RAIL SAFETY INVESTIGATION REPORT

DERAILMENT OF PACIFIC NATIONAL SERVICE 5CM3

GRIFFITH TO LEETON RAIL SECTION

11 JANUARY 2007
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Released under the provisions of Section 45C (2) of the Transportation Administration Act 1988 and Section 67 (2) of the Rail Safety Act 2008

Investigation Reference 04343
Published by: The Office of Transport Safety Investigations
Postal address: PO Box A2616, Sydney South, NSW 1235
Office location: Level 17, 201 Elizabeth Street, Sydney NSW 2000
Telephone: 02 9322 9200
Accident and incident notification: 1800 677 766
Facsimile: 02 9322 9299
E-mail: info@otsi.nsw.gov.au
Internet: www.otsi.nsw.gov.au

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ACRONYMS AND ABBREVIATIONS

ARTC .......... Australian Rail Track Corporation
ATSB ........... Australian Transport Safety Bureau
CCSB .......... Constant Contact Side Bearer
CFCLA .......... Chicago Freight Car Leasing Australia
CWR .......... Continuously Welded Rail
DCC .......... PN’s Divisional Control Centre, Adelaide
DIP .......... Directly Involved Parties
ITSSR .......... Independent Transport Safety and Reliability Regulator (replaced by the Independent Transport Safety Regulator (ITSR) on 1 July 2010)
JWR .......... Jointed Welded Rail
LAU .......... Local Appendices Units
NCCS .......... Network Control Centre South, Junee (previously known as Junee Train Control (JUCO))
OTSI .......... Office of Transport Safety Investigations
PN .......... Pacific National Pty Ltd
POD .......... Point of Derailment
POM .......... Point of Mount
PPL .......... Patrick PortLink
RFS .......... Rural Fire Service
RIC .......... Rail Infrastructure Corporation (replaced by the Country Rail Infrastructure Authority (CRIA) on 1 July 2010)
RTE .......... Rail Temperature Error
TCI .......... Track Condition Index
TOA .......... Train Occupancy Authority
TOC .......... Train Operating Conditions (Manual)
TRB .......... Train Register Book
WTSA .......... Welded Track Stability Analysis
## GLOSSARY

<table>
<thead>
<tr>
<th>Alignment</th>
<th>The horizontal position of a track measured in relation to survey marks. The measurement of alignment is from survey marks to the line rail.</th>
</tr>
</thead>
<tbody>
<tr>
<td>AK Car</td>
<td>A track-recording vehicle, which incorporates an inertial system fitted to a modified passenger vehicle, to measure track geometry continuously along the track. The AK car measures the tracks vertical (top) and horizontal alignment, gauge, cross level and twist.</td>
</tr>
<tr>
<td>Anchors</td>
<td>Devices (other than resilient fastenings) interfacing between a rail and the supporting ties or bearers designed to prevent longitudinal movement of the rail relative to the ties.</td>
</tr>
<tr>
<td>Ballast</td>
<td>Crushed rock packed under and around sleepers to hold track in position, spread weight, and provide drainage.</td>
</tr>
<tr>
<td>Block</td>
<td>A portion of the line with defined limits between which only one train is allowed at any one time.</td>
</tr>
<tr>
<td>Bog Hole</td>
<td>When water is trapped in the ballast and formation, the pumping action of the trains running on the track will soften the formation causing bog holes. This will degrade the ballast so it cannot support the track.</td>
</tr>
<tr>
<td>Bogie</td>
<td>A structure incorporating suspension elements and fitted with wheels and axles, used to support rail vehicles at or near the ends and capable of rotation in the horizontal plane. It may have two or more axle sets, and may be the common support of adjacent units of an articulated vehicle.</td>
</tr>
<tr>
<td>Bolster</td>
<td>A bogie component which forms the main transverse structural member through which load is transferred to a wagon’s suspension and side frames.</td>
</tr>
<tr>
<td>Buckle</td>
<td>See “Misalignment”.</td>
</tr>
<tr>
<td>Constant Contact Side Bearers (CCSB)</td>
<td>CCSBs provide rotational resistance between the bogie and the vehicle body to stabilise the bogie and thus prevent a three-piece bogie from hunting. A CCSB uses rollers, which provide almost no rotational resistance and only act as a constraint to the rolling motion of the wagon body, typically above 80km/h.</td>
</tr>
<tr>
<td>Continuous Welded Rail (CWR)</td>
<td>Track where the rail is joined by welding (and other non-moveable joints such as glued insulated joints) in continuous lengths between fixed points or in lengths greater than 220m, and where adjustment controls are in place.</td>
</tr>
<tr>
<td>Coupler</td>
<td>A mechanism to join two rail vehicles together.</td>
</tr>
<tr>
<td>Creep</td>
<td>The permanent or progressive longitudinal movement of rails in track caused by expansion or contraction of the rail or the action of traffic.</td>
</tr>
<tr>
<td>Crib</td>
<td>The area between adjacent sleepers.</td>
</tr>
<tr>
<td>Crib Ballast</td>
<td>The track ballast located between adjacent sleepers.</td>
</tr>
<tr>
<td><strong>Cross level</strong></td>
<td>Cross level is the difference in elevation of the tops of opposite rails measured at right angles to the alignment of the track.</td>
</tr>
<tr>
<td><strong>Crossover</strong></td>
<td>The means by which trains pass from one track to an adjacent parallel track. A Crossover is constructed from two turnouts (one on each track facing opposite directions) and connecting plain trackwork.</td>
</tr>
<tr>
<td><strong>Dogspike</strong></td>
<td>A metal spike that is driven into a pre-drilled hole in a timber sleeper to hold the rail foot against vertical and lateral movement.</td>
</tr>
<tr>
<td><strong>Down and Up Rail Lines</strong></td>
<td>Trains that run away from Sydney are Down trains. The lines that carry them are Down lines. Trains that run towards Sydney are Up trains. The lines that carry them are Up lines. The ‘Down’ rail in NSW is the right hand rail facing in the direction that a train would travel to reach Sydney; conversely the ‘Up’ rail is the left hand rail.</td>
</tr>
<tr>
<td><strong>Flange (Wheel)</strong></td>
<td>The larger diameter, inner part of the train's wheel. It is used as the primary means of guidance, steering the train along the track through the interaction between the gauge face of the rail and the wheel flanges.</td>
</tr>
<tr>
<td><strong>Gauge</strong></td>
<td>The distance between the inside running (or gauge) faces of the two rails, measured between points 16 mm below the top of the rail heads. Standard gauge is track gauge measuring 1435mm (and used throughout NSW).</td>
</tr>
<tr>
<td><strong>Green Card</strong></td>
<td>A maintenance card attached to a wagon to alert wagon maintenance and operational staff that a <strong>non-safety critical defect</strong> exists on the wagon.</td>
</tr>
<tr>
<td><strong>Hunting</strong></td>
<td>The excessive side to side movement of a bogie during travel, attributed to worn or defective components.</td>
</tr>
<tr>
<td><strong>Misalignment</strong></td>
<td>A short, sharp sideways movement of track. It can result in either a sharp radius curve or an 'S' shape. Also referred to as a buckle.</td>
</tr>
<tr>
<td><strong>Network Controller</strong></td>
<td>A qualified worker who monitors and controls train movements from a Control Centre.</td>
</tr>
<tr>
<td><strong>Neutral Temperature</strong></td>
<td>The rail temperature at which a properly adjusted track will be stress free. Usually set at 35°C.</td>
</tr>
<tr>
<td><strong>Pod</strong></td>
<td>The void or space under a steel sleeper which is packed with ballast.</td>
</tr>
<tr>
<td><strong>Pumping</strong></td>
<td>Sleeper movement where the sleeper moves up and down as rail traffic passes over it. This movement often results in the degradation and contamination of the ballast structure (see Bog Hole).</td>
</tr>
<tr>
<td><strong>Rail Temperature Error (RTE)</strong></td>
<td>An expression of rail adjustment in °C indicating the extent of rail adjustment deviation in relation to the standard neutral temperature (35°C). It is calculated by subtracting the Theoretical Measured Temperature from the Actual Measured Temperature.</td>
</tr>
<tr>
<td><strong>Red Card</strong></td>
<td>A maintenance card attached to a wagon to alert wagon maintenance and operational staff that a <strong>safety critical defect</strong> exists on the wagon and that it should be withdrawn from service until the necessary repairs have been effected.</td>
</tr>
</tbody>
</table>
**Road/rail Vehicle**
A vehicle that is capable of running on both road and rail. Often these are standard road vehicles that have retractable assemblies fitted front and rear which incorporate a pair of flanged rail wheels. Also commonly referred to in the rail industry as a ‘hi-rail’ vehicle.

**Safeworking**
Systems and procedures for the working of trains safely and for the protection of employees, passengers, freight and vehicles on or about the line.

**Staff**
The token used in a train staff system, the possession of which gives the train driver authority to enter a block section.

**Staff and Ticket**
The Staff and Ticket system is used in bi-directional single line territory, in lieu of rail vehicle detection systems, to give a train sole occupancy of the section and prevent other trains from entering the same section.

**Tamping**
The process by which ballast is packed around the sleepers of a track to restrain the sleepers from movement.

**Top and Line**
Describes two rail parameters; **top** refers to the surface (straightness, or continuity) of the top of the rail; **line** refers to the correct alignment of the side (or gauge face) of the rails. They are related to the ‘base operating conditions’ or standards that identify the vertical and horizontal alignment limits that would affect rolling stock ride and, if excessive, could cause derailment.

**Track Condition Index (TCI)**
A numerical evaluation, provided by the Track Recording Car, of general track condition.

**Train Control**
A control centre which manages train movements on a designated area of the country rail network. The Australian Rail Track Corporation (ARTC) has two Train Control Centres in NSW, Network Control Centre North (NCCN) at Broadmeadow and Network Control Centre South (NCCS) at Junee.

**Track Occupancy Authority (TOA)**
A formal authority for qualified workers and their equipment to occupy a defined portion of track for a specified period. It may be also granted for movement of track vehicles singly or in convoy.

**Tread**
Rail tread is the area of the wheel’s circumference which is in contact with the rail head during normal running conditions.

**Turnout**
The assembly of stock rails, point switches, crossings and closure rails by means of which rolling stock may be diverted from one track to another. (see Points)

**WOLO**
Speed restrictions applied during hot weather.

**Welded Track Stability Analysis (WTSA)**
An inspection of rail adjustment, ballast profile and condition, fastening condition and areas of potential concern. The analysis requires inspectors to assess critical track features for each ½ km of track. These include the condition of all track components, the prevailing track geometry and any movement that may have taken place since the last assessment. It then ascribes a weighting to each of the parameters and determines a nominal “percentage loss of stability”.

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**Derailment of Pacific National Freight Service 5CM3, Griffith to Leeton Rail Section, 11 January 2007**  
**vi**
EXECUTIVE SUMMARY

At approximately 5:30pm on 11 January 2007, ten container wagons on Pacific National’s freight service 5CM3 derailed approximately 3km North West of Leeton in the Riverina region of NSW. The train consisted of three locomotives and 27 container wagons conveying 69 shipping containers, and was en route from Griffith to Melbourne.

The derailment occurred on a straight section of track as the train was slowing in preparation for a temporary speed restriction just beyond the Griffith Road level crossing. The 17th and 19th to 27th wagons derailed and the train came to rest blocking the level crossing. Police, Roads and Traffic Authority and Leeton Shire Council personnel attended and directed road traffic to an alternative crossing. Fortunately, the crew was not injured and there were no other persons involved in the derailment.

The ten derailed wagons, three shipping containers on one of the wagons which overturned, 220m of track and the road surface at the level crossing sustained varying degrees of damage. The NSW Rural Fire Service responded to a small grass fire caused by the derailment.

The investigation found that the derailment was caused by a lateral misalignment of the track at 615.987km. The two main track-related factors contributing to the lateral misalignment were found to be:

- excessive compressive forces in the rail, and
- failure of the track structure to contain the compressive forces.

In addition, it was found that although the Australian Rail Track Corporation (ARTC) had appropriate processes in place to monitor and measure the condition of the track, errors and omissions in the records meant that an accurate depiction of the track condition was not being recorded; this was particularly the case in regard to the annual welded track stability analysis (WTSA) which did not detect any problems warranting other than routine programmed maintenance. As the primary tool for detecting the potential for misalignments, the WTSA has some limitations in that there are some conditions which it does not analyse.
In the area of the derailment, track adjustments had been made which involved the conversion of 220m sections of jointed welded rail (JWR) to continuous welded rail (CWR). The conversions involve the removal of the rail ends containing the bolt holes and welding in a section of new rail. Every weld is recorded on a form referred to as a welding return.

The welding returns, which recorded the welding work done under contract on the Griffith to Leeton section, contained a number of errors, omissions and anomalies, and had not been signed-off appropriately. The welder, who was familiar with his employer’s welding return documentation, was required to use the ARTC form but was not provided with adequate instruction in its compilation. The welder understood the adjustment calculation procedure but had misinterpreted some column headings on the form, resulting in incorrect entries. A consequence of the incorrect entries on the form was that the Rail Operator, who checked the welds some days after they were completed, did not have complete and accurate data on which to base his assessments.

Full details of the Findings and Recommendations of this rail safety investigation are contained in Parts 3 and 4 respectively, but the key remedial action to be undertaken by ARTC includes the following safety action:

- revising its WTSA and associated processes to take into account additional factors that may improve its outcomes as a tool for identifying sections of line showing the potential for misalignments;
- improving maintenance of continuously welded rail track, with an emphasis on sleeper maintenance, through a review of the relevant engineering standards;
- improving accountability for the correct adjustment of rail; and
- placing greater emphasis on programmed walking inspections to detect defects and anomalies in track.
PART 1  FACTUAL INFORMATION

Accident Synopsis

1.1 At approximately 5:30pm\(^1\) on 11 January 2007, 10 container wagons on Pacific National’s (PN) freight service 5CM3 derailed approximately 3km North West of Leeton in the Riverina region of NSW. The train consisted of three locomotives and 27 container wagons carrying 69 shipping containers\(^2\), and was en route from Griffith to Melbourne. There were no injuries. The NSW Rural Fire Service (RFS) was required to respond to a small grass fire caused by the derailment.

Accident Narrative

Before the Derailment

1.2 The train was marshalled at Griffith. Before departing, the crew were advised by a signaller at Griffith that a temporary speed restriction (WOLO) was in place because of expected high temperatures and that the train’s maximum operating speed would be restricted to 70km/h.

1.3 Although the decision to impose a WOLO had been followed by a track patrol carried out between 11:34am and 2:50pm, the Australian Rail Track Corporation’s (ARTC) track maintenance staff based at Griffith remained concerned about the stability of the section of track between Griffith and Narrandera because of the prevailing high temperatures. Consequently, they initiated a second patrol, using a road/rail vehicle, to follow the train as it departed Griffith at 4:50pm.\(^3\)

1.4 The train was driven at or below 70km/h until encountering a temporary speed restriction of 60km/h approximately 3km from the Griffith Road level crossing. The train was then on a slight uphill grade and the driver maintained the throttle in notch one (the lowest throttle setting) so as to keep

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\(^1\) Times referenced to Network Control Centre South (NCCS) times; Australian Eastern Summer Time.

\(^2\) Whilst 5CM3 operated under PN’s accreditation, 16 of its 27 wagons were owned outright by Patrick Portlink (PPL) and a further 9 were owned by Chicago Freight Car Leasing Australia (CFCLA) but leased to PPL.

\(^3\) The first patrol did not detect any defects but the second patrol was despatched with a view to providing timely advice to Train Control in the event that 5CM3 encountered, or caused, any track problems.
the train in tension and reduce in-train forces. The uphill grade had the effect of gradually reducing the overall train speed and the driver continued to allow the train's speed to further decrease in preparation for a 40km/h temporary speed restriction commencing just past the crossing. As the train neared the level crossing, both crew members saw road traffic beginning to bank-up on either side indicating that the crossing warning lights and bells had been activated.

The Derailment

1.5 As the train passed over the level crossing, it lost brake pipe pressure without obvious reason and the brakes applied automatically. The driver then slowed the train\(^4\) with the lead locomotive coming to a stand at approximately 615.361km\(^5\) and the train blocking the level crossing.

1.6 Immediately after the train came to a stand, the assistant driver left the locomotive to investigate and found that several wagons had derailed. He then checked the level crossing to ensure that no road traffic had been involved in the incident. Having been apprised of the situation by the assistant driver, the driver reported the derailment to ARTC’s Network Controller located at the Train Control Centre at Junee (NCCS) and PN’s Divisional Control Centre (DCC) in Adelaide. Concurrently, the assistant driver and a truck driver, who had been waiting at the level crossing, used their feet to extinguish a small grass fire caused by the derailment. NCCS and DCC were advised of the fire and the fact that it had been extinguished.

1.7 The driver and his assistant then secured the train after which the assistant driver carried out a more detailed assessment of the situation. He found that 10 of the last 11 wagons had derailed, with the 3rd last wagon having rolled onto its side. (See Photos 1-4).

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\(^4\) When confronted with a sudden loss of air resulting in an emergency application of the brakes, the driver must assume that the train has derailed and/or divided. The driver then has to avoid braking heavily so that the attached portion of the train remains stretched to avoid a ‘concertina’ effect among following rolling stock.

\(^5\) There were discrepancies between the final position of the leading locomotive relative to the 616.000km distance peg, on the ‘Down’ side, and a survey peg, on the ‘Up’ side. By convention in NSW, the ‘Down’ rail in NSW is the right hand rail facing in the direction that a train would travel to reach Sydney; conversely the ‘Up’ rail is the left hand rail. The conflicting distances are discussed in more detail in Paragraph 1.19 and Part 2, Other Safety Matters.
Photo 1: Overview of derailment site

Photo 2: 5CM3 blocking the level crossing, and the burnt trackside area
Photo 3: Overturned wagon NQPY 14602 (3rd wagon from rear).

Photo 4: Final position of overturned wagon
1.8 A subsequent mobile phone conversation between the driver and PN’s Local Area Coordinator at Leeton was overheard by an ARTC employee who was in the Coordinator’s office at the time. Aware that a track patrol vehicle was following the train, this employee alerted the vehicle’s operator to the derailment. The operator then stopped, removed the track patrol vehicle (road/rail vehicle) from the line, reported to the Network Controller that he was clear of the line, and then headed to the derailment site by road.

**After the Derailment**

1.9 Officers from the NSW RFS based at Yanco arrived on site at 6:00pm and satisfied themselves that the grass fire had been fully extinguished. NSW Police officers from Leeton arrived next and took brief statements before breath testing both crew members. The Police, in conjunction with the Roads and Traffic Authority and Leeton Shire Council, then commenced to divert traffic to another crossing point.

1.10 ARTC’s Risk and Safety Officer was notified of the derailment by Train Control at 5:43pm and arrived from Wagga Wagga at approximately 8:00pm. He assumed control of the site and closed the line pending the arrival of investigators from the Office of Transport Safety Investigations (OTSI) and the Independent Transport Safety and Reliability Regulator (ITSRR) next morning from Sydney, and a rolling stock recovery team from Cootamundra.

1.11 Due to the presence of unidentified markings on various wheels from the three locomotives, the OTSI investigator directed that all three locomotives be sent to Junee Railway Workshop for more detailed examination over a pit. This examination was concluded at 12:00pm on 13 January 2007. The OTSI Investigator released the units to return to service having concluded the markings were not related to the derailment.

1.12 Officers from ITSRR also directed that five CQBY Class wagons, which had not derailed, be ‘red carded’ and stabled in Leeton Yard pending clarification on the set-up of their constant contact side bearer (CCSB) units.

**Location of the Derailment**

1.13 The derailment occurred 3km North West of Leeton on the branch line connecting Junee, via Griffith, to the Western line at Roto (see *Figure 1*).
Train Information

1.14 The train consisted of two X Class locomotives (X46 and X51), one T Class locomotive (T390) and 27 flat bed container wagons carrying 69 shipping containers loaded with agricultural produce. The train measured approximately 586 metres in length and weighed approximately 1,860 tonnes. Prior to departure from Griffith, the driver and assistant driver identified two wagons with non-safety critical defects. One was already ‘green carded’ and they ‘green carded’ the other one.
Track Information

1.15 The line is owned by the Rail Infrastructure Corporation (RIC) and is part of a series of lines collectively called the Country Regional Network. Under the terms of an agreement, the Country Regional Network is currently managed by ARTC on behalf of RIC. ARTC is responsible for infrastructure maintenance and train control functions on this network.

1.16 The track between Griffith and Leeton is a standard gauge, single line, Class 3W track. The track consists predominantly of 40kg/m continuously welded rail (CWR) fixed to timber sleepers by dogspikes, and interspersed irregularly with steel sleepers. The immediate area surrounding the site of the derailment is relatively flat and straight as is indicated in the Curve and Gradient Diagram at Figure 2.

1.17 Class 3 welded tracks should normally permit the operation of passenger and some freight trains at up to 100km/h. However, because the track was not up to the required standard, a series of temporary speed restrictions had remained in place since 6 August 2004, restricting trains to a maximum of 80km/h between 616.300 and 658.330km. The temporary speed restrictions are discussed in more detail in Part 2.

1.18 The approach to the Griffith Road level crossing is straight, but immediately beyond the level crossing the track curves at a radius of 540m. At the time of the derailment, the temporary speed restriction of 40km/h was in place on this curve due to its non-standard alignment.

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6 The speed restrictions issued in August 2004 pre-date ARTC’s assuming responsibility for the management of the Country Regional Network in September 2004.
Distance Measurement

1.19 There was a difference of approximately 200m between the distances on the kilometre posts in the area of the derailment and those recorded on the survey pegs. ARTC advised that it considered the survey pegs to have been more accurately positioned. However, it was necessary to use the less accurately positioned kilometre posts to describe the position of the derailed train relative to the surrounding rail infrastructure as the infrastructure is described relative to kilometre posts.

Operations Information

1.20 The safeworking system for the Griffith to Leeton section is Staff and Ticket, controlled under ARTC’s Network Rule ANSY 506 Staff and Ticket System. The train had authority from Train Control to traverse the section and the crew was in possession of the staff at the time of the incident.
1.21 The movement of the road/rail vehicle that preceded the train out of Griffith and the one that later followed, were authorised by the Network Controller at NCCS who issued separate Track Occupancy Authorities (TOA) as prescribed under ARTC’s Network Rule ANWT 304 *Track Occupancy Authority*.

**Communication Equipment**

1.22 The train crew had access to a WB 450.050 MHz portable radio handset and a mobile telephone with which to contact Train Control and signallers. The train’s three locomotives were not fitted with radios as required by NSW’s *Rail Safety (General) Regulation 2003*, issued on 31 March 2006 for implementation with effect 1 September 2006. PN sought, and was granted, an extension for some of its locomotives to continue to operate without such equipment until 1 December 2006. This was subsequently extended to 31 March 2007, but the three locomotives were not among those for which PN had sought an extension.

**Crew Information**

1.23 The train was operated by two experienced drivers from PN based out of Leeton, both of whom were familiar with, and qualified for, the route. They were within their medical and competency assessment periods. From discussions with them and an examination of their rosters, there was nothing to suggest either of them was suffering from fatigue.

1.24 Both crew members returned negative results when breath tested by the Police at 6:20pm. No drug testing was undertaken.

**Meteorological Information**

1.25 The train crew described the weather conditions at the time of the derailment as hot, dry and clear. The Bureau of Meteorology recorded a maximum temperature of 44.0°C at Griffith, approximately 48km North West of the derailment site and a maximum of 42.4°C at Narrandera, approximately 29km to the South East.
Damage

1.26 The train travelled approximately 240m in a derailed state. Damage was confined to 10 derailed wagons towards the rear of the train and to three shipping containers on the 3rd last wagon which overturned. Some of the derailed wagons were subsequently repaired and others scrapped.

1.27 The road surface at the level crossing was badly scoured as can be seen in Photo 5. In addition, approximately 220m of track had to be repaired before the line could be re-opened on 16 January 2007, albeit with a 10km/h temporary speed restriction in place.
PART 2 ANALYSIS

2.1 Main line derailments of the type involving 5CM3 are typically caused by one or a combination of the following factors:

- inappropriate wagon loading;
- inappropriate train marshalling;
- inappropriate train handling;
- incompatibilities between the track and the rolling stock;
- deficiencies in the rolling stock; and
- deficiencies in the track condition and structure.

Analysis of Evidence at Derailment Site

2.2 An inspection of the track leading to the point at which 5CM3 derailed revealed markings on the rail and on the 1st of the derailed wagons (17th in the consist) indicating that a wheel flange climbed the gauge face of the ‘Down’ rail at 615.989km and that the wheel dropped off the rail head at 615.987km (see Photos 6 and 7). As the flange climbed the gauge face, steel was shaved from the face with the shavings depicted in Photo 8 being found at approximately 615.992km, i.e., approximately 3m prior to the point of mount (POM) on the rail head of the ‘Down’ side rail.

2.3 The evidence shows that the train derailed in the process of travelling over track which was misaligned (see Photo 9). The track had misaligned over approximately 23.6m into an ‘S’ shape with a maximum displacement of 200mm at the centre of each of the reverse curves. The difference between the length of the misaligned section of rail and the equivalent straight section of rail amounted to approximately 19mm. (See calculations at Appendix 1) However, the source of this 19mm cannot be determined. A portion would be the result of the release of pent-up compressive stresses in the rail in the process of misaligning, but evidence of creep in adjacent sections of rail indicates that some of the excess rail came from outside the 23.6m section.
Photo 6: Point of mount (POM) evident on head of “down” rail at 615.989km

Photo 7: Point of derailment (POD) near sleeper at 615.987km
Photo 8: Steel shaving found within area of track misalignment and prior to point of mount

Photo 9: View of rear of 5CM3 after it derailed beyond the area of buckled track
Train Loading, Marshalling and Handling

2.4 **Loading and Marshalling.** None of the wagons carried a load which exceeded the permissible limits and all containers remained attached and secured to the wagons during the derailment. There were two empty NQPY type wagons positioned 4th and 5th in the train. This is contrary to the *Loading and Marshalling Requirements of Intermodal Wagons* contained in PN’s Train Inspection Manual TIM 05-02_06 which states:

“Lightly loaded wagons shall, where possible, be marshalled to the rear of the train.”

However, technical advice received by OTSI indicated marshalling was unlikely to be a cause or contributory factor in this instance given the train was comparatively short and travelling at a relatively low speed.

2.5 **Train Handling.** As he approached the level crossing at 615.815km, the driver noted that the overall train speed was reducing and allowed it to ‘coast’ in anticipation of a 40km/h temporary speed restriction beyond the crossing. Neither he nor the assistant driver recalled seeing or feeling any abnormality with the track or the train in the moments before the derailment. They only became aware of a problem when the emergency brakes applied suddenly. The driver then responded correctly and efficiently in bringing the train to a stand.

2.6 Each of the train’s locomotives was fitted with a Hasler data logger but the recorders were not fully functional or properly calibrated. There was a 50 minute time differential between the tapes on the 1st and 2nd locomotives (X46 and X51 respectively), and 11 minutes between the 1st and the 3rd locomotive (T390). The 3rd locomotive was also not recording brake cylinder pressure. Despite this, there was sufficient data to establish that the train had been operated generally within normal parameters and within the permissible WOLO track speed limits after its departure from Griffith. It was determined that the train was travelling at approximately 48 km/h at the time of the derailment.

2.7 The data on X46 was correct and, significantly, it showed that at 5:31pm the train suddenly lost brake pipe pressure resulting in an application of the train’s brakes. The data logger evidence served to corroborate the driver’s
statement as to the manner in which he was operating the train prior to the application of the emergency brakes and his response to their application. From the data and the measurements taken at the scene, it was established that the train derailed before it entered the area where the 40km/h temporary speed restriction applied.

Incompatibilities Between the Track and Rolling Stock

2.8 The track at the derailment site was reopened on 16 January 2007 with a 10km/h speed limit imposed pending further track resurfacing and tamping. On the day the track was reopened, an ARTC team leader, undertaking a track inspection whilst riding with the driver on freight service 2MC2, reported ‘rough riding’ of lead locomotive X46 to Train Control7. (X46 is the same lead locomotive as on 5CM3.) However, this report did not nominate a track location; did not mention whether X46 was being driven long or short end leading; and did not indicate what action was taken by the network controller other than to contact the local PN representative at Leeton.

2.9 Opinion elicited from several drivers regarding rough riding of the “X” Class locomotive prompted OTSI to review the maintenance reports for the three 5CM3 locomotives for the previous 12 months. The only report of rough riding was of X51 on 28 August 2006. The records indicated that X51 was examined subsequently but no fault was found.

2.10 PN maintenance representatives further indicated that, historically, there were ride problems with the X Class locomotive which were typically linked to either faulty axle boxes, train handling, poor track condition or a combination of these factors, particularly if being driven long end leading.

2.11 The two X Class locomotives on 5CM3 had had the necessary repairs to their axle boxes, had not had any further adverse reports and, on the day of the derailment, lead locomotive X46 was being driven short end leading with trailing locomotives long end leading. It was concluded, therefore, that there were no significant issues in relation to the interaction between the track and rolling stock which caused or contributed to the derailment.

7 This report to NCCS is referenced as Number TCR 382 2007 and quotes the ARTC team leader as describing the locomotive as exhibiting “…extremely rough lateral and excessive side slap”.

Derailment of Pacific National Freight Service 5CM3, Griffith to Leeton Rail Section, 11 January 2007
2.12 Ten wagons derailed, the 17th and 19th to 27th, with the front bogie of the 17th, NQPY 14577, being the first to derail to the ‘Down’ side. At 67.6 tonnes, this wagon was lighter than the 16th and 18th wagons which both weighed approximately 75.5 tonnes. This marginal weight differential is considered unlikely to have caused or contributed to the derailment.

2.13 The 18th wagon, NQPY 14640, did not derail but had ballast sitting in the bolster of the leading bogie and markings on the lead automatic coupler which indicated a recent mismatch in vehicle heights had occurred. These markings were likely to have occurred during the derailment sequence and the ballast in the bolster would have been flung up by the rear wheels of the 17th wagon after they had derailed.

2.14 The 19th wagon, NQPY 14634, and subsequent wagons also derailed to the ‘Down’ side (see Photo 10).

2.15 An on-site examination of all wagons was conducted by investigators from ARTC, ITSRR and OTSI. While the treads and flanges on a number of wheels on the 17th and 19th wagons were damaged during the derailment,
there was no evidence of scale, abnormal wear, or skidded wheels existing before the derailment. The flange thickness and rim thickness of all wheels on these wagons were within specification. In addition, there was no evidence of any of the centre castings on any of the derailed wagons having seized, nor was there any indication on the automatic couplings, wheel flanges, bolster gibbs or container twist locks that the wagons had been hunting prior to the derailment. There was also no evidence that the bogie frames had twisted. The damage that was apparent to these wagons’ wheels, axles and bogie frames was entirely consistent with derailment forces.

2.16 Of the two wagons “green carded” at Griffith, one (NQPY 14596) had a defective carrier plate within the coupling system and the other (NQPY 14901) had a defective triple valve in its braking system. The former problem was first detected on 3 January 2007. These defects are not considered to have caused or contributed to the derailment.

2.17 ITSSR officers had concerns about the way in which the constant contact side bearers (CCSB) in five CQBY wagons\(^8\) were set up because the metal roller was positioned with its axis aligned longitudinally (along the wagon) rather than laterally (across the wagon).\(^9\) However, because these rollers are designed to help to dampen wagon body roll and control bogie hunting tendencies, the latter at speeds in excess of 80km/h, it is unlikely that the way in which they had been set up contributed to the derailment, especially as it occurred at only 48km/h.

**Track Condition and Structure**

2.18 CWR track is complex in its structure with high levels of co-dependence between components. Any deficiencies in components affect the strength and rigidity of the track as a whole and must be detected early and corrected

\(^8\) The affected wagons were identified as CQBY 2047 (6th position wagon in consist), CQBY 2014 (7th position wagon), CQBY 2036 (8th position wagon), CQBY 2046 (10th position wagon) and CQBY 2071 (16th position wagon).

\(^9\) The matter was addressed by ITSRR issuing an Improvement Notice to CFCLA, the owner of the wagons, and a Notice of Emerging Safety Concern to other operators. The Improvement Notice was closed in June 2007 on the basis of a satisfactory response from CFCLA, after they implemented a redesign of the roller arrangement within the CCSB cage.
quickly to prevent deleterious effects. In the absence of strength and rigidity, thermal stresses cannot be contained within the rail.

2.19 Keeping the track structure strong and rigid begins with the maintenance of a well drained, full depth and full width profile made up of well-graded sharp ballast. The ballast, in turn, must firmly contain high quality sleepers with tight-fitting, or preferably resilient, rail fastenings. The rail must also be kept on its designed alignment and prevented from creeping.

2.20 The most critical of the factors that can lead to a misalignment in CWR is stress within the rail and this factor is the most difficult to detect. In NSW, rail is correctly adjusted if it is stress-free at a rail temperature of 35°C, which is referred to as the neutral temperature. Good track structure and adjustment will resist stresses induced by rail temperatures up to 75°C. However, without actually cutting the rail, the indicators or symptoms of excessive stress can only be detected by careful visual inspection. Trained maintenance staff will examine changes in alignment, creep, scratch marks at anchors, anchors bearing against sleepers, bulking of ballast in cribs ahead of sleeper movement, slight gaps in loose ballast at sleeper ends or a depression in the crib ballast behind the sleeper as indicators of rail stress. While some observations can be made from on board a locomotive or a road/rail vehicle, detailed observations can only be made by experienced staff conducting a walking inspection.

2.21 An inspection of the track over the preceding 3kms, and at the location of the derailment, found that alignment, ballast, formation and gauge met the requirements of ARTC’s Rail Adjustment Manual RTS 3640 and RIC’s Track - Maintenance Standards C 2009 Base Operating Condition Standards of Track Geometry. Additionally, there was no evidence of sleepers pumping or bog holes. However, some other conditions were not to the required standards.

2.22 Steel sleepers were irregularly interspersed between timber sleepers with the condition of the timber sleepers varying from ‘poor’ (ineffective) to ‘fair’

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10 Limitations of these methods are discussed in OTSI’s report Derailment of Freight Australia Limited Cement Service 4VM9 22 December 2004, which can be found on the OTSI website www.otsi.nsw.gov.au. Limitations are also highlighted in ARTC’s Engineering Standard TEP 14 Track Examination: Track patrol and front of train examination.
(effective)\textsuperscript{11}, with the greater number falling into the latter category. Although the condition of some timber sleepers was within standard, their effectiveness could be considered only marginal, particularly as some fastenings in the timber sleepers were able to be rotated or extracted with ease by hand. Fastenings are intended to provide lateral and vertical restraint and resistance to torsional forces. ARTC’s RTS 3640 Part 1, Fundamentals, Section 7 indicates that fastenings provide approximately 30\% of the resistance to buckling. Though the loose spikes may have held gauge, they do not provide restraint to vertical and torsional movement of the rail unless they are secure and tight. Such movement is necessary to allow a rail to misalign.

2.23 Ballast compaction within steel sleepers ranged from poor to fair, which meant that the lateral movement of the sleepers was being poorly restrained. Sleepers had moved laterally to both the ‘Up’ and ‘Down’ sides of the design track alignment prior to the POM with the maximum extent of movement being approximately 120mm. The track had been straightened by approximately 60mm due to the impact of the wheels on the sleepers after the POD (see Photos 11 to 15).

2.24 Both the ‘Up’ rail and the ‘Down’ rail had crept towards Sydney by 60mm and 38mm respectively relative to reference marks at the 616.000km location (see Photo 16). These measurements are greater than creep measurements at the 616.500km location, by 45mm on the ‘Up’ rail and 33mm on the ‘Down’ rail. It is likely that the majority of this displacement was due to the straightening impact force of the derailed wheels.

\textsuperscript{11} As defined in ARTC’s Engineering Standard TMS 06 Timber sleepers – Maintenance standards.
Photo 11: Gaps left by sleeper displacement on the ‘Up’ side

Photo 12: Gaps left by sleeper displacement on the ‘Down’ side
Photo 13: Gaps left on the ‘Down’ side by straightening forces
Photo 14: Close-up of typical lateral sleeper displacement in misalignment area
Photo 15: View from rear of train looking back towards Griffith
Though compliant with individual standards, the general condition of sleepers and fastenings in the 3km preceding the derailment site gave rise to reservations about whether the track was sufficiently rigid to resist lateral
movement. Prior to ARTC’s takeover of responsibility for the Country Rail Network in September 2004, it was RIC’s policy that major re-sleepering occur on a five-yearly cyclic basis. In several areas where this programme was in place, including the Leeton to Griffith section, timber sleepers were replaced with steel sleepers.

2.26 With an expected average life of timber sleepers of 25 years, it could be anticipated that 20% of sleepers would be replaced each cycle. A check of 56 sleepers, 36 prior to the POM and 20 after it, revealed the following comparison between actual and expected conditions:

<table>
<thead>
<tr>
<th>Quality</th>
<th>Expected Number</th>
<th>Actual Number (existing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel or timber with life &gt;10 years</td>
<td>33</td>
<td>19</td>
</tr>
<tr>
<td>(16 steel + 3 timber)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Timber with life of 5 – 10 years</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Timber with life of 1 – 5 years</td>
<td>10</td>
<td>19</td>
</tr>
<tr>
<td>Timber – life expired</td>
<td>2</td>
<td>9</td>
</tr>
</tbody>
</table>

Table 1: Comparison of expected and actual quality of sleepers

The figures show that re-sleepering over the preceding years had not produced the required distribution of good sleepers in the vicinity of the misalignment.

2.27 The importance of sleeper maintenance is evident from RTS 3640 which indicates that 60% of the resistance to lateral movement is provided by the sleeper in the ballast. Significantly, poor quality sleepers and fastenings transfer additional load to better quality components, concentrating additional loading onto the ballast in the immediate area which can cause it to become overloaded. It is likely in the derailment location that the majority of the resistance to buckling was transferred to the 16 steel sleepers. Since the ballast contained within the steel sleepers was found generally to be inconsistent in depth and compaction, these conditions severely compromised the track’s ability to resist buckling.
In summary, there were a number of track conditions in the vicinity of the derailment which significantly reduced the rigidity of the track structure and increased the likelihood of a misalignment occurring, particularly during times of high temperature. These conditions included:

- poor sleeper condition,
- ineffective fastenings,
- poor rail anchorage,
- inconsistent ballast depth and compaction under steel sleepers, and
- irregular placement of the steel sleepers.

**Risk Mitigation Strategies and Effectiveness**

**ARTC’s Track Maintenance and Inspection Requirements**

2.29 ARTC has published standards and procedures for the construction, inspection and maintenance of the track throughout its network. Table 2 is an extract from Engineering Standard TEP 13 *Track Examination Handbook: System Overview* which stipulates the relevant inspection schedule and standards for Class 3 lines.

2.30 Track buckles when it is excessively stressed and/or when the components upon which it relies for rigidity, i.e., the formation, ballast, sleepers and fasteners, become degraded. TEP 13 provides standards which are intended to mitigate the risk of buckles and requires that, depending on their severity, defects must be either repaired immediately or within a specified period, or be monitored and managed through the application of load limits and speed restrictions.
2.31 Several other types of mandatory track inspections are also conducted on an annual or bi-annual basis. These include:

a. **Track geometry recording** on a bi-annual basis to:
   i. graph the track condition and rate the ride quality of the track,\(^{12}\)
   ii. identify locations where track geometry parameters are exceeded,
   iii. allow the categorisation of the severity for any exceedents, and
   iv. inform the extent of any temporary speed limits to be placed on the track.

b. **Sleeper inspection and marking** on an annual basis to identify sleepers that require replacement.

c. **Ultrasonic testing** on an annual basis to identify internal defects within the rail, e.g., flaws or fractures.

2.32 In addition to these inspections, the Welded Track Stability Analysis (WTSA) is conducted annually on every 500m of welded track, in accordance with ARTC’s Engineering Standard TEP 11 *Track Examination: Field examination for welded track stability analysis*. Whilst some factors in the WTSA are influenced by the above inspections, the WTSA enables calculations to be performed based on the current condition of the track.

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\(^{12}\) The ride quality rating of the track is referred to in ARTC Engineering Standards in the comparative terms of the Track Condition Index (TCI). TCIs are a weighted average score calculated by dynamic measurement of the track gauge, track twists, track alignment, track top and distance with a specially equipped rail vehicle referred to as the ‘AK car’.
made to identify locations with the potential to misalign which, in turn, informs maintenance and repair priorities.

2.33 The road/rail inspection that preceded the passage of the train was initiated because of concerns about the possible effect that the prevailing high temperatures might be having on the condition of the track. The inspection was conducted at an average speed of 22.5km/h which is consistent with ARTC’s Engineering Standard TEP 14 *Track Examination: Track patrol and front of train examination* which recommends that this type of inspection be carried out at a nominal speed of 20km/h. At this speed, only the most obvious of deficiencies, such as signs of misalignment, would have been apparent. However, it was not expected that the high speed “heat patrol” would detect the deficient track conditions that led to the eventual misalignment. The emptiness of the steel sleeper pods and the lack of evidence of proper adjustment should have been detected by earlier walking inspections, yet there is no evidence of this being the case.

**Track Maintenance Records**

2.34 Track maintenance records supplied by ARTC indicated the following inspections were carried out in the Griffith to Leeton section between September 2006 and January 2007:
<table>
<thead>
<tr>
<th>Inspection Type</th>
<th>Last Conducted</th>
<th>OTSI Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Track Patrols 3 Days (Maximum interval)</td>
<td>05/01/07, 08/01/2007, 10/01/07 &amp; 11/01/2007</td>
<td>• Defect forms indicate that the track patrols covered area from 583.000km to 660.414km and that the only recorded defect was at 605.780km i.e., approximately 10km from the point of derailment (POD). &lt;br&gt;• The 1st hi-rail ‘heat’ patrol on 11/01/07 was immediately prior to passage of SCM3 and no track abnormalities were detected.</td>
</tr>
<tr>
<td>Front of Train (Monthly)</td>
<td>20/12/2006</td>
<td>• From 583.000km to 660.414km. &lt;br&gt;• No defects reported.</td>
</tr>
<tr>
<td>Detailed Walking (Every 3 Months)</td>
<td>Between 25/10/06 &amp; 07/11/2006</td>
<td>• There was no evidence to confirm that an earlier inspection, scheduled for 01/07/2006, was conducted. &lt;br&gt;• Oct/Nov inspection – forms were dated 23/10/06 &amp; 26/10/06, however, there was no data, defects, or inspection comments recorded between 613.230km &amp; 616.400km. &lt;br&gt;• Records for either side of the area between 613.230km &amp; 617.900km showed mostly Priority 3 defects, mainly involving ineffective/failed sleepers.</td>
</tr>
<tr>
<td>Track Geometry Recording (AK Car) (Every 6 months)</td>
<td>18/09/2006</td>
<td>• Six emergency(^\text{13}) exceedences located with the closest to the point of derailment being at 639.242km i.e., 23km from the POD. &lt;br&gt;• Closest Category 1(^\text{14}) exceedence was at 614.514km i.e., 1.5km from the POD. &lt;br&gt;• Closest Category 2(^\text{15}) or 3(^\text{16}) exceedence was a Category 3 located at 615.710km i.e., 290m from the POD.</td>
</tr>
<tr>
<td>Ultrasonic (Speno) Testing (Annually)</td>
<td>28/10/2006</td>
<td>• No significant defects were reported in vicinity of the POD.</td>
</tr>
<tr>
<td>WTSA (Annually)</td>
<td>02/09/2006</td>
<td>• Indicated that the stability loss for the 500m section between 615.500km and 616.000km was 13% i.e., ARTC was not required to take any specific action. &lt;br&gt;• However, the WTSA for that section also shows ineffective anchors, alignment errors and varying degrees of creep in both ‘Up’ and ‘Down’ rail with the latter being incorrectly transposed from the field sheets into ‘TrackStab’ (ARTC’s computer WTSA analysis program).</td>
</tr>
</tbody>
</table>

Table 3: Findings from inspections of the Griffith to Leeton section

\(^{13}\) Emergency exceedences require immediate rectification with no regard for resources (refer to RIC Civil Engineering Standard C2011 Base Operating Condition Standards of Track Geometry – Standing Orders).  
\(^{14}\) Category 1 exceedences require rectification within 24hrs of assessment.  
\(^{15}\) Category 2 exceedences require rectification within 7 days of assessment.  
\(^{16}\) Category 3 or 4 exceedences require no immediate response other than continual monitoring and scheduling for routine planned maintenance.
2.35 With the exception of a detailed walking inspection planned to have been completed by 01/07/2006 (per Work Order No. 312015/016), the records showed that inspections were generally conducted at the specified intervals and that defects, several of which were defects designated as low priority in the vicinity of the derailment, were actioned within specified limits. There was, however, little detail contained in the related documents or maintenance histories pertaining to the actual condition of, or work done on, the track.

Welding

2.36 The only record of track adjustments within the Griffith to Leeton section provided by ARTC was contained in 17 welders returns (numbers 1178-1196 less 1181 and 1194) covering work between 616.000km and 635.500km. In determining the procedure followed by the welder, it is important to note that the work being performed was the conversion of 220m sections of jointed welded rail (JWR) to CWR. This involves cutting off the rail ends containing the bolt holes and replacing the removed rail with a closure, a length of rail of at least 2.2m. The closure is free welded at one end, and then the other end is welded after making an appropriate adjustment taking into account the rail temperature and the length of rail being adjusted.

2.37 An adjustment weld requires anchor points to be established; intermediate anchors and resilient fastenings to be removed; the track to be marked at \( \frac{3}{4} \), \( \frac{1}{2} \) and \( \frac{1}{4} \) points; tensor jacks to be applied; the rail to be vibrated over its full length; and measurements made of the proportion of movement generated at each of the quarter points. After the weld has been allowed to cool, the jacks have to be removed, all fastenings and anchors replaced, and anchor points removed.

2.38 The work performed by the welder was recorded on an ARTC form titled “Weekly Return – Aluminothermic Welding / Adjustment” (Appendix 1 to ARTC’s Engineering Practices Manual RAP 5391, “Aluminothermic Welds – Identification, recording and reporting”. RAP 5391 gives brief instructions on use of the form. Further instructions are given in RTS 3640, which also outlines the procedure for conversion of JWR to CWR.
2.39 The welders returns recording the welding work on the line contained a number of errors, omissions and anomalies, and had not been signed-off appropriately. The welder, who was from interstate, was familiar with the quite differently laid out, far more comprehensive form (incorporating explanatory notes) provided by his employer, MVM Rail. Nonetheless, he was asked to use the ARTC form without adequate instruction despite it being quite different in format and content to what he was used to. When interviewed, the welder showed that he understood the adjustment calculation procedure but had misinterpreted the requirement under some of the headings of the form. However, he claimed to have ‘filled the forms out as best he could’.

2.40 Welders Return 1180 dated 9 May 2006, a copy of which is at Appendix 2, was of most interest as it detailed the work carried out on a portion of track commencing within 100m of the POD. The anomalies and omissions that it contained are detailed at Appendix 3.

2.41 A table for calculating Adjustment Gap Size is contained in Appendix 4.12 to RTS 3640, a copy of which is at Appendix 4. It is based on the standard neutral temperature of 35°C. However, the welder was not provided with a copy of this document and used a MVM Rail table for adjusting at a neutral temperature of 38°C instead. To determine the adjustment for 180m lengths for which there was no set of values in this table, the values for 192m lengths were used and a 2-3mm provision made for the difference.

2.42 A consequence of these incorrect entries on the form was that the Rail Flaw Detection Operator, who checked the welds some days after they were completed, would have had no meaningful figure against which to check the punch mark spacing.

2.43 An examination of the track back to about 616.200km did not find any trace of chalk or other more permanent marks marking out quarter points for checking of stress distribution during adjustment. However, it is likely that chalk marks would no longer be visible after eight months of weathering.

2.44 Because of the errors in the completed returns, they do not present a true and accurate record of the welding work. Therefore, it cannot be determined
if the track was correctly adjusted in the immediate vicinity of the derailment. Further, the welding work on the track between Narrandera and Griffith was not included in any ARTC audit program.

2.45 It was noted from ‘RICSpeed’\textsuperscript{17} records for the Leeton to Griffith section that, since the welding and re-sleepering was completed, there have been continuing problems in maintaining top and line. This has culminated in the application of long term, speed restrictions of 80km/h over the majority of the section and, in particular, between 616.300km and 658.330km.

\textbf{Measurement of Stability and Stress}

2.46 The Welded Track Stability Analysis (WTSA) relies on the assessment of any individual percentage loss of stability attributable to rail adjustment, condition of anchors, ballast profile deficiencies, track disturbance due to resleepering and ballast work, and track condition, in accordance with ARTC’s Engineering Standard TEP 09 \textit{Track Examination: Calculation of welded track stability from field information}. The sum of these assessments provides a “\textit{preliminary stability assessment}” which is then adjusted to take into account increased stability loss due to “\textit{location factors}” applicable to each 500m of track resulting in a “\textit{final stability assessment}”. Location factors include curvature, grade, braking zones, directional working and bunching points such as level crossings (e.g., the level crossing at 615.815km), crossovers, bridges and changeover of fastening types.

2.47 Both TEP 09 and TEP 11 require that a location receive “\textit{immediate attention or evasive action}” when its loss of track stability is 55% or more. The standards do not require action in instances where the WTSA score is less than 40%, but a score between 40% and 50% requires “\textit{programmed attention}”. The WTSA evidence provided by ARTC and which was prepared on 31 October 2006 showed a cumulative stability loss of only 13% - well below the level requiring any active intervention.

2.48 While the WTSA is an important tool it does have limitations in that it does not take into account:

\textsuperscript{17} RICSpeed refers to a list of temporary speed restrictions for the NSW Country Rail Network compiled and promulgated by RIC on a weekly basis.
a. the effects of loose or missing fastenings;
b. the density of steel sleepers intermingled with timber sleepers;
c. loss of ballast or degree of compaction within steel sleepers; or
d. the redistribution of stress caused by spot tamping.

Though there is provision for adjustment for unidirectional working, there is none for bidirectional working, but there is arguably some justification for taking into account the fact that daily freight services (such as 5CM3), the main users of this line, routinely run loaded in the ‘Up’ direction only. Indicative train masses are in the order of 1,590 gross tonnes empty and between 2,170 and 3,310 gross tonnes loaded.

2.49 Records relating to the 2006 WTSA did not display any obvious problems with the structure or stability of the track but the following anomalies were noted:

a. field staff had used superseded versions of the forms contained in TEP 11, hence critical information such as rail temperatures and gap measurements was not recorded, or provided for, on the WTSA Data Collection form;

b. track alignment details between 615.883km and 618.878km were not provided in the WTSA Data Collection form. Similarly, alignment data was missing from the February 2005 Resurfacing Before and After Measurement Sheets and the May 2006 Welding Weekly Returns. These omissions appear contrary to TEP 11, which requires the measurement of track alignment compared to survey information, and Table 1 of Civil Engineering Standard C2011 Base Operating Condition Standards of Track Geometry C2009, which lists alignment as one of the six geometry conditions to be measured;

c. creep measurements in the WTSA Data Collection form dated 02/09/2006 were incorrectly transposed when transferred to the
TrackStab Stability Report\textsuperscript{18}, with the figures shown for the ‘Up’ rail being recorded for the ‘Down’ rail and vice versa;

d. the TrackStab Stability Report did not include the additional allowance of 12\% for the curvature of the track at the level crossing at 615.815km; and

e. there was no evidence from the WTSA forms to suggest that any location factors had been taken into account.

2.50 Some of the records relating to the 2005 WTSA contained similar anomalies.

2.51 No documentation contained comments regarding the ballast depth or compaction for the steel sleepers used in the section. Further, despite a specific recommendation being made in the OTSI systemic investigation report, Steel Sleeper Introduction on NSW Class 1 Mainline Track\textsuperscript{19}, that:

\begin{quote}
“field inspection guidance be provided to Maintainers that would assist with steel sleeper maintenance tasks and the identification of potential problems associated with steel sleepers”,
\end{quote}

there were still no specific standards or instructions for the ongoing inspection of ballast levels or compaction in steel sleeper pods. The only reference to any maintenance requirements is contained within the initial installation requirements of ARTC Engineering Standard TCS 10 Steel sleepers – Usage and installation standards.

2.52 Stress in rail cannot be conveniently observed or measured by non-destructive means, so the WTSA relies on the accuracy of relevant input information and data. Given the errors and omissions contained in the WSTA prepared on 31 October 2006, OTSI completed a recalculation based on the original field data sheets but using corrected data. The result was a loss of stability in the order of 28\%, still well below the active intervention threshold.

\textsuperscript{18} The TrackStab Stability Reports provided by ARTC have a ‘Date of Report’ of 5/02/2007, which is post incident. This date is a computer generated printout date and does not reflect when the data was actually collected in the field, or entered into the system. The data for this report was actually collected on 18/09/2006 and 31/10/2006.

\textsuperscript{19} OTSI initiated investigation released in 2005. Available at www.otsi.nsw.gov.au
2.53 In the process of recalculating the WTSA, a Rail Temperature Error (RTE) of -6°C near the point of derailment was discovered. This was due to net creep of 10mm in the ‘Up’ rail between 615.500km and 616.000km and average curve pull-in of 25mm in the 540m radius curve just beyond the derailment site. On the basis that the rail is recorded as having been adjusted to a neutral temperature of 38°C by contract welders in early May 2006, the “effective” neutral temperature in the track just prior to the area of the derailment should have been 29°C. It is estimated the temperature of the rail reached on the day of the derailment would have been in the order of 60-70°C. At these temperatures the compressive force or stress within the rail should have been between 37 and 50 tonnes and, as such, should still have been contained by the track structure. (See Appendix 5 for calculations.)

Creep

2.54 Information from the WTSA data collection notes (field notes compiled on 18 September and again on 31 October 2006) showed an increase, albeit minor, from zero creep on the ‘Down’ rail on 18 September 2006 at the 616.000km peg to 8mm on 31 October 2006. There were also similar differences to this at nearby sites. ARTC was not able to advise what prompted the re-measurements undertaken in October. TEP 09, Section 5 Secondary analysis advises a range of conditions that warrant secondary analysis but there was nothing in the original WTSA to indicate such conditions were present at the time of the September measurements.

2.55 The extent of ‘creep’ measured after the derailment has been attributed largely to derailment impact forces. However, a check calculation was performed to see if it would have been significant had it existed prior to the derailment. The result showed that the increase in stability loss would not have been sufficient to elevate it to a level requiring intervention in accordance with TEP 09.

Post misalignment reassessment

2.56 In the three years prior to the derailment, there were no reports of track misalignments or derailments in the Leeton to Griffith section or any analysis which indicated that ARTC had identified this location as one which had the
potential to misalign. However, seven months after the derailment, ARTC supplied information which identified this location and two others in the same section as high risk areas. A post derailment reassessment was necessary in accordance with ARTC’s Engineering Standard TEP 28 *Reporting of misalignment on welded track* which requires that, following a misalignment, detailed information is gathered and analysed such that corrective action can be taken to address the failure.

2.57 It is noted that the parameters analysed in TEP 28 conducted post-misalignment appear to be more comprehensive than those in TEP 09 which aims to identify sites with the potential to misalign using the WTSA. TEP 09’s *Amendment Record* confirms that ARTC has not amended its procedures in response to lessons learned from other post-misaligned investigations. Misalignments continue to occur at points not identified by the process required by TEP 09.

**Cumulative effect of trackwork, defects and disturbance on degraded track**

2.58 An examination of various other records provided by ARTC revealed that:

a. from August 2004 to June 2009, a number of temporary speed restrictions were imposed, such that between 50% and 85% of the 48km of track between Leeton and Griffith at any given time was under some level of temporary speed restriction due to degraded track conditions; and

b. at the time of the derailment, and in the area leading up to the derailment site, 50% of the same section of track had the permanent (or maximum) track speed of 100km/h reduced to 80km/h due to degraded track conditions.

2.59 TEP 09 provides for a secondary analysis for “priority locations” identified through the primary WTSA. The secondary analysis includes confirmation of the accuracy of the input data, assessment of the cumulative effects (of defects) within a 500m section, re-evaluation of the effect of track disturbances and re-calculation of the location factor. The cumulative effect of low priority defects has previously been identified by ARTC as causal factors for misalignment in their report into a misalignment and derailment at
Menindee on 31 December 2004. However, OTSI has been unable to ascertain from ARTC if their analytical processes had evolved to take into account the cumulative effect that low priority defects can have in combination with track disturbance.

2.60 In addition to the welding, there had been a considerable amount of resurfacing work undertaken through and commencing near the derailment site some 11-13 months before the incident (see Figure 3). Between November 2005 and January 2006, a total of 2,394 steel sleepers were installed within the Griffith to Leeton section between 614.000km and 620.000km. Some corresponding resurfacing records were supplied, however, they only covered the section between 614.000km and 616.030km, so it could not be verified that the sleeper pods between 616.300km and 620.000km were adequately packed after installation.

![Parameters affecting stability](image)

**Figure 3:** Potential local trackwork factors affecting track stability
2.61 The WTSA takes into account the influence of “\textit{major track disturbance}” in the form of resleepering and ballast work, and its reduction in effect over time to zero after a maximum of six months. However, the WTSA does not consider how the timeframe and magnitude might be increased when a number of disturbances are acting on the same rail section. In this instance, there had been a concentration of disturbances: resleepering, resurfacing and associated tamping in particular, near the transition point of the level crossing (and near the misalignment point) with different works starting or finishing in close proximity. In such circumstances, it may be prudent to undertake a further (secondary) analysis, as is currently the case at priority locations, or at least conduct a verification of the initial WTSA results.

2.62 Further, no follow-up is required in response to a high WTSA score arising from multiple disturbances other than the imposition of a temporary speed restriction. Traffic forces will restore the friction bond between timber sleepers and disturbed ballast, but they do not improve the stress distribution in the rail. Instruments are available that can non-destructively check the residual stress in rail by lifting a short section and comparing displacement with applied force. Areas that have been subject to multiple disturbances may warrant application of this technology.

\textbf{Adequacy of the Emergency Response}

2.63 The actions of the driver and his assistant following the derailment were timely and appropriate. However, examination of the voice logs recorded at the time revealed there was some confusion on the part of the Network Controller as to the location of the incident and which level crossing was blocked. There was also initial indecision as to which ARTC incident response staff would respond.

2.64 The logs also revealed that the Network Controller did not advise the hi-rail driver of the derailment ahead contrary to ARTC Network Rules ANGE 206 \textit{Reporting and Responding to a Condition Affecting the Network (CAN)} and ANGE 208 \textit{Responding to a Major Incident}. It was fortunate that the ARTC employee did alert the hi-rail driver on his own initiative on overhearing the conversation between the driver and PN’s Local Area Coordinator.
Additionally, the Network Controller did not establish the exact location of the incident for purposes of directing the NSW Police.

2.65 ARTC’s Network Rule ANGE 204 *Network Communications* and the related Network Procedure ANPR 721 *Spoken and written communication* require a structured approach to radio communications which obliges those who are communicating to reach a complete and shared understanding of those matters under discussion. ANGE 204 states:

“Open-channel communication must use the standard terms and protocols in this Rule and in Network Procedure ANPR 721...”

The Network Controller and the driver conversed on several occasions during the afternoon of 11 January 2007, but their communication did not conform to ARTC’s stated requirements.

2.66 The callout list of ARTC’s on-call safety officers was out-of-date and unclear, evidenced by the fact that four calls were needed before the Network Controller had direct contact with the relevant safety officer covering the region in which the derailment occurred.

**Other Safety Matters**

**Maintenance of operational documentation**

2.67 ARTC’s document control system is not utilised consistently by field staff, who rely on forms from previous entities or outdated or locally modified forms in preference to those in ARTC’s standards, and which are available on their intranet.

2.68 Documents such as the train control diagram/graph, the Griffith Signallers’ Train Register Book (TRB) and Train Occupancy Authorities (TOA) pad assist Network Controllers to maintain awareness of what activities are occurring on the network at any particular time. Their use is mandatory. The documentation at NCCS contained a number of anomalies including:

a. several instances where important information such as train consist detail for 5CM3 was not annotated on a train control graph;

b. key train numbers and safeworking documents had not been accurately referenced;
c. the issue of a TOA to the operator of the hi-rail that followed the train out of Griffith authorised movement over more than one section, contrary to ARTC Network Rule ANWT 304 Track Occupancy Authority;\(^{20}\)
d. incorrect train numbers recorded in the Griffith Signallers TRB;
e. an instance where a TOA had not been properly shown as having been ‘fulfilled’ (completed);
f. the TOA documentation in use at the time had been superseded;
g. inconsistencies between the train control graph at NCCS and the TRB at Griffith regarding the authorisation, issue and commencement times of WOLOs during the period 4 – 11 January; and
h. the train control graph used by the Network Controller allowed for details relating to loads carried by ‘Down’ trains but not for ‘Up’ trains and as a consequence there was no information on the graph relating to the load being carried by 5CM3.

2.69 It was also established that ARTC’s Train Operating Conditions (TOC) Manual and Local Appendix Units (LAUs) relating to specific requirements in the Leeton to Griffith section were outdated\(^{21}\), had key information omitted\(^{22}\) and were in some cases inaccurate.\(^{23}\) Although ARTC inherited these documents in September 2004, this suggests the documents had not been reviewed as regularly as necessary. The omission of the location and name of the level crossing from the LAU covering the derailment site affected the

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\(^{20}\) ANWT 304 states: “A TOA may include more than one section, provided it does not extend …into the yard limits controlled by another Signaller, or…. beyond an unattended location where a train is shunting in the section ahead.” The train was scheduled to shunt at Leeton which is classified by ARTC as an unattended location. However, when the crew of the train ‘cut in’ the signal box to facilitate the shunting, the interlocking would then be considered attended, or ‘controlled’.

\(^{21}\) Whilst the ARTC website shows the TOC Manual was last updated on 10 August 2004, the actual document is a scanned copy and has sections dated 1999. Similarly, the website shows that LAU 525 for Griffith and LAU 550 for Leeton as both being last updated on 10 August 2004. However, the actual documents located on the website are both dated December 2002.

\(^{22}\) The level crossing at 615.850km is not shown on any map or diagram in either the LAU for Leeton or the TOC Manual.

\(^{23}\) LAU 525 for Griffith shows the location of Griffith Station as 640.375km, which differs by some 20km from that shown in the TOC Manual (660.697km).
quality of initial information given by the Network Controller to the emergency services.

**Anomaly in Network Rules**

2.70 ARTC Network Procedure ANPR 720 *Protecting Trains* provides a list of specific actions that must occur to protect a delayed or disabled train in track circuited territory from immediately following rail traffic, but makes no specific reference to the actions required in staff and ticket, or non-track-circuited territory, as is the case between Griffith and Leeton. As such, the derailed train was unprotected against the following road/rail vehicle.

**Anomaly in Train Consist of 5CM3**

2.71 There were minor inconsistencies in the locomotive sequence provided by PN to ARTC, an error which was then consistently replicated in other train consist records.

**Fatigue**

2.72 An examination of the Network Controller's roster over the preceding 14 days revealed that, on the day of the derailment, he was on his eighth consecutive shift though some of them appeared on the roster as “spare” shifts so did not involve train control duty. He was also working what is locally termed a ‘double-back’, i.e., he ceased work at 6:30am and recommenced at 2:30pm on the same day. Given the hot weather conditions in the region and the shortened turn around time between shifts, there is the possibility that the Network Controller obtained limited sleep in the short daytime break. The practice of double-backs following night shifts is contrary to good rostering practice and ARTC’s normal practice of 12 hour breaks between shifts.

2.73 Research has established that basic human biological functions vary according to a 24 hour cycle known as the circadian rhythm.\(^{24}\) It has also been established that, during the periods 3:00am to 5:00am and 2:00pm to 4:00pm, there is a dip in the body’s circadian rhythm and that, though one may be awake during these periods, one is less alert and more prone to

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\(^{24}\) For further information on the circadian rhythm refer to Flinders University website at [http://som.flinders.edu.au/FUSA/NEUROSCIENCE/sleep.htm](http://som.flinders.edu.au/FUSA/NEUROSCIENCE/sleep.htm)
error. At the time of the derailment, the Network Controller was operating close to a period of circadian ‘low’.

OTS was unable to obtain more information from the Network Controller as he retired from work during the early stages of the investigation. However, in combination, the above considerations point to it being very likely that he had an accumulated sleep debt that may have contributed to a loss of concentration:

“Less sleep than required can lead to ‘sleep debt’ which can adversely affect fatigue and reaction times, concentration and judgement and decision making. Sleep debt is accumulative and over several days the effects can be compounded.”

The cumulative effects of extended wakefulness, prior sleep loss and circadian rhythm are likely to have caused a fatigued condition which contributed to the Network Controller’s communications and safeworking lapses.

Remedial Actions

On 17 January 2007, ITSRR issued an Improvement Notice to ARTC expressing concern about the adequacy of their “… system for identifying, managing and controlling risks associated with track misalignment …”. The Notice was not issued in response to this derailment, but was the consequence of on-going concerns which were elevated by this occurrence and other derailments at the time, particularly on the Main South line. ITSRR was not satisfied with the response and more recently issued a consolidated list of requirements. In some instances, these requirements are considered to be at the heart of ARTC’s Safety Management System and its track maintenance obligations, and the latter is a matter upon which OTSI has commented in previous investigation reports. At the time of completion of this investigation, ITSRR reports the status of actions to be addressed as “still open”.

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27 Refer to the OTSI reports into the derailments at Bethungra in 2004 and in the Nevertire – Nyngan Rail Section in 2006, Steel Sleepers (2004), and on the Steel Sleeper Introduction on NSW Class 1 Main Line Track (2005).
PART 3 FINDINGS

Causation

3.1 The derailment of PN freight service 5CM3 was caused by a misalignment in the track at 615.987km as it was being traversed by the train. The misalignment was of such magnitude that rolling stock travelling below the allowed speed could not negotiate the reverse curves with a radius of approximately 60m resulting from the misalignment.

Contributory Factors

3.2 The investigation could not determine the specific cause of the misalignment. However, it was most likely due to structural weaknesses in the track that were not detected during programmed track condition monitoring and that may have been contributed to by mistakes made in the welding process during the conversion of the track from JWR to CWR.

3.3 The track structure lacked the structural rigidity to constrain the forces acting on it, particularly the buckling forces arising from the very hot prevailing conditions. Specifically:

- a disproportionate number of loose fastenings in the predominately timber sleepers transferred the buckling forces to the intermittently placed steel sleepers; and
- the steel sleepers did not contain a sufficient quantity of compact ballast to provide the critical mass essential to resist lateral movement.

3.4 Although ARTC had appropriate processes in place to monitor and measure the condition of the track, errors and omissions in the records meant that a true and accurate indication of the situation was not being represented. This was particularly the case with regard to the WTSA completed on the basis of data collected in 2006 which did not detect any problems warranting other than routine programmed maintenance.

3.5 The welding returns recording the welding work on the line, including a portion of track within 100m of the derailment, were not filled out in the
manner intended and were not signed-off appropriately. As a consequence, it remains impossible to determine whether of not the track was correctly adjusted in the welding process.

3.6 No significant factors in the derailment sequence were identified as attributable to unsatisfactory performance on the part of the crew or operation of the rolling stock.

Anticipation and Management of Risk

3.7 ARTC has an established maintenance and defects management system to identify and manage the risks associated with track defects and failures which relies on accurate measurement and recording by maintenance staff and subcontractors. However, the accuracy of some assessments is being affected through reliance on inaccurate or incomplete information on inspection sheets and unverified records of track maintenance undertaken apparently without adequate supervision, monitoring or auditing.

3.8 There are track conditions that are not included in the WTSA, the primary tool for detecting the potential for misalignments, and consequently appear not to attract particular attention during routine track inspections. These include:

- the effects of loose or missing fastenings;
- the density of steel sleepers intermingled with timber sleepers;
- loss of ballast or degree of compaction within steel sleepers; and
- the redistribution of stress caused by spot tamping.

It is noted that these and other additional factors are routinely examined more comprehensively in accordance with TEP 28 after a misalignment has occurred.

3.9 Despite a specific recommendation made in a previous OTSI Investigation Report, no specific standards or instructions have been produced to cover the ongoing inspection of ballast levels or compaction in steel sleeper pods.

3.10 The use of the hi-rail (visual) inspections to detect track abnormalities was largely ineffective as it was not expected that the high speed “heat patrol” would detect the deficient track conditions that led to the eventual
misalignment. The emptiness of the steel sleeper pods and the lack of evidence of proper adjustment should have been detected by earlier walking inspections but were not.

3.11 The extent of trackwork in the vicinity of the derailment location (and level crossing) and the length of time it might have affected the line could have been well in excess of what is catered for in the WTSA. It may be prudent, therefore, to give such a combination of circumstances special consideration in the WTSA process.

Effectiveness of the Emergency Response

3.12 The emergency and local road traffic arrangements were generally well managed though the following points were noted:

- the Network Controller was unsure as to the location of the incident;
- it was not the Network Controller who advised the hi-rail driver of the incident;
- ARTC’s callout list was out-of-date.

Other Matters that would Enhance the Safety of Rail Operations

3.13 An examination of NCCS documentation revealed a number of anomalies including:

- non-compliance with the document control system;
- train consist information not annotated on the train control graph;
- the second TOA issued to the hi-rail contravened ANWT 304;
- incorrect train numbers recorded in the Griffith TRB;
- use of superseded TOA documentation;
- inconsistencies between the train control graph and the Griffith TRB in relation to WOLO details; and
- inadequate provision for recording all appropriate train details on the train control graph.

3.14 Three other issues were also noted:
• ARTC’s TOC Manual and LAUs, although inherited from RIC in September 2004, were still outdated, incomplete and contained inaccuracies;

• ARTC Network Procedure ANPR 720 does not make provision for the protection of trains in non-track-circuited territory; and

• there were inconsistencies in the locomotive sequence provided to ARTC by PN.

3.15 Fatigue may have contributed to the communications and safeworking lapses on the part of the Network Controller. He was working a ‘double-back’ shift following a night shift which is contrary to good rostering practice and ARTC’s normal practice.

3.16 This incident indicates that rail operators continue to operate locomotives in NSW that are not equipped with fully functioning data loggers. It is important that this be rectified both to provide operators with a useful management tool and to provide reliable data for use in the investigation of incidents.
PART 4 RECOMMENDATIONS

4.1 In order to prevent a recurrence of this type of accident, the following remedial safety actions are recommended for implementation by the specified responsible entities.

Australian Rail Track Corporation Ltd

4.2 Check the adjustment of the rail in the Leeton to Griffith section between 615.500km and 635.500km.

4.3 Revise the current WTSA in response to research into the:
   - adequacy of inputs;
   - efficacy of the current weightings given to the factors considered;
   - triggers for secondary analysis; and
   - responsiveness to analysis of the causes of derailments.

4.4 Maintain the five-yearly cyclic program for timber sleeper replacement and reclaim the backlog.

4.5 Reinforce standards for maintenance of track containing steel sleepers.

4.6 Ensure that all employees, contractors and sub-contractors, who are required to participate in rail adjustment activity, are briefed on and understand current standards, procedures and documentation.

4.7 Reinforce the critical importance to track stability of correct adjustment, good quality sleepers, secure fastening and clean, sharp ballast in the training material provided to welders, track examiners and line managers in the track discipline.

4.8 Ensure line managers conduct quality checks of work undertaken by rail welders and adjusters.

4.9 Apply a conservative default loss of stability until adjustment can be physically checked by cutting the rail, or using a stress measuring technique when any doubt exists about the current state of adjustment due to lack of physical evidence.
4.10 In contract documents to be used when engaging contractors to carry out rail safety work on ARTC managed infrastructure, nominate all specific relevant standards, procedures, manuals and forms that are to be used and ensure that the contractor has access to them, understands them and applies them to the works.

4.11 Audit the documentation used at NCCS so as to identify and rectify the use of inaccurate, incomplete and out-of-date material, and non-compliance with the document control system.

4.12 Amend relevant Network Rules and / or Network Procedures to include actions required in non-track-circuited territory to protect a delayed or disabled train against immediately following rail traffic.

4.13 Cease the practice of ‘double-back’ shift rostering.

**Pacific National Pty Ltd**

4.14 Ensure all locomotives are fitted out with radio systems that comply with current legislative requirements.

4.15 Ensure that the data loggers installed in locomotives are properly synchronised and calibrated, and are maintained in a fully functional condition in accordance with current guidance material.

4.16 Ensure train consist records and information provided to other parties accurately reflects the actual marshalling of each train.

**The Independent Transport Safety Regulator**

4.17 Pursue compliance with, and satisfactory closure of, Improvement Notices issued to ARTC in relation to the management of misalignments.

4.18 Note the issues which have been highlighted by this investigation in relation to:

- maintenance of locomotive data loggers in fully operational condition,
- radio communications equipment installed in locomotives.
Appendix 1 Calculation of Change in Length of Rail Due to Misalignment

The track misaligned into an ‘S’ shape with a maximum displacement of 200 mm at the centre of each of the reverse curves, each with a radius of approximately 60 m. The length of rail in the misaligned section is calculated as follows:

\[
\begin{align*}
\cos \theta &= \frac{59.8}{60} \\
\theta &= 4.6795^\circ \\
\cos \phi &= \frac{59.9}{60} \\
\phi &= 3.3084^\circ \\
d &= 2 \times 60 \times \sin \theta + 4 \times 60 \times \sin \phi = 23.64\text{m}
\end{align*}
\]

Distance along curve = \(2\pi \times 60 \times \theta/180 + 4\pi \times 60 \times \phi/180 = 23.659\text{m}\)

\(\delta d = 19\text{mm}\)

This calculation indicates that there was approximately 19mm of excess rail in a length of approximately 23.64m.
## Appendix 2  ARTC’s Welders Return 1180

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### Notes
- Name: [Redacted]
- Signature: [Redacted]
Appendix 3  Use of ARTC Weekly Return – Aluminothermic Welding / Adjustment – by MVM Rail Welder

Commentary on “Weekly Return – Alulminothermic Welding / Adjustment” - Number 1180 – completed by MVM Rail Welder (see Appendix 2).

Introduction

The work that had been performed on 8 May 2006 involved eliminating rail joints and adjusting the rail so that it would be stress free at 38°C. To do this the welder cuts approximately 2m length of rail from each side of an existing joint. He then inserts a roughly 4m ‘closure’ rail into the gap. One end of the closure rail is ‘free welded’ to the rail in track. That is, no stress applying jacks are used. The weld at the other end of the closure rail is called an adjustment weld. It must be carried out at a temperature below the neutral temperature so that the rail may be stressed into tension by the application of hydraulic jacks.

The amount of tension to be applied to a length of rail depends on the temperature at which the weld is done and the length of track between ‘anchor points’. Anchor points are established in the track by applying sufficient anchors to the foot of the rail to ensure that the rail stress cannot be transmitted beyond that point.

Rail foot anchors are then removed between the anchor points and the weld to be performed to enable the rail to be vibrated into a stress free state prior to any gap measurements being taken and tensors being applied. The rail is again vibrated during tensing to ensure the stress is distributed along the full length of the rail being adjusted. Chalk marks are placed on the foot of the rail and the underlying sleeper plates at several points so that the strain distribution can be checked. Anchors are re-applied after the tensing to prevent stress redistribution caused by rail creep over time.

Weekly Return 1180

The welder’s Weekly Return 1180 provided details for an adjustment weld at 616.086 km. This weld was located at a point just 100m from the point of derailment. It provides the information that the length of rail being adjusted was 180m. The rail temperature at which the weld was performed was provided as 17°C.
The welder was interviewed and advised:

- He was not supplied with ARTC’s Engineering Practices Manual RTS 3640 *Rail Adjustment Manual* containing charts to enable him to base the adjustment on a neutral temperature of 35°C.

- Instead, he used MVM Rail's "*Rail Stress Adjustment Table*" based on a neutral temperature of 38°C.

- This table did not provide gaps for an adjustment length of 180m, so he used the nearest length provided, which was 192m.

- He was not supplied with ARTC’s Engineering Practices Manual RAP 5391 *Aluminothermic Welds – Identification, recording and reporting*.

- He was not familiar with the “Weekly Return” form with which he was supplied and which he was required to complete. He did the best he could.

He explained the entries he made on the Form as shown below.

**Note:** Comments in **Red** indicate omissions, anomalies, incorrect entries, or where the entry is contrary to the intent of the heading.

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<td>Distance between punch marks after rail is welded</td>
<td>Filled in by Supervisor. Dimension given is actually the figure from the Punch Marks Before column (i.e., 1000mm) less the figure from the Actual Gap mm column (Sum of weld gap and gap size calculated from adjustment table for rail length and temperature)</td>
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<td>----------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
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**Adjustment Details**

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<td>Sum of weld gap and gap size calculated from adjustment table for rail length and temperature</td>
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<td>Rail Required gap mm</td>
<td>Gap size calculated from adjustment table for rail length and temperature (excluding weld gap)</td>
<td>Standard weld gap (25mm)</td>
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<tr>
<td>Rail Add (A) or Remove (R) mm</td>
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<td>Code R given without mm figure as required by RAP 5391</td>
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<td>Signature of the person in charge of the weld or adjustment</td>
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</table>

There is also a section to be completed by the Rail Flaw Detection Officer:

<table>
<thead>
<tr>
<th>Heading / Subheading</th>
<th>Required Information</th>
<th>Actual Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasonic and Alignment Test</td>
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<td></td>
</tr>
<tr>
<td>Rail Fail No. OR Alignment Failure No.</td>
<td>Indicate if Rail Flaw Report or Weld Alignment Failure form completed</td>
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**Punch Mark Check**

<table>
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<th>Actual Information</th>
</tr>
</thead>
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<td></td>
<td>Distance between punch marks to be inserted by Rail Flaw Detection Officer</td>
<td>Measurement generally there, but sometimes omitted. Only one entry (a figure of ‘93’) appears on Return 1180 (on 8/5/06 for 616.308km) which is inconsistent with the entries on other forms.</td>
</tr>
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</table>
A 76mm figure is shown on an entry dated 8/05/2006 in the “Weekly Return - Aluminothermic Welding/Adjustment” for the week ending 15/05/2006, under the column Actual Gap mm, for adjustment of a 180m section of rail from 616.020km to 616.200km.

This and other entries were discussed with the welder concerned. It was determined that this figure represents an adjustment figure of 51mm calculated by taking the adjustment figure from the MVM Rail Adjustment Table for a 15ºC rail temperature and a 192m rail length, adjusting it down to allow for the rail length being 180m, and then adding the weld width allowance of 25mm.

When interviewed, the welder showed that he understood the adjustment calculation procedure but had interpreted the column heading “Actual Gap mm” to mean the gap that had to be present after adjusting the rail length, and before tensioning the rail. He interpreted the next column, headed “Required Gap mm”, to require entry of the gap to be achieved after tensioning, i.e., the weld gap of 25mm.

The welder stated that his procedure was to place punch marks either side of the proposed adjustment location, spaced 1000mm apart. He then entered the punch mark spacing into the ARTC Weekly Return under the heading “Punch Marks – Before”. The rail temperature was then measured and the necessary adjustment calculated using MVM Rail’s adjustment table based on a neutral temperature of 38ºC. He then added the required weld gap to this figure, entered the resulting figure under the heading “Rail – Actual Gap mm”, and trimmed the rail to give this gap. Under the heading “Rail – Required Gap mm” he entered the required weld gap, in this case 25mm. He then tensioned the rail to achieve this gap, and completed the weld. The figures in the “Weld No.” and “Punch Marks – After” columns were entered later by the Supervisor after the weld had cooled. It appears that the latter figure was obtained by subtracting the “Actual Gap” figure from the “Punch Marks – Before” figure.

A consequence of these entries on the form was that the Rail Flaw Detection Operator who checked the welds some days after they were completed, would have had no meaningful figure against which to check the punch mark spacing.
### Appendix 4  ARTC Table for Calculating Adjustment Gap Size

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August 2006

Australian Rail Track Corporation
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Appendix 5 Calculation of Stability Losses

Rail is an elastic material. It lengthens or shortens in a manner linearly proportionate to the force applied. The force (F) required to produce a particular shortening in a length of rail can be calculated using the formula:

\[ F = Y \times A \times \frac{\delta L}{L} \]  
(Formula 1)

Where:
- \( Y \) = the Young’s Modulus of steel = 200 \( \times 10^5 \) tonnes force/m\(^2\)
- \( A \) = the cross sectional area on which the force is applied = 5000 mm\(^2\)  
  (approx) or 5000 \( \times 10^{-6} \) m\(^2\) (for an 80 lb/yd rail)
- \( \delta L \) = change in length
- \( L \) = the length of rail on which the force is applied

Rail also expands or contracts linearly with temperature change. The change in length (\( \delta L \)) is provided by the formula:

\[ \delta L = c \times L \times \delta t \]  
(Formula 2)

Where:
- \( c \) = the thermal co-efficient of linear expansion for steel = 1.2 \( \times 10^{-5} \) per \(^0\)C
- \( L \) = the length of rail on which the temperature change acts
- \( \delta t \) = change in temperature

In order to calculate the compressive force induced in a rail due to temperature rise, the above Formulae 1 and 2 may be combined using \( \delta L \) as the common link. Formula 3 is hence derived as follows:

\[ F = Y \times c \times A \times \delta t \]  
(Formula 3)

From this formula the Force in the long welded rail may be calculated for 80 lb/yard rail:

\[
F = Y \times c \times A \times \delta t \\
= (200 \times 10^5) \times (1.2 \times 10^{-5}) \times (5000 \times 10^{-6}) \times \delta t \\
= 1.2 \times \delta t
\]
That is, the Force increases by approximately 1.2 tonnes force for each degree rise in temperature above the “neutral” temperature, which is the temperature at which the rail is stress-free.

In accordance with ARTC standards rail is stress-free at 35 °C. However, the rail was adjusted to MVM Rail’s standards, which uses a neutral temperature of 38 °C.

When the temperature rises to 60 °C, the force in the rail becomes 1.2 x 22 = 26.4 tonnes force.

At 70 °C the force becomes 38.4 tonnes force.

If, as in the case under consideration, the neutral temperature is not 38°C, but 29°C, as determined from WTSA calculations, the force is increased proportionately. At 60 °C the force will be 1.2 x 31 = 37.2 tonnes force. At 70 °C the force is 49.2 tonnes force.
Appendix 6   Sources, References, Submissions and Acknowledgements

Sources of Information

- Bureau of Meteorology
- Officers of the NSW Rural Fire Service, MIA Zone
- Pacific National Ltd
- Crew members of 5CM3
- Patrick Portlink
- Australian Rail Track Corporation Ltd (ARTC)
- Independent Transport Safety and Reliability Regulator (ITSRR)

References

- Passenger Transport Act 1990 (NSW)
- Transport Administration Act 1988 (NSW)
- Rail Safety Act 2008 (NSW)
- ARTC Network Rules and Procedures
- ARTC Train Operating Conditions Manual
- ARTC Infrastructure Engineering Standards
- ITSRR Incident Site Field Report (ID 78584)

Submissions

The Chief investigator forwarded a copy of the Draft Report to the Directly Involved Parties (DIPs) to provide them with the opportunity to contribute to the compilation of the Final Report by verifying the factual information, scrutinising the analysis, findings and recommendations, and to submit recommendations for amendments to the Draft
Report that they believed would enhance the accuracy, logic, integrity and resilience of the Investigation Report. The following DIPs were invited to make submissions on the Draft Report:

- Pacific National Pty Ltd
- Patrick Portlink
- Chicago Freight Car Leasing Australia
- Australian Rail Track Corporation Ltd
- Rail Infrastructure Corporation
- Independent Transport Safety Regulator (ITSR)

Submissions were received from the following Directly Involved Parties and were taken into consideration by the Chief Investigator in the compilation of the final report:

- Pacific National Pty Ltd
- Chicago Freight Car Leasing Australia
- Australian Rail Track Corporation Ltd
- Rail Infrastructure Corporation
- Independent Transport Safety Regulator (ITSR)

**Acknowledgements**

The locality map reproduced as *Figure 1* is used with the permission of *Geoscience Australia*. 