Australian Government
Australian Transport Safety Bureau

Derailment of MTM train TD1064

Near Rushall Station, Melbourne, Victoria | 6 February 2016

Investigation

ATSB Transport Safety Report
Rail Occurrence Investigation
RO-2016-002
Final – 16 May 2018

Cover photo: ATSB

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Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150 (24 hours)
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

Addendum

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Safety summary

What happened

At about 1650 on 6 February 2016, metropolitan passenger train TD1064 was travelling towards Melbourne between Merri and Rushall Railway Stations when it derailed one bogie on a small-radius curve. There was one minor injury reported.

The derailed car was foul of the adjacent track and there was the potential for more serious consequences had a train from the opposite direction been passing at the time.

What the ATSB found

The ATSB found that the leading right-hand wheel of the second car climbed the outside rail of the small-radius curve. The main factors contributing to the derailment were the high coefficient of friction between wheel and rail and the geometry of a rail joint. The train was being operated within the speed limit for this curve and the manner of its operation did not contribute to the derailment.

It was found that the train's wheel flanges and the rail's gauge-face had low levels of lubrication. The performance of rail lubricators on the metropolitan network had diminished prior to the derailment, leading to a deficiency in lubrication on the network. This was probably the result of a decline in lubricator maintenance. Rail lubricator maintenance was being transferred from contractors to Metro Trains Melbourne (MTM) staff and this transition was not adequately managed.

The derailment at this point on the curve was triggered by a lateral angular discontinuity at a mechanical rail joint, resulting in a localised increase in the wheel-to-rail lateral force. The network's track geometry standard did not preclude the presence of such a discontinuity.

While not mandated by MTM, a check rail on this small-radius curve (installed adjacent to the inner rail) would have provided an additional defence against flange-climb and derailment. A network standard to potentially address derailment risk at higher-risk locations was under consideration at the time of this derailment.

A number of other safety factors were identified that were not directly causal to this incident. They included the ineffective locating of some rail lubricators within the network, a high tolerance on allowable track geometry deviations at this and similar low-speed mainline locations, and a failure to address a wide-gauge defect on this curve.

What's been done as a result

MTM have undertaken a range of actions including the wide-spread installation of new electronic lubricators and significant changes to the management of track condition and faults. These actions, when taken in concert, are expected to reduce the risk of derailment on small-radius curves.

Safety message

The potential for flange-climb derailment on small-radius curves is sensitive to track condition and lubrication between wheel and rail gauge-face. It is therefore important to maintain lubrication across the network and address reductions in performance flagged by unusual wheel wear or evidence of metal loss at the wheel-rail interface.

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Occurrence

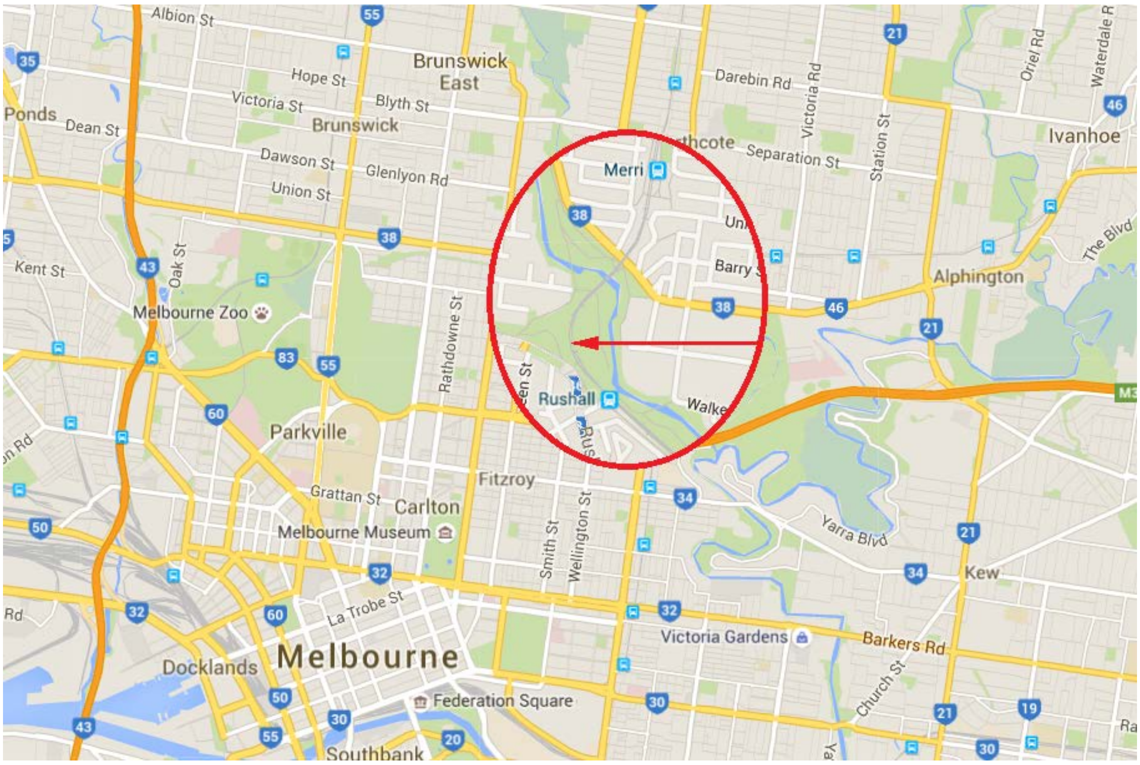
The Melbourne metropolitan rail network and its passenger rolling stock are operated by Metro Trains Melbourne (MTM)[1].

On 5 February 2016, the wheels on this six-car trainset were subject to scheduled machining. This returned the wheels to the ‘as-new’ wheel profile and the train was returned to normal service the next day.

On 6 February 2016, this trainset operated scheduled services from Craigieburn to Flinders Street Station, then Flinders Street Station (via the City Loop) to South Morang. From there, the train ran to Southern Cross then returned to South Morang where it formed the 1630 South Morang-to-Flinders Street service TD1064.

Service TD1064 departed South Morang as scheduled. At about 1650, when travelling between Merri and Rushall Railway Stations (Figure 1), the leading bogie of the second car derailed. The train derailed on a small-radius curve travelling at a speed of about 20 km/h.

Figure 1: The derailment location within the Melbourne suburb of North Fitzroy.



The immediate area of the derailment location is shown enlarged.
Source: Google Maps, annotated by the Chief Investigator Transport Safety (Vic)

The train quickly came to a stop with the leading-end of the second car foul of the adjacent line (Figure 2). The driver was initially unsuccessful in attempts to contact Metrol[2] via the train radio system[3]. The driver subsequently established contact using a company-issued mobile phone about six minutes after the derailment. It was then about another minute before any approaching rail traffic could be halted.

1 MTM is a consortium of Hong Kong’s MTR Corporation (formerly Mass Transit Railway), Australia’s John Holland Group and UGL Rail, a division of UGL (formerly United Group Limited).

2 Metropolitan Train Control Centre. The control centre for all rail traffic in the Melbourne metropolitan region.

3 The GSM-R digital train radio system for the Melbourne metropolitan rail network that was brought into operation in 2014

Figure 2: View of the derailed leading-end bogie of the second car

The leading-end of the second car derailed, and is shown sitting foul of the clearance of the opposite (adjacent) running line.
Source: Chief Investigator, Transport Safety (Vic)

There was one reported passenger injury and minor track and train damage. The double-track location was returned to service in time for the morning peak period the following day.

On 11 February 2016, five days after the derailment of TD1064, a track regulator derailed on the same curve, a short distance from the first derailment. Following this second derailment, there were further track works undertaken on the Rushall curve.

Context

Location

The train was negotiating a 118 m radius-curve, the most severe mainline curve on the MTM network. Known as the ‘Rushall curve’, it was located in North Fitzroy about seven rail km from the Melbourne CBD. The curve had a permanent speed restriction in the Up[4] direction of 30 km/h.

This small-radius curve existed as a remnant of a triangular junction that originally connected the (then) Epping Line to the Royal Park-to-Northcote Loop (also known as the Inner Circle Line). The connection was severed in 1965 and the Royal Park-to-Northcote Loop was subsequently closed. The curve that formed the junction’s eastern leg remained as a portion of the main line between Merri and Rushall Stations (Figure 3).

Figure 3: Derailment location on the 118 m Rushall curve

The red dotted lines indicate the layout of the closed sections of the original junction.
Source: Google Earth, annotated by the Chief Investigator, Transport Safety (Vic)

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[4] Towards Melbourne

Track construction and condition

Travelling towards Melbourne, the Rushall curve was on a 1-in-70 downgrade. It was constructed using wooden sleepers supporting typically 13.7 m lengths of rail joined by mechanical (fishplated) joints in a staggered[5] pattern. Around the point-of-derailment (PoD), rails were on double-shoulder base plates generally attached by plate screws. Rails were mostly secured using resilient fasteners with some use of dog-spikes.

The most recent MTM engineering inspection[6] of the curve was on 2 March 2015 at which time the track was reported as being fit-for-purpose for one year.

Examination of the track following this derailment found evidence of pumping[7] and angular misalignment at mechanical joints. The gauge-face of the outside rail (high leg) had sustained noticeable side wear.

Track geometry

Network tolerances

MTM engineering specification (track)[8] included fault bands for key geometric parameters including track gauge, cant, twist, rail lateral alignment (line) and vertical variation (top) (Figure 4). The fault bands were the same for tangent and curved track.

Figure 4: MTM track geometry maintenance tolerances.

		TRACK CLASS & MAXIMUM SPEED											
		1/HP	2M	2	3		4		5		Note (i)	Sidings	Stop Services Note (ii)
TRACK GEOMETRY PARAMETER	Limit	160 km/h	130 km/h	115 km/h	100 km/h	90 km/h	80 km/h	65 km/h	50 km/h	40 km/h	25 km/h	15 km/h	0 km/h
Wide Gauge (mm) (Applies to both Tangents and Curves)	A	18	18	18	20	21	21	23	25	26	27	28	38
	B	12	12	12	13	14	14	15	16	16	17	18	
Tight Gauge (mm)	A	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-14	-18
	B	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	-8	
Cant (mm)	A	28	30	35	40	45	55	55	55	57	59	61	65
	B	18	20	25	30	35	45	45	45	46	47	49	
Twist / 3.5m (mm)	A	15	18	20	25	28	30	35	40	41	42	43	45
	B	10	12	15	18	23	25	27	30	33	35	36	
Twist / 10m (mm)	A	30	35	40	45	50	55	57	60	61	62	63	65
	B	18	20	30	35	37	40	45	50	51	52	53	
Line (mm)	A	18	20	25	30	32	35	37	40	50	55	60	65
	B	10	12	18	20	23	25	30	35	37	38	41	
Top (mm)	A	18	21	25	28	31	35	37	40	42	43	45	50
	B	12	13	20	22	24	25	27	30	32	34	36	

Note (i) Speeds below 25 km/hr require drivers to be stopped and given an operating speed.

Note (ii) Zero speed means suspension of service until work lifts the track geometry parameters to 15 km/hr capability or better.

The condition tolerances for the Rushall curve were those pertaining to a track speed of 40 km/h (outlined in red).
Source: Metro Trains Melbourne, annotated by Chief Investigator, Transport Safety (Vic)

The engineering specification stated that:

- An ‘A’ fault was to be removed or corrected so that it fell into the ‘B’ fault band, or better. It was permitted to apply a speed restriction to move an ‘A’ fault to the ‘B’ band.
- ‘B’ faults were to be considered when assessing trends and when planning track maintenance, and did not require immediate corrective action.

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5 When rail joints on the Up and Down rails are not opposite (adjacent to) each other, but are positioned alternately.

6 Referred to as Curve Close Inspection in MTM procedures, and entails a thorough walking inspection by track engineers.

7 The dynamic vertical action of the track structure that occurs during the passing of a train. Where the track structure spans an area of degraded subgrade (e.g. with deficient drainage), this action can force fine ballast particles, soil, and water to the surface, fouling the ballast and reducing its load-bearing qualities.

8 MTM Engineering Specification Track, MTSP 030100-01 Track Geometry Maintenance Tolerances, Version 1, September 2012

The Jolimont – South Morang line, that included the Rushall curve, was classified as Track Class 3 (100 km/h) and the geometry tolerances for this class and speed applied for the majority of this line. However, the engineering specification stated that for locations where the line speed was less than the Track Class speed, the fault parameters corresponding to the line speed for that location should be applied. On that basis, for the Rushall curve, the 40 km/h fault limits applied (outlined in red in Figure 4).

Track geometry recording car pre-derailment

The track geometry of the derailment curve was measured using the IEV100 track recording vehicle on 1 December 2015, about two months before the derailment. This identified three ‘A’ faults within the curve based on the 100 km/h line speed (Figure 5). When re-assessed against the requirements for 40 km/h track, only the two wide-gauge faults (at 7.577 km and 7.516 km) remained as ‘A’ faults. Neither of these faults was near the Point-of-Flange-Climb (PoFC) at about 7.554 km.

Figure 5: ‘A’ faults identified within the Rushall curve by the IEV100 recording vehicle

Location of peak (km)	Parameter	Magnitude recorded (mm)	Class 3 (100 km/h) ‘A’ fault threshold (mm)	Class 5 (40 km/h) ‘A’ fault threshold (mm)
7.577	Wide gauge	34	20	26
7.537	Twist (short)	30	25	41
7.516	Wide gauge	33	20	26

Source: MTM track geometry recording 1 December 2015

Post-derailment geometry measurements

Following the derailment, the track geometry through the location was measured over a distance of 90 m from the estimated PoFC back towards Merri station. The geometry was measured using a KRAB[9] track recording trolley that reflects the track’s geometry in an unloaded state. This unloaded measurement would typically be an underestimate of track irregularity compared to the geometry during the passage of a train or the track recording vehicle.

At the estimated PoFC, measured geometry was below the 100 km/h and 40 km/h ‘B’ fault limits for all parameters except gauge. At the PoFC the gauge was about 16 mm wide. This is at the lower limit of the 40 km/h ‘B’ fault band and so would not be considered a critical defect.

Larger irregularities were found away from the PoFC. A static wide-gauge of 29 mm was measured by the KRAB at 7.572 km and was probably the same fault (of 34 mm) identified at 7.577 km by the IEV100 on 1 December 2015, prior to the derailment.[10]

Rail wear

Measurement of the 90 m of track approaching and including the PoFC showed that rail wear was comfortably within the specified limits for top and side wear, and percentage of head loss.

The inner face of the outside rail at the derailment location displayed a generally worn profile consistent with its situation within a small-radius curve. The gauge-face angle was within the network’s permitted maximum of 26 degrees (to the vertical). The measured angle of the gauge-face at the estimated PoFC was about 17 degrees and the highest measured gauge-face angle within the curve was 23 degrees (about 75 m prior to the PoFC).

9 Named after its Czech manufacturer.

10 The IEV100 recording of 34 mm was measured under load and was higher than the static measurement of 29 mm.

Rail gauge-face surface condition

The coefficient of friction at the wheel/rail interface can have a significant impact on the risk of flange-climb derailment. The higher the friction between the contact surfaces, the greater the potential for a wheel to climb the gauge-face of the rail.

The gauge-face of the outer rail was clean and dry, with no visual evidence of either lubricant or contaminants and with a roughened surface (Figure 6).

Figure 6: Gauge-face at estimated point-of-flange-climb

Source: Chief Investigator, Transport Safety (Vic)

Below the worn gauge-face there were steel filings (snow) on the rail foot and ballast (Figure 7).

Figure 7: Metal filings deposited on the track ballast

Source: Chief Investigator, Transport Safety (Vic)

The presence of both the rough gauge-face surface and metal filings below the rail were indicative of high friction and wear conditions and hence indicated a probable deficiency of lubrication between gauge-face and wheel-flange.

The train

Configuration

Train TD1064 comprised two 3-car Alstom X'Trapolis sets (9M-1305T-10M and 1M-1301T-2M) coupled as a 6-car train. The sets were based at the Craigieburn depot and their maintenance was up-to-date.

Post-derailment vehicle inspections

Inspections were conducted on the lead bogie and suspension of car 1305T. Tests and inspections included assessment of bogie frame, suspension and traction components and connections with the leading car. No defects or deviations from specification were identified.

There were witness marks indicating impact between the bogie and the bump stops that limit bogie rotation. Similar marks were found on other X'Trapolis vehicles suggesting that this contact was not uncommon within the fleet. MTM analysis indicated that a static clearance of about 25 mm should have existed at the bump stops when travelling on a 118 m curve.

Wheels

Recent machining

On 5 February 2016, the wheels on both car-sets were subject to a scheduled machining on the underfloor wheel lathe at the Epping Workshops. The wheels were returned to the MP2[11] wheel profile that represents the standard wheel profile for the X'Trapolis fleet. Following the machining, the total distance run to derailment was 79 km.

Post-derailment wheel inspections

Inspection identified circumferential machining grooves from recent machining. On the tread running surfaces, these grooves had been removed and burnished by rolling contact. The burnished regions were consistent with abrasion of the wheel treads from normal tracking of the wheelsets. There were no material defects detected on any wheels during visual inspection.[12]

All wheel flanges on both sides of the train exhibited a localised band of coarse scoring. This scoring was more pronounced on the wheels on the right-hand side of the leading three-car set (in the direction of travel between Merri and Rushall stations), and therefore on those wheels that had been running on the outside of the derailment curve. The scoring damage in the area of the 'throat' (the tread-to-flange radius) was consistent with adhesive wear, and indicated the wheel flanges had been bearing against the rail head. These wheels were dry and did not exhibit any signs of track lubricant.

The wear condition of the first wheel to derail was consistent with other wheels on the right-hand side of the train. The wheel exhibited a band of scoring about 10 mm wide, located within the radius and onto the flange (Figure 8). The location of the wear, like other wheels on the right-hand side of the leading three-car set, indicated that the flange had been riding high on the rail head during curving prior to the derailment.

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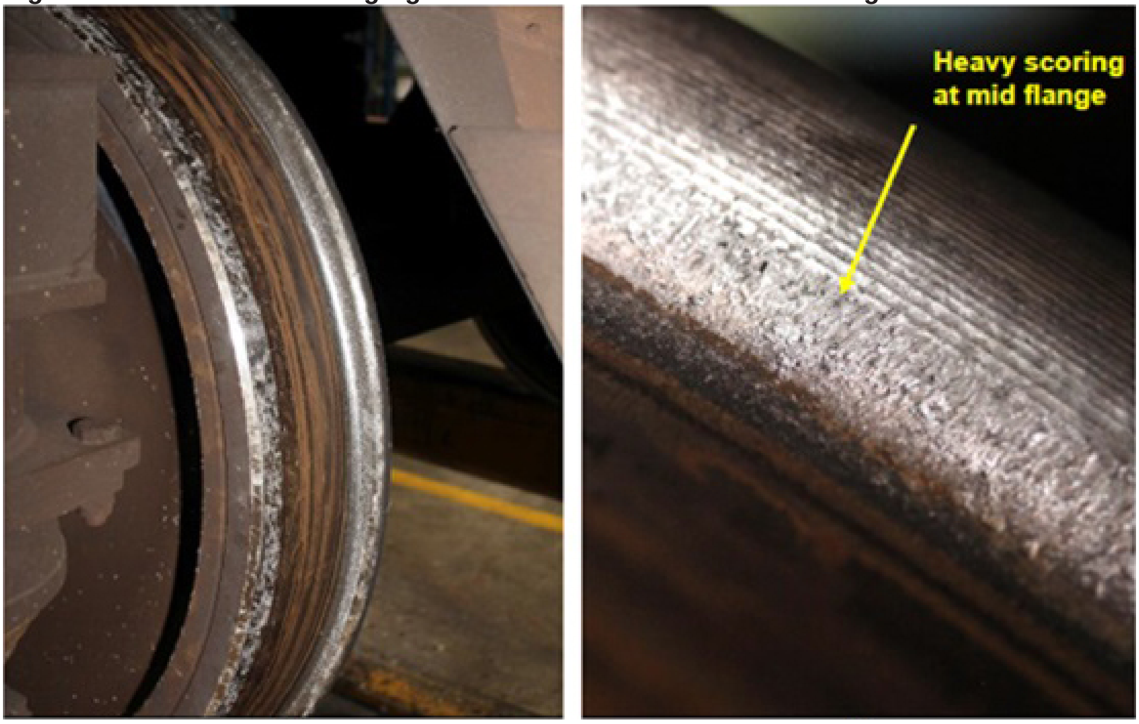
[11] The MP2 wheel profile was developed in the 1980s for the Comeng Disc-braked fleet, and has subsequently been applied to the wheels of all bogies with minimal axle-steering capacity.

[12] ALS Industrial Material Evaluation Report 030362-1-1, 2016

Figure 8: Views of the leading right-hand wheel of car 1305T showing observed wear



The left-hand photograph shows a general view of the wheel's condition. The right-hand photograph shows the heavy scoring within the throat (the tread-to-flange radius) and extending to mid-flange. The machining marks can also be seen to the outside of the scoring. This wheel was the first to derail and also exhibited ballast abrasion markings at the outer edge of its tread.
Source: ALS Industrial

Fleet-wide wheel deterioration

MTM rolling stock division began identifying dry and rough flanges on its fleet in December 2015. The extent of the dry wheel flange issue across the MTM suburban fleet then increased during January 2016 and coincided with increasing wheel wear rates on the V/Line[13] VLocity fleet.[14]

Train driver

The driver had been a Melbourne electric train driver for 11 years. He commenced duty at Epping at 1540, a little more than an hour prior to the incident. The operation of the train was consistent with MTM's requirements, including speed through the derailment curve. The driver underwent a Preliminary Breath Test at Flinders Street station, returning a negative result.

Simulation of train TD1064 passage through Rushall curve

Site evidence indicated that the derailment had occurred as a result of a wheel climbing the outside rail. A computer simulation was conducted of the transit of train TD1064 through the Rushall curve[15] to identify features that might have contributed to or influenced this flange-climb tendency.

[13] V/Line operates Victorian regional rail services. Its trains also operate on the Melbourne metropolitan network

[14] Institute of Railway Technology VLocity Wheel Wear Investigation for V/Line Pty Ltd, Report No. Monash/RT/2016/1144, 1 April 2016

[15] Dynamic simulation of wheel-to-rail contact was conducted by the Institute of Railway Technology, Department of Mechanical Engineering, Monash University. The simulation used Universal Mechanism (UM) software developed by the Laboratory of Computational Mechanics in Russia.

A flange-climb derailment is the climbing of a wheel up the rail gauge-face, then onto, along and over the top of the rail. The simulation used Nadal's[16] single wheel L/V limit criterion to evaluate the potential for flange climb where L is the lateral force of wheel-on-rail, and V is the vertical force of wheel-on-rail (Figure 9). The Nadal equation is widely used by the railway industry.

Figure 9: Nadal criterion for flange-climb derailment

$$\frac{\mathrm{L}}{\mathrm{V}} \geq \frac{\tan(\alpha) - \mu}{1 + \mu \tan(\alpha)}$$

Where:

L = Lateral Force

V = Vertical Force

α = Flange Angle

μ = Coefficient of Friction

The equation defines the L/V ratio at and above which flange-climb is expected to occur for contact conditions defined by coefficient of friction and flange angle.
Source: Nadal equation

The Nadal equation relates the L/V ratio to the physical conditions at the wheel-rail contact. Flange-climb is likely when the L/V ratio equals or exceeds the right-hand side of the equation that is composed of the coefficient of friction between rail and wheel (μ) and the wheel flange angle (α). The required L/V ratio for flange-climb reduces, and therefore the potential for flange-climb increases, as:

- wheel-to-rail friction increases
- wheel flange angle (to the horizontal) decreases

The L/V ratio that occurs at the wheel-rail contact point is an outcome of the dynamic response of the train to the track geometry. The potential for flange climb increases as L/V increases and therefore as:

- the lateral force (L) increases
- the vertical force (V) decreases, such as during wheel unloading.

Rail lubrication

Lubrication can be used to reduce friction levels between rail gauge-face and wheel flange. MTM used mechanical rail lubricators (known colloquially as 'grease pots') to dispense grease to the rail gauge-face at certain locations. The rail lubricator intended to service the outside rail of the Rushall curve (travelling towards Melbourne) was located about 20 m past Merri Railway Station and about 330 m before the Rushall curve (Figure 10).

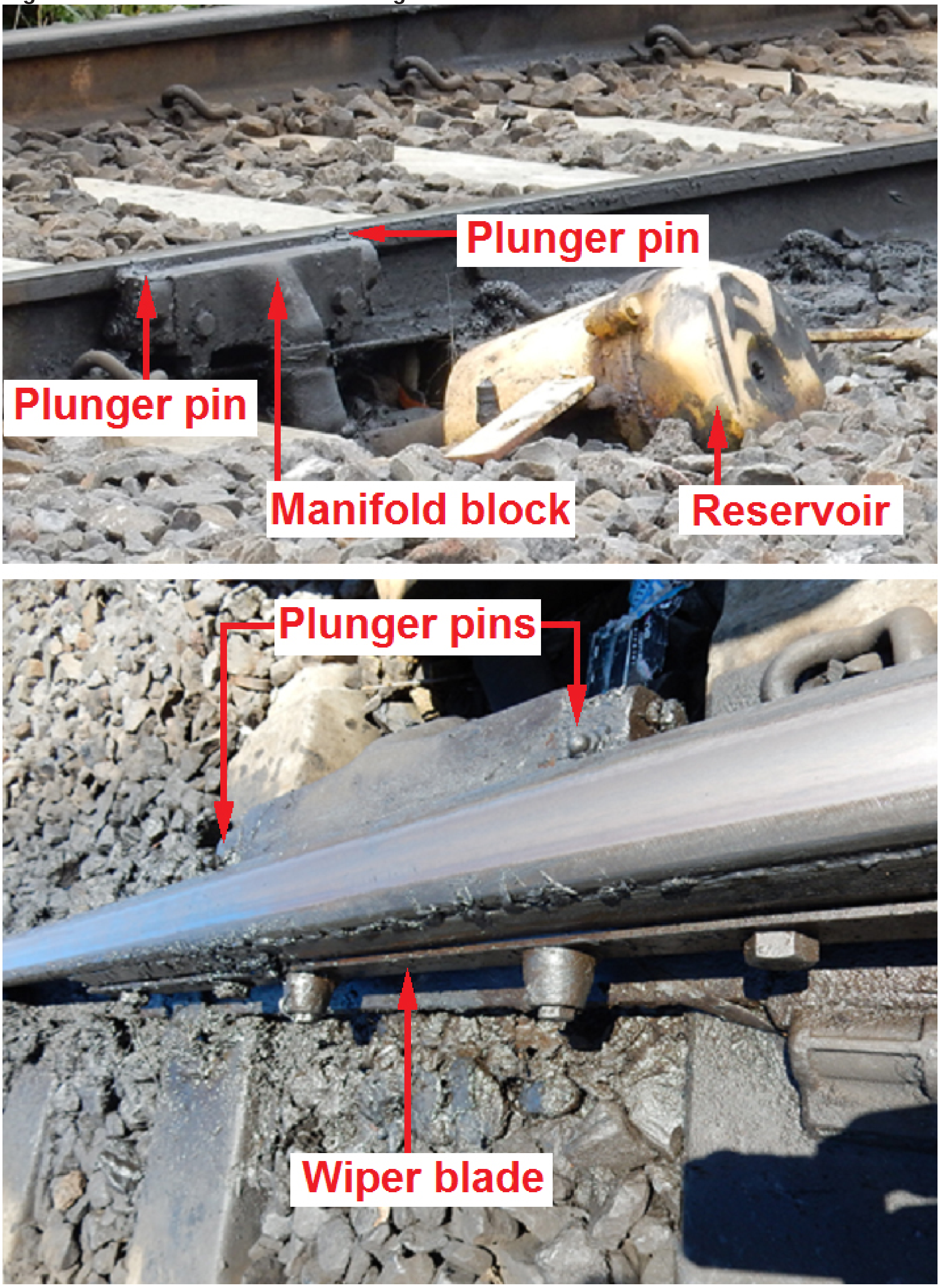
[16] Nadal, M.J., *Locomotives à Vapeur*; (Collection: Encyclopédie Scientifique, - Bibliothèque de Mécanique Appliquée et Génie, 1908).

Figure 10: Location of the rail lubricator, identified as point A

The train was travelling from Merri toward Rushall. Point A represents the position of the rail lubricator on the Up (Melbourne-bound) track, and point B depicts the start of the 118 m curve (the target curve for lubrication) in red. The yellow dotted line represents tangent track and the yellow solid line is the intervening curve. The distance from A to B (orange) was about 330 m.
Source: Google Earth, annotated by the Chief Investigator, Transport Safety (Vic)

The lubricator ahead of the Rushall curve was typical of that used on the Melbourne Metropolitan network (Figure 11). A spring-loaded piston within the lubricator reservoir pressurises the grease. When two lubricator plunger pins (integral to the manifold block) are actuated by a passing wheel tread, grease is pumped from the manifold block to a dispensing 'wiper' blade attached to the gauge-face of the rail. From here grease is picked up by wheel flanges (assuming effective flange contact with the rail head) and distributed along the gauge–face.

Figure 11: The rail lubricator servicing the outside rail of the Rushall curve



Source: Chief Investigator, Transport Safety (Vic)

Lubricant

MTM uses ROCOL Curve Grease in its rail lubricators. It is lithium dioxide-based, and contains solid graphite dispersed in highly-refined mineral oil to provide low friction and a high load-carrying capacity. It works by depositing a 'boundary lubricant' on the rail gauge-face (a thin film that remains effective under extreme pressures) and has a working temperature range from -10 ºC to 150 ºC.

The product has been in use since 1998 and the manufacturer has supplied MTM since 2010 – the amount supplied to MTM having increased over the previous two years. The manufacturer advised that in the past five years there have been no changes to the product's composition (formulation) and no changes to the composition of its material components or their specifications. The product is also supplied to New South Wales (NSW) railways.

The supplier does not provide technical guidance to the customer on dosage rates or on the optimum location of rail lubricators. The manufacturer advised that the presence of metallic fines (snow) below the rail would indicate a lack of lubrication.

Rail lubricator maintenance

Rail lubricators were subject to scheduled servicing during a process known as a Pit Cleaning Occupation (PCO). In this process, the immediate environment around and between station platforms was serviced and maintained.

Through 2015, rail lubricators were maintained by Sunstone Resources Pty Ltd[17] under contract from MTM. These arrangements changed towards the end of 2015 and MTM advised that it ceased using Sunstone for lubricator maintenance in December 2015.

Around this time, one individual from the Sunstone lubricator maintenance team joined MTM. He and an existing MTM employee were tasked with training other MTM track maintenance staff in lubricator maintenance. MTM advised that it had been difficult to organise safeworking arrangements for access to the track during this transition period and that lubrication activities were subsequently fully re-established in February 2016.

Records for rail lubricator maintenance on the South Morang line from July 2015 to February 2016 (Figure 12) indicated that monthly inspection and maintenance had been conducted through to December 2015, and that no further maintenance had then occurred until after the derailment.

Figure 12: Recorded lubricator maintenance on the Rushall curve lubricator

Date	Piston movement (cm)	ATSB notes
18/7/15	24	
15/8/15	22	
12/9/15	25	
11/10/15	19	
14/11/15	10	Reduced quality of record
12/12/15	18	Reduced quality of record
12/2/16	15	Following derailment

This table displays the dates of lubricator maintenance on the Rushall curve lubricator. The piston position is an indication of the amount of grease remaining in the pot. A piston position of 30 cm indicated that the lubricator 'pot' was nearing empty.
Source: Metro Trains Melbourne

17 Founded in 2013 with shareholders MTR (Hong Kong), John Holland Group and UGL Limited. Sunstone Resources has subsequently ceased operation.

The lubricator inspection records provided no detail on the extent of any refill and whether the piston movement measurement was taken before or after refill. Other entries on these records, around inspection activities undertaken and lubricator settings, were identical across all records.

Inspection frequency

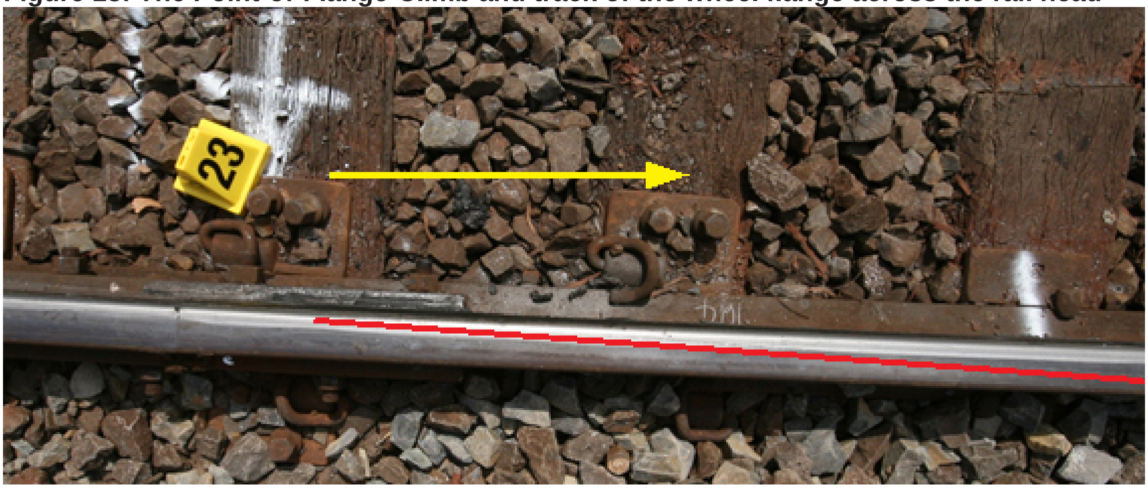
The relevant MTM work instruction[18] specified the steps associated with lubricator maintenance, the tools required and management accountabilities. This instruction stated that the asset manager was responsible for determining the type and frequency of lubrication inspection in order to ensure a safe and efficient track infrastructure.

MTM advised that the maintenance plan required that lubricators be inspected every three months. This differed from the monthly interval specified up until 2012 and was reportedly the result of a risk assessment process. Irrespective of this reduced frequency of planned inspection, records indicate that the Sunstone maintenance team were inspecting lubricators on a monthly cycle.

Related occurrences

On 11 February 2016, five days after the derailment, a track regulator[19] travelling towards Melbourne derailed on the Rushall curve at a subsequent mechanical joint on the Up track. The flange-climb was again just beyond a rail joint in the outside rail (Figure 13). The derailment had occurred despite hand-greasing of the rail gauge-face following the first derailment.

Figure 13: The Point-of-Flange-Climb and track of the wheel flange across the rail head



The photograph is annotated to show the direction of train travel (yellow arrow) and the flange track along and across the rail head (red line). Note that the point of flange-climb commenced immediately after the rail joint.
Source: Chief Investigator, Transport Safety (Vic)

[18] MTMI 033100-04, L2-TRK-MAI-005 *Track Maintenance Instruction, Rail Lubricator – Examination and Servicing*, Version 1, effective 14 June 2013.

[19] Maintenance vehicle used to distribute and profile track ballast.

Safety analysis

The derailment

Train TD1064 was travelling towards Melbourne when it derailed on the tightest curve on the metropolitan mainline network. The train was being operated within the speed limit for this curve and its manner of operation did not contribute to the derailment.

Site observations identified that the train derailed as a result of flange-climb by the leading right-hand wheel of the second car.

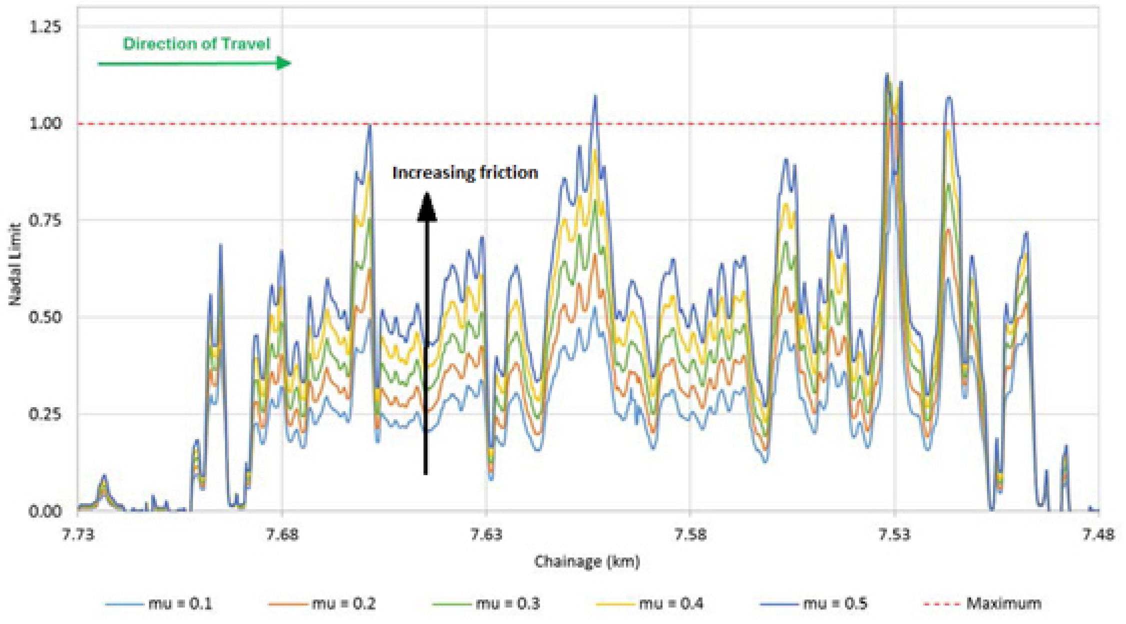
Wheel-rail coefficient of friction and lubrication

Coefficient of friction

At the point of flange-climb, the rail gauge-face surface indicated high-friction wheel-to-rail contact. Metal filings from this contact were also observed at the base of the rail. Based on measurements from across the network, expert opinion[20] was that the coefficient of friction between the gauge-face and wheel flange was probably around 0.45 at the derailment location.

The coefficient of friction between the wheel and rail has a significant influence on the risk of flange-climb derailment. Simulations applying flange-climb criterion to this curving scenario showed that the potential for flange-climb increased significantly with increasing friction (Figure 14).

Figure 14: Simulation results for the derailed car (1305T) for a range of friction conditions



The diagram shows the estimated Nadal index through the Rushall curve for a range of wheel-rail coefficients of friction. The higher the coefficient of friction, the greater the likelihood of flange-climb derailment.
Source: Institute of Railway Technology (Monash University)

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20 Friction measurements undertaken by the Institute of Railway Technology (Monash University) elsewhere in the Victorian rail network have found that for rough, dry surfaces (such as those observed at the Rushall derailment site), gauge-face friction levels of around 0.45 could be expected.

Relationship between lubrication and coefficient of friction

The relationship between the coefficient of friction and lubricant film thickness is well-established. The higher the lubricant film thickness, the lower the coefficient of friction between wheel flange and rail. For example, a friction coefficient of 0.15 is considered to represent a well-lubricated contact condition, whereas around 0.45 would represent an unlubricated interface.

In the case of small-radius curves, effective lubrication is critical. In this instance, there were clear signs of abrasive metal-to-metal contact indicating that lubrication between rail and wheel was inadequate.

Network lubrication

Metro Trains Melbourne (MTM) rolling stock division identified an increasing rate of dry and rough wheel flanges from December through to this derailment. This increased presence of dry flanges in the MTM fleet was almost certainly the result of a deterioration in rail lubrication across the network. The dry summer conditions may have also added to a reduction in lubrication performance.

MTM advised that previous periods of dry and rough flanges in 1987, 2006 and 2012 were identified as likely being the result of issues with the filling and servicing of rail lubricators. The most recent period of dry flanges was also likely to be associated with lubricator inspection and maintenance.

Rail lubricator maintenance

The arrangements for maintaining lubricators were changed towards the end of 2015 when MTM ceased using its affiliated contract company. There was then no further inspection of lubricators on the South Morang line until after the derailment in February 2016.

MTM advised that their maintenance plan required that lubricators be inspected every three months, although up to December 2015, lubricator inspection was reportedly on a monthly cycle. MTM track managers were aware of the specified maintenance cycle of three months and this may have influenced them in taking several months to establish an effective lubricator maintenance regime.

Fleet rolling stock wheel condition indicated that the degree and standard of network rail lubrication had started declining in December 2015 and had further deteriorated through January and early February 2016. The most probable reason for this deterioration was a reduction in the effectiveness of rail lubrication across the network. This probably resulted from inadequate lubricator maintenance during the transition from contracted to internal maintenance.

MTM was aware of the fleet-wide deterioration in wheel condition, but the response was inadequate to prevent this derailment.

Location of lubricators

MTM managed flange-to-rail lubrication using fixed rail lubricators. Guidance on the placement of rail lubricators was provided in an MTM procedure[21], and included the advice that lubricators:

- should not be positioned at or near small-radius curves[22] (defined as being with radii less than 300 m)
- should not be positioned at locations where there was no or minimal wheel flange contact (such as on tangent track)
- should not be co-located (adjacently on each rail), but rather each lubricator should be located at the entrance to the curve it was intended to service

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[21] MTPR 033100-04 L2-TRK-PRO-031 *Track Procedure Rail Lubrication,* Version 1. Effective 14 June 2013.

[22] Due to the potential for inefficient and often excessive lubrication and contamination of the running surface.

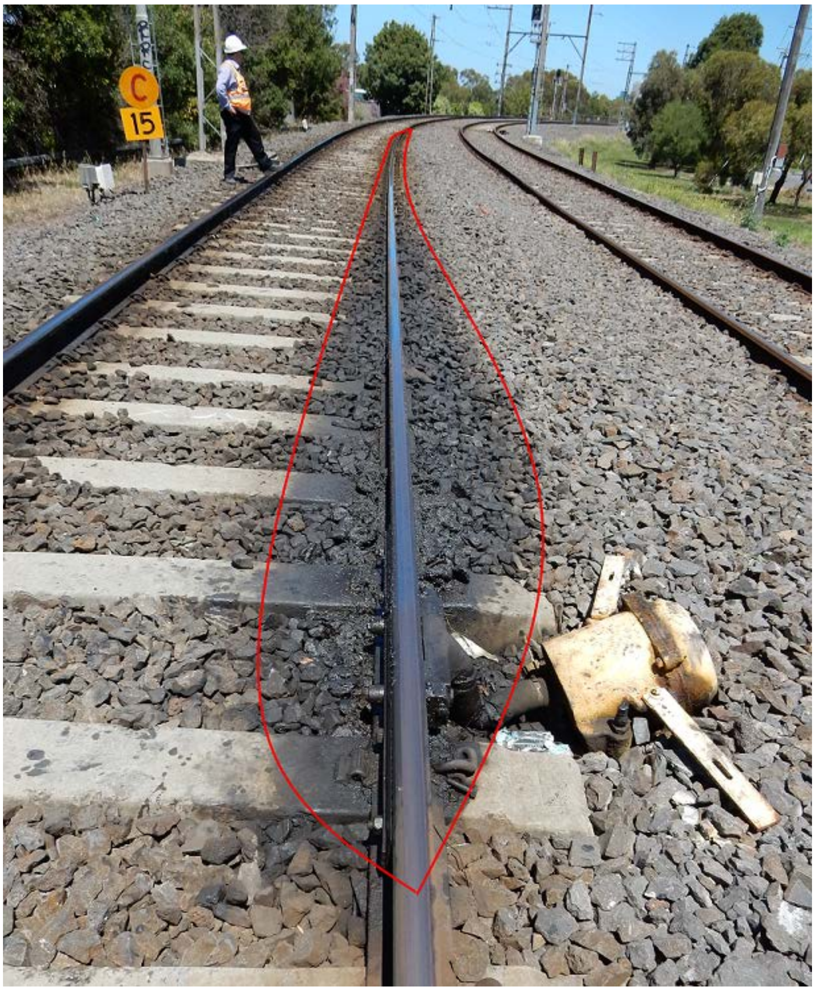
- should be located at the beginning of a moderate-radius feeder curve ahead of the more severe target curve.

Specialist advice provided to MTM's predecessors was that track lubricators should be located at the lead-in to the target curve. Two reports (prepared in 2000[23] and 2007[24]) provided information about the effective siting of rail lubricators. Many of the lubricators examined during these studies were located on sections of tangent track distant from the curves being serviced. Advice was provided that such positioning was not suitable for efficient lubrication. In addition, the practice of co-locating lubricators (for each rail) was identified as ineffective and undesirable.

MTM's procedure (June 2013) for locating rail lubricators reflected the advice provided within these specialist's reports. However, a recent MTM audit found that 43 per cent of lubricators were in fact located on tangent track. This would have resulted in an inefficient use of lubricant and the potential for lubricator performance to be less effective than desired.

The lubricator that was provided to service the gauge-face of the outside rail of the left-hand Rushall curve (Up track) was located on tangent track in advance of an intervening right-hand curve. This would have led to less-effective pick-up of lubricant, and where pick-up did occur, too much of that lubricant being deposited directly back onto the track (Figure 15).

Figure 15: Rail lubricator for the Rushall curve Up track and grease plume



This image shows the rail lubricator for the Rushall curve, located on tangent track. The grease plume indicates that much of the lubricant has been flung off the wheel and deposited on the track. Note that the right-hand curve in the distance is an intervening (opposite) curve, and is not the one intended to be served by this lubricator. The left-hand Rushall curve is further in the distance and not shown on this photograph.
Source: Chief Investigator Transport Safety (Vic)

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23 Rail Services Australia Technical Report (December 2000).

24 Marich Consulting Technical Note on track lubrication (November 2007).

Wheel-to-rail contact

Wheel surface condition

Compared to a typical worn wheel, the recently-machined wheels of train TD1064 had roughened flanges. There was heavy scoring of the throat, and some remaining circumferential machining grooves towards the flange tip (Figure 16). The scored and grooved area was within the band that would contact the rail gauge-face, and it is probable that this roughened surface contributed to an increased coefficient of friction between wheel and rail.

Figure 16: Comparison between derailed wheel (left) and normally worn wheel (right)

This image depicts the difference between the surface condition of the derailment wheel (left) and a typical worn wheel (right). The derailment wheel shows heavy scoring within the throat (the tread-to-flange radius) and residual machining grooves, compared to the relatively smooth finish on the normally-worn wheel.
Source: Chief Investigator, Transport Safety (Vic)

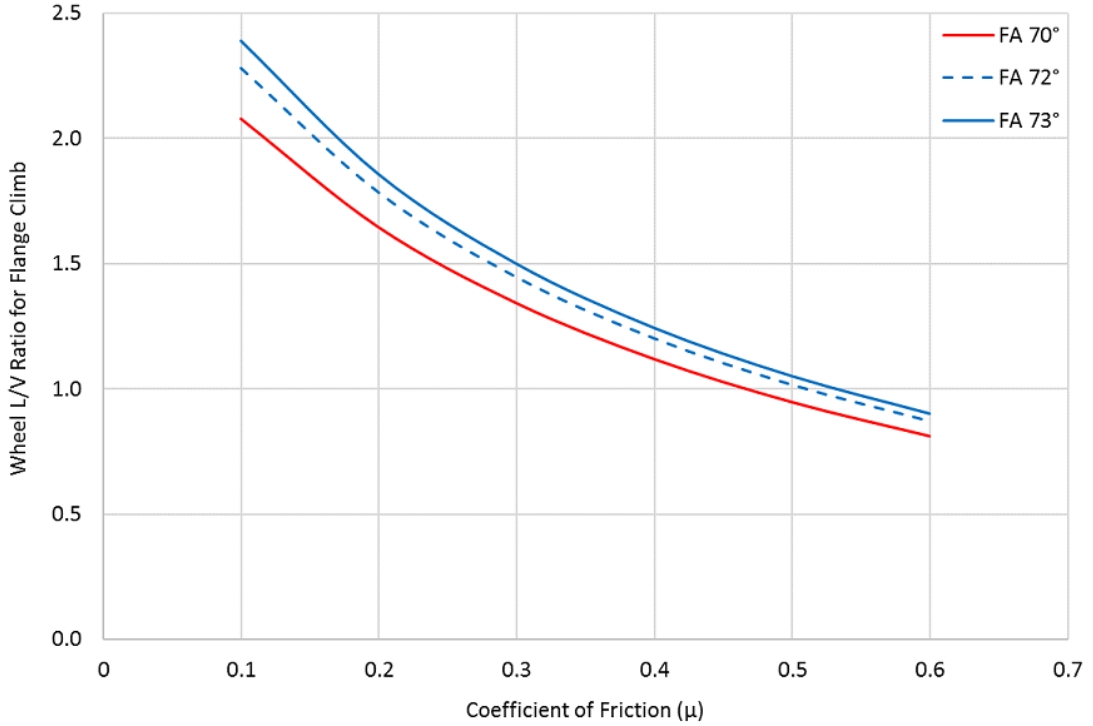
It is probable that there was insufficient lubrication on those parts of the network traversed prior to the derailment, leading to the wheels suffering excessive abrasive wear and scoring. The roughened surface and machining grooves increased the likelihood of a flange-climb event. Application of lubricant to the wheel flange after machining of the wheels, and/or an improved surface finish, can reduce friction and reduce the risk of flange-climb by a newly-profiled wheel set.[25]

[25] Transportation Research Board (2005) *Flange Climb Derailment Criteria and Wheel/Rail Profile Management and Maintenance Guidelines for Transit Operations,* The National Academies Press pp25.

Wheel profiles

The current MP2 wheel profile has been in service on the Melbourne network for more than 20 years, with no known reported issues. The MP2 wheel flange angle of 70 degrees (to the horizontal) provides good protection against flange-climb, particularly when combined with effective rail lubrication in sharp curves. As the MP2 wheels wear, the flange angle increases to around 72 degrees, which improves protection against flange climb (Figure 17).

Figure 17: L-on-V ratio for flange climb, for a range of flange angles (FA)



The figure shows the effect of flange angle on the relationship between the L/V ratio required for flange climb and contact coefficient of friction. The MP2 wheel profile in a new or newly-machined condition represents the worst case in terms of flange-climb risk, with a flange angle of 70°. As this profile wears, the flange angle increases to an average of around 72° (matching the typical gauge-face profile), with an upper level of around 73°, and the potential for flange-climb reduces.
Source: Institute of Railway Technology (Monash University)

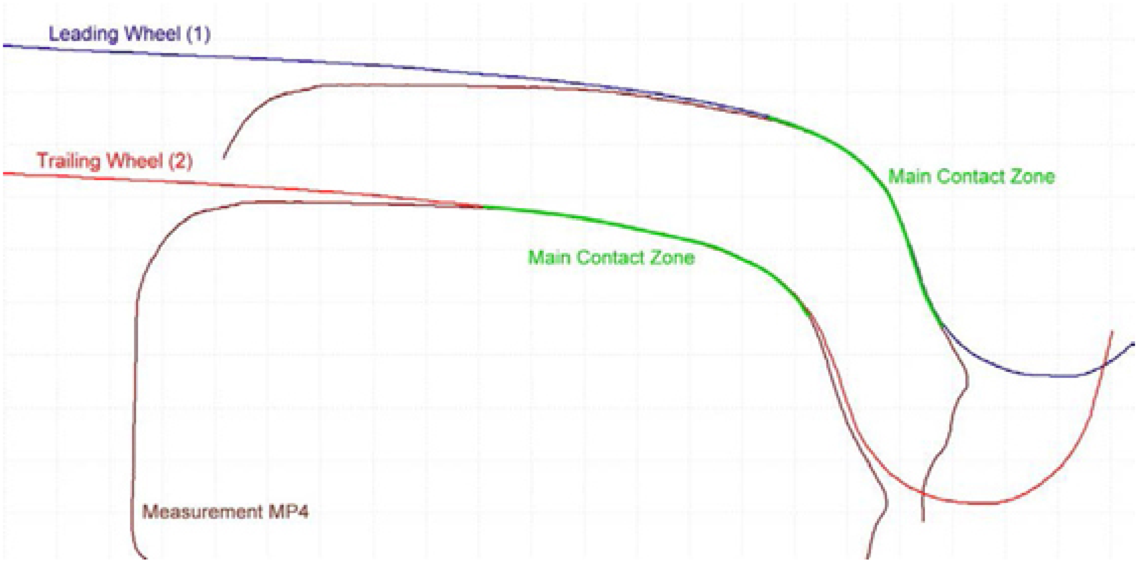
The wheels of derailed car 1305T had been re-machined to the MP2 wheel profile the day before the derailment and had only run over a distance of 79 km. Although the MP2 profile provided good protection against flange-climb, the flange angle of the newly-machined wheels increased the risk of flange-climb compared to wheels that were in a worn condition.

Wheel-to-rail contact

Measured profiles of the outside rail in the derailment curve generally matched closely with the worn MP2 wheel profile. The gauge-face angle was generally around 18 degrees (to the vertical) which was consistent with the flange angle of 72 degrees (to the horizontal) of worn wheels. The angle of the gauge-face was also well within the network limit of 26 degrees.

An overlay of wheel and rail profiles (Figure 18) showed no significant abnormality and rail contact conditions were generally consistent with expectations. Comparison between this overlay and a worn wheel-to-rail overlay found that the newly-machined wheel rode slightly higher on the rail.

Figure 18: Wheel - rail profile overlay for the right-hand wheels of the derailed bogie

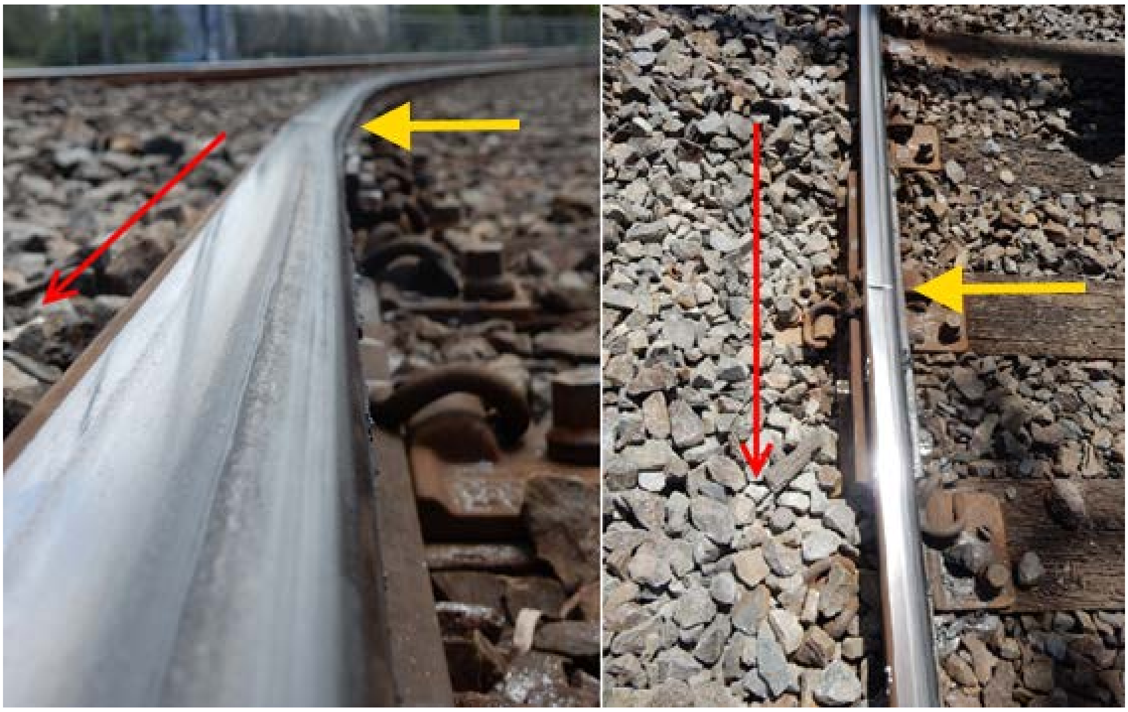


Source: Institute of Railway Technology (Monash University)

Angular discontinuity at rail joint

The mechanical rail joint located just prior to the estimated Point-of-Flange-Climb (PoFC) had created a lateral angular discontinuity (kink) in the line of the rail (Figure 19).

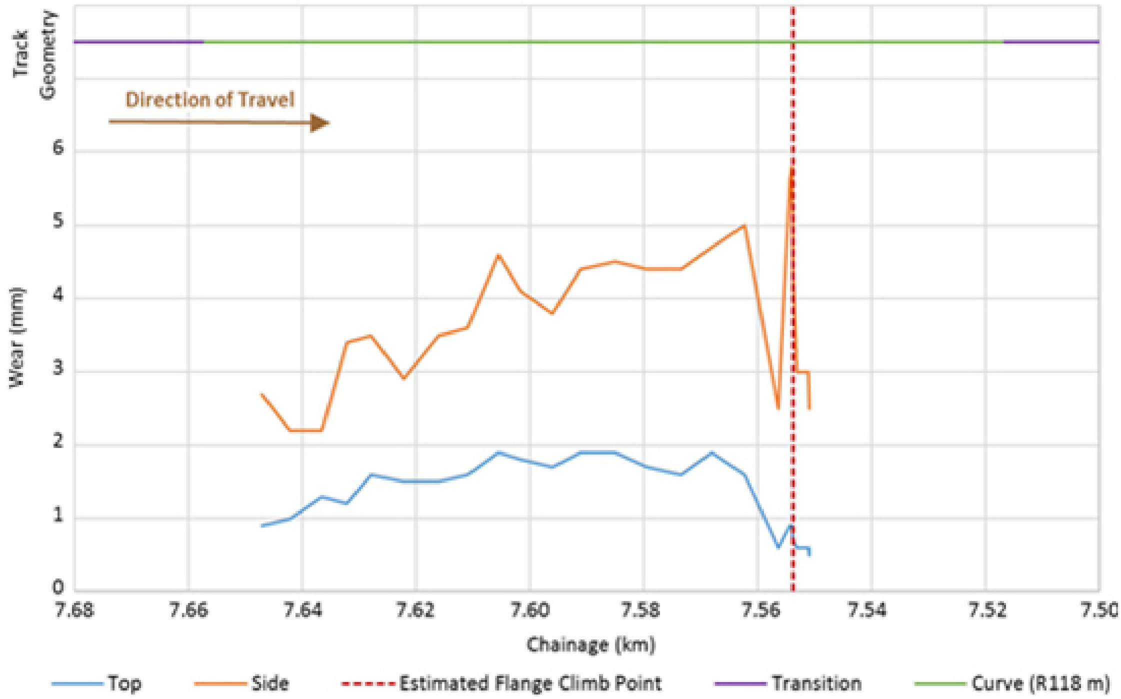
Figure 19: The outside rail and the lateral angular discontinuity at the mechanical joint



The two images depict the angular change in the line of rail at the mechanical rail joint (indicated by yellow arrows) that was about 0.6 m ahead of the first detectable point of flange climb. The train's direction of travel is shown by the red arrows.
Source: Chief Investigator, Transport Safety (Vic)

The angular discontinuity at the mechanical joint would have had the effect of increasing the wheel-to-rail angle-of-attack to the rail and causing a peak in the wheel-to-rail lateral force. This peak is also evidenced by the peak in rail head side-wear at this location (Figure 20).

Figure 20: Top and side-wear for the outside rail of the derailment curve



This figure shows the sharp increase in side-wear at the estimated PoFC, just beyond the mechanical joint. The sharp increase in side-wear correlates with the angular discontinuity at the mechanical rail joint.
Source: Institute of Railway Technology (Monash University)

It is therefore probable that in the context of poor lubrication and existing track geometry, the angular discontinuity at the mechanical joint was sufficient to initiate flange-climb at this particular point on the curve. A second derailment a few days later involving a track machine, was also the result of flange-climb by its leading right-hand wheel just beyond a subsequent mechanical joint.

Identification and management of joint misalignment

The network's track geometry standard did not include any specific requirement to directly assess a localised angular discontinuity at a mechanical joint. The measurement and monitoring of rail line is specified within the network maintenance standards (Figure 21).

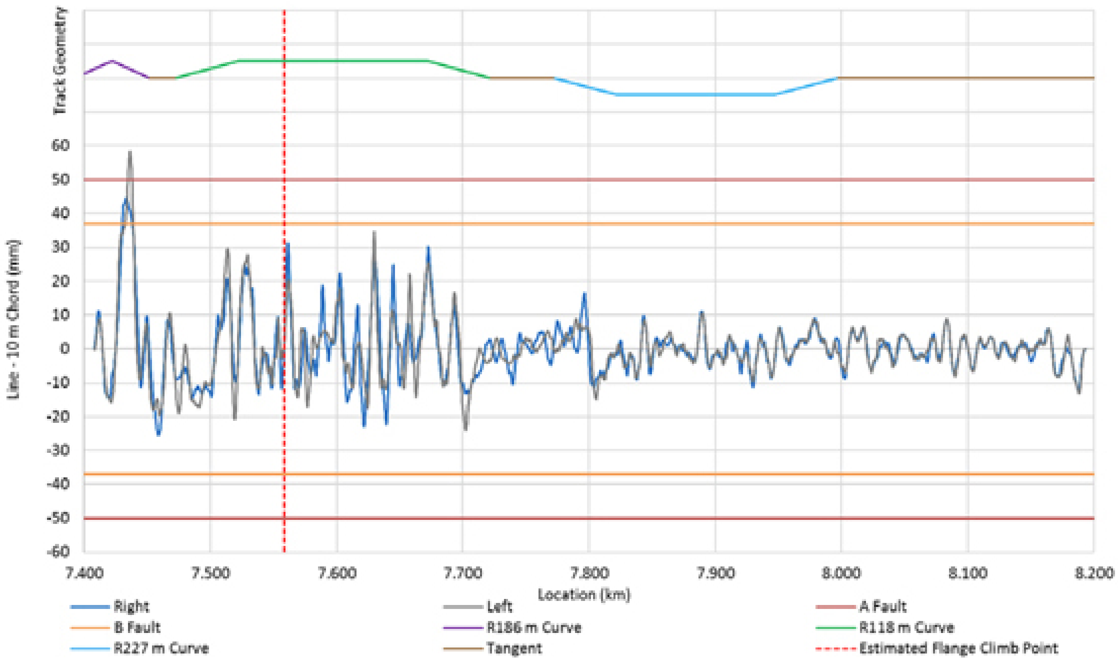
Figure 21: The MTM network line variation standard for 110 km/h and 40 km/h speeds

	Class 3 (100 km/h)	Class 5 (40 km/h)
A Fault	30 mm	50 mm
B Fault	20 mm	37 mm

The table shows the fault criteria for 100 km/h track, as applied to the corridor, and 40 km/h track, as applied to the Rushall curve.
Source: Extracted from MTM maintenance specifications

The track geometry recorded after the derailment showed several peaks (positive) and troughs (negative) in rail line deviation (Figure 22). In the area of the derailment, all peaks and troughs were below the 40 km/h 'B' Fault criteria. The series of peaks leading to the PoFC are consistent with the joint spacing.

Figure 22: Track 'line' through the Rushall curve measured following the derailment



Source: Institute of Railway Technology (Monash University)

In December, prior to the derailment, the IEV100 track recording vehicle had also detected variations in the line of both rails within the Rushall curve. There were two recorded deviations in each rail, although neither at the Point-of-Derailment. Again however, all line faults were below the threshold for a 'B' fault applied to 40 km/h track and so did not require maintenance action.

In the context of the prevailing high friction wheel-rail conditions, the general track condition and geometry and the re-profiled wheels, the geometry at the mechanical joint was sufficient to result in flange-climb at that location.

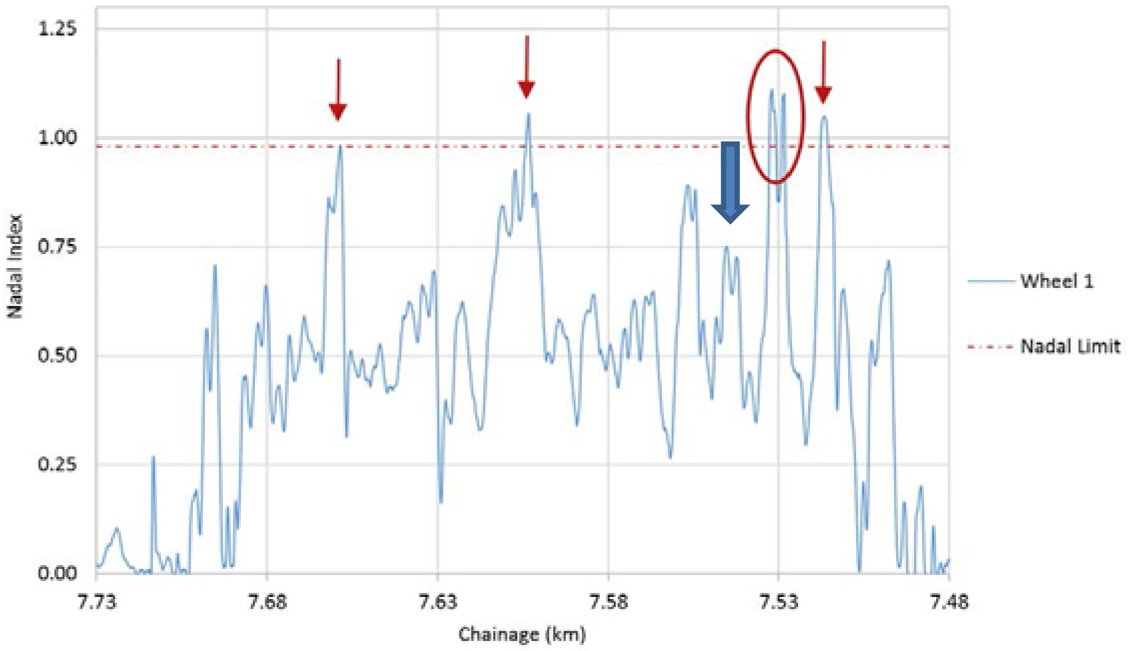
Noting that track 'line' was within the applied network track geometry maintenance tolerances, there was no other system in place to identify that the degraded state of geometry at a mechanical joint may be such as to promote a flange-climb event.

Influence of other track geometry on potential for flange-climb

In simulation studies using a coefficient of friction of 0.5, the criterion for flange-climb was exceeded at four locations within the Rushall curve (Figure 23). The derailment of train TD1064 did not occur at any of these points, but rather a smaller peak in Nadal Index that, when combined with the effects of the mechanical rail joint, produced the conditions for flange climb.[26] Nevertheless, the potential for flange-climb existed at several locations through the curve and partial climbing at these locations was possible. For the three days prior to the derailment, the car-set's logger recorded numerous acceleration transients at various locations through the Rushall curve, suggesting unusual tracking behaviour.

[26] The data resolution and modelling used in the simulation were such that the localised effects of the mechanical joint were not modelled.

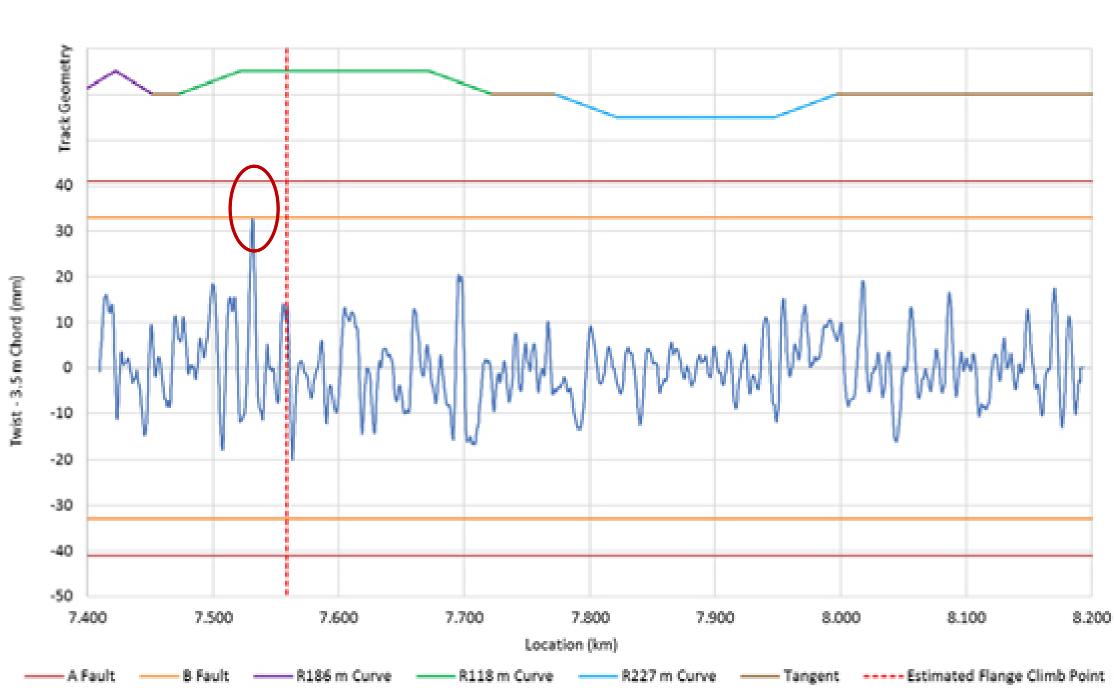
Figure 23: Results of the simulation (the Nadal index) for a coefficient of friction of 0.5



The simulation showed that the Nadal index of 1, that is the threshold for derailment, was potentially exceeded at four locations. The greatest exceedance is circled on the figure. The PoFC was at a smaller peak with an index of about 0.75 (identified by the blue arrow). This data resolution and modelling used in the simulation did not account for the localised effect of the joint.
Source: Institute of Railway Technology (Monash University)

The maximum Nadal Index calculated by simulation occurred at a point at which a number of track geometric features combined to make the train susceptible to flange-climb, in particular a peak in track twist (Figure 24).

Figure 24: Measured track short twist through the Rushall curve



The short twist (3.5 m chord) in track geometry (circled) coincided with the maximum Nadal Index circled in Figure 23. This figure is plotted in the opposite direction to Figure 24.
Source: Institute of Railway Technology (Monash University)

The peak in Nadal Index occurred where there was an in-phase[27] lateral alignment variation towards the inside of the curve and out-of-phase[28] variations in left and right rail 'top', leading to the track twist.The combined effect of a change in lateral alignment towards the inside of the curve and the partial wheel unloading associated with the twist increased the L-to-V ratio to a critical level, increasing the likelihood of flange-climb.

Tolerances within track geometry standards

At the simulated point of highest risk of flange-climb, track geometry, including top, line, twist and gauge, was compliant with the network's 40 km/h limit that was applied to the Rushall curve (Figure 25). However, in the prevailing high-friction conditions, a combination of these compliant geometric irregularities, particularly twist and line, resulted in a high chance of flange-climb.

Figure 25: Geometric parameters at the maximum L/V

	Measured parameter at the Maximum L/V		Class 3 (100 km/h)	Class 5 (40 km/h)
Line	28 mm	A Fault	30 mm	50 mm
		B Fault	20 mm	37 mm
Top	< 20 mm	A Fault	28 mm	42 mm
		B Fault	22 mm	32 mm
Short Twist	33 mm	A Fault	25 mm	41 mm
		B Fault	18 mm	33 mm

Source: Chief Investigator, Transport Safety (Vic)

The current network tolerances on track geometry for low-speed curves did not prevent the potential for flange-climb reaching these critical levels, suggesting that the current track geometry limits were inadequate for small-radius mainline curves where flange-climb risk is at its highest.

Influence of cant excess at lower train speeds

At the PoFC, the track cant of 77 mm was close to the design level and well within the network's tolerances. However, the train's low speed of 20 km/h meant that the cant at the PoFC was in excess of the equilibrium cant[29] of about 40 mm for that train speed. This excess cant condition would have increased the leading wheel angle-of-attack and propensity for flange climb.

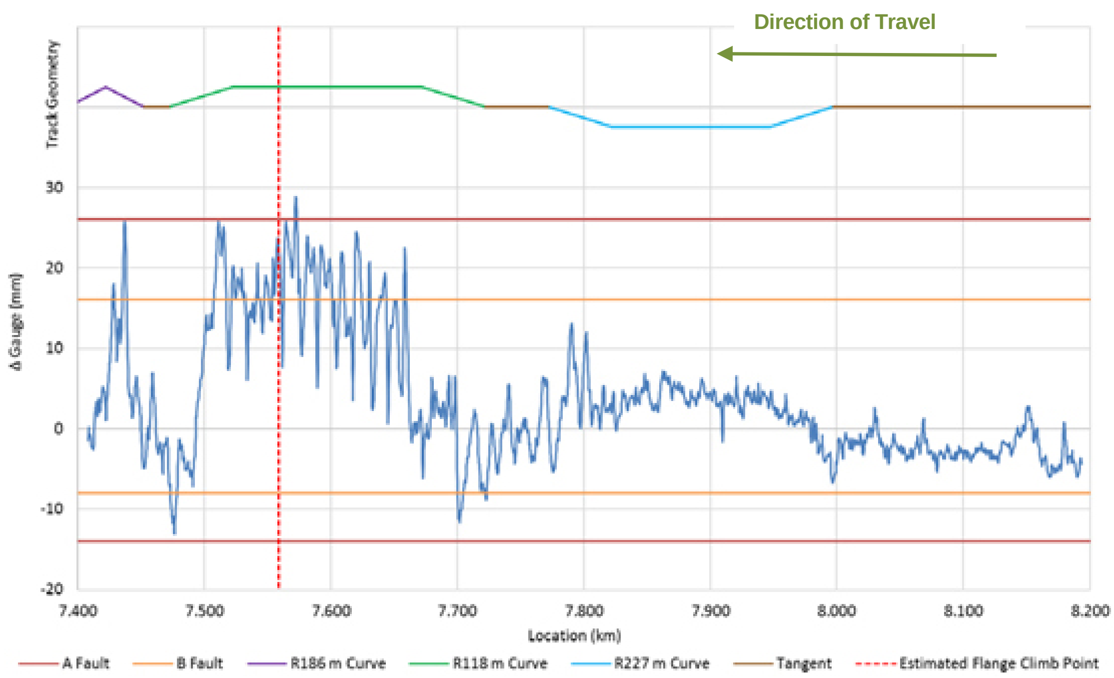
Management of wide gauge

Gauge-widening of small-radius curves was a standard, documented, MTM practice[30] in which track maintenance staff were trained. The network standard specified that for curves of 120 m radius and less (as was the Rushall curve), the track gauge may be widened by up to 12 mm.

Post-derailment measurement identified that track gauge through the curve was variable and often exceeded the specified widening of up to 12 mm (Figure 26).

[27] Both rails having a lateral alignment variation occurring roughly at the same point.
[28] Meaning one rail is peaking while the other is in a trough.
[29] The cant at which the centrifugal force developed during the movement of a train on a curved track at a particular speed is balanced by the cant provided.
[30] MTPR 033000-08 *MTM WELDED TRACK MANAGEMENT MANUAL*, v2, Chapter 8, clause 1.13.

Figure 26: Track gauge through Rushall curve measured after derailment



This diagram shows numerous exceedances of the wide gauge 'B' limit and one 'A' limit exceedance within the Rushall curve.
Source: Institute of Railway Technology (Monash University)

The post-incident track measurement also identified a wide-gauge 'A' fault[31] although the fault was not at the PoFC, and so did not contribute to the derailment.

Records indicate that the wide-gauge 'A' fault had been present since early 2015, and had not been corrected. The history of this fault can be tracked over time (Figure 27).

Figure 27: History of wide gauge "A' fault

Date	Wide Gauge	Recorded km[32]	Comment
1/3/15	33 mm	7.571	Work order TR005087 No evidence of close-out.
1/12/15	34 mm	7.577	Recorded by IEV100
7/12/15			'A' fault closed-out on Ellipse[33]
11/2/16	29 mm	7.572	KRAB post-incident (static)

Source: MTM maintenance records

In terms of flange-climb, the effect of wide gauge is related to an increase in wheel angle-of-attack.

In this instance the wide gauge of over 30 mm was excessive, and this 'A' fault was permitted to exist for an extended period, contrary to network standards. The fault was closed-out on the asset management system even though it had not been rectified.

31 For the 40 km/h curve, the 'A' fault band for wide gauge was 26 mm and above.
32 The small variations in recorded km position are considered within tolerance across the different recording systems.
33 *Ellipse* is an asset management and resource planning application used by MTM.

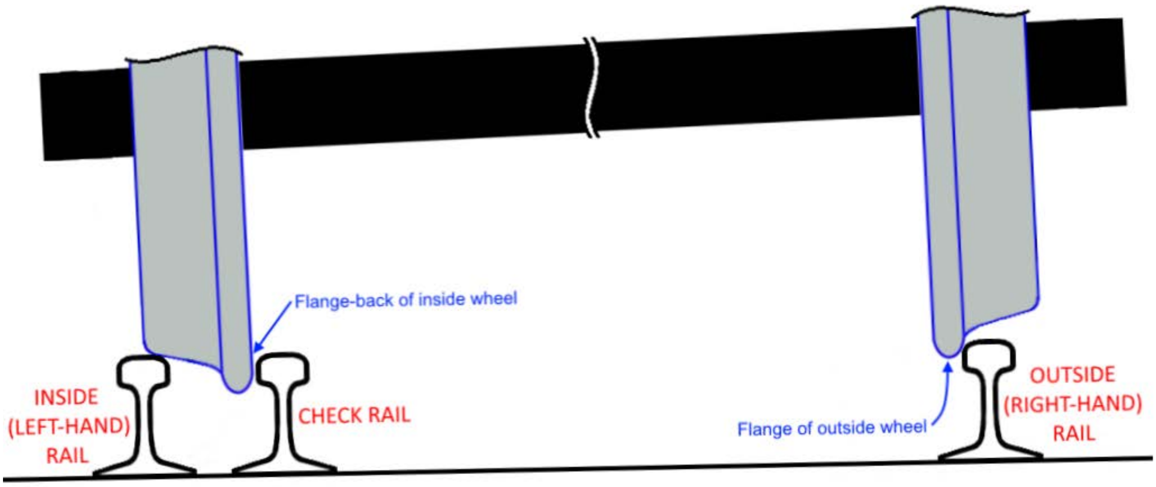
Risk mitigation for small-radius curves

MTM infrastructure standards had no special requirements for the management of derailment risk on small-radius curves. Following risk assessments in 2013[34], the potential need for further derailment protection at high risk locations was flagged. The development of an associated network standard was still under consideration at the time of the Rushall derailment.

Use of Check Rails to mitigate risk of flange climb

One possible method of derailment protection on small-radius curves is a check rail. A check rail (laid closely parallel to and inside the running rail) can be installed on severely-curved track to reduce the risk of derailment and to limit rail head and gauge-face wear. This extra rail comes into contact with the back of the wheel flange and can be used on sharp curves (and other locations) as a check against the opposite wheel of the wheelset climbing the high rail[35]. This restriction to lateral displacement also serves to distribute the lateral force on the wheelset, relieving some of the force on the outside flange (Figure 28).

Figure 28: Use of a check rail in a curve



This illustration demonstrates how a check rail interacts with the back face of the inside wheel flange.
Source: Chief Investigator, Transport Safety (Vic)

Check rails have long been a common global track engineering feature, although their use in Australia has diminished. Check rails were previously used on the Melbourne metropolitan rail network until their general use was discontinued at some point during the 1960s. Check rails had previously been installed on the Up and Down Rushall curves (Figure 29).

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[34] MTM Project Engineering Support, Regional Rail Link, Derailment Containment: *RRL Derailment on High Risk Locations* (Draft, v1, advised by MTM as being current).

[35] Australasian Railway Association Glossary for National Code of Practice and Dictionary of Railway Terminology.

Figure 29: Historical use of check rails on Rushall curve c1965.

The red arrows show check rails on both Up and Down tracks. The left-hand track in this image is the derailment curve.
Source: Bob Wilson, annotated by the Chief Investigator Transport Safety (Vic)

The use of check rails is mandated in several overseas jurisdictions, but not in Australia. Other Australian jurisdictions advised as follows:

- In NSW, check rails now exist on only a few lines of Tourist & Heritage status. Apart from these operations, NSW country and metro lines have no curvature below 150 m radius and no longer use check rails
- In South Australia, the Adelaide Metro (a broad-gauge network) has no curvature more severe than 200 m radius and does not use check rails for curve derailment prevention. They advised, however, that they do make use of check rails for derailment prevention in locations where critical buildings or structures are in extremely close proximity to the track and considered to be vulnerable

Information from sampled international jurisdictions was that:

- In the United Kingdom, check rails are required on passenger lines with curves having a horizontal radius of 200 m or less[36]
- Irish Rail[37] also required check rails for curves having a radius of 200 m or less.[38] Its infrastructure standards also warn of the possible requirement for check rails where curve radius is more than 200 m but occurs on a hazardous embankment (from a derailment point of view), and where it carries heavy traffic likely to cause severe rail side wear
- In the United States of America, four transit operators use what is termed a restraining rail for small-radius curves. The radius below which the restraining rail is mandated varies between operators and ranges between 152 m and 305 m[39].

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[36] UK Railway Group Standard GC/RT5021 December 2011.

[37] Otherwise known as Iarnród Éireann, Irish Rail is the operator of the national Broad-Gauge railway network of Ireland (Republic of Ireland and jointly with Northern Ireland Railways).

[38] Irish Rail standards I-PWY-1154: *Horizontal Curvature Design*, Issue 1.0, 7/1106, and I-PWY-1106: *Track Construction Standards*, Issue 1.0, 13/09/2005.

[39] Transportation Research Board (2005) *Flange Climb Derailment Criteria and Wheel/Rail Profile Management and Maintenance Guidelines for Transit Operations,* The National Academies Press pp 37.

Delay in reporting derailment

Prompt reporting of incidents to the control centre is important to allow emergency response and also to prevent possible further incidents or injuries. In this case the train derailed and one carriage was foul of the adjacent Down passenger line.

The driver was initially unsuccessful in trying to contact Metrol via the train radio, and subsequently made contact by using a company-issued mobile phone. This led to a significant delay of about 7 minutes between the derailment and the halting of traffic through the location.

The Digital Train Radio System (DTRS) has several levels of call with escalating priority and treatment by Metrol. The DTRS log showed that in this instance the driver initially made three lower-priority Train Controller Calls (TCC). A TCC is placed in a queue for the train controller for that track group to respond when able. The driver's recollection was that he pushed the Train Emergency Call (TEC) button, the level 2 priority call that should be used in an emergency but where there is no immediate danger, however, the system did not recognise or register this call. Post-incident testing of the DTRS by MTM found that once a TCC call was queued, the system would not override it with a TEC call. The system required that the lower-priority call first be cancelled by the driver prior to initiating a higher-priority call.

There is also a Rail Emergency Call (REC) feature on the DTRS that is the highest-priority call. REC calls go to Metrol and to other trains on the same line, to enable those train drivers to take immediate action. It should be used when an emergency could physically affect other trains, such as in the event of a derailment where an adjacent running line is or may be fouled. As this derailed train was lying foul of the other track, an REC call would have been appropriate.

Findings

From the evidence available, the following findings are made with respect to the derailment of train TD1064 near Rushall Station on 6 February 2016. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- There was insufficient lubrication between wheel flanges and the outside rail of the 118 m small-radius curve (Up track) between Merri and Rushall Railway Stations.
- The performance of rail lubricators on the network had diminished in the months leading up to the derailment.
- **The maintenance of rail lubricators had become less effective in the months leading up to the derailment. This work was being transferred from contractors to internal Metro Trains Melbourne (MTM) staff and the transition was not adequately managed. [Safety Issue]**
- The flanges of the train's recently-machined wheels had machining grooves and had been roughened through a lack of network lubrication, resulting in a higher contact surface coefficient of friction. This increased the probability of flange-climb compared to a typical wheel worn on a well-lubricated network.
- Recent machining of the train's wheels had returned them to the 'as-new' wheel profile that had a lower flange angle (to the horizontal) than a typical worn wheel. This increased the probability of flange-climb.
- A lateral angular discontinuity at a mechanical joint in the outside rail resulted in a localised peak in the wheel-to-rail lateral force and probably an increased wheel/rail angle-of-attack. This initiated the flange-climb at this particular point on the curve.
- **The network's track geometry standard did not include any specific requirement to limit a localised lateral angular discontinuity in rail line at a mechanical joint. [Safety issue]**

Other factors that increased risk

- **The positioning of the rail lubricators at this and several other locations on the network was not consistent with MTM guidelines and probably reduced their effectiveness. [Safety issue]**
- **The network's track geometry standards were probably unsuitable for small-radius Broad-Gauge curves. A combination of track geometry irregularities had increased the probability of flange-climb at several locations on the small-radius Rushall curve. [Safety issue]**
- **Track geometry through the Rushall curve was not managed in accordance with MTM network standards. A wide-gauge 'A' fault was not rectified in the field despite being closed-out on the asset management system. [Safety Issue]**
- **There was no network standard that directly dealt with increased derailment risk on small-radius curves. [Safety Issue]**
- **The Digital Train Radio System did not allow a Train Emergency Call to override an initial lower-priority call. [Safety Issue]**

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to rail industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

Rail lubricator maintenance

Number:	RO-2016-002-SI-01
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

The maintenance of rail lubricators had become less effective in the months leading up to the derailment. This work was being transferred from contractors to internal Metro Trains Melbourne (MTM) staff and the transition was not adequately managed.

Proactive safety action taken by MTM

MTM has reinforced adherence to its Management of Change Process through recruitment and new training. It has also implemented improved collaboration across MTM departments, including the establishment of a cross-divisional Wheel/Rail Interface Committee to monitor and address wheel-to-rail interface matters.

Additionally, MTM has updated its rail lubrication strategy based on an assessment of alternative lubrication technologies. This has resulted in the roll-out of electronic lubricators across the MTM network, with technical information and training to support the change.

Action number: RO-2016-002-NSA-003

Current status of the safety issue

Issue status: Adequately addressed

Justification: The safety action taken by MTM should address the safety issue.

Standard for angular discontinuity at mechanical joints

Number:	RO-2016-002-SI-02
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

The network’s track geometry standard did not include any specific requirement to limit a localised lateral angular discontinuity in rail line at a mechanical joint.

Proactive safety action taken by MTM

MTM has revised its track fault management system to include specific guidance on the risk of fault clusters and wheel-climb risks. The revised procedures address the identification and removal of misaligned fishplated joints.

Action number: RO-2016-002-NSA-004

Current status of the safety issue

Issue status: Partially addressed

Justification: The safety action taken by MTM in combination with other actions pertaining to track maintenance should reduce risk associated with the safety issue.

Location of rail lubricators

Number:	RO-2016-002-SI-03
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

The positioning of the rail lubricators at this and several other locations on the network was not consistent with MTM guidelines and probably reduced their effectiveness.

Proactive safety action taken by MTM

MTM has implemented a network-wide lubrication strategy resulting in the widespread introduction of new electronic lubricators and the interim refurbishment and relocation of existing mechanical lubricators until such time as electronic lubricators are installed across the entire network. The new MTM Wheel/Rail Interface Committee has been tasked with overseeing the performance of the new lubrication system.

Action number: RO-2016-002-NSA-005

Current status of the safety issue

Issue status: Adequately addressed

Justification: The safety action taken by MTM should address the safety issue.

Track geometry standards

Number:	RO-2016-002-SI-04
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

The network’s track geometry standards were probably unsuitable for small-radius Broad-Gauge curves. A combination of track geometry irregularities had increased the probability of flange-climb at several locations on the small-radius Rushall curve.

Proactive safety action taken by MTM

MTM has undertaken to review, and update as required, its network maintenance standards applied to small-radius curves and specifically maintenance tolerances on those geometric irregularities that increase the probability of flange-climb derailment.

Action number: RO-2016-002-NSA-006

Current status of the safety issue

Issue status: Partially addressed

Justification: The safety action taken by MTM in combination with other actions pertaining to track maintenance should reduce risk associated with the safety issue.

Management of wide gauge defect

Number:	RO-2016-002-SI-05
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

Track geometry through the Rushall curve was not managed in accordance with MTM network standards. A wide-gauge ‘A’ fault was not rectified in the field despite being closed-out on the asset management system.

Proactive safety action taken by MTM

MTM has improved its management of Temporary Approved Non-Conformances (TANC) to provide better oversight, visibility and reporting of decisions to deviate from the network standard. TANCs existing for 28 days or greater will also be subject to approval by a separate technical authority within MTM to validate that there are effective controls to manage risk associated with the TANC.

Action number: RO-2016-002-NSA-007

Current status of the safety issue

Issue status: Adequately addressed

Justification: The safety action taken by MTM should address the safety issue.

Standard for derailment risk on small-radius curves

Number:	RO-2016-002-SI-06
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

There was no network standard that directly dealt with increased derailment risk on small-radius curves.

Proactive safety action taken by MTM

MTM has updated its track management system to provide more specific criteria on the treatment of faults that contribute to flange-climb risk on small-radius curves. The revised procedures also provide guidance to consult with the Principal Technical Lead to assess potential wheel-climb risk and control measures.

Action number: RO-2016-002-NSA-008

Current status of the safety issue

Issue status: Partially addressed

Justification: The safety action taken by MTM in combination with other actions pertaining to track maintenance and rail lubrication should reduce flange-climb risk.

Train radio functionality

Number:	RO-2016-002-SI-07
Issue owner:	Metro Trains Melbourne
Operation affected:	Rail: Passenger – metropolitan and regional
Who it affects:	Owners and operators of passenger rail services in Victoria

Safety issue description:

The functionality of the Digital Train Radio System (DTRS) did not allow an emergency call to override an initial lower-priority call.

Proactive safety action taken by MTM

MTM has enhanced its driver training to highlight the operation of the DTRS for normal and emergency use, including the need to cancel a lower-priority call prior to initiating an emergency call. MTM is also reviewing the functionality of similar digital radio systems used by other rail operators, and options for changing the functionality of the DTRS.

Action number: RO-2016-002-NSA-009

Current status of the safety issue

Issue status: Partially addressed

Justification: The safety action taken by MTM should reduce risk associated with the safety issue. Improved DTRS functionality that provides automatic override of a lower-priority call would further reduce risk.

Additional safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

In addition to the other proactive safety actions, Metro Trains Melbourne has introduced new and revised standards for wheel turning and flange surface roughness. MTM has also established a program of cultural change that has included re-training in the management of track defects and reinforcement of accountabilities.

General details

Occurrence details

Date and time:	06 February 2016 – 1650 EST	
Occurrence category:	Incident	
Primary occurrence type:	Derailment	
Location:	Melbourne metropolitan rail network, 7.07 km from Flinders St station	
	Latitude: 37° 47.886’ S	Longitude: 144° 59.445’ E

Train details

Train operator:	Metro Trains Melbourne	
Registration:	TD1064	
Type of operation:	Suburban passenger	
Persons on board:	Crew – 1	Passengers – Unknown
Injuries:	Crew – Nil	Passengers – 1
Damage:	Minor	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Metro Trains Melbourne (train operator)
- Monash Institute of Rail Technology (consultant)
- ITW Polymers & Fluids (lubricant supplier)

References

Iwnicki S (2006), *Handbook of Railway Vehicle Dynamics,* CRC Press, pp 221

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to:

- Metro Trains Melbourne
- Office of The National Rail Safety Regulator

Extracts of this draft report were provided to:

- Institute of Rail Technology (Monash University)
- ITW Polymers & Fluids

Submissions were received from Metro Trains Melbourne, Monash University and ITW Polymer. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Australian Transport Safety Bureau

Enquiries 1800 020 616
Notifications 1800 011 034
REPCON 1800 020 505
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Investigation

ATSB Transport Safety Report
Rail Occurrence Investigation
Derailment of MTM train TD1064 near Rushall Station, Melbourne, Victoria on 6 February 2016

RO-2016-002
Final – 16 May 2018