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ATSB TRANSPORT SAFETY REPORT
Rail Occurrence Investigation RO-2008-013
Final

Derailment of train 2PM6 – near Loongana, Western Australia

11 November 2008

Figure 1: Derailment site showing separated front and rear portions of train 2PM6.

Abstract

At about 1655[1] on Tuesday 11 November 2008, freight train 2PM6 derailed on the Nullarbor Plain approximately 11 km west of Loongana in Western Australia. There were no injuries as a result of the derailment but there was significant damage to rolling stock and track. The investigation found that the combined effects of atmospheric wind and induced wind due to train movement was likely to have been sufficient to initiate the overturning and subsequent derailment of a lightly loaded, double stacked wagon and other vehicles. Two safety issues were identified relating to the suitability for double stacking of certain wagon types, particularly in high-wind operations, and maintenance of container securing mechanisms. The train operator has taken safety action to address those issues.

FACTUAL INFORMATION

Location and environment

The derailment occurred east of Kalgoorlie, Western Australia on a straight section of track near the 1251.200 km[2] point on the Trans Australian Railway. At this location the train was about 24 km into a 450 km straight section of track where the maximum freight train speed is set at 110km/h. There were no temporary speed restrictions in force at the time of the derailment. The track is relatively level and constructed on a limestone rock and earth base surrounded by sparse bluebush and other low level vegetation.

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[1] The 24-hour clock is used in this report to describe the local time of day. Western Daylight Time (WDT).

[2] Distance in kilometres from a track reference point located at Coonamia in South Australia.

Track structure

The Australian Rail Track Corporation (ARTC) is responsible for access to, and the maintenance of, the section of track over which train 2PM6 was travelling at the time of derailment. Transfield Services perform track maintenance under contract to the ARTC.

The track structure consists of a ballast bed having a minimum depth of 250 mm supporting concrete sleepers and continuously welded 47 kg/m rail. The sleepers were spaced at approximately 666 mm centres with the rails fastened to the sleepers using resilient clips. The track near the derailment site was straight and almost level and the track was elevated about 1 m above the natural ground surface.

Freight train 2PM6

Freight train 2PM6 was an intermodal freight service owned and operated by Pacific National. It consisted of two locomotives (NR101 leading and NR62 trailing), two crew accommodation carriages and 41 freight wagons (12 of which were multiple platform vehicles[3]). Train 2PM6 was loaded with a combination of double and single stacked containers on container flat and well[4] wagons. The front portion of the train mainly consisted of single stacked containers with the rear portion mainly double stacked containers. The ratio of double and single stack container loading was around 1:1. The train was 1655 m long and weighed a total of 3622 t.

The train crew consisted of two sets of two drivers. The two crews worked rotating shifts with one crew driving while the other rested. The resting crew were accommodated in a fully equipped crew van marshalled immediately behind the locomotives. The driver at the time of the derailment had about 8 years train driving experience. Both train drivers were appropriately qualified, assessed as competent and medically fit for duty.

Environmental conditions

The Bureau of Meteorology (BoM) has automatic weather observation stations at various locations on the Nullarbor Plain. The closest weather stations to the derailment site were at Forrest, approximately 113 km to the east and Balgair, approximately 142 km to the west. The BoM weather observations for Balgair (wind, temperature, relative humidity) were not recorded on 11 November 2008.

The maximum temperature at Forrest on 11 November 2008 was 40.9 degrees Celsius at 1322 and remained in the high 30's until late in the afternoon. No rain was recorded on the day.

Information based on the weather charts, satellite and radar images, shows a surface trough was moving through the Goldfields and Eucla regions during the day. The surface trough, combined with a middle level trough to the west, caused a line of thunderstorms to propagate through the area. The hourly weather observations at Forrest showed a rapid wind speed increase at around 1900, as the mean wind speed peaked at 55 km/h from the WNW at 1909. The daily maximum wind gust was 85 km/h at 1918. The radar images also indicated the presence of thunderstorms at Forrest during the peak wind gust at around 1900 to 1920.

Although there are no observations available at Loongana, the radar imagery showed a line of storms approached and moved through Loongana from about 1700 to 1720. The magnitude of the maximum wind gust at Loongana on the day could be similar to that recorded at Forrest.

Occurrence

On the morning of the derailment, the drivers signed on for duty at 1010 at Parkeston, Western Australia and went to the fuelling point to take

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[3] Multiple platform vehicles on train 2PM6 included 5 pack, 5-unit and 2 unit freight wagons. 5-pack – An articulated wagon comprising five platforms, the adjacent ends of individual units being supported on a common bogie and permanently connected by a device which permits free rotation in all planes. Note, these do not always consist of five units; they could be 2-packs, 3-packs etc. 5-unit – A wagon consisting of five permanently coupled platforms, each platform independently supported on a pair of bogies. Note, 5-units are the most common but they do not need to consist of five units, i.e. there could be 2-units, 3-units in the same configuration. Source: ARA Glossary for the National Codes of Practice and Dictionary of Railway Terminology.

[4] A well wagon is a flat car having the height above rail of the underframe/deck structure reduced between the bogies to provide additional vertical load space.

control of train 2PM6. After departing Parkeston at 1104, train 2PM6 successively crossed three train services at Golden Ridge (1MP2 at 1126), Curtin (1MP9 at 1153) and Bonderoo (1MP5 at 1431). The driver reported that the train was running very well and was able to maintain 110 km/h with the aid of a tail wind. After passing through Nurina and entering the 450 km straight section of track, the drivers observed pockets of lightning and wind induced dust moving towards them from a north to north-easterly direction.

The drivers said the train continued along the straight and that the wind was coming from predominantly the left (northern) side of the locomotive. While travelling at an estimated 106 or 107 km/h, the wind became stronger, the conditions were dusty and the speed of the train reduced rapidly. The driver said they lost an estimated 35 km/h over about 3.5 km. While slowing, the driver (who was seated on the left side of the locomotive) noticed a 'ball of dust' coming towards the train. He called the co-driver to 'come over and have a look at this'. With both drivers looking back along the train from the left (northern) side of the locomotive, the 'ball of dust' hit the train. At this time the drivers said the train surged, the locomotive wheel-slip light came on briefly and then the train surged a second time. Shortly after the second surge brake pipe air was lost. The driver of the train estimated the speed of the train to be about 70 km/h when the first surge was felt. He also described the sensation of the train slowing over the 3.5 km as 'like hitting a brick wall', despite the throttle being set at eight notches (full power).The second driver added that 'it started to rain at this time with the storm front hitting us, so we thought it (the locomotives) was just slipping a bit with the sudden wind hitting the side of the train'

The driver said that upon seeing the brake-pipe air being lost, the crew suspected the train had derailed. The crew then bailed off[5] the locomotive independent brake and gradually reduced power to keep the train stretched. The train then progressively slowed and about 900 m after the initial loss of air, the lead locomotive stopped about 50 m short of the 1,249 km post.

At about 1655 the driver contacted train control to advise that train 2PM6 had stopped due to a suspected derailment and he would advise again when further information was available.

The hand-held radio was then set to 'repeater mode' to enable the drivers to communicate with train control while off the locomotive. Both drivers then alighted from the locomotive and walked back to inspect the train. They subsequently reported that the train had derailed at the 34th freight wagon and separated between wagons 36 and 37. It was reported that there was a gap of approximately 400 m between the 36th wagon and the remaining group of derailed wagons (Figure 1).

The drivers also reported that three of the derailed wagons, including a 'five-unit' wagon, had overturned. This resulted in freight containers, wheel-sets, bogies and debris being scattered mainly along the southern side of the track. The last wagon in the train had derailed the leading bogie only and remained upright while still coupled to the derailed and overturned portion of the train ahead[6].

Damage and Recovery

A total of eight freight wagons[7] were derailed with the majority sustaining significant damage. Some freight containers had become detached from their wagons and were ejected to the southern side of the track. Other containers remained attached to wagons which had fallen on their side, and were damaged after being dragged alongside the track by the front portion of train.

At about 1320 on 12 November 2008, the undamaged front portion of train 2PM6 departed the derailment site and continued its journey via Adelaide to Melbourne.

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[5] Bail off is a term used to describe the action of:

- preventing the locomotive(s) brake from applying automatically during a train brake application, or
- releasing the locomotive(s) independent brake during a train brake application.

[6] The initial report from the drivers was that the last vehicle had not derailed. Further inspection though revealed that the leading bogie had derailed towards the south side of the track.

[7] In the direction of travel, the derailed vehicles of train 2PM6 were one 2-unit wagon, two single unit wagons, one 5-unit wagon and four single wagons.

Track and rolling stock recovery crews, heavy lift cranes and equipment were deployed from Kalgoorlie WA and began arriving at the derailment site on the evening of 12 November 2008.

Approximately 750 m of track was damaged in the derailment and the recovery of derailed wagons and freight containers began on 13 November 2008. The restoration of track occurred in conjunction with the recovery of rolling stock and was re-opened to traffic at about 1830 on 15 November 2008, a little over 4 days after the derailment. Containers and other freight were stored beside the track to allow track restoration and were removed from site between 13 and 17 November 2008. Damaged wagons that could not be re-railed were stored beside the track and removed from the area between 5 and 8 January 2009.

ANALYSIS

Mid-morning on 12 November 2008, investigators from the Australian Transport Safety Bureau (ATSB) arrived at the derailment site. Damaged and derailed wagons, rolling stock components and damaged track were examined and photographed on site.

Other evidence was provided to investigators from the ARTC, Pacific National and the BoM. The evidence included train control graphs, locomotive data logs, train consist and inspection information, track diagrams, train driver/co-driver statements, medical fitness, fatigue and training records and weather observations.

The location of wagons, scattered components, displaced containers and score marks on track and rolling stock components were examined on-site. While the point of derailment was evident, no clear cause as to why train 2PM6 derailed at this location could be identified at that time.

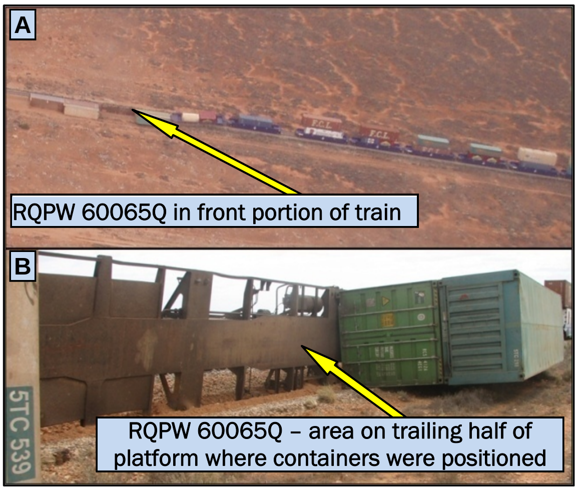
Sequence of events analysis

Site observations

Examination of the derailment site focused on the 35th wagon RQPW 60065Q as it was considered most likely to have been the first wagon to derail (Figure 2).

The two-unit wagon ahead of RQPW 60065Q (CQWY 5008J-2) was considered to have derailed as a consequence of being pulled to the right of the track after wagon RQPW 60065Q had overturned onto its side. The trailing unit of CQWY 5008J had derailed but remained upright and attached to the front portion of the train.

Figure 2: RQPW 60065Q showing location of displaced containers.



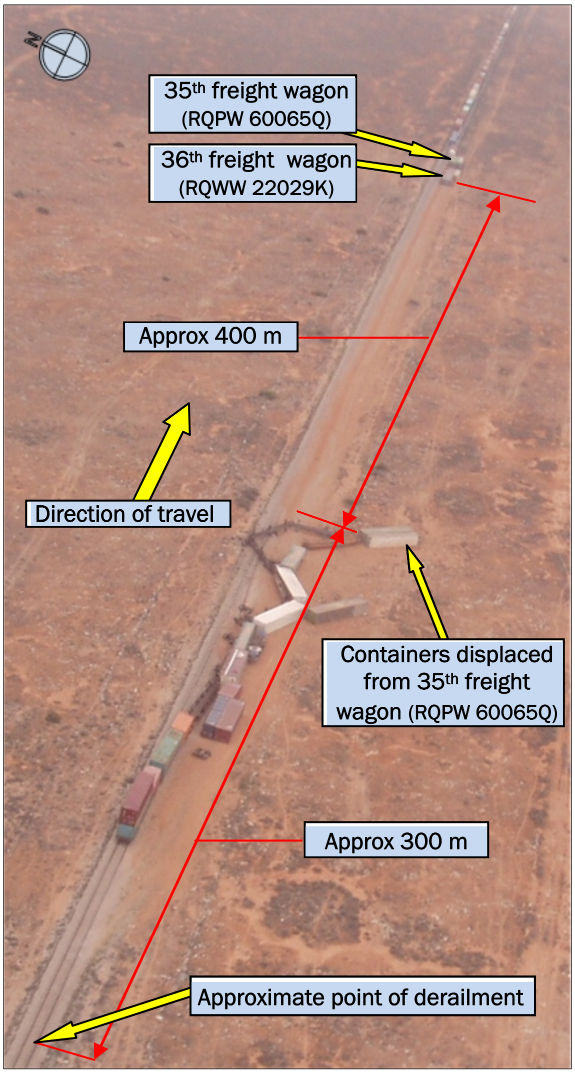
The 36th freight wagon (RQWW 22029K), positioned behind RQPW 60065Q, had overturned on its right side and remained coupled (Figure 1). All four double stacked containers remained locked to wagon RQWW 22029K.

The key observations were:

- A single diagonal wheel contact mark along the head of the rail on the south side was visible for about 1.2 m. The mark extended from the outside to the inside of the rail head, indicating that a wheel had dropped off towards the inside of the track.
- No wheel flange climb or contact marks were evident on the head of the north rail opposite the visible point of derailment on the south rail.
- Damage to sleepers and resilient clips on the inside of the south rail was more severe than damage to the same items outside the north rail.
- Wheel flange contact marks with resilient fasteners and sleepers on the outside of the north rail spanned about 3 m before no further evidence of wheel contact was visible.
- When wagon RQPW 60065Q overturned, two of the four double stacked containers from this

wagon had been displaced about 400 m before the train came to stop (Figure 3).

Figure 3: Aerial view of derailment site showing derailed front & rear portions of train



- The containers displaced from RQPW 60065Q were located at the front of the derailed rear portion of the train and were about 25 m from the track. (Figure 3).
- Both double stacked containers that had been displaced from the trailing end of wagon RQPW 60065Q remained attached to each other and came to rest on their side (Figure 3).
- The derailed 5-unit wagon (RRQY 07304F, positioned 37th), had bunched up and rolled onto its side in an arc formation immediately behind the two containers that had been displaced from RQPW 60065Q. RRQY 07304F had also displaced most of its load and shed its bogies.

Track condition

The track near the derailment site was elevated about 1 m above the natural ground surface. It was straight, almost level and appeared to be in good condition with a full ballast profile for both shoulder and crib[8].

There was no evidence to indicate that a track defect may have contributed to the derailment of train 2PM6.

Locomotive data and train handling

Train data log information from locomotive NR 101 showed that 18.6 km before the point of derailment, train 2PM6 was travelling consistently in notch eight (full throttle) at a maximum speed of 105 km/h. The data then shows that at about 17 km before the point of derailment there was a gradual loss of speed from 105 km/h to 92 km/h over a distance of 7.4 km. An increase in speed back up to 105 km/h is then indicated over the next 7 km. After maintaining this speed for about 1 km, speed again decreased over the next 3.8 km to 84 km/h, despite the locomotive still being at full throttle. Calculations indicate that the derailment occurred at this speed.

This data supports the pre-derailment account of the train driver regarding the loss of speed being related to the onset of strong winds.

The data log information then shows that when the first indication of brake-pipe reduction was recorded by the data log on NR 101, the speed further reduced to 75 km/h. The reduction of power by the driver (from notch eight to notch seven) commenced 7 seconds after this loss of air indication. Power reduction continued over the next 48 seconds until the locomotive came to a stop, still in power notch two, about 50 m short of the 1249 km post. During this time, the data log shows that the train brake handle was left in the running position and the locomotive brakes were not allowed to apply until the train was stationary.

This data supports the train driver's post-derailment account of trying to keep the train stretched. Of note is that the first indication at the

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[8] A full crib and shoulder and crib is indicated when ballast's surface is level with the top surface of each adjacent sleeper and has the required amount of ballast at the ends of each sleeper.

lead locomotive of brake-pipe air loss, was recorded as 37 seconds after the time the train commenced to derail (point of derailment). The brake-pipe would have vented to the atmosphere at the time of, or shortly after, the derailment and near the place where the first wagon derailed. Therefore, it appears that the propagation rate of the reduction in brake-pipe air pressure took up to 37 seconds to reach (and register) at the lead locomotive. Given that the first wagon to derail was 1381 m behind the lead locomotive, this propagation time is not unreasonable. In total, the train came to a stop about 85 seconds and 900 m after the derailment.

It is considered that train 2PM6 was handled in a manner that endeavoured to keep the train stretched as much as possible, thereby reducing the risk of the train concertinaing due to buff forces[9]. However, when the train brake handle is left in the running position, the locomotive feed-valve will attempt to maintain the brake-pipe pressure at 503 kPa (brakes released). With the length of train (post derailment) in this instance being 1381 m, the brakes towards the front may have only applied with minimal force or not at all during the 48 seconds it took for the train to stop after the loss of air had registered at the lead locomotive.

It follows that the train may have been able to safely stop in a slightly shorter distance had the brake valve been placed in the service zone[10] when the loss of air was first noticed. The locomotive brakes could still have been prevented from applying and, providing the brake-pipe air was not reduced below a full service application, the desired locomotive power could have been maintained by the driver[11].

Rolling stock condition

The RQPW class is a flat platform intermodal container wagon, capable of transporting double stacked containers at a maximum speed of 110 km/h[12] at a maximum gross weight of 78 t. Manufactured in Australia beginning in 1983, the RQPW class of wagons were built to comply with Railways of Australia standards.

Wagon RQPW 60065Q was loaded with four empty containers that were double stacked and fastened to the wagon platform using retractable twist-locks[13]. The combined weight of the containers was 20.11 t. During the derailment sequence, wagon RQPW 60065Q overturned onto the south side of track allowing the bogies to disengage from the wagon body. No mechanical deficiencies were identified with bogies, wheels and axles on wagon RQPW 60065Q.

Containers on RQPW 60065Q

During the derailment, two 12.2 m (40 foot) containers that were positioned on the trailing end of wagon RQPW 60065Q became detached and were ejected about 25 m to the south side of the track, coming to rest as a pair on their sides. One twist lock was torn from the centre left corner on the wagon platform (high side after overturning) and remained located in the lower container. Closer inspection revealed that this twist lock casting was a replacement that had not been fully welded and correctly reinforced in accordance with the original design and construction. Welds securing the twist lock casting were superficial and structurally unsound. While the failed twist lock casting may have been subjected to loads outside of normal operational parameters as a result of the derailment sequence, it was considered likely that the inferior weld and lack of reinforcement could have resulted in a future failure even under normal operational loads. It was also considered possible that maintenance work on other twist lock castings could be of a similar inferior quality.

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[9] Buff Force is a compressive in-train force experienced through wagon couplers that increases after the train has transitioned from a slack to a bunched (compressive) condition. In this case, the trailing portion of the train was braking while the locomotives remained under power to reduce the buff forces.

[10] The normal brake handle operation range for the application of brakes that is used without entering the emergency braking zone.

[11] Power is lost when brake-pipe pressure reduces below a full service application.

[12] 115 km/h is permitted between Perth and Kalgoorlie, 110 km/h is permitted between Kalgoorlie and Adelaide.

[13] A twist lock is a latching device used to secure ISO containers to rigid, skeletal and platform vehicles.

Twist locks from the two corners that contacted the ground had probably been sheared off during the overturn and subsequent dragging of the containers alongside the track. The remaining rear twist lock shaft (on the high side after overturning) had been torn out from the wagon and was retained in the container corner casting after separation from the wagon. There was no evidence to suggest that an unsecured load contributed to the derailment of train 2PM6.

Weather observations

Weather observations recorded at Forrest were used as an indication of conditions in the greater region of the derailment site. Table 1 shows wind gust and air temperature data recorded on 11 November 2008. The data was sampled at various intervals (mostly hourly), with wind gust data being the highest wind speed recorded during the 10 minutes beforehand[14].

Although the data recorded at the Forrest weather station was 113 km ahead of the train, it shows the variations in wind direction and a general increase in wind speed in the afternoon and evening. A track inspector who had been travelling on the track ahead of train 2PM6 on the day of the derailment, reported that strong gusts of wind had shaken his road/rail vehicle. He considered that the wind conditions were some of the most extreme he had experienced during his career.

Table 1: Data from BoM Forrest Weather Observation Station 11 Nov 2008[15]

Time	Air Temp °C	Wind Gust	
		km/h	Direction
1200	38.2	42	NNW
1300	40	37	NNW
1400	39.6	31	WNW
1500	39.7	28	NW
1600	39.1	17	SW
1605	39	42	WSW
1615	39.1	48	WNW
1700	38.2	41	N
1800	37	35	NNW
1857	35.2	67	NNW
1859	33	67	WNW
1909	32.2	74	WNW
1945	32.3	67	WNW
1950	32.4	46	WNW

Intense local weather conditions can often develop that are difficult to detect on standard synoptic charts. While weather forecast information for capital cities and larger regional townships is detailed and includes weather warnings with predicted wind speeds and direction, weather forecasts in remote areas are provided in a generalised format. A weather forecast issued at 0426 by the nearest BoM meteorological office at Eucla on the day of the derailment predicted fresh north-east to north-west winds ahead of a south-west change during the day. No warnings were issued with the forecast.

Severe winds in thunderstorms are usually caused by a downdraught of cold air. The BoM describes a localised downdraught as downburst, and if they are less than 4 km across, they are referred to as a microburst.[16] Very severe downdraughts (or microbursts) can produce wind speeds of more

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[14] The Bureau of Meteorology apply a tolerance of + or - 8 km/h for maximum wind gust values.

[15] Table adjusted to compensate for Western Daylight Time (WDT).

[16] Bureau of Meteorology - 'The Wonders of the Weather' Bob Crowder - 1995.

than 200 km/h while only affecting areas of up to 1 km wide.[17]

The descending air is forced to spread out laterally near the earth's surface, often creating severe wind squalls with associated dust, similar to that experienced by the crew of train 2PM6.

It is probable that the downdraught of cold air in the form of a microburst in the vicinity of the derailment site created wind speeds significantly higher than those recorded at the Forrest weather station.

Wind induced lateral force, especially that acting on the side of a rail wagon, is considered to contribute significantly to body roll and potential wagon roll-over. The ATSB, therefore, closely examined the possibility that the severe environmental conditions at the time of the derailment may have led to a wagon roll-over scenario. Similarly, the factors that serve to resist roll-over were also examined.

Derailment scenario

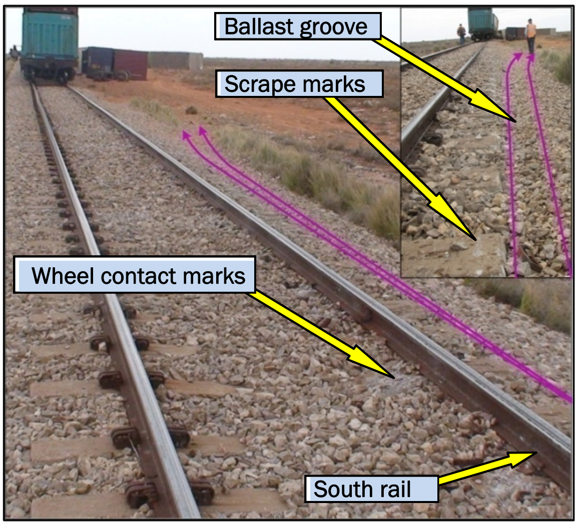
A wagon's lateral stability largely depends on the relationship between lateral and vertical forces. A common derailment scenario is for a track defect, rolling stock defect or inappropriate train handling to cause undesirable lateral force and contribute to a flange climb derailment. The scenario would normally be associated with wheel flange markings extending from the inside to the outside of the rail head.

In this case, there was evidence of an impression left by a wagon wheel as it diagonally crossed the head of the south rail, but it crossed from the outside to the inside of the rail head. The mark started faintly and was visible over a distance of about 1.2 m. For the last 400 mm, the wheel left a heavier indentation as it left the rail head immediately before dropping off towards the inside of the track. After dropping, first evidence of contact was where a resilient clip and steel resilient clip anchor housing had been crushed.

The corresponding wheel on the north rail had derailed to the outside. No flange climb marks were visible on or across the head of the north rail. The first strike mark by a wheel outside the north rail was evidenced by a faint mark on the top radius section of the resilient clip closest to the rail web.

Damage to resilient clips, steel resilient clip anchor housings and sleepers on the inside of the south rail increased significantly (implying high vertical wheel loading) while damage to the same components on the north rail opposite were light and no longer evident after four wheel strikes (implying low or negligible vertical wheel loading). Wheel contact damage on the surface of the sleepers within 300 mm of the south rail extended for about 15 m before scrape marks (probably from a bogie side frame) started to appear on the concrete sleeper surface outside the south rail (Figure 4).

Figure 4: Displaced ballast and sleeper damage



These scrape marks were evident on the top of about nine sleepers before they were no longer visible and damage started to increase on the southern side sleeper ends.

Grooving of the ballast on the south side commenced at about the same time as wheel impact damage to the surface of the sleepers inside the south rail started to diminish. A groove in the ballast slowly tapered away from the track and disappeared over a distance of about 18 m. Thereafter, only flat scrape marks were left on the ground, consistent with an attached pair of overturned containers and wagon components being dragged alongside the track.

The evidence indicated that wheel unloading above the north rail allowed the corresponding wheel on the south rail to drop inside the track.

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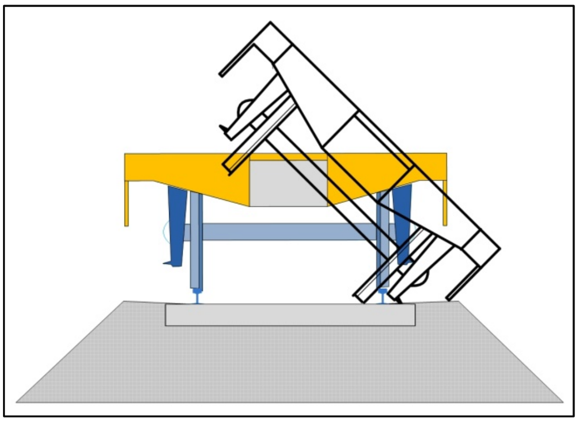
[17] Australian Geological Survey Organisation & Bureau of Meteorology - Natural hazards and the risks they pose to South-East Queensland - 2001

The severity of the marks on sleepers and fasteners indicate heavier impacts and contact force on the south side. When compared to the south side, the north side damage was minimal, evident by light markings and resilient clip displacement over a short distance.

The combination of the wheel unloading and light damage to sleeper fittings on the north rail indicated that a wagon (most likely to be wagon RQPW 60065Q) and its load of containers progressively began to lean towards the south side of the track before overturning onto its side (Figure 4).

When considering a roll-over scenario, it is likely that the profile of the disturbed ballast was caused by the side frame and steps of wagon RQPW 60065Q (considered to have been the first derailed wagon) as it tilted sideways. In addition, as the wheels on the south side had dropped to the inside of the rail, the gap was reduced between both the wagon side frame and steps and the track components immediately before contact was made with each of these items (Figure 5).

Figure 5: Overlay of rolled RQPW wagon



Wind force calculations

The side of a double stacked container wagon will act like a sail when considering wind induced lateral forces acting on a wagon. As the combined side area of a loaded wagon increases, so too will the resultant wind force acting on the wagon.

It is also important to consider the shape of the side area exposed to wind when considering wagon roll-over due to wind force. Consequently, other factors such as a wagon's total mass and the distribution of this mass should also be examined when considering wind induced wagon roll-over.

There are no criteria documented in the current Code of Practice for the Defined Interstate Rail Network (CoP) to take into account the effects of wind loading on rail vehicles. However, an Australian Standard developed by the Rail Industry Safety and Standards Board (RISSB) does include this consideration in AS 7509.2, titled *Railway Rolling Stock - Dynamic Behaviour – Part 2 - Freight Rolling Stock*. The standard states that rolling stock susceptible to overturning in high winds should undergo wind loading assessment. Rolling stock with a large side area, such as a double-stacked container wagon, is listed as an example in the standard.

The standard does not specify a process, but indicates factors that should be considered such as the drag co-efficient (usually determined from wind tunnel testing) relevant to the wagon being tested. The acceptance criteria specified is that wheel unloading on one side of any bogie should not exceed 90%.

RQPW class wagon

A wind load assessment had not been conducted on the RQPW class wagon. However, in 2005, SCT Logistics (SCT) engaged the Royal Melbourne Institute of Technology University[18] (RMIT) to carry out wind tunnel testing on three rail wagon profiles. Those tests looked at the aerodynamic forces caused by crosswinds that are considered to have a significant influence on wagon roll-over and measured the relationship between wind angles and the coefficient used to calculate wind force. The primary objectives of the study were to determine the effects of steady crosswinds and to predict the effects of unsteady wind conditions on rail wagons.

Tests were carried out using 1/15th scale models of a SCT high cube wagon having a total height of 5.59 m, a high cube wagon with an extra 300 mm added to the roof profile, and a double stacked container well wagon.

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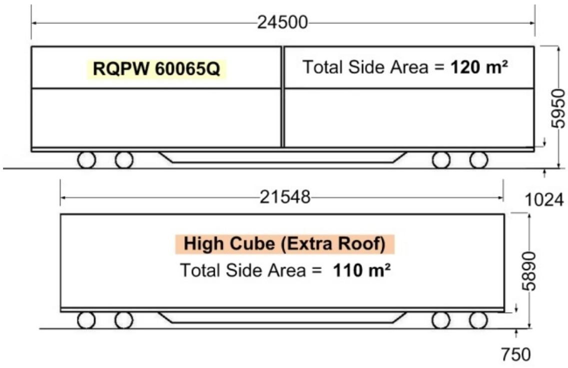
[18] Tests were conducted by the School of Aerospace, Mechanical and Manufacturing Engineering at RMIT University for SCT Logistics prior to production of the SCT High Cube wagon fleet.

On train 2PM6, wagon RQPW 60065Q was loaded with four 12.2 m long (40 foot) containers that were positioned with two 2.89 m high containers on the bottom layer and two 2.03 m high containers mounted above. This configuration created a total side area of 120 m² (Figure 6).

Figure 6: Wagon profile and area comparison



When considering the profile that loaded wagon RQPW 60065Q would have presented to winds and comparing these figures with the wagon models subjected to wind tunnel testing, the SCT high cube wagon with extra roof is found to be the closest match. Therefore, the wind tunnel results for the SCT high cube wagon with extra roof were used as the closest reference for calculating the percentage of wheel unloading on wagon RQPW 60065Q for different wind speed and vehicle speed combinations.

For train 2PM6, the load configuration of wagon RQPW 60065Q exhibited a poor profile with respect to wind load by having a large side surface area, light weight and high centre of side area. In calculating the percentage of wheel unloading, a simplified method assumes that the wagon's centre of mass acts continuously at the centre point between the two rails (that is, the wagon suspension is rigid and does not permit body roll). When the train is travelling at a speed of 90 km/h, 100% wheel unloading on wagon RQPW 60065Q is calculated to occur when atmospheric wind speed is about 80 km/h and at an angle of between 60 degrees and 80 degrees relative to the direction of travel.

Given the test results described above and the observations provided by the train crew and the BoM, it is likely that the wind conditions existing in the area at the time of the derailment were sufficient to result in significant wheel unloading of one or more wagons.

Consideration of body roll

Under normal operating conditions, a wagon will oscillate on its bogies and suspension and external forces such as wind loading can increase wagon body roll from side to side. The consequence of this movement is the wagon's combined centre of mass will also shift from side to side, significantly affecting the calculations for predicted roll-over risk due to wind. The magnitude of this movement for the same roll angle will increase as the height of the centre of mass increases above rail level. The critical elements are the roll angle and the height of the centre of mass above the rail level.

In this case, wagon RQPW 60065 was loaded with 12.2 m containers arranged in a double stack configuration. Two full height containers were on the bottom and two half height containers on top. Pacific National advised that the containers were empty. Consequently, load shift was unlikely to be a factor and each container's centre of mass was assumed to be at its centre of volume.

Table 2: Wind speed and angle for predicted 100% wheel unloading

Roll angle	**Wind speed**	**Wind Angle**[19]
0 degrees	**80 km/h**	**60 – 80 deg**
5 degrees	**70 km/h**	**60 – 90 deg**
10 degrees	**50 km/h**	**70 – 90 deg**
15 degrees	**30 km/h**	**80 deg**

Using the container weights documented in Pacific National's manifest report for the train, the wagon's combined centre of mass was calculated at 2.1 m above rail level. Table 2 illustrates the calculated results for predicted 100% wheel unloading for different angles of wagon tilt.

It should be noted that the calculated combined centre of mass was approaching the 2.5 m limit

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[19] Wind angle describes crosswind yaw angle in the direction of train travel. Results were derived from calculations under a range of crosswind yaw angles, from a full head wind to a crosswind (10 degree increments, 0–90 degrees).

documented in the Freight Loading Manual[20]. As described previously, the lateral shift in centre of mass is larger for the same roll angle as the height of the centre of mass increases above the rail level. To identify the influence that centre of mass has on wind induced wagon roll-over, calculations were made with all dimensions remaining constant, except for centre of mass which was lowered by 400 mm to 1.7 m above the rail level.

Table 3 illustrates the calculated results for predicted 100% wheel unloading at different roll angles if the centre of mass is lowered to 1.7 m above rail level.

Table 3: Centre of mass lowered to 1.7 m above rail level

Roll angle	**Wind speed**	**Wind Angle**
0 degrees	**80 km/h**	**60 – 80 deg**
5 degrees	**70 km/h**	**70 – 90 deg**
10 degrees	**60 km/h**	**60 – 90 deg**
15 degrees	**50 km/h**	**50 – 90 deg**

The wind speed required for 100% wheel unloading at zero and five degrees body roll remains almost identical to when the centre of mass is at 2.1 m. However, higher wind speeds are required for the higher roll angles when the centre of mass is lower. This implies that a wagon is likely to better resist wind induced roll over if its centre of mass is lower.

Freight loading standards

A critical issue relating to vehicle stability is the combined centre of mass (rail vehicle and load) above rail level. The CoP Freight Loading Manual states that for interstate routes, the combined centre of mass shall not exceed 2500 mm. The RISSB standard (AS 7509.2) is more stringent, specifying a maximum combined centre of mass of 2290 mm above rail level for standard gauge freight wagons.

In this case, the combined centre of mass for wagon RQPW 60065Q was calculated to be about 2100 mm. While this is within the limits specified above, calculations imply that keeping a lightly loaded wagon's combined centre of mass as low as possible is likely to improve the wagon's stability with respect to wind induced body roll and wheel unloading.

Pacific National has train loading and container handling procedures that specify parameters to match the loading of container types/sizes to individual wagon classes. Automated procedures are in place to ensure high deck wagons are not loaded with containers that can infringe the loading gauge.

The Pacific National Freight Loading Manual FLM03-09 did not comprehensively consider lightly loaded or empty double stacked container vehicles or identify classes of other freight vehicles as to their suitability for operation under high wind conditions.

National Codes of Practice

The Code of Practice for the Defined Interstate Rail Network Volume 1 - General Requirements and Interface Management, states that network owners should have systems in place to manage infrastructure restriction information where the safety of the network may be affected. The ARTC communicates restriction information through the placement of permanent and temporary trackside signs, train notices and through train control where train crews are provided with warnings and restrictions at short notice. Warnings to train crews are 'provided as soon as practicable such as not to jeopardise safety, and detail whether trackside signs have been installed'.

The Code of Practice Volume 3 also requires the train crew to pay attention to weather and track conditions as well as the length and mass of the train. The CoP states that where a condition exists that is hazardous, an emergency message can be sent to train control. The crew of train 2MP6 had observed a series of intermittent dust storms around their train after passing through Nurina and had a minimal amount of warning before the strong wind and dust storm struck and derailed their train near Loongana.

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[20] Code of Practice for the Defined Interstate Rail Network – Rolling Stock - Freight Loading Manual – January 2003

Summary

The weather forecast issued by the BoM on 11 November 2008 did not predict that there was a possibility of adverse conditions in the Eucla district. The strong wind experienced by the train crew prior to the derailment was described as a localised event.

For a train travelling at 90 km/h, wind force calculations using the RMIT test data indicates that a wind speed of 80 km/h could have resulted in 100% wheel unloading of wagon RQPW 60065Q.

When taking into account a wagon body roll angle of 5 degrees calculations show that wind speed required for 100% wheel unloading for wagon RQPW 60065Q reduces to 70 km/h. As the wagon tilts further, the required wind speed reduces significantly.

As described by the train drivers and evidenced on the locomotive data-log, it is probable that a downdraught of cold air in the vicinity of the derailment site produced winds greater than 70 km/h with sufficient side and frontal force to quickly slow the train and commence a derailment event.

As the four containers on wagon RQPW 60065Q were empty, the distribution of load or a shift of load in transit is unlikely to have contributed to the derailment.

Calculations indicated that the combined effects of atmospheric wind, induced wind due to train movement and wagon body roll could have been sufficient to initiate the overturning of the lightly loaded double stacked wagon RQPW 60065Q. The wheel contact marks on sleepers and displaced ballast profile on the southern side of the track indicate that this scenario was the most likely initiator for the derailment of 2PM6.

A number of risk controls can be implemented to reduce a wagon's risk of wind induced roll-over:

- keeping a wagon's combined centre of area as low as practicable
- keeping a wagon's combined centre of mass as low as practicable and evenly distributed across the width of the vehicle
- avoiding double stacking large empty containers onto any one wagon or platform.

Similar derailments

On 1 November 2006, the ATSB commenced an investigation into a derailment of a freight train near Tarcoola, South Australia. The final report[21] stated it was possible that the combined effects of strong winds at the time and the wagons' natural oscillations while travelling could have been sufficient to initiate overturning and derailment of the wagon's lightly loaded with double stacked freight containers.

Despite the extensive practice of containers being loaded in a double stack configuration in Australia, the ATSB could find no records of other wind induced derailments of double stacked wagons in Australia.

On a bridge in Ohio's Sandusky Bay (USA) on 30 January 2008, a train encountered wind gusts of more than 80 km/h before derailing 10 double stacked container wagons into the bay. The railway organisation reported they had placed coal cars on the parallel track to block the wind in an attempt to reduce the wind effect on double stacked container trains as they passed over the bridge. A similar derailment occurred at the same location in February 2003.

On 9 August 2006 in North Dakota (USA), a number of double stacked container wagons were blown into the Sheyenne River. It was reported that thunderstorm downburst winds had impacted on the high side profile container cars as they crossed the Luverne Trestle Bridge, 48 m above the Sheyenne River Valley floor.

In Manitoba (Canada) on 1 November 1999, two well wagons loaded with empty double stacked containers derailed and came to rest leaning towards an adjacent track. A train travelling on the adjacent track collided with the leaning containers causing significant damage to the locomotives. The investigation[22] found that high cross-winds exaggerated the natural oscillation of the well wagons and contributed to the derailment. The recorded wind speed, 23 km from the derailment site, was between 67 km/h and 83 km/h with gusts up to 107 km/h.

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[21] ATSB Rail Safety Investigation Report 2006012

[22] Transportation Safety Board of Canada (TSB) railway investigation report number R99W0231.

Safety Notices

In March 2009 Queensland Rail (QR) issued a safety notice[23] to employees to advise operational staff of the potential effect that weather and environmental conditions may have on train operations. The safety notice states:

> Where it is required to operate rail traffic in adverse conditions such as:
>
> - heavy rain,
> - high wind or,
> - reduced visibility, for example:
>   - fog or smoke
>
> and these conditions affect or have the potential to affect the safe operation of rail traffic and people on the network, the rail traffic crew will operate their rail traffic to suit the current conditions and advise Network Control of the conditions.
>
> Network Control should consult with Rail Traffic Crew, Track Maintenance Supervisors and other resources available and determine other factors which may impact on the running of rail traffic.
>
> Where information is available to Network Control that relates to the network, the Network Controller will advise if it is unsafe for rail traffic to travel.
>
> The Network Controller will impose such special conditions as may apply when rail traffic travel under adverse conditions and these include but are not limited to:
>
> - continual monitoring;
> - restricted speed;
> - increased exchange of information to ensure safety; and
> - updates on changes to weather conditions.

FINDINGS

Context

At about 1655 on 11 November 2008, Pacific National train 2PM6 derailed about 11 km west of Loongana, Western Australia.

From the evidence available, the following findings are made with respect to the derailment of train 2PM6 and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The configuration of four 12.2 m double stacked empty containers on wagon RQPW 60065Q provided a large side profile that was susceptible to high side wind forces.
- It is probable that the downdraught of cold air in the form of a microburst in the vicinity of the derailment site created wind speeds significantly higher than those recorded at the Forrest weather station.
- The combined effects of atmospheric wind, induced wind due to train movement and wagon body roll were most likely sufficient to initiate the overturning of the lightly loaded double stacked wagon RQPW 60065Q.
- The Pacific National Freight Loading Manual FLM03-09 did not comprehensively consider lightly loaded or empty double stacked container vehicles or identify classes of other freight vehicles that exhibit a large vertical surface area and their suitability for operation under high wind conditions. [*Significant safety issue*]

Other safety factors

- Previous maintenance work to replace one twist lock on wagon RQPW 60065Q was not carried out in accordance with the original design. Welds securing the twist lock casting were superficial and structurally unsound allowing the twist lock assembly to be torn from the wagon body during the derailment. [*Minor safety issue*]

Other key findings

- Rolling stock defects were not considered to have contributed either directly or indirectly to the derailment of train 2PM6.
- Train handling was not considered to have contributed either directly or indirectly to the derailment of train 2PM6.
- Train 2PM6 may have been able to safely stop in a shorter distance post derailment if a service application of the train brake had been made.
- A number of risk controls can be implemented to reduce the risk of wind induced roll-over:

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[23] Queensland Rail - General Operational Safety Manual - Version 1.2 (QR Weekly Notice 26/03/2009)

- keeping a wagon's combined centre of side area as low as practicable
- keeping a wagon's combined centre of mass as low as practicable and evenly distributed across the width of the vehicle
- avoiding double stacking large empty containers onto any one wagon or platform.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety 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.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Pacific National

Freight vehicles not identified for operation in high winds

Significant safety issue

The Pacific National Freight Loading Manual FLM03-09 did not comprehensively consider lightly loaded or empty double stacked container vehicles or identify classes of other freight vehicles that exhibit a large vertical surface area and their suitability for operation under high wind conditions.

Action taken by Pacific National

Pacific National has amended its procedures to specifically identify each class of wagon and its suitability for double stacking. As a result of Pacific National's investigations into this incident, Pacific National has now prohibited RQPW wagons being loaded with double stacked containers. In addition, Pacific National is reviewing options to modify its Train Management System (TMS) to alert Train Planners and thereby prevent train consists from being confirmed if RQPW and similar wagons are double stacked.

Pacific National is to update current Freight Loading instruction FLM03-09 to specifically exclude double stack loading of RQJW, RQNW, RQPW, RQDY and VQDY wagons and any other wagons of similar design which have the capacity to carry 2 x 40 ft containers in tandem on a single deck.

Pacific National is also to update current Freight Loading instructions to address the requirements of the new RISSB standard AS7509.2 which now include a requirement to wind loading.

Pacific National will introduce an early warning system for double stack trains operating under high wind conditions.

Pacific National is to amend standard driver's instructions to slow trains and be prepared to stop when high winds are observed.

ATSB assessment of action taken

The ATSB is satisfied that the action taken and proposed by Pacific National will adequately address the safety issue.

Twist lock inspection and maintenance

Minor safety issue

Previous maintenance work to replace one twist lock on wagon RQPW 60065Q was not carried out in accordance with the original design. Welds securing the twist lock casting were superficial and structurally unsound allowing the twist lock assembly to be torn from the wagon body during the derailment.

Action taken by Pacific National

Pacific National has advised that the organisation is in the process of amending maintenance inspection procedure WMM04-01' Twistlocks and Container Devices' to include a specific task to inspect all container twistlock castings on RQPW and similar wagons.

ATSB assessment of action taken

The ATSB is satisfied that the action proposed by Pacific National will adequately address the safety issue.

SOURCES AND SUBMISSIONS

Sources of information

Train crew

Pacific National

Australian Rail Track Corporation

Bureau of Meteorology

Royal Melbourne Institute of Technology University

Submissions

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

A draft of this report was provided to the Australian Rail Track Corporation, Bureau of Meteorology, Office of Rail Safety WA, Pacific National, Royal Melbourne Institute of Technology University and the train driver.

Submissions were received from the Australian Rail Track Corporation, Bureau of Meteorology, Office of Rail Safety WA and Pacific National. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

REFERENCES

An Experimental Investigation of Aerodynamic Properties of High Cube and Double Stack Container Railway Carriages; F. Alam and S. Watkins – RMIT University Melbourne.

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Natural hazards and the risks they pose to South-East Queensland - Australian Geological Survey Organisation & Bureau of Meteorology – 2001.

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