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Safety summary

What happened

At about 0940 on 31 January 2013, a Queensland Rail passenger train failed to stop at the Cleveland station platform and collided with the end-of-line buffer stop, the platform and the station building at a speed of about 31 km/h. There were 19 people on board the train (including the driver and a guard); three people were on the platform and five were in the station building. A number of people were treated for minor injuries and transported to hospital for further examination.

At the request of the Queensland Government, the ATSB initiated an investigation into the accident.

Train T842 at Cleveland Station

Source: Dept of Transport and Main Roads, Queensland

What the ATSB found

The information contained in this preliminary report is derived from the initial investigation. The object of an ATSB safety investigation is the early identification of safety issues so that action can be taken to reduce any safety-related risk. Since the investigation is on-going, readers are cautioned that new evidence may become available that alters the circumstances depicted in this report.

Based on evidence available to date, the ATSB has found that local environmental conditions resulted in the formation of a contaminant substance on the rail running surface. This caused poor adhesion at the contact point between the train's wheels and the rail head. The braking effectiveness of T842 was reduced as a result of reduced adhesion and the train was unable to stop before hitting the end-of-line buffer stop.

The ATSB has concluded that Queensland Rail's risk management procedures did not sufficiently mitigate risk to the safe operation of trains when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion.

What's been done as a result

The ATSB has recommended that Queensland Rail take action to address the safety risk associated with contaminated rail running surfaces which lead to reduced wheel/rail adhesion.

Queensland Rail have proposed and initiated a precautionary risk mitigation strategy in response to the collision of train T842 at Cleveland station on 31 January 2013. The strategy includes the formation of a Wheel Rail Interface Working Group tasked to specifically identify and assess any potential wheel/rail interface risks, particularly for Queensland Rail's fleet of 160/260 class trains being operated under certain conditions.

Queensland rail have also implemented precautionary risk controls including; identifying and treating rail-head contaminants at any localised black spot locations, a review of train speed limits around the network and by providing drivers with enhanced train handling advice.

Safety message

Rail operators should recognise that train braking performance may be significantly impaired when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion. Rail operators should put appropriate measures in place to assess and mitigate the risk to the safe operation of trains under these conditions.

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The occurrence

Events prior to collision

In the days prior to train T842 colliding with the buffer stop at Cleveland Station, a tropical low formed in the Gulf of Carpentaria before tracking in an easterly direction toward the west coast of Cape York Peninsula. Just prior to its making landfall near Kowanyama the Bureau of Meteorology identified this system as a Category 1 Tropical Cyclone, Oswald. After landfall, Oswald rapidly weakened into a low pressure system, tracking southward and inland from the Queensland coast and into northern New South Wales. The low pressure system brought damaging winds, heavy rainfall and flooding to areas of south-eastern Queensland.[1]

These weather conditions resulted in the closure of several sections of the Brisbane suburban rail network, including the Cleveland line, where a tree and other debris had fallen on the railway damaging the overhead power infrastructure.

The Cleveland rail line was closed to rail traffic between Wellington Point and Cleveland station at 1442 on 27 January 2013. Rail services to Cleveland station remained suspended until the night of 30 January when an inspection of the overhead wiring was made by maintenance staff. On 31 January 2013, services on the Cleveland line recommenced with the first train arriving at Cleveland Station at 0440 and later departing at 0451. A further 11 services arrived and departed Cleveland before service T842.

Service T842

The crew of the accident train consisted of a driver and guard who commenced duty at 0615 on 31 January 2013. The crew were initially tasked to operate service 1E29 from Beenleigh Station to Bowen Hills. This service departed at 0643 and arrived at Bowen Hills Station at 0753, where the crew was relieved by another driver and guard[2].

The crew then had a short break before commencing their next task of operating service T842, a 6-car Doomben to Cleveland train, departing Doomben at 0755. The service was scheduled to arrive at the Bowen Hills Station at 0811 but arrived at 0816 due to operational delays.

The crew were verbally briefed by the train crew they were relieving on the train’s performance, commonly referred to as a train handover report. There was nothing in this report to indicate that there were any issues with the operation of the train.

The train departed Bowen Hills Station and was scheduled to stop at all stations to its final destination of Cleveland. The train arrived at Roma Street at 0822 having stopped at the previous two stations.

The train then departed Roma Street at 0823 continuing to stop at all stations without incident until the section between Cannon Hill and Murarrie, where it was held at a red signal near the Queensport Road South crossing. Here the train was held for about 16 minutes due to an overhead electrical supply failure which resulted in train operations being reduced to single line running. Service T842 was required to wait for an opposing inbound service heading to Brisbane Central.

Once cleared, train T842 continued its journey and arrived at Murarrie Station at 0903. The train departed Murarrie at 0904, continuing towards Cleveland.

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1 Bureau of Meteorology Special Climate Statement 44 – extreme rainfall and flooding in coastal Queensland and New South Wales 5 February 2013.

2 Bowen Hills Station is a common Queensland Rail train crew change point.

The collision

As train T842 was approaching Wellington Point Station (two stations before Cleveland), the driver heard a train control radio report of a platform over run of another train at the next station, Ormiston. The driver was contacted by his guard to confirm that he had heard the report of the platform over run.

Having been alerted to another train's (1A29) issue in stopping on approach to Ormiston Station, the driver approached the platform at reduced speed and experienced little difficulty in stopping the train at the platform. The driver noticed that, towards the end of the stopping sequence, his console indicated some wheel slide but he did not consider this unusual and it was barely noticeable.

At 0936 train T842 departed Ormiston Station, accelerating to the posted line speed of 70 km/h. There was no indication of any wheel slip on departure from the station and it appeared to the driver that the rails were dry.

The train continued towards Cleveland and was rounding the left-hand curve in the 70 km/h section when the driver observed that signal CD12P located between the Wellington Street overpass and the Gordon Street overpass was showing a green aspect. The green aspect of CD12P indicated to the driver that the train would have a proceed aspect at the next signal (CD12), allowing the train to enter Cleveland Station.

Figure 1: Location of Ormiston and Cleveland stations

Source: Google Earth

The train was on a straight section of the track with a posted speed of 80 km/h but, as the section was short, the driver elected not to increase the speed of the train in anticipation of the left hand curve and 70 km/h section of track located just past the Gordon Street overpass.

When the train was in the vicinity of the Gordon Street overpass the driver applied the train's brakes to maintain the train's speed on this downhill section of track at 70 km/h. After 3 seconds the driver released the brake and then reapplied the brake 10 seconds later. This action was usual driving practice and done in anticipation of slowing the train to 25 km/h for the track turnout[3] located 84 m before Cleveland Station.

Shortly after the train exited the Gordon Street overpass and about the time that the driver started to brake for his approach to Cleveland Station, light rain started to fall.

The driver noticed that the train was not slowing as expected. A minimum brake application followed by a half-way brake application at this location was usually sufficient to slow the train to the required speed. The driver had no recollection of the wheel slip/slide alarm activating and continued to be concerned that the train was not slowing.

The driver then moved the brake controller to the half way position and then further into the full service brake[4] position. He observed that there was still no appreciable reduction in the train's speed. He then saw that the Cleveland home signal (CD12) was showing a yellow proceed aspect and the associated junction indicator was illuminated, indicating the train was to pass through the turnout into the southern platform. While the driver's focus remained on trying to slow the train, the train was now about 100 m from passing CD12 and about 270 m from the turnout.

The driver was becoming increasingly concerned as the train rapidly approached the turnout, so he moved the train brake to the emergency position and also applied the park brake before entering the points. The train proceeded through the points at a speed of close to 56 km/h and into the down platform located on the southern side of the station. The speed as the train entered the platform remained close to 56 km/h.

As the train approached the platform the driver removed his foot from the driver safety control[5]. At this point, the driver had exhausted all available avenues at his disposal to stop the train.

The train continued along the platform towards the buffer stop[6] at the end of the line, slowing gradually as it moved along the platform.

At 0940 the train collided with the buffer stop at a speed close to 31 km/h, shearing the buffer stop from its foundation and rotating it onto its side. The train then rode up and over the buffer stop and collided with an overhead power line mast located immediately behind. The impact flattened the mast and brought down the overhead high voltage wiring onto the train and platform. The train continued into the station building where it came to rest.

When the train had come to a stop, the driver placed an emergency call alerting train control to the collision and seeking urgent assistance.

The guard

The guard was located in the front driver cab of the fourth car. At Ormiston Station, the guard observed a 'shudder' as the train stopped, but was not concerned as the train did not overshoot the platform. The guard observed that the train departed Ormiston Station normally.

On approach to Cleveland Station, the guard was standing and preparing to change cabs for the train's subsequent departure. As the train traversed the points at the turnout, the guard noted that he was rocked from side to side. He attributed this to higher than normal speed. Shortly thereafter, realising that the train might not stop before the end of the platform and anticipating an impact, the guard braced himself against the dashboard.

Both the driver and guard sustained superficial injuries.

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3 A combination of a set of points, V crossing and guard rails which permits traffic to turnout from one track to another. Source: National Guideline Glossary of Railway Terminology Version 1.0, 3 December 2010.

4 The maximum braking position for normal service operations.

5 A vigilance system which reacts by making a penalty brake application if a continuous control input required of the driver is interrupted or not detected, commonly called the "dead man's pedal".

6 A structure erected at the end of a track at main line terminals or dead end sidings which is intended to stop rolling stock.

Passengers

There were 17 passengers on the train at the time of the collision. The majority of the passengers were seated in the front three cars of the train, with nine located in the first car.

Some passengers travelling on the service had observed unusual braking at Ormiston Station, which they variously described as 'jolting', or 'grip and release'. Passengers observed no further anomalies on the journey between Ormiston and Cleveland until the train traversed the points, when some passengers observed that the train was approaching the end of the line at speed.

With no warning or announcement and little time to assess the situation and prepare, some passengers were able to brace for the impact while others were not. Two passengers were standing in preparation to exit the train at the time of collision.

Passengers sustained varying degrees of injury associated with the impact, including bruising, muscle strain and soreness. One passenger sustained a superficial head wound when their head struck a framed poster. No passengers were admitted to hospital.

A number of passengers reported an enduring psychological reaction to the event following the collision.

The station

There were four members of the public and four Queensland Rail employees on the Cleveland Station platform or within the station vestibule and buildings at the time of the collision. One person located in the station amenities block sustained minor injuries after being trapped amongst building debris. This person was rescued by a member of the public after a short period of time.

Train station staff

Two of the three station staff were in the station office at the time of collision and did not observe the train on its approach. One staff member was located at the station end of the platform, and a spare driver was located at the door to the staff meal room. Both of these staff members observed the train approach the station at a higher than normal speed and both noted the absence of any sounds normally associated with train braking.

Post collision

Emergency response coordination

At 0940[7] the Train Control Operator received an emergency call from the driver of train T842 advising that his train had collided with the buffer stop.

At 0941[8] a passenger activated the emergency door release in the second car and the spare driver on the station platform directed them to remain on the train due to the overhead train power lines being pulled down during the collision. However, one passenger exited the train, and was followed by another three passengers. These passengers then left the station. One of the four returned at a later time and received medical assistance.

The Train Control Supervisor received a call on the emergency line from a Cleveland Station staff member at 0942[9]. The staff member informed the Train Control Supervisor that the train cabin had gone through the toilet block and that the person in the toilet had been rescued. The station phone was then passed to the spare driver and the Train Control Supervisor informed him that the power lines had been de-energised, but had not been isolated and earthed and that it was therefore not

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7 Source: Train Control voice recording

8 Source: On board CCTV footage

9 Source: Train Control voice recording

deemed safe for anyone to exit the train or to be on the platform. He also directed the spare driver to have the station master call an ambulance.

The spare driver passed the message to the guard and passengers in the second car to remain on the train. Remaining passengers complied and waited for advice on when it was safe to leave.

Meanwhile, Cleveland Station customer service staff were busy attempting to secure the station and providing assistance to the passengers and members of the public in the station.

At 0946[10] the guard contacted the Train Control Operator to ascertain the status of the power lines and whether or not the passengers could leave the train. The Train Control Operator said that the overhead power had been 'switched off.' The guard then replied that he would start letting passengers off. Soon after, at 0947[11], the guard activated the emergency door release in the fifth car and the two passengers in the rear of the train departed.

At 0949[12] the Train Control Operator contacted the driver advising him that passengers should not be permitted to leave the train due to the power lines being down on the platform.

At 0953[13] Queensland Fire and Rescue Service contacted the Train Control Supervisor to advise that they were on site at Cleveland Station. The Train Control Supervisor advised that the overhead power was de-energised, but not yet isolated and earthed, and was therefore to be treated as live.

At 0953[14], the remaining passengers and crew were escorted from the train under the supervision of Emergency Services personnel, and were then provided with medical assistance.

At 1000[15], Cleveland Station customer service staff advised the Train Control Supervisor that all passengers had been evacuated from the train.

At 1021[16], the Queensland Rail Incident Commander arrived to manage the site.

At 1034[17], the Queensland Rail Electrical Control Operator confirmed that the overhead power had been earthed and it was now safe for passengers and crew to disembark the train. However this had occurred some 30 minutes beforehand.

At 1128[18], the Queensland Rail Incident Commander confirmed that 13 passengers and the driver had been transported to Redlands Hospital for examination and medical treatment and at 1135[19] the Queensland Fire and Rescue completed an under-train inspection.

Vehicle rescue

Vehicle recovery operations were planned and commenced at 1142 on the day of the collision. The four trailing cars of train T842 were inspected on site and found to be in a condition suitable for travel by rail.

Diesel service L822 was despatched from Mayne Yard situated near Bowen Hills and was on standby at Wellington Point by 1252. The service was then despatched to Cleveland where it was used to recover the last three undamaged cars in the train. This phase of the operation was completed at 1950.

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10 Source: Train Control voice recording
11 Source: on train CCTV footage
12 Source: Train Control voice recordings
13 Source: Train Control voice recordings
14 Source: on train CCTV footage
15 Source: Queensland Rail internal debrief
16 Source: Train Control voice recordings
17 Source: Electrical Control Operator log book
18 Source: Queensland Rail internal debrief
19 Source: Queensland Rail internal debrief

At 2035 service LF73 departed Bowen Hills and travelled to Cleveland and subsequently recovered the trailing car in the remaining portion of the train. This phase of the operation was completed at around 2330 when the car had been successfully separated from the two damaged leading cars.

The two leading cars of train T842 had sustained significant damage and had to be lifted by crane from the site onto low bed loaders to be transported by road.

Figure 2: Recovery from IM5173

Source: The Courier Mail

Extraction of the damaged cars from the site commenced at around 0200 on 1 February 2013 and was finally completed at 0430 when the lead car of the train was secured to a low loader trailer.

The four trailing cars in train T842 were transported by rail to Mayne Yard in Brisbane and the remaining two cars were transported by road to Redbank for storage.

Infrastructure repairs

Repairs to the infrastructure commenced at 0500 on 1 February 2013 once the rolling stock had been cleared from the site.

At 0600 operations had begun to release the overhead power mast structure and the damaged buffer stop from the debris at Cleveland Station with the removal of the damaged buffer stop completed at 1305.

The positioning of a temporary buffer stop, replacement of the overhead power mast foundation, the replacement of the mast and overhead wiring, together with repairs to the signals, were tasks conducted over the following days. These repairs were completed by 0113 on 3 February 2013. Temporary repairs were also made to the Cleveland Station building over this time.

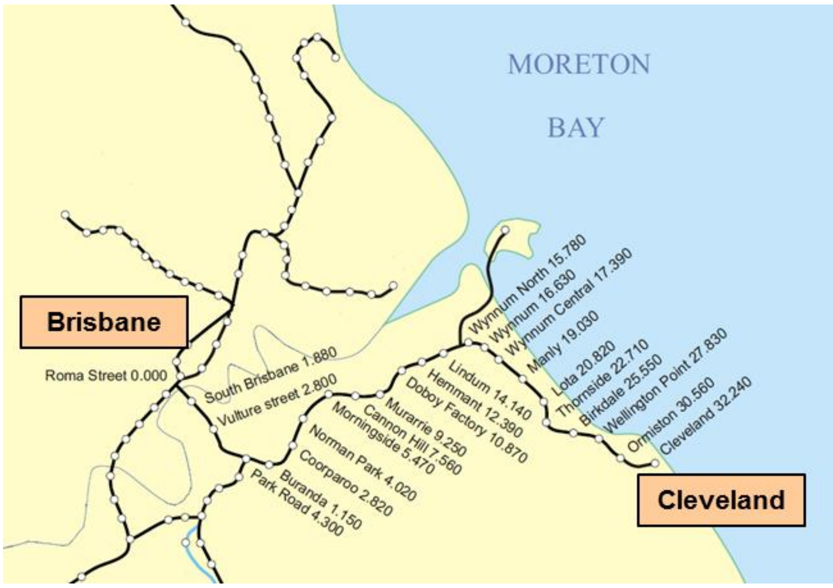
At 0310 on 3 February 2013 test train HF74 departed Mayne Yard for Cleveland to test the infrastructure repairs. At 0434 this service then departed Cleveland on the return journey and at 0500 the emergency response was declared to be over and normal services to Cleveland were resumed.

Context

Location

Cleveland is a coastal suburb located approximately 25 km east-southeast of Brisbane CBD. By rail, Cleveland is a terminating station about 32 track kilometres from Roma Street Station (Brisbane).

Figure 3: Location of Cleveland



Source: Queensland Rail. (Extract from System Maps, modified for clarity)

Organisation

Queensland Rail provides suburban commuter rail services on the City network, covering Brisbane, Ipswich and the Sunshine and Gold Coasts. Queensland Rail also provides long distance passenger services to other major centres in Queensland. The Cleveland rail line is part of the Queensland Rail City network with passenger services at about 30 minute intervals during week days shortening to about 15 minute intervals during the peak period.

Infrastructure

Track

The track structure between Ormiston and Cleveland Stations consists of 50 kg/m rail fastened to concrete sleepers laid on a bed of hard rock ballast. The track approaching Cleveland Station has a falling grade[20] of 1:130 from about the Wellington Street overbridge to just before the turnout, where the track grade transitions to level into the station platform.

Inspections following the collision showed no evidence of obvious track defects or misalignments. The track geometry measurement car run carried out in September 2012 found the track to be within tolerances and of sound alignment.

The rail along this section was in good condition with some side wear on the high leg of the curve on the approach into Cleveland Station. Rail lubricant residue was obvious on the bottom of the

[20] A measure of the rate at which the railway is inclined (rising or falling). Gradients are signed +ve (rising) or –ve (falling) in respect of the direction of travel. Source: National Guideline Glossary of Railway Terminology.

gauge face of this rail indicating the rail lubrication of this length of track is being maintained. There was no evidence of rail lubricant on the head (top) of the rail. The rail wear was within limits.

The rail on curves is generally ground every two years and this track section was last ground in June 2012. The rail on the tangent (or straight) track has not been included in the rail grinding cycles. This track carries around 8 million tonnes of traffic per year consisting of light axle load vehicles and there was no evidence of distress or damage on the rail head. The rail wheel contact patch was narrow and centred, indicating that rail grinding was not necessary.

There are two turnouts on the approach to Cleveland Station, 650A and 650B. Turnout 650A divides the single track approaching the station into the two platforms and is a 1 in 12, 60 kg, fixed heel switch, with a rail bound manganese (RBM) crossing. This turnout is fixed to concrete bearers and uses resilient clips to fasten the rail to the sleepers. The turnout was observed to be in very good condition. Turnout 650B is on the approach to Cleveland Station platform 2 and provides access to a storage road. Turnout 650B is identical to 650A and was found to be in a similar condition.

Buffer stop

The buffer stops located at the end of the platform tracks at Cleveland Station are reinforced concrete structures with rubber fenders. The buffer structure is made of a 2.9 m high concrete block protruding 1.7 m out of the ground attached to a pair of horizontal reinforced concrete beams, one under each rail. The rubber fender is attached to the concrete block and has an adapter plate attached to match the couplers used on the CityTrain fleet. The buffer has been designed for a 200 tonne train with an impact speed of 5 km/h.

Overhead traction system

The overhead traction power equipment is the structures and overhead equipment necessary for the traction power supply of electric trains. Queensland Rail trains operate on a 25 kV AC traction system. Trains collect power through a pantograph when in contact with the single overhead contact wire that is supported by catenary wires cantilevered from trackside masts.

Environmental conditions

At 0930 on the day of the occurrence, the BoM weather station located at Brisbane Airport, approximately 20 km north-west of Cleveland Station recorded a temperature of 25.7 °C and relative humidity of 72 per cent. Wind was from the north-northeast at 13 km/h. At 0900 the BoM weather station recorded cloudy conditions.

While no rainfall was recorded at Brisbane Airport at the time of the occurrence, there was evidence of light rain falling at Cleveland as train T842 approached the station.

Site conditions

In the morning preceding the collision at Cleveland, Queensland Rail Train control reports record three incidents where trains had overshot the platform at Ormiston, the station before Cleveland.

- At 0542, the first revenue service to Cleveland (service number 1802) overshot the station platform by six cars. The driver reported a very slippery track.
- At 0834, the driver of service number 1A25 (from Cleveland) reported that the train had overshot the platform by five cars due to a slippery, wet track.
- At 0927, the driver of service number 1A29 (from Cleveland and the train immediately prior to the incident train, T842) reported that the train had overshot the platform by three cars. The driver advised there were gum leaves on the track that may have contributed to the slide.

The driver of T842 overheard the conversation over the train control radio about the slippery conditions at Ormiston Station and reduced the speed of the train to about 40 km/h. In addition, the Train Control Operator advised the driver of train T842 to exercise caution through Ormiston Station.

While slippery conditions were not specifically reported at Cleveland Station, reports of slippery conditions at Ormiston (about 2 km away) along with leaf litter on the track suggests that conditions of reduced track adhesion existed in the area near Cleveland immediately before the collision of train T842.

Visual inspection of the track leading into Cleveland Station undertaken by Queensland Rail staff following the collision found evidence of a film of black scale type material deposited on the rail head adjacent to the running surface. Samples were collected from the rail head and the wheels of train T842 and were preserved for further analysis.

These samples were sent to the University of Queensland and were analysed for substances such as woody or leaf material, oils, grease, soaps, corrosion products, soil, rock and other particles.

Preliminary results from the analysis of the samples showed leaf tissue, iron oxide, a combination of natural oils and hydrocarbon oil, solid lubricant additive and woody particles.

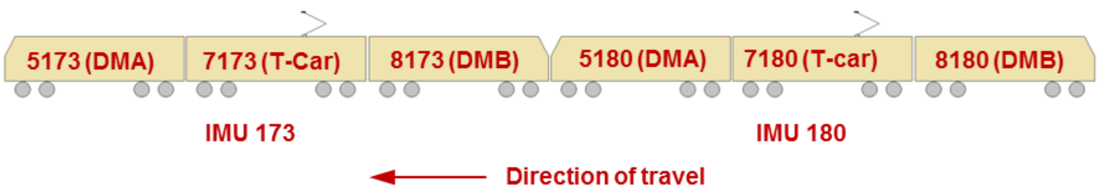
When located on the contact patch between the wheel and rail the combination of these contaminants has been found to reduce levels of wheel/rail adhesion under certain climatic conditions.

Train information

Queensland Rail currently operates 28 Interurban Multiple Unit 160 class electric trains, numbered 161 to 188 (IMU160) and 36 Suburban Multiple Unit 260 class electric trains, numbered 261 to 296 (SMU260). Each IMU160 and SMU260 unit consists of two driving motor cars (DM car) coupled to either end of a non-powered trailer car (T-car), to form the typical set configuration of DMA – T car - DMB. The IMU160 and SMU260 class trains are similar in construction and operation, with the addition of a passenger toilet facility in the IMU160. The IMU160 and SMU260 class electric trains were constructed by a Downer EDI Rail Pty Ltd/Bombardier Transportation Australia Pty Ltd joint venture and progressively delivered to Queensland Rail between 2004 and 2011.

In service, the IMU160 or SMU260 configuration typically operate either as a single 3-car set or coupled with another set to form a 6-car train. The tare weight for each configuration is 128.2 t and 256.4 t respectively. At the time of the occurrence two 3-car sets (IMU173 and IMU180) were coupled to form train T842 (Figure 4). IMU 173 and IMU180 were delivered to Queensland Rail on 5 February 2008 and 17 June 2010 respectively.

Figure 4: Train T842 configuration



Braking system

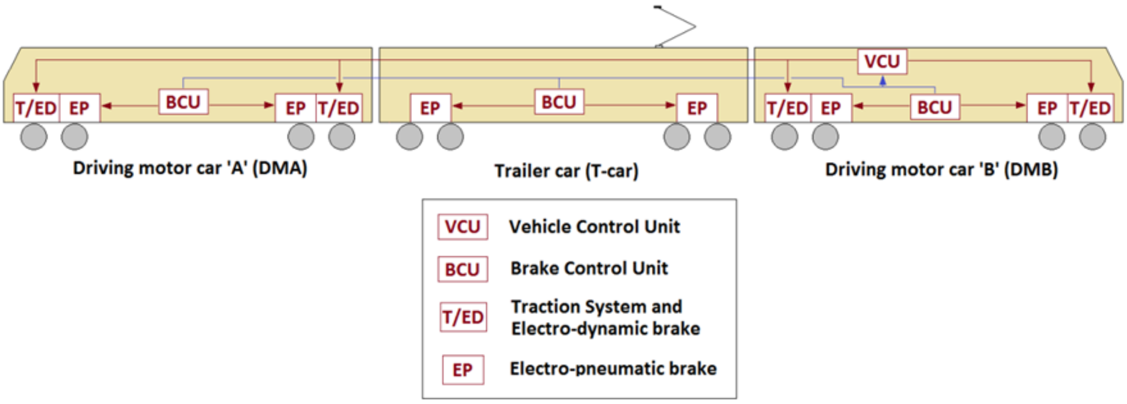
The IMU160 (and SMU260) trains are equipped with both electro-dynamic (ED) and electro-pneumatic (EP) braking systems. These braking systems have been used since the introduction of the suburban electric train fleet in 1976.

The ED system uses the electric traction motors fitted to the axles of each bogie of the DM car to provide regenerative braking[21] The electric energy generated during regenerative braking is fed back into the overhead power supply system.

The EP system provides a friction brake[21], through the application of air pressure from the brake reservoir to the disc brake units fitted to each axle of the train. As the T-car is non-powered, braking effort for it, when required, is provided by the EP system only.

The application of the ED and EP braking systems of the IMU160 class is managed by interconnected microprocessor-based Vehicle Control and Brake Control Units (VCU and BCU respectively). Each 3-car set is fitted with a VCU that controls the electric motors via a traction converter in each DM car, providing either power or regenerative braking as required. BCU's are fitted to each car (DM and T-car) of the 3-car set to control the application of EP braking for each car and to interface with the VCU in providing ED braking (Figure 5).

Figure 5: IMU 160 braking system configuration



The braking system is designed to preference ED braking to maximise the effect of the retardation provided by regenerative braking and to reduce wear on friction brake components. EP braking will supplement ED braking as required to provide the required brake demand.

Operation of the brake control lever by the driver causes a brake demand signal to be transmitted to the VCU and BCU, initiating the braking system. The braking effort provided by the ED and the EP systems is then blended by the BCU dependent on vehicle speed and loading to ensure the braking effort satisfies required brake demand. The blending of the braking systems during a normal service brake application provides the maximum braking rate during stopping, while maintaining passenger comfort.

Typically the primary braking effort for the train is provided by the ED system of each DM car. The braking is blended by the BCU so that each DM car provides the required brake effort for its mass plus half the mass of the T-car, due to the T-car being fitted with the EP system only.

In situations where low adhesion between the wheel and rail head may occur the VCU and BCU control systems incorporate a Wheel Slip Protection (WSP) feature that provides wheel slip/slide control in the event of an axle losing adhesion with the surface of the rail head. WSP for each of the ED (VCU controlled) and EP (BCU controlled) systems work independently although the BCU in the T-car transmits speed reference signals to the VCU.

The WSP systems of each DM car integrate the application of ED and EP braking to ensure the preference for ED braking is maintained (where possible) in controlling a slide while controlling

21 Refer to Glossary section of this report for definitions.

any EP application on the T-car to improve stopping distances, wheel life and reduce brake pad wear in the wet.

If a wheel slide has been detected in the preceding two stops, the control system of the 3-car set modifies the blending of the braking effort provided by each of the DM cars. In this situation the braking effort is now evenly distributed across all three cars of the train with the T-car providing friction braking through its EP system. In this mode when a DM car reduces its ED braking effort the T-car will automatically blend additional braking effort to compensate. Under wheel slide conditions the BCU in the T-car will manage slide control of its axles using the EP system while the DM cars will continue to manage slide through the ED system.

Train T842 experienced slippery conditions when stopping at Ormiston Station. This initiated the WSP and modified the blending of braking effort provided by the DM cars to then integrate the application of ED and EP braking for each of the two 3-car sets.

In conditions where poor adhesion is encountered or when a specified variance between the brake demand signal and ED brake effort achieved is detected for a time period, the traction system is inhibited. Control of the wheel slide is then passed to the BCUs of each car and EP braking is used to bring the slide under control through the action of anti-skid valves acting on the brake cylinders of each axle.

Emergency brake

A failsafe emergency brake system is provided on each 3-car set. The emergency brake operates on the EP system and applies full brake cylinder pressure on each car. The WSP function continues to operate during emergency braking; however, the ED braking system is disabled to avoid wheel slip from over-braking.

Park brake

A driver operated park brake is fitted to three of the axles on each DM car. The park brake, when selected, is applied through the release of air pressure enabling the spring actuated mechanism to apply pressure the disc brake of the corresponding axle.

The disc brake mechanism is common to the park brake and EP braking systems. The park brake unit is fitted with an anti-compound valve[22]. Under normal conditions the anti-compound valve prevents approximately 80% of the additional force from the parking brake should they both be applied simultaneously.

Under low adhesion conditions the application of the park brake could affect the operation of the WSP system. Queensland Rail has issued an instruction to drivers advising that the use of the park brake in emergency situations should be avoided. However it is unlikely that the operation of the park brake of train T842 contributed to the collision.

Brake inspection and tests

Under-vehicle inspections on wheel tread surfaces for all cars revealed minor wheel tread flats[23] at three near equal positions about the tread circumference of an axle on the leading car (DMA 5173) and one wheel flat of an axle on the last car (DMB 8180). It is possible that the multiple wheel tread flats on 5173 indicate that WSP may have briefly been compromised. The equal spacing around the wheel circumference is indicative of the brake activation and release function while WSP was attempting to control the slide.

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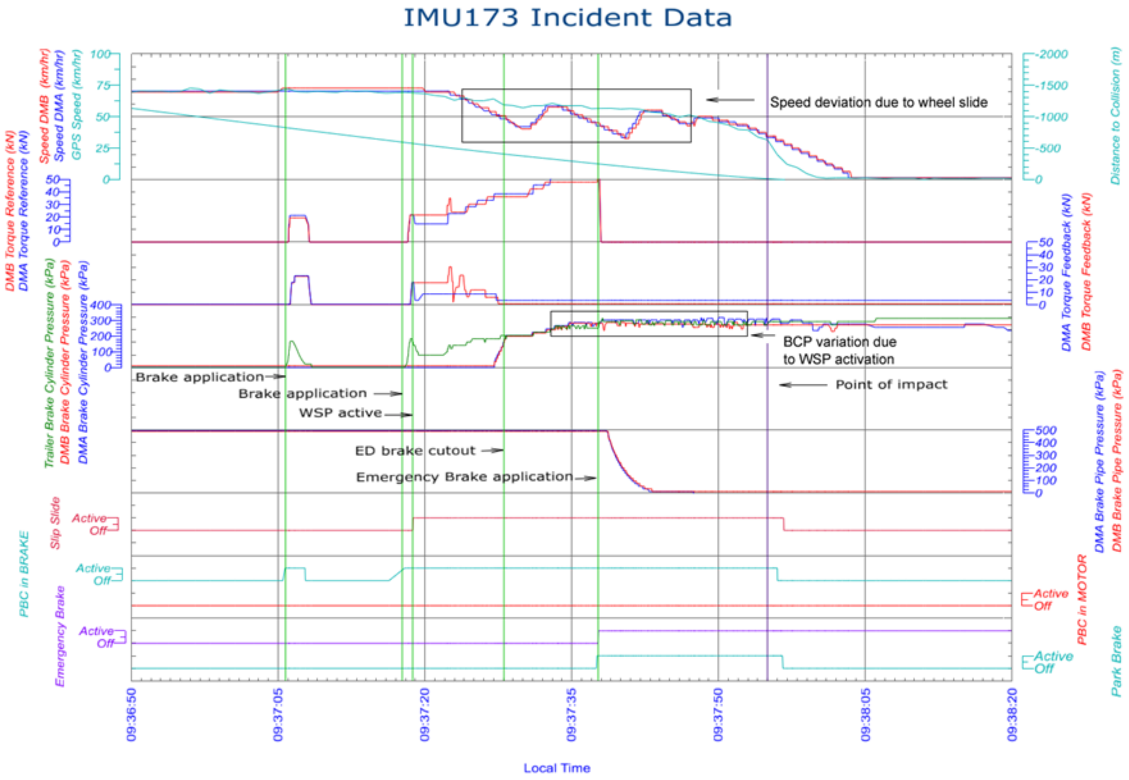
22 Refer to Glossary section of this report for definitions.

23 Loss of roundness of the tread of a wheel usually caused by wheel slip or wheel slide. Source: National Guideline Glossary of Railway Terminology Version 1.0, 3 December 2010.

Analysis of information extracted from IMU 5173's data logger (Figure 6) shows the train was travelling about 69 km/h (0937.18) when the driver made a service brake application to slow the train about 590 m from the Cleveland Station. Less than one second later, the WSP system detected slide. Brake cylinder pressures, particularly after the application of the emergency brake at 56 km/h, display numerous fluctuations as the WSP system intervened to apply and release the brakes in attempting to control the slide. Fluctuations in speed were also recorded where the WSP system remained active throughout the service brake and emergency brake applications until the point of impact.

Figure 6: Extract of data log from IMU5173



A series of static brake tests were carried out on the two leading cars involved in the accident. Brake tests were carried out at the Redlands maintenance facility to verify if the brake pad clamp forces on all disc rotors were in accordance with Queensland Rail specifications.

In preparation for the tests, the brake calipers were wound back to remove and inspect the friction pads and brake discs. There was no evidence of abnormal wear on the pads or disc rotors. For each axle set, pressure transducers were placed between each actuating piston either side of the disc rotor. Regulated air pressures were set for each of the tests at 270 kPa and 290 kPa. Three tests were carried out on each disc rotor and the results were digitally recorded.

All tests found brake clamping forces were within specified limits with an average force of 1400 kg at 270 kPa and 1600 kg at 290 kPa.

Test train IMU292

On Wednesday 13 February 2013, a series of tests were conducted to measure the stopping distance of a train similar to the train involved in the Cleveland collision under a range of wheel/rail adhesion conditions.

A near-level section of track was used and all brake activations were commenced at a speed of 70 km/h. The heads of the rails were lubricated for each test with water, undiluted truck wash and a mixture of water and truck wash respectively. Test car set IMU292 was also fitted with piping to direct the truck wash and water onto the contact patch between the head of the rail and the wheels. Transducers were connected to the train's brake cylinders and valves to convey data to temporary on-board recording equipment in order to assess the operation of the train's braking system.

Initial tests were made on dry track to determine the time and deceleration rate of IMU292 under EP brake/no regenerative brake, EP brake/regenerative brake and emergency brake. Results showed when under emergency brake, the test train came to stop in 10.4 seconds with a deceleration rate of 1.329 m/s^2. Queensland Rail brake performance criteria for this test allow an acceptable time range of between 9.9 –13.2 seconds and deceleration rates of between 1.05 –1.4 m/s^2.

A total of 12 tests were carried out. In two of the tests when truck wash was applied to the rail head the train took 28.5 seconds (0.487 m/s^2) and 31.4 seconds (0.442 m/s^2) respectively to stop using a full service brake application (EP brake/no regenerative brake).

Following the tests data was extracted from the test train's Vehicle Control Units, Brake Control Units, data loggers and forward-facing video. A video camera was also mounted on the driver's vestibule to record the activation of slip/slide warnings and other functions on the driver's console.

The data from the accident train and test train IMU292 were separately analysed and compared. Analysis of data from both trains indicates that the braking system on the Cleveland-bound accident train was working as designed when operating under low adhesion conditions.

Train driver

The driver of train T842 had been employed as a train driver for 20 years with current training and route knowledge competencies to operate trains on the Brisbane Suburban Area Network. The driver had been assessed as fit for duty in accordance with the requirements of the National Standard for Health Assessment of Rail Safety Workers.

Following the collision the train driver was tested for blood alcohol content. This test returned a negative result. There was no indication that the driver's performance was affected by physical, medical or cognitive factors.

Safety analysis

Track adhesion and friction

In relatively simple terms, friction is the force encountered that resists the movement of one object against another object. The coefficient of friction is the ratio of the friction force between the two objects to the force pressing them together. A slippery surface will have a low coefficient of friction. Static friction force is the force required to initiate sliding whereas kinetic friction force is the force required to maintain sliding. Kinetic friction is generally lower than static friction. That is, less force is required to maintain sliding once an object is already sliding. In a rail context, adhesion is used to define the friction that is available to transfer the driving (or braking) force between the wheel and the rail[24]. As the coefficient of friction decreases, the friction available for adhesion also decreases.

The steel-steel (wheel-rail) contact patch is relatively small (about 1 cm^2). Under braking, the contact area can be divided into a stick area (adhesion) and a slip area. As the braking effort increases, the stick area decreases until a saturation point at which point the stick area disappears completely. When this occurs, the contact patch is in a state of pure sliding with no rotation of the wheel and, due to the static-kinetic friction relationship, less braking effort is required to maintain sliding. Consequently, the best braking performance is available when a level of adhesion is maintained at the wheel-rail contact patch, which in turn is dependent on the coefficient of friction.

The coefficient of friction is strongly influenced by the introduction of other materials at the interface between the two objects, either to increase friction or decrease friction. In the context of this accident, samples of a film of black scale were found on the rail head. Preliminary examination revealed that the scale contained traces of leaf tissue, iron oxide, a combination of natural oils and hydrocarbon oil, solid lubricant additive and woody particles.

A number of studies have examined the relationship between wheel-rail friction and adhesion[25]. The studies found that that the levels of friction and adhesion were reduced depending on the type of contamination. **Table 1** provides a comparative indication of the friction/adhesion levels relevant to the type of contamination present at the wheel-rail contact patch. The studies indicated that a damp leaf film produced significantly reduced levels of friction and adhesion.

Table 1: Scale of friction/adhesion

Condition of rail surface	Scale of friction/adhesion
Dry, clean rail	Good
Wet, clean rail	↓
Greasy rail	↓
Moist rail	↓
Damp leaf film on rail	Very poor

Considering the evidence of a film of leaf tissue and oils on the rail head, combined with light rain falling at Cleveland as train T842 approached the station, the rail running surface almost certainly exhibited poor adhesion at the contact between the train's wheels and the rail head, resulting in wheel slide. Preliminary analysis has shown that the driver's operation of the train was in accordance with normal practice and that the train's brake system worked as designed. Therefore the primary factor which led to the collision of train T842 with the buffer stop and station building at Cleveland was poor wheel/rail adhesion.

24 Sometimes the term 'traction' is used for driving and the term 'adhesion' used for braking.

25 Wheel-rail interface handbook, edited by R. Lewis and U Olofsson (2009)

The newer, fully disc-braked and WSP-equipped trains in the Queensland Rail fleet appear particularly susceptible to wheel slide in conditions of low adhesion and are not fitted with any device to improve adhesion (aside from the WSP system). Older trains in the fleet are fitted with wheel tread brakes which 'scrub' the wheel tread each time the brakes are applied which improves the coefficient of friction between the wheels and the rail.

Many railways around the world have risk control systems to actively monitor and control levels of adhesion around their networks. These include both the forecasting of where and when low adhesion may occur (based largely on environmental conditions) and also systems for improving wheel/rail adhesion that are fitted to the train or applied to the track. In the United Kingdom, where conditions of low adhesion are a prevalent and well understood problem (particularly in autumn with leaf contamination of the rails), rail operators are required to have systems to identify and treat low adhesion 'black spots' in their networks. In addition trains in the UK are fitted with wheel/rail friction modification systems like automatic sanding (which applies sand or Sandite[26] to the wheel/rail interface to improve adhesion when wheel slip is detected).

At the time of the collision at Cleveland, Queensland Rail did not have a system in place to actively identify, monitor and treat the risks associated with conditions of low adhesion around their network.

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26 Sandite is a substance used on railways in the UK, Ireland and the Netherlands to combat leaves on the line which can cause train wheels to slip and become damaged with flat spots. Sandite consists of a mixture of sand, aluminum and a unique type of adhesive.

Preliminary findings

From the evidence available, the following preliminary findings are made with respect to collision of train T842 with the station platform at Cleveland and should not be read as apportioning blame or liability to any particular organisation or individual.

- Preliminary analysis of the train driver’s actions on approach to Cleveland Station with respect to speed and braking indicates that they were consistent with sound driving practice and did not contribute to the accident.
- Preliminary analysis of available data indicates that the operation of the braking systems on train T842 was consistent with the test train and system design parameters.
- Local environmental conditions resulted in the formation of a contaminant substance on the rail running surface that caused poor adhesion between the train’s wheels and the rail head.
- Queensland Rail’s risk management procedures did not sufficiently mitigate risk to the safe operation of trains when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion. (*Significant safety issue*)
- During the period immediately following the collision, when the train control staff were working hard to coordinate the emergency response, there were a series of communication issues which resulted in incomplete information being provided to key personnel. This resulted in the Train Control Operator and train guard miscommunicating the status of the downed overhead power lines, leading to the guard permitting some passengers to exit the train before emergency services had ensured it was safe to do so.

Safety issues and actions

The safety issues identified during the preliminary stage of 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 the rail industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

Queensland Rail

Number:	RO-2013-005-SI-01
Issue owner:	Queensland Rail Limited
Type of operation:	Rail Transport Operator
Who it affects:	All owners and operators of rolling stock fitted with electro-pneumatic disc actuated braking systems incorporating wheel slip/slide protection control.
Risk at time of occurrence:	Significant

Safety issue description:

Queensland Rail's risk management procedures did not sufficiently mitigate risk to the safe operation of trains in circumstances when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion.

Action taken by Queensland Rail

Queensland Rail provided a response on 1 March 2013 detailing the initiation of the following targeted precautionary mitigation strategies in response to the collision of train T842 at Cleveland Station on 31 January 2013.

- The formation of a Wheel Rail Interface Working Group. The Working Group, sponsored by the Executive General Managers - Rail Operations and Safety, Assurance and Environment, is tasked to specifically identify and assess any potential wheel rail interface risks, particularly for Queensland Rail's fleet of 160/260 class trains being operated in certain conditions, and to determine if any further engineering, administrative or other safety risk controls should be considered and implemented.

  The Working Group comprises a range of internal and external stakeholders including rolling stock, rail network, and train service delivery engineers, technicians and managers; key rail union representatives from the Rail Tram and Bus Union and Australian Federated Union of Locomotive Employees; and an experienced independent rail safety risk management consultant. The Working Group is also supported by a range of subject matter expertise including for program, risk, safety and human resource management and train manufacturer Bombardier. It is important to note that Queensland's Rail Safety Regulator also has a nominated observer on the Working Group to ensure Queensland Rail continues to effectively manage its rail safety risks.

  The Working Group's key deliverables, as outlined within its Terms of Reference are to develop:

- A list of evidence based hazards and the likelihood of future risk associated with 160 and 260 class units
- A plan of control, addressing future risk, prioritised and classified as short, medium and long term controls
- Any plan of control needs to provide mitigation strategies which focus on safety, customer service and service continuity.

One of the Working Group's first tasks was to develop a comprehensive risk assessment of any potential wheel rail interface issues for the 160/260 class of trains operating on the network and their associated safety risk controls. The risk assessment was independently validated and recommended a number of precautionary risk controls to be adopted, in addition to existing controls, whilst further medium and longer term testing and assessments continued. These precautionary risk controls include:

- Identify and treat track rail-head contaminants at any localised black spot locations.
- Build track contaminant risk identification into routine track inspection processes to help inform track gangs to be on the lookout for related contaminants.
- Assess whether current vegetation control processes have the potential to cause or contribute to contamination of the rail.
- Ensure there are no parts of the network where train crews are exposed to acute reductions in line speed without receiving advance graduated speed reduction notice.
- Provide train crews of 160/260 fleets with enhanced train handling advice that when approaching stop signals and other critical points, that they should aim to reduce speed to 50% of line speed when observing a single yellow signal and, not exceed 30 km/per hour when within 150 metres of red signals/critical stopping points, unless a lower speed is indicated, in which case the lower speed applies.
- Review current driver training processes and adapt training materials to specifically address any identified class 160/260 unique characteristics.
- Encourage train crew to report all excessive wheel slip occurrences on 160/260 fleet.
- Monitor and further analyse data logger information of trains, as per new explanatory procedure if they are subject to an excessive wheel slip occurrence.
- Continue research to ascertain whether 160/260 class train brakes are releasing long enough in wheel slip scenarios for the wheel sets to recover prior to the brake system reapplying brakes.
- Research wheel cleansing modification opportunities.
- Review planned new generation rolling stock specifications to ensure current wheel slip lessons learnt are considered.
- Review train crew training around:
    - Known fleet specific hazards and fleet characteristics; and
    - Defensive driving techniques

Queensland Rail's Executive General Management had no hesitation in accepting all of these recommended precautionary controls and ordered their immediate implementation.

- Queensland Rail continues to test and assess wheel rail interface risks around its 160/260 class fleet including reviewing what possible further controls should be implemented.
- In addition to these wheel rail interface controls and processes, Queensland Rail also provided a Critical Safety Alert to staff regarding the importance of both providing and following

documented Safety Management System instructions whenever an incident is or may be impacted by overhead electrical infrastructure.

Queensland Rail also continues to fully support and coordinate with the ATSB in its ongoing investigation.

ATSB response:

The ATSB notes that Queensland Rail is in the process of implementing its precautionary mitigation strategies to provide for the safe operation of rolling stock but the residual safety risk remains significant and further action is required.

Recommendation

The ATSB recommends that Queensland Rail take action to mitigate risk to the safe operation of their trains in circumstances when local environmental conditions result in contaminated rail running surfaces and reduced wheel/rail adhesion.

Ongoing ATSB investigation activities

The ATSB's investigation is continuing and will focus on:

- Safety Management System procedures for the management of risk including any history of similar events and strategies to mitigate risk arising from vehicle operation.
- Procedures in relation to the operation of rail vehicles in poor adhesion conditions and the training of drivers.
- Operational characteristics and performance of wheel slip protection systems.
- Design and inspection of buffer stop assemblies.
- Design of overhead traction support structures.
- Emergency management and rescue.
- Crashworthiness of the incident train.
- Requirements of the Queensland *Transport (Rail Safety) Act 2010.*

General details

Occurrence details

Date and time:	31 January 2013 0940	
Occurrence category:	Accident	
Primary occurrence type:	Collision	
Location:	Cleveland railway station, Brisbane, Queensland	
	Latitude: 27° 31.455’ S	Longitude: 153° 15.975’ E

Train: T842

Train operator:	Queensland Rail Limited	
Registration:	T842	
Type of operation:	Passenger	
Persons on board:	Crew – 2	Passengers – 17
Injuries:	Crew – 1	Passengers – Multiple minor injuries
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Bureau of Meteorology
- Queensland Rail Limited
- Queensland Department of Transport and Main Roads

References

Used where reference material has been quoted or specifically referred to in the report. Must use academic referencing standards, for example:

Lewis R, & Olofsson U, (editors) *Wheel-rail interface handbook*, (2009) Woodhead Publishing Limited, pp. 510-527.

RAIB, Station overrun at Stonegate, East Sussex, 8 November 2010, Report 18/2011, November 2011. Autumn Adhesion Incidents, Parts 1,2 and 3, November 2005.

RISSB, National Guideline Glossary of Railway Terminology

Rolfe ST, Barsom JM 1977, *Fracture and fatigue control in structures, applications of fracture mechanics*, Prentice-Hall New Jersey, pp. 414-440.

Rollingstock Engineering QR Services Report, Document No. 200907/P, Version 1.0, Dated 25.08/2009. Source Queensland Rail

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, the 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: Queensland Rail, the crew of train T842, Department of Transport and Main Roads. Submissions from those parties were reviewed and the report was amended where considered appropriate.

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 fare-paying passenger operations.

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 safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

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.

Terminology used in this report

Occurrence**:** accident or incident.

Safety factor**:** an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (for example, engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor**:** a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor**:** a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding**:** any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue**:** a safety factor that (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 operational environment at a specific point in time.

Risk level**:** The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety action taken during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical safety issue:** associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant safety issue:** associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor safety issue:** associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action**:** the steps taken or proposed to be taken by an organisation or agency in response to a safety issue.

Glossary

- Regenerative Brake- This form of braking is when the traction motors are switched over to act as generators and therefore convert the kinetic energy of the train into electricity. In regenerative braking the electricity generated is recycled back into the overhead power supply if there is a difference in potential. This type of braking is affected by traffic density.[27]
- Friction Brake - Friction braking is achieved by increasing the air pressure in disc brake units (brake cylinders) mounted adjacent to every wheel. An increase in brake cylinder pressure will result in a proportional increase in force being applied to brake blocks that contact the disc brake rotors fitted to the axles resulting in an increase in friction braking effort and an increase in the deceleration rate of the train.[27]
- Anti-compounding - The parking brake unit is fitted with an anti-compound valve. The anti-compound valve prevents the addition of the force from the parking brake unit to the force from the service brake unit should they both be applied simultaneously.[27]

[27] Rollingstock Engineering QR Services Report, Document No. 200907/P, Version 1.0, Dated 25.08/2009. Source Queensland Rail