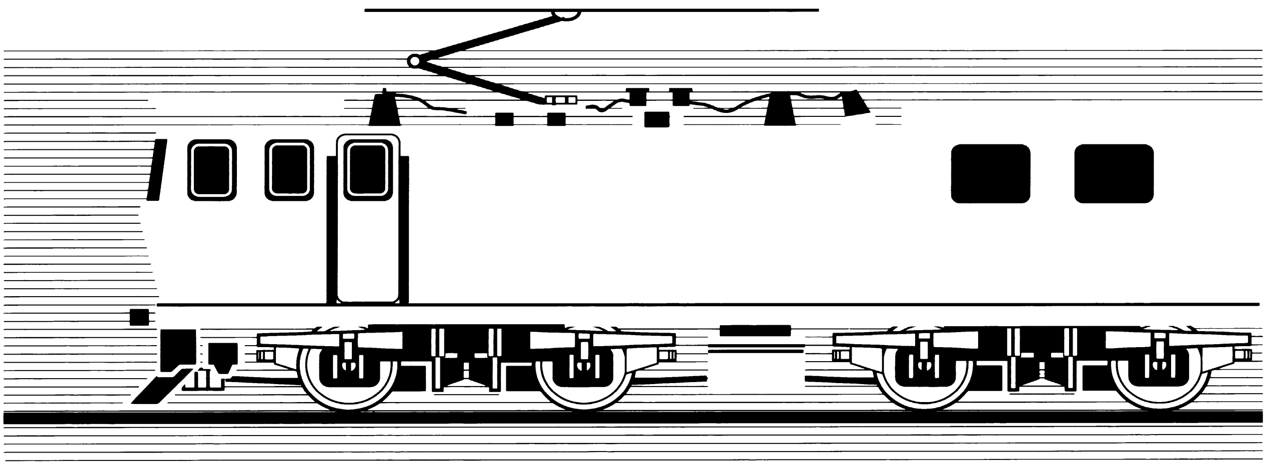
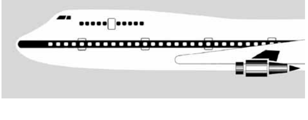
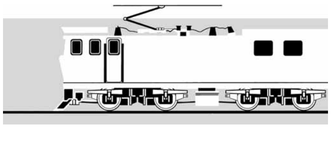
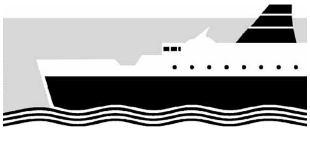


RAILWAY OCCURRENCE REPORT

03-110 express freight Train 337, derailment, Kaimai Tunnel west portal 9 August 2003

TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 03-110

express freight Train 337

derailment

Kaimai Tunnel west portal

9 August 2003

Abstract

On Saturday 9 August 2003, at about 0135, eastbound express freight Train 337 derailed about 7 m before the west portal of Kaimai Tunnel, between Hemopo and Whatakao. Five empty wagons and one loaded wagon derailed at a failed rail joint.

There were no injuries.

Safety issues identified included:

- the suitability of the standards for rail end mismatch and deformity at joints
- the security of a fishplated joint fastened with less than the full number of bolts
- the length of time the temporary joint remained in track
- the train exceeding the temporary speed limit
- the inspection of the train following the application of the emergency brakes.

Two safety recommendations were made to address these issues.

Contents

Figures

Abbreviations

ECMT	East Coast Main Trunk
kg/m	kilograms per metre
km	kilometre(s)
km/h	kilometres per hour
kPa	kilo pascals
m	metre(s)
mm	millimetres
NDT	non destructive testing
PACT	paved concrete track
POD	point of derailment
t	tonne(s)
Toll NZ	Toll NZ Consolidated Limited
Tranz Rail	Tranz Rail Limited
UTC	co-ordinated universal time

Data Summary

Train type and number:	express freight Train 337
Date and time:	9 August 2003, at about 0135[1]
Location:	Kaimai Tunnel west portal
Persons on board:	crew: 1
Injuries:	nil
Damage:	moderate track damage
Operator:	Tranz Rail Limited (Tranz Rail)
Investigator-in-charge:	P G Miskell

[1] Times in this report are New Zealand Standard Time (UTC + 12) and are expressed in the 24-hour mode.

1 Factual Information

1.1 Narrative

1.1.1 On Friday 8 August 2003, Train 337 was a scheduled express freight service from Auckland to Mount Maunganui via Te Rapa, and was crewed by a locomotive engineer. The train departed from Te Rapa with a consist of locomotive DFM 7322 hauling 40 bogie wagons with a weight of 895 t and a total length of 677 m.

1.1.2 On Saturday 9 August 2003, at about 0135, when the train was about 500 m into the Kaimai Tunnel, there was a sudden drop in brake pipe pressure that activated the automatic train brake and brought the train to a stop.

1.1.3 The locomotive engineer thought the train had burst a hose and the train had parted, so after advising train control he donned a facemask, gathered the portable radio, torch, spanner and a replacement brake hose and walked down the side of the train until he reached a break in the train, of about 90 m, between UK 14093 and the next wagon. He did not inspect past the leading wagon on the rear section of the train.

1.1.4 The locomotive engineer recovered all the coupling components and using the portable radio suggested to the train controller that he return to the locomotive and move the train slowly back to couple up and then continue on to Mount Maunganui. The train controller authorised this movement.

1.1.5 When the train was again coupled and ready to move forward, the locomotive engineer carried out a brake test before moving off. After the train had moved about 500 m, there was another rapid drop of brake pipe pressure that again activated the automatic train brake and stopped the train. The locomotive engineer advised the train controller of the situation, and walked back to re-examine the train.

1.1.6 At about 0230, the locomotive engineer advised the train controller that the train had this time parted at a different place and that several wagons had derailed. After further discussion with the train controller, the locomotive engineer uncoupled the wagon immediately in front of the first derailed wagon and took the front portion of the train to Whatakao crossing loop, about one kilometre beyond the tunnel.

1.1.7 The train controller commenced the recovery of the disabled portion of the train in accordance with the Kaimai Tunnel Emergency Procedures Plan.

1.1.8 A subsequent investigation showed the point of derailment (POD) to be 63.323 km East Coast Main Trunk (ECMT) where a rail joint had broken (see Figure 1).

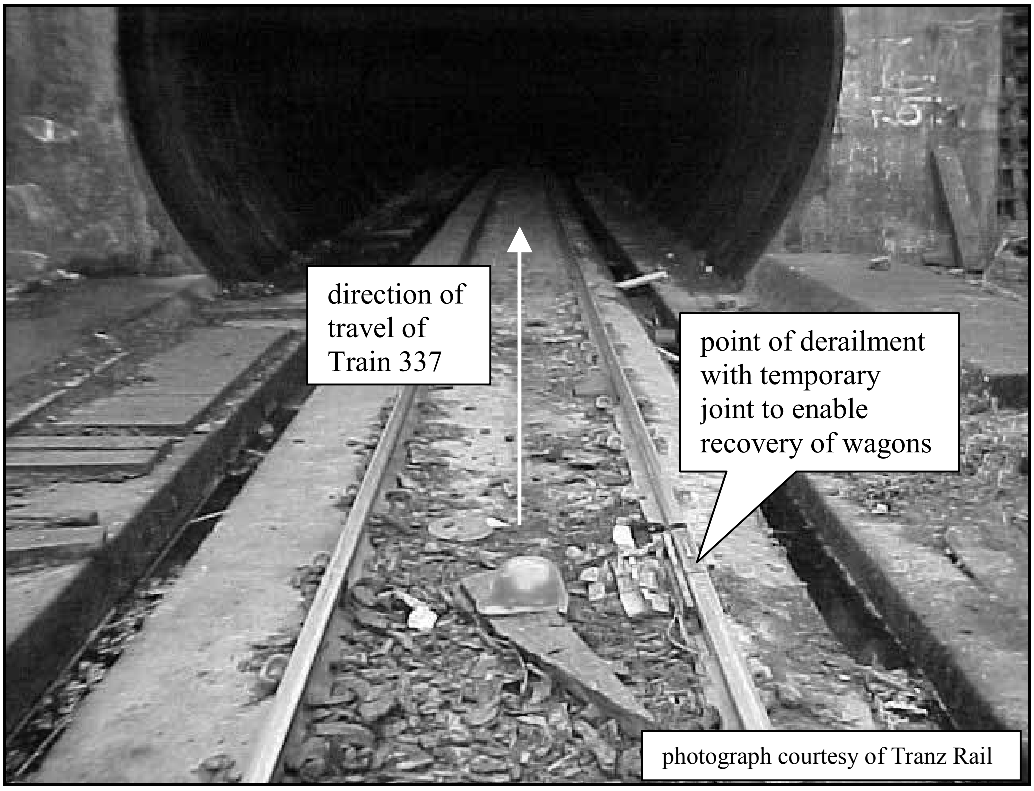


Figure 1
Track at the point of derailment

1.2 Site and tunnel information

1.2.1 The rail joint at the POD was on an extension of the tunnel's paved concrete rail bed and about 7 m outside the west portal of the 8.9 km long Kaimai Tunnel. The derailment occurred on an 820 m radius right-hand curve on a uniform ascending grade of 1 in 324.

1.2.2 The maximum authorised line speed for freight trains on the ECMT was 80 km/h. However, at the time of the derailment there was a temporary speed restriction throughout the entire length of Kaimai Tunnel that limited the maximum line speed to 50 km/h because of rail condition.

1.2.3 About 7000 trains with a combined gross weight of 7.7 million tonnes passed through the tunnel in the 12 months before the derailment.

1.3 Track details

1.3.1 The track through Kaimai Tunnel consisted of 50 kg/m rail fastened to a continuous concrete pad with Pandrol[2] fastenings at 800 mm centres. The concrete pad extended about 70 m outside the tunnel portals. The rails were seated on a 10 mm thick continuous rubber-bonded cork pad, except where recent re-railing had taken place. At retailed sites the continuous rubber-bonded cork pad was replaced by short-length, 10 mm thick rubber pads at the fastenings only. The POD was at a bolted joint connecting old and new rail, where there was a Pandrol fastening. There was no rubber pad at the failed joint.

1.3.2 The particular system of a continuously reinforced concrete slab used in Kaimai Tunnel was known as PACT (paved concrete track) and was laid using a purpose-built, slip-form paving machine in 1977. The concrete slab profile incorporated a 1 in 20 slope in the rail-seat area to support the rail at the correct inclination.

[2] Pandrol was the name of the supplier of the rail fastening system.

1.3.3 The Pandrol fastening system consisted of a spring clip driven into cast iron malleable shoulders to generate clamping forces on the rail foot. The shoulders were glued using an epoxy resin into holes drilled into the concrete. The resilient pad under the rail cushioned imperfections in the rail bed and absorbed the high-frequency vibrations that could otherwise abrade the rail seat and contribute to the loosening of fishplated joints as well as providing an electrical insulation between the rail and concrete pad for reliable track circuit operation.

1.3.4 Since the early 1960s Tranz Rail had been seeking a technical and economic solution to fasten rails to concrete structures. The PACT system developed in England appeared to be an acceptable solution for Kaimai Tunnel in that:

- the initial line and level were retained accurately without the need for periodic adjustments
- the rails could be laid at ambient temperature because the high lateral stiffness of the concrete slab reduced the risk of track buckling and the need for periodic distressing
- the improved track geometry attainable under load virtually eliminated the risk of derailment due to track geometry irregularities
- because of the preservation of track geometry the introduction of speed restrictions was less likely to be necessary.

1.3.5 Bark and fertiliser that fell from trains and accumulated around the rail combined with the high-sulphur-content water migrating from the tunnel, resulting in significant corrosion to the foot of the rail and rail fastenings.

1.3.6 In March 2002, both the left and right rails from the 63.323 km (POD) to 64. 090 km were replaced. The rail was initially laid in 76 m lengths and then welded to form longer lengths. Five of the 22 welds on the replacement rail were not done. The joint on the right-hand rail at the POD was one of 5 fishplated joints left in the replacement rail. The rail ends of the original and new rail on the left-hand rail, opposite the joint at the POD, were welded.

1.3.7 Tranz Rail used a 5-level classification index to describe rail condition. Worn rail or rail in poor condition was allocated an index of 1, while relatively new rail in good condition had an index of 5. At the time of the derailment, the original rail to the west of the joint at the POD had a classification of 2, while the newer rail to the east of the joint had a classification of 5.

1.3.8 The replacement rail was manufactured by One Steel Australia, during November 2001, to the identical profile as the original 1978 rail from Workington, England.

1.4 Bolted rail joints

1.4.1 A rail joint served the following functions:

- provided a connection between the rails, that acted as a continuous girder to provide a uniform running surface and alignment
- provided a resistance to deflection, similar to that of the adjacent rail
- prevented vertical and lateral movement of the rail ends relative to each other.

1.4.2 The Tranz Rail Infrastructure Engineering Handbook stated in part that:

> - for rails longer than 10 m, an expansion gap of 5 mm between the rail ends is to be allowed for when the rail temperature is between 21°C and 25°C
> - combined batter and dip at a bolted joint must be less than 6 mm
> - the fishplates must be secured with the full number of proper sized bolts.

1.4.3 The handbook also stated in part:

> Bolted rail joints consist of standard fishplates held in position by track bolts having a tension sufficient to firmly support abutting rail ends. Bolted joints with vertical or gauge mis-match must be corrected by grinding or welding prior to the passage of a train.

1.4.4 Tranz Rail had no records of any vertical mismatch between the head worn original rail and replacement rail, nor whether grinding or head welding occurred at the time the new rail was laid.

1.4.5 Tranz Rail was unable to provide a record of the rail gap at each of the 5 fishplated joints. However, the person in charge of the rail replacement work believed that 5 mm gaps were set at the joints.

1.4.6 All the 5 joints remaining in track were fastened with 2 bolts per fishplate instead of the 4 required (see Figure 2). The bolt at each rail end was not fitted.

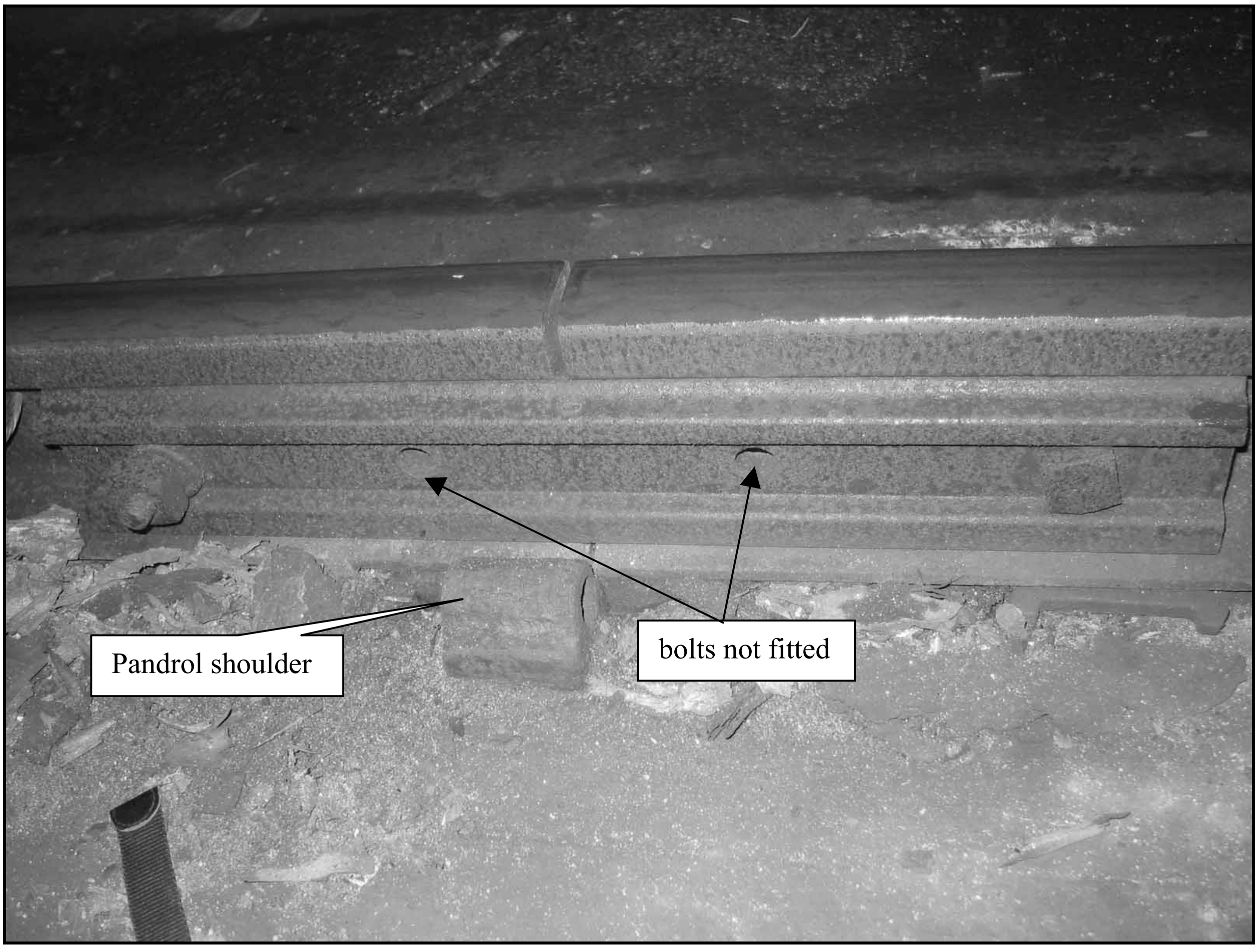


Figure 2
Bolted joint with 2 bolts only

1.4.7 For rails longer than 8 m, it was at the manager's discretion whether or not a temporary speed restriction was necessary for fishplated joints with 2 bolts i.e. a bolt at each rail end. At the time of the derailment, the section of track between 63.21 km and 72.19 km that included the failed joint was covered by a 50 km/h temporary speed restriction.

1.5 Track inspections

1.5.1 Tranz Rail Track Code required that the ECMT line be inspected twice per week.

1.5.2 The track between 52 km and 146 km ECMT including Kaimai Tunnel was inspected on 5 and 7 August 2003. The track inspector did not identify any non-conforming track conditions near the POD during these inspections.

1.5.3 Tranz Rail's EM 80 track evaluation car measured and recorded track geometry between Mount Maunganui and Hamilton 2 days before the derailment. A deflection of 1 mm beyond the acceptable maintenance limit was recorded at the POD. Tranz Rail Engineering Handbook required the defect to be fixed within 4 weeks.

1.5.4 A rail flaw non-destructive testing (NDT) car tested rail through Kaimai Tunnel 18 months before the replacement rail was laid. The testing technology was based on recording the time taken for an ultrasonic sound wave to travel between the running surface and the bottom of the rail and back. If a defect was found, the ultrasonic wave was reflected or dispersed, making it possible to identify the location, orientation and nature of the defect. The following defects near the west portal were identified:

Metrage	Description	Size/Priority	Rail/Location	Defect Removed
63.600	Bolt hole crack	Small	Right/Web	14.9.2000
63.610	Bolt hole crack	Large	Right/Web	14.9.2000
63.613	Split web	Large	Right/Web	25.9.2000
63.900	Horizontal split web	Medium	Left/Head	25.9.2000

1.5.5 On 27 March 2003, the rail flaw detection car tested rail through Kaimai Tunnel. No evidence of fatigue cracks or manufacturing flaws was identified in the replacement rail.

1.5.6 On 9 July 2002, Tranz Rail carried out an engineering inspection and audit of Kaimai Tunnel and found that welding of the joints in the replacement rail had not been completed.

1.5.7 On 17 July 2002, Tranz Rail instructed Transfield Services[3] to weld the remaining joints in the replacement rail. On 26 August 2002, Tranz Rail closed out the audit after Transfield generated a work order to weld the remaining bolted joints. A follow up inspection was not carried out to confirm that the joint elimination had been completed.

1.6 Examination of the failed rail section

1.6.1 Not all fragments of the failed rail joint were recovered during a search of the area surrounding the point of derailment (see Figure 3).

1.6.2 A fatigue fracture ran from the end bolt hole parallel with the running surface of the rail to the rail end. This fracture surface, marked A in Figure 4, was smooth and heavily polished.

1.6.3 A second fatigue fracture surface, marked B in Figure 4, was also heavily polished.

[3] Transfield Infrastructure Services Limited was contracted to Tranz Rail Limited to inspect and maintain the rail infrastructure assets.

1.6.4 A vertical deformation of 5 mm was measured on the new rail at the failed rail joint (see Figure 4).

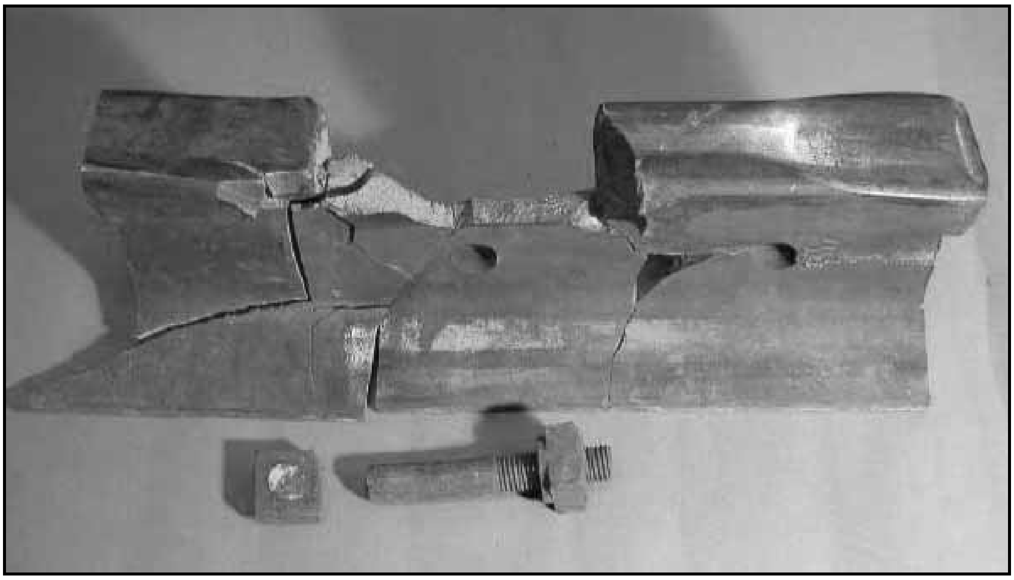


Figure 3
Recovered section of failed rail end

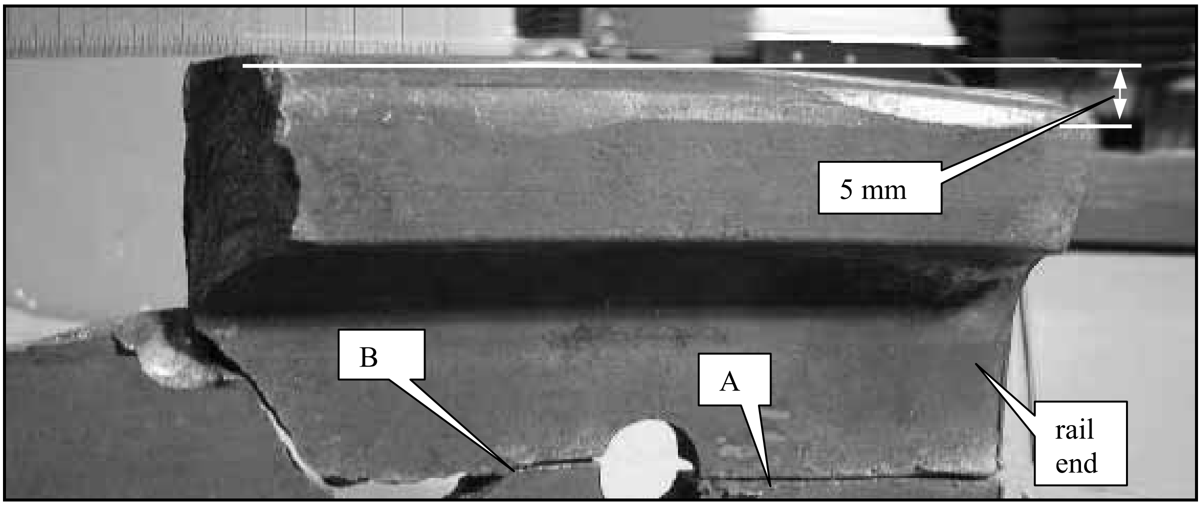


Figure 4
Vertical deformation on the new rail at the failed joint

Figure 5
Horizontal deformation on the new rail at the failed joint

1.6.5 The rail head was battered to the extent that metal flowed 10 mm to the outside of the head of the new rail (see Figure 5).

1.6.6 There were highly polished marks from the fishplate under the rail head of the deformed section of the replacement rail, and on the foot region of the original rail at the rail joint.

1.6.7 The bolt hole next to the end of the rail was undamaged but corroded. A significant wear/polishing pattern was present on the side of the other bolt hole facing the end of the rail. The edges of the hole were burred indicating that a significant amount of deformation had taken place.

1.7 Locomotive event recorder

1.7.1 The event recorder data was downloaded from the locomotive and made available for analysis.

1.8 Kaimai Tunnel emergency procedures

1.8.1 Tranz Rail had recently carried out a review of all major tunnel procedures and produced integrated emergency procedures covering both the internal operations and external interfaces with agencies such as Police, Fire and Ambulance, as well as the availability of specialist underground expertise from the New Zealand Mines Rescue Service, Huntly.

1.8.2 Section L2 of Tranz Rail's Working Timetable related to the operation of rail service vehicles through Kaimai Tunnel, with particular emphasis on ventilation and emergency procedures.

1.8.3 As this was the first derailment to have occurred in Kaimai Tunnel since the introduction of the emergency procedures, the investigation included a review of the tunnel emergency procedures. The following key points were established:

- the incident was classed as a tunnel emergency by Tranz Rail
- the locomotive engineer of Train 337 was appropriately equipped with a respirator when inspecting and re-coupling the train
- the site manager held a site safety briefing with all staff involved in the recovery operations before they entered the tunnel
- a mines rescue representative was on site to monitor air quality during the recovery operations.

1.9 Personnel

Locomotive engineer

1.9.1 The locomotive engineer was a qualified Grade 1 locomotive engineer and held a current operating certificate. He had held Grade 1 certification for 15 years.

Track inspector

1.9.2 The track inspector had been involved with track maintenance, renewals and inspection on the ECMT for about 20 years and was appointed to the position of track inspector in December 1999.

2 Analysis

The derailment

2.1 The derailment was caused by a rail failure at a bolted joint about 7 m outside the west portal of Kaimai Tunnel. The rail probably failed because of high-impact wheel loadings caused by a significant step between the running surface of the original rail laid in 1977 and that of the replacement rail laid in March 2002.

2.2 Analysis of the event recorder output data showed that Train 337 was travelling at about 68 km/h when there was a sudden drop in brake pipe pressure from 550 kPa to 300 kPa, indicative of a burst hose or a derailed train and subsequent train parting. Although the train exceeded the temporary speed restriction of 50 km/h by 18 km/h, and subjected the joint to high dynamic loading it was unlikely that the train's excessive speed caused the derailment. However, had other trains been passing over the joint at similar speeds, the resulting higher dynamic loadings on the joint would have contributed to an accelerated rail failure.

Rail replacement

2.3 The rail defects identified within the first 600 m of the tunnel by the rail flaw detection car in September 2000 could be expected to occur from time to time. Tranz Rail had defined procedures to deal with the defects, including temporary speed restrictions being imposed until the defects were corrected.

2.4 The 760 m of replacement rail was programmed because of its general poor condition and the localised concentration of rail defects. However, the joint failure and subsequent derailment would have been avoided had the joint been welded like the adjacent rail.

2.5 The risk of a joint failure would have been reduced had there been no vertical mismatch between the running surface of the old and new rail, and the full complement of 4 bolts used to secure the joint.

2.6 Although the 5 bolted joints on the section of replacement rail were secured with 2 bolts per joint, the track complied with Tranz Rail standards by imposing a 50 km/h temporary speed restriction over the affected track.

2.7 Because each bolted joint was adjacent to a Pandrol shoulder, a closure rail at least 4 m long should have been cut in to avoid the Pandrol shoulder and then each end of the closure rail welded to eliminate the joint. In view of the safety action taken regarding the welding of joints at the time the rail is replaced, no safety recommendation regarding this issue has been made.

Inspections

2.8 Track inspections are used as a means of identifying conditions that could lead to service failures of essential components. A visual inspection of the rail would probably detect an external defect, but it was unlikely that a track inspector would have identified a fatigue crack in the rail when travelling across the joint in a hi-rail vehicle. However, the excessive rail end batter on the right-hand rail at the POD should have provided clear evidence of a potential problem, but went undetected.

2.9 Although the EM 80 recording run 2 days before the derailment identified track geometry at the POD marginally outside the acceptable maintenance tolerance limit, it was not of sufficient severity to warrant immediate attention.

2.10 The initiation of the fatigue crack at the POD probably occurred sometime after 27 March 2003, when the rail flaw detection car last tested the rail in the Kaimai Tunnel.

2.11 Had a follow-up engineering inspection been carried out to confirm that all the rail joints within the replacement rail had been welded or had Transfield confirmed that the joint elimination was complete before Tranz Rail closed out the audit, the derailment probably would not have happened.

Joint failure

2.12 Most rail failures have their origin in fatigue. Fatigue is a cumulative process causing, initially, internal damage then cracking and ultimately fracture of the rail. Significant hammering and rail end deformation from the axle loading cycles that passed over the step joint since its formation led to uneven compressive loads on the rail and the introduction of bending stresses. As a result, the initial fatigue crack grew from the end bolt hole, parallel with the running surface towards the rail end. The fracture surfaces were smooth and heavily polished, consistent with 2 opposing fractured surfaces being hammered together by the axle loadings for a considerable period of time.

2.13 Once the initial fatigue crack had developed to a critical size and probably grown across to the end of the rail, a second fatigue crack developed until a section of the head of the rail parted from the rail. Following this, massive impact forces were applied to the remaining section of the rail, causing further fractures and deformation of the rail.

2.14 The slab concrete base supporting the rail was more rigid than conventional ballasted track. The combined impact loadings from the abrupt rail height mismatch and the absence of the resilient pad directly under the rail would have been much higher than experienced with conventional track. Joints, including welded joints, must be ground with a rail grinder to a true running surface in both top and gauge to correct any variation that cannot be otherwise corrected.

2.15 The magnitude of the vertical height mismatch between the old and new rail when the joint was formed in March 2002 could not be determined accurately. However, the horizontal head flow distortion of the new rail at the time of the derailment suggested that the vertical height mismatch was likely to have been more than 5 mm. While Tranz Rail had tolerance limits for combined batter and dip at a bolted joint, there was no corresponding standard for an abrupt deviation when a joint was formed. A safety recommendation to address this issue has been made to the operator.

2.16 It was likely that the 10 mm thick rubber pad was not placed between the concrete pad and the rail at the POD when the rail joint was formed in March 2002.

2.17 The polishing marks from the fishplates indicated that significant flexing had taken place consistent with the high-impact loadings on the end of the new rail. The amount of movement of the fishplates was exacerbated by the use of one fish bolt to secure each end of the joint. Deformation of these bolt holes also confirmed that significant movement had taken place in this region.

2.18 A metallographic examination of the head of the rail revealed that the microstructure and hardness were as specified for “as rolled” rail and did not contribute to the rail failure.

Kaimai Tunnel emergency procedures

2.19 This investigation, and the Tranz Rail debrief, confirmed the adequacy of the emergency procedures. Although the Police control section of the emergency procedure was not activated, this was appropriate in the circumstances. However, it was appropriate to have a Mines Safety representative on site to monitor the air quality until all the wagons were recovered from the tunnel.

3 Findings

Findings are listed in order of development and not in order of priority.

3.1 Train 337 had probably already derailed when the train first parted. Had the locomotive engineer inspected the rear section of the parted train he probably would have found the derailed wagons.

3.2 The derailment occurred at a failed rail joint.

3.3 The rail joint failed because:

- it was formed with a vertical mismatch between the running surfaces of the rail laid in 1977 and the replacement rail laid in March 2002, resulting in high impact loadings
- it was formed with fishplates that were secured with 2 bolts only instead of the required 4, resulting in increased flexing at the joint
- it was not supported by a resilient pad to cushion imperfections in the rail bed and absorb high-frequency vibrations.

3.4 An initial fatigue crack developed at the joint in the replacement rail from the end bolt hole to the rail end.

3.5 The fatigue crack in the replacement rail was not identified by inspection.

3.6 The passage of trains over the joint since its formation led to a gradual deterioration until its failure. Any train travelling in excess of the authorised speed served to accelerate the deterioration.

3.7 Although Train 337 travelled across the joint faster than the authorised speed, its speed did not in itself cause the derailment.

3.8 Had the rail joint been welded at the time the replacement rail was laid or soon after the engineering inspection of 9 July 2002, the derailment would probably have been averted.

3.9 The rail specification and manufacture did not contribute to the derailment.

3.10 The Kaimai Tunnel Emergency Procedures were adequate.

4 Safety Actions

On 29 June 2004 the Chief Executive of Toll NZ Consolidated Limited[4] confirmed that:

- all rail joints at the derailment site have been welded and Transfield will weld any future rail joints in the Kaimai Tunnel promptly (e.g. those arising from re-railing or installing closures after rail defects)
- Toll Rail contract audit regimes for track asset and compliance to procedures are continuing. This includes audit of Track Inspector findings
- further engineering review of the Kaimai Tunnel track and progress with track maintenance is programmed for July 2004.

[4] New owner of Tranz Rail, effective from 5 May 2004.

5 Safety Recommendations

Safety recommendations are listed in order of development and not in order of priority.

5.1 On 15 September 2004 the Commission recommended to the Chief Executive of Toll NZ Consolidated Limited that he:

5.1.1 ensure that in all cases of a train parting, the whole train is inspected before any attempt is made to couple up and move off. (066/04)

5.1.2 determine tolerance limits for abrupt vertical and horizontal deviations at a rail joint at the time of its formation. (067/04)

5.2 On 7 October 2004 the Chief Executive of Toll NZ Consolidated Limited replied:

066/04 Toll NZ intends to review procedures for train inspection following train partings and burst hoses.

This will include analysis of incident statistics and actual practices supplied by Locomotive Engineers (and staff deployed to provide assistance).

It is expected this review will be completed by end of December 2004.

5.3 On 31 August 2004 New Zealand Railways Corporation was assigned responsibility for the long-term operation and maintenance of the National Rail system owned or managed by the Crown.

5.4 On 1 October 2004 safety recommendation 067/04 was re-directed to the Chief Executive of New Zealand Railways Corporation.

5.5 On 5 October 2004 the Chief Executive of New Zealand Railways Corporation replied:

067/04 New Zealand Railways Corporation need to carry out further analysis before deciding whether to implement this recommendation. This will be placed before the Track Technical Committee for consideration, after which we will be able to determine implementation options.

Approved on 22 September 2004 for publication

Hon W P Jeffries
Chief Commissioner

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03-110	express freight Train 337, derailment, Kaimai Tunnel west portal, 9 August 2003
03-109	diesel multiple unit passenger Train 3347, driveshaft failure, Meadowbank, 27 June 2003
03-104	express freight Train 380, derailment, Taumarunui, 16 February 2003
03-103	hi-rail vehicle and express freight Train 142, track occupancy irregularity, Amokura, 10 February 2003
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02-118	express freight Train 484, near collision with hi-rail vehicle, Tauranga, 7 August 2002
02-117	express freight Train 328 signal passed at stop, Te Rapa 31 July 2002
02-116	express freight Train 533, derailment, near Te Wera, 26 July 2002
02-112	passenger fell from the Rail Forest Express, Tunnel 29, Nihotupu Tramline, Waitakere, Saturday 4 May 2002

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