Report 96-108

Train 404

Hamilton

31 May 1996

Abstract

On Friday, 31 May 1996, at about 2034 hours Train 404, the Rotorua - Auckland *Geyserland Express*, derailed at slow speed while crossing from the East Passenger Loop to the West Loop at Hamilton. There were no injuries. The cause of the derailment was an axle failure on the trailing axle of the railcar. Safety issues identified were the need to improve the inspection and testing regime for Silver Fern axles.

Transport Accident Investigation Commission

Rail Incident Report 96-108

Train type and number:	Express Passenger, 404 (Silver Fern RM 24)
Date and time:	31 May 1996, 2034 hours
Location:	Hamilton, 542.210 km, North Island Main Trunk
Type of incident:	Derailment
Persons on board:	Crew: 3 Passengers: 14
Injuries:	Nil
Nature of Damage:	RM 24: Substantial
Investigator in Charge:	R E Howe

1. Factual Information

1.1 On Friday, 31 May 1996, Train 404 was the scheduled *Geyserland Express* operated by Tranz Rail Limited (Tranz Rail) between Rotorua and Auckland. The service comprised Silver Fern two-coach railcar, RM 24.

1.2 Train 404 was crewed by a Locomotive Engineer (LE) and two train attendants. There were 14 passengers on board when the train departed Hamilton Station at approximately 2032 hours.

1.3 At approximately 2034 hours the train was leaving the East Coast Main Trunk (ECMT) via the East Passenger Loop and entering the North Island Main Trunk (NIMT) through crossovers 166 and 164 to the West Loop (refer Figure 1 for locality diagram). The LE estimated the train speed to be 10 km/h. The first unusual indication to the LE was when he felt a "dragging effect" on his train when his driver's position was at approximately 164 A points. He stated he throttled back from notch 1 to idle (notch 0), his first thought being that he may have a hand brake problem. He returned to notch 1 to evaluate his assessment, but then some 15 to 20 seconds following the first indication he felt a further and more pronounced dragging effect. He immediately throttled back to idle and applied the train brakes. The train stopped, "approximately 15 to 18 metres" from where he felt the second dragging effect, with the rear bogie at approximately 542.24 km NIMT[1].

1.4 The LE inspected his train and found the trailing bogie of RM 24 was derailed and the number 1 (trailing) axle, A side (right side in direction of travel), was broken on the outside of the wheel (refer Figure 2 and Figure 3).

1.5 There were no injuries to staff or passengers. Passengers were bussed to their destinations and RM 24 secured for later recovery.

1.6 The event recorder was removed from RM 24 and the data extracted. Analysis of the data revealed inaccuracies in a number of parameters. In particular, low speed during acceleration and deceleration, and train speed prior to derailment, could not be confirmed directly from this source. Later inspection found a broken wire was causing an intermittent fault in the speedometer reading. The train throttle position was recorded accurately on the event recorder and the data extracted showed a throttle change from notch 1 to idle 29 seconds before the train came to rest, idle to 1 at 16 seconds and 1 to idle at five seconds.

1.7 The first indication on the track of the axle failure was an impact mark on the right check rail at the entry to 166A crossing opposite 542.167 km. Heavy score marks were present on the back of the left-hand switch of 166A between 542.205 km and 542.209 km. There was evidence of an axle derailing at the trailing points of turnout 166 A. These marks continued through to the facing points of turnout 164 B, following which increased track damage occurred and marks indicated a further axle was derailed through the crossing of turnout 164 B.

1.8 Inspection of the railcar following the derailment revealed that the right side of number 1 axle had sheared off in the journal area outside the right wheel. The remaining stub of the axle was worn heavily and showed signs of high temperature and plastic flow (Figure 4). The axle box showed signs of substantial damage (Figure 5). The number 1 axle was found to be skewed clockwise on the track with wheel A (right side) offset behind wheel B.

[1] The derailment of Train 404 occurred as it travelled off the ECMT and onto the NIMT. To avoid confusion all kilometrages in the derailment area are related to the equivalent NIMT kilometrages.

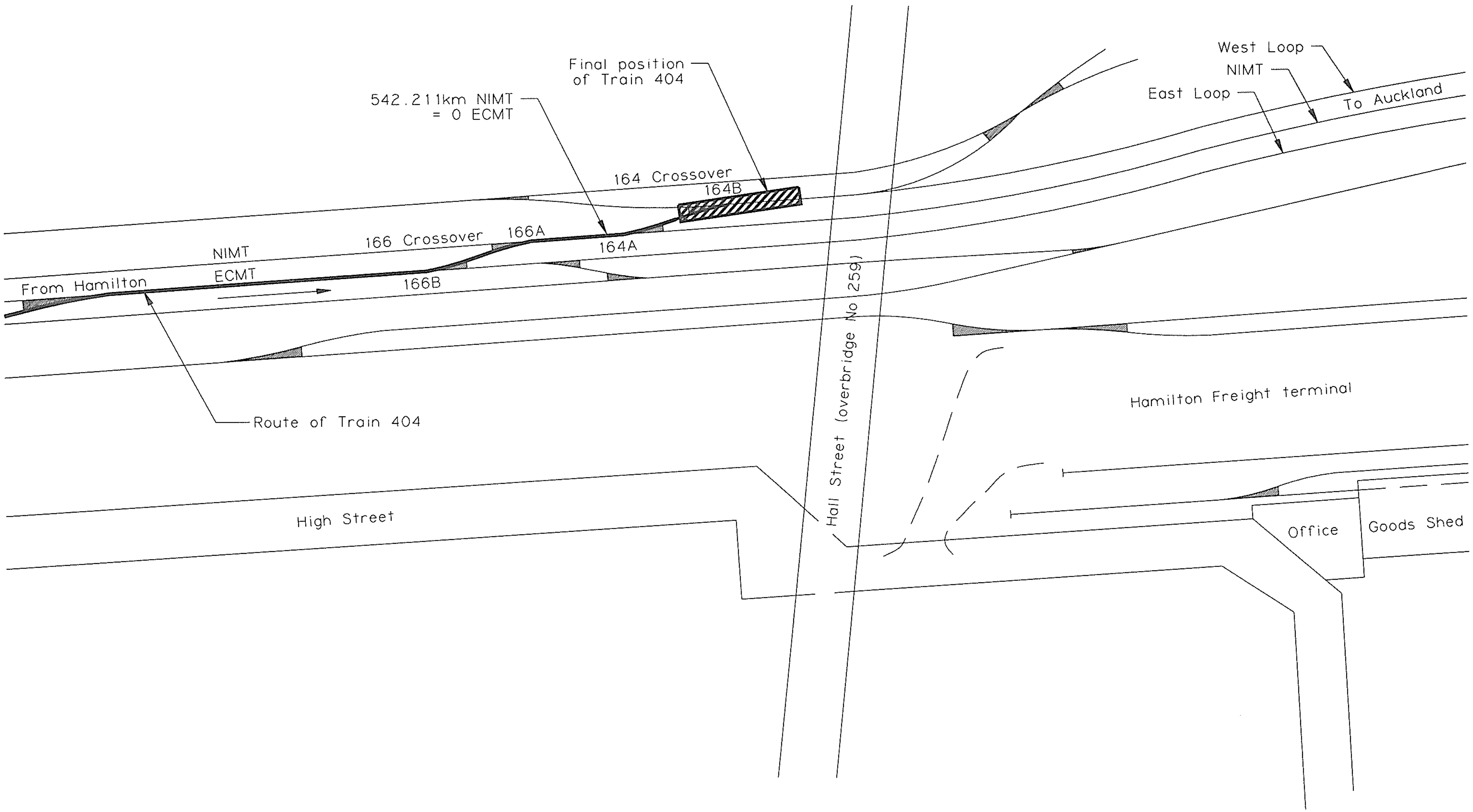

Figure 1
Locality diagram, (not to scale)

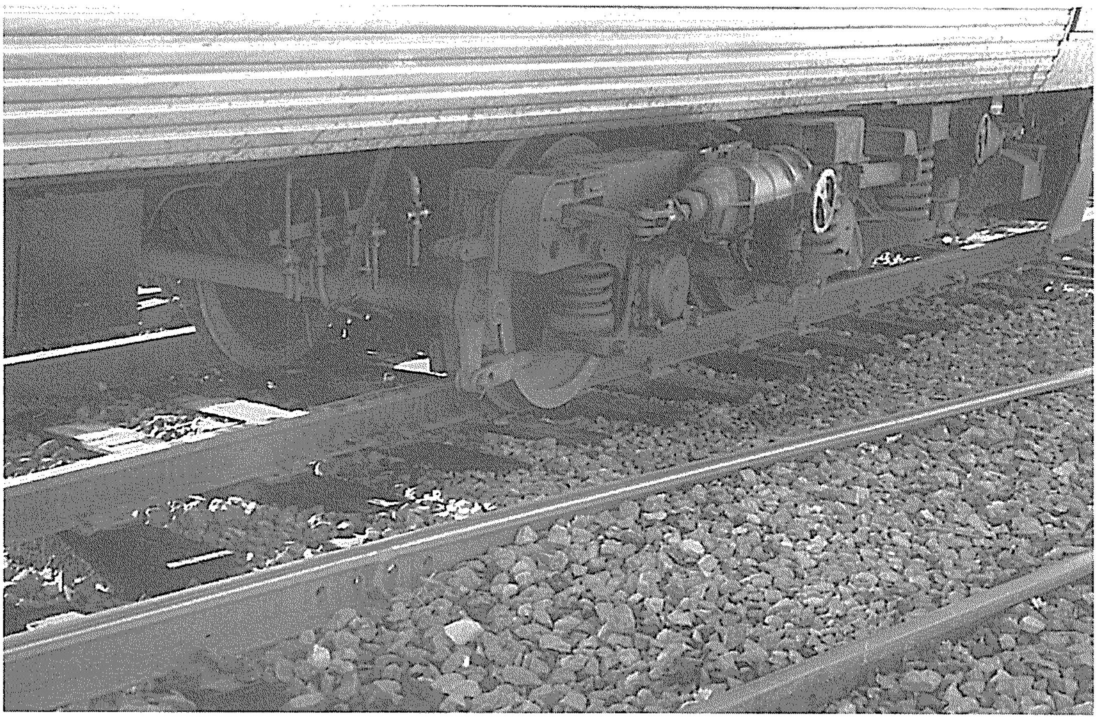

Figure 2
The derailed trailing bogie of RM 24. View from left side in direction of travel with number 3 axle at left and number 1 axle (obscured) at right.

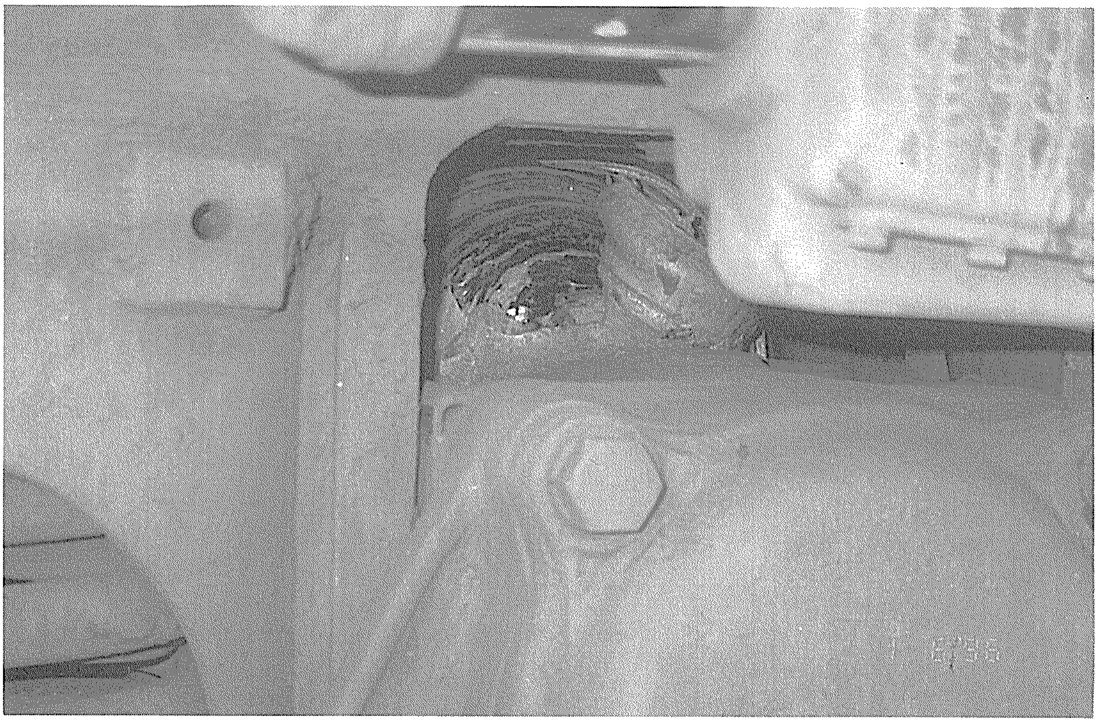

Figure 3
View of the failed number 1 axle taken from the right side through the side of the bogie.

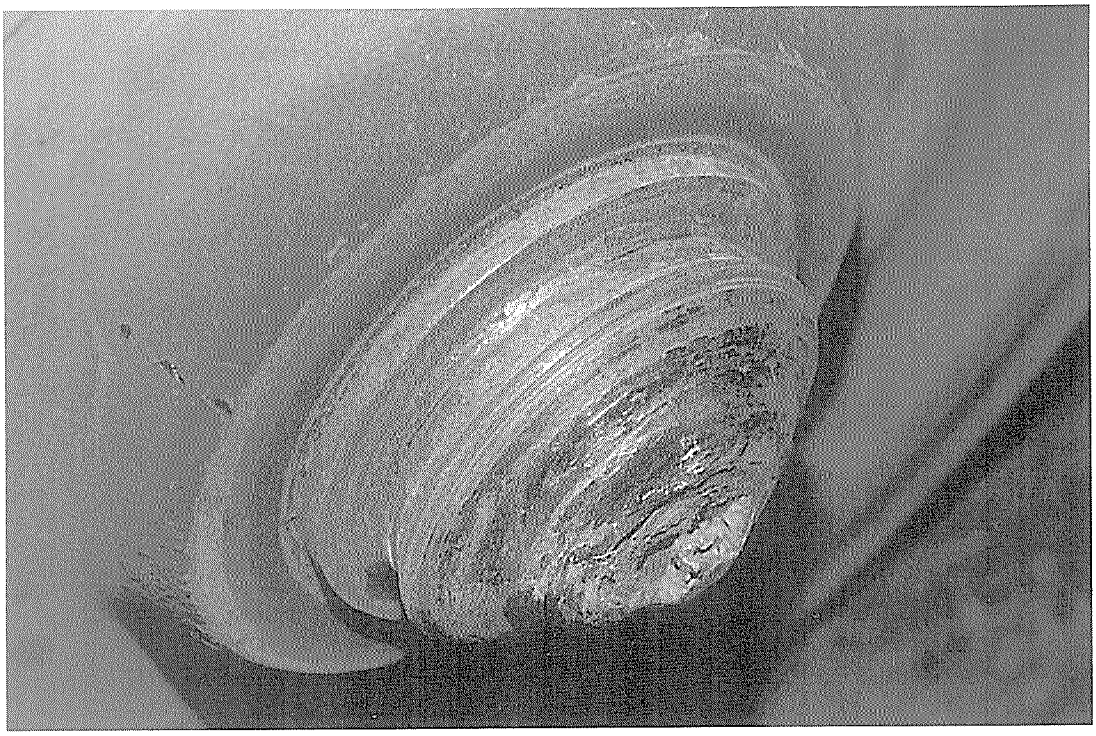

Figure 4
Worn stub of number 1 axle

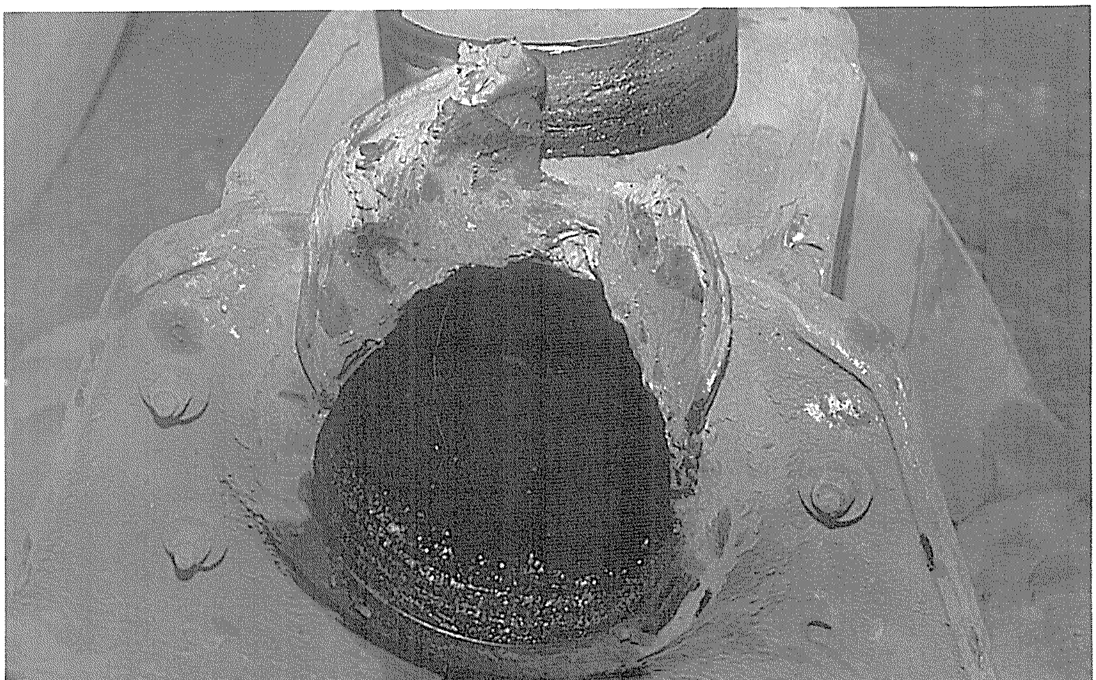

Figure 5
Worn axle box, number 1 axle

Axle history

1.9 Axle number 1 of RM 24 was a driven axle underneath the main engine. Axle numbers 1 and 3 on the trailing bogie were the axles with the heaviest load (approximately 14.6 t) on the two-coach railcar.

1.10 The number 1 axle from RM 24 was identified as axle 69805N.

1.11 Axle 69805N was an original axle supplied with the Silver Fern railcar order in 1972. Tranz Rail records showed that the axle had been fitted to RM 24 during a bogie change at Hutt Shops in May 1993 and had travelled 590,000 kms between 1993 and 1996. The total distance travelled by the axle since its introduction in 1972 was not available due to discontinuous records of mileage and kilometrage. The recent average of approximately 200,000 kms per year was achieved with higher utilisation than in earlier years and it is likely that the total distance covered by the axle was approximately 4,000,000 kms.

1.12 The stamping on axle 69805N indicated a new set of wheels was fitted in 1974. The wheel push on pressure recorded was 120 T (overlaying a faint 125 T stamping), 30 T in excess of the normal pressure of 90 T. Tranz Rail believed the fitting of new wheels and the higher pressure were related to a wheel shift problem that arose in the early seventies. Currently Tranz Rail use a wheel push on pressure equivalent to 90 T. The wheels fitted in 1974 were tyred and tyre replacement had been carried out since then as dictated by tyre thickness.

1.13 The tyres on axle 69805N had a tyre thickness value of 52 at the time of the derailment. This can be compared to 67 at new and a 35 condemning limit, i.e. they were approximately half worn. The tyres on the number 3 (driven) axle had a tyre thickness value of 48. The number 2 axle (idle), had solid wheels.

1.14 Tranz Rail said they were unable to determine whether axle 69805N had any previous history of being involved in a derailment or collision. A symmetry check carried out on the axle after the derailment on 31 May 1996 proved satisfactory.

Inspection and overhaul of axles, axleboxes and bearings

1.15 Tranz Rail "Work Instructions 09.01.2 - Effective 23 April 1993" laid down the following procedure for the Roller Bearing Overhaul Group for the roller bearings associated with the Silver Fern.

6. Procedure

6.1 General

6.1.1 Wheelsets pass through the cleaning area before being presented to the bearing group for the inspection of bearings.

6.1.2 Where the wheelsets are from bogies undergoing overhaul, the axleboxes and bearings are to be overhauled.

6.1.3 If the wheels on the wheelset require replacement or new tyres, the axleboxes and bearings are to be overhauled.

1.16 Tranz Rail advised the catalyst to bogie overhaul or wheel or tyre replacement was tyre wear and estimated retyring of the Silver Fern driven axles would generally be required every four to five years, depending on distance travelled.

1.17 Tranz Rail "Wheelset Manual: Notes and Instructions, 22 November 1995" included the following requirements for "Examination and Testing of Axles".

> **Examination and Testing of Axles**
>
> Whenever wheelsets are removed from under locomotives and rolling stock, a thorough examination is to be made to ensure that all axles are sound and straight. Bent axles are not to be straightened under any circumstances. All locomotive and rolling stock wheelsets (including rail cranes and heavy track machinery) passing through workshops for retyring, rewheeling, or bearing maintenance must have axles ultrasonically or fluorescent magnetic particle tested.

1.18 Records showed the last ultrasonic inspection of axle 69805N was on 10 March 1993 at Hutt Shops, and no defects were recorded as a result of this inspection. Records at Hutt Shops go back to 1987 and this was the only record of an inspection of this axle at Hutt since that date. Such tests were also carried out at Otahuhu until 1992 but Tranz Rail do not hold records of these tests.

1.19 Tranz Rail "Instructions for the overhaul of axle boxes bogie X28020" (applicable to the Silver Fern) included the following requirement for overhaul:

> **3. Overhaul**
>
> (a) All wheelsets presented for overhaul are to have the axleboxes and their bearings stripped, cleaned and inspected.

and clarified that this did not include removal of the bearing inner race in the following clause:

> **6. Inspection - Bearing and Components**
>
> (a) The cylindrical bearing is to be inspected for defects in the outer race cage and rollers.
>
> The cylindrical bearing arrangement has two sets of rollers. Type C, which is now superseded by Type A, allows the roller/cage assembly to slide out of the common outer race. Type A has two roller/cage assemblies each with a captive outer race. Each type has a common inner sleeve or race.
>
> To inspect the outer race of a Type A bearing, sufficient rollers are withdrawn from the cage to enable the cage and remaining rollers to be extracted.
>
> Type C bearing are still being supplied ex Inventory and are to be used.
>
> The inner race, which remains on the axle journal, is to be similarly inspected before the axlebox assembly is remounted.

A detailed procedure for removal and replacement of the inner race, if inspection showed this was warranted, was in clause 10 of the Instructions which included:

> **10. Removal and Replacement of Inner Sleeve, Slinger or Thrust Bearing Inner Race**
>
> (a) If the special puller, Appendix A Page 24 is not available, evenly heat the outer diameter of the slinger with a heating torch and lever the slinger off with a bar. The induction heater may also be used to heat the slinger.

(b) Removal of the bearing inner sleeve and the thrust bearing inner race, is accomplished using a bearing withdrawal tool.

(c) Before remounting the above parts, carefully clean and inspect the journal for wear or damage. Pages 10 and 11 of Appendix A detail the tolerances.

Tranz Rail advised that currently there is no register of bearing overhaul or renewal covering removal and replacement of the inner race and they do not know whether the inner race on axle 69805N had ever been removed to allow inspection of the journal (bearing area of the axle).

Tests and research

1.20 The failed portion of axle 69805N was sent for analysis. The resulting report included the following conclusions:

- The axle failed as a result of fatigue.
- The major cause of failure was that the applied stresses were higher than the fatigue limit at the point of origin.
- The fatigue initiated at the edge of the run out taper of the inner bearing race.
- The bearing shrink fit acted to create a stress concentration.
- Corrosion occurred under the shrink fit and may have increased the loadings at this point.
- Corrosion under the tapered run out would have reduced the fatigue performance of the axle steel.
- The axle was manufactured in accordance with BS 24 part 1: 1956.
- The dimensions of the axle under the shrink fit were within the tolerances specified.
- Examination of the wheels revealed that there was no evidence of any unusual wear pattern or flats.

1.21 The report stated no defect or significant metallurgical condition peculiar to the axle was revealed which may have encouraged failure. It concluded that normal service conditions induced stresses which exceeded the fatigue limit. This implied that similar axles would be prone to fatigue failure. The report noted it was probable that the fracture propagated to an arrest mark at 6.4 mm depth relatively slowly, as the fracture surface in this area was smooth and polished.

1.22 A metallographic section was taken through the surface of the failed axle next to the fracture to evaluate corrosion present. Examination of this section revealed corrosion pits approximately 0.015 mm deep. No cracks were observed. The report concluded that the corrosion present would have reduced the stress at which a fatigue crack would initiate. Figure 6 shows the relative position of the axle failure.

1.23 Examination of the bearing rollers revealed that although they were covered with burnt oil the surface was mainly undamaged. A line of wear was however present on some of the rollers. This line of wear was relatively coarse and was probably caused after the major failure.

1.24 Following the incident Tranz Rail commissioned a report on fatigue crack growth for the Silver Fern axle based on assumed stress levels and crack depths. This indicated that cracks of 0.5 mm to 3 mm depth should not have grown by fatigue at the stress levels assumed, and that there must have been some additional factor(s) which led to the failure of the axle. (The 3 mm depth was chosen as the crack depth which should always be detected by ultrasonic detection techniques.)

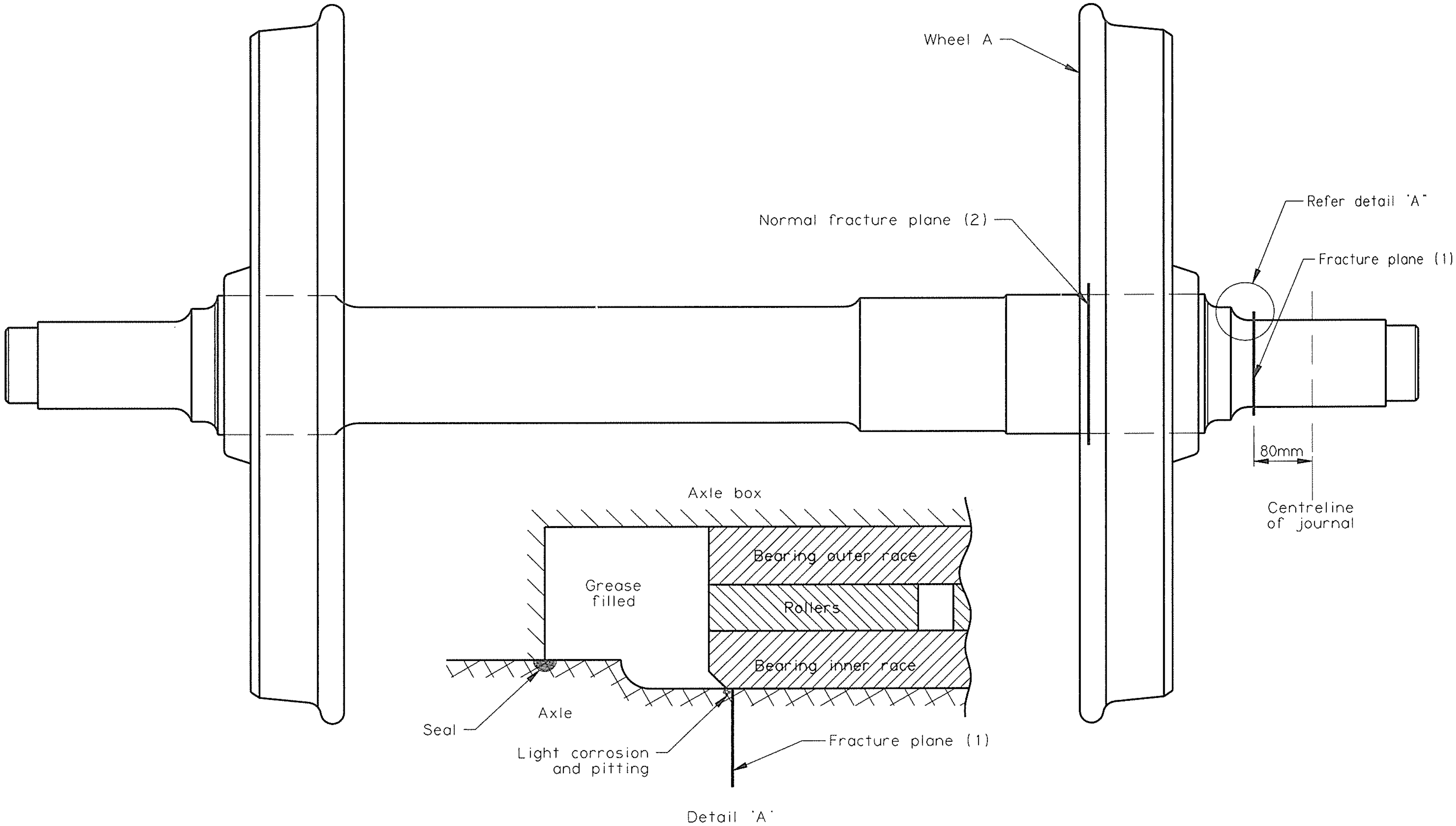

Figure 6
Relative position of the axle failure, (not to scale)

Track condition

1.25 The track was heavyweight rail on timber sleepers which had been in place for approximately four years. Fastenings were tight and ballast condition was good.

2. Analysis

Derailment

2.1 The damage to the axle box and stub bearing indicated axle failure occurred some time prior to derailment. While it was not possible to define an exact time or location, from the extent of the damage it was likely that the failure occurred before the arrival of Train 404 at Hamilton.

2.2 Following failure of the axle, the axle box was free to drop within the limitations of its keeps. The stub end of the axle was also free to move longitudinally as wear developed, as shown by the skewed position of the axle when the railcar came to rest. The dynamic factors resulting from this progressive failure allowed the number 1 axle to derail to the right side opposite 452.210 km.

2.3 The actual sequence of events and cause of track damage prior to derailment could not be determined accurately due to the nature of the failure. The LE's recollection, supported by the recorded throttle position on the event recorder log, indicated the first dragging effect he felt commenced when number 1 axle was at the crossing of turnout 166B. This coincided with the impact mark on the check rail entry and subsequent score marks on the back of the switch rail. Similar evidence indicated the second and more severe dragging effect was felt when the rear bogie was negotiating the points of turnout 164B, at which time the effect of the derailed number 1 axle would have become more evident.

Axle failure

2.4 The fracture plane was at the inside of the tapered run out underneath the inner bearing race in the journal area of the axle. This is not recognised internationally as a highly stressed area of rolling stock axles and is generally not prone to fatigue failure. Fracture in the journal area is not uncommon following bearing failure, but in this case there was no evidence of bearing failure prior to fracture. A fracture plane in the wheelseat area is the normal result of in-service fatigue failure (refer Figure 6, fracture zone(2)).

2.5 The only two significant factors which could have reduced the fatigue limit of the axle steel to emerge from the laboratory analysis were the shrink fit of the bearing and the surface corrosion. Inspection of other Silver Fern axles at Hutt Shops showed that these factors were not unique to axle 69805N which raised an immediate concern as to the potential for the failure of similar Silver Fern axles in service.

2.6 The nature of the shrink fit used for the inner bearing race (heating in oil) should have had a minor effect as a stress concentrator. The corrosion evident in the area was also minor, although it had the potential to lower the fatigue limit to about 60% of that for a polished sample. Singularly or collectively these factors do not explain the failure which occurred, although it is considered Tranz Rail should review the need for a taper, and if retained look at specific sealing options to limit corrosion.

2.7 The fatigue crack growth calculation study concluded the initial cracks should not have grown by fatigue at the stress levels defined by Tranz Rail. However there was no doubt the axle failed in fatigue. Although the study may not have made full allowance for the effects of corrosion and shrink fitting it is unlikely that more detailed consideration of these factors would have altered the conclusions reached.

2.8 Other factors considered which may have initiated the failure of axle 69805N were:

a. That the axle had been subject to severe stress or deformation during its service life. Tranz Rail were unable to supply any details as to derailments or other events involving this axle which may have initiated these. A symmetry test carried out following derailment showed no distortion of the axle. No conclusion could be reached as to the possible effect of this factor.

b. That the service stresses imposed on axle 69805N at various frequencies were higher than Tranz Rail assumed thus explaining the crack propagation to failure within the approximate four year period Tranz Rail were ultrasonically testing axles for defects. The possible effect of this factor can not be determined until service stresses are established, and this is reflected in the recommendations arising from this report.

2.9 The inability to determine any unique factors which explained the failure of axle 69805N raised doubt as to the integrity of similar Silver Fern axles in service and resulted in the recommendations detailed in section 5.

3. Findings

3.1 The number 1 axle of RM 24 failed in service as a result of fatigue.

3.2 The number 1 axle failure occurred some time before progressive deterioration initiated the derailment of the train.

3.3 The low speed at which the derailment occurred, while the train was negotiating a crossover, limited the potential for serious consequences of the axle failure.

3.4 The failure did not occur in the wheelseat area where conditions of maximum stress, potential stress concentration from wheel fitting and corrosion normally cause in-service failures.

3.5 No characteristics unique to axle 69805N were identified to explain the unexpected failure of this axle in service.

3.6 Factors common to all Silver Fern axles, which contributed to a reduced fatigue limit for the failed axle, were a stress concentration caused by the inner bearing shrink fit and corrosion in the area of the inner bearing run out taper.

3.7 Crack propagation to failure should not have occurred at the stress levels assumed for the axle.

3.8 The actual stress levels applying in the axle in service are not known.

3.9 The requirement to ultrasonically test Silver Fern axles at approximately four year intervals during overhauls, was not effective in detecting the crack before its propagation led to failure.

3.10 No procedure was in place to assess any deterioration of the axle surface underneath the inner bearing which could have adversely affected fatigue limits.

3.11 Corrosion present at the inside of the tapered run-out on the axle indicated the taper concentrated the effect of any potential corrosion arising from axle seal deficiency.

3.12 All similarly loaded Silver Fern axles have the potential to fail in the manner of axle 69805N.

4. Safety Actions

4.1 Immediately following the incident Tranz Rail ultrasonically tested all Silver Fern railcar wheelsets and all spare wheelsets and no defects were found. Procedures were introduced to ultrasonically test all Silver Fern axles at 50,000 km intervals, i.e. approximately every 12 weeks.

4.2 By January 1997 Tranz Rail Ltd had removed for inspection all bearing inner races on axles number 1 and 3 driving wheel sets. Following the inspection any surface corrosion was ground out and sealed against further corrosion.

4.3 Tranz Rail are manufacturing two new axles for the Silver Fern as the first stage of a phased replacement programme for powered axles.

5. Safely Recommendations

5.1 As a result of the investigation of this incident it was recommended to Tranz Rail Limited that it:

5.1.1 Dismantle and inspect for fatigue cracks as a matter of urgency all axles under the three axle bogies currently in service on the Silver Ferns. Reassembly of uncracked axles should include action to prevent corrosion at the tapered gap between the axle and inner bearing. (044/96).

5.1.2 Ensure all other axles on the Silver Ferns are similarly treated when next in the workshop, and that all spare axles are similarly treated before installation. (045/96).

5.1.3 Review the procedures during programmed wheel replacement to include monitoring of the condition of the axle surface and the effectiveness of corrosion prevention. (046/96).

5.1.4 Confirm the ability of existing equipment, operators and procedures to detect all cracks over 2 mm deep in the position on the axle where this failure originated, using prepared test pieces as necessary to ensure this can be achieved consistently. (047/96).

5.1.5 Establish the service stresses being developed in the driven axle of the three axle bogie, and from this determine the related fatigue crack growth rates and implement an inspection regime to detect such cracks and remove any axle from service before it fails. (048/96).

5.2 Tranz Rail Limited responded:

5.2.1 Safety recommendation 044/96 - Tranz Rail Ltd notes TAIC's alteration in the wording of the final recommendation from the revised preliminary recommendation. The three axle bogies of all Silver Fern railcars have been removed, inspected and returned to service in accordance with the recommendation.

Action has been initiated to implement all the safety recommendations although 048/96 has been addressed by a different approach and therefore the safety recommendation has been superseded.

5.3 Tranz Rail advised the following details of the different approach adopted to recommendation 048/96:

5.3.1 This safety recommendation has been reviewed and examined in detail. Because of the nature of the service stresses and the difficulty to determine and implement a regime to detect fatigue cracks and remove any axle from service before it fails, an alternative solution has been adopted. Instead of the procedure in clause 5.1.5, all driving axles will be replaced over the next 24 months to eliminate any short term problems. The future service life of axles will be subject to further ongoing review.

16 April 1997

M F Dunphy
Chief Commissioner