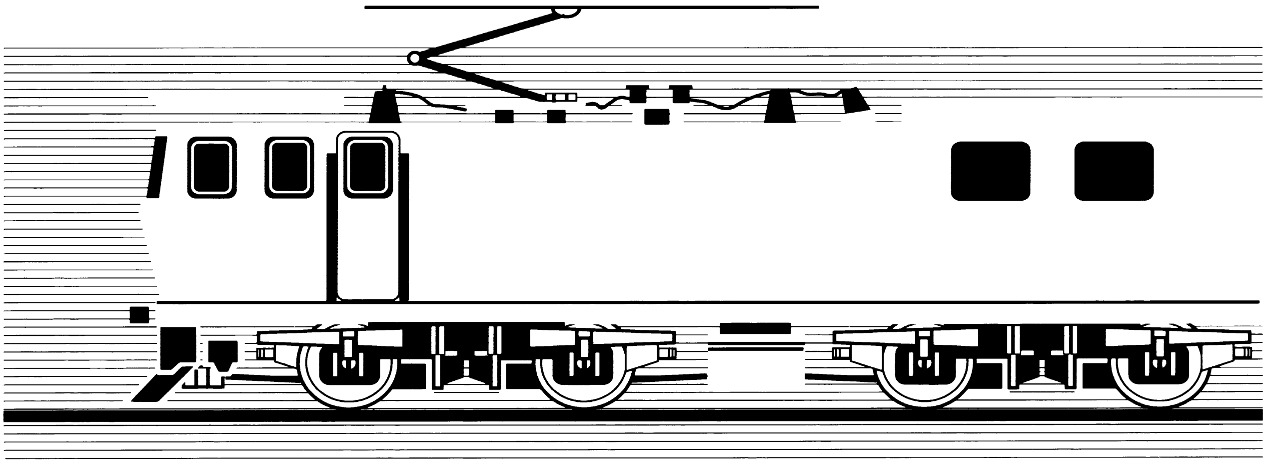
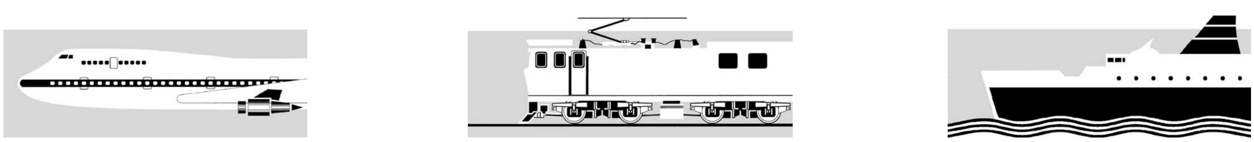


R A I L W A Y   O C C U R R E N C E   R E P O R T

03-109 **diesel multiple unit passenger Train 3347, driveshaft failure, Meadowbank** **27 June 2003**



TRANSPORT ACCIDENT INVESTIGATION COMMISSION

NEW ZEALAND

Report 03-109

diesel multiple unit passenger Train 3347

driveshaft failure

Meadowbank

27 June 2003

Abstract

On Friday 27 June 2003, Tranz Metro Train 3347 was an Auckland to Papakura diesel multiple unit passenger train. At about 0915, a driveshaft on passenger car ADL 810 failed as the train approached Purewa Tunnel, between Meadowbank and Glen Innes stations. The DMU driver stopped the train about 200 m short of the tunnel.

The free end of the failed driveshaft was not sufficiently restrained and it punctured the floor of the passenger compartment.

The 3 passengers travelling in ADL 810 were not injured.

The safety issues identified included:

- recording and tracking of the maintenance and service history of individual DMU driveshafts
- installation and maintenance standards for driveshafts
- inspection procedures and criteria for acceptance or rejection of individual driveshafts
- design of the safety stirrup to contain the driveshaft in the event of a failure.

Four safety recommendations were made to the Chief Executive of Toll NZ Consolidated Limited to address these issues.

Contents

Figures

Abbreviations

AC	alternating current
DMU	diesel multiple unit
Hz	hertz
km/h	kilometres per hour
kW	kilowatt
m	metre(s)
NIMT	North Island Main Trunk
rpm	revolutions per minute
Toll NZ	Toll NZ Consolidated Limited[1]
Tranz Rail	Tranz Rail Limited
UTC	co-ordinated universal time

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

Data Summary

Train type and number:	diesel multiple unit passenger Train 3347
Year of manufacture:	1985
Date and time:	27 June 2003 at about 0915[2]
Location:	Meadowbank
Persons on board:	crew: 2 passengers: 4
Injuries:	crew: nil passengers: nil
Damage:	driveshaft failure and subsequent damage to piping and floor of passenger car ADL 810
Operator:	Tranz Rail Limited (Tranz Rail)
Investigator-in-charge:	P G Miskell

[2] 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 27 June 2003, Train 3347 was a Tranz Metro[3] diesel multiple unit (DMU) passenger service from Auckland to Papakura. The service was crewed by a DMU driver and a train manager.

1.1.2 Train 3347 consisted of powered passenger car ADL 810 leading, and non-powered passenger car ADC 860 trailing.

1.1.3 The train departed from Auckland with 5 passengers on board. The train manager checked the passengers' tickets soon after departure, then moved to the front of the train and sat near the DMU driver. One passenger alighted from the train at Orakei leaving 3 passengers seated in the leading car and one in the trailing car.

1.1.4 At about 0915, while travelling at about 75 km/h and about 400 m from Purewa Tunnel, between Meadowbank and Glen Innes on the North Island Main Trunk (NIMT), the DMU driver heard a loud bang and saw the transmission engage light illuminate momentarily on the cab display panel. He suspected a broken driveshaft and immediately applied the brakes, stopping the train about 200 m short of the tunnel.

1.1.5 The DMU driver shut down both engines before alighting to assess the damage. He found that the free end of the driveshaft from No. 2 transmission to No. 3 final drive had punctured a hole in the floor of the passenger compartment (see Figure 1). The driveshaft was resting on No. 3 axle.

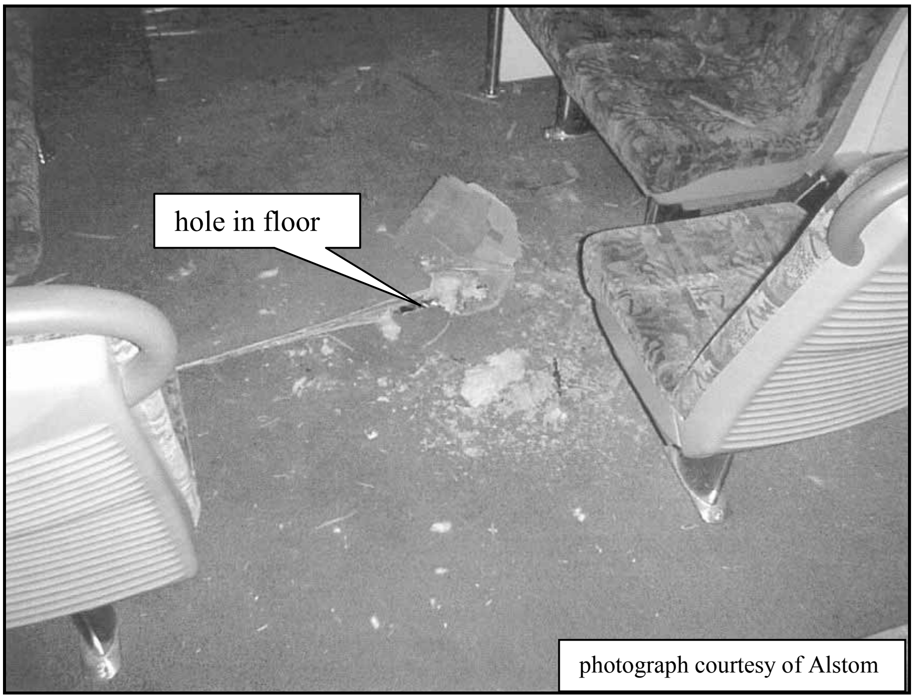


Figure 1
Damaged floor of passenger car ADL 810

1.1.6 The 3 passengers who were in the leading car and sitting near where the driveshaft punctured the floor were shaken but not injured.

[3] Tranz Metro was the group within Tranz Rail with responsibility for the operation of suburban rail passenger services.

1.1.7 The DMU driver advised the train controller of the incident and of his intention to isolate No. 2 engine and continue to Westfield mechanical repair depot at reduced speed using No. 1 engine only. All passengers were disembarked at the next station, Glen Innes.

1.2 Site information

1.2.1 Train 3347 travelled on the Down Main of the NIMT from Auckland to Papakura. From Meadowbank the approach to Purewa Tunnel was up a 2 km long 1 in 140 gradient.

1.3 General description and operation of ADL and ADC diesel multiple units

1.3.1 The ADL and ADC passenger cars used on the Auckland suburban passenger network were formerly owned by Westrail and operated in Perth, Australia. ADL 810 and ADC 860 were built in 1985 by A. Goninan and Company Limited of Newcastle, New South Wales and were commissioned on the Auckland network during 1993. The 2 cars operated as a permanent combination.

1.3.2 ADL/ADC passenger cars were restricted to a maximum operating speed of 90 km/h.

Consist

1.3.3 The DMUs were designed to operate as a 2, 4, 6 or 8 car consist. Each pair of cars comprised a powered car and a non-powered car. The powered car was fitted with 2 Cummins 6-cylinder diesel engines, each capable of developing 212 kW of power at 2100 rpm. The trailer non-powered car was fitted with a Detroit diesel engine coupled to an alternator to provide 125 kW of auxiliary power.

Motor car ADL 810

1.3.4 The powered car provided traction for the 2-car consist. The drive from each engine was through a Voith hydraulic transmission unit to an axle-mounted final drive. The Voith transmission included 2 drive systems: one through a torque converter and the second through a fluid coupling (see Figure 2). The transmission engaged the torque converter to move the train from standstill, and automatically change to direct fluid coupling drive according to engine throttle setting and train speed but generally between 50 and 60 km/h.

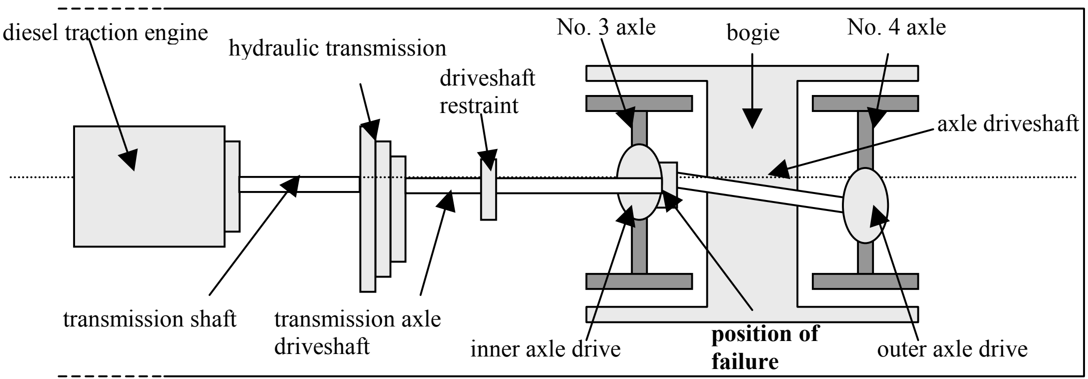


Figure 2
Schematic of driveshaft

Trailer car ADC 860

1.3.5 The trailer car provided no traction but was equipped with a Detroit diesel alternator to supply 415/240 volts 50 Hz AC power to both the motor car and trailer car for the operation of the air conditioning, lighting, headlights, crew-compartment heating, radiator cooling and the air compressor.

1.4 Inspection and maintenance

1.4.1 When Tranz Rail acquired the DMU fleet from Westrail in 1993, it also received the respective drawings and maintenance schedules. The maintenance schedule was revised and has been constantly updated to better reflect New Zealand operating conditions. Tranz Rail Mechanical Code M2000 determined that ADL passenger rolling stock was to be inspected at the following intervals:

- daily check
- A-Check every 6 weeks
- B-Check every 3 months
- C-Check every 6 months
- D-Check every 12 months.

1.4.2 The daily check, carried out by qualified maintenance staff at the servicing depot, provided the opportunity to check any defects reported by drivers, to observe signs of overheating and brake block wear and to listen for any unusual sound.

1.4.3 The A-Check specified, among other things, a visual inspection of driveshaft universal joints.

1.4.4 The 3-monthly B-Check specified the following work on the transmissions of ADL passenger cars to include:

- taking an oil sample
- lubricating final drive torque arm
- greasing universals and splines of driveshafts.

The C-Check and D-Check contained no additional work required for transmissions, but B-Check requirements were covered in both higher order checks.

1.4.5 The most recent B-Check on ADL 810 was carried out on 16 May 2003. The fitter certified that all the required maintenance checks on the transmissions were carried out. In addition he checked for loose driveshaft bolts and examined the universal joint caps for any sign of rotation. The examination did not identify any problems with bolts or caps but 2 grease nipples were replaced, one of which was on a transmission driveshaft. However, the fitter could not recall specifically which grease nipple was replaced, but did confirm that it was at the transmission end.

1.4.6 Tranz Rail advised that while no specific formal training for maintaining driveshafts had been given to maintenance staff, they had access to brief instructions provided by the driveshaft manufacturer. These instructions covered the storage, transportation, fitting and greasing of driveshafts but did not include what signs to look for regarding abnormal operation, nor detailed drawings.

1.4.7 Tranz Rail advised that there were no reported faults pertaining to driveshafts on ADL 810 and there was no reported unscheduled maintenance carried out on the driveshafts between 16 May and 27 June 2003. ADL 810 was scheduled to have its next A-Check on 4 July 2003.

1.4.8 Tranz Rail had not determined a design life for the driveshaft, but stated it was practice to change out the driveshaft at the same time as a bogie change. Bogies were changed out on condition rather than at any particular time interval.

1.5 Driveshaft service history

1.5.1 The failed driveshaft was identified from the make and model details forged into the universal joint cross (see Figure 3). It was a model 587.35 and made by GWB. GWB was an established

German manufacturer now owned by Dana Corporation. There was no formal New Zealand agent for GWB but Driveshaft Specialties NZ Limited represented GWB and had access to GWB technology. Driveshaft Specialties had serviced the driveshafts since the DMU fleet was commissioned in New Zealand in 1993.

Figure 3
Universal joint cross

1.5.2 A GWB catalogue illustrated the general pattern of construction of one of the GWB joint types, including the model 587 (see Figure 4). Each bearing consisted of 2 rows of needle rollers.

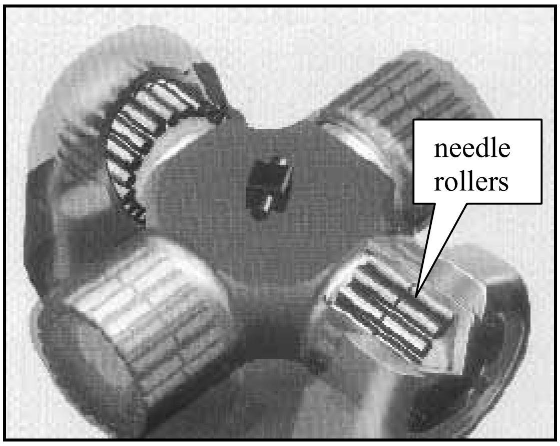


Figure 4
A GWB universal joint

1.5.3 The GWB inspection instructions stated in part:

> Journal cross and bearing assembly
>
> Check visually
>
> - journal cross
> - bearing bushes
>
> Possible damage to the journal cross
>
> - clean running surfaces (2), faces (1) with nylon brush
> - check shadings on the running surfaces for smallest surface damage
> - pitting and shading show the part can no longer be used.

1.5.4 The type of universal joint most commonly encountered in New Zealand was the Spicer, manufactured by Dana Corporation. The GWB universal joint was significantly different from the Spicer joint in both construction and manner of its inspection. The most significant difference for the operator was that the Spicer joint was allowed to develop some detectable slackness in service while the GWB was not. Spicer gave a procedure for detecting the end of useful life by measuring the amount of slack in the universal joint while GWB Inspection Instructions, which were not available to maintenance depot staff, stated in part:

> **Checking of Play**
>
> The checking refers to the joint bearings (journal assemblies), to the centre bearing for double joints with spigot and to the spline parts of the length compensation and must be adapted to the lubrication intervals. If the checking shows a noticeable play, the universal joint must be dismounted and sent to GWB for repairs.

1.5.5 In other words, if the bearing was dismantled for inspection, any damage visible at the time of inspection was grounds for rejecting the component as unsuitable for future use.

1.5.6 Tranz Rail operated a total fleet of 19 two-car DMU sets, all acquired second-hand from Westrail. Each 2-car set had 2 driveshafts. Tranz Rail provided records of 9 driveshafts from the fleet having been serviced by Driveshaft Specialties but could not provide a complete record of the maintenance history of individual driveshafts.

1.5.7 Driveshaft Specialties had records for servicing 33 DMU driveshafts, but could not rule out the possibility of any particular driveshaft being serviced more than once.

1.5.8 The former owner/operator of the DMU fleet, Westrail, kept maintenance records for a period of 7 years only. Consequently there were no maintenance records available for the 8-year period the fleet had operated in Perth.

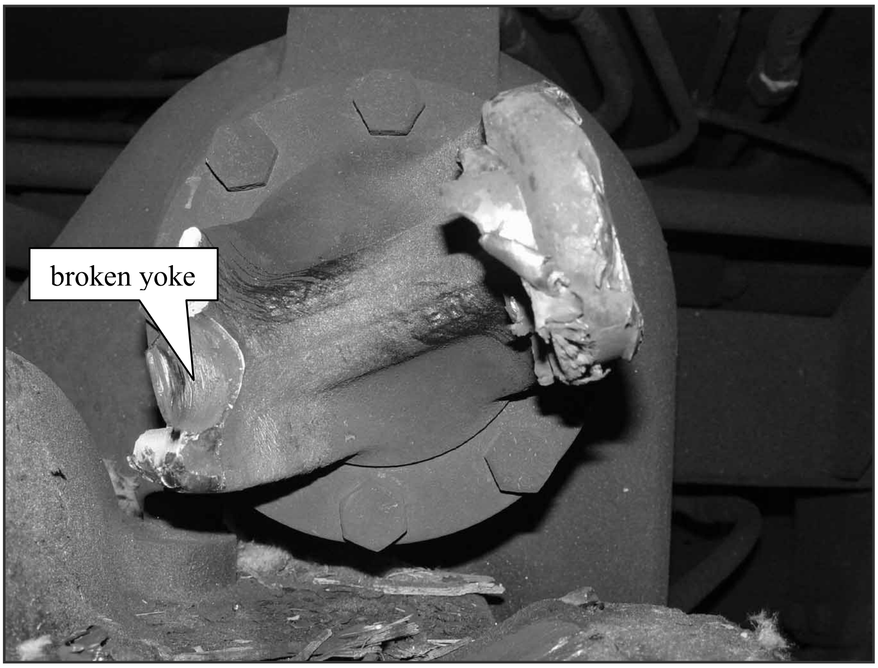


Figure 5
Damaged yoke

1.6 Post-incident inspection

1.6.1 The yoke on the axle end of the driveshaft failed (see Figure 5). The flailing driveshaft damaged pipe work under ADL 810 and penetrated the saloon floor. One end of the driveshaft remained attached to the hydraulic transmission while the free end was resting on the axle. A tubular safety stirrup was in place to restrain the driveshaft (see Figure 6).

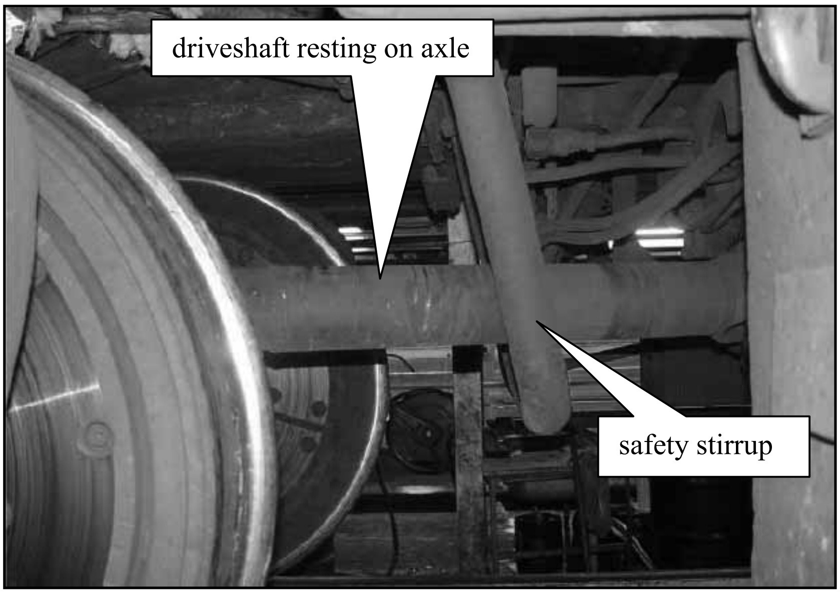


Figure 6
Driveshaft safety stirrup

1.6.2 The failed driveshaft was removed and taken to an independent driveshaft specialist for detailed examination. Damage to the failed end of the driveshaft made it difficult to remove some of the bearings. However, removal was achieved without further damage to critical components.

1.6.3 When dismantled, the bearing assembly was found to contain dry remnants of grease consistent with it being subjected to the heat generated in the universal joint up until the time of failure. One of the bearing races showed evidence of pitting and spalling.

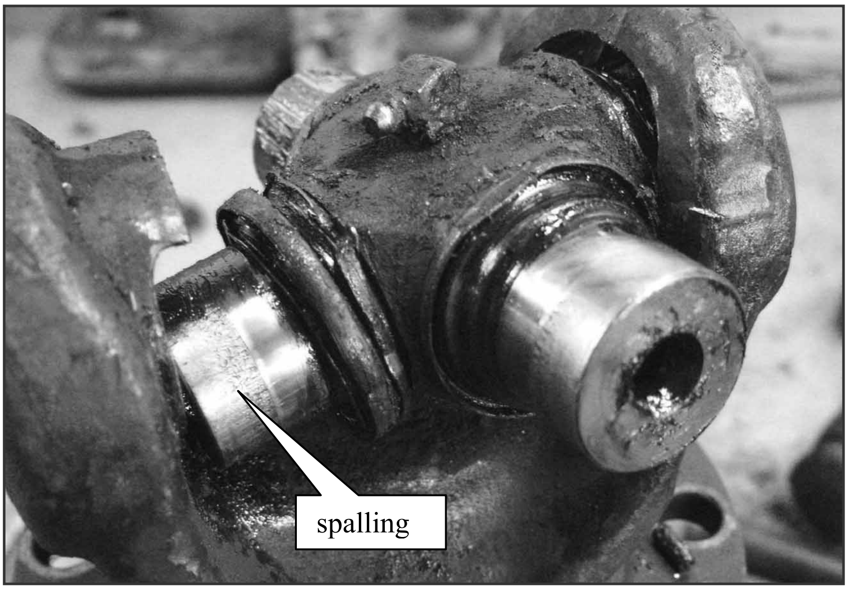


Figure 7
Spalling and pitting on bearing races

1.6.4 The left-hand bearing from the end of the driveshaft that did not fail was examined and there was also evidence of spalling and shedding of flakes of steel on the 2 races (see Figure 7). Fresh grease was visible in the universal joint.

1.6.5 The driveshaft had the reference DS9141 stamped into it. If the driveshaft had been serviced within New Zealand it would have had either a 5-digit number with no alphabetic prefix or a 4-digit number prefixed by DSS.

1.6.6 The sliding-joint section of the driveshaft can be assembled in many different positions, only one of which is correct. The manufacturer marked the correct alignment with 2 arrow marks facing each other. The failed driveshaft exhibited different markings, having one arrow and a line of punch marks (see Figure 8).

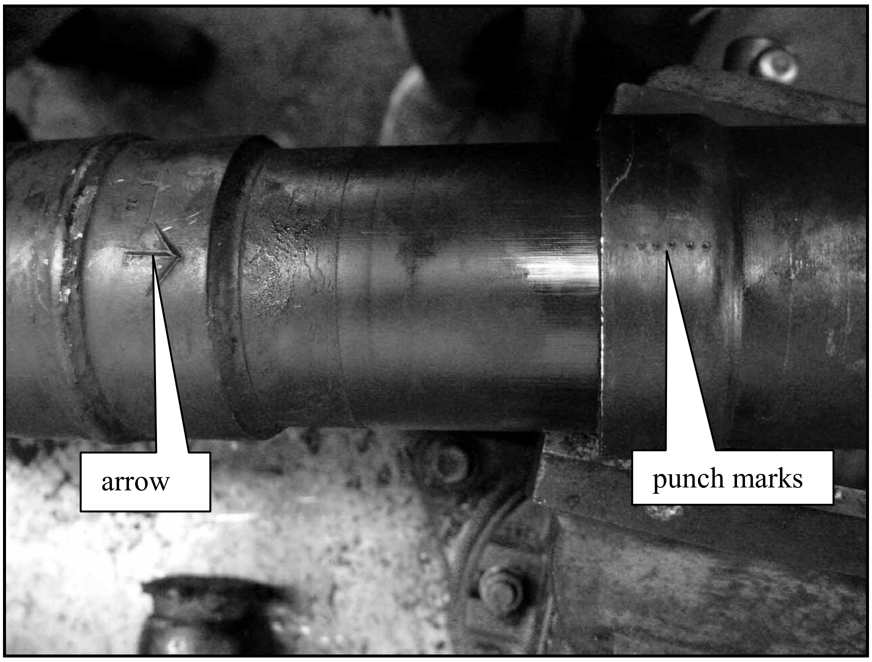


Figure 8
Sliding-joint section of the failed driveshaft

1.7 Personnel

The DMU driver

1.7.1 The DMU driver had been driving DMU passenger services since 1996. His certification was current at the time of the incident.

The train manager

1.7.2 The train manager gained full and final certification for Guard's Licence in March 2002.

The fitter

1.7.3 The person who carried out the most recent B-Check on ADL 810 was qualified to carry out the inspection. He had worked at Alstom's[4] Westfield Depot for 12 years and had more than 10 years' maintenance experience working on the DMU fleet.

[4] Alstom Transport New Zealand Limited was contracted by Tranz Rail to provide mechanical inspection and maintenance services on locomotives and wagons including DMUs.

2 Analysis

2.1 The failure of the universal joint was consistent with the bearing being excessively worn, becoming overheated and subsequently seizing, resulting in the yoke bearing housing fracturing and releasing the driveshaft.

2.2 Bearings can fail if they are re-assembled with one needle roller too few, allowing the other rollers to run slightly askew. However, since there were no markings on the driveshaft to show that the bearing had been dismantled since ADL 810 was commissioned on the Auckland network in 1993, this possible cause was considered unlikely.

2.3 The bearing failure was consistent with a lubrication failure. Either the bearing had not been properly greased or the grease had degenerated. Because there was fresh grease in the joint assembly that did not fail, it was most likely that all bearings were greased at the same time. However, because of the heat build-up leading to the subsequent failure of the universal joint, the age of the remaining grease within the bearing could not be determined.

2.4 The torque applied to the driveshaft caused the outermost rows of rollers to be most heavily loaded and therefore most prone to fatigue failure of the bearing surface. The damage to the raceways in both of the crosses was as expected when a bearing had run to the end of its useful life. The failure of the bearings caused the failure of the driveshaft.

2.5 The spalling and shedding flakes of steel on the still-intact universal joint were caused by the formation of many small fatigue cracks in the surface of the bearing race. These cracks penetrated the race and eventually joined up to allow small particles to break off completely. Such surface damage marks the end of the life of a roller bearing and signals eventual failure.

2.6 As long as the DMU continued to move after the driveshaft had failed, the free end would continue to be rotated by its connection to the final drive in the bogie. The safety stirrup intended to restrict the motion of the driveshaft prevented it falling to the track, but could not prevent the driveshaft from striking the underside of the passenger compartment floor. A safety recommendation to review and revise the design of the restraint has been made to the operator.

2.7 In the event of a failure of a universal joint there was a serious risk of separation of the sliding joint in the driveshaft. Should the driveshaft continue to rotate and not be closely confined, it could not only flail beneath the floor but could also fling away the unattached end of the driveshaft, similar to a slingshot. This would pose an unacceptable risk to anyone in the vicinity. A safety recommendation to address this issue has been made to the operator.

2.8 The DMU driver responded immediately to the sound of the flailing driveshaft and the visual warning displayed on the cab panel and stopped the train. His alertness probably prevented further damage to both the passenger compartment floor and under-carriage components, which may have led to injuries to the passengers.

2.9 The universal joint was well past the end of its acceptable or useful safe life at the time it failed. Had Tranz Rail developed written instructions consistent with GWB Inspection Instructions it was likely that the bearing would have been dismantled within the 10-year time period since the DMUs were commissioned, and any damage visible at the time of inspection would have been grounds for rejecting the component as unsuitable for continued use. A safety recommendation to address this issue has been made to the operator.

2.10 Maintenance staff may have been more used to the Spicer universal joint that could develop an acceptable amount of play whereas GWB universal joints could not. The Tranz Rail maintenance schedule did not specify when the driveshaft on a DMU was to be automatically overhauled other than to say it was to be changed out at the same time as bogies. There was a general understanding among maintenance staff that when a driveshaft was greased the person undertaking the greasing was expected to look at the driveshaft and advise when it needed replacement. However, there were no standards available on which to make that assessment. A safety recommendation to address this issue has been made to the operator.

3 Findings

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

3.1 The driveshaft failed as a result of a bearing in the universal joint overheating and seizing.

3.2 There was no evidence that lack of greasing or improper physical maintenance contributed to the failure of the driveshaft.

3.3 The safety stirrup did not adequately restrict the motion of the failed driveshaft.

3.4 There were no records available that enabled the time in service or the maintenance history of the failed driveshaft to be established.

3.5 The failed driveshaft was probably last disassembled before 1993 at a time when it was in use in Perth, Western Australia.

3.6 There were no written procedures governing the installation or maintenance of driveshafts on the DMU fleet.

3.7 Tranz Rail's maintenance schedule contained no specific criteria or service schedule for the replacement of driveshafts on the DMU fleet, other than on condition.

3.8 The lack of installation, maintenance and replacement procedures and standards contributed to this accident.

3.9 The actions of the DMU driver did not contribute to the driveshaft failure.

4 Safety Actions

4.1 On 9 September 2003, Tranz Rail advised that following this incident all ADL passenger cars were inspected for signs of driveshaft distress but no problems were found.

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 establish an inspection procedure and criteria for acceptance or rejection of individual DMU driveshafts in service with the assistance of the universal joint manufacturer. (058/04)

5.1.2 establish installation and maintenance standards for driveshafts and instruct all relevant maintenance staff in their use. (059/04)

5.1.3 revise the design of the safety stirrup to better constrain the driveshaft and reduce the risk of injury in the event of a driveshaft failure. (060/04)

5.1.4 individually identify all driveshafts on the DMU fleet so that their maintenance and service history can be recorded and tracked. (061/04)

5.2 On 5 October 2004 the Chief Executive of Toll NZ Consolidated replied:

058/04 Toll NZ accepts this recommendation.

059/04 Toll NZ accepts this recommendation.

060/04 Toll NZ accepts this recommendation.
Restraints have been fitted to the original driveshaft safety loop at a lower height than the original The tubing that has been added below the original vertical restraint will arrest the shaft should a universal joint fail at the final drive end before the shaft makes contact with the underside of the floor.

061/04 Toll NZ accepts this recommendation.

Approved on 22 September 2004 for publication

Hon W P Jeffries
Chief Commissioner

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Price $ 20.00 ISSN 0112-6962