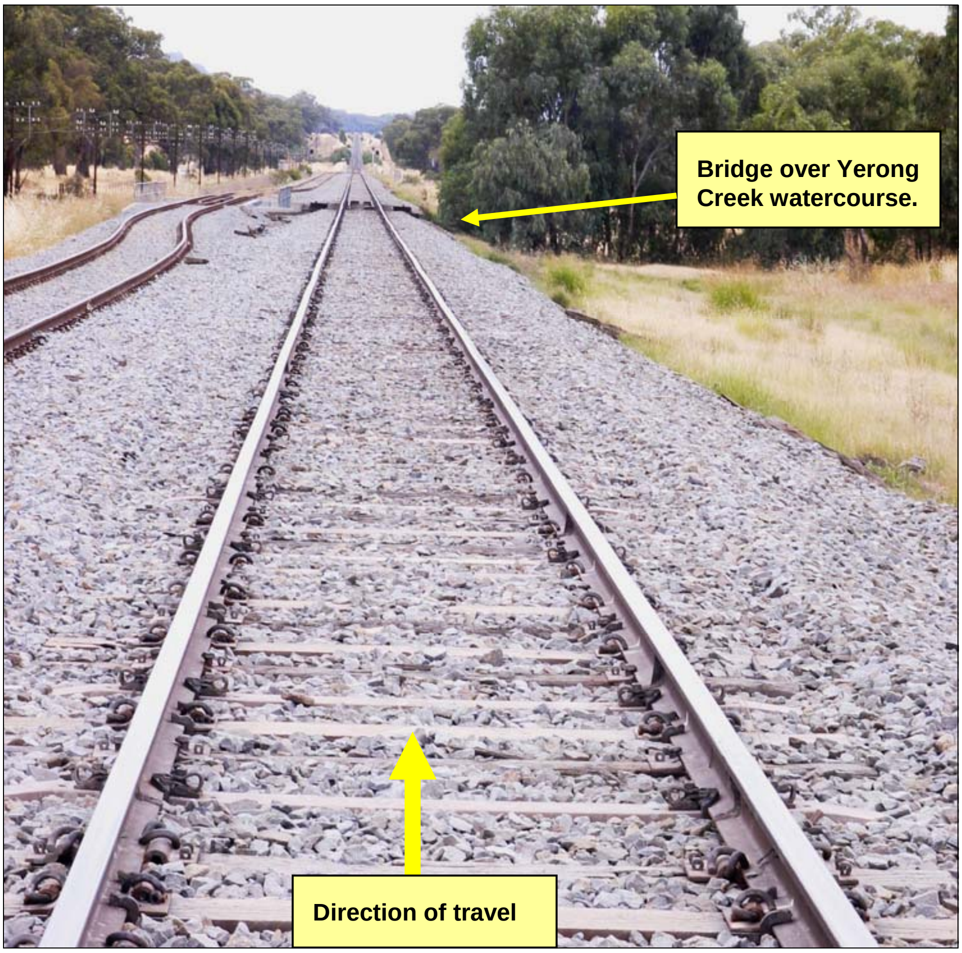
Rail creep at Yerong Creek was monitored by rail creep monuments 500 m apart. Measurements were taken every six months. The most recent measurements prior to the derailment were taken on 28 September 2005. These measurements revealed that the rail was creeping in the Down (‘southerly’) direction; this is the opposite direction to which train 3AB6 was travelling. The amount of creep (a maximum of 37 mm) was not excessive at these monitoring points, and no excessive bunching was indicated.

In general terms, track structure consists of ballast, sleepers, fasteners and rail. When track work such as resleepering is carried out the bond between these components, and hence lateral and longitudinal track stability, is disrupted. This is particularly so if, as in this instance, trains are travelling over the track while such work is in progress.

The likelihood of track instability being exacerbated by undetected localised rail creep and bunching needs to be considered. Continuous welded rail is laid in a stress free state (or the equivalent thereof). This rail is then monitored for creep at fixed points at intervals of 500 m in this instance, thereby giving an indication of stress changes within the rails. The assumption is that open track is homogenous and will experience a relatively long distance stress distribution effect as a result. However, it is known that compressive forces can build up within much shorter intervals, for example, in a 100 m section that leads up to a fixed point such as a turnout. It is also known that rail creep tends to bunch at the bottom of grades. The misalignment at Yerong Creek was within 410 m of the lowest point at Yerong Creek station.

32 Rail creep – the longitudinal movement of rails.

Figure 17: Lowest point at Yerong Creek station, to the north of misalignment



The monitoring at 500 m intervals did not detect any excessive rail creep. In addition, it would normally be anticipated that track stability would have been at its lowest at the time of the highest temperature; on 1 January 2006. However, there was a temperature variance of 33°C in just over three days before the derailment.

It is likely that as a result of ongoing maintenance on this area of continuous welded rail, the track was not homogenous in terms of its ability to resist rail creep. Detection of this by visual means, and by using annual Welded Track Stability Analysis measurements, would be unlikely. Localised long term bunching does not leave the same evidence as localised short term bunching. A relatively creep resistant section of track, as little as 100 m in length, had probably developed. As a result, the adjacent track had become less creep resistant over time. In effect, a bunching point had probably developed in track that was incorrectly classified as homogenous for maintenance purposes.

It is possible that the track experienced some minor lateral movement on 1 January 2006 on a scale that was not readily detectable but which resulted in a reduced friction bond between the sleepers and ballast. The horizontal alignment measurements that were taken on site immediately adjacent to the major misalignment indicate the probability that the track had become unstable. It is probable that the dynamic forces imparted by the passage of train 3AB6 at a speed of 111 km/h in combination with thermally induced forces within the rails were sufficient to overcome the track's weakened lateral resistance and resulted in the misalignment.

The ARTC submitted:

> It is known that misalignments generally occur at locations of high rail stresses or weakest lateral restraint and it is for this reason that the track structure has certain 'safety factors' built in to accommodate small deviations below Standard.
>
> The track structure at the scene of the derailment could be considered good and compliant with Standards and therefore well able to resist any 'misalignment forces'…
>
> <u>Conclusion</u>
>
> ARTC believes that the theory of the misalignment is not supported by the evidence.

The fact that a small track misalignment was found the day after the derailment about two kilometres to the south lends support to the scenario that a track misalignment caused the derailment. This misalignment was also within the area that was re-sleepered between 9 and 29 of November 2005. (Notations of the attending track personnel attributed the misalignment to the passage of train 3AB6.)

The intervals at which steel sleepers had been left after the resleepering work and the possible effect on track stability also has to be considered. Random wide pattern steel sleepers can cause variations in track stiffness which can impact on the riding qualities of rollingstock, particularly empty wagons. An increase in lateral forces can then occur. While no evidence exists that the steel sleepers at Yerong Creek contributed directly to track instability, an interval of one in 8 to one in 30 as found at the derailment site is not in accordance with standard TCS10.

Post Derailment track shift

The ARTC has commented:

> The evidence available on the site clearly shows some sleepers in the original position and some in a new or 'misaligned' position. Wheel marks on these sleepers and particularly on consecutive 'original' and 'misaligned' sleepers and the fact that these marks indicate only 1 bogie was derailed at that time.
>
> The orientation and location of the marks indicate that for the marks to have occurred, either the track misaligned after and as a result of the derailment or the derailed wheel was able to describe a sinusoidal path of pitch 600 mm and amplitude 400 mm down the track at close to 111 km/h.
>
> The more logical scenario is the former.

The NSW Independent Transport Safety and Reliability Regulator (ITSRR) has commented:

> Photographs, at hand, at ITSRR strongly support that derailed wheels caused the rail to depart from the sleeper plate prior to being moved in a lateral direction. The investigation in the draft report does not sufficiently negate the possibility that the track was misaligned by the derailed rolling stock.

Examination of the evidence shows that the section of track referred to in the comments above is on the northern side (after) of the point of derailment as shown in Figure 11. It is probable that the forces imparted by the derailed wheels caused the track after the point of derailment to move further laterally following the derailment. The evidence also indicates that the sleepers in question, although they have become detached from the rail, were on the misalignment curve at the northern extremity, not on the straight track alignment.

The was no sleeper movement (relative to the rails) found to the south of the point of derailment; sleepers were offline but still attached to the rails. The misalignment of the track in this area cannot be attributed to the derailment given that it was not subjected to the significant forces arising from the derailed wheels. There is no known case either nationally or in the United Kingdom or North America of 'whiplash' of track upstream of a derailment. Therefore, the misalignment probably existed prior to the derailment and is probably causal rather than consequential in the derailment sequence.

2.3.7 Summary

The track at Yerong Creek was monitored and maintained in accordance with the applicable standards and, apart from the high temperatures four days before the derailment, significant variations in environmental conditions should not have been a factor. Site observations revealed no obvious defects or exceedences that, in isolation, could have been direct contributors to the track misalignment. Notwithstanding this, the fact is that it is probable that a misalignment occurred.

Examination of the evidence shows that the misalignment probably existed prior to the derailment and that the derailment was probably a consequence of the misalignment.

It is likely that a combination of:

- thermally induced forces within the rails;
- a modified track structure and altered rail neutral temperature[33] as a result of recent track work; and
- the level of dynamic force resulting from the speed of train 3AB6.

combined to cause the track misalignment. In addition, steel sleepers in the vicinity of the misalignment were not installed to the pattern specified in the appropriate standard, and may have contributed to the reduction in track stability.

A comprehensive search of literature and discussions with experts in the field of rail management revealed that the science of detecting stresses within rails in situ, using non-destructive tests, is in its infancy. Current cutting edge technology consists of hand-held devices that have not been designed for use in monitoring rail stresses throughout whole rail networks. The tools to detect random localised stress exceedences do not yet exist. The ATSB determined that there was nothing that the ARTC, the track maintainer, could have realistically done at the time to detect these stresses and hence prevent this derailment.

33 The temperature of the rail when it is in neither compression nor tension.

The ATSB acknowledges that both the ARTC and the NSW rail regulator have procedures in place to reduce as much as possible, given the current level of technology, the risk of track stresses building up to the point of track instability.

2.4 ARTC submission

The ARTC considered in depth the possibility that the broken brake compression rod of the first bogie to derail caused the derailment. This scenario has been analysed by the ATSB and is considered unlikely as it does not provide a satisfactory explanation for:

- the force needed to break the compression rod,
- lack of surface damage to the compression rod and wheel flange,
- the mechanism for the observed derailment pattern of other wheels,
- the track misalignment found following the derailment.

In its submission, the ARTC contended that the brake compression rod had failed at some time before the point of derailment and that the rod initiated the derailment by passing under the trailing wheel-set of the bogie. In support of its hypothesis the ARTC provided the following comment with respect to two sleeper gouge marks near the start of the derailment sequence:

> …photograph 044 shows 2 flange marks on the head of a sleeper (Up side of track). The marks indicate an oblique mark was made first and then a 'parallel' mark made second which would indicate a leading wheel was derailed firstly and then the trailing wheel followed. This supports the bogie being adversely steered with the leading Up side wheel having a high angle of attack, climbing the rail and then pulling the trailing wheel set after it.

Analysis showed that these sleeper gouge marks (shown in Figure 18 below) are not necessarily from the first bogie to derail, or even from just one bogie; however, if they were both from the first derailed bogie, then they are not consistent with the hypothesis that the trailing axle's wheels derailed first after passing over the broken brake compression rod (found on that bogie). The lead axle would have had to derail first to achieve the angle to the rail indicated by the marks.

Analysis shows that if the trailing wheel in the bogie passes over an obstacle such as the compression rod, the wheel passing over the rod has further to travel, and would be inclined to steer the bogie in a clockwise motion in plan view. This would tend to steer the leading axle towards rail climb and derailment in the opposite direction to that which actually occurred.

Figure 18: Marked sleeper referred to in ARTC submission

In its submission the ARTC also argued that the impact marks on the level crossing before the derailment site could have been caused by the brake compression rod on the leading derailed bogie. It was proposed that this impact could have broken the compression rod. However, the force needed to break the compression rod (210 tonnes), if it was caused by an impact with the level crossing surface, would probably have torn away sections of the crossing, not simply scuffed the surface.

It was also proposed that the compression rod could have broken prior to the level crossing, and that the marks on the bitumen surface are evidence of this. The investigation found:

- No trace of bitumen was found on any of the wagon components examined to indicate that they had made contact with the roadway at the level crossing.
- The marks do not match the dimensions of the broken end of the compression rod.
- There was no theory or evidence found for the event necessary to break the compression rod prior to the level crossing.

ARTC also submitted that the light oblique intermittent marks found on the head[34] of the Down rail between the level crossing and the derailment site were caused by the broken compression rod. However, the broken compression rod would have rotated around the pin at the end of the dead lever, which is above rail level. In addition, the head of the rail is canted towards the four foot. The compression rod would have rotated down at an angle such that it could only have struck the outside

34 The head of the rail is the polished top surface that the wheel treads run on.

top edge of the rail and not the head of the rail. Therefore, it is considered that it could not have caused these marks.

3 FINDINGS

3.1 Context

From the evidence available, the following findings are made with respect to the derailment of freight train 3AB6 at Yerong Creek on 4 January 2006 and should not be read as apportioning blame or liability to any particular organisation or individual.

3.2 Contributing factors

- The stability of the track in the vicinity of the derailment at Yerong Creek was probably diminished by thermal and creep induced forces within the rails combined with a modified track structure as a result of recent track work.
- The unrestricted speed of train 3AB6 on a relatively hot day provided sufficient dynamic force to cause the track, with its diminished stability, to misalign. *[Safety Issue]*
- The track had been maintained based on the assumption that rail creep is sufficiently homogenous in open track to be manageable if monitored at 500 m intervals. It is likely that the rail creep in the area of the derailment was not homogenous as a result of long term and recent track work. Ballasted track structure based on continuous welded rails is sufficiently non-homogenous to enable bunching points to develop over time in open track. If localised rail bunching occurs, a build up of compressive longitudinal forces in the rail, sufficient to cause a misalignment, can occur over a short distance. Undertaking track work that breaks the bond between the sleepers and ballast can result in localised creep and bunching of rail. The current approach to creep measurement, that is, monitoring rail movement every 500 m, may not detect these localised variations. *[Safety Issue]*

3.3 Other safety factors

- The random wide pattern installation of steel sleepers that existed at Yerong Creek can cause localised variations in track stiffness which can impact on the riding qualities of rollingstock resulting in an increase in forces, including lateral forces. *[Safety Issue]*
- The train manifest had not been updated and hence the location of the dangerous goods was incorrectly stated; this led to an escalation of the response and the closure of the Olympic Highway by attending emergency services. *[Safety Issue]*
- The current imposition of precautionary temperature-related speed restrictions recognises maximum temperature extremes but does not allow for a situation where daily temperature variations (minimum to maximum) are significant. *[Safety Issue]*

3.4 Other key findings

- The lateral forces at the point of mount were such that the flange of the trailing left wheel of the lead bogie of RQSY 34448, the first wheel to derail, climbed the rail head and derailed to the Up side of the rail. This derailment sequence was repeated for the three following wagons.
- The failure and rotation of the compression rod of bogie RCYD 26426 probably occurred as a result of the derailment.
- There were no defects found in the two derailed wagons examined which could have caused train 3AB6 to derail.
- There were no readily apparent defects in the remaining wagons that were examined on site that could have caused train 3AB6 to derail.
- The actions of the train crew did not contribute to the derailment.
- Site investigations revealed no obvious defects or exceedences in the track that alone could have caused the track misalignment.
- With the exception of the pattern of steel sleeper placement, the track at Yerong Creek was monitored and maintained in accordance with the relevant standards.
- The condition of the track between Albury and Macarthur had reached the point where the ARTC reduced the WOLO threshold to 32°C in January 2005.
- The ARTC and the ITSRR have procedures in place to reduce as much as possible the risk of track stresses building up to the point of track instability.

4 SAFETY ACTIONS

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

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

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the rail industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

4.1 Australian Rail Track Corporation

4.1.1 Influence of Temperature on Track Stability

Safety Issue

The unrestricted speed of train 3AB6 on a relatively hot day provided sufficient dynamic force to cause the track, with its diminished stability, to misalign.

The current imposition of precautionary temperature-related speed restrictions recognises maximum temperature extremes but does not allow for a situation where daily temperature variations (minimum to maximum) are significant.

Response by the ARTC

The ARTC in its submission did not accept that its approach to managing the impact of temperature on track stability was a safety issue.

ATSB safety recommendation RR20080001

The Australian Transport Safety Bureau recommends that the Australian Rail Track Corporation takes further action to address this safety issue.

4.1.2 Steel Sleepers

Safety Issue

The random wide pattern installation of steel sleepers that existed at Yerong Creek can cause localised variations in track stiffness which can impact on the riding qualities of rollingstock resulting in an increase in forces, including lateral forces.

Response by the ARTC

Prior to the derailment, the ARTC had undertaken a program to identify and conduct remedial action where steel sleepers have not been installed in accordance with standards. The ARTC had also indicated that they will be resleepering the Melbourne to Sydney corridor with concrete sleepers. This program has been confirmed and will ultimately result in the removal of all steel sleepers from the Melbourne to Sydney main line.

ATSB safety recommendation RR20080002

The Australian Transport Safety Bureau recommends that the Australian Rail Track Corporation takes action to address this safety issue.

4.2 Pacific National

Safety issue

The train manifest had not been updated and hence the location of the dangerous goods was incorrectly stated; this led to an escalation of the response and the closure of the Olympic Highway by attending emergency services.

Response by Pacific National

With regard to the documenting of the location of dangerous goods on trains, Pacific National has advised as follows:

> Pacific National has issued Local Safety Notice 0702 'BA AB Services ex Tottenham' This is in relation to the reversing of these services at Tottenham. The driver must endorse the load consist stating that the load has been reversed.

This is an interim measure until such time as Tottenham is redeveloped allowing the AB/BA services to continue after an engine change without reversing the train. The AB/BA services are the only services that are subject to this arrangement; all others go into/exit from the Melbourne Freight Terminal.

4.3 All track maintainers in Australia

Safety Issue

The track had been maintained based on the assumption that rail creep is sufficiently homogenous in open track to be manageable if monitored at 500 m intervals. It is likely that the rail creep in the area of the derailment was not homogenous as a result of long term and recent track work. Ballasted track structure based on continuous welded rails is sufficiently non-homogenous to enable bunching points to develop over time in open track. If localised rail bunching occurs, a build up of compressive longitudinal forces in the rail, sufficient to cause a misalignment, can occur over a short distance. Undertaking track work that breaks the bond between the sleepers and ballast can result in localised creep and bunching of rail. The current approach to creep measurement, that is, monitoring rail movement every 500 m, may not detect these localised variations.

ATSB Safety Advisory Notice RS2007003

The Australian Transport Safety Bureau advises that all track maintainers in Australia should consider the implications of this safety issue and take action where considered appropriate.

APPENDIX A : TECHNICAL ANALYSIS REPORT

Method of Examination

The components retained by the ATSB for laboratory examination included the two broken clevis arms from the forward end of the compression rod and a single retaining pin. The broken clevis ends were examined optically using a binocular microscope and at higher magnification using the scanning electron microscope (SEM). Material characterisation including metallography, hardness and quantitative chemical analysis was also performed on the broken component.

Visual Examination

Initial examination of the parts received revealed that the end of the compression rod clevis was broken transversely through both sides of the component. The fractures occurred through the middle of the fourth and fifth adjustment holes, refer Figure A. The broken pieces were relatively uniform in shape and free from any obvious signs of distortion.

A uniform level of light corrosion product was observed on each of the four fracture surfaces. The fracture surfaces were clean and free of such product when first observed at the Yerong Creek derailment site.

The corrosion product was removed from the fracture surfaces[35], which revealed only features consistent with gross overload, for example shear lips and river patterns. The crack origins on each of the four fracture surfaces could be traced back to the internal edge of the adjustment holes and those labelled in Figure B.

No evidence of progressive crack fatigue growth was observed that might otherwise suggest the component had failed prior to the Yerong Creek accident.

A small surface layer of bright crystalline fracture features was also observed and extended inward from the surface for approximately 1 mm. These features are typically produced from overload behaviour on a case-hardened steel component.

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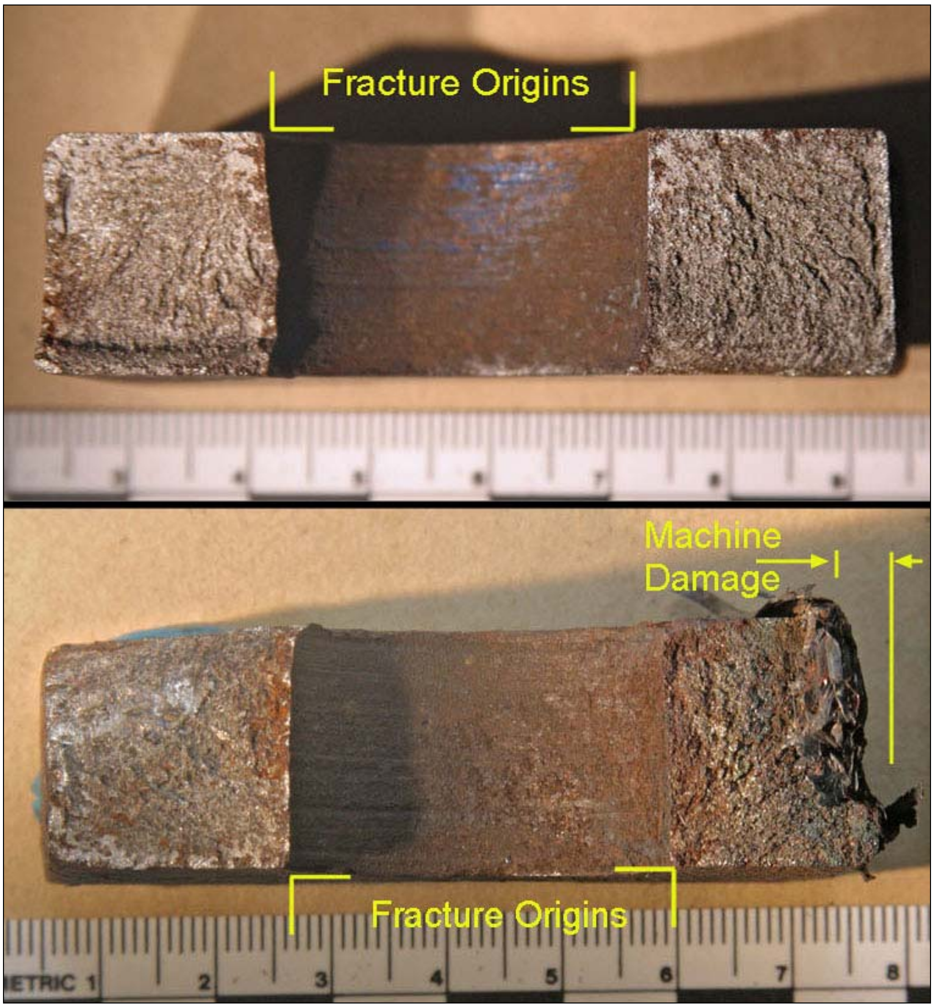
35 The corrosion product on the fracture surfaces was removed by ultrasonic immersion using a solution of 1.5 w/v aqueous Alconox.

Figure A: General view of the broken end section from the compression rod as received by ATSB

A notable feature on the lower edge of one the clevis pieces, was the presence of mechanical damage that had been produced from severe metal-to-metal contact. Machining and material loss were clearly apparent on the lower surface, see Figure B. Through-thickness measurements indicated that approximately 4 mm of steel had been removed at this location. The fracture surface adjacent to the wear damage was discoloured from the heat generated during the contact event.

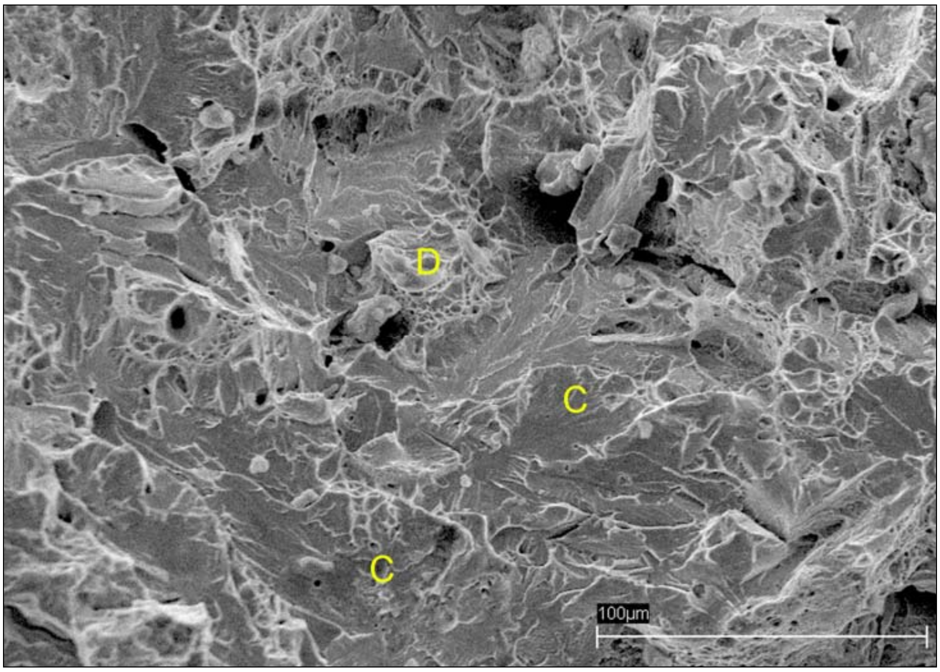
Figure B: View of the fracture surfaces from each half of the compression rod clevis. The fracture origins and machine-damaged area is labelled



Scanning Electron Microscopy (SEM)

Examination of all four fractures of the broken compression rod was performed at high magnification using the SEM. The fracture examination revealed the presence of brittle cleavage facets over most surfaces, refer Figure C. Small patches of ductile overload were also observed as well as an intergranular region associated with the surface hardened outer layer of steel.

Figure C: The component broke in a brittle manner with mainly flat cleavage facets, labelled 'C', present on the fracture. Some regions of ductile overload were also observed, labelled 'D'



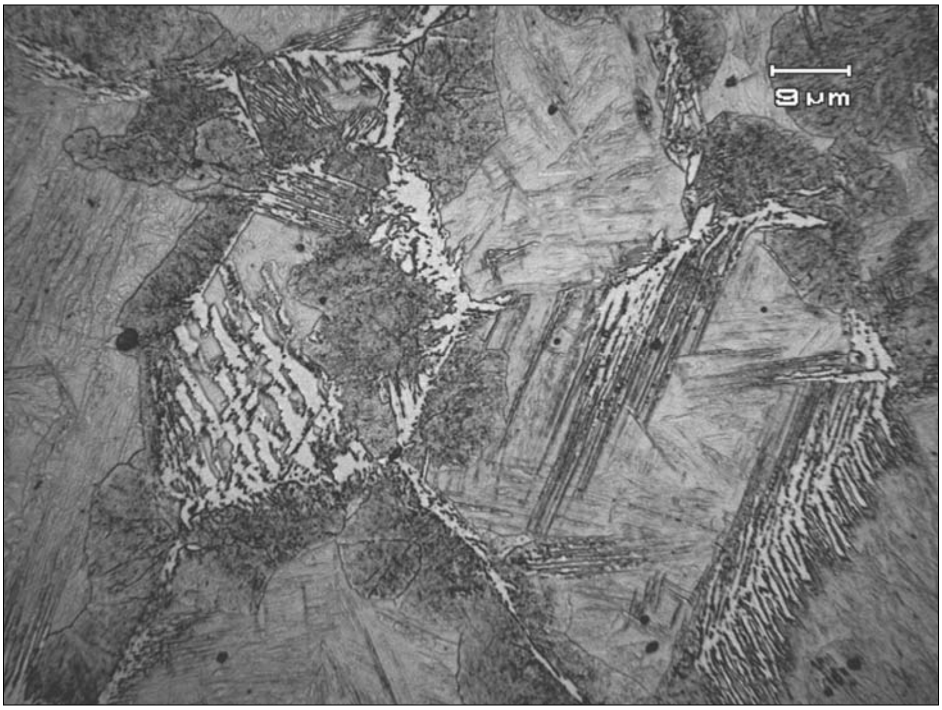
Metallography

Samples of material in a plane parallel, and immediately adjacent to the fracture surfaces, were removed from the broken clevis section of the compression rod for microstructural examination. The samples were prepared using metallographic techniques and the microstructure of the steel comprising the compression rod examined in the as-polished and etched conditions.

Examination of the etched metallographic specimens revealed a steel microstructure that consisted primarily of ferrite and laths of upper-bainite, see Figure D. The presence of bainite in the microstructure indicates that an intermediate cooling rate had been used during the heat treatment process at manufacture.

A microstructure different to the core was observed to extend from the outer surface of the component and then inward for approximately 1 mm. The micro-features indicated that it had probably been case-carburized during manufacture. This type of heat treatment is typically used to improve surface properties such as hardness and wear resistance.

Figure D: The compression rod microstructure was comprised mainly of ferrite and upper-bainite



Note: Microstructure prepared using 1% Nital etchant.

Chemical Analysis

Quantitative chemical analysis of the steel comprising the broken clevis section was performed by Spectrometer Services Pty Ltd[36]. The results of the analysis, see Table 1, indicate that the steel was a carbon steel with a major alloying addition of manganese (Mn) and a minor alloying addition of silicon (Si). No engineering drawings, material specifications or other such literature, were supplied with the broken compression rod, but based on the chemical results it was probably a semi-killed low carbon steel equivalent to SAE-AISI 1030[37].

Table 1: Chemical composition of the failed compression rod

	Fe	C	Mn	Si	S	P	Ni	Cr	Mo	Cu	V	Nb	Ti	Al	B
Wt%	Rem	0.28	0.84	0.07	0.027	0.012	<0.01	0.02	0.01	<0.01	<0.01	<0.01	<0.01	<0.005	<0.0005

Material Hardness

Hardness measurements from the broken clevis were performed using a Vickers diamond pyramid indentor and a 30 kg indentation mass. The measurements indicated that the hardness level of the steel progressively decreased from the surface toward the core to a depth of approximately 3 mm. The Vickers hardness of

36 Spectrometer Services Pty. Ltd. Report Reference Number 06/630, 3 March 2006.

37 ASM Handbook Volume 1, Properties and Selection: Iron Steels and High Performance Alloys, ASM International, 1990, page 150.

the component at the surface measured 887 HV[38], while the core hardness measured 396 HV, see Table 2.

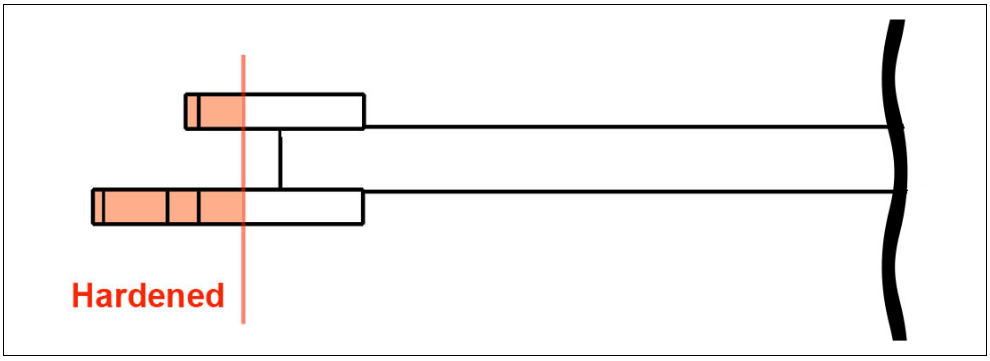
Surface hardness measurements were also taken at a number of positions along the length of the rod. The measurements showed that the hardness of the rod was significantly less than that of the broken clevis. This indicates that only the clevis end section had been heat-treated in order to improve the surface properties, while the rod had been left in a softer, more ductile condition, see Figure E.

No mechanical property data was found in the published literature for SAE-AISI 1030 with a mainly bainitic microstructure. However, hardness values for this steel have been published to vary between 130 HV and 196 HV[39].

Table 2: Vickers hardness results for the steel comprising the compression rod

Hardness HV_{30}	Distance from Surface (mm)	
887	0.0	Surface
763	0.4	
575	0.8	
508	1.3	
493	1.8	
481	2.3	
396	9.7	Core

Figure E: Illustration of the compression rod showing how the end of the fractured clevis section had been case-hardened with respect to the rest of the rod



38 Vickers hardness (VH) of a material is determined using variable loads and a diamond pyramid indentor. The VH number is calculated by using both the load and surface area of the permanent impression made by the indentor. All ranges of hardness can be tested using this technique.

39 Metals Handbook, Vol.1 - Properties and Selection: Irons, Steels, and High-Performance Alloys, ASM International 10th Ed. 1990.

Stress Analysis

A simple calculation was made to determine the statically applied load required in order to exceed the inherent design strength of the compression rod to failure. A few assumptions were made on the material properties of the steel comprising the rod to make the calculation. As the hardness results indicate, the profile through the clevis section varies from very hard at the outer surface, to a somewhat softer condition in the core. Rather than using an average hardness value, core hardness values were used in the strength calculations. By using the core values, an estimate of the minimum force required to produce complete failure in a tensile overload situation was made. Figure F shows a schematic of the broken clevis end of the compression rod. The calculation was as follows:

The core Vickers hardness of 396 HV was converted to an equivalent ultimate tensile value of ~1290 MPa.

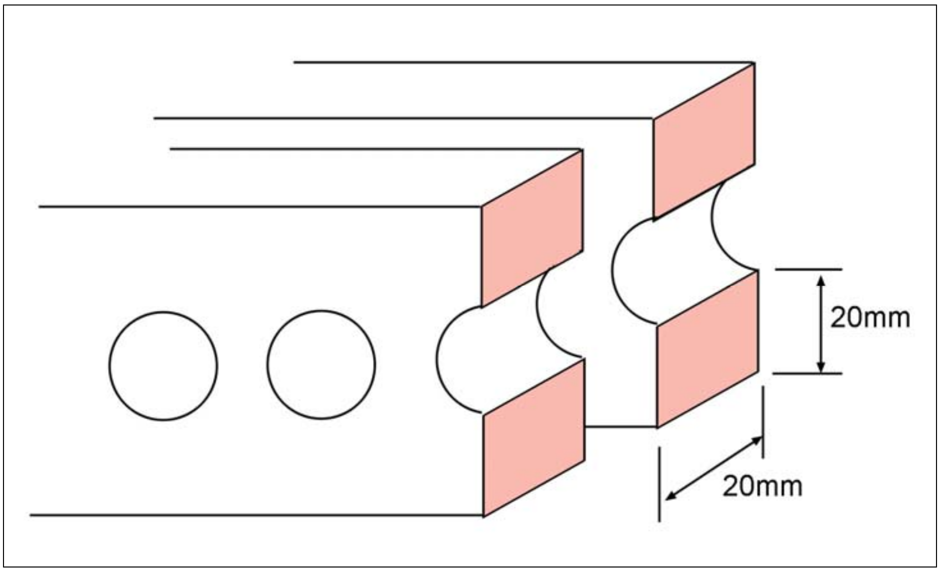
σ = Force / Area
$1290\text{x}10^{6}$ = Force / [$4\text{x}(20\text{x}10^{-3}\text{x}20\text{x}10^{-3})$]
Force = 2064 kN

Converting the answer in Newtons (N) to kilograms force (Kg), where 1 N equals 0.10197 kg:

Load = $2064\ \text{x}10^{3}$ x 0.10197
= 210466 kg or ~210 t

Therefore the minimum tensile load needed to structurally overload the component was calculated as a tensile application of ~210 t, or equivalently ~2064 kN.

Figure F: Schematic of the broken rod clevis



APPENDIX B : SOURCES AND SUBMISSIONS

Sources of information

Bureau of Meteorology

Cowin International Railroad Consulting Pty Ltd

Lockhart Shire Council

Operating crew of Pacific National freight train 3AB6

Officers of the Australian Rail Track Corporation

Officers of the Independent Transport Safety and Reliability Regulator, NSW

Officers of the National Transportation Safety Board, USA

Officers of the Office of Transport Safety Investigations, NSW

Officers of Pacific National

Officers of the Rail Accident Investigation Branch, UK

References

National Transportation Safety Board USA 2006, Railroad Accident Brief: Operation of Amtrak Passenger Train Over CN Misaligned Track, Arcola, Louisiana, June 26, 2006 NTSB Report Number: RAB-06-08, adopted on 21 Dec 2006, NTSB website

Office of Transport Safety Investigations, NSW 2005, RAIL SAFETY INVESTIGATION REPORT - Steel Sleeper Introduction on NSW Class 1 MainLine Track.1996 – 2004, OTSI File Ref: 02619 ,OTSI website

Submissions

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

A draft of this report was provided to:

a) The Australian Rail Track Corporation (ARTC)

b) Pacific National

c) The Independent Transport Safety & Reliability Regulator (ITSRR)

d) The Office of Transport Safety Investigations (OTSI)

e) A small number of individuals.

The Australian Rail Track Corporation

The ARTC submitted a substantial and detailed analysis of some aspects of the draft report. The suggestions therein were incorporated where appropriate into the final report.

Pacific National

Pacific National submitted updated information that was incorporated into the final report.

The Independent Transport Safety & Reliability Regulator

The ITSRR submitted comment on the meaning of some of the site evidence relating to timber sleeper damage and displacement. Further detail has been added to section 2.1.1 of the final report to outline the logic that was used when analysing this site evidence.

The Office of transport Safety Investigations (OTSI)

The OTSI made several suggestions that have been incorporated where appropriate into the final report.

APPENDIX C : MEDIA RELEASE

Track misalignment causes derailment

An ATSB investigation has found that a number of factors combined to cause the derailment of a freight train at Yerong Creek in southern NSW on 4 January 2006, any one of which may not have resulted in a derailment in its own right.

The Australian Transport Safety Bureau investigation into the derailment concluded that a track misalignment occurred as a result of localised stresses in the rail that had built up until the track moved as the train passed over it.

The track at this location, the main rail corridor between Melbourne and Sydney, has rails that have been welded into one continuous length, in accordance with modern international practice.

The investigation found that the track had not reacted evenly to the forces upon it, and that this had led to a fault in the track, in the form of excessive localised stress in the area of the misalignment.

The investigation found that such localised stresses are very rare, and difficult to detect, even with the best modern technology.

The ATSB acknowledges that both the ARTC and the NSW rail regulator have procedures in place to reduce as much as possible the risk of track stresses building up to the point of track instability.

The ATSB has issued a safety advisory notice to all track maintainers in Australia to highlight this limitation of present technology when managing continuous welded rail.