Report 01-107

passenger express Train 201

derailment

Otaihanga (near Paraparaumu)

6 June 2001

Abstract

On Wednesday, 6 June 2001, at about 1841, express passenger Train 201 *Overlander* derailed when a wheel on the leading axle of the trailing bogie of the power van fractured as the train approached Otaihanga Road level crossing near Paraparaumu on the North Island Main Trunk. There were no injuries to train crew or passengers and damage was limited to the trailing bogie of the power van.

The safety issue identified was the suitability of the wheel set for use in passenger rolling stock.

As a result of the actions taken by the operator following this incident, no safety recommendations are included in this report.

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Abbreviations

AAR	Association of American Railroads
BS468	British Standard 468
cwr	continuous welded rail
kg/m	kilograms per metre
km	kilometre(s)
km/h	kilometres per hour
LE	locomotive engineer
m	metre(s)
Tranz Rail	Tranz Rail Limited
TC	train controller

Data Summary

Train type and number:	passenger express Train 201	
Date and time:	6 June 2001 at about 1841	
Location:	Otaihanga (near Paraparaumu)	
Persons on board:	crew:	3
	passengers:	70
Injuries:	crew:	nil
	passengers:	nil
Damage:	broken wheel on power van	
Operator:	Tranz Rail Limited (Tranz Rail)	
Investigator-in-charge	D L Bevin	

1. Factual Information

1.1 Narrative

1.1.1 On Wednesday, 6 June 2001, Train 201 was the Auckland to Wellington *Overlander* passenger express and consisted of locomotive DX5022, one power van marshalled behind the locomotive and 3 passenger cars. The train was crewed by a locomotive engineer (LE), a train manager and a train assistant, and conveyed 70 passengers.

1.1.2 Shortly after Train 201 had departed from Palmerston North the LE had made several attempts to contact the train manager by radio to discuss passenger work enroute, but had been unsuccessful. He remembered making a brake application before negotiating a 75 km/h restricted curve near Longburn but could not remember making any more applications after that. The LE thought he would probably have had the locomotive in notch 5 or 6 to keep the train speed up as he travelled towards Shannon. At about 1739 he became aware that the brakes were applied when the train speed began to drop in terrain where the speed should have been maintained by the throttle settings he was using.

1.1.3 At about 1740, Train 201 passed through Shannon and shortly after, the LE received a radio call from the train controller (TC) who advised him that a member of the public had reported seeing “some sparks or a glow” from a wheel set on the left-hand side of the train as it had passed through Shannon. The LE advised the TC that he would stop the train and check the wheels at Levin, which was the next scheduled passenger stop, a few minutes away.

1.1.4 On arrival at Levin at about 1751, the LE checked the wheels on the left hand side of the train in the direction of travel but could not find any evidence of overheating. He didn’t touch the wheels but put his hand close to them and said “the wheels were warm but not burning”. He also kicked the brake blocks to ensure that they were free of the wheels and all moved freely before he returned to his locomotive cab and advised the TC that “all the brakes on the carriages were released, the guard’s vans (power van) were released but they were a bit hot like they’d stuck on when I made an application. I’m not too sure but they’ve released anyway, but they are a bit warm....” After departing Levin he regularly checked both sides of the train by looking back but did not see any evidence of sparks or a glowing wheel.

1.1.5 At about 1841, as Train 201 passed over Otaihanga Road level crossing near Paraparaumu, the LE responded to a “a big gush of air” from the brake valve in the locomotive which signified a burst air hose. He immediately looked behind him and saw sparks coming from the right-hand side of his train. He called the TC by radio and advised him that it looked as though the train had derailed.

1.1.6 The train came to a stop about 309 m south of the Otaihanga Road level crossing. The LE went back to see what had happened and found that both axles of the trailing bogie of power van AG147 had derailed. The power van had remained upright. The locomotive and three passenger cars were still on the track and there were no injuries to passengers or crew. The LE thought he was travelling about 95 km/h at the time of the derailment.

1.2 Personnel

1.2.1 The LE was a certified grade 1 LE and had about 30 years experience driving trains. In the two weeks leading up to the incident the LE had worked 10 shifts. There was nothing excessive in the hours worked during that time.

1.2.2 The LE said that significant events in his personal life were concerning him at the time.

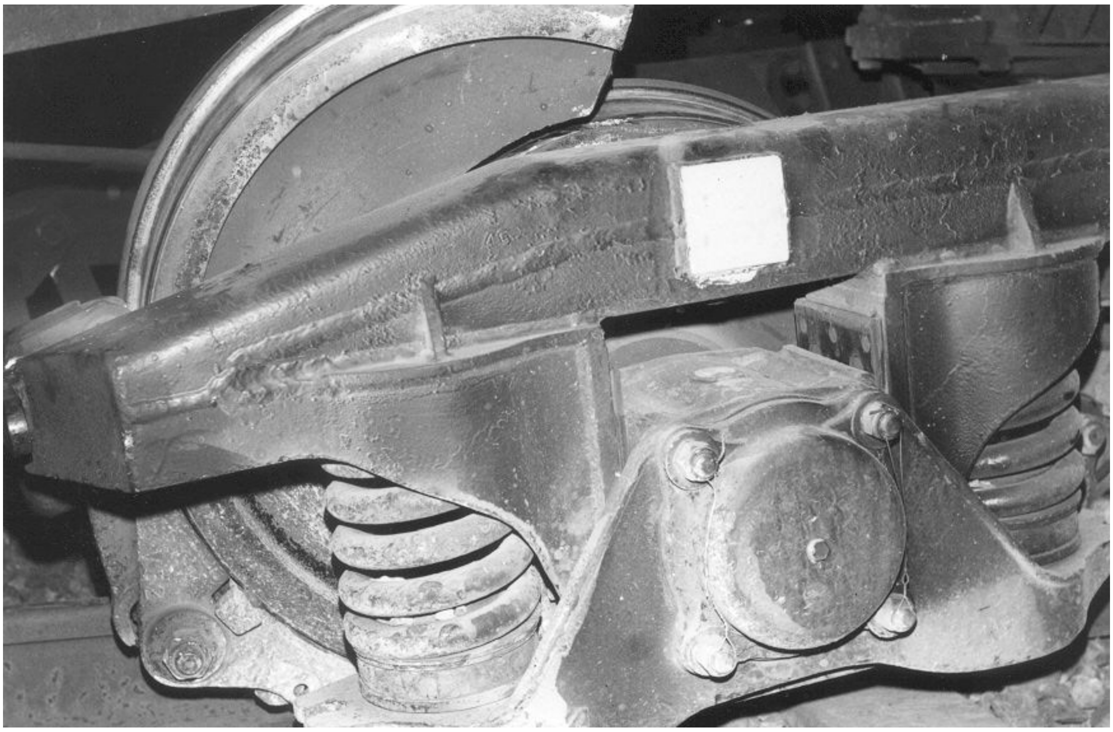

Figure 1
The fractured wheel lodged between the brake block and bogie side frame (photograph courtesy of Tranz Rail).

1.3 Locomotive controls, instruments and performance

1.3.1 The LE thought the DX class locomotive was normally slow to respond to throttle changes at the best of times owing to the power configuration, so the effect on train performance resulting from an extended brake application of 50 kPa on a light passenger train would probably not be noticed. These comments were supported by other locomotive engineers.

1.3.2 The locomotive speedometer was located in a position independent of the main instrument panel. The light was defective, and the LE had to rely on a small spotlight in the cab directed at the speedometer to enable him to read it. This light was distracting in the otherwise darkened cab, and it required a concentrated effort on his part to read the speedometer.

1.4 The locomotive event recorder

1.4.1 Data from the locomotive event recorder was downloaded and supplied for analysis. This established that Train 201 was travelling at about 80 km/h at the time of the derailment. The maximum authorised line speed for the train in that area was 100 km/h.

1.4.2 The data confirmed the LE's thought that he had made a brake application about 5 minutes after departing from Palmerston North. This brake application reduced the train speed from about 92 km/h to about 67 km/h in preparation for the 75 km/h speed curve and once the train had negotiated the curve the LE had increased speed again but had not released the brakes. The locomotive event recorder data showed that the brakes were not released for a further 19 minutes.

Analysis 1

1. Once the train had negotiated the curve for which the LE had made the initial brake application he applied power to increase speed but did not release the brakes. As he throttled up the usual slow response time of the DX class locomotive probably absorbed any additional effect of the brake application on the performance of the light train and would therefore not have alerted the LE to the situation.

2. Having a low-powered spotlight shining onto the speedometer to assist the LE to see what the train speed was would not only have been a distraction but would have made the train's relatively low speed for the selected notch settings less obvious.

3. The LE had both work and personal matters on his mind at the time, and these probably contributed to his forgetting to release the brakes after rounding the 75 km/h curve.

1.5 Site information

1.5.1 Otaihanga Road level crossing was situated at 51.61 km, between Waikanae and Paraparaumu, and about 150 m south of a left-hand curve in the direction of travel of Train 201. The approach from the north was on continuous welded rail (cwr). This was designed to be continuous over the level crossing and included 2 insulated joints which formed part of the cwr (joints 2(a) and 2(b) on Figure 2). The track structure approaching the level crossing was 50 kg/m rail on concrete sleepers except for 3 timber sleepers under joints 2(a) and 2(b).

1.5.2 Joint 2(b) had been renewed during 2000 and as a temporary measure the 11 m long pre-built insulated joint had been installed with temporary bolted joints (joint 1 and joint 3) awaiting thermit welding to restore the cwr. Welding had not been carried out at the time of the derailment.

1.5.3 The condition of the 4 joints in the vicinity of the point of derailment were:

- joint 1 — Joint tight with 9 mm gap. Vertical movement of 10 mm under load
- joint 2(a) — Joint bond broken with a 14 mm gap. No vertical movement under load
- joint 2(b) — Good condition, fully bonded. No vertical movement under load.
- joint 3 — Joint tight with 15 mm gap. Vertical movement of 25 mm under load with signs of mud pumping.

1.5.4 The first evidence of the derailment were the marks of the derailed wheel inside the right-hand rail in the direction of travel on the first sleeper past insulated joint 2(a). This established the point of derailment at 51.62 km.

1.5.5 The northern edge of the bitumen seal on the Otaihanga Road level crossing (refer Figure 3) showed evidence of having been hit by both the fractured left-hand wheel (wheel 1) and the derailed right-hand wheel (wheel 2) but there were no further marks from these 2 wheels on the level crossing surface beyond the immediate point of impact.

1.5.6 About 5 m past the northern edge of the bitumen were two deep narrow gouge marks which ran to the south edge of the level crossing bitumen (refer Figure 3). These marks were made by the flanges of wheels 3 and 4 on the second axle, which had also subsequently derailed. These flange marks continued on damaged sleepers for about another 300 m south to where the train eventually stopped.

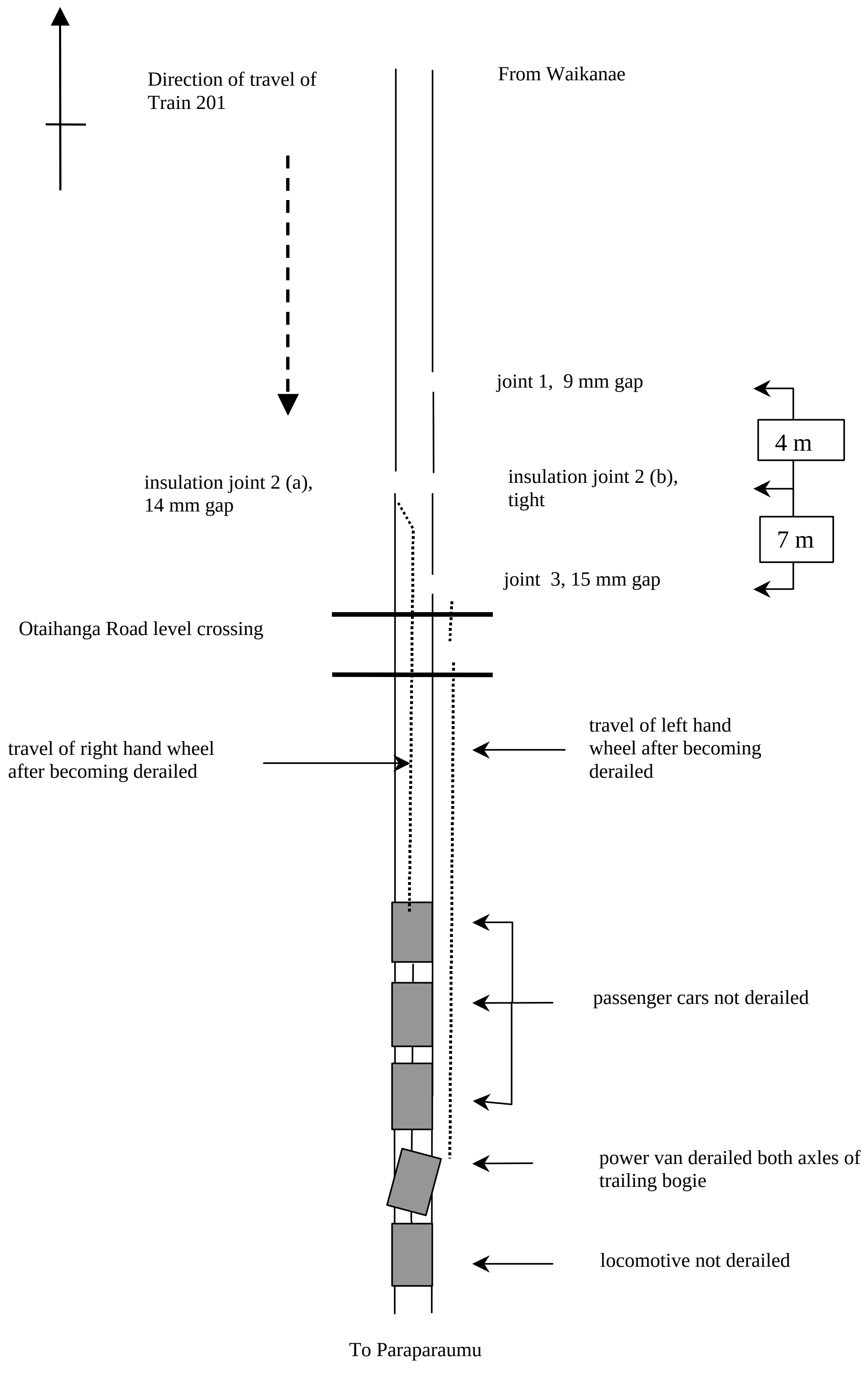

Figure 2
Derailment site plan (not to scale)

Figure 3
The northern edge of Otaihanga Road level crossing

1.5.7 When wheel 1 fractured, the broken-off section lodged between the brake block at the front of the bogie and the bogie side frame (refer Figure 1) and prevented the axle and wheel 2 from turning. After wheel 2 had derailed, it skidded along the sleepers and ballast for about 10 m before it hit the northern edge of the level crossing bitumen after which it continued to skid for another 300 m along sleepers and ballast south of the level crossing until the train stopped. The portion of the flange and wheel surface of wheel 2 making contact with the ground was worn almost flat. There was no evidence on the rail surface to suggest it had been skidding prior to the point of derailment.

Analysis 2

1. Wheel 1 probably fractured a short distance before the point of derailment, allowing wheel 2 to derail almost immediately. With wheel 1 jammed and probably making little contact, if any, with the rail surface, wheel 2 on this axle supported most of the weight. The marks in the bitumen at the northern edge of the level crossing showed that wheel 2 hit the surface with a greater impact than wheel 1 (refer Figure 3), suggesting that wheel 1 may almost have been "floating" at that time.

2. The impact of wheels 1 and 2 with the northern edge of the level crossing probably caused them to bounce up under the power van as there were no further marks of contact between these wheels and the sealed surface of the level crossing. The force of the impact probably derailed wheels 3 and 4 as there were no marks in the northern edge of the bitumen from these wheels. The clean cuts near the south edge of the bitumen suggested that these wheels had made contact with the surface almost immediately after the impact and while they were travelling over the level crossing.

1.6 Design specifications for passenger car bogie wheel sets

1.6.1 The wheel involved in this incident was supplied in accordance with the specifications defined in Clause 1.4 of Association of American Railroads (AAR) M-107-84 (the manual), which stated that:

> For passenger car service the various classes are intended generally as follows:
>
> Class L - High speed service with more severe braking conditions than other classes and light wheel loads
>
> Class A - High speed service with severe braking conditions, but with moderate wheel loads
>
> Class B - High speed service with severe braking conditions and high wheel load.
>
> Class C - (1) Service with light braking conditions and high wheel loads. (2) service with heavier braking conditions where off-tread brakes are employed.

1.6.2. Clause 1.4 of AAR M-107-84 listed the types of wheels to be used for passenger rolling stock but did not define what was considered light or heavy braking. There were no criteria to restrict either Class B or Class C wheels to be used for locomotive-hauled passenger rolling stock.

1.6.3 Tranz Rail considered that as M-107-84 of the manual was an American standard, terms such as "light braking" and "high wheel loads" needed to be interpreted in light of American practice and, because of variables such as stopping distance, wheel diameter and train handling, it could be misleading to directly associate New Zealand usage of Class C wheels with either option under Clause 1.4.

1.6.4 Approximately 4 years ago Tranz Rail adopted AAR material grades for solid disc wheels in place of wheel discs to BS468 Class E standard. 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.

1.6.5 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 BS468 and while present they effectively prevented the formation of thermal cracking. Class C wheels had a higher carbon content than BS468, and this made them slightly less fracture resistant once the compressive stresses were reduced through normal use. 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.

1.6.6 Bogies with curved plate wheel discs and to Tranz Rail design drawing X28020 were used under locomotive-hauled passenger rolling stock. Class B wheel discs were normally used for this type of bogie but Type 14[1] Class C wheel discs had been used in the past and were used on this occasion because Class B wheel discs were not in stock.

1.6.7 The temporary use of Type 14 straight plate wheel discs under locomotive-hauled passenger cars was formally approved prior to their use in this plate wheel discs on locomotive-hauled passenger rolling stock. The key differences between the normal passenger disc and the Type 14 disc were the material type and plate shape.

1.6.8 The Class C wheel set involved in the incident had been installed in power van AG147 in March 2001.

[1] Type 14 wheel discs were straight plate design of AAR Class C steel standard, previously manufactured to BS468 Class E standard, and were the most common wheel disc in use.

1.7 Examination of the failed wheel

1.7.1 A section of the wheel rim and disk web had separated from the remainder of the wheel, which was still attached to the axle. Examination of the initiation region of the fracture surface revealed that 5 different pre-existing cracks were present (refer Figure 4).

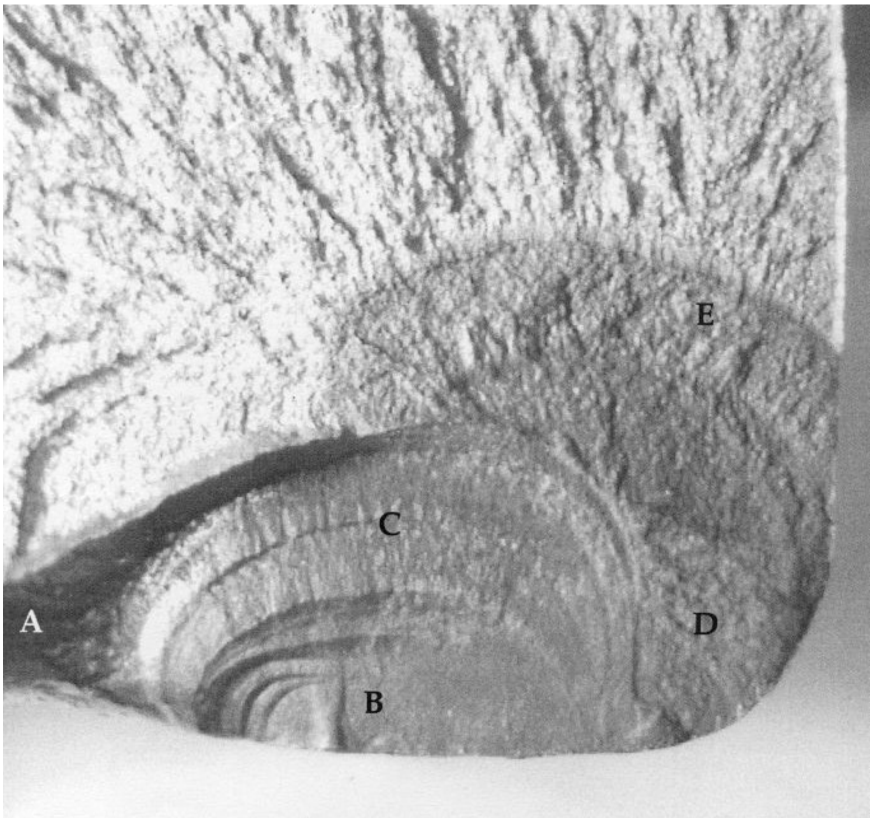

Figure 4
The surface of the fractured wheel showing the 5 cracks

These cracks were:

- Crack A consisting of a group of cracks which ran across the mid-section of the rim-bearing face
- Crack B consisting of 2 cracks that initiated on the surface of the rim-bearing face.
- Crack C was a single arced crack that grew from crack B
- Cracks D and E ran from the edge of crack C nearest to the front of the rim.

1.7.2 Thermal crack initiation can be associated with power braking, a normal braking procedure where the locomotive throttle is left open while the brake is applied. The purpose of this procedure is to bring the train to a smooth stop by keeping the couplings between the passenger cars taut as the train slows and stops.

1.7.3 Two micro-structural bands were visible in the fractured wheel. These were the result of the fractured wheel having twice been overheated to a temperature in excess of the transition "austenising"[2] temperature for the steel, followed by relatively slow cooling taking place.

1.7.4 The fractured wheel was sent to a laboratory for testing and analysis. Those tests confirmed that its construction met the AAR standards for a Class C wheel.

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[2] The heat treatment of steels to form Austenite (a face centred cubic crystal structure) from ferrite (a body-centred cubic crystal structure). Austenite is produced in carbon steels at temperatures above 723 degrees Celsius.

1.7.5 Hardness testing was carried out on the adjacent bogie wheels and indicated that all had been overheated at least once and showed minor cracking damage.

1.8 Post-incident wheel set inspection

1.8.1 Following the derailment the wheels on all locomotive-hauled passenger cars were examined by Tranz Rail and surface cracking was found in some wheels. The result of the examinations was:

	Passenger Cars	AG Vans
Total number of wheel sets examined	268	68
Number of Class C wheel sets	19	14
The number of Class C wheel sets found showing crack initiation similar to cracks A and B	15	12

Of the 336 wheel sets in service in the locomotive-hauled passenger rolling stock fleet 33 (10%) were of the Class C type and of that number 27 (82%) showed signs of crack initiation.

1.9 Previous overheating of power van AG147 wheels

1.9.1 On 10 September 2001, Tranz Rail advised:

> Van AG147 derailed at Otaihanga on 6 June 2001 as a result of a broken wheel. Tranz Rail has discovered that the van may have had hot wheels on one bogie on 12 May 2001 while on the southbound Northerner (Train number 20311).
>
> During a locomotive change at Palmerston North the van was noticed to have hot wheels on one bogie. Both the Locomotive Engineer and Train Examiner are emphatic that it was only the bogie closest to the locomotive that was hot - the other (which had the broken wheel in June) was not. The Train Examiner also recalls that the other carriages were in a normal condition.
>
> Bogie brake rigging was checked after the June incident and nothing untoward was found. As a result of the May occurrence information a triple valve change has been ordered for the van as a precaution.

1.9.2 Discussions with the LE of Train 203 from Palmerston North on 12 May confirmed that the wheels affected by overheating on that day were on the leading bogie of AG147 and that the brakes were cut out prior to departure from Palmerston North. The wheels were checked regularly enroute to Wellington, but no further overheating was experienced.

Analysis 3

1. Type 14 Class C wheel discs had been used previously on locomotive-hauled passenger rolling stock when Class B wheel discs were not available. No problems had been experienced during those times, and the use of a Type 14 wheel disc in this instance was based on past experience.

2. Tranz Rail interpreted the AAR Class C intended general use "service with light braking conditions and high wheel loads" as not unacceptable for use on New Zealand locomotive-hauled passenger rolling stock. This was not unreasonable, given the differences between USA and New Zealand systems. However, this incident and the post-incident inspection programme had revealed Class C straight plate wheel discs were not suitable for New Zealand conditions, and their use on locomotive-hauled passenger rolling stock has been discontinued.

3. During the post-incident inspection, cracks were found in other Class C straight plate wheel discs on locomotive-hauled rolling stock which were consistent with Crack A and were probably the result of normal passenger speeds and braking patterns.

4. Cracks B and C were typical of fatigue cracks and were possibly caused by thermal fatigue as a result of power braking. None of the other Class C wheels were cut open to see if similar fatigue cracks were also present in them, but Tranz Rail issued a special bulletin following the derailment (refer Safety Action 4.1) which prohibited the use of power braking above a notch 2 throttle setting on passenger trains.

5. Crack D occurred as a result of overload, possibly due to the overheating at Palmerston North on 12 May 2001, one month earlier. Tranz Rail staff were adamant that the fractured wheel was not involved, but that incident would have provided an opportunity for overload through overheating. However, it was not possible to confirm this because of the time between that reporting and the subsequent derailment of AG147.

6. Crack E probably occurred as a result of the heating and cooling of the wheel when the brakes were applied for about 19 minutes as Train 201 travelled between Palmerston North and Shannon and later cooled between Shannon and Levin. Overload would have occurred when the wheel cooled down and the surface went into tension. The tensile loading due to the thermal stress would have been in addition to the normal operating stresses.

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 curved plate disc or a more tolerant material grade (eg BS468 Class E or AAR Class B) been used. Tranz Rail's records did not contain evidence of any similar high speed incidents with locomotive-hauled passenger rolling stock.

8. Track condition at the point of derailment was below desirable standards. The temporary joints had been in the track for about one year without welding, and without being placed under speed restriction. Despite the adverse effect this had on cwr stability, and the joint deterioration with concrete sleeper support leading to vertical movement of the track, the track condition was not a major factor in the derailment.

9. The stresses that the wheel had already been subjected to meant it was probably only a matter of time before it fractured with the ongoing stresses of normal wear and tear.

2. Findings

2.1 Power car AG147 derailed at Otaihanga as a result of a fractured Class C wheel.

2.2 The wheel fractured because of the presence of thermal stress cracks, which were probably caused by earlier major overheating incidents. It finally failed after it was again overheated and cooled down enough to produce a high tensile stress in the rim. This stress combined with normal operating stresses and caused the overload from a pre-existing crack.

2.3 The final overheating of the wheel resulted from a prolonged brake application between Longburn and Shannon.

2.4 Class C wheels were not robust enough in design to have been used on locomotive-hauled passenger cars in New Zealand.

2.5 The poor track condition noted at the point of derailment did not cause the derailment, but may have been the final catalyst to initiate total failure of the wheel.

2.6 The reason for the prolonged brake application between Longburn and Shannon was not clear, but may have resulted from the LE being preoccupied with work-related and personal matters and the difficulties caused by the absence of a light in the speedometer.

3. Safety Actions

3.1 On 8 June 2001, Tranz Rail issued Special Bulletin 488, which stated that:

> **PASSENGER TRAINS**
>
> While investigations continue into a derailment on Wednesday 6 June 2001, the following restriction will apply to Locomotive hauled passenger trains. When Power braking (braking against an open throttle) is not to be used above **Notch 2**.

3.2 On 12 June 2001, Tranz Rail advised that:

> All locomotive hauled cars have been examined for signs of cracking and crack initiation was found in some wheels. Both these wheels and those on the derailed AG147 relate to a batch of wheel sets (Class C) produced during 2000, using standard type 14 wheel discs... Steps have been taken immediately to individually manage each affected vehicle.

3.3 On 9 July 2001, Tranz Rail advised that:

> Specific steps taken to "individually manage each vehicle" concerned making arrangements for the inspection and subsequent operation of each vehicle, depending on its location at the time.

3.4 On 14 January 2002, Tranz Rail advised all Type 14 straight plate wheel discs to AAR Class C standard on locomotive-hauled passenger rolling stock were replaced with curved plate wheel discs to AAR Class B standard following this incident. Tranz Rail introduced a policy prohibiting the use of AAR Class C straight plate wheel discs on locomotive-hauled passenger rolling stock in the future.

Approved for publication 05 June 2002

Hon. W P Jeffries
Chief Commissioner