Australian Government
Australian Transport Safety Bureau

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AUSTRALIAN TRANSPORT SAFETY INVESTIGATION REPORT
Rail Occurrence Investigation No. 2007/004
Final

Derailment of Train 6MP9 – Bates, SA, 10 June 2007

At about 0040[1] on Sunday 10 June 2007, westbound freight train 6MP9 derailed at the 716.7 km mark[2] near Bates in SA.

There were no injuries as a result of the derailment, however, there was significant damage to the track and rollingstock. Of 10 wagons that separated from the train, four overturned.

The investigation found that a broken rail, emanating from a transverse rail defect, had probably caused the derailment.

Location and Environment

The derailment occurred at the 716.7 km mark approximately 210 km west of Tarcoola on the Trans-Australia Railway. The track in this area is mildly undulating as it passes through numerous sand dunes and is surrounded by low-level vegetation. At the time of derailment the weather was fine and clear. A minimum temperature of 0.5 degrees Celsius was recorded at the Tarcoola airport weather station, close to the time of derailment.

1 The 24-hour clock is used in this report to describe the local time of day, Central Standard Time (CST).

2 Distance in kilometres from a track reference point located at Coonamia in SA.

Freight train 6MP9

Train 6MP9 was operated by SCT Logistics. It originated in Melbourne and was travelling to Perth via Adelaide. On leaving Adelaide it comprised three locomotives (G538 leading, XR555 and G528 trailing) and 75 wagons. The train was 1789 m long with a total weight of 5954 tonnes.

The train crew consisted of two sets of two drivers. The 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 and fuel tanker. The driver at the time of the derailment had about 17 years train driving experience. Both train drivers were appropriately qualified, assessed as competent and medically fit for duty.

Track Information

Construction of the standard gauge (1435 mm) Trans-Australian Railway commenced in 1912, was opened for traffic in 1917, and substantially remains on the same alignment today, however the track has been substantially upgraded since that time.

Figure 1: Wagons ABFY 3111 (foreground) and PBGY 54 (background) looking west towards Perth.

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government, Department of Infrastructure, Transport, Regional Development and Local Government.

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.

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

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Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

The Australian Rail Track Corporation is the accredited owner responsible for access to, and the maintenance of, the section of track over which train 6MP9 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 are spaced at approximately 666 mm centres with the rails fastened to the sleepers using resilient clips. The track near the derailment site consisted of a series of short tangent and 800 m radius left and right hand curves. Heading in a westerly direction, towards the point of derailment, the track had a descending 1 in 132 gradient leading into a 1 in 100 ascending gradient commencing at about the 717.2 km mark.

The posted track speed through the derailment site was 80 km/h. There were no temporary speed restrictions in force at the time.

Occurrence

The two drivers involved in the derailment booked on for duty at 0800 on Friday 9 June 2007. They were transferred by bus from Thebarton to Islington (SA), joining the train before departing at about 1030. They drove the train through to Tent Hill (119.5 km)[2] and were relieved by the second crew. Just before midnight at Mungala (667.0 km)[2] the crew once again changed.

At 0018 the train passed through the railway siding of Barton (693.5 km)[2], before it entered the Barton to Bates section. About 18 minutes, later, travelling at a speed of approximately 80 km/h, the driver felt a tug from the rear of the train. He commented to the second driver that the experience was unusual on this section of track. A few seconds later, the driver noticed a decrease in brake pipe pressure. Realising that the train may have parted he released the locomotive brakes and briefly powered-up. This action stretched the train and separated the front and rear portions thus minimising the risk that the rear portion would collide with the slowing front portion of the train. He finally brought the train (leading locomotive) to a stop approximately 2340 m from the point of derailment.

Post occurrence

When the train finally came to a stop, the second driver went back along the train to find out what had occurred. In the mean time, the driver radioed train control to advise that their train had lost brake pipe pressure and had stopped at the 719.0 km mark. The second driver subsequently reported that the train had separated into three main parts. The front portion of the train consisting of 53 wagons and 3 locomotives remained on the track. The second section of train consisting of three wagons also remained on the track but it was about 550 m behind the end of the leading portion of the train. The third section of the train was about 350 m behind the second section with 11 wagons derailed. The first four wagons had overturned, these were the 57th to 60th from the front of the train. The next seven wagons immediately behind remained upright but were uncoupled and skewed at various angles. All 11 wagons had derailed to the left-hand side of the track (looking to the west). Behind the derailed rear section, the last eight wagons remained coupled and were on the track with the last vehicle located approximately 2700 m from the lead locomotive G538.

When the train crew confirmed the severity of the derailment, train control contacted a work gang at Barton who prepared to respond at daybreak.

ANALYSIS

On 10 June 2007, an investigation team from the Australian Transport Safety Bureau (ATSB) was despatched to investigate the derailment at Bates in SA.

Evidence was sourced from the train drivers, the Australian Rail Track Corporation, Pacific National and SCT Logistics. Evidence included; interviews, photographs, train-running information, voice and data logs, engineering documentation, site plans and maintenance policies/procedures.

The examination of this evidence established that:

- There were no mechanical defects or deficiencies with the train that would have contributed to the accident.
- Train speed was not considered to be a factor in the derailment. The train was travelling very close to 80 km/h, the allowable track speed at the time of the derailment.
- The train drivers were appropriately trained and qualified. Train handling was not considered to be a factor. The train driver responded appropriately to the derailment by stretching the train, thereby mitigating the risk of any rear end collision on the down grade.

- The two drivers were medically fit at the time of the derailment and fatigue was not considered a factor.

- One displaced wagon wheel-set had a partially shattered wheel, this breakage was considered consequential not contributory.

Examination of the track

An examination of the track at the 'point of derailment' uncovered several broken rail segments with signs of a transverse defect[3] type known as a 'detail fracture'. In one case, (Fig. 2) the defect appears to have originated from a horizontal crack beneath the gauge corner and has propagated across approximately 65 percent of the railhead breaking through the lower/non-visible part of the rail near the web. The defect was not new as there were signs of corrosion at the fracture face. The derailment occurred during a cold part of the evening when the rail would have been under significant tensile stress and therefore more likely to break under the dynamic load of the train. It is probable that the rail initially failed at this defect when 6MP9 passed over it.

A further secondary defect, (Fig. 3) 170 mm before the primary break probably caused a section of rail, about 0.5 m in length, to break away from the rail under the train. Once this had occurred, the derailment was almost inevitable. Two pieces of recovered rail showed significant evidence of wheel batter on their leading face indicating that wheels had probably travelled over these broken sections of rail after it failed.

Subsequent ultrasonic inspection of recovered rail segments revealed additional defects deep within the railhead.

All recovered rail sections exhibiting detail fractures were from one particular rail section having the following identifying marks:

Applicable Standard:	AS 94lb (1964)[4]
Manufactured:	AIS[5] 11/1970

3 Transverse defect - An internal defect within the railhead. The origin of the defect is usually an imperfection within the steel. These imperfections are detrimental to the fatigue life of the rail and are not visible until the defect has reached the rail surface. Rail breakage usually occurs before the defect becomes visible.

4 AS E22 – 1964 Steel Rails, the applicable Australian Standard at time of manufacture.

5 AIS – Australian Iron & Steel manufactured November 1970.

A section of this rail was tested for its chemical composition and to ascertain its underlying microstructure.

Figure 2: Primary break exhibiting transverse defect with horizontal crack (red arrow), and showing orientation of metallographic sample (green line).

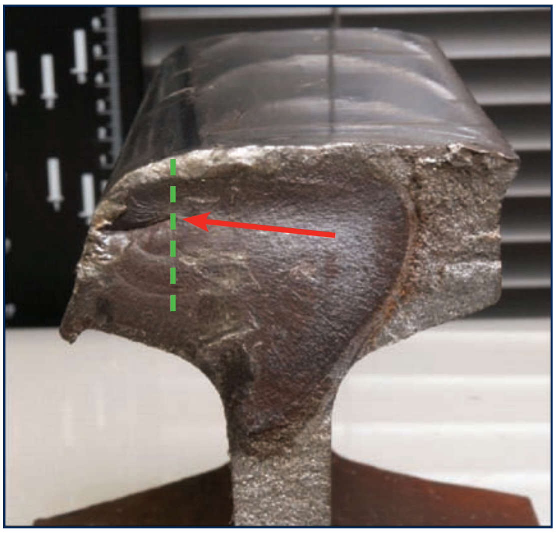
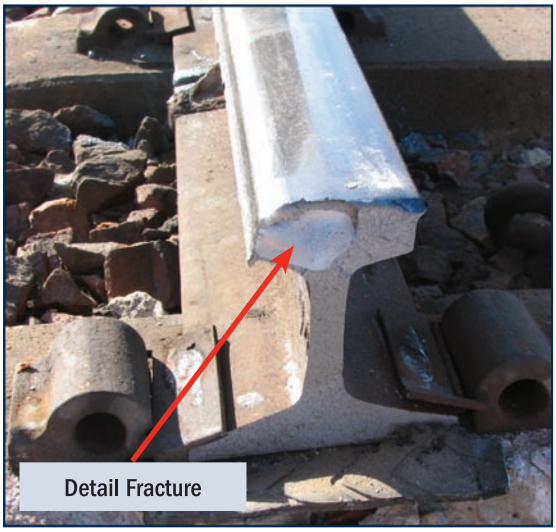


Figure 3: Secondary break exhibiting a transverse defect 170 mm before the point of derailment.



The analysis determined that the chemical composition was consistent with the requirements of AS E22 – 1964 Steel Rails, the applicable Australian Standard at the time of manufacture. The analysis further determined that there was no evidence of any underlying microstructure anomaly. A further review of the rail properties in comparison with the current Australian Standard AS 1085.1 – 2002 determined that the rail largely complied with the requirements of the current standard. Based on the analysis it was concluded that the failure was probably initiated by a hydrogen-induced crack. With the additional material and product testing requirements of AS 1085.1 – 2002 it is likely that rail manufactured to the current standard would contain fewer defects with less likelihood of premature failure when compared with the older AS E22 – 1964.

Given that the cause of the derailment was a hydrogen-induced crack in the rail, it is appropriate to examine the engineering maintenance controls used to identify this type of failure mode and whether they could have detected the crack before it caused the derailment.

Safety management system

The integrity of track is fundamental in running a safe railway as is the routine maintenance and inspection of the track in guarding against track failure and possible train derailment.

Track integrity is dependent on a complex interrelationship of many track elements including the sub-base, ballast bed, sleepers, rail/rail joints and fastening systems. The failure or degradation of any one of these elements can compromise the safe operation of the railway. Inspection and maintenance strategies are therefore essential elements in guarding against the risk of track failure.

Existing rail maintenance strategies rely on three primary areas of inspection to detect rail faults:

- Visual inspection/track patrols.
- Mechanised track geometry testing/ measurement.
- Rail flaw detection/ultrasonic inspection.

Visual inspection and ultrasonic inspection are the main methods for detecting rail defects.

In South Australia, accredited rail infrastructure owners such as the ARTC, are required to demonstrate safe rail operations through their operation of a comprehensive 'Safety Management System' (SMS). The SMS is required to satisfy the underlying intent of the Australian Standard 'Railway Safety Management' AS 4292.1 – 2006.

Section 6 of the standard prescribes that an organisation:

> …shall have in place procedures for inspection and testing of safety-related engineering and operational systems. The procedures shall define the location, method, level of detail and frequency of inspection and testing…

The ARTC uses its code (ARTC Track and Civil Code of Practice) as the basis for assessing/ recording the condition of its track and determining remedial maintenance actions. The code outlines basic documentation requirements at section 1.4.1 part (d) and prescribes:

(a) *Documentation*

In addition to the general documentation required in Volume 4, Part 1 the following documentation relating to rail and weld defects should be maintained:

(i) rail tonnages over nominal track sections;

(ii) specifications or work instructions for ultrasonic testing;

(iii) defective rail/weld report;

(iv) defective listing status;

(v) report of defect removal.

the code further provides details on the inspection processes, ie the frequency and scope of inspection. Section 1.4.1 part (a) and (l) prescribe:

(a) *Patrol inspection*

The interval between patrol inspections for visible rail defects should not exceed 7 days.

(i) *Continuous ultrasonic inspection*

Identification of defects should be carried out via continuous ultrasonic testing at a frequency of 15 MGT[6] during the service life of the rail.

Technical aspects of this testing should be based on the Railways of Australia (Australasian Railway Association) report 'WZ/89/A/92 Ultrasonic Testing of Rail in Railway Applications'.

In footnote [1] and [2] of the ARTC code, (hereunder) it is stated:

> *[1] Under the Code's operating regime up to 12 MGT per year, the frequency equates to about one continuous ultrasonic testing inspection per year with some flexibility for timing of the testing.*

6 MGT – Million Gross Tonnes

[2] After appropriate analysis the frequency may be varied for the lighter axle load operating regimes and for newer rail.

Following any derailment, it is normal practice to review the inspection and maintenance criteria to determine whether these were consistent with the relevant requirements, and further, to determine whether the requirements are adequate.

Maintenance History

Selection of insert

The maintenance records provided by ARTC's maintenance contractor, Transfield Services, revealed that they had used worn rail[7], approximately 5 m in length, to cut-out/replace a track defect at the derailment site. No records were available to indicate the original source or history of the section of rail they used.

Where part worn rail is re-used, care must be taken not to introduce inferior or previously condemned rail into the track. Record keeping procedures should ensure the compatibility of rail sections including profile, hardness, age, etc and whether it is necessary to subject it to an ultrasonic inspection before it is reused.

Patrol inspection

The ARTC records show that patrol inspections were carried out on 25 May 2007, 31 May 2007 and 8 June 2007. The frequency of inspection generally met or exceeded the standard prescribed in the ARTC's code. The last patrol inspection (two days before the derailment) did not identify any visible defects near the derailment site and there was no history of any defect at or near the derailment site.

The signs of corrosion at the fracture face indicate that the defect was not new, it probably existed at the time of the previous patrol inspection, two days before the derailment. Patrol (visual) inspections have a limited likelihood of detecting this type of defect particularly if a crack or defect has not broken through the surface of the rail or is below the railhead as occurred on this occasion. It is unlikely that an increase in patrol frequency would have been effective in identifying the rail fault which probably led to the derailment.

Ultrasonic inspection

The inspection of rail for subsurface structural defects is done using ultrasonic rail-inspection equipment. This equipment can be either hand held or fixed to a self-propelled rail mounted vehicle. Hand held equipment is suitable for spot inspection and is used to check the integrity of small sections of rail before it is cut-in/inserted into track when replacing faulty sections. Hand held equipment is also used to verify a potential defect when it is detected during a vehicle-mounted ultrasonic inspection.

The rail insert used by Transfield at the derailment site comprised curve worn rail that was welded in situ on 28 August 2002 using the thermit welding process.

At section 1.2.1 the ARTC code requires that:

(b) *Part worn rail*

Prior to its reuse in track part worn rail should be assessed for conformance with Table 1.5.

Table 1.5 refers to Figure 1.1 'Rail Acceptance: Ultrasonic Testing Flow Diagram' in the Code. This diagram highlights the need to test rail ultrasonically (where its ultrasonic history is unknown) before it is used in unrestricted traffic operations.

At the time the section of worn rail was used, a documented ultrasonic history was not available for the insert and therefore it should have been ultrasonically tested before allowing unrestricted traffic operations over the track.

Available records show that continuous ultrasonic inspection was conducted on 12 August 2005 and 1 July 2006, well before the derailment. These inspections did not reveal any reportable defects. Given that no defects were found the following conditions might have existed at the time of these inspections:

- no defects were present,
- the defects were present but went undetected due to their orientation, or

7 It is common practice to use 'worn rail' to replace a defective section of rail. The section of 'worn rail' is selected on the basis of having a profile matching that of an existing rail rather than using new rail that may have an incompatible profile.

- the defects were less than the minimum[8] detectable size.

If left long enough, quite small defects can grow to a critical size and cause the rail to fail suddenly which is likely to be what occurred on this occasion.

Frequency of ultrasonic inspection and defect growth rate

Factors that influence the growth rate of defects in rail include the quality and age of the rail, residual stresses, on-site temperature differential, track curvature, axle load, dynamic train forces due to speed and cumulative train tonnage over the track.

Of these, the influence of cumulative train tonnage (MGT) on track is well documented in technical studies/papers and has been factored into the ARTC's inspection intervals for 'continuous ultrasonic inspection'. This is reflected in the ARTC code at Section 1.4.1 part (I) and associated footnotes. The track infrastructure manager can readily monitor cumulative train tonnage and the history of track defects. Inspection strategies can be adjusted to mitigate the risk of track failure based on this information.

The track at the derailment site underwent 'continuous ultrasonic inspection' more than 12 months before the derailment. In the ARTC code, it is suggested that one 'continuous ultrasonic inspection' be undertaken where traffic volumes equate to approximately 12 MGT per annum.

During the investigation, the ARTC supplied information to indicate that an average of approximately 10 MGT traversed the track annually at the derailment site. Therefore, the 12 monthly inspection cycle did conform with the requirements of the ARTC code. However, the code does not appear to address factors such as rail quality/age, on-site temperature and issues such as wagon impact loading in determining whether there is justification in increasing the frequency of inspection. Research indicates that defect growth from initiation to 10 percent of its final size is relatively slow but then accelerates quite rapidly through to failure. As the rail defect grows, the chance of detecting it increases, but the load bearing capacity of the rail reduces which increases the risk of a rail failure. Increasing the frequency of 'continuous ultrasonic inspection' may help capture a greater number of defects earlier in the growth phase and desirably before they result in a catastrophic failure.

FINDINGS

Context

At about 0040 on Sunday 10 June 2007, a westbound freight train 6MP9 derailed at the 716.7 km mark near Bates in SA.

Based on the available evidence, the following findings are made with respect to the derailment but should not be read as apportioning blame or liability to any particular individual or organisation.

Contributing safety factors

A broken rail emanating from a transverse defect probably caused the derailment of train 6MP9 near Bates, SA on 10 June 2007.

The track at the derailment site was tested using 'continuous ultrasonic inspection' approximately 12 months before the derailment. The frequency of inspection was in accordance with the relevant ARTC code. However the ARTC code does not take into consideration rail quality, age, ambient temperature profile, train impact loadings, etc. *[Safety Issue]*

Other safety factor

The section of rail where the failure occurred had been used to replace an earlier defect at the derailment site. No records were available to indicate the original source of the replacement section of rail including its ultrasonic testing history. The rail insert had not been ultrasonically inspected before it was used in unrestricted traffic operations. *[Safety Issue]*

Other key findings

There were no identified mechanical defects or deficiencies with the train.

Train handling and speed were not considered factors in the derailment.

One wagon wheel was found partially shattered, this was probably as a consequence of the derailment and did not cause it.

8 Continuous ultrasonic inspection is a mature technology and has been effective in finding defects within rails. The technology is widely used by railways throughout the world. It can however fail to identify reportable defects dependent on defect orientation and condition of the surrounding rail and does not eliminate the risk of broken rail derailment. Given the limitations of continuous ultrasonic inspection, complementary defect management strategies are desirable to reduce the risk of defects going undetected.

Patrol inspections were carried out regularly. It is unlikely that increasing the frequency of these inspections would be effective in detecting the type of rail defect which led to the derailment.

It was not possible to determine how long a number of transverse defects had been present in the broken rail section. However, the track was tested using 'continuous ultrasonic inspection' approximately 12 months before the derailment and no defects were detected at that time.

Hand ultrasonic inspection of recovered rail segments from the derailment site revealed additional flaws within the railhead of these sections.

Chemical and microstructure analysis of the rail section determined that it was compliant with the requirements of AS E22 – 1964 Steel Rails, the applicable Australian Standard at the time of manufacture. The analysis further determined it was largely compliant with Australian Standard AS 1085.1 – 2002, the current standard. However the additional material and product testing requirements of AS 1085.1 – 2002 make it likely that rail manufactured to the current standard would contain fewer defects with less likelihood of premature failure when compared with the older AS E22 – 1964.

SAFETY ACTIONS

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 actions, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during the 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.

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.

Australian Rail Track Corporation

Frequency of 'continuous ultrasonic inspection'

Safety Issue

The track at the derailment site was tested using 'continuous ultrasonic inspection' approximately 12 months before the derailment. The frequency of inspection was in accordance with the relevant ARTC code. However the ARTC code does not take into consideration rail quality, age, ambient temperature profile, train impact loadings, etc.

Action taken by the Australian Rail Track Corporation

The Australian Rail Track Corporation has initiated the following safety actions:

- A review of the frequency of ultrasonic testing of track on the Trans-Australian Railway to include a mid period inspection.
- A review of the ARTC Code of Practice to ensure that it considers the age of the asset, exposure to significant temperature variations, increases in axle loading and transit speed.

ATSB assessment of action

The Australian Transport Safety Bureau notes that the Australian Rail Track Corporation has taken action to address this safety issue.

Documentation and Ultrasonic Inspection

Safety Issue

The section of rail where the failure occurred had been used to replace an earlier defect at the derailment site. No records were available to indicate the original source of the replacement section of rail including its ultrasonic testing history. The rail insert had not been ultrasonically inspected before it was used in unrestricted traffic operations.

Action taken by the Australian Rail Track Corporation

- A review of current practices in relation to the selection and testing of rail to be used as inserts.
- A review of data gathered by ultrasonic test vehicles to identify and prioritise reportable sized flaws.

- A review of the trends of recorded wheel impact data, ultrasonic rail testing and broken rail trend analysis.

ATSB assessment of action

The Australian Transport Safety Bureau notes that the Australian Rail Track Corporation has taken action to address this safety issue.

SUBMISSIONS

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

A draft of this report was provided to the train drivers, the Australian Rail Track Corporation, Department of Transport, Energy & Infrastructure, Pacific National / Patrick and SCT Logistics.

These parties have made a number of comments and observations on the draft report and where considered appropriate, the text of the report was amended accordingly.

MEDIA RELEASE

Broken rail probable cause for derailment

The ATSB has found that a broken rail emanating from a rail defect was the most probable cause of the derailment of a freight train in South Australia.

The Australian Transport Safety Bureau has today released its final report into the investigation of a derailment on 10 June 2007 near Bates in SA in which 11 wagons in the middle of the train derailed and 4 overturned and were extensively damaged.

The investigation established that the derailment probably resulted from an undetected flaw in the rail which caused a section to break away under the train. While track at the derailment site had been ultrasonically tested for cracks in the past, the frequency of these inspections did not adequately take into consideration issues such as the rail quality, age, ambient temperature profile and train impact loadings.

In the interests of enhancing future rail safety, the Australian Rail Track Corporation has been proactive in adopting a number of measures to address the safety issues identified by the ATSB. These include an increase in rail testing frequency and a review of their Code of Practice to enhance engineering maintenance/testing procedures in relation to ultrasonic rail flaw detection.

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