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ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Rail Occurrence Investigation Report 2006005
Final

Derailment of Train 5MB7

Benalla, Victoria

2 June 2006

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The Australian Transport Safety Bureau is grateful to Interdynamics Pty Ltd (www.interdynamics.com) for the computer program, FAID 330E, which was used during the analysis of the fatigue factors.

The ATSB acknowledges the cooperation of all who participated and assisted in this investigation.

Abstract

At approximately 0644 Eastern Standard Time on 2 June 2006 the crew of Interail freight service 5MB7 reported that their train had derailed while traversing the No. 3 points located at the Melbourne end of the Benalla crossing loop. Both locomotives derailed along with 19 wagons. Two track machines stabled within the cripple road adjacent the crossing loop were heavily damaged along with the nearby Victorian Railway Institute Hall which sustained severe structural damage.

There were no serious injuries as a result of the collision.

The investigation found that the driver of train 5MB7 had probably failed to correctly interpret and respond to signal ES6377. As a result he was unable to slow the train to a safe speed when traversing No. 3 points located at Melbourne end of the Benalla crossing loop.

In the interest of enhancing future rail safety the ATSB has made seven recommendations which include a review of crew resource management strategies, an examination of mentoring responsibilities and reviewing processes for the re-certification of drivers.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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 enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, 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 proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

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 (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, risk controls and organisational influences.

Contributing safety factor: a safety factor that, if it had not occurred or existed at the relevant time, then either: the occurrence would probably not have occurred; or 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.

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.

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

Critical safety issue: associated with an intolerable level of risk.

Significant safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable.

Minor safety issue: associated with a broadly acceptable level of risk.

EXECUTIVE SUMMARY

At approximately 0644[1] on 2 June 2006, the crew of Interail freight service 5MB7 reported that their train had derailed while traversing the No. 3 points located at the Melbourne end of the Benalla crossing loop. Two locomotives and 19 wagons derailed, 16 wagons sustained major damage. Two track machines stabled in a cripple road[2] adjacent the crossing loop were heavily damaged. A Victorian Railway Institute Hall near the site also sustained severe structural damage.

There were no serious injuries to the crew of the locomotive or the operators of the track machines. The train drivers were however taken to hospital for observation and treated for shock. There is no evidence to suggest that there were any medical or toxicology issues that affected the performance of either the driver or the co-driver.

There were no defects identified with the signalling system. The signalling system was regularly maintained in accordance with applicable maintenance standards and there was no history of signalling abnormalities.

As a result of its investigation the ATSB concluded that the factors which contributed to the derailment of train 5MB7 on the 2 June 2006 were:

- The driver was not expecting to cross a train at Benalla and thus assumed that he was being routed through the main line.
- The driver probably failed to correctly interpret and then respond to signal ES6377. As a result he was unable to slow the train to a safe speed for negotiating the facing points.
- The driver responded some 14 seconds beyond the available sighting point of No. 2 Signal. Had he responded earlier he could have slowed the train and potentially reduced the consequences of the derailment.
- Two-driver operation is a primary defence employed by Interail in guarding against unintended driver actions, the failure of the co-driver to look for and then validate/respond to the signal aspect displayed by signal ES6377 and No. 2 Signal was a clear breakdown in this defence and probably a contributing factor in the derailment.
- The driver and co-driver were both probably in a state of degraded arousal/vigilance when they passed signal ES6377 and while approaching No. 2 Signal.

Safety actions recommended include a review of crew resource management strategies, examination of mentoring responsibilities, and improving processes for the regular re-certification of drivers.

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1 All times throughout this report are Eastern Standard Time (EST). As times from various sources differ marginally, all times have been referenced to the Adelaide CTC event logger then adjusted by 30 minutes to correct for EST.

2 Cripple Siding - The short section of track located off the Benalla crossing loop, used for storing disabled trains, rollingstock and track maintenance machines.

1 FACTUAL INFORMATION

1.1 Overview

At approximately 0644 on 2 June 2006, Interail freight service 5MB7, derailed while traversing No. 3 points located at the Melbourne end of the Benalla crossing loop. Both locomotives, EL56 leading and EL58 trailing, came to rest on their right hand side approximately 230 m from the point of derailment. A total of 19 wagons derailed, 16 sustained major damage. Two track machines stabled on the cripple road adjacent the crossing loop were heavily damaged and the Victorian Railway Institute Hall, near the site, sustained severe structural damage when one wagon jack-knifed into the building.

There were no serious injuries to the crew of the locomotive or the operators of the track machines. The train drivers were taken to hospital for observation and treated for shock.

1.1.1 Location

Benalla is a regional city (Fig.1) in north-eastern Victoria and is located approximately 190 km north-east of Melbourne and 550 km south-west of Sydney. The Benalla crossing loop is located on the main Melbourne to Sydney rail line and is part of the Defined Interstate Rail Network (DIRN).

Figure 1: Location of Benalla, Victoria

Map - Geoscience Australia. Crown Copyright ©.

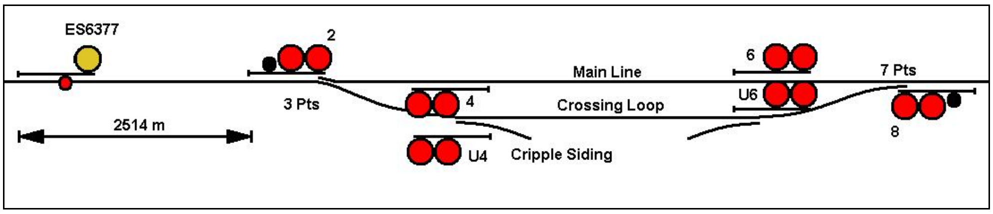
This section of the DIRN consists for most part of a standard gauge single line with crossing loops to facilitate the passing of trains. The DIRN is parallel to the intrastate broad gauge rail track diverging slightly at several locations to accommodate broad gauge stations/passenger platforms and yards.

Figure 2:: Aerial photograph Benalla derailment site (S36°32.6’ E145° 59.3’) with position of locomotives/wagons superimposed on image.

The Benalla crossing loop (Figures 2 and 3) is located 195.96 track km from a zero/reference mark located near Melbourne's Southern Cross station and is approximately 1.8 km north-east of the Benalla CBD. The crossing loop is 898 m in length. The section of track approaching Benalla is relatively flat with some curves linked by straight sections.

Line speed approaching Benalla is 115 km/h reducing to 15 km/h for trains that are signalled or routed into the Benalla crossing loop. Entrance into the Benalla crossing loop is controlled by No. 2 Signal. Advance warning is provided by signal ES6377. The derailment occurred at No. 3 points which are located at the Melbourne end of the crossing loop.

Figure 3: Signalling schematic, down approach to Benalla



The Australian Rail Track Corporation (ARTC) is responsible for access to and the management of the maintenance of this section of the DIRN. The maintenance is performed by a private company, Works Infrastructure, under contract.

The Victorian broad gauge main line runs close to and mainly parallels the standard gauge line adjacent this section of the DIRN but deviates near the derailment site.

1.1.2 Signalling & communications

Train control

The ARTC network incorporates way-side signalling controlled remotely from a Centralised Traffic Control (CTC) centre in Adelaide. Voice communication between trains and train control is achieved using UHF radio.

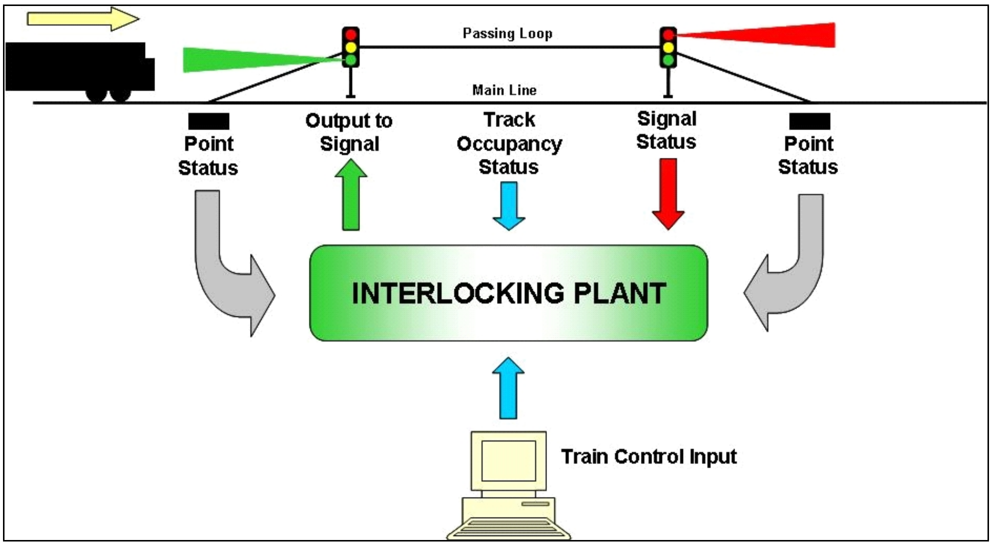
The signalling system Violet Town to Benalla, is remotely controlled by an ARTC train controller working the Victorian north-east CTC Board. Signal, points, track and train movement data for the CTC system is captured by an event logger.

Signalling – basic principles

Modern railway signalling has evolved from fairly simple manually operated devices, through to advanced computer technologies interfacing with state of the art electrical/electronic safety systems. These systems ensure the effective interlocking between points and conflicting train routes (Fig. 4) thereby ensuring the safe passage of trains.

However, information passed to a train driver is often quite basic and comes in the form of a 'proceed authority' that simply gives the train driver permission to access a defined section of track and additionally may provide information such as permissible track speed[3] or route information[4].

Figure 4: Elements of railway signalling – Interlocking plant



Train protection on the ARTC north-east line substantially comprises fixed (speed) signals, the driver observing and responding appropriately to these signals, an onboard train 'Vigilance' system and on most occasions a co-driver. Currently, the ARTC network does not use any form of 'Positive Train Control'[5] as a defence against driver error.

In a contemporary speed signalling system as exists in the Benalla area, colour light signals convey a 'proceed authority' and 'speed information'. With respect to the crossing loop at Benalla, the low speed aspect displayed by No. 2 Signal indicates that the route ahead is clear and that a train must not exceed 15 km/h. This speed is the safe/mandated speed for trains traversing Benalla No. 3 points set reverse.

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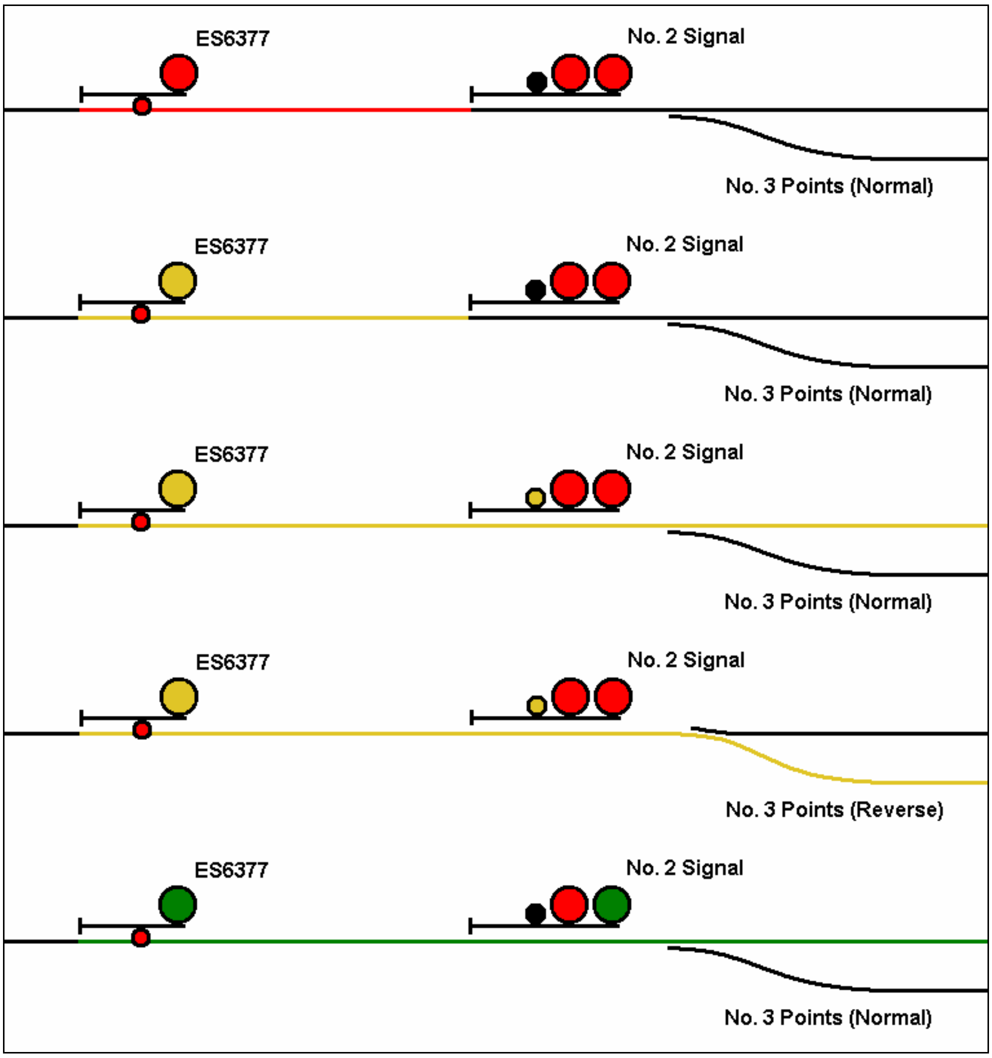
3 Speed signalling – Indicates to a driver maximum permissible speed and that the block ahead is occupied/clear.

4 Route signalling – Indicates to a driver the route to be taken and that the block ahead is occupied/clear.

5 'Positive Train Control (PTC)' - In this report refers to technologies such as Advanced Train Control (ATCS), Positive Train Separation (PTS) or the European Train Control Systems (ETCS) all of which are designed to prevent train collisions by enforcing tasks like train separation, speed control and related safety functions.

Figure 5: Available signal aspects at ES3677 and No. 2 Signal - Benalla. See definitions at Table 1.

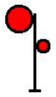
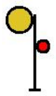
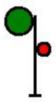


The grouping of the coloured lights within a speed signalling system and the correct interpretation of the information by a train driver is essential for the train to pass through a set of points safely.

Benalla comprises a main line and crossing loop. Entrance into the Melbourne end of Benalla is controlled by No. 2 Signal. Signal ES6377 provides the train driver with advance warning of the status of the line ahead and whether No. 2 Signal is at stop or clear for low speed or clear for normal speed. The signal sequence diagram at Fig. 5 shows the signal aspects that a train driver can expect to see when approaching Benalla from the south, Violet Town. The matrix at Table 1 describes the meaning of each available signal aspect. The signal sequence diagram and matrix shows that signal ES6377 should only ever show Green over Red if the route through Benalla is set for the main line. If the route is set for the crossing loop signal ES6377 should only ever show Yellow over Red.

The Code of Practice Victorian Main Line Operations ARTC document TA 20 prescribes that a driver on sighting a signal displaying a Yellow over Red may proceed but must be prepared to stop at the next signal.

Table 1: Meaning of signal aspects at ES3677 and No. 2 Signal - Benalla.

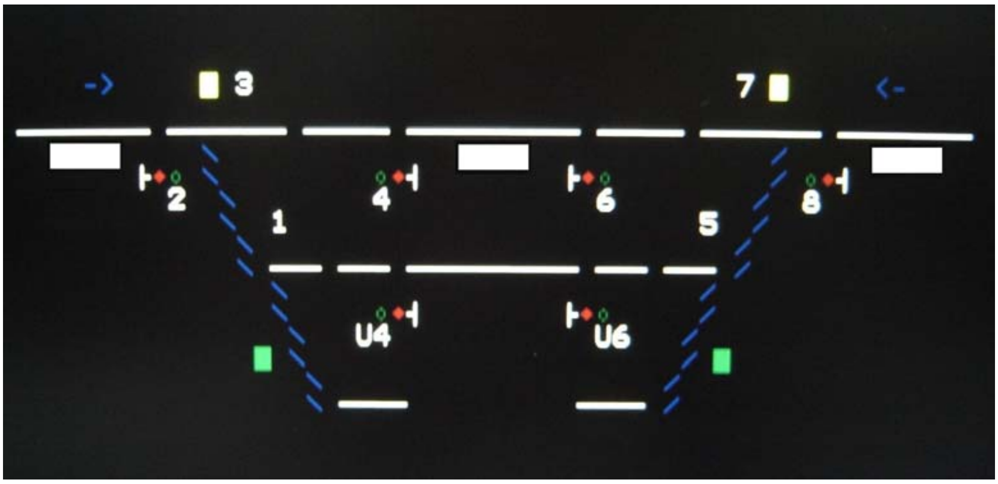
Indication	Meaning	Occasion for use
ES6377 - Permissive Signal, does not require 'Train Control' authority to proceed after coming to a stop, when signal is displaying a stop indication		
 Red Red	Stop	Block is not clear.
 Yellow Red	Caution (normal speed)	Proceed prepare to stop at next signal.
 Green Red	Clear (normal speed)	Block is clear, next signal is at 'Clear' or 'Caution' for normal speed.
No. 2 - Absolute Signal requires 'Train Control' authority to proceed after coming to a stop, when displaying a stop indication.		
 Red Red No Light	Stop	Block is not clear
 Green Red No Light	Clear (normal speed)	Block is clear, next signal is at 'Clear' or 'Caution' for normal speed.
 Red Red Yellow	Caution (low speed)	Proceed at low speed, prepare to stop.

CTC event logging

In general, the ARTC uses a CTC system throughout its Victorian network to provide real time monitoring and control of field hardware including signals, points, track circuits and the associated management of train movements operating throughout its network. This includes the Violet Town to Benalla section and the Benalla interlocking area.

At the time of the accident train 5MB7 was under the direction of the ARTC train controller located in Adelaide, SA. The section of track between Violet Town and Benalla including the crossing loops at each end are remotely controlled from the Victoria north east CTC Board (Fig. 6 - Graphics Overview). Signal, points, track and train movement data is recorded by the CTC system and can be replayed in the event of an incident/accident.

Figure 6: Graphics Overview - Benalla, Victoria north east CTC Board located in Adelaide, SA



Hardware description

The hardware components that make up the signalling system at Benalla comprise:

1. points machine (Fig. 7)
2. safety relays (Fig. 8)
3. search light signal mechanism (Fig. 9)
4. cabling, aerial wires, wiring, terminals and connectors.

Figure 7: No. 3 points machine adjacent relay room

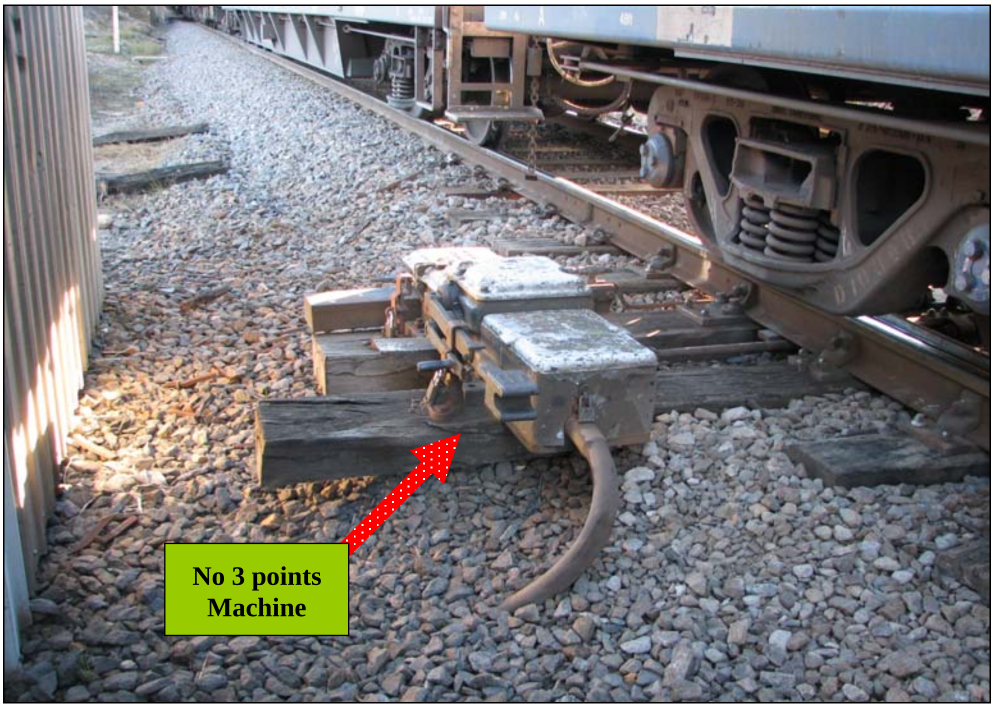
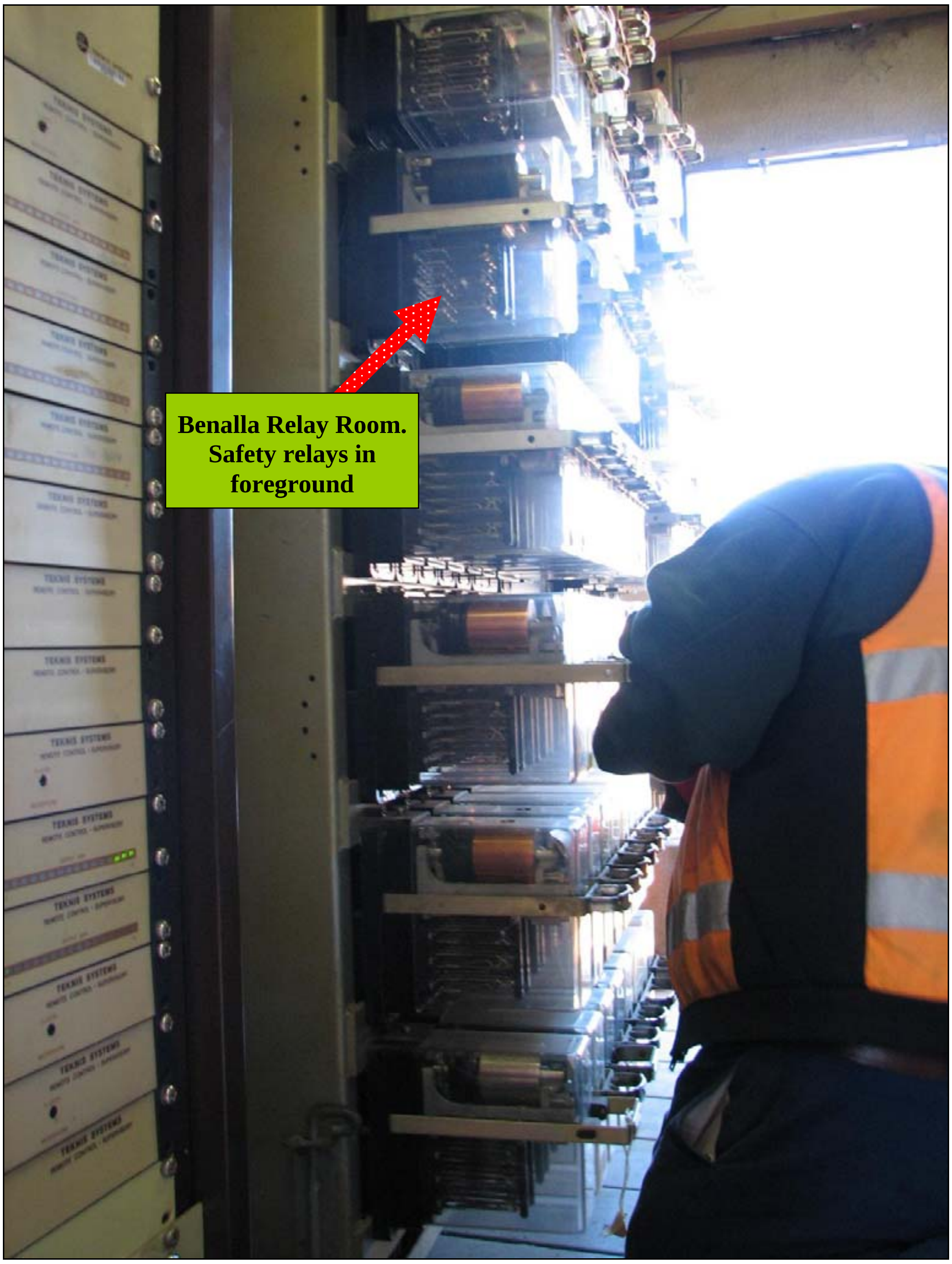


Figure 8: Benalla signal relay room



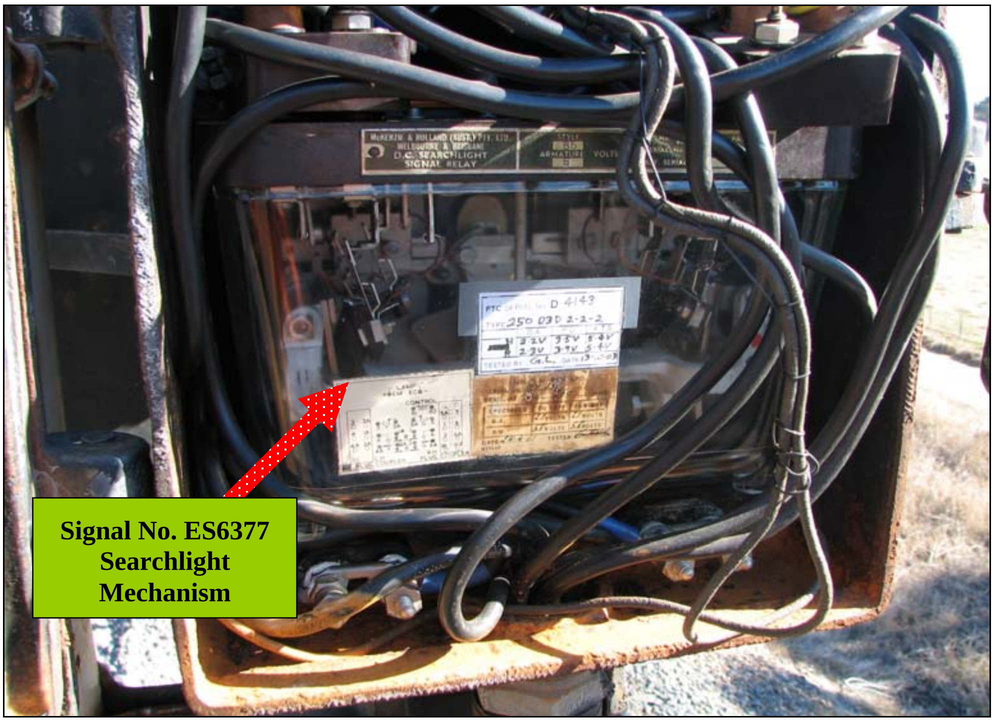
Most of the hardware is located within a secure relay room and/or equipment location boxes, except for external cables, aerial wiring and devices such as the signals and point machines.

Circuit description

At Benalla the operation of the signals and points machines is controlled by safety relays.

The configuration of relays/contacts in a circuit dictates the logic conditions which control the safe operation of the signalling field equipment. All signalling equipment is hard wired in accordance with an approved schematic and wiring/circuit diagram.

Figure 9: Searchlight signal mechanism ES6377, Benalla



Signalling circuits are typically broken into finite building blocks each performing a discrete function, for example the function of a circuit may be to detect the position of a points machine. Further, each finite building block can be examined in terms of the individual elements that make up the building blocks, for example a set of contacts within a points machine may be used to detect the position of each switch rail. In most cases it is possible to come to an accurate understanding of circuit integrity by testing each discrete building block and the individual elements that make-up each building block.

In some cases validating the pre-accident integrity of a signalling system requires an examination of test data, recorded (CTC) data and operational events.

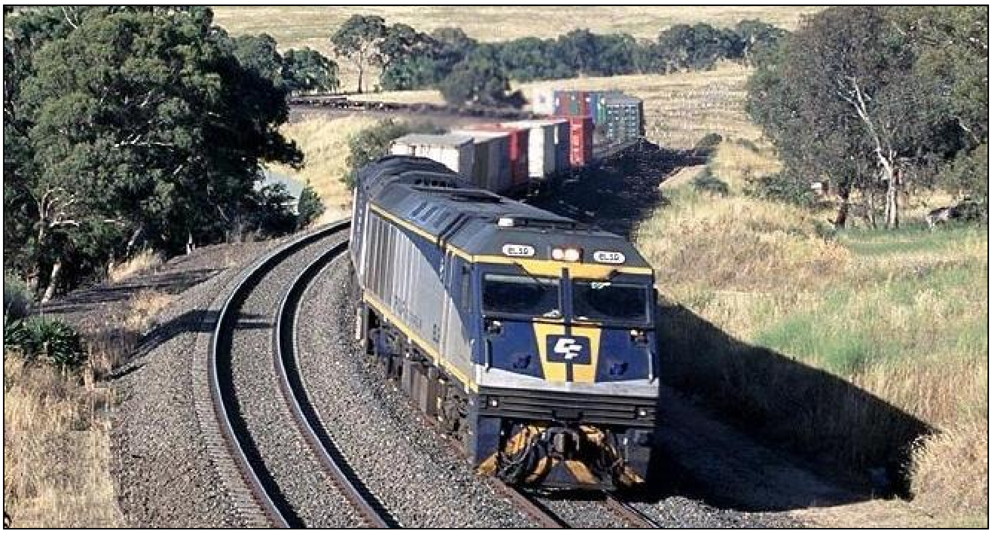
1.1.3 Train information

Train 5MB7 was operated by Interail, a wholly owned subsidiary of Queensland Rail. A driver and co-driver crewed train 5MB7, which consisted of two EL class locomotives EL56 (Fig. 10) leading and EL58 trailing, hauling 34 wagons with a total weight of 1,838 tonnes. The train had an overall length of 706 m including the locomotives. Locomotives EL56 and EL58 were on lease from Chicago Freight Car Leasing Australia (CFCLA) the wagons were on lease from Queensland Rail and CFCLA.

1.1.4 Crew of locomotive (train 5MB7)

At the time of the accident 5MB7 was manned by a crew consisting of the driver, ‘Level 3’ qualified and co-driver ‘Level 4’ qualified.

Figure 10: Locomotive EL56 leading and EL58 trailing



Photograph – Made available with permission of Mr Paul Jones Copyright ©.

The driver had approximately five years experience in the rail industry having worked for Freight Corp, Austrak, Freight Australia and South Spur Rail Services before being employed by Interail in April 2005. He started his working life as a shunter and had undertaken various roles before progressing into the driving grades. He was trained/qualified to Interail's requirements as a Level 3 driver which meant that he had to be supervised by a Level 4 or Level 5 driver when undertaking driving duties. He had two and a half years experience as a 'second person' and more than two years as a Level 3. Although familiar with the Junee to Sydney and Junee to Melbourne routes, he was required to be supervised.

The co-driver had approximately five years experience in the rail industry having worked for Freight Corp and Freight Australia before being employed by Interail. He started his working life as a shunter before progressing through the driving grades. He was trained/qualified to Interail's requirements as a Level 4 driver. He was familiar with the Junee to Sydney and Junee to Melbourne routes. He had more than two and a half years experience as a 'second person' plus one year as a Level 3 and approximately one year as a Level 4 driver. He had been upgraded to Level 4 approximately six months before the derailment.

Medical & toxicology

Interail use the National Transport Commission (NTC) *National Standard for Health Assessment of Rail Safety Workers*, hereinafter referred to as the National Health Standard, as a basis for assessment of 'Safety Critical Workers' engaged by their company.

The investigation established that:

- The driver was medically examined on 18 March 2005 at Junee. His records indicate that he was 'Fit for Duty – Meets all relevant medical criteria' as prescribed by the National Health Standard.
- The co-driver was medically examined on 25 October 2004 at Junee. His records indicate that he was 'Fit for Duty – Meets all relevant medical criteria'.

- Both the driver and co-driver were requested to undertake breath testing following the derailment. Tests were administered by the Victoria Police and returned zero readings.

Table 2: Train 5MB7 – Summary of driver/co-driver particulars

Details	Train Driver	Co-driver
Gender	Male	Male
Qualifications	Driver – Level 3 (must be supervised)	Driver – Level 4
Experience	5 years.	5 years.
Trained/Re-trained	To Interail requirements.	To Interail requirements.
Medical Status	Fit to National Standards – Valid to 18 Mar 2010.	Fit to National Standards – Valid to 1 Jan 08.
Medical Restrictions	None – 'Fit for Duty – Meets all relevant medical criteria'	None – 'Fit for Duty – Meets all relevant medical criteria'
Tests (Drug/Alcohol)	Zero readings	Zero readings

1.1.5 Train crew account

At 0900 on 1 June 2006, the two drivers involved in the derailment started duty at the Junee depot, NSW. They then drove their train, Interail service 3BM7 from Junee to Somerton (Vic) arriving at 1545. From there they drove by car to hotel accommodation in Melbourne before finishing work at approximately 1630. Both drivers had a meal before going to bed; the driver indicated he was asleep by 1830.

Both drivers were rostered to commence duty at 2330 on 1 June 2006 however, due to service delays, were not summoned until about 0230 on 2 June 2006. In his statement, the driver indicated that he woke at approximately 0030, expecting a wake-up phone call and could not get back to sleep thereafter. The co-driver indicated that he only got approximately four hours sleep before the wake-up phone call.

Both train drivers booked out of the hotel at approximately 0230 on 2 June 2006 and then drove by car to Somerton to join their train 5MB7. Train 5MB7, a scheduled service from Melbourne to Brisbane, arrived at Somerton at 0340. The crew changeover occurred as scheduled with the previous drivers reporting the earlier part of the journey as uneventful. No train defects were identified.

The train departed Somerton at 0344 with the two drivers involved in the derailment onboard.

The first part of the journey was uneventful. Train 5MB7 crossed a southbound freight train (4BM4) at Wallan at 0434 and the XPT passenger train (8612) at Longwood at 0600. The two drivers swapped driver/co-driver roles before departing Longwood.

Train 5MB7 continued on its journey passing through Violet Town before entering the Violet Town to Benalla section. The driver stated that as he approached the Benalla outer signal ES6377 he observed it to be displaying a 'green' aspect, he called out to the co-driver that the signal was clear. The co-driver acknowledged the driver's call but did not actually check the aspect of the signal as he was apparently looking for a mobile telephone battery charger in his crew bag.

In the final approach to Benalla, the driver saw No. 2 Signal displaying a 'Caution (low speed)' signal and stated that he immediately throttled off and made an emergency brake application while simultaneously alerting the co-driver regarding the risk of an impending derailment.

The train continued past No. 2 Signal and through No. 3 points, set reverse, at high speed. It began to roll-over and collided with two track machines stabled in the cripple road adjacent to the crossing loop and then collided with the Victorian Railway Institute Hall adjacent the accident site.

Immediately following the derailment, the driver attempted to contact the ARTC train controller using the train control radio but it had been damaged as a result of the derailment. He then used the train's local radio to issue an emergency call to alert any other trains that might be near the site. He used a mobile telephone to contact the ARTC train controller and advise of the derailment and request attendance by emergency services.

1.1.6 Witness accounts

The derailment was witnessed by two Works Infrastructure employees who were tending the track machines stabled in the cripple road at the time of the accident. They were communicating with the ARTC train controller in preparation for the day's work. The evidence provided by the Works Infrastructure employees was limited to an observation of the train entering the crossing loop at high speed and the subsequent derailment. They were not able to provide information as to why the accident may have occurred. There were no reports of injuries or post-incident stress from the Works Infrastructure employees.

1.1.7 Post accident response

The total time that elapsed from when the driver of train 5MB7 contacted the ARTC train controller to the arrival of the emergency services was 17 minutes. The train crew had suffered only minor injuries and were taken to the local hospital for observation. There were no dangerous/toxic goods of any kind being carried on train 5MB7 at the time of the derailment.

The standard gauge track through Benalla was closed to all rail traffic from the time of the accident through until restoration work was completed at 1005 on Saturday 3 June 2006.

1.1.8 Loss and damage

Two locomotives and 19 wagons derailed. The two locomotives involved in the derailment sustained extensive damage with an estimated repair cost of $3 million. Of the 19 wagons derailed, 12 are likely to be repaired with the remainder being written off.

Two track machines stabled within the cripple road adjacent the crossing loop were heavily damaged. The Victorian Railway Institute Hall near the site sustained severe structural damage and was subsequently demolished.

The main line and crossing loop were both damaged as a result of the derailment, a total track length of 200 m required replacement. The up starter signal 4/U4 and associated gantry were destroyed.

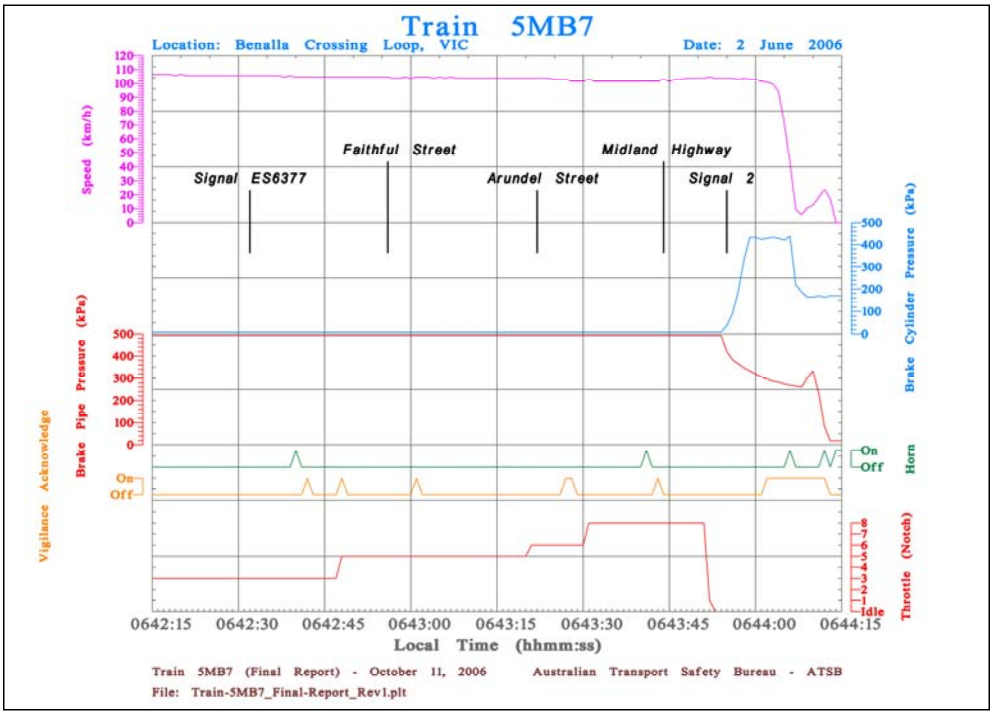
2 ANALYSIS

The section of line over which the derailment occurred is part of the DIRN and is an essential corridor for the running of interstate rail traffic. It is therefore important that restoration works are carried out quickly and efficiently. However, it is also important to collect any perishable evidence before restoration work commences.

To facilitate the process ATSB and ARTC personnel flew from Adelaide to Benalla on a chartered flight and were on site by 1030 on 2 June 2006.

Testing of the Benalla signalling hardware and circuits was undertaken over the period 2 to 3 June 2006. Information available from these tests was examined in conjunction with recorded CTC data and locomotive data (Fig. 11) and combined into a sequence of events list, section 5.1 of the Appendixes.

Figure 11: Data down load from Fischer locomotive data logger.



Based on a preliminary analysis of evidence, including statements from the train crew, it was concluded that:

- there were no mechanical deficiencies relating to the train which contributed to the derailment
- there were no deficiencies in the track condition that contributed to the derailment
- that neither of these two factors would have had a significant bearing on the final outcome of the derailment, noting that the speed at which the train traversed No. 3 points set reverse was approximately 100 km/h[6].

6 Maximum allowable speed for a facing movement over reverse points was mandated at 15 km/h.

Based on the preliminary analysis it was evident that the correct operation and observation/interpretation of signal ES6377 was required for train 5MB7 to negotiate the facing points and enter the crossing loop at a safe speed.

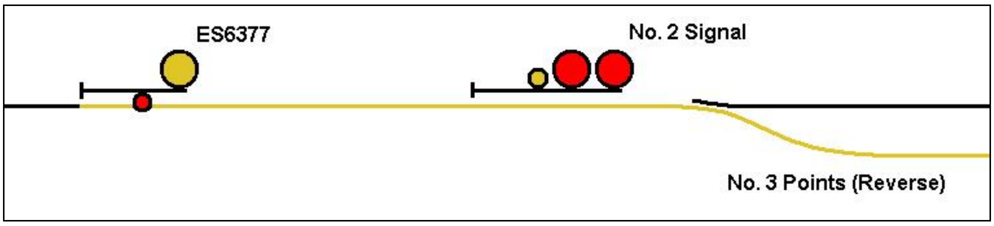
The balance of the report therefore focuses on identifying the most probable factors that contributed to the derailment which are:

- the operation of the railway signalling system (and associated risk controls to assure safe operations)
- the performance of the train crew (and associated risk controls to assure safe performance).

2.1 Sequence of events analysis

At 0629:54 the train controller in Adelaide set the Benalla crossing loop for an 'auto-cross'[7]. This was to allow train 5MB7 and train 5SM5, a Melbourne bound Pacific National (PN) freight train, to cross at Benalla. Train 5MB7 was being routed into the crossing loop and 5SM5 onto the main line. For this crossing configuration, No. 3 points was set to the reverse position, No. 2 Signal cleared to a 'Caution (low speed)' aspect and signal ES6377 (Fig. 12) should correspondingly have cleared to a 'Caution (normal speed)' aspect.

Figure 12: Signal ES6377 displays 'Caution (normal speed)' with No. 2 Signal displaying 'Caution (low speed)'.



From 0629:54 through to 0630:26 the signalling system undertook a series of automatic validations and checks before allowing the Violet Town to Benalla block to become available for train 5MB7. Similarly, from 0630:13 through to 0630:26 the signalling system undertook a similar series of validations and checks before allowing the Glenrowan to Benalla block to become available for train 5SM5.

The CTC system logged train 5MB7 occupying 2A track within the Violet Town to Benalla block at 0636:32. At this time the train was approximately 13.5 km from Benalla. The CTC system logged the opposing train movement 5SM5 as occupying 8A track within the Glenrowan to Benalla block at 0641:02. Both trains were now travelling towards Benalla for what was to be a routine train cross.

As train 5MB7 approached Benalla the sun was just below the horizon, the first signs of light were just evident on the horizon, there was no moon. The weather was fine and dry, the morning was cold and there was no discernable fog. Visibility was good.

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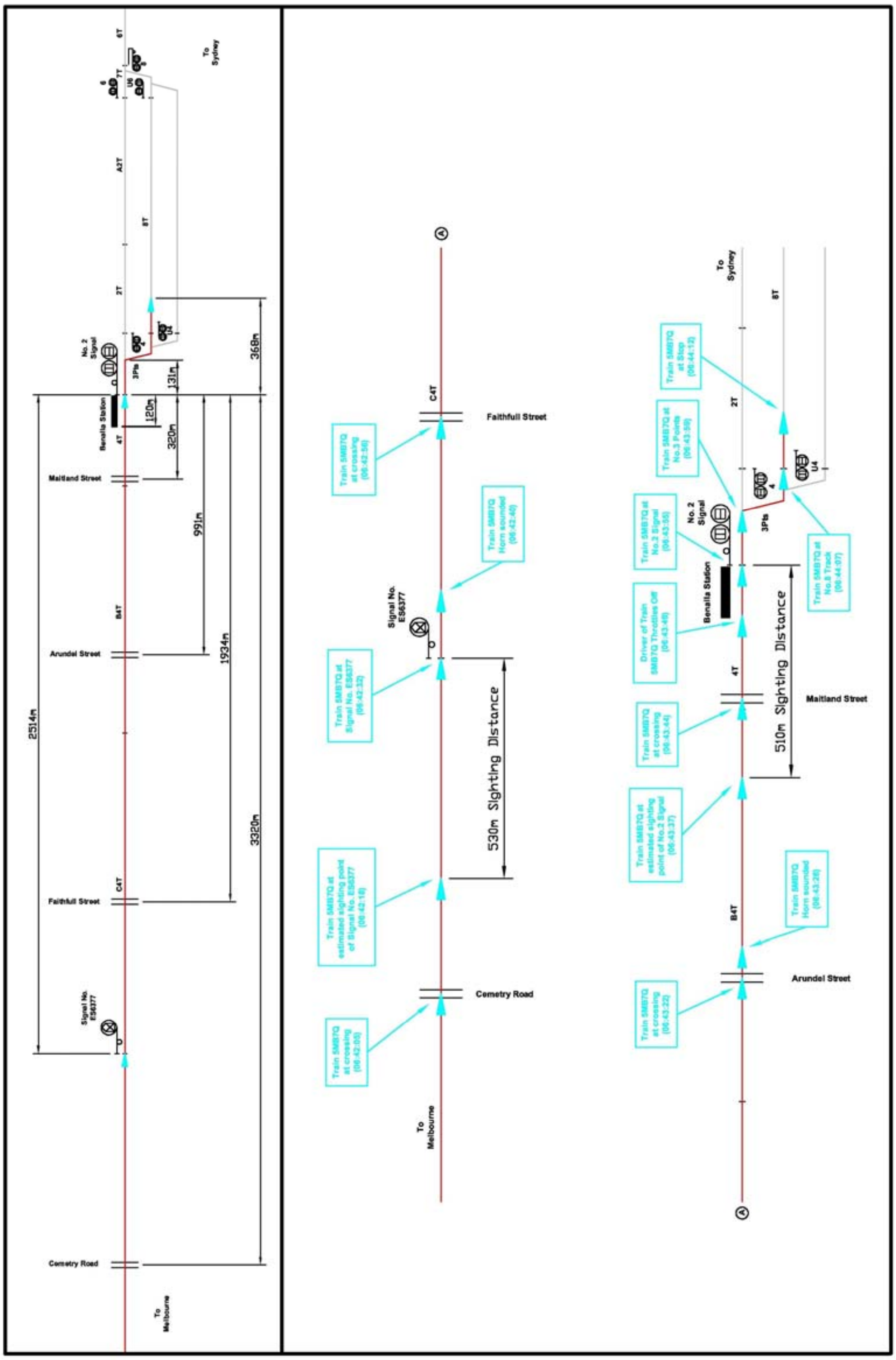
7 'auto-cross' - A control function within a Centralised Train Control (CTC) system that allows the Train Controller to set the automatic crossing of two trains at a crossing loop.

Train 5MB7 continued its journey towards Benalla, passing Cemetery Road level crossing at 0642:05 (Fig. 13). The train passed the Benalla outer signal ES6377, (Fig. 13 and 14) at 0642:32 travelling at an estimated speed of 106 km/h.

Figure 13: Benalla 'CTC & Loco Log sequence graphic'

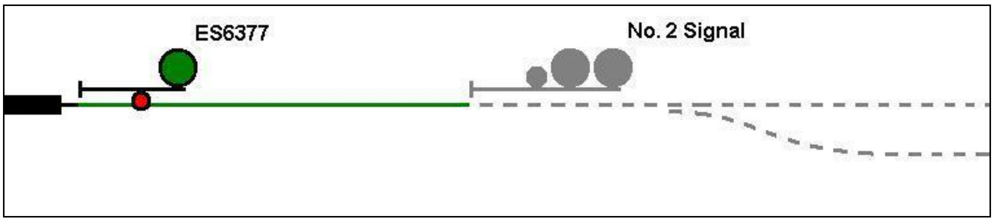


During the interview with the train driver, he said that he had not received any information regarding a crossing movement at Benalla. Although it is not custom or practice for train control to provide this information, had the driver infrequently crossed with trains at Benalla, it is reasonable to assume that he would not expect a cross and would therefore have expected that signal ES6377 would be displaying a ‘Clear (normal speed)’ aspect.

Figure 14: Outer signal No. ES6377 looking towards Benalla. ES6377 is a three aspect signal. Top arm as shown is displaying ‘Normal Speed Proceed – Yellow Aspect’

In his statement, the driver indicated that he was sure that signal ES6377 was displaying a ‘Clear (normal speed)’ aspect (Fig. 15). Had he seen this aspect it would be natural to interpret this indication to mean that the route was set for the main line, ie No. 3 points was set normal and the train could proceed at full line speed, 115 km/h.

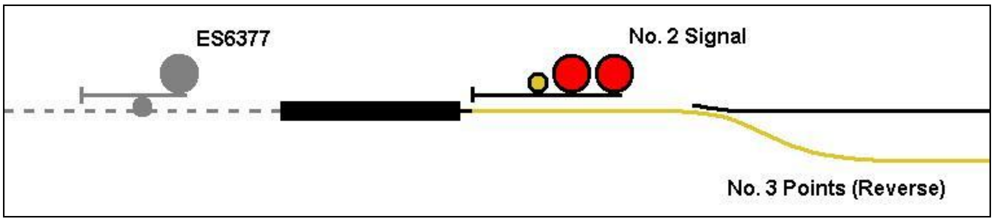
Figure 15: Train driver stated that signal ES6377 was displaying a 'Clear (normal speed)'



At 0642:40 the driver sounded the train whistle (Fig. 11) in advance of Faithful Street level crossing. The train then travelled over Faithful Street level crossing at 0642:56 followed by the Arundel Street level crossing at 0643:22. The driver again sounded the train whistle at 0643:26 before traversing the Midland Highway level crossing at 0643:44. The locomotive data logger shows the vigilance system was reset on five occasions in close succession during the period 0642:42 to 0643:43 at intervals ranging from six to 26 seconds.

Figure 16: No. 2 Signal – Viewed from the Midland Highway level crossing at a distance of 320 m.

Figure 17: Train driver stated that signal No. 2 was at 'Caution (low speed)'.



The final reset of the vigilance system occurred at 0643:43 when the train was just in advance of the Midland Highway level crossing and 350 m from No. 2 Signal (Fig. 16). At 0643:51 the train was 120 m from the signal and just in front of the Benalla passenger platform when the driver reacted to the 'Caution (low speed)' aspect displayed by No. 2 Signal (Fig. 17).

The train driver throttled off immediately and made an emergency brake application.

Figure 18: Damaged track machine (tamper) stabled within cripple road

Figure 19: View of derailment site from 'Over-way Bridge' looking north east.

The train continued past No. 2 Signal at 0643:55 travelling at an estimated speed of 104 km/h. It then traversed No. 3 points, set and locked in the reverse position, at an estimated speed of 100 km/h passing the adjacent cripple road.

The train now lurched heavily to the right just before it began to roll-over, dragging wagons off the track, colliding with No. 4/U4 Signal gantry and then the two track machines (Fig. 18) stabled within the cripple road. One wagon jack-knifed into the adjacent Victorian Railway Institute Hall causing severe structural damage. The CTC system logged train 5MB7 as occupying the first track, No. 8, within the crossing loop at 0644:07.

The two locomotives finally came to a stop at 0644:12 resting on their right hand side 370 m past No. 2 Signal. Of the 19 wagons derailed, (Fig. 19) 16 had sustained major damage.

2.2 Signalling system

The train controller in Adelaide selected Benalla for an 'auto-cross', with No. 3 points set reverse. For this configuration, the signal system is designed to clear No. 2 Signal to a 'Caution (low speed)' and signal ES6377 should correspondingly only ever clear to a 'Caution (normal speed)', Fig. 12.

The driver of train 5MB7 stated that signal ES6377 was displaying a 'Clear (normal speed)' aspect (Fig. 15) and he interpreted the indication as a route set for the main line. The driver also stated that when he saw No. 2 Signal it was displaying a 'Caution (low speed)' aspect (Fig. 17) and as he traversed No. 3 points they were set reverse.

Signalling – control circuits, tests and maintenance data

Signal circuits are designed to fail-safe, ie if a fault occurs a signal viewed by a train driver should revert to a more restrictive or 'Stop' indication until the fault is identified and the system is repaired.

Signalling systems are complex pieces of safety equipment that require regular inspection and maintenance to ensure reliability of operation and to guard against any unwanted operation. The Australian Standard *Railway Safety Management* AS4292.1-1995 Part 1 at section 6.4 prescribes that an organisation must have in place procedures for inspection and testing of safety-related engineering and operational systems. Maintenance documentation generally provides a detailed schedule of works, including the frequency of inspection/servicing that should be adhered to in providing for the safe operation of these systems.

It is normal practice to fully validate the operation of signal control circuits following any reported or perceived signalling irregularity. This involves an examination of maintenance standards, historic records and engineering tests.

Following the derailment, testing and analysis was conducted on the Benalla signal system to check the integrity of the signal interlocking and associated hardware to determine if it was functioning as designed. The testing was also to identify any possible fault or anomaly that may have caused an incorrect signal aspect to be displayed to the train driver (as he described).

2.2.1 Technical analysis - No. 2 Signal

CTC data covering the period 0611:45 through to 0805:57 for 2 June 2006 was downloaded and made available to the ATSB for review and analysis.

The replay files pertinent to the accident were extracted with relevant information being analysed to identify whether there were any unusual occurrences in the lead-up to or during the accident.

The investigation established that from 0629:49 through to 0630:26 the Benalla interlocking, set and locked No. 3 points reverse and cleared No. 2 Signal.

By design the ARTC CTC system in Adelaide only shows No. 2 Signal at stop or clear. It does not show or record whether the signal is at 'Clear (normal speed)' or 'Caution (low speed)'. However, it is possible to determine the status of No. 2 Signal based on available evidence.

- The train driver stated that he observed No. 2 Signal displaying a 'Caution (low speed)' aspect; the normal speed aspect (upper arm) was in the 'Stop' position.
- An examination of the CTC data confirmed that during the entire period as 5MB7 approached Benalla, No. 3 points remained set and locked in the reverse position and that No. 2 Signal continuously displayed a clear aspect.
- When No. 3 points are set in the reverse position (for the crossing loop) the signal circuits will only allow the clearing of No. 2 Signal to 'Caution[8] (low speed)'.
- The indication on the Adelaide CTC board that No. 2 Signal is at 'Stop' requires proof that both the normal and low speed aspects of No. 2 Signal are at 'Stop'. This is achieved through a signal circuit called 2NGP, which proves both the electrical and mechanical components of No. 2 Signal are at 'Stop', and a signal indication circuit called 2NGKF (communicates this status to the Adelaide CTC system). When No. 2 Signal was cleared at 0630:26, the indication circuit at Adelaide CTC recorded a change in state from 'Stop' to 'Clear'. This confirmed that the normal speed signal mechanism on No. 2 Signal was not mechanically stuck in the clear position at the time when No. 2 Signal was cleared.

Comprehensive tests were undertaken including a check of the circuit design integrity and an examination of the status of the signal mechanism, relays, wire count, insulation and continuity tests. No faults were found and the signal system was established to be operating in accordance with its intended design.

It is therefore concluded that No. 2 Signal only ever displayed a 'Caution (low speed)' aspect once No. 3 points had been set reverse at 0629:54 and as train 5MB7 approached it. The fact that No. 2 Signal was displaying the correct aspect was corroborated by the train driver's statement.

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8 The signal circuits will only allow clearing of No. 2 Signal to 'Clear (normal speed)' if No. 3 points are set in the normal position (for the main line).

2.2.2 Technical analysis - signal ES6377

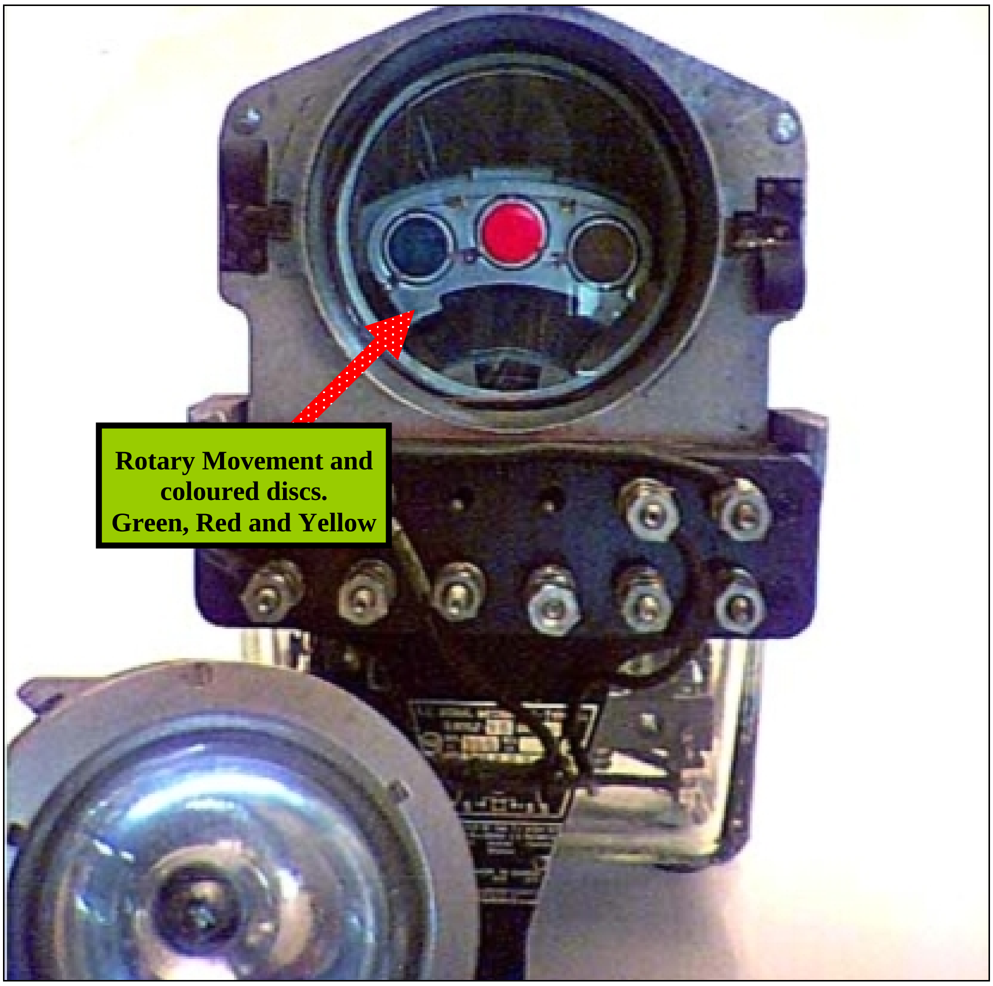
Having established that No. 2 Signal was correctly displaying a 'Caution (low speed)' aspect, signal ES6377 was examined for integrity of operation including the correct interlocking between it and No. 2 Signal.

The ARTC CTC system in Adelaide does not report on, or record, the status of signal ES6377. Therefore the correct operation of ES6377 can only be determined through post accident tests/observations and analysis of historical evidence.

Signal ES6377 consists of a searchlight signal mechanism, 'McKenzie and Holland DC Searchlight Relay' (style B5, 6 volt DC), mounted on a signal mast with associated fittings.

A searchlight signal mechanism comprises an electromechanical device consisting of an incandescent lamp at the rear of a metal box (housing), an assembly of three discs (yellow, red and green) immediately in front of the lamp called a rotary movement (Fig. 20) and a lens in front of the rotary movement.

Figure 20: Typical 'Searchlight Mechanism' showing the rotary movement and three coloured discs green, red and yellow.



The searchlight relay is polarity sensitive, ie when power is applied the rotary movement pivots to expose a yellow or green disc depending on the polarity of the applied DC voltage. When power is removed the rotary movement falls by gravity to the central position to display a red disc.

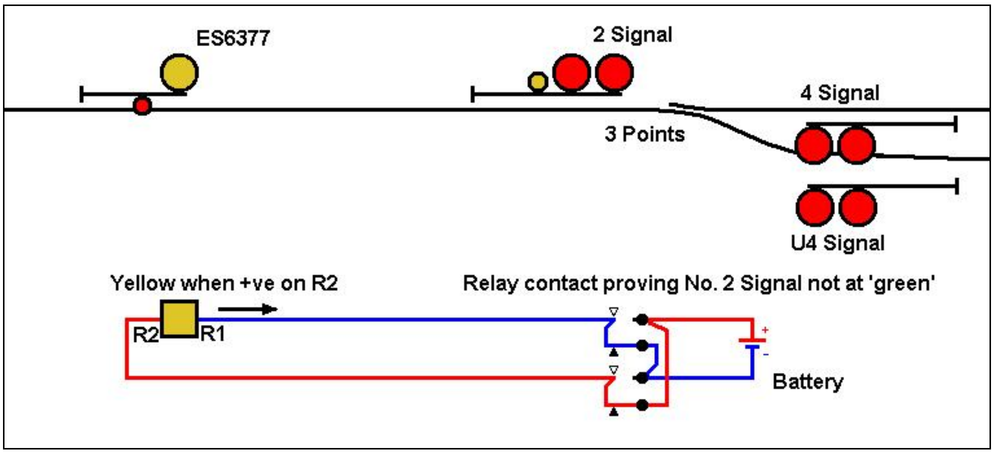
Two modes of failure could result in signal ES6377 displaying an incorrect/green aspect:

- An electrical failure of the signal circuit, ie the electrical integrity of circuit failed and the signal mechanism was incorrectly energised; or
- a mechanical failure of the signal mechanism, ie the mechanism was seized in the wrong position.

Signal ES6377 - Electrical circuits

The circuit that supplies power to signal ES6377 is a two wire line circuit that extends from the Benalla relay room through to the signal. A failure of the wiring insulation and/or associated hardware could result in a false electrical feed to signal ES6377 thereby causing it to display an incorrect aspect. To minimise the chance of this type of failure, all circuits are 'double-cut', ie both the positive and negative circuit legs are isolated using a set of relay contacts. This design feature provides a high degree of electrical integrity. Following the derailment, tests were undertaken to check for any incorrect wiring and/or degraded wiring. The tests included contact validation and wire count, insulation and continuity testing and a check of the circuit's design integrity. One of the primary areas checked included the integrity of the interlocking/polarised circuit, see Fig. 21 and Fig. 22.

Figure 21: Simplified circuit - ES6377 showing pole changing circuit. Mechanism at 'yellow' when No. 2 Signal top arm at 'red'.



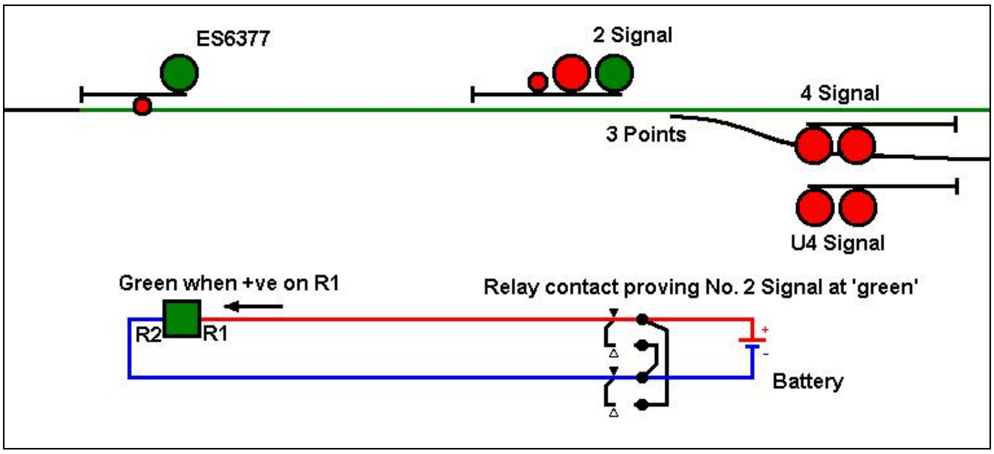
The simplified circuit diagram at Fig. 21 illustrates that when No. 2 Signal is not displaying a 'green' indication that signal ES6377 can only be energised to display a 'yellow' aspect. Similarly the circuit diagram at Fig. 22 illustrates that when No. 2 Signal displays a 'green' indication that signal ES6377 is energised to display a 'green' aspect.

Testing of the circuit established that it was functioning correctly, all wiring was electrically sound and the signal mechanism responded freely and correctly to the applied battery polarity.

The tests confirmed that there was no fault with the signal ES6377's circuit functionality that would have caused it to display a false 'green' aspect during the time train 5MB7 approached the Benalla crossing loop.

The operation of ES6377 could not be electrically faulted.

Figure 22: Simplified circuit - ES6377 showing pole changing circuit. Mechanism at 'green' when No. 2 Signal top arm at 'green'.



Signal ES6377 – Mechanical mechanism

Having confirmed the electrical integrity of signal ES6377 the analysis focused on validating the mechanical integrity of the signal mechanism/rotary movement. The use of gravity to return the rotary movement to the central position (display a red disc) when power is removed is a design feature referred to as fail-safe.

However, searchlight signals contain moving parts and there have been some rare instances where the rotary movement has become stuck and displayed a false green or yellow indication instead of red. To guard against this undesirable event, the design of the Benalla signal circuits electrically prove the position of the rotary movement for signal ES6377 (Fig. 23 and Fig. 24).

If the rotary movement is detected in the wrong position, ie displaying a green or yellow instead of red, the opposing signals, 'Up Starter' signals No. 4/U4, are prevented from clearing, ie retained at stop.

Figure 23: Simplified circuit – 4/U4 Signal is held at 'red' if signal ES6377 is displaying a 'green' aspect.

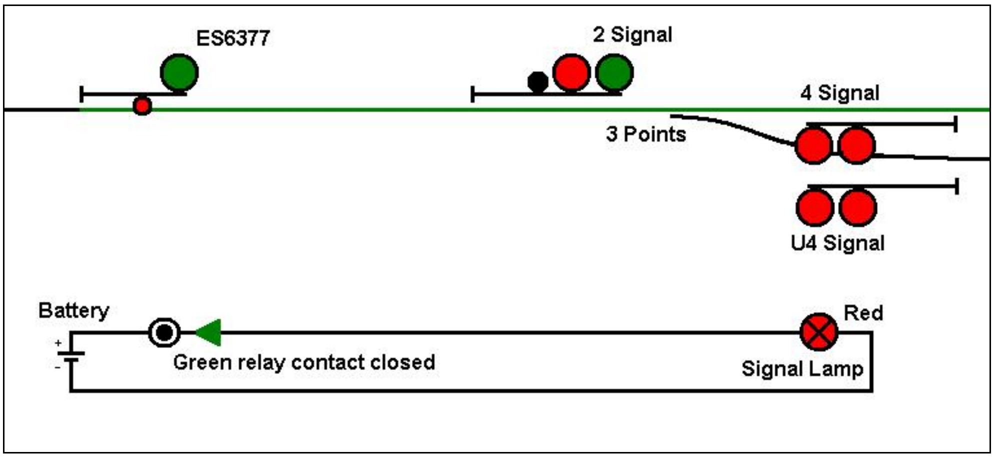
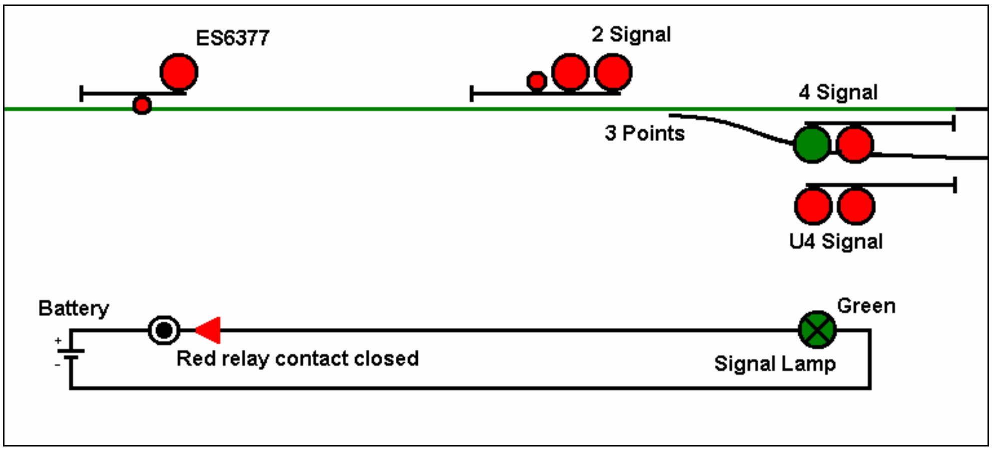


Figure 24: Simplified circuit – 4/U4 Signal proves that ES6377 is displaying a 'red' aspect before it can clear to 'green'.



When considering train movements, Table 3 shows that the previous three movements through Benalla were all travelling in the up direction which requires 4/U4 signals to be cleared. As all three movements passed through Benalla under the appropriate signal indication, this verifies that the mechanism in signal ES6377 was displaying a 'red' aspect. This confirms that signal ES6377 was not displaying a 'green' indication as train 5MB7 approached due to a mechanical fault (stuck rotary movement) in the signal mechanism.

Following the derailment and when first inspected signal ES6377 was observed to be correctly displaying a 'red' indication. This further reinforced the conclusion that signal ES6377 was not mechanically stuck in the 'green' position.

Table 3: Record of train movements through Benalla from 2200, 1 June 2006 through to the time of derailment

Train ID	Direction of Travel	Date and time through Benalla	
8621	Down[9]	01 June 2006	2214 (Actual)
5MB4	Down	01 June 2006	2234 (Actual)
9642	Up[10]	02 June 2006	0036 (Actual)
4BM4	Up	02 June 2006	0234 (Actual)
8612	Up	02 June 2006	0514 (Actual)
5MB7	Down	02 June 2006	0644[11]
5SM5	Up	02 June 2006	0644[12]

ES6377 was finally examined for correct mechanical function. There were no signs of wear in the mechanism or observations that would suggest the mechanism had been stuck or malfunctioned. The mechanism was observed to operate freely and returned to the 'Stop' position under gravity when electrical power was applied and then removed.

2.2.3 Signal faults, incidents and maintenance

A review of signal faults and incidents was undertaken for the Benalla area, with a particular focus on any wrong-side-signal failures[13]. The period June 2004 through to June 2006 was examined. Only seven incidents were considered worthy of analysis, see Table 4.

Of these seven incidents, three involved signal sighting issues, and four were Signal Passed at Danger (SPAD) events.

Of the signal sighting issues, No. 2 Signal was obscured by trees on two occasions and signal ES6588 on one occasion. On the day of the derailment trees did not obstruct sighting of either signal.

All of the reported SPAD events were unique, that is, there were no repeat SPAD events and all SPAD events involved different signals on each occasion. There was

9 'Down' movement – trains travelling in a direction from Melbourne towards Sydney.

10 'Up' movement – trains travelling in a direction from Sydney towards Melbourne.

11 5MB7, the train that derailed did not pass through Benalla. The time 0644 is the estimated time of derailment.

12 5SM5, up train movement, did not cross 5MB7 at Benalla because of the derailment and damage to the track and associated infrastructure. The time 0644 is the time 5SM5 was recorded as being at No. 8 Signal, the home signal located at the Sydney end of the Benalla crossing loop.

13 A failure in the signalling system which causes a potentially dangerous situation to exist. For example, if a train is not detected by the signalling system, or if a train is approaching a level crossing and the flashing lights and/or boom gates fail to operate, or where a proceed signal is displayed where a STOP signal should be displayed. (Source: Glossary for the National Codes of Practice and Dictionary of Railway Terminology)

only one SPAD event involving signal ES6377. All four SPAD events were as a result of a signal restoring to stop in the face of a train movement. Of these events one was caused by a faulty track circuit, one was most probably as a result of track workers and the remaining two were classified as no fault found. None of these events are classified as wrong-side-signal failures.

Table 4: Signal incidents covering period June 2004 through to June 2006

Date	Time	Description
13/05/2006	1405	SPAD - 4 Signal restored in face, possible gang working
30/04/2006	1945	Signal Sighting - ES6588 obscured by trees
24/12/2005	1425	Signal Sighting - 2 Signal obstructed by trees
11/11/2005	2235	SPAD - Signal 6747 restored in face, no cause found
28/09/2005	1605	Signal Sighting - 2 Signal obstructed by trees
28/09/2005	1535	SPAD - ES6287 restored in face, track circuit failure
30/05/2005	1832	SPAD - ES6377 restored in face, no cause found

An analysis of available data did not find any ‘wrong-side-signal’ failure event or other signalling incident similar to that reported by the driver at Benalla in the lead-up to the derailment of train 5MB7.

The signalling equipment was regularly maintained in accordance with prescribed ARTC/WI contract/maintenance requirements. ARTC maintenance requirements are consistent with industry best practice and carried out on a periodic basis. Maintenance periods vary on each item of equipment being maintained. Without being limited, maintenance includes the cleaning and checking of relays, cleaning and adjustment of point machines, cleaning of signal lenses, battery checks/maintenance, checking wiring integrity, terminals and fuses, the replacement of signal lamp on an as required basis and the correct functionality of signal control circuits. No issues were identified during any routine maintenance activity/inspection, the last inspection before the derailment was scheduled for 20 May 2006 and performed on 25 May 2006.

Summary of signalling system:

- A physical inspection of the site established that there were no signs of vandalism or graffiti that may have rendered any part of the signalling system ineffective.
- There were no mechanical or electrical defects identified with the signalling system and/or hardware that would have resulted in signal ES6377 displaying a false ‘green’ indication.
- No maintenance anomalies were identified. Maintenance was performed in accordance with the appropriate requirements.
- Based on the available incident data there were no identified ‘wrong-side-signal’ failures or other abnormal operational events that would qualify as requiring further investigation. There were no reported events at the location that were similar in nature to that reported by the driver in the lead-up to the derailment.

All evidence indicates that No. 3 points were set in the reverse position for the entire period while train 5MB7 approached Benalla and that No. 2 Signal only ever displayed a 'Caution (low speed)' for that period. Testing confirmed that signal ES6377 would only display a 'Caution (normal speed)' when No. 2 Signal was displaying a 'Caution (low speed)'. All available evidence established that ES6377 only ever displayed a 'yellow' signal aspect, not a 'green' aspect during the period while train 5MB7 approached it. It is concluded that the signalling system functioned correctly.

2.3 Train crew actions

The braking distance for freight trains is significant, particularly when travelling at high speed and requires advance planning by the train driver who may need to commence braking several kilometres in advance of a projected stopping point. For a freight train such as train 5MB7 operating at 115 km/h, the braking distance can be in excess of 1.5 km. As a result, a basic requirement for effective train handling is knowledge of the line ahead so the driver can take the appropriate action to control the train's speed and negotiate any track conditions safely, in this instance traversing the No.3 points leading into the Benalla crossing loop. The signalling system at Benalla provided this advance information and the correct interpretation of the information by the train driver was vital in ensuring the safe handling of the train.

As freight train 5MB7 approached Benalla on Friday morning 2 June 2006, the correct operation and observation/interpretation of signal ES6377 was essential if the train was to enter the crossing loop at a safe speed, in this case, 15 km/h.

An essential requirement for effective train handling is sound driver competency, good route knowledge and a high degree of vigilance. Three primary areas of 'human performance' risk in operating trains involve:

- incapacitation, for example a driver failing to respond to external stimuli as a result of reduced vigilance, distraction, fatigue, collapse due to a medical condition, etc;
- failure to correctly observe/interpret stimuli, for example 'Signals Passed at Danger' (SPAD), incorrect observation of signals; and
- poor speed control of a train, for example a train driver over speeding or misjudging braking distance.

Strategies to mitigate the risk of these factors include:

- periodic driver medical examinations
- shift rosters structured to minimise fatigue
- two driver operation[14]
- training[15]

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14 Two driver operation - the built in redundancy of having a co-driver to avoid a single person error that might arise from the effects of degraded vigilance, distraction, fatigue, etc.

- train vigilance systems[16].

There was no evidence to suggest that there were any medical or toxicology issues that affected the performance of the driver or co-driver of train 5BM7 that may have contributed to the derailment.

An examination of the driver/co-driver records established that there were no safety breaches or performance issues with either employee while working for Interail. Neither employee was involved in any operational accident, safety related incident or SPAD. Neither employee was reprimanded or disciplined while working for Interail. Limited information was available regarding the driver/co-driver performance before being employed by Interail, however, it is known that the co-driver, the Level 4 operator, was involved in an earlier derailment on 15 March 2004 at Alumatta, while working for Freight Australia. He was not the driver at the time of the derailment and an examination of that incident established that he was not an active party in the derailment, ie his actions did not contribute and could not have prevented the derailment.

Based on available information, there is no evidence to suggest that there were any significant past performance issues with either the driver or co-driver.

Having established that signal ES6377 was displaying the correct aspect (ie did not display a 'green' aspect) during the approach of train 5MB7 the remaining analysis focuses on the actions of the driver and co-driver namely:

- the driver perceiving and calling a 'green' aspect at signal ES6377
- the driver's late response to No. 2 Signal, and
- the co-drivers failure to check the driver's call of the aspect for signal ES6377 and failure to observe No. 2 Signal.

2.3.1 Driver perceiving and calling a 'green' aspect

Signal ES6377 - sighting

An examination of signal ES6377 established that each aspect, red, yellow and green was distinct and clearly visible at a distance of 530 m. There were no trees or any other physical obstructions along the track that may have compromised the driver's view of the signal. Based on a train speed of 110 km/h the driver had 17 seconds of uninterrupted sighting, to correctly recognise and respond to the signal.

- The colours displayed by signal ES6377 were clearly distinguishable (Fig. 25) as 'red', 'yellow' or 'green'.
- The driver had clear and ample sighting available while approaching signal ES6733.

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15 Training should ensure that a driver is competent to undertake assigned duties and includes sound route knowledge of the track, understanding the meaning of signal aspects, etc. Such a system should check/monitor driver performance for route knowledge and safety breaches - eg exceeding mandated speed limits, signals passed at danger, failure to correctly observe signals, etc.

16 Vigilance system - an on board/train system that periodically tests the driver for alertness and applies an automatic brake application if they fail to respond appropriately.

Figure 25: Signal ES6377, top arm showing the 'red', 'yellow' and 'green' aspects.

No. 2 Signal - sighting

An examination of signal No. 2 established that the aspect was clearly visible at a distance of 510 m. Trees along the track that may have compromised the driver's view of the signal had been trimmed such that the limit of available sighting at this location was only due to track curvature. Fig. 16 shows No. 2 Signal viewed at a distance of 320 m:

- Signal sighting was assessed as good; the colour displayed by each of the signal aspects on No. 2 was clear and unmistakable.
- The driver had clear and ample sighting available while approaching signal No. 2.

Based on medical records neither driver had any known sight impairment and should have been able to correctly read and interpret the signal aspect(s) displayed by signal ES6377 and No. 2 Signal.

Previous hours of work

Fatigue can have a very significant effect on human performance. It can reduce attention, increase reaction times and affect memory. When fatigued, it can take longer for a person to perceive and interpret information and longer for them to decide on, and carry out, an appropriate course of action. Fatigue can also affect a person's ability to judge distance, speed and time. Typically, individuals will be unaware of the effects of moderate levels of fatigue on their performance.

Fatigue can arise from a number of sources, including the nature and duration of work, insufficient rest or sleep, and the time of day (with performance generally most affected during the period 0300 to 0500, and a smaller decrement occurring in the period 1500 to 1700). Systems for managing fatigue are common in the rail industry where workers are frequently required to work rotating shifts which mean early morning starts and/or late night finishes depending on the work roster. Rail organisations generally manage fatigue of rail safety workers under their safety management systems.

Table 5: Actual hours worked by Driver and Co-driver

	Start		End	
	Day	**Time**	**Day**	**Time**
Driver	26-May-06	1200	26-May-06	2230
	27-May-06	0600	27-May-06	1615
	01-Jun-06	0900	01-Jun-06	1630
Co-driver	26-May-06	0200	26-May-06	0900
	29-May-06	0800	29-May-06	1400
	30-May-06	0200	30-May-06	0930
	30-May-06	1730	31-May-06	0310
	01-Jun-06	0900	01-Jun-06	1630

Interail use the Fatigue Audit InterDyne[17] (FAID) rostering software to assist with the fatigue management of its train drivers. The software calculates a fatigue ‘score’ using an algorithm which takes into account factors including the cumulative effect of shifts over the previous seven days, time worked on the current shift and ‘time of day’ or circadian effects. Rosters are generally developed using the FAID software by setting a maximum allowable fatigue ‘score’ and adjusting individual work rosters to ensure that the maximum score is not exceeded. Many companies do not actively adjust the fatigue score to account for actual hours worked which may be greater than rostered hours worked. Interail, however, has developed their FAID tool to ensure that the fatigue score not only takes into consideration the *Master Roster* (ie planned hours) but is updated from the *Live Run* roster (ie actual hours) and re-calculates a fatigue scores for the remainder of the roster period.

Nevertheless ,the FAID program does not make allowances for sleep quality, individual differences in the need for sleep or factors in the work environment such as the type of task, noise, light and vibration which may have an affect on the rate at which individuals become fatigued when working.

The hours worked (Table 5) for the train driver/co-driver involved in the Benalla derailment were assessed using the FAID program. The FAID score based on the hours worked in the seven days before the derailment were calculated and found to

17 The FAID program was developed in partnership with the Centre for Sleep Research at the University of South Australia. Investigations by the Centre for Sleep Research suggest that a fatigue score of 40 to 80 is moderate, 80 to 100 is high and 100 to 120 very high. The FAID program is used by many organisations in the aviation, rail and marine industries in developing rosters in an endeavour to effectively manage fatigue.

be less than 80. However, the score is based on the assumption that the person's time off duty included an appropriate period of recuperative sleep.

Although an assessment of the driver and co-driver's level of fatigue based on the FAID program appears to be acceptable, the hours they had worked coupled with poor sleep/recovery opportunities and the time of day, may have been factors that affected their vigilance in the time immediately prior to the derailment.

Driver vigilance

Driver vigilance can be defined as the state of alertness needed to detect stimuli, appreciate their context and respond accordingly. For a train driver, vigilance often requires a response to both anticipated and unpredictable events over relatively long periods of time. Without being limited the driving task includes:

- correctly monitoring the track/trackside ahead
- adherence to signs and speed boards
- adherence to fixed signals, and
- responding to train vigilance devices.

A lapse in vigilance can result in:

- the incorrect identification of topography/a failure of route knowledge
- a failure to notice trackside signs and speed boards
- a failure to perceive changes in track gradient or curvature
- a failure to notice a signal at danger and respond correctly
- mistakes in identifying signal aspects
- expectation bias, for example, correctly spotting a signal aspect but assuming that it will change to a less restrictive aspect based on previous experience, and
- the pre-empting of vigilance activation devices (to prevent penalty brake applications).

Arousal is a mental state that affects a person's ability to carry out various tasks including the monitoring of the environment and searching for objects. Levels of arousal can be affected by environmental factors such as sleep loss/fatigue, time of day, or by a monotonous task. During certain times of the day and night, performance and alertness are also impaired due to the human biological clock.

During times of low arousal, people can suffer from drowsiness and diminished cognitive, motor and sensory skills; reaction time may increase significantly. The driver's attention may wander from the task at hand and be diverted for long enough to miss vital stimuli even when it is within their visual field. However, during these periods it is still possible for a driver to respond to simple tasks, such as pre-empting of vigilance devices, controlling the locomotive throttle, etc. Under these circumstances, automatic behaviours continue to be exhibited even when the awareness of tasks that are being performed is lost.

The drift from an alert state to a drowsy state can be manifested by body movements and behaviours. A train driver may exhibit a slowed response to external stimuli yet still execute automated tasks, such as activating the train vigilance device.

Based on an examination of events in the last minutes before the derailment the following observations have been noted:

- The driver's time to respond to No. 2 Signal, at 'Caution (low speed)', appeared excessive. He responded some 14 seconds beyond the available sighting point of the signal. Allowing for a two and a half second reaction time, the train had travelled 370 m beyond the point where the driver could have first responded to the unfolding emergency.
- The driver's biological clock (circadian rhythm) was probably close to one of its most vulnerable points. The incident occurred at 0643, this is close to the time (0300 to 0500) when performance is most affected.
- The driver and co-driver had both experienced disturbed/broken sleep. In his statement, the driver indicated that he woke at approximately 0030 expecting a wake-up phone call and could not get back to sleep thereafter. The co-driver indicated that he only got approximately four hours sleep before the wake-up phone call.

These factors all tend to suggest that the driver and co-driver may have been fatigued and in a degraded state of arousal/vigilance in the lead up to the derailment.

Train vigilance system:

Locomotive EL56 was fitted with a vigilance system designed to periodically test the driver for alertness. The system is designed to apply the train's brakes if the driver fails to respond within a specified time period.

The onboard train vigilance system fitted to EL56 was a Fischer Industries Pty Ltd 'Vigi' - Electronic Vigilance Control Unit Mk 6. The system comprises an electronics control module, brake cylinder pressure switch, pedestal pressure switch, penalty solenoid valve, isolating valve and power supply as well as a driver interface elapsed time indicator.

The elapsed time indicator displays to the driver, via six light emitting diodes, the time since the previous reset.

After initial power up, the vigilance system releases the train brakes or having been reset by the vigilance push button, begins timing.

The vigilance system installed on train 5MB7 was a fixed time based system. Although the system will reset following a brake application, throttle movement or vigilance push button activation, the timing cycle is fixed at 90 seconds. Fixed time based vigilance systems are less than effective in protecting against automatic behaviour and are particularly susceptible during periods when a driver is fatigued or in a degraded state of arousal as was reported in the October 1998 study undertaken by the Monash University for Freight Corp.[18].

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18 Investigation into the Effectiveness of Driver Vigilance Control Systems on Locomotives – Monash University Accident Research Centre (October 1998) found:

'The VCS timing cycle in FreightCorp trains is fixed. Even if crew members were to use the system as it is intended to be used, it is likely that crew members would become used to timing of the warning light and respond by reflex action (ie automatically). A variable and unpredictable cycle time would prevent automaticity from developing.'

Vigilance systems that operate randomly discourage automatic behaviour.

2.3.2 The co-driver

Safety policies/procedures, training and two driver operation are primary defences against unintended errors. Interail's 'Train Crew Development' manual provides details of the functional responsibilities of drivers. With respect to level three and four drivers the manual states:

> Level 3
>
> …the main duties are to drive locomotives hauling various freight services as required, learning in the process, the full duties and responsibilities of a driver. At all times working under the supervision of the driver and performing duties as required to ensure the safe and on timely passage of Interail freight services.
>
> Level 4
>
> Responsible for the safe and efficient running of freight services while also responsible for the supervision and control of the second crew member to ensure the safe and efficient discharge of duties.

By definition, the co-driver as a 'Level 4 Operator' was responsible for ensuring the driver, a 'Level 3 Operator', was discharging his duties in a safe and efficient manner including the period while train 5MB7 approached Benalla. In practice this means that the two drivers work as a team to ensure that the train is being driven safely and efficiently by using a system of checks and validations which includes the calling of signal aspects.

The co-driver stated that he was looking for a phone charger in his crew bag during the period the train was approaching signal ES6377. The available sighting distance[19] for signal ES6377 is 530 m. At 110 km/h the co-driver must have been pre-occupied/in a low state of arousal for at least 17 seconds to have missed seeing the aspect displayed by signal ES6377.

At 0643:37 train 5MB7 was 510 m (sighting point) from No. 2 Signal. However, the driver first responded to the unfolding emergency at 0643:51 by throttling off. This was 14 seconds after passing the sighting point. Allowing for two and a half seconds driver reaction time, the train had travelled 370 m beyond the sighting point before he responded.

Based on the statement from the co-driver, it is evident that he was unaware of the aspect displayed by No. 2 Signal and only became aware of the unfolding emergency when warned by the driver. It would therefore appear that the co-driver was in such a low state of arousal or was so pre-occupied with other events (for the period) 0642:15 - the sighting point for signal ES6377 through to 0643:51 - driver throttling off) as to have been oblivious of his surrounding environment.

The failure of the co-driver to look for and then validate/respond to the signal aspect displayed by ES6377 and No. 2 Signal meant that the driver's actions in

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19 Sighting distance – The distance along the track where a limit of authority warning prior to a limit of authority can be first reasonably viewed by the train crew of an approaching train, and the physical location of that limit of authority warning.

misinterpreting and failing to responding appropriately to these signals went unnoticed. Had the co-driver been more alert he would probably have corrected the driver's actions and thus the derailment may have been avoided.

2.4 Train control

At the time of the derailment, train 5MB7 was under the direction of the ARTC train controller who was working the Victorian north-east CTC Board. Based on interviews with the driver/co-driver and a review of the voice tapes, it was evident that there was no dialogue regarding the train cross and/or the proposed routing of train 5MB7 into the Benalla crossing loop.

A factor which influences driver behaviour is expectation. If the train driver did not expect a train cross at Benalla he may simply have missed the appropriate warnings and failed to act accordingly. A person's perception of the probability of a given event is strongly influenced by past events and the frequency with which they occur. It was evident that the train driver was not expecting[20] to cross a train at Benalla and that he probably assumed that he was being routed along the main line. He would therefore have expected that signal ES6377 was displaying a 'green' aspect.

Although it is not common practice for a train controller to advise a train driver regarding a cross/out-of course routing scenario, it is possible that the provision of this critical piece of information may have pre-warned the driver and raised his level of arousal/concentration regarding the imminent cross.

It is common practice in some transport sectors, marine and aviation, to routinely provide traffic information and enhance the appreciation of operational risks when working in close proximity with other vessels/aircraft.

By pre-warning the train driver regarding the cross it is possible that he would have been more alert approaching Benalla and thus correctly responded to the information displayed by signal ES6377.

2.5 Organisation – safety management system

Organisational commitment is fundamental for running a safe railway. It is essential to establish clear policies and instructions through an appropriate Safety Management System (SMS) that provides drivers with the skills to handle trains effectively, the knowledge to make correct decisions (including lifestyle training, route and train handling knowledge, etc) and ensuring that these skills are fit for purpose. An essential part of every SMS should include the regular assessment and monitoring of driver performance.

In recent years many rail operators have invested heavily in the training of drivers. The concept of 'professional driving' is a term that has been coined and is reflective of drivers who are fully aware of and manage those key factors that are perceived as necessary for superior driving performance.

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20 Neither the train driver nor co-driver had received advice from the ARTC Train Controller regarding a train cross at Benalla.

A ‘professional driver’ will aspire to high levels of conduct and competency that help in preventing unwanted actions. This includes:

- appropriate lifestyle
- adopting defensive driving skills
- good in cab discipline
- superior train handling and route knowledge skills, and
- good communication protocol.

It is important that drivers are aware of their respective roles and responsibilities, for example, the Interail procedures prescribe that a Level 3 driver is required to be under supervision until signed off as being competent to become a Level 4 driver. The co-driver was not authorised to assess or signoff his colleague. It was therefore inappropriate for him to assume that his colleague should be unsupervised while driving the train based on his own personal observations without an independent assessment having been undertaken by an authorised officer. The co-driver should have been more vigilant and observed the actions of his colleague particularly at critical stages of the train’s journey. Organisations must clearly communicate these expectations to employees.

An audit of Interail’s SMS by the Public Transport Safety Victoria[21] (PTSV) shortly after the Benalla derailment identified weaknesses in the area of driver training; in particular Interail was unable to provide evidence that demonstrated requisite driver safeworking and route knowledge skills in the Victorian jurisdiction.

The finding was further reinforced by information supplied by Interail to the ATSB. The ‘Interail Train Crew Development’ manual as supplied to the ATSB following the derailment was a draft document only. It was deficient in that it did not list the minimum requirements to undertake a particular driving role and also did not define in detail the necessary requirements to meet particular competency levels. For the driver involved in the derailment, there was little evidence to support his attained competency level. It was also not possible to determine his progression within the grades that is between Level 3 to Level 4. Based on the records supplied, the driver was not on any of the ‘Train crew progression tables’. A review of the document ‘Driver Qualifications for all roads’ did not indicate that he had been passed as competent for the EL Class of locomotive, or any other locomotive, although his ‘Periodical/Progressive Assessment Report’ dated 28 June 2005 stated ‘Assessed as Competent’ on the EL Class.

Both the driver and co-driver were out of date with respect to their Victorian safeworking re-certification. Re-certification is required every two years.

During the investigation it was noted that documentation was being developed by Interail to cover rostering principles and guidelines for shift workers. These

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21 The Victorian Rail system operates on the principle of ‘co-regulation’. The state regulatory body, Public Transport Safety Victoria (PTSV), a separate statutory office within the Department of Infrastructure (DoI), accredits all rail owners/operators in Victoria, subject to satisfying the accreditation criteria set out in the Transport Act 1983. Both the ARTC and Interail are accredited within Victoria and regularly audited by PTSV.

observations suggest that the company is improving management systems and training to address:

- driver training/re-certification, ongoing monitoring and associated documentation
- lifestyle/living with shift work
- crew resource management, with a particular focus on driver/co-driver support strategies to reduce single person errors.

It is possible that better management systems that identified and addressed the apparent weaknesses in driver safeworking and route knowledge skills and improved fatigue/crew resource management may have reduced the risk of the derailment.

3 FINDINGS

3.1 Context

From the evidence available, the following findings are made with respect to the derailment of Interail freight train 5MB7 at Benalla, Victoria on 2 June 2006.

These findings identify the different factors that contributed to the accident and should not be read as apportioning blame or liability to any particular individual or organisation.

3.2 Contributing factors

These findings identify the various events and conditions that increased safety risk and contributed to the derailment of train 5MB7.

1. The driver was not expecting to cross with a train at Benalla and thus assumed that he was being routed through the main line.
2. The driver probably failed to correctly interpret and then respond to signal ES6377. As a result he was unable to slow the train to a safe speed for negotiating No. 3 points.
3. The driver responded some 14 seconds beyond the available sighting point of No. 2 Signal. Had he responded earlier he could have slowed the train and potentially reduced the consequences of the derailment.
4. Two driver operation is a primary defence employed by Interail in guarding against unintended driver actions. The failure of the co-driver to look for and then validate/respond to the signal aspect displayed by ES6377 and No. 2 Signal was a clear breakdown in this defence and probably a contributing factor in the derailment.
5. The driver and co-driver were both probably in a state of degraded arousal/vigilance when they passed signal ES6377 and while approaching No. 2 Signal.

3.3 Other safety factors

These findings identify other events and conditions that increase the safety risk.

1. The Interail’s safety management systems with respect to driver certification, safeworking, route knowledge, fatigue management and crew resource management were deficient.
2. Although not a mandated requirement, had the Australian Rail Track Corporation train controller pre-warned the driver of 5MB7 regarding the cross at Benalla, it is likely that the driver would have been better prepared to correctly interpret and responded to signal ES6377.
3. The fixed time base vigilance system installed on locomotive EL56 was possibly ineffective in ensuring an adequate level of driver alertness.

3.4 Other key findings

These are findings that are not defined as safety factors or may be positive events and conditions that reduced the risks associated with the occurrence.

1. There was no evidence to suggest that there were any medical or toxicology issues that affected the performance of either the driver or co-driver.
2. There was no evidence to suggest that there were any previous performance (discipline, Signal Passed at Danger events, etc) issues with either the driver or co-driver.
3. Following the derailment, the driver of 5MB7 responded appropriately in warning approaching train movements of the derailment.
4. There were no identified mechanical deficiencies with the locomotives and/or rollingstock that contributed to the accident.
5. There were no identified track deficiencies that contributed to the accident.
6. There were no mechanical or electrical defects identified with the signalling circuits and/or hardware prior to, or after the derailment, that would have resulted in signal ES6377 displaying a false ‘green’ indication during the approach of train 5MB7.
7. The colours displayed by signal ES6377 were clearly distinguishable as ‘red’, ‘yellow’ or ‘green’.
8. The driver had ample sighting available while approaching signal ES6733 to respond appropriately.
9. There were no maintenance issues identified with the signalling system that would have contributed to the derailment.
10. The emergency services response to the derailment was effective and efficient.

4 SAFETY ACTIONS

As a result of its investigation, the ATSB makes the following recommendations with the intention of enhancing future rail safety. Rather then provide prescriptive solutions, these recommendations are designed to guide interested parties on the issues that need to be considered. Recommendations are directed to those agencies that should be best placed to action the safety enhancements intended by the recommendations, and are not necessarily reflective of deficiencies within those agencies.

4.1.1 Safety actions already taken

Interail and Department of Infrastructure (DoI)

The ATSB acknowledges that some of the recommendations detailed below have/are already being put into place by both Interail and Public Transport Safety Victoria.

4.1.2 Recommended safety actions

RR20070015

The ATSB recommends that the Australian Rail Track Corporation consider the benefits of pre briefing or warning train crews (by radio) about timetabled and also non-scheduled train crosses.

RR20070016

The ATSB recommends that Chicago Freight Car Leasing Australia review the effectiveness of their current fixed time based train driver vigilance systems with a view to ensuring that drivers maintain an optimal state of alertness at all times while performing driving duties.

RR20070017

The ATSB recommends that Interail monitor and review processes in place to ensure that train crews are competent to undertake work at their designated level of responsibility and that this is acknowledged and recorded within the employee files. (For example, evidence that demonstrates requisite driver safeworking and route knowledge skills.)

RR20070018

The ATSB recommends that Interail monitor and review processes in place to ensure that driver re-certification is regularly reviewed and recorded.

RR20070019

The ATSB recommends that Interail review their current crew resource management practices with a view to ensuring that a co-driver is sufficiently alert and actively participating in the operation of the train, particularly during periods of high risk operation.

RR20070020

The ATSB recommends that Interail's training strategies clearly articulate and communicate mentoring responsibilities and what this entails. (For example, the responsibility of a Level 4 driver in managing a Level 3 driver.)

RR20070021

The ATSB recommends that Interail should review opportunities to improve its systems that identify weaknesses in driver safeworking and route knowledge skills and improve fatigue management to ensure drivers are fully fit for duty.

5 APPENDIXES

5.1 Sequence of events list

Table 6: Benalla 'sequence of events list'

Date	Time	Time(EST)	Short/Mnemonic	State	Details
02/06/2006	05:59:49	06:29:49	ESELDF1	1	Benalla interlocking selected
02/06/2006	05:59:54	06:29:54	ESELDF1FL	1	Auto cross selected (see footnote 7)
02/06/2006	05:59:54	06:29:54	P3RWKF	1	No 3 points set reverse. (Note: No 2 signal requires 3 points normal for signal ES6377 to display green aspect)
02/06/2006	06:00:13	06:30:13	S2RGKF	1	No 2 signal cleared for 5MB7. (Note: No 2 signal remains clear until 06:43:58 when 5MB7 occupies 3 track and restores signal to stop)
02/06/2006	06:00:13	06:30:13	S2RGKFFL	1	No 2 signal approach operated not set
02/06/2006	06:00:26	06:30:26	S2NGKF	0	No 2 Signal reverse/not normal
02/06/2006	06:00:26	06:30:26	S2RGKFFL	0	No 2 signal approach operated set
02/06/2006	06:06:32	06:36:32	T2AK2	1	2A track becomes occupied, ie 5MB7 detected on down approach circuit.
02/06/2006	07:13:10	06:39:36	EL56	1	Vigilance activation
02/06/2006	07:14:54	06:41:20	EL56	1	Vigilance activation
02/06/2006	07:15:39	06:42:05	EL56		5MB7Q passed Cemetery Rd Xing
02/06/2006	07:15:52	06:42:18	EL56		Estimated sighting point for signal ES6377
02/06/2006	07:16:06	06:42:32	EL56		5MB7Q passed ES6377
02/06/2006	07:16:14	06:42:40	EL56	1	Horn Blown
02/06/2006	07:16:16	06:42:42	EL56	1	Vigilance activation
02/06/2006	07:16:22	06:42:48	EL56	1	Vigilance activation
02/06/2006	07:16:30	06:42:56	EL56		5MB7Q passed Faithful St Xing
02/06/2006	07:16:35	06:43:01	EL56	1	Vigilance activation
02/06/2006	07:16:56	06:43:22	EL56		5MB7Q passed Arundel St Xing
02/06/2006	07:17:01	06:43:27	EL56	1	Vigilance activation
02/06/2006	07:17:11	06:43:37	EL56		Estimated sighting point for No. 2 Signal
02/06/2006	07:17:15	06:43:41	EL56	1	Horn Blown
02/06/2006	07:17:17	06:43:43	EL56	1	Vigilance activation
02/06/2006	07:17:18	06:43:44	EL56		5MB7Q passed Midland Hwy Xing
02/06/2006	07:17:23	06:43:49	EL56		First driver response to No 2 signal (estimate) stated signal showing 'low speed' aspect
02/06/2006	07:17:25	06:43:51	EL56	1	Throttled off
02/06/2006	07:17:28	06:43:54	EL56	1	BPP dump
02/06/2006	06:13:55	06:43:55	P3TK	1	3 track occupied ie track immediately past No 2 signal becomes occupied by presence of 5MB7Q.
02/06/2006	06:13:55	06:43:55	S2NGKF	1	No 2 signal normal, restored to stop position by 5MB7Q passing signal, ie occupation of No 3 track.
02/06/2006	07:17:29	06:43:55	EL56		No 3 track ie track immediately past No 2 signal becomes occupied by presence of 5MB7Q.
02/06/2006	06:13:58	06:43:58	S2RGKF	0	No 2 signal restored to stop position by 5MB7Q passing signal, ie occupation of No 3 track.
02/06/2006	07:17:33	06:43:59	EL56		5MB7Q passed over No. 3 points
02/06/2006	07:17:36	06:44:02	EL56	1	Vigilance activation
02/06/2006	07:17:40	06:44:06	EL56	1	Horn Blown
02/06/2006	07:17:40	06:44:06	EL56	1	Vigilance activation
02/06/2006	06:14:07	06:44:07	T8TK	1	No 8 track, ie passing loop track becomes occupied by presence of 5MB7Q.
02/06/2006	07:17:43	06:44:09	EL56	1	Vigilance activation
02/06/2006	06:14:10	06:44:10	T2TK	1	No 2 track, ie main line shows as occupied, due to track being broken by derailment.
02/06/2006	07:17:46	06:44:12	EL56		Train at stop
02/06/2006	07:17:46	06:44:12	EL56	1	Horn Blown
02/06/2006	07:17:48	06:44:14	EL56	1	Horn Blown
02/06/2006	07:02:47	07:32:47	ESELDF1FL	0	Auto cross not selected (see footnote 7)
02/06/2006	07:06:16	07:36:16	ESELDF1	0	Benalla interlocking not selected
02/06/2006	07:35:57	08:05:57	ESELDF1	1	Benalla interlocking selected

5.2 Submissions

Section 26 of the *Transport Safety Investigation Act 2003*, requires that the Executive Director may provide a draft report, on a confidential basis, to any person whom the Executive Director considers appropriate, for the purposes of:

a) Allowing the person to make submissions to the Executive Director about the draft; or

b) Giving the person advance notice of the likely form of the published report.

The final draft of the report has been made available for comment to the following directly involved parties:

a) Australian Rail Track Corporation (ARTC)

b) Chicago Freight Car Leasing Australia (CFCLA)

c) Department of Infrastructure - Public Transport Division

d) Department of Infrastructure - Public Transport Safety Victoria

e) Interail

f) Driver of train 5MB7

g) Co-driver of train 5MB7

h) Works Infrastructure (WI)

The ARTC and Interail made a number of submissions on the draft report issued to directly involved parties. Their comments and observations have been incorporated into the report where they are supported by valid evidence and agreed to by the investigation team.

5.3 Media Release

The ATSB has found that the major derailment of an Interail freight train at Benalla in Victoria on 2 June 2006 occurred because the train driver did not correctly interpret and respond to a signal.

The Australian Transport Safety Bureau investigated the accident which resulted in of the derailment of two locomotives which sustained heavy damage along with 19 wagons and two track machines which were located in an adjacent siding. A nearby Victorian Railway Institute Hall also sustained heavy structural damage as a result of the derailment.

There were no serious injuries to the train crew or other people.

The investigation concluded that the driver of the train failed to correctly interpret and then respond to a signal and that the co-driver was ineffective in preventing the derailment as he was pre-occupied and not fully alert.

In the interest of enhancing future rail safety the ATSB has made a series of recommendations which include a review of crew coordination, an examination of mentoring responsibilities, and a review of processes for the re-certification of drivers.

Copies of the report can be downloaded from the ATSB's internet site at www.atsb.gov.au, or obtained from the ATSB by telephoning (02) 6274 6478 or 1800 020 616.

Derailment of Train 5MB7 Benalla, Victoria, 2 June 2006