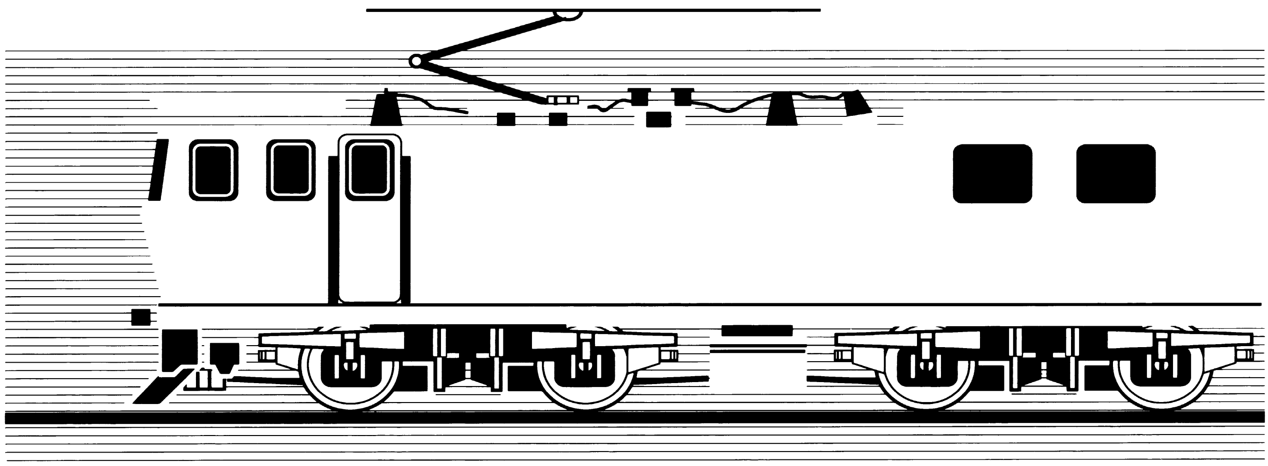

RAILWAY OCCURRENCE REPORT

04-126 **express freight Train 244, derailment inside Tunnel 1, North Island Main Trunk, near Wellington** **11 October 2004**

TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 04-126

express freight Train 244

derailment

inside Tunnel 1, North Island Main Trunk

near Wellington

11 October 2004

Abstract

On Monday 11 October 2004 at about 0007, the sixth wagon on Train 244, a Wellington to Karioi express freight service, derailed at 4.458 km on the North Island Main Trunk line, inside Tunnel 1 after the right wheel on the leading axle of the leading bogie fractured. The train travelled a further 4 km before the locomotive engineer looked back along his train, saw sparks and stopped the train that was by then inside Tunnel 2.

The derailed wagon caused some minor damage to the rail bridge over State Highway 1 at Ngauranga Gorge and to ground-level signalling equipment inside Tunnel 2.

The safety issues identified were:

- the suitability of the wheel profile used on the dedicated Wellington to Karioi ZH wagon fleet
- the overheat code standard used to determine when a wheel should be withdrawn from service.

As a result of the actions taken by Toll NZ Consolidated Limited, no safety recommendations have been made.

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Abbreviations

AAR	Association of American Railroads
BHN	Brinell hardness
Bridge 4	Bridge 4 North Island Main Trunk, Ngauranga Gorge State Highway 1 subway
BS	British Standard
kg/m	kilograms per metre
km	kilometre(s)
km/h	kilometres per hour
m	metre(s)
mm	millimetre(s)
NIMT	North Island Main Trunk
POD	point of derailment
t	tonne(s)
TIC	Train Inspection Certificate
Toll Rail	Toll NZ Consolidated Limited
UTC	coordinated universal time

Data Summary

Train type and number:	express freight Train 244
Date and time:	11 October 2004, at about 0007[1]
Location:	4.458 km North Island Main Trunk, inside Tunnel 1, near Wellington
Persons on board:	crew: 1
Injuries:	crew: nil
Damage:	minor to derailed wagon ZH1115 and moderate to rail infrastructure
Operator:	Toll NZ Consolidated Limited (Toll Rail)
Investigator-in-charge:	P G Miskell

[1] Times in this report are New Zealand Daylight Times (UTC + 13) and are expressed in the 24-hour mode.

1 Factual Information

1.1 Narrative

1.1.1 On Monday 11 October 2004, Train 244 was a Wellington to Karioi express freight train and consisted of 2 DC class locomotives in multiple[2] hauling 12 empty ZH wagons with a gross weight of 235 t, and a total train length of 206 m. The train was crewed by a locomotive engineer.

1.1.2 Train 244 departed from Wellington at about 0002, and a few minutes later the locomotive engineer felt a slight surge after the train entered Tunnel 1. The train continued through the tunnel and across Bridge 4, the rail bridge over State Highway 1, Ngauranga Gorge, between Tunnel 1 and Tunnel 2.

1.1.3 When the train was about halfway through Tunnel 2, the locomotive engineer felt another surge, so he opened the cab window, looked back along his train and saw sparks coming from beneath one of the wagons. He immediately made a normal brake application and stopped the train inside the tunnel.

1.1.4 The locomotive engineer called train control to advise that he had stopped the train at about 8.7 km and he would go back to see what had caused the sparks. He found that the leading bogie of wagon ZH1115, the sixth wagon behind the locomotives had derailed.

1.1.5 The Up and Down Main lines between Wellington and Porirua were closed to rail traffic until the derailed wagon was cleared from the track.

1.2 Site information

1.2.1 Train 244 started a 7 km long steady climb, at a ruling gradient of 1 in 110, about one km from Wellington Yard (see Figure 1).

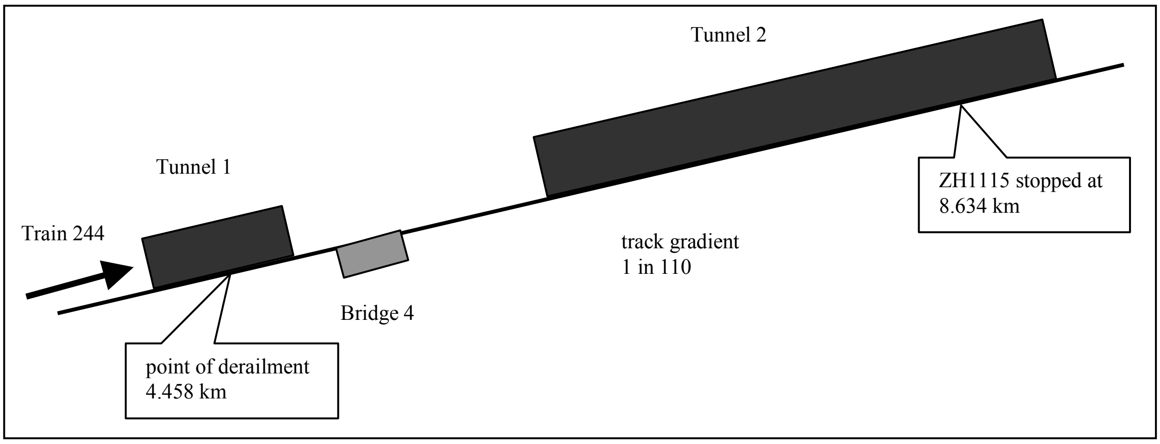

Figure 1
Derailment site plan (not to scale)

1.2.2 Marks on the inside of the right running rail and a wheel flange mark across the rail head to the right side identified the point of derailment (POD) at 4.458 km, on straight track near the middle of Tunnel 1. There were impact marks, about 110 mm long, on the running edge of the right rail spaced equivalent to the wheel circumference for about 120 m before the POD. The first impact marks on the sleepers from the derailed wheelset were 3.7 m past the POD. A second set of impact marks on the sleepers started 9.3 m past the POD, indicating that the trailing wheelset of the leading bogie had derailed at that point.

[2] Multiple means that hoses and jumper cables are coupled and controlled from the lead locomotive.

1.2.3 When Train 244 stopped in Tunnel 2, the derailed wagon, ZH1115, was at 8.634 km, about 1200 m from the north portal. The right-hand wheel on the leading wheelset of the leading bogie had fractured and was leaning out at an angle of 45 degrees and was displaced about 250 mm out from the end of the sleepers.

1.2.4 The track materials through the tunnels consisted of 50 kg/m continuous welded rail fastened to treated pinus radiata sleepers with predominately R Type[3] fastenings.

1.2.5 The track geometry on the straight track leading up to the POD was within acceptable maintenance tolerance limits. The most recent track evaluation car run from Wellington to Palmerston North occurred on 8 August 2004. There were no track geometry exceedances identified near the POD during the run, nor were there any outstanding priority 1 or 2 track issues near the POD.

1.2.6 The crib ballast between sleepers covered the upper face of the sleepers throughout both tunnels. These full cribs limited track damage in the tunnels to minor bruising on some sleepers. There was superficial damage to the concrete abutments on Bridge 4 as well as some bent screwspikes, a few bent hook bolts and breaks to the inner bridge guardrails at each abutment.

1.2.7 The derailed wagon destroyed some signalling equipment and a few traction bond wires inside Tunnel 2.

1.3 Operating information

1.3.1 The section of track where the derailment occurred was Double Line, with both Up and Down Main lines. Trains travelled on the left-hand line in the direction of travel.

1.3.2 Express freight trains running between Wellington and Palmerston North were restricted to a maximum authorised speed of 80 km/h.

1.4 Locomotive event recorder

1.4.1 The event recorder data from the leading locomotive was downloaded and a printout provided for analysis.

1.5 Personnel

1.5.1 The locomotive engineer gained his first grade certification in 1994 and was qualified to drive freight trains and locomotive-hauled passenger trains.

1.5.2 The locomotive engineer started his shift at about 2310 on Sunday 10 October 2004. He coupled the locomotives on to the train, and carried out a pre-departure terminal brake test.

1.5.3 The locomotive engineer said that the train felt normal when leaving Wellington Yard and climbing towards Tunnel 1. He considered the train's initial surge, when travelling through Tunnel 1, was due to the trailing locomotive not being set up correctly. He said that the train seemed to travel normally for the next few minutes, but he suspected that things were not right when he felt a second surge when the train was near the middle of Tunnel 2.

1.5.4 When he looked back along the train and saw sparks coming from under one of the wagons, he immediately made a normal, light brake application to stop the train.

[3] R Type fastenings consisted of a ribbed canted bedplate fastened to a sleeper with a 180 mm screw spike through a spring washer and rail clip.

1.5.5 After the locomotive engineer confirmed with train control that the leading bogie of the sixth wagon behind the locomotives had derailed and was leaning out towards the Down Main line, he shut down both locomotives and waited for assistance.

1.6 Train handling

1.6.1 A number of locomotive engineers have commented that driving a loaded unit train such as a milk train, a coal train, or the pulp train (loaded return service of Train 244) presented special challenges. Generally these unit trains are shorter but convey as much gross tonnage as longer trains carrying mixed freight.

1.6.2 Good train handling can be attributed to 3 major factors, the most important being the judgement and skill of a locomotive engineer. To properly control a train, a locomotive engineer must anticipate and plan ahead, so that no matter what problem arises it is a locomotive engineer's prompt assessment and reaction that ensures smooth and proper train handling. A locomotive engineer's performance is enhanced by the proper use of the air brakes, dynamic brake, and combinations of air and dynamic braking and judicious use of the throttle.

1.6.3 The second factor is the condition of the locomotive and rolling stock, especially the braking system. The third factor is for a locomotive engineer to have a thorough knowledge of the physical characteristics of the route to be traversed.

1.6.4 A train is a complex mechanical system of wagons, loads and springs that interact with the track in many ways. These interactions are in turn dependent on the arrangement of the wagons within the train, length and weight of the train, track condition, track geometry and gradient, train speed, characteristics of the locomotive consist and the prevailing weather conditions.

1.7 Design specification for freight wagon wheels

1.7.1 In 1997, Tranz Rail[4] replaced the British Standard (BS) 468 Class E material standard for solid disc wheels with the Association of American Railroads (AAR) standards. The material grades progressively introduced were AAR Class B for locomotive-hauled passenger rolling stock, and AAR Class C primarily for freight and locomotive use. The failed flat-plate wheel on derailed wagon ZH1115 was manufactured to AAR standard M-107-84 Class C.

1.7.2 Wheels to AAR standards were all rim quenched, resulting in high initial residual compressive stresses in the rim. These compressive stresses were greater than in a wheel manufactured to BS 468 and while present they effectively prevented the formation of thermal cracking. Class C wheels had a higher carbon content than the equivalent BS 468, making them slightly less fracture resistant once the compressive stresses were reduced through normal use and a reduction in tyre thickness. Class C wheels also had a higher carbon content than Class B wheels and as a result were even more prone to work hardening. They were also more brittle and had lower fracture resistance, which made them more prone to cracking than Class B wheels.

1.8 Wagon ZH1115

1.8.1 Wagon ZH1115 had a tare weight of 19.96 t. The wagon was part of a dedicated fleet of such wagons used to convey pulp from Karioi, between Waiouru and Ohakune, to Port of Wellington for export. These high-capacity box wagons were converted from ZA wagons at Hillside workshops, to create a higher, wider body and were fitted with fibreglass sliding doors.

[4] Tranz Rail was the operator of the rail network before 5 May 2004.

1.8.2 The derailed wheel set was assembled at Hillside workshops on 11 October 1999. The axle was recorded as number 41940. The press-on records for the new wheel set were as follows:

A side	
Axle Diameter	175.08 mm
Wheel Diameter	174.81 mm
Interference	0.27 mm
Max. Press-On Force	85 t
ID Number	217

B side	
Axle Diameter	175.07 mm
Wheel Diameter	174.80 mm
Interference	0.27 mm
Max. Press-On Force	85 t
ID Number	216

1.8.3 Mechanical Code M9202, Wagon and Inspection Manual, required that freight wagons be given a pre-departure inspection before a train was permitted to depart a terminal. Inspection requirements for underneath the wagon deck included:

- observe the condition of the brake blocks
- confirm that the handbrakes were released and the lever was in the crotch
- rectify any leaking brake hoses or replace burst hoses
- check the wheels/tyres
- check bogie springs
- check for loose/hanging brake gear and rigging.

The code required a Train Inspection Certificate (TIC) be signed off by a qualified person as confirmation that the train had been inspected and was in a proper condition for safe running. The completed TIC was then attached to other train documentation and retained in the locomotive cab until the train reached its destination. The locomotive engineer confirmed that he was given a signed TIC before Train 244 departed.

1.8.4 Code M9202 also required all freight wagons to undergo a B-check and a C-check at a defined frequency. A B-check covered safety critical items and was performed whenever 2 or more brake blocks were changed, or after an incident. The more detailed C-check was performed every 24 months, with an upper limit of 27 months.

1.8.5 The B-check and C-check included the following examination:

Wheels:	
Flanges:	Not sharp (use Gauge 13090426 if in doubt).
Tyre Tread:	No obvious defects of the following types: Skids Shelling or spalling Grooving.
Tyres: (portion showing only)	No obvious defects of the following types: Discolouration indicating overheating.

1.8.6 All 8 brake blocks on ZH1115 were changed at each of the last 3 B-checks carried out at Karioi on 14 September 2004, 12 August 2004 and 20 July 2004 respectively. No other components were replaced during the most recent B-check inspection on 14 September 2004.

1.8.7 Toll Rail's Mechanical Code M2000 section 3.19, wheelsets, stated in part:

> (e) Overheating
>
> i A wheel must not show signs of having been overheated as evidenced by a reddish brown discoloration, on the face of the rim, i.e., extending on the face more than 100 mm into the plate area measured from the inner edge of the rim;

1.8.8 An examination of the fractured wheel indicated that a reddish brown discolouration had extended to between 40 mm and 50 mm from the inner edge of the rim into the disc. The reach of the discolouration into the disc was within Toll Rail's standards. However, an external rail wheel expert concluded after ultrasonic testing of other flat-plate discs used on the Karioi ZH wagon fleet that the discs were overstressed before the 100 mm heat discolouration limit was reached.

1.8.9 The most recent C-check on wagon ZH1115 was completed at Wellington on 19 June 2004. During the check the float on both bogies was found to be out of tolerance and adjustments made to comply with standards. Other work included the replacement of the leading wheel set on the trailing bogie because of thermal cracking.

1.8.10 The fractured wheel had been re-profiled on 3 separate occasions since entering service in 1999. The initial wheel re-profiling work was carried out on 16 January 2001, for which Toll Rail could not provide any other details. However, on 12 June 2003 all wheelsets on wagon ZH1115 were re-profiled at Wellington depot at which time skids/flats greater than 40 mm were removed from the failed wheelset. On 7 May 2004, the derailed wheelset was again re-profiled to remove thermal cracks and skids on the tread.

1.9 Brake blocks on the Karioi ZH wagon fleet

1.9.1 Up until 25 September 2004, all ZH wagons in the Karioi fleet were fitted with non-asbestos composite brake blocks referred to as Type 4741. These brake blocks had a recommended mating surface that included wheels manufactured to AAR Class C standard. The coefficient of friction for the brake blocks ranged from 0.27 when the train was operating at low speed to about 0.15 when the wagon was travelling at the maximum authorised line speed.

1.9.2 A trial commenced on 25 September 2004, in which the brake blocks on the Karioi ZH fleet were replaced with a type referred to as LT 14. The replacement brake blocks had a lower coefficient of friction than the Type 4741, ranging from 0.20 to 0.11 depending on the operating speed. Toll Rail expected the trial brake blocks to have a longer in-service life without compromising braking efficiency. To date, the trial has confirmed Toll Rail's expectations.

1.9.3 The manufacturer of LT 14 brake blocks advised that the LT 14 blocks could withstand a maximum continuous operating temperature of 275°C and short-term operating temperature of 475°C.

1.10 Examination of the failed wheel

1.10.1 Three pieces of the broken wheel were examined. The 3 pieces consisted of almost equal halves of the rim, labelled A and B, with part of the outer regions of the hub attached, and the hub itself (see Figure 2). Fracturing had occurred across the rim into the hub and circumferentially around the hub.

Figure 2
View of both sides of the fractured wheel

1.10.2 Along the fracture, piece A exhibited a fine, fairly flat crack face, about 30 mm wide with an initiation point at the surface of the tread (see Figure 3). There was a small lip at the tread's surface. The lip was slightly impressed from the surface and appeared to have been a result of mechanical damage.

Figure 3
Fracture face of piece A showing origin of fracture and direction of propagation

1.10.3 A fine crack, labelled Zone 1, penetrated the tread approximately normal to the surface and had a depth of about 12 mm (see Figure 4). Beyond the fine crack there was evidence of coarser cracking with radiating lines orientated normal to the crack front, labelled Zone 2. This extended for about 6 mm. Beyond Zone 2, there was evidence of semi-ductile fracture with deep river lines radiating into the remainder of the rim, labelled Zone 3.

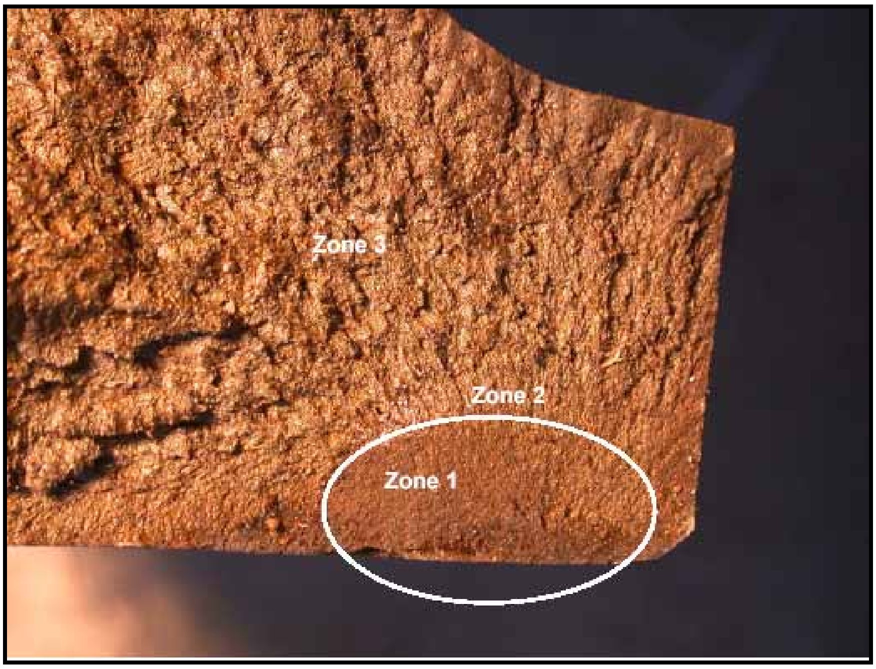

Figure 4
Close-up of crack origin showing the 3 distinct zones

1.10.4 Zone 3 promulgated roughly normal to the surface of the tread and extended into the outer region of the hub where it changed direction and promulgated circumferentially in opposing directions around the hub to give the typical semi-brittle appearance of a sudden fracture in the material (see Figure 5).

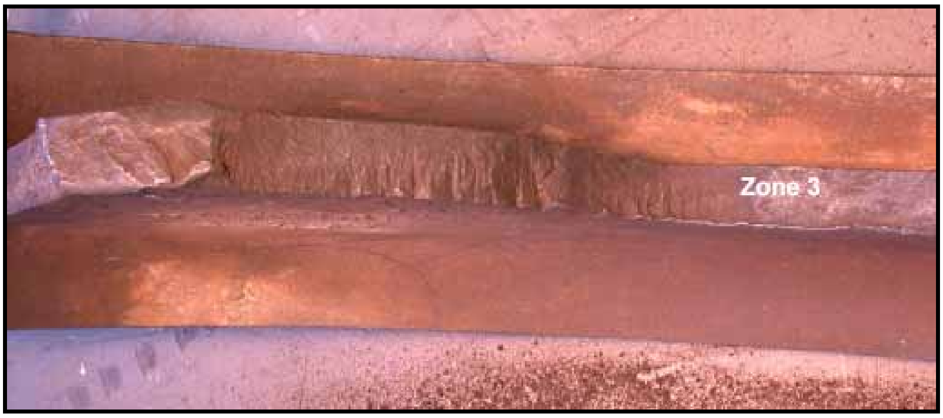

Figure 5
Semi-brittle failure in Zone 3

1.10.5 The hub exhibited a crack through its centre boss. The hub crack met the crack from the rim (see Figure 6).

Figure 6
Crack in hub boss meeting the circumferential crack from the rim

1.10.6 The surface of the tread exhibited small surface cracks. These were generally dispersed and orientated mostly across the tread (see Figure 7). There was evidence of transverse surface cracking near the failure origin. The surface of the tread was shiny, and spalling[5] had occurred, particularly near the radius between the tread and the flange.

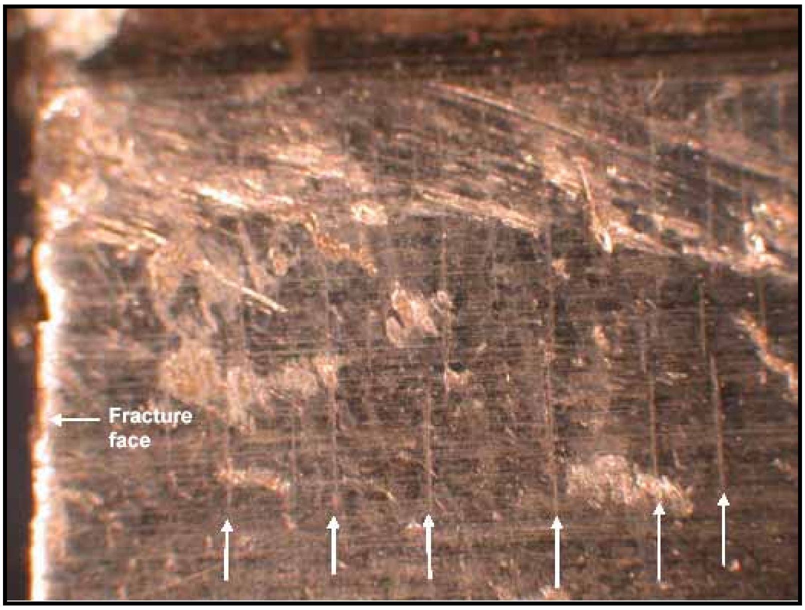

Figure 7
Transverse cracking near the outside of the tread

[5] Spalling is a form of wear. Particles fracture from a surface in the form of metal flakes and are the result of surface fatigue.

1.10.7 A microscopic examination of a cross-section from the rim through the fracture origin, normal to the tread, was made and the following characteristics were observed.

- A significantly modified microstructure about 6 mm extending circumferentially from the fracture origin. The region was about 1.0 mm deep at the fracture and tapered toward the surface 6 mm distant from the fracture.
- There were several zones within the modified region showing progressively finer structures toward the surface.
- There was a small zone of lightly tempered martensite at the surface and tip of the fracture origin.
- The body material exhibited large grains of pearlite and occasional ferrite, indicative of a high-carbon steel consistent with the requirements of AAR M-107-84.
- No significant deformation of material was observed in the region of the crack origin.

1.10.8 A circumferential section was taken through the transverse cracks, shown in Figure 7, away from the fracture origin, to examine for additional evidence of material damage. This revealed the following features.

- Eleven trans-granular cracks extending normally from the surface up to about 0.415 mm into the surface of the tread. The average depth of the cracks was about 0.25 mm.
- A small amount of deformation was observed at the surface of the tread at one of the cracks. However, this was not considered significant.

1.10.9 A piece of the fractured wheel was sent to a laboratory for chemical analysis. The tests confirmed that the material was consistent with the requirements of AAR M-107 -84, Class C.

1.10.10 A section with parallel sides was taken from the rim and hardness tests were conducted in several places. The results showed that the rim was harder than the hub and that the hardness of the rim was generally consistent with that specified for an AAR M-107-84 Class C freight railway wheel with a Brinell hardness (BHN) of between 321 and 363 BHN.

1.11 Other similar incidents, involving ZH wagons from the Karioi fleet, but not investigated by the Commission

Derailment of Train 245, near Feilding, 29 January 2004

1.11.1 On Thursday 29 January 2004, Train 245 was a southbound express freight service travelling from Karioi to Wellington. The train consisted of 2 locomotives hauling 16 ZH class wagons loaded with wood pulp and was crewed by a locomotive engineer.

1.11.2 After departing Karioi and travelling about 17 km, the train was stopped at Waiouru when the locomotive engineer noticed what appeared to be “fire” from under one of the wagons. He inspected the train and bled air from the brake system on the seventh wagon, ZH1236, but did not cut out the brakes on the wagon.

1.11.3 At about 1612, wagon ZH1236, derailed at 152.95 km NIMT near Feilding, about 140 km south of Waiouru, after wheel 3B fractured in a radial direction from the tread to about halfway through the plate, from where the fracture turned 90º and ran circumferentially around the wheel hub, meeting up with the radial crack (see Figure 8). The fracture initiated from an existing crack that occurred during a previous overheat that probably happened days before the event that caused the final failure. The initial crack surface showed little mechanical damage or corrosion, indicating the crack was relatively new.

Figure 8
Outer portion of failed wheel on ZH1236

1.11.4 Maintenance staff attending the derailment noted that all wheels on the ZH wagons were hotter than normal. However, the wheels on ZH1236 were hotter than the wheels on the other wagons.

1.11.5 The failed wheel was a solid wheel of a straight-plate design, manufactured from material to AAR Class C. The wheel was discoloured about 50 mm into the plate from the inner edge of the rim.

1.11.6 The wheel overheat was probably caused by either the brakes being overcharged by the shunt locomotive at Karioi, or by an intermittent fault in the braking system on wagon ZH1236. Given that wheels hotter than normal were reported on all wagons on the train, it was probable that the shunt locomotive caused the overheating.

Derailment of Train 245, near Levin, 23 May 2004

1.11.7 On Sunday 23 May 2004, express freight Train 245 travelling from Karioi to Wellington consisted of 2 DX class locomotives hauling 11 ZH class wagons loaded with wood pulp. At about 1528 the trailing wheelset of the trailing bogie on the rear wagon ZH865 derailed and was dragged about 5 km. The train stopped at 90.32 km NIMT near Levin.

1.11.8 The rim of the wheel had broken into 2 sections and had detached from the hub (see Figure 9). The wheel fracture appeared to have originated from small cracks at the wheel rim, followed by rapid tensile failure. The tread surface had thermal cracks more than 40 mm and numerous rim cracks in the 12 to 14 mm range. Therefore, the wheel exceeded the condition limits at the time of failure. The leading wheelset had significant thermal cracking and a worn flange. The leading bogie was undamaged, but both wheelsets showed signs of overheating with discolouration and blistering of the paint. The discolouration extended about 30 mm into the disc from the rim, somewhat less than the code limit of 100 mm.

1.11.9 The event recorder data was downloaded and no evidence of protracted power braking or heavy breaking was identified. However, the tail end monitor data was not operating for a few days prior to the derailment. The absence of the data prevented the actual pressures at the rear of the train being determined.

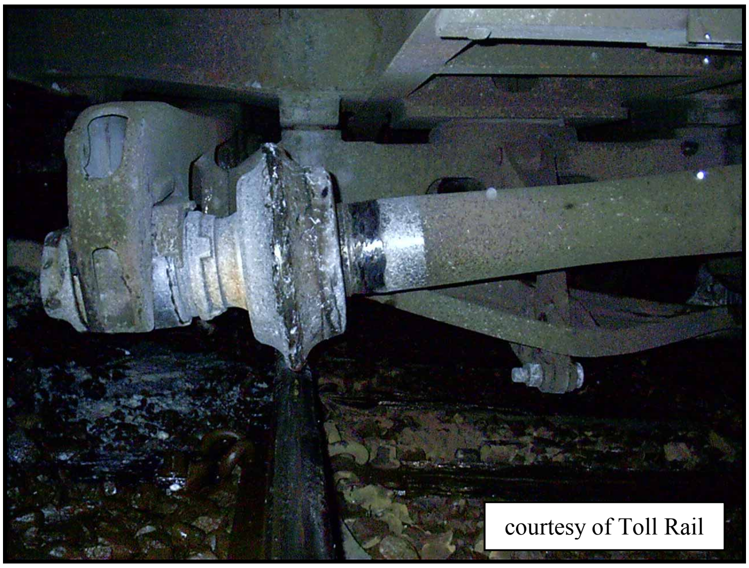

Figure 9
Derailed wheelset on wagon ZH865

1.11.10 A brake system test on ZH865 was carried out 2 days after the derailment. The test revealed that the triple valve was leaking from the vent continuously when the brakes were in the applied position. The triple valve did not respond correctly to the slow release test, occasionally the brakes would release prematurely and on other occasions the brakes would remain applied while a drop in brake pipe pressure was observed when a slow increase would normally be expected. A replacement triple valve was fitted and the wagon brakes re-tested. The replacement triple valve behaved normally.

1.11.11 Two other sources of air leakage were also identified on ZH865:

- missing VTA valve
- split rear hose.

When combined with the faulty triple valve the effect on the brake response would be:

Condition 1 – Starting with brakes released and fully charged.
A leak-induced pressure drop from normal operating pressure of 550 kPa to 410 kPa would have caused a brake application. The brakes would not release again until the train pipe pressure increased beyond 410 kPa (impossible unless the leak was plugged,) or the reservoirs became depleted through leakage. Since the brake pipe pressure could not be raised, the brakes would remain applied.

The triple valve on ZH865 had an internal fault that caused leakage from the train pipe supply when the brakes were applied. This would have dropped the train pipe pressure at the rear of the train even further if the brakes applied in response to a burst hose.

Condition 2 - System fully charged and brakes already applied
The drop in pressure due to the split hose, combined with a further drop as the defective triple valve vented air in the applied condition, would trigger an even greater level of brake application. It would not be possible to release the brakes again unless the reservoir pressure dropped (due to leakage) below that at which the train pipe could be supplied against the leak.

Condition 3 - Brakes fully discharged
The brakes would not fully charge following the start of the leak. However, the brakes would still react normally to changes in train pipe pressure, although the brake force applications would be reduced in proportion to the available pressure.

In all cases the effect of a missing VTA[6] would limit the brake application to that for an empty wagon. This would restrict the brake force on the defective wagon and make the dragging brakes much less obvious to the driver.

1.11.12 The investigation carried out by Toll Rail into the derailment identified that the wheel failure was most likely triggered by the following sequence:

> A sudden drop in pressure due to a rear hose splitting during the journey may have applied the brakes on the trailing wagons. The triple fault on ZH865 on would have resulted in a further apparent pressure drop for ZH865 and the trailing wagons and may have prevented the brakes releasing. The missing VTA would reduce the amount of brake force applied making the problem less noticeable on a loaded train. The drop would not have to be large to trigger a brake application and might not cause a noticeable pressure drop at the front of the train.
>
> The low brake pipe pressure should have been identified from the tail end monitor readout, but it may have been defective and the locomotive logger was not recording the values.
>
> The protracted and unintentional brake application caused the wheel to overheat, the wheel was probably already highly stressed due to previous overheating incidents and with existing cracks in the tread and rim, it failed.
> A lack of lubrication and subsequent seizing of a valve stem caused the leak in the triple valve. The lack of lubrication appeared to be the result of age and wear rather than due to incorrect assembly.

2 Analysis

2.1 The wheel probably failed as a result of a small crack having been present in the hard brittle surface of the tread. The fine region of the fracture in Zone 1 was evidence of quite rapid crack propagation that extended about 12 mm into the rim. The crack in Zone 2 propagated faster and for a shorter time than in Zone 1. The remainder of the fracture, through the rim and hub occurred through semi-ductile overload.

2.2 The wheel exhibited signs of overheating evidenced by the following characteristics.

- The about 6 mm long region of material that exhibited a modified microstructure contained tempered martensite. Martensite is a transformation product that is formed only on cooling from austentite, a high temperature phase that requires a minimum temperature of 725°C. Martensite cannot be formed unless austentite is formed first.
- Reheating to an elevated temperature, possibly in the region of 500 - 600°C, somewhat below the transformation temperature, had occurred subsequent to the formation of martensite as indicated by; the presence of an irregular profile of partially tempered martensite in the tread and the softening of an area to a hardness level below that of the base material.
- The modified region extended to a depth of about 1.0 mm. This indicated that considerable heating had occurred and there was probably a region on the other side of the fracture that contained similarly modified material.

[6] A VTA valve changes the braking ratio for either a loaded or empty wagon.

- The cross-section taken between the fracture origin and the outer edge of the rim exhibited patches of untempered martensite and tempered martensite that together had an uneven contour that sometimes followed the contour of the untempered martensite above them. This indicated that the modified surface was as a result of heating in service and not as a result of the manufacturer's heat treatment.

2.3 According to code AAR M107-84, Class C wheels were to be heat treated by quenching and tempering the rim to impart a compressive stress distribution in the rim and obtain hardness in the range of 321 to 363 BHN. To achieve this, required fairly full tempering of the martensite to a depth of about 3 mm. The maximum depth of tempered martensite found was about 1.0 mm at the fracture origin and the depth was not uniform, indicating that all of the modification to the microstructure had occurred through the exposure to elevated in service temperatures.

2.4 Martensite can form on the surface of the tread during normal operations. This material usually spalled off in service and would not present any problems unless the spalling exceeded code limits. Occasionally a fatigue crack can propagate into the rim and lead to failure. Although there was no obvious cause of the crack that lead to failure, the presence of other cracks near to the failure origin and others up to 0.415 mm long indicated that it was very likely that a crack of similar magnitude may have been present at the origin of the fracture.

2.5 A single cause for the in-service overheating of the rim and wheel disc failure could not be established. However, it was likely to be from one, or a combination of, the following reasons:

- the loaded pulp train from Karioi to Wellington was a relatively short but heavy unit train and as a consequence the wagons can be subjected to frequent heavy braking
- the use of a flat-plate disc on the dedicated Karioi ZH wagon fleet
- the code discolouration standard used to indicate when a disc should be withdrawn from service.

2.6 Driving the Karioi to Wellington pulp train presented special challenges to a locomotive engineer. The need for late, heavy braking could be avoided provided a locomotive engineer planned his train handling and set up the train for a speed reduction earlier than he would when driving a mixed freight train over the same route. The outcome from judicious route planning would be the elimination of the need for late braking, resulting in a reduced rim temperature and ultimately less stress being imparted into the disc.

2.7 Because of the differences in design, manufacture and composition between BS468 and AAR standards, it was difficult to compare performance of the respective wheel discs. Accordingly, it was not possible to determine if such a failure would have occurred had either a more tolerant material grade, say AAR Class B or an S-plate disc been used (see Figure 10). However, Toll Rail had no record of a similar failure occurring on an S-plate disc. Because of the action already taken by Toll Rail to replace the flat-plate disc with a stress-resistant S-plate disc, no safety recommendation has been made to address this issue.

2.8 Although overheating of the wheel on wagon ZH1115 led to its failure inside Tunnel 1 and similar earlier wheel failures that caused derailments to the pulp train at Feilding and Levin, in all 3 derailments the extent of wheel discolouring was within the code specification of 100 mm. Because of the safety action taken by Toll Rail to reduce the 100 mm discolouration threshold to 30 mm before the wheel would be withdrawn from service, no safety recommendation has been made to address this issue.

2.9 The crack that initiated the wheel failure was likely to have been present before the train departed Wellington Yard. Although the pre-departure inspection of Train 244 was carried out in compliance with Toll Rail procedures, the person carrying out the inspection was not required to, nor would have been able to, identify the crack on the wheel tread.

2.10 The maintenance inspections on ZH1115 were current, with the most recent B-Check being carried out 24 days before the incident. Although it was not possible to determine when the small initiation crack developed, it was unlikely that such a defect would have been detected during the recent B-Checks carried out at Karioi.

2.11 The derailment occurred within about 5 minutes of the train departing Wellington Freight Yard. Because the train was climbing a gradient during that time, it would still have been accelerating and not reached its maximum operating speed. There were no speed-restricted curves before the train reached the POD that would have required the locomotive engineer to make a brake application and reduce train speed. Therefore, it was unlikely that the locomotive engineer's train handling contributed to the overheating of the rim that eventually caused wagon ZH1115 to derail. The crack that caused the wheel to fail would have been present before the train departed Wellington.

2.12 Low friction LT14 type brake blocks had been under trial on the dedicated Karioi ZH wagons for a few weeks before the derailment occurred. These low friction brake blocks were introduced primarily to reduce the incidence of skids and flats on the wheel tread. However, one of the consequences of using these brake blocks on the short, heavy train was that the train brakes had to be applied earlier, and for a longer period, in order to slow the train sufficiently to negotiate speed-restricted track sections. Therefore, it was probable that the tread on the flat-plate disc was, over numerous brake applications, subjected to temperatures that ultimately resulted in the formation of the surface cracks that finally caused the wheel to fracture.

2.13 Analysis of the event recorder data indicated that the train was travelling at about 70 km/h, or 10 km/h less than the maximum authorised speed, when wagon ZH1115 derailed at 4.458 km NIMT, about midway through Tunnel 1. The derailed wagon travelled a further 4.176 km before the train stopped.

2.14 Train 244 was travelling in Notch 6 for about a minute before reaching the POD. During that time the train slowly accelerated from about 55 km/h to 70 km/h. The locomotive engineer's assumption that the slight surge he felt after entering Tunnel 1 was due to an incorrectly set-up trail locomotive was not unreasonable. He acted appropriately by looking back along the train after feeling a second surge then stopping the train.

2.15 The track geometry at the POD was within maintenance tolerances and did not contribute to the derailment.

3 Findings

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

3.1 Wagon ZH1115 derailed inside Tunnel 1 as a result of a fractured wheel.

3.2 The material properties of the failed wheel were consistent with the requirements of AAR M-107-84, Class C.

3.3 The failed wheel showed signs of having been overheated to a temperature in excess of 725ºC.

3.4 The discolouration as a result of overheating of the fractured wheel was less than the 100 mm limit, indicating that 100 mm was an excessive tolerance for straight-plate discs for determining that wheels should not run in service.

3.5 The flat-plate wheel discs were less resistant to fatigue cracking than "S" plate discs with a wider tread.

3.6 The wheel probably failed as a result of a small crack in the surface of the tread initiating the full cracking and fracture.

3.7 The maintenance inspections on ZH1115 were current.

3.8 The actions of the locomotive engineer did not contribute to the derailment.

3.9 The track at the point of derailment was within maintenance tolerances and did not contribute to the derailment.

4 Safety Actions

4.1 On 18 July 2005, Toll Rail advised, in part, that the following actions had been taken or were in progress.

Design/Code Changes:

- An external rail wheel expert from Monash University has been on site reviewing the wheel overheating standards and has made recommendations to help identify wagons at risk so that corrective action can be taken.
- The overheat limit for wagon wheel discolouring has been reduced from 100 mm to 30 mm.
- All new Type 14 and Type 18 wheels require an improved crack resistant design "S" plate disc and wider rim.
- All ZH wagons in the Karioi traffic have had their flat-plate disc wheels replaced.
- All Karioi ZH wagon wheels and new wheels are being painted with temperature sensitive paint.
- The air brake triple valve overhaul period has been reduced from "on failure" to a phased 14-year overhaul.
- The standard LT22 and prototype LT14 brake blocks are being evaluated to identify if there are any issues likely to cause excessive heat in instances of over braking or over charging.
- Introducing load cells to check actual brake forces.
- Wheel lathe operator instructions are being upgraded. This will be supported with operator training.

Audit:

- The Karioi shunting locomotive brake system has been inspected. A fault that could result in over-charging was found and is being overhauled.
- The train inspection process at Karioi was reviewed – operating personnel were acquainted with the need to specially focus on wheel condition and brake performance.
- All ZH wagons in the Karioi circuit have been inspected and had wheels checked for cracks using the magnetic particle inspection process. Suspect wheels have been removed. Only wheels verified with ultrasonic stress measurement have been retained in service.

- Braking tests performed on ZH wagons involved in incidents or found to have overheated wheels, have not pointed to consistent faults that are directly linked to wheel failure.
- All ZH wagons in the Karioi traffic are having special monthly wheel inspections to evaluate the impact of changed parameters.

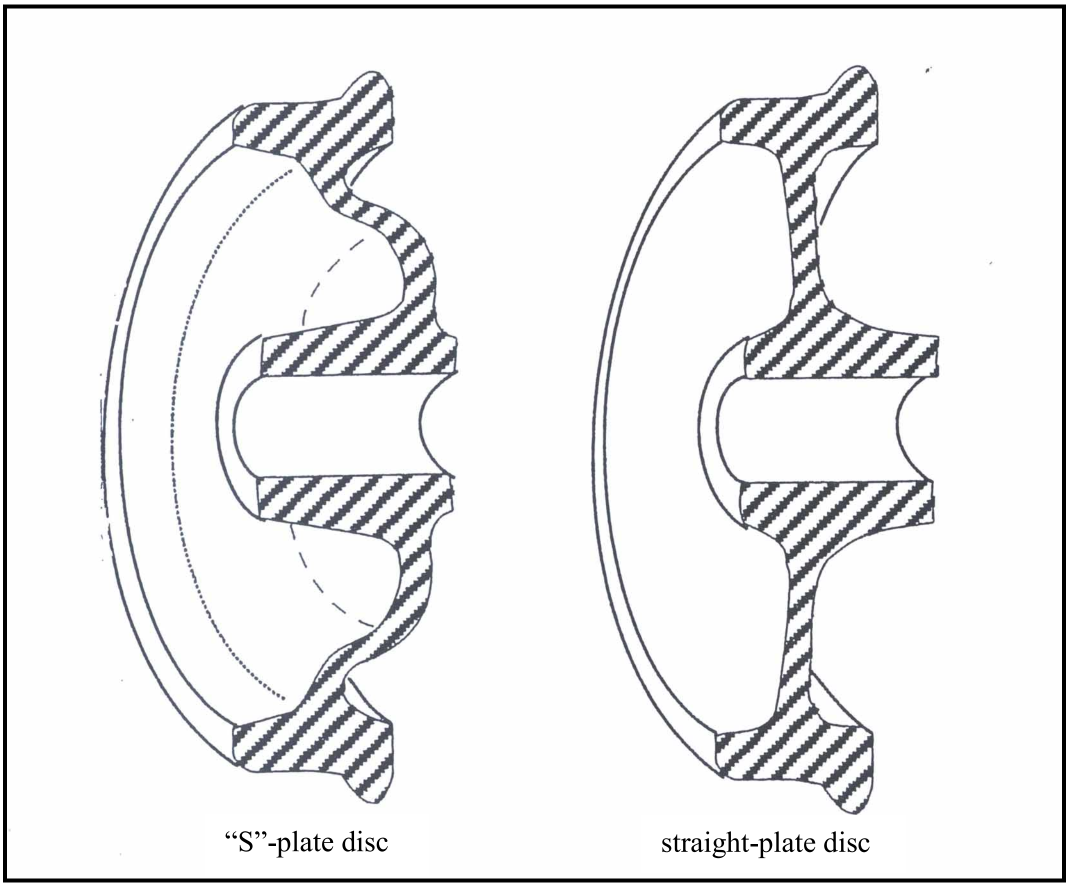

Figure 10
Wheel types

5 Safety Recommendations

5.1 In view of the safety actions taken by Toll NZ Consolidated Limited, no safety recommendations have been made.

Approved on 27 October 2005 for Publication

Hon W P Jeffries
Chief Commissioner

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