Derailment of Coal Train EG37

Connors Range
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The purpose of this report is to enhance safety. Therefore, this report is confined to matters of safety significance and may be misleading if used for any other purpose.

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Executive summary

On 1 July 2001 at approximately 0538 hours, EG37, a Locotrol II-equipped[1] coal train operated by QR, was hauling 120 fully loaded wagons from Coppabella to Hay Point, Mackay, and commenced to negotiate the steep descent of the Connors Range.

Shortly after, the Driver reported to the Train Control Centre in Mackay that he had a 'runaway' train and that he had been in Emergency Brake for some minutes.

As EG37 reached a speed of 93 km/h, it entered a left curve in the track approximately 38 km from Hay Point. The front portion of the train, including the first 28 wagons, separated from the remainder of the train but stayed on the track. Seventy-four of the following wagons, the two remote locomotives and the Electric Locomotive Control Unit[2] (ELRC) derailed at that time. The last 18 wagons on the rear of the train remained on the track.

Within seconds of separating from the rest of the train, the front portion of the EG37 commenced to rapidly decelerate. It stopped some two minutes later and approximately two kilometres beyond the point of separation.

Neither of the Drivers was injured as a result of the accident.

It was later determined that the sequence of events had been triggered by an extended loss of the Locotrol radio signal[3] at the top of the range and that the back-up safety mechanism in the Train Brake system of EG37's ELRC had failed due to a supernumerary errant O-ring lodged in the seat of the cut off portion of the Brake Pipe Control Valve. As a result of that failure, the Remote Feed Valve at the ELRC remained open and fed air into the Train Brake Pipe throughout the accident sequence, opposing Train Brake applications made by the Driver. Consequently, the braking capacity of EG37 was reduced to something less than half its normal braking capacity and was insufficient to allow the Driver to control the speed of the train as it travelled down the range.

Despite extensive testing, the investigation has not been able to determine the reason for the extended loss of Locotrol radio signal.

It could not be precisely determined when the errant square-section O-ring was introduced into the Brake Pipe Control Valve. However, if relevant overhaul, bench test and functional checks had been followed in accordance with the then current procedures, the fault should have either been clearly identified or clues may have been provided as to its existence.

Immediately following the accident, in the absence of any clearly identified fault at that time, QR introduced modified procedures for handling trains down the Connors Range.

Following the identification of the fault in the Train Brake system, modified functional test procedures were introduced within the maintenance program, which specifically checks the cut off function of the Remote Feed Valve and has increased the frequency of that check by requiring it to be carried out at Terminal Examinations.

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[1] Refer to the L*ocotrol System Design* section of this report for further details on the Locotrol system

[2] Refer to the *Locotrol System Design* section of this report for further details on the ELRC

[3] The radio signal used to control locomotives in the centre of a train

As a result of this investigation, a number of outstanding safety actions have been identified. It is recommended that QR progress those safety actions as part of the process of continuous improvement within its Safety Management System. Those safety actions relate to:

- Underlying reason/s for the extended loss of Locotrol radio communications;
- Threshold limits for both frequency and length of Locotrol radio communication interruptions;
- Real-time information about the status of Train Brake continuity;
- Mechanisms or options to ensure adequate Train Braking efficiency in abnormal and emergency situations;
- Train maintenance practices and procedures;
- Adherence to prescribed train operating procedures;
- Arrangements in relation to Authorised Persons;
- Fitment of Dataloggers; and
- Collection and recording of evidence for safety investigations.

Refer to the *Analysis* and *Safety Action* sections of this report for further detail on the issues and safety actions described above.

Terms of reference

In pursuance of the powers given to me under Section 103/2 of the *Transport Infrastructure Act 1994*, I hereby require you to chair a joint QT/QR investigation and report on the circumstances and cause of the accident involving a derailment on Black Mountain (DOT reference 920) which occurred on 1 July 2001 and report your findings in writing to Bruce Couch, A/Manager, Rail Safety Accreditation, Queensland Transport by 1 August 2001 (should a full report be unable to be provided by this date, an interim report must be submitted).

The investigation will:

- Undertake a systemic investigation into the accident;
- Establish the factual circumstances leading to, and immediately following the accident;
- Identify the direct cause or causes of the accident and any other contributing factors including human factors or any underlying matters that may have caused or contributed to the accident;
- Examine the systems and procedures which were in place prior to the occurrence and establish if appropriate risk management procedures were in place and/or applied to minimise the risk of an accident;
- Provide an estimate of direct and associated costs with the accident;
- Identify any safety actions to prevent, to reduce the risk of recurrence, future injury or damage and generally improve any safety system.

The investigation report should be based on a systemic style investigation approach and should not be written in a manner which apportions blame.

The inquiry team will comprise:

Ms Kerryn Macaulay	Investigation Team Chairperson, Australian Transport Safety Bureau
Mr John Pistak	Manager Infrastructure Maintenance, Mackay, QR
Mr Ian Rossow	Manager Locomotive Engineering, Brisbane, QR
Mr Geoff Featherstone	Manager Service Delivery, Goonyella/Newlands, Mackay, QR
Mr Graham Guy	A/Principal Advisor (Rail Safety Accreditation), QT

Bruce Couch
A/Manager (Rail Safety Accreditation)
3 July 2001

Investigation methodology

The purpose of this investigation was to enhance rail safety. First, by determining the sequence of events which led to the accident and second, by determining why those events occurred. Of particular importance was the need to understand what the accident revealed about the safety environment within which this particular rail operation was being conducted, and to identify deficiencies with the potential to adversely affect safety.

The Reason model was used as a framework for the analysis of this accident.

The model of accident causation developed by James Reason has become one of the most widely applied systemic approaches to accident and incident analysis[4]. Reason maintains that most accidents result from an interaction of factors, rather than a simple error or violation on the part of operational personnel. Whilst some of those factors, including local task and workplace conditions, can have an immediate effect on the operation being performed, other factors relating to organisational or systemic processes, may remain unnoticed for considerable periods. Individually, each of those factors is generally insufficient to cause a breakdown in safety. However, a combination of organisational and task factors may promote an environment conducive to human or technical error, leading to a safety hazard. Should defences designed to warn and protect against those hazards be absent or inadequate, then a safety breakdown may be the outcome. It was therefore necessary to look behind the actions of operating personnel in order to examine other areas with the capacity to influence safety.

During the investigation, information was obtained and analysed from a number of sources, including:

- A visit to the accident site and other locations associated with the accident;
- Extraction of data from the Datalogger of the lead locomotive of the accident train (EG37) and analysis of that data;
- In-cab observations of train operations in the accident site area;
- A review of aspects of QR's Safety Management System;
- A review of company technical and operational procedures and practices, including maintenance and training;
- Interviews with personnel directly associated with the accident;
- Interviews with management and safety personnel relevant to the accident;
- A review of relevant national and international safety occurrences;
- Train performance simulations using extracted Datalogger information;
- In-field and depot examinations and testing of the operational status and adequacy of Train Brake and radio systems on the locomotives and ELRC of EG37; and
- In-field testing of possible radio signal interference in the accident site area.

Appreciation must be extended to the many operational and technical staff from QR who provided unfettered cooperation to the investigation team, enabling the team to complete their task in a timely fashion and to be assured that all relevant safety issues had been considered.

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[4] REASON, J. 1990, Human Error, (Cambridge University Press: Cambridge)

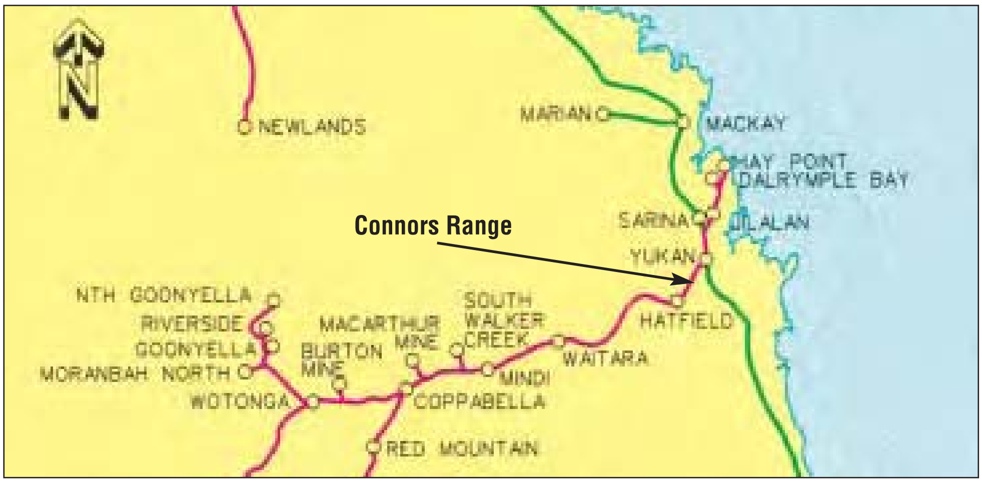
1. FACTUAL INFORMATION

1.1 Location

1.1.1 General

Connors Range (usually referred to as Black Mountain) is located within the Goonyella Rail System approximately 20 km south-west of Jilalan (see fig. 1). The Goonyella Rail System is located in Central Queensland between latitudes 21°18'S and 23°09'S and longitudes 147°31'E and 149°17'E.

Figure 1:
Location map of Goonyella Rail System



Connors Range is predominantly a downgrade of between 1:50 (2 per cent) to 1:55 (1.8 per cent), in the direction of travel of a loaded train. That downgrade is broken into two sections, being Hatfield to Black Mountain and Black Mountain to Yukan. Those two sections include 24 curves with 45 mm or 50 mm cants. Medium to heavily wooded areas of trees cover the range.

At the time of the accident, the maximum posted speed for travelling down the range was 40 km/h, with speed boards located on the range to remind Drivers of that limit.

The Hatfield to Black Mountain section is 8.275 km in length. The first 2 km of that section is a steep ascending grade until the crest of Connors Range is reached after which a steady descending grade continues to Black Mountain.

The Black Mountain to Yukan section is 9.225 km in length. A steady descending grade continues from Black Mountain for approximately 4 km after which the downgrade becomes less steep and has some undulations.

Electric locomotives operate predominantly coal trains throughout the Goonyella Rail System. The Goonyella Rail System is electrified by an AutoTransformer system with the overhead line equipment operating at 25,000 volts, 50 hertz, alternating supply (25 Kv, 50 Hz, AC). Distribution is via a contact wire suspended from a catenary wire which feeds electric power through pantographs[5] on the electric locomotives.

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[5] Pantograph – the 'arm-like' device on the top of a locomotive that maintains contact with the overhead wiring system in order for a continuous supply of electricity to be provided to the locomotive.

1.1.2 Track details

The rail track from Hatfield through to Yukan is constructed to Concrete Sleeper Track Type 60-2 (continuously welded 60 kg/m rail on 28 tonne axle load sleepers). The track is narrow gauge (1067 mm). Ballast is crushed rock to a depth of 250 mm below the sleepers. Shoulders are generally 250 mm to 350 mm past the end of sleepers.

Bi-directional duplicated track is in place from Jilalan to Coppabella, with passing loops at 5 – 13 km intervals.

The track was re-layed in 1987. Since that time, the track has had ballast undercutting, re-sleepering and re-railing work completed by infrastructure track staff as part of periodical maintenance.

A Track Recording Car completed a periodical inspection on the rail track in the Connors Range area on 3 May 2001. The results of that inspection indicated that all recorded parameters, including cant and versine (curvature), were within threshold limits as prescribed by Civil Engineering Track Standards, Module 9. Those results were compared with the previous Track Recording Car inspection in that area which had been conducted on 26 October 2000. That comparison indicated there had been a minor deterioration in the cant and curvature of the transition of the curve on which the derailment of EG37 had occurred. Further details on the track geometry in the area of the derailment site are referred to in the *Simulations* section of this report.

Rail grinding had been carried out in the vicinity of the derailment site on 5 June 2001. Changes in cant and curvature would not have occurred as a result of rail grinding activities.

1.1.3 Train control

The Train Control Centre in Mackay is responsible for controlling train movements throughout the Goonyella Rail System.

Train movements are controlled by electronic remote control signals utilising track circuitry for track occupancy. That system is known as Remote Control Signalling (RCS).

Goonyella Train Control is split into two Train Control boards, being the Far West Board covering all trains in the Goonyella Rail System west of Coppabella, and the Near West Board covering all traffic from Coppabella to the ports at Dalrymple Bay and Hay Point. The Near West Board was the board controlling train movements covering the area of the derailment.

Communication on the Goonyella Rail System between Train Drivers and Train Controllers is via a UHF radio system known as Train Control Radio (TCR). A TCR radio is provided in the cab of each locomotive together with a special combined radio, which can work either as a TCR radio or a Trunk radio, thus providing redundancy. Those radios operate on frequencies between 403 and 420 MHz.

All signal changes and radio conversations are recorded at the Train Control Centre in Mackay. The track signalling system and UHF voice radio systems were operating normally at the time of the accident.

Train information such as locomotive consist[6] details, wagon and loading details are recorded on QR's Freight Management System.

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[6] Consist – is a grouping of locomotives in a train.

1.1.4 Type of operation

The Goonyella Rail System services the 13 Central Queensland coalmines located in the Mackay hinterland region of the Bowen basin. Export coal is transported to the ports of Hay Point and Dalrymple Bay situated some 20 km from the Jilalan Depot, prior to shipment overseas.

69,162,576 tonnes of coal was shipped on the Goonyella Rail System on 7,669 trains for the period 3 July 2000 to 1 July 2001. Those figures included 4,368 trains hauling 40,261,204 tonnes to the port of Dalrymple Bay and 3,301 trains hauling 28,901,372 tonnes to the port of Hay Point. The Goonyella Rail System weekly average for that period was 147 trains hauling 1,330,050 tonnes.

The figures referred to in the previous paragraph are total numbers and weights of loaded export-coal trains only. An equal number of empty coal trains also traverse the system each year. Other traffic also operates on the Goonyella Rail System including 50 domestic coal trains, 230 grain trains and 350 work-related trains. Infrastructure Services also operate on the system using Track Machines to conduct programmed and ad hoc maintenance. No passenger services operate on the Goonyella Rail System.

1.2 Train information – EG37

Coal train EG37 was scheduled to operate from Coppabella to Hay Point with a departure time shortly after 0400 hours.

EG37 was a 5-header[7] train with three 3000 class locomotives at the front of the train, referred to as lead locomotives, and two 3000 class locomotives in the centre of the train, referred to as remote locomotives. EG37 was a Locotrol II-equipped train, allowing the Driver to control the remote consist of locomotives by UHF radio via the ELRC(119), which was located immediately behind the two remote locomotives. The lead and remote locomotives were required to operate in Multiple Unit mode whilst travelling down the range. The *Locotrol system design* section of this report provides an explanation of relevant aspects of the Locotrol system.

EG37 was hauling 120 fully loaded coal wagons, 60 attached to the lead locomotives and the remaining 60 attached to the remote locomotives with a total length of approximately 2 km. The all up weight of the train was approximately 13,032 tonnes.

1.3 Sequence of events

The incoming crew was provided with a handover briefing from the previous operating crew before departing from Coppabella. That briefing was in accordance with company procedures. The outgoing crew commented that the train's Dynamic Brake[8] was a little 'sluggish'. No other technical faults or anomalies with the operation of the train were reported to the incoming crew and none had been noted in the Train Handover Sheet for service EG37 or the Locomotive Serviceability Certificate for Lead Locomotive 3160.

The Driver of EG37 made two Train Brake applications prior to the Connors Range. No problems with Train Brake performance were noted on those occasions.

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[7] Header –traditionally, the term related to the number of locomotives at the **front** of a train though the term is now used more broadly and simply refers to the **total** number of locomotives on a given train regardless of their location within that train.

[8] Dynamic brake – applies to locomotives only and not wagons. As a train descends a grade, dynamic braking uses the pull of gravity on the train to generate electricity that is then run through resistor grids and dissipated as heat. The traction motors are used as generators that retard the movement of the train, causing it to slow or brake.

When approaching Hatfield, a location approximately two kilometres before the top of the Connors Range, the Driver contacted Train Control and was advised that EG37 was cleared to operate through to Yukan, a location two kilometres north-east of the bottom of the range. The speed of the train at that time was 54 km/h.

Figure 2:
Route down Connors Range

Mosaic photography provided by Queensland Department of Natural Resources

EG37 had slowed to 35 km/h by the time it reached the top of the range and had reduced speed by a further 15 km/h when the Driver closed the throttle 15 seconds after passing an AutoTransformer.

At the Point of Balance[9], EG37 had slowed to its lowest speed of 17 km/h. At that time, the Driver commenced to engage Dynamic Brake. Over a period of about one and half minutes, the Driver continued to increase Dynamic Brake. The train commenced to accelerate slowly during that time. Before Dynamic Brake had been fully applied, the Driver reported that the Locotrol display indicated that a communications interruption (Com Int) had occurred (see fig. 2). The red Com Int warning light was illuminated and the Dynamic Brake indication was flashing at Dynamic Brake level '8'.

The train Datalogger[10] indicated that the Driver made an initial application of Train Brake (reduction in Brake Pipe pressure of 50 kpa) when the speed of the train had reached 32 km/h. Further application of Train Brake was made over a period of approximately one minute. The speed of the train had reached 48 km/h at the time Full Service[11] braking was applied. The Driver reported that at no time did he feel the Train Brake was having any effect in controlling the speed of EG37.

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[9] Point of Balance – where the length of a train is equally distributed on either side of the crest of a hill/mountain range. At this point, forces required to hold the train from descending in either direction are zero.

[10] Datalogger – a device fitted to a locomotive which independently records various parameters including time, power and brake settings, Train Brake pressures, train speed etc and which may be used for train performance monitoring or accident and incident investigation.

[11] Full Service Braking – maximum application of Train Brake under normal conditions. Brakes should be fully applied throughout the length of the train under Full Service Braking.

Some 21 seconds later, with the speed of the train having reached 52 km/h, the Driver applied Emergency Brake[12]. However, the train continued to accelerate to a speed of 93 km/h over a period of approximately five and a half minutes. Both the Driver and the Second Driver reported that they had difficulty remaining seated during the latter part of the sequence as significant lateral and longitudinal forces were buffeting EG37 as its speed increased. The Second Driver recalled that he had been thrown from his seat on three separate occasions.

The Second Driver advised that he 'pulled the tap'[13] when he was aware that the train was not slowing after the Driver had made an Emergency Brake application from the locomotive control console. The Second Driver reported that he did not experience a 'rush of air' from the Train Brake Pipe. The Datalogger does not show this action as the Train Brake Pipe was at or near zero pressure at that time.

At the time the speed of EG37 reached 93 km/h, it had entered a left curve in the track approximately 38 km from Hay Point. The front portion of the train, including the first 28 wagons, separated from the remainder of the train and stayed on the track. Seventy-four of the following wagons, the two remote locomotives and the ELRC derailed at that time. The last 18 wagons on the rear of the train remained on the track (see fig. 3).

According to the Driver's recollection of events, he selected the Emergency Pantograph Down button on the console in the locomotive cab some time shortly before or just after the derailment. The Train Datalogger shows that this button was pressed shortly after the train separated.

Within seconds of separating from the rest of the train, the front portion of the EG37 commenced to rapidly decelerate. It stopped some 123 seconds later and approximately two kilometres beyond the point of separation.

Figure 3:
General view of accident site

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[12] Emergency Braking - maximum application of Train Brake under emergency conditions. The only difference between Full Service Braking and Emergency Braking is that when Emergency Braking is selected, air is released from the Train Brake Pipe more rapidly than under Full Service Braking. Therefore, brakes are fully applied throughout the length of the train much more rapidly.

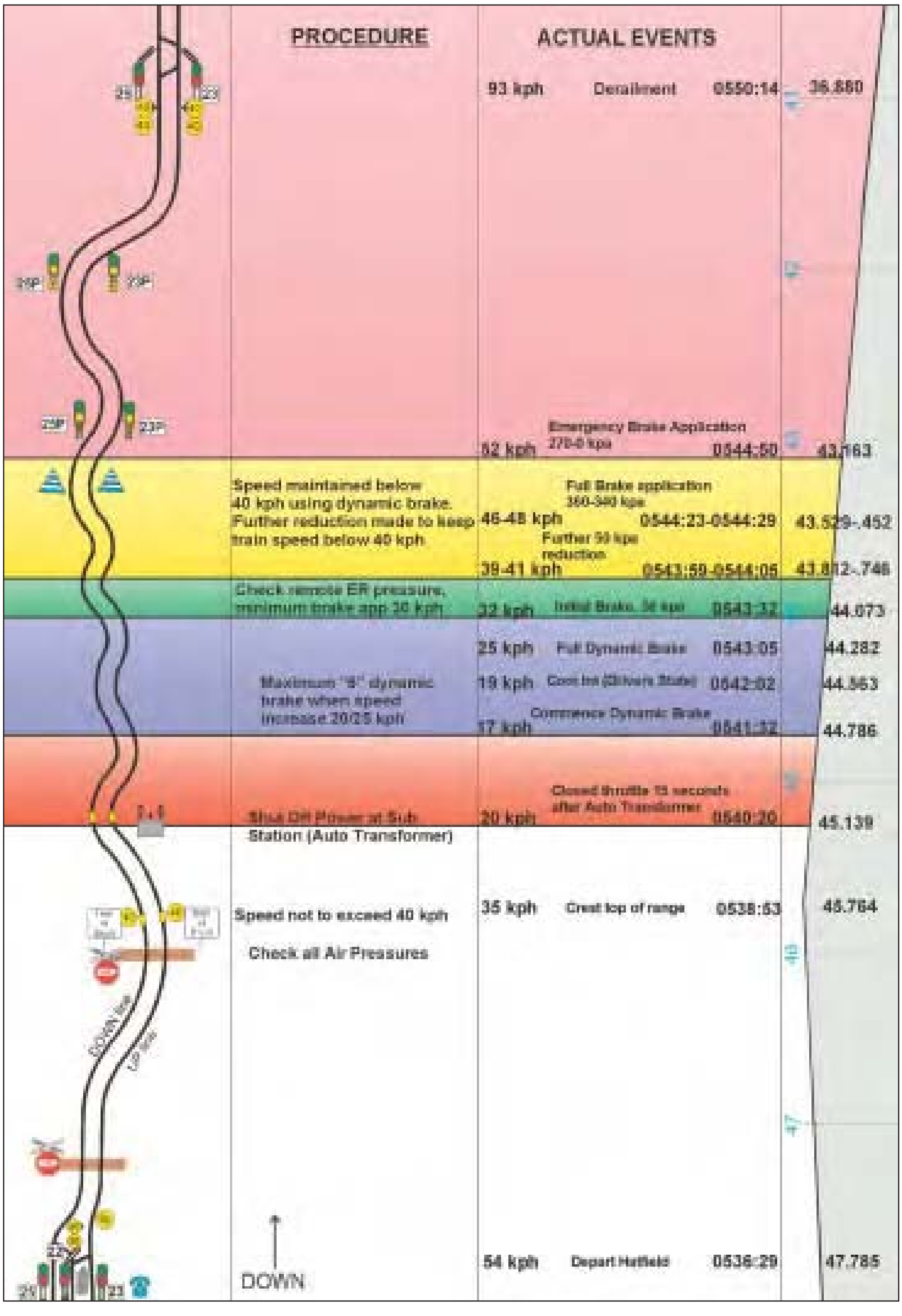
[13] 'Pulled the tap'- refers to opening the manual Emergency Brake Pipe Cock. This is a large bore 'tap' in the Driver's cab which is directly connected to the Train Brake Pipe, and will rapidly exhaust the Train Brake Pipe pressure to atmosphere. It is provided as a backup to the Driver's Train Brake valve, and can be operated by the Second Driver in an emergency if it is suspected that the normal Train Brake control has not worked.

The Driver had been in contact with Train Control and had warned that he had a 'runaway' train. Other coal services were prevented from entering the area and an emergency response was initiated in accordance with company procedures.

Both Drivers reported that the red Com Int warning light remained illuminated throughout the entire accident sequence as well as the flashing green 'Feed Valve IN' light.

Note: A diagram of the prescribed procedures for handling trains down the Connors Range compared with the actual events described above, can be viewed at figure 4.

Figure 4:
Comparative presentation of written procedure for handling trains down Connors Range and actual events relating to EG37



1.4 Injuries

Neither of the Drivers was injured as a result of the accident sequence.

1.5 Damage

Seventy-three coal wagons, two 3000-class electric locomotives and one ELRC unit were damaged beyond repair during the accident sequence.

Approximately 700 m of rail and 500 sleepers, including associated pads, clips and spacings, required replacement. One thousand metres of overhead wiring and nine supporting masts required replacement. In addition, the foundations of those nine masts needed to be repaired.

One land-slip detector, located at the site of the derailment, was destroyed.

1.6 Estimated costs

The replacement cost of the rollingstock was estimated to be $20,000,000.

The cost of the recovery operation, including hire of machinery, wages, and the repair/replacement of track and overhead wiring and associated infrastructure, was estimated to be $600,000.

The cost of the investigation, including wages, tests and research, was estimated to be $125,000.

1.7 Personnel

Operation of coal trains on the Goonyella Rail System requires two Drivers. The *Traincrew Subsidiary Agreement (1996)* defines ‘Two Driver Operations’ as *the operation of a train by two qualified locomotive Drivers who share both the driving and operational responsibilities.* The control of the train lies with the Driver who is physically operating the train from the Driver’s seat on the right side of the locomotive cab. In addition, the *Traincrew Subsidiary Agreement* states that a Team Leader is *the Driver who has been classified or appointed longer. The Team Leader’s role differs from that of a Second Driver only in those extraordinary circumstances where a leadership decision is required.* It is therefore possible that the Team Leader, in any given combination of Drivers, may be either the Driver or the Second Driver. In the case of EG37, the Second Driver would have been the appointed Team Leader.

1.7.1 Driver

Certificate of Competence to handle heavy trains on Mountain Range	15 August 1995
Medical (Driver Cat 1)	5 April 2001 – deemed fit for duty
Time on duty prior to accident	5 hours 40 minutes
Last re-accreditation	10 December 1999

The Driver had worked his previous shifts in accordance with the scheduled roster. His actual worked roster was entered into a fatigue modelling software program[14]. The results did not reveal significant fatigue index scores.

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[14] Fatigue modelling program – the program used by QR is the FAID program (Fatigue Audit Inter*Dyne*) developed by Inter*Dynamics* Pty Ltd using the fatigue assessment formula and factors developed by the Centre for Sleep Research (CFSR) at the University of South Australia. The program provides for a risk assessment of an individual’s fatigue based on their rostered tasks.

1.7.2 Second Driver

Certificate of Competence to handle heavy trains on Mountain Range	20 January 1995
Tutor Driver	2 February 1998
Medical (Driver Cat 1)	13 June 2001 – deemed fit for duty
Time on duty prior to accident	5 hours 40 minutes
Last re-accreditation	14 August 1996 (Prior to the accident, the Second Driver had been scheduled for re-accreditation on 30 July 2001)

The Second Driver had worked his previous shifts in accordance with the scheduled roster. His actual worked roster was entered into a fatigue modelling software program. The results did not reveal significant fatigue index scores.

1.8 Environmental factors

Weather observations taken by the Queensland Bureau of Meteorology (BOM) at Mackay at 0600 hours on 1 July 2001 indicated that it was clear in the Mackay area with a southerly wind of some 10 Kts, gusting up to 15 Kts. The temperature at that time was 16.8 degrees Celsius with a dewpoint of 16 degrees Celsius. The humidity was 94 per cent. The last rain in the area had been recorded as 8 mm on 29 June 2001 with no rain being recorded since 0900 on that day.

There were no weather recording devices on the Connors Range at the time of the accident other than a rainfall-recording device installed by QR to assist with predictions of land slippage in the area. Rainfall recording and transmitting functionality of that equipment was not working at the time of the accident and therefore no data was available. The associated slip detection equipment had recorded no appreciable land movements.

The weather observations at Mackay were interpolated by BOM staff for the Black Mountain area of the Connors Range. The weather in that area was described as clear with a southerly wind of less than 10 Kts. The temperature was calculated to be 14 degrees Celsius with a dewpoint of 10 degrees Celsius. The humidity was 77 per cent.

1.9 Recorded information

1.9.1 Train control

The voice recording of the transmissions between Channel 01 West Train Control (Train Control) and the Driver of EG37, was quarantined after the accident and a written extract of that recording was completed. The Driver of EG37 contacted Train Control at 0550:37 hours and broadcast that EG37 was coming down the range ‘out of control’ and was in emergency braking.

At 0552:35, the Driver inquired whether Train Control was aware of any overhead power supply problems. Train Control confirmed that the power supply on the overheads in the area had been lost. At that time, the Driver informed Train Control that he had selected the pantographs on the locomotives to the emergency DOWN position and that EG37 was slowing to a halt. The Driver also indicated that he was not aware at that time whether his train was complete. Train Control advised that there were no other trains in the area.

At 0553:08, the Driver advised that EG37 had come to a halt. Shortly after, the Driver and Train Control agreed that it would be safer if the crew of EG37 remained in the cab of the locomotive until electrical line staff had inspected the area and declared that it was safe for the crew to disembark from the locomotive.

At 0558:30, Train Control contacted the Train Coordinator at Coppabella and advised that all trains were to be held in the area until further notice. Other parties were contacted and advised of the accident in accordance with company procedures.

1.9.2 Data logger

The Datalogger from Lead Locomotive 3160 was removed at approximately 0737 by a QR employee approved to do so by the investigation team, prior to the front section of EG37 being removed from the area. QR personnel later downloaded the data using facilities at the Jilalan Depot. Those actions were performed in accordance with the appropriate instructions. Full details of the information derived from that Datalogger have been included at Appendix A. An abbreviated data extraction of significant events during the accident sequence of EG37, is presented in figure 5. The remote locomotives were not Datalogger-equipped.

Figure 5:
Data extraction of significant events from Datalogger of Lead Locomotive 3160

Corrected time	*Train Brake Pipe Pressure Kpa*	*Brake Cylinder Pressure Kpa*	*Throttle Position*	*Dynamic Brake*	*Train Speed km/h*	*Location (km from Hay Point)*	*Significant Event*
5:36:29	500	0	F	0	54	47.785	EG37 passes Hatfield departure signals
5:38:53	500	0	8	0	35	45.764	EG37 arrives at top of Connors Range
5:40:05	500	0	7	0	21	45.226	EG37 passes Auto Transformer at 45.225 km
5:40:20	500	0	0	0	20	45.139	Driver closes throttle
5:41:05	500	0	0	0	17	44.913	EG37 passes hold point at Hatfield – train balanced (half train on either side of top of Connors Range)
5:41:32	500	0	1	1	17	44.786	Driver commences to engage Dynamic Brake
5:42:11	500	0	C	1	19	44.595	**Comm-Int (from Driver's statement – 'short straight at the top of the range' – 44.430 to 44.750 km – 'plus flashing DB 8')**
5:42:14	500	0	F	1	19	44.579	
5:42:17	500	0	C	1	19	44.563	
5:42:20	500	0	C	1	19	44.548	
5:42:23	500	0	C	1	19	44.532	

Corrected time	Train Brake Pipe Pressure Kpa	Brake Cylinder Pressure Kpa	Throttle Position	Dynamic Brake	Train Speed km/h	Location (km from Hay Point)	Significant Event
5:43:05	500	0	F	1	25	44.282	Full Dynamic Brake engaged at this time
5:43:32	450	0	F	1	32	44.073	Driver makes an initial application of the Train Brake (reduction of 50 kpa)
5:43:56	450	0	F	1	39	43.844	Entire train now on down-grade of Connors Range
5:43:59	440	0	F	1	39	43.812	Further Train Brake application
5:44:23	360	0	F	1	46	43.529	Further Train Brake application
5:44:29	340	0	F	1	48	43.452	Full Service application of Train Brake – Train Brake Pipe pressure equalises at 340 kpa
5:44:50	270	0	F	0	52	43.163	Emergency application of Train Brake
5:44:53	0	160	F	0	53	43.119	Brake Pipe pressure at 0 kpa
5:44:56	0	270	F	0	53	43.075	Rate of acceleration decreases temporarily
5:44:59	0	310	F	0	54	43.031	Locomotive Brake at 310 kpa
5:46:47	10	310	F	0	63	41.255	Rate of acceleration increases temporarily
5:47:05	10	310	F	0	64	40.938	Black Mountain
5:47:47	10	310	F	0	68	40.165	Rate of acceleration increases temporarily
5:50:14	10	310	F	0	93	36.880	Position of Lead Loco 3160 when front portion of train separates – inferred from speed data
5:50:20	0	310	F	0	88	36.729	Driver selects Emergency Pantograph DOWN
5:52:17	0	310	F	0	0	34.950	Stopped Position of Lead Loco 3160

1.10 Post-accident site activities and observations

The accident site was located on the outside of a left curve at a position some 37.5 km from Hay Point.

The 29th wagon, the leading wagon of the derailment, had suffered moderate damage. It was later re-railed and taken down the Connors Range to the Jilalan Depot.

The main wreckage, including 73 wagons, the two remote locomotives and the ELRC, was confined within a distance of 276 m (The normal operating length of that part of the train prior to the accident was 1,211.7 m). Several wagons were 'stacked' vertically (see fig. 6) and many others were 'buried' under other wagons and coal (see fig. 7). They had all experienced significant impact forces during the accident sequence and were substantially damaged. However, the main portion of the ELRC was relatively undamaged and was located on top of several wagons (see fig. 8).

Figure 6:
View of derailment site showing several wagons 'stacked' vertically

The trailing 18 wagons of EG37 remained on the track after the derailment. Those wagons were later attached to a diesel locomotive and taken back up the Connors Range where they were stowed at Hatfield (see fig. 9).

Figure 7:
View of derailment site showing several wagons 'buried' under coal and other wagons

Figure 8:
View of derailment site showing ELRC119 'perched' on top of several wagons

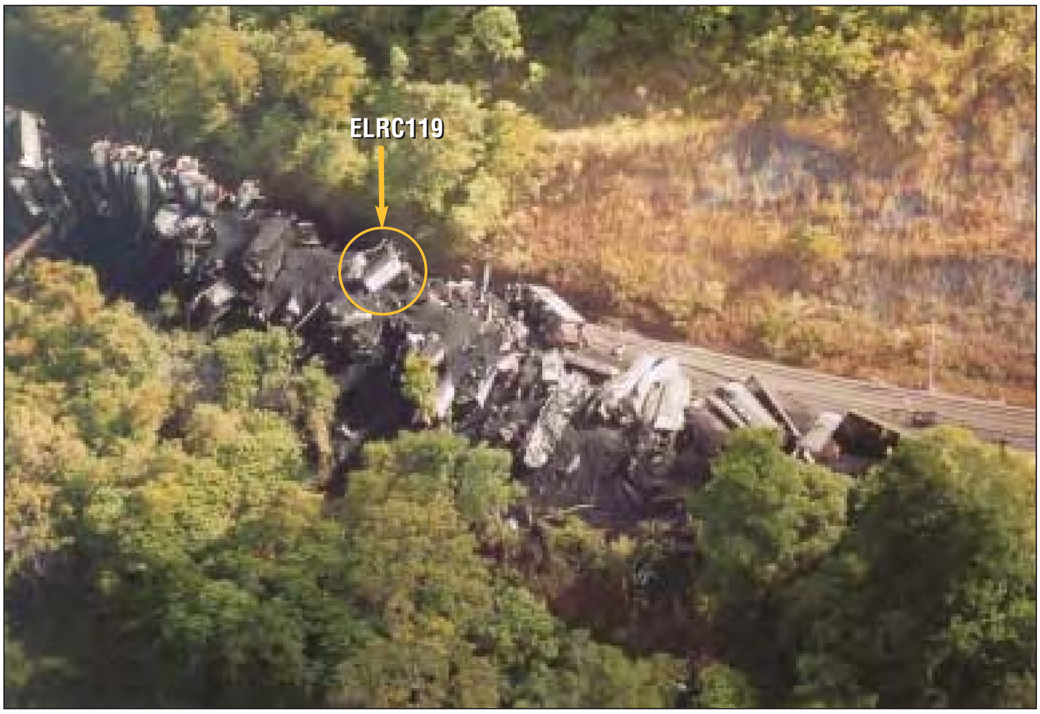

Figure 9:
View of derailment site showing trailing 18 wagons, which remained on the track

Of the rolling stock that could be readily inspected, brake systems were checked for any anomalies including the possibility that Brake Pipe Cocks[15] had been in the OFF position prior to the accident sequence. Although some Brake Pipe Cocks were observed to be in the OFF position, fresh marks and related damage indicated that those Brake Pipe Cocks had been closed as a result of the accident sequence.

Personnel at the site also reported that there was heat and the smell of train brakes emanating from some of the wheels in the area of the derailment but no detailed assessment was made.

Personnel who were dispatched to the area to assist the crew and inspect the front portion (first 28 wagons) of EG37, reported that there was significant heat and a strong acrid smell emanating from the locomotives and the wagons. The brake blocks[16] of the wagons were later found to be 'hard on' except for wagon seven, which had not applied during the accident sequence and were reported by the Second Driver to be cold. The Second Driver also reported that he had not observed any Brake Pipe Cocks in the OFF position while he was applying wagon hand brakes to the 28 wagons.

The cab of Lead Locomotive 3160 was inspected. The Dynamic Brake was set at Full and the Train Brake had been selected to the Emergency position. The Locotrol console indicated that the train had been operating in Multiple Unit Mode.

The front portion of EG37, pulled by diesel locomotives, later proceeded to Hay Point to unload its coal. The train then returned to Jilalan Depot where the electric locomotives and wagons were stored for further inspection.

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[15] Brake Pipe Cocks - the hand operated 'taps' or valves in the Train Brake Pipe at each end of every vehicle. They are provided in order to close off the ends of the Train Brake Pipe when required.

[16] Brake Blocks - the friction material, which is pressed against the surface of the wheel tread by the movement of the brake cylinder piston. Often made of cast iron or some composite material, brake blocks are the main source of wear in the train brake system.

The recovery operation continued around the clock to remove damaged rollingstock from the track and to restore damaged rail, the overhead power supply, and related infrastructure (see fig. 10). The track was re-opened for operation at 1910 hours on Thursday 5 July, with train services operating in accordance with a modified procedure (Refer to *Safety Action Taken* in this report).

Figure 10:
Recovery operation in progress

Several days after the accident, ELRC119 was removed to the Jilalan Depot maintenance facilities for further inspection as it was considered important in establishing the likely cause of the accident. The investigation team had requested that ELRC119 be recovered from the derailment site without further damage. However, it was considered too dangerous for personnel to complete the task during the recovery operation. Consequently, ELRC119 was recovered after the wreckage was pushed out of the way and the track was reopened. During both the accident sequence and the recovery, ELRC119 suffered extensive damage. The underframe was broken in two pieces and the roof and sides were severely crushed. The unit needed to be cut open and all external connections substituted. Inspection and testing of ELRC119 commenced on 11 July.

1.11 Medical issues and toxicology

Local police did not attend the scene of the accident. As a general policy, QR advises the police only on those occasions where there are injuries or public safety is at risk. On such occasions, the police are informed at an early stage. As the derailment of EG37 did not result in injuries or a risk to public safety, it was not considered necessary to inform the police.

The Driver and Second Driver were interviewed by QR personnel before being taken to the Sarina Medical Centre in order to arrange for blood tests. However, medical staff were not available at that time. The Drivers were then taken to the Sarina Police

Station approximately six hours after the accident in order to undergo a breath test. Sarina Police Station is located about 2 km from QR's Jilalan Depot and some 20 km from the accident site.

Both the Driver and Second Driver of EG37 voluntarily submitted to breath tests. Those tests were conducted in the presence of a QR employee who was a designated Authorised Person[17] for the purposes of the investigation of EG37's derailment. The results of those tests were negative.

Although requested to do so, both crewmembers indicated they were unwilling to submit to a blood test for the presence of drugs, citing that they did not like needles.

QR's policy in relation to alcohol and drugs is contained within its Safety Management System documentation and is described in Policy SAFEPOL14. The purpose of that policy is to *set the arrangements for the management of risks associated with alcohol and other drugs in the workplace.*

Subsection 7.1.2 of that policy describes company procedures in relation to alcohol and drug testing and states that testing can only be undertaken in accordance with:

1. The Queensland *Traffic Act 1949* by a police officer; and
2. The Queensland *Transport Infrastructure Act 1994* by a police officer or an Authorised Person under the provisions of the Act.

The *Traffic Act 1949* requires that train drivers must have a blood alcohol level of 0.00 per cent whilst on duty.

Section 104 of the *Transport Infrastructure Act 1994* refers to the powers of Authorised Persons to investigate railway occurrences.

Subsection 104(5) states:

> The authorised person may require an employee of a railway manager or operator to take an alcohol test, drug test or medical examination if the person reasonably suspects that:
>
> (a) the employee caused, or was directly involved in, the incident; and
>
> (b) the result of the test or examination may help in deciding the circumstances and probable causes of the incident.

Subsection 104(6) states:

> The test mentioned in (5) must take place within 2 hours after the incident happens.

Subsection 116 (2) of the *Transport Operations (Passenger Transport) Act 1994* allows for the Chief Executive Officer (Queensland Transport's Director General) to appoint certain other persons of a railway to act as Authorised Persons for that railway. The Queensland Transport Director General has, under that provision, delegated that power to QR's Chief Executive Officer to authorise persons in relation to QR

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[17] Authorised Person –Section 116(2) of the *Transport Operations (Passenger Transport) Act 1994* states that the chief executive may appoint any of the following to be an Authorised Person for the railway:

a) an employee of the railway manager or operator;

b) a person prescribed under a regulation;

c) if the chief executive intends to require the Authorised Person to investigate a matter under the *Transport Infrastructure Act 1994*, section 103(2) about the railway

  i. an employee of the railway manager or operator; or

  ii. any other person.

operations only, provided they meet certain criteria. QR maintains a list of Authorised Persons.

No QR employee, as a designated Authorised Person, has the power or qualification to conduct breath or blood tests, however, they have the power to require those tests to be taken. The Authorised Person who had escorted the Drivers to the Sarina Police Station later indicated that he was not entirely clear about his legal powers to require personnel to undertake breath or blood tests. That Authorised Person had completed both a QR Rail Accident Investigation Course and a Drug and Alcohol Policy Course, however, he considered that the relationship between those courses had not been well articulated by QR.

1.12 Locotrol System Design

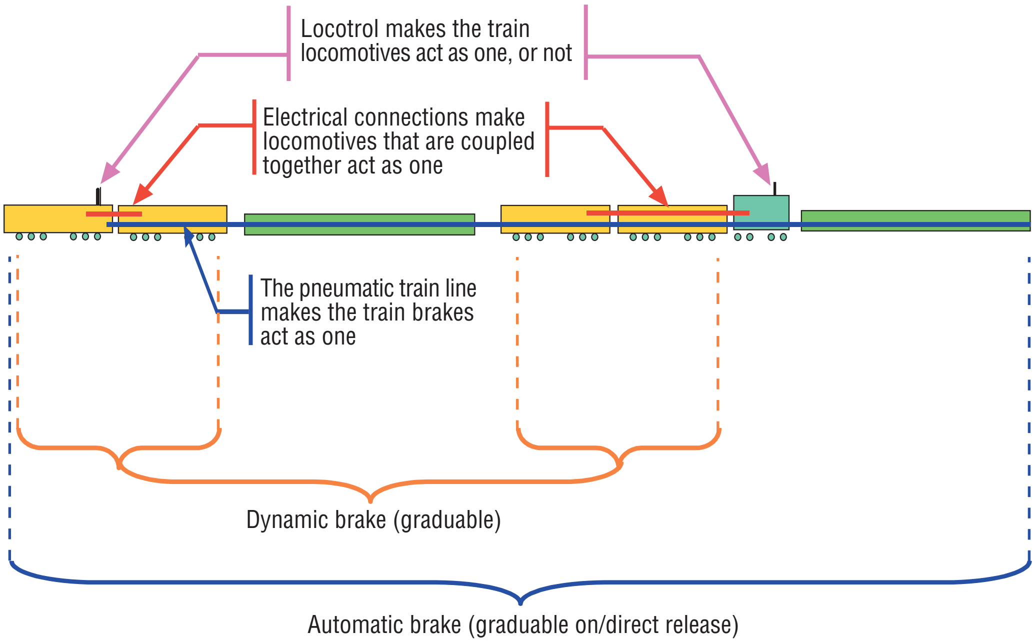
EG37 was a Locotrol II-equipped train, which allowed the Driver to control the consist of locomotives in the centre of the train by UHF radio.

QR has been using the Locotrol system since 1972. The system was designed by Harris Corp of USA and is sold and operated worldwide. Locotrol II was commissioned for use by QR in 1985.

EG37 consisted of three lead locomotives controlled in the normal way by a Multiple Unit cable and Train Brake Pipe hoses. In addition, there were two remote locomotives halfway through the train controlled by the Locotrol II radio system via ELRC119.

An ELRC is virtually a controlling unit but without motive power. The ELRC has all the necessary electrical and Train Brake outputs to control the adjacent remote locomotives by Multiple Unit cable and Train Brake Pipe (see fig. 11). The ELRC also provides a second Train Brake Valve in the Train Brake Pipe, which enables faster, and more precise, Train Brake applications and releases.

Figure 11:
Schematic of Locotrol system during normal operation



The Locotrol system operates such that the lead and remote locomotives can operate either in Multiple Unit or Independent Mode. When Multiple Unit Mode is used, train operation control signals applied by the Driver in the lead locomotive consist, are mirrored in the remote locomotives. When conditions require the operation of the lead consist and the remote consist at different throttle levels and/or Dynamic Braking levels, the Independent Mode is used. A mode selector switch and independent controls on the Locotrol console in the lead locomotive, provide for that method of control.

The Locotrol system uses Data Radios for communication between the lead locomotive and the ELRC unit. For redundancy[18] purposes, two radios are provided in the lead locomotive and two radios are provided in the ELRC unit. Those radios can be automatically switched by the Locotrol system such that if a communications loss occurs, then the alternative radio can be tried in an attempt to re-establish a radio signal.

While the primary means of communication with the ELRC is by Data Radios from the lead locomotive, the normal continuous Train Brake Pipe also plays a vital safety role in those cases when the ELRC radio system fails or the train is in terrain that prevents radio signals reaching the ELRC.

If radio communication is lost for any reason, the ELRC goes into a state of Com Int and then starts a 2-minute timer. As a fail-safe[19] measure, if no further communications have been received after two minutes, the ELRC initiates a reduction in power to IDLE of the remote locomotives and closes the ELRC Remote Feed Valve (Feed Valve 'cut out').

When the Feed Valve 'cut out' command is given, Feed Valve 'cut out' is achieved by delivering Main Reservoir[20] air pressure into the '53A' pipe, which connects to the cut-off portion of the Brake Pipe Control Valve (see fig. 12). This action results in the Train Brake Pipe being sealed at the ELRC and prevents any further Train Brake releases or applications by the ELRC. The train then becomes a 'head-end-only'[21] train, but is still under the control of the Driver. All Train Brake applications and releases are then propagated only from the front of the train and not also from the ELRC.

Within this 2-minute period, with the Feed Valve 'cut in', the ELRC also monitors its flow transducer. If any significant airflow is detected, the ELRC initiates a reduction in power to IDLE of the remote locomotives and closes the ELRC Brake Pipe Control Valve in the same way as that described in the previous paragraph. The airflow detected is most likely to be caused by the ELRC pumping air into the Train Brake Pipe, therefore opposing a Train Brake application made by the Driver at the front of the train. Such a response is also to provide a fail-safe mechanism in order that the Driver achieves the braking effort that he has commanded and not something less than is necessary under the circumstances.

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[18] Redundancy – provision of two or more means of accomplishing a task where one alone would suffice in the absence of failure.

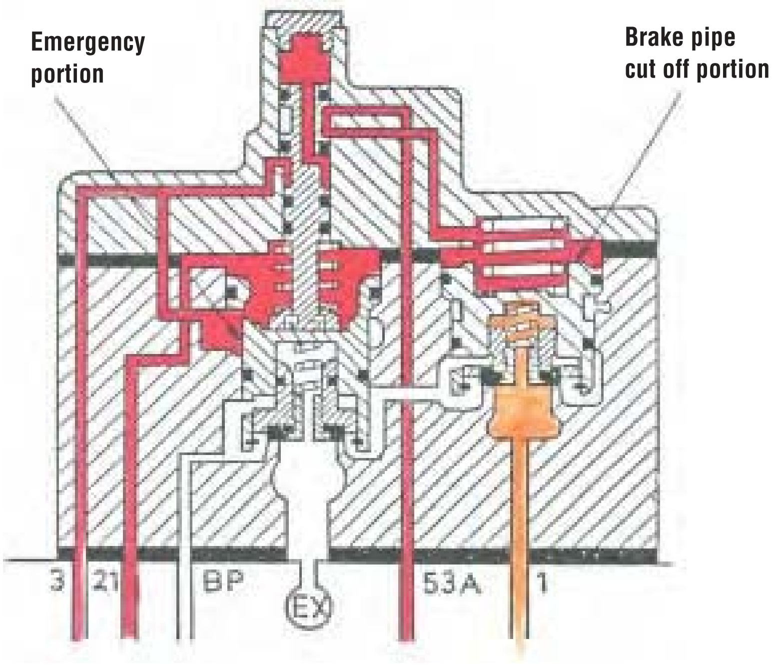
[19] Fail-safe – the capability of a component, an item of equipment, or a system to ensure that any failure in a predictable or specified mode will result only in that component, item or system reaching and remaining in a safe condition ie there will not be an unacceptable compromise in operational safety.

[20] Main Reservoir – a storage tank for cooling and storing compressed air for subsequent use in braking and other pneumatic systems on board locomotives.

[21] Head-end-only – a situation where a train is controlled only by the locomotive/s at the front of the train and not by additional locomotives in the centre or rear of the train. All applications and releases of Train Brake Pipe are propagated from the front of the train. Therefore, the time for brake applications to propagate through the entire length of the Train Brake Pipe to the rear of a train takes longer compared to when an additional Train Brake Pipe control valve is situated in the centre and/or rear of the train to assist with this process.

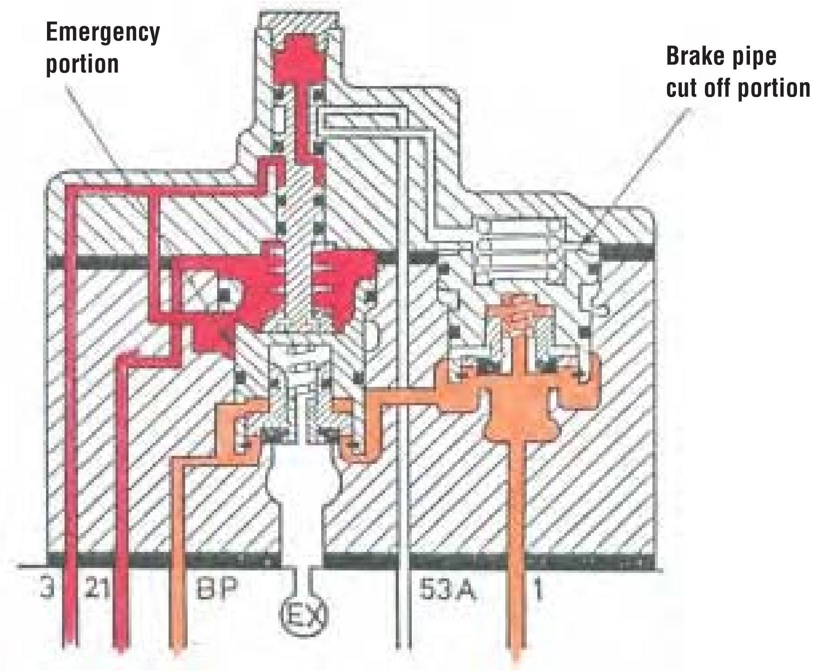
When Locotrol radio communications are operating normally via Data Radios as previously described, and with the Feed Valve ‘cut in’, the Brake Pipe Control Valve is open and allows air to flow freely between the Brake Pipe and the Relay Valve in the ELRC (see fig. 13). The Relay Valve is controlled by the Driver’s actions in the lead locomotive. Train Brake applications and releases made by the Driver in the lead Locomotive, are mirrored in the ELRC. If the Driver commands Feed Valve out (for example, as part of a normal test procedure) or the Remote Feed Valve in the ELRC cuts itself out for some reason, the Driver would receive a Feed Valve OUT indication on his Locotrol console. During a state of Com Int, however, a Driver does not receive real-time information about the status of the Remote Feed Valve.

Figure 12:
Schematic of Brake Pipe Control Valve during Remote Feed Valve ‘cut out’



Feed valve cut-out or break in two

Figure 13:
Schematic of Brake Pipe Control Valve with Remote Feed Valve ‘cut in’



Brake pipe control valve charging position

1.13 Post-accident tests and research

It was apparent that the braking performance of EG37 was insufficient to bring the train under control during the sequence of events that led to its derailment. A significant portion of the investigation was focussed on determining the reasons for that apparent degraded performance. Extensive testing was also completed to establish the reasons for the extended loss of Locotrol radio signal.

Highly experienced technical staff with qualifications in areas including, but not limited to, rollingstock engineering, signals and communications, infrastructure, and rail operations and training, conducted or supervised the majority of the tests that are referred to in this section of the report. Whilst this section of the report is a presentation of factual information, it also contains references to the analysis and conclusions of those experts from both technical and verbal reports that were provided to the investigation team.

1.13.1 Simulations

Training simulator Rockhampton

Simulations were carried out in the simulator at QR’s Rockhampton training facility. At the time those simulations were conducted, a mechanism to explain why the Train Brake system of EG37 was not able to control the speed of the train during the accident sequence, had not been determined.

A number of scenarios were considered and modelled. The scenario that appeared to most closely model the speed profile of EG37 during the accident sequence was when the simulator was programmed to mimic EG37 with the Train Brake Pipe closed at the 40th wagon.

However, it was known at the time that the brake fade values that were programmed into the simulator, were not necessarily accurate and probably overemphasised the brake fade that would, in reality, be experienced.

Engineering

The Fortran simulator at Rollingstock Engineering Division in Brisbane was used to attempt to reproduce the speed profile of EG37 with a reduced braking force and with an increasing level of Brake Fade. The results were overlaid on the speed profile of EG37 taken from the Datalogger, and it was evident that there was a good correlation of the curves. Therefore, it was considered that EG37 descended the Connors Range with somewhere in excess of 34 of the 120 wagons with brakes applied. In addition, a large number of those wagons toward the rear of the section of the train with brakes applied would only have been lightly applied.

NUCARS[22]

Rollingstock Engineering Division was requested to provide calculations and dynamic simulations to explore the mechanism of derailment. Information derived from the Datalogger obtained from Lead Locomotive 3160 suggested that the coal wagons derailed at a speed of 93 km/h. The first wagon to derail was most certainly a VSA class[23] wagon as it was the only class of wagon in the section of the train that experienced the derailment. Hand calculations predicted an overturning speed of approximately 110 km/h for a loaded VSA wagon. NUCARS simulations were requested to determine whether the geometry of the entry to the curve at 37.65 km would be expected to cause overturning or some other derailment mechanism.

There are normally two mechanisms of derailment in this type of accident – flange climb and overturning. Flange climb occurs when an outside wheel-flange literally climbs or jumps the rail. Overturning occurs when the inside wheels unload to such an extent that that the body pivots about the outside wheels and falls to the outside of the rail. The usual cause of overturning is the centrifugal force that results from the combined effects of the speed, curvature of the track and any track irregularities.

Initial simulations were conducted by incorporating the nominal 40 m transition[24] into a 300 m curve with 45 mm superelevation[25]. Those simulations showed that at a speed of 93 km/h, the load on the wheels on the low rail[26] reduced to 12 per cent of their static load[27] at the end of the transition. The load then stabilised at a value of 39 per cent in the body of the curve. Those results indicated that overturning should not have occurred in that instance.

Data derived from a Track Recording Car that was used for a track inspection in the Black Mountain area on 3 May 2001, revealed that the average curve radius for the derailment curve was approximately 290 m with an average superelevation of 27 mm.

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[22] NUCARS – (New and Untried Car Analytic Regime Simulation) is a general purpose program for modelling rail vehicle transient and steady state responses. It belongs to a class of programs commonly termed multi-body simulations. The program is widely accepted in the rail industry and allows accurate simulations of dynamic systems in either new or existing designs.

[23] VSA class – a class of coal wagon that is registered at 106 tonnes gross.

[24] Transition – the design alignment of track comprises straights (or tangents) and curves. To reduce lateral forces and resulting oscillation when a train enters a curve from a straight, transition curves are provided. Transition curves are ‘shallower’ (greater radius) than the main curve. The design of the transition is dependent on the radius of the main curve and the designed track speed at that location.

[25] Superelevation – the design difference in the level of the two rails in curved track (the level of the outer rail is higher than the inner rail). The higher the maximum designed track speed, the greater the difference in the level between the inner and outer rails on a given curve in order to reduce lateral forces which could result in overturning of rollingstock.

[26] Low rail – rail on the inside of the curve.

[27] Static load – the force that a wheel imparts to the rail when the vehicle is stationary.

Simulations using that information resulted in the load on the wheels on the low rail reducing to 8 per cent at the end of the transition, with 27 per cent in the body of the curve.

The digital data from the Track Recording Car was then transformed into the required format and the simulation was repeated with the actual measured alignment data of the track. Those simulations showed total unloading of the wheels on the low rail for approximately 10 m, then oscillating about an average of 27 per cent load in the body of the curve (see fig. 14).

Simulations with the actual transition length of 26 m and extended cant ramp length of 79 m but no perturbations[28] superimposed, showed that those long wavelength discrepancies from the nominal 40 m length, had an adverse effect at 93 km/h. Those results indicated that overturning of the wagon was highly likely under the actual conditions of the track at that speed.

The lateral to vertical force ratio (L/V)[29] for the leading wheels on the high rail[30] reached a maximum (sustained for 2 m) of only 0.42, indicating that it was unlikely that the derailment was a result of flange climb (see fig. 15).

The maximum lateral track shifting force[31] sustained for 2 m travelled, was just over the limiting force of 81kN for 26 tonne axle load according to QR's technical standard STD/0026/TEC. Given the safety factor in the limit and considering that the derailment occurred early in the morning when the rail was most likely in tension and concrete sleepers were used, it was considered unlikely that track shift would have occurred at that time. Therefore, movement of the track under the influence of the train at the speed of 93 km/h, can be discounted as a mechanism of derailment.

It was concluded from the simulations that the cause of derailment was dynamic overturning of one or more wagons at a speed of 93 km/h. That dynamic overturning occurred about the high rail at the end of the entrance transition of the curve approximately 37.59 km from Hay Point. The resultant forces were affected in part, by minor variations to the correct cant and curvature of the track at that location.

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[28] Perturbations – the introduction of deliberate deviations to otherwise perfect simulation track data in order to replicate the real world conditions of variations under and over the mean track profile.

[29] L/V – the ratio of horizontal wheel flange force and the vertical wheel load. When the L/V ratio is too great, derailment usually occurs because of wheel flange climb on the high rail.

[30] High rail – rail on the outside of a curve.

[31] Track shifting force – the force required to physically shift the normal alignment of the track.

Figure 14:
NUCARS simulation showing total unloading of wheels on the low rail for approximately 10 m in area of derailment

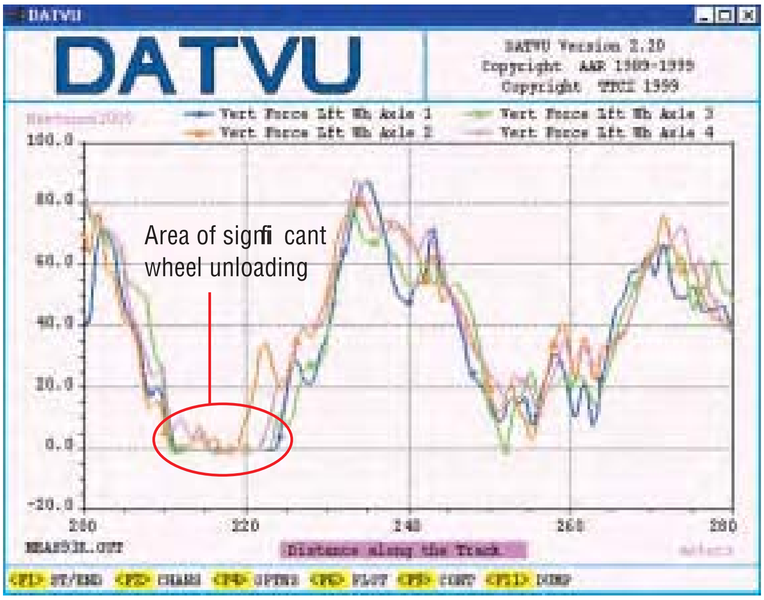
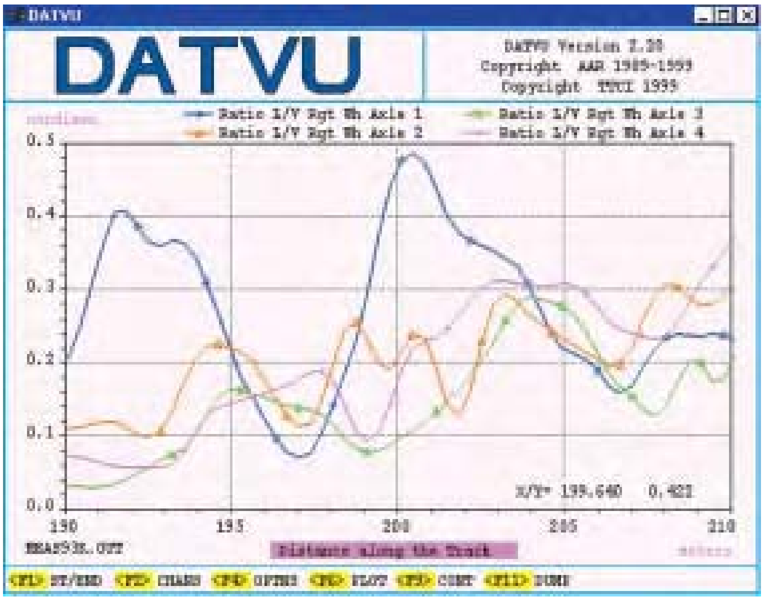


Figure 15:
Results of L/V ratios in area of derailment



1.13.2 Locotrol system tests

Radios

Tests were carried out on the two Locotrol radios recovered from ELRC119 in accordance with guidelines set by the Network Services Officer for QR (Radio). No defects were noted that may have contributed to the loss of radio signal on the Locotrol system and the radios were capable of normal operations.

Following recovery of ELRC119 from the accident site to the rollingstock maintenance facilities at Jilalan Depot, the ELRC unit was cut open using a cutting torch under the supervision of the investigation team and the normal air and electrical connections severed in the accident were restored. A full program of testing was then able to commence. Additional testing was undertaken on the radio system. Radio continuity[32] was immediately established when the rebuilt ELRC119 was coupled to Lead Locomotive 3160. That radio continuity was maintained throughout subsequent testing. The Locotrol logic controlling the radio communication and changeover was thoroughly tested with no problems identified.

The testing systematically examined all known failure modes and subjected the equipment to considerable vibration and temperature extremes. The testing also simulated difficult terrain conditions by disconnecting the antenna at the ELRC and producing high power reflections to the radios.

The radio power supplies were subject to particular attention including bench testing which simulated extremes of load, heat, cooling and sudden load changes. Although the power supplies did not entirely perform within specification, they were capable of normal operations.

There was no evidence of any faults or anomalies that may have contributed to the extended loss of Locotrol radio communications between Lead Locomotive 3160 and ELRC119 during the accident sequence.

Testing of the functionality of the lead locomotive train lines[33] was also undertaken and revealed no problems. However, the ELRC train lines were completely destroyed as a result of the accident sequence and its subsequent recovery, and were not able to be tested.

Another possible cause of the Locotrol communication interruption, which was considered, was a loss of power in the ELRC unit. The power supplies were thoroughly tested as previously discussed. The circuit breakers had been found in the ON position when the ELRC was recovered. The wiring was severely damaged, and the Multiple-Unit cable connection to the next locomotive was destroyed. As such, any theory of loss of power by a drop out of the Multiple-Unit cable, could not be pursued.

The radios and the power supply on Lead Locomotive 3160 were also checked with no defects found.

Lead Locomotive 3160 has since been released for normal operations. To date, no similar problems of extended loss of Locotrol radio communications has been reported.

The tests done by the Radio Technician included a check on the antennae and cable. Although one aerial on the ELRC had been destroyed, all other aerials revealed no faults or anomalies that may have contributed to the extended loss of Locotrol radio communications.

Brake system

When the Train Brake system of the ELRC was brought into working order, and testing commenced, it was noticed that the Brake Pipe Control Valve was not functioning correctly.

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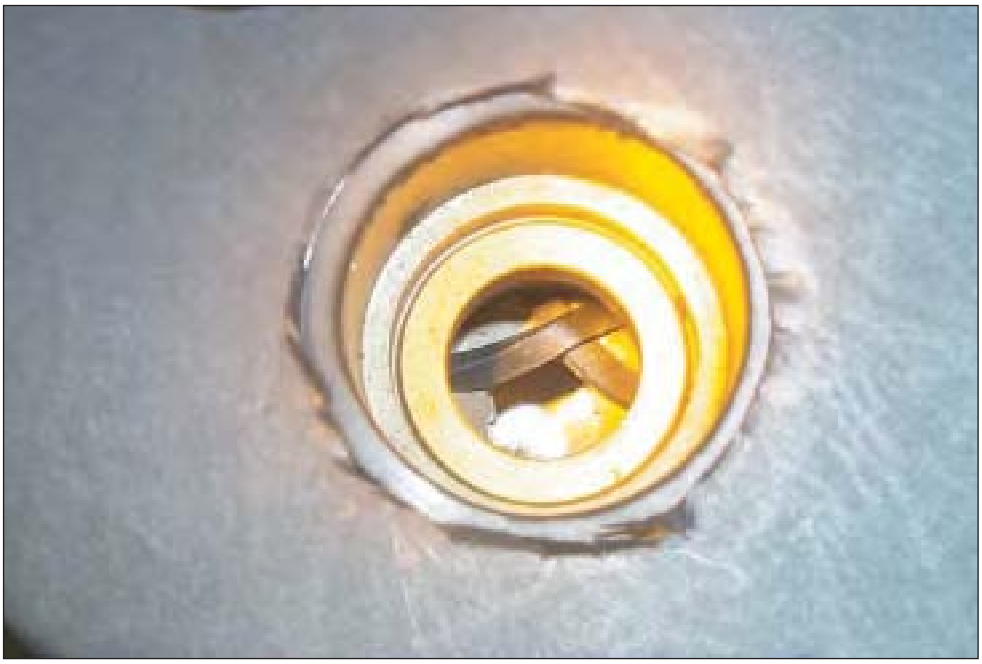
[32] Radio continuity – the establishment and maintenance of a reliable radio signal.

[33] Train lines – the electrical wires that run between locomotives. The signals transmitted on those lines control the locomotive.

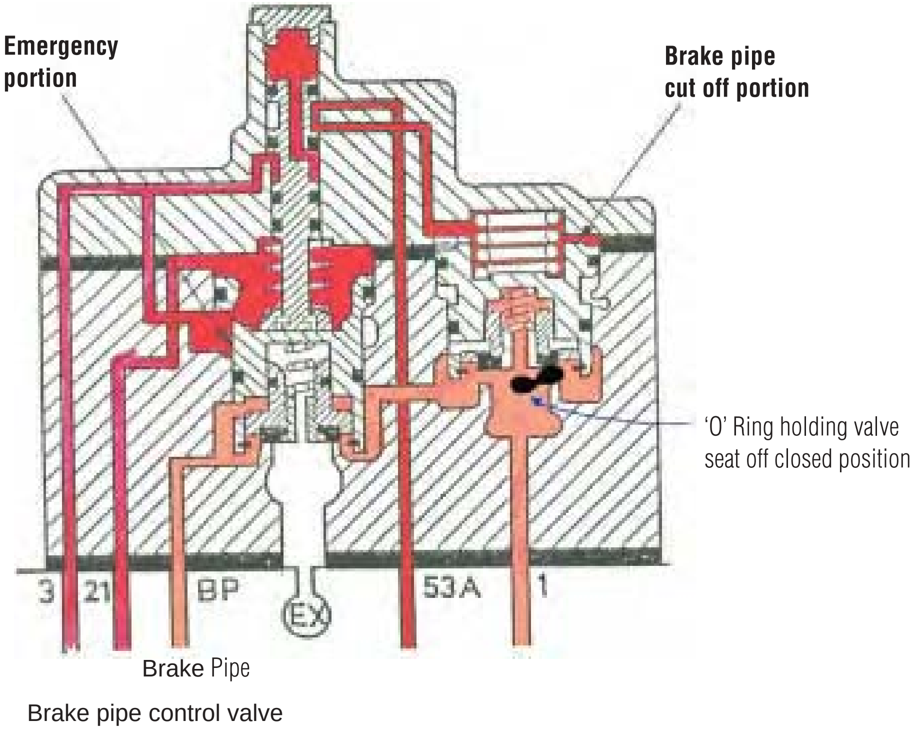
Upon disassembly of the Brake Pipe Control Valve, an errant square-section O-ring was observed to be lodged in a figure-8 shape across the seat of the Brake Pipe cut off portion of the valve and was holding the Brake Pipe Cut-Off Valve open (see fig. 16). This would have been the case even if the Main Reservoir air through '53A' were trying to close the valve (see fig. 17).

Figure 16:
Errant O-ring found lodged in seat of cut off portion of the Brake Pipe Control Valve on ELRC119



Note: Black cardboard has been placed on the face of the valve to prevent glare during photography.

Figure 17:
Schematic diagram showing how errant o-ring prevented normal cut off function of Remote Feed Valve



ELRC119's brake equipment rack was examined further to determine whether the errant O-ring had been dislodged from another part of the brake system or if it was clearly a supernumerary component.

The remaining valves in the Automatic Brake[34] portion of the rack were removed and functionally tested on the test rack in the Brake Room of the Jilalan Depot rollingstock maintenance facilities. All O-rings were in-situ and accounted for. All valves were found to be functioning normally and within acceptable limits. The valves were then stripped and inspected with no defects found.

A further test was conducted to explore a theory for how the errant O-ring may have been introduced into the Brake Pipe cut off portion of the Brake Pipe Control Valve. A Brake Pipe Control Valve was fitted onto the ELRC brake equipment rack with two O-rings 'stacked' on top of each other in the inlet seal position of the Brake Pipe cut off portion of the valve. A situation like this may occur if there were an O-ring both on the Brake Pipe Control Valve and another which had remained on the 'flat face' of the brake rack following a changeover of Brake Pipe Control Valves during, say, a 144-week ELRC inspection.

That test was performed eight times. In all eight tests an O-ring was found to migrate into the port of the Brake Pipe Cut-Off Valve. On six of those occasions, the defect was detected as the remaining O-ring did not seat properly and there was an air leak from around the valve when a functional test was performed.

On the other two occasions, the remaining O-ring seated correctly in the face of the valve and the ELRC passed the functional test.

In normal train operations, recharging the Brake Pipe via that valve causes a large volume of air to pass through that port. It was considered that this would be sufficient to cause the O-ring to pass into the seat area of the cut off portion of the valve.

In a test of Brake Pipe recharges, an O-ring lodged under the valve seat and formed a figure 8, consistent with what was observed in the Brake Pipe Control Valve found in EG37.

Other tests that were conducted also showed a tendency for the O-ring in the port to lodge under the valve seat as long as it was oriented in a particular way. It would appear that it would depend on how the O-ring was forced into the Brake Pipe Cut-Off Valve port as to how long (due to the effect of Brake Pipe recharges) it would take before the O-ring manoeuvred into a position sufficient to lodge under the cut-off valve seat.

While those tests did not conclusively prove that this was the mechanism of how the O-ring was introduced into the valve, they did provide a possible scenario to explain how functional tests may not have detected the fault prior to the accident.

1.13.2 Brake tests

QR's Brake Engineer, Technical Services, calculated that EG37 required a minimum of 60 wagon brakes to be fully applied in order for it to have been able to 'Balance the Grade'. A train has 'Balanced the Grade' when it has sufficient braking effort applied to maintain a constant speed while descending a particular gradient, without accelerating or decelerating.

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[34] Automatic Brake - generic term for a Train Brake which provides for control of the brake on every vehicle in the train and automatically goes to emergency stop in the case of a loss of control. In other words, it is fail safe. The train will automatically stop if the train becomes uncoupled, if the Train Brake Pipe is ruptured or if a Train Brake valve is opened by passengers.

Inspection of brake blocks and wheels

Inspection at the accident site of two of the remote locomotive bogies did not reveal any sign of heat stressing of the wheels.

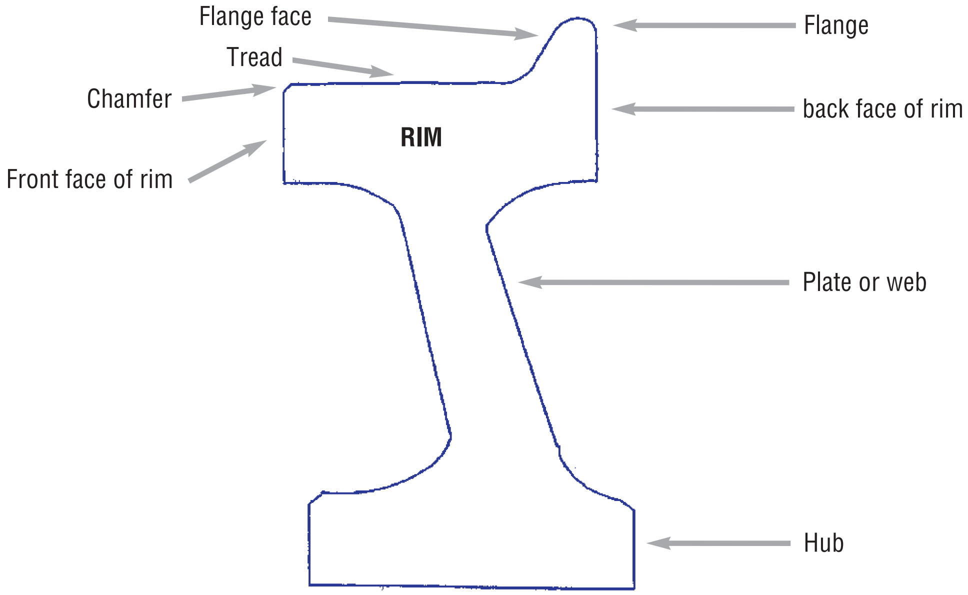
Inspection of the wheels and brake system on the three lead locomotives from the front portion of EG37 showed signs of significant heat stress. This was particularly evident in areas of the brake blocks and wheels that were not affected by their movement over rails subsequent to the derailment. As stated in an earlier section of this report, the front section of EG37 later proceeded to Hay Point, then returned to the Jilalan Depot before the Brake Engineer was able to inspect the rollingstock.

Inspection in the Jilalan Depot of wagons from the front portion of EG37, and in the Hatfield yard of the rear wagons which had not derailed, did not reveal any evidence of the number of wagon brakes that were working or not working on the train during the accident sequence. Most of those wheels showed signs of severe heating.

Wagon wheels on both VHS-type and VSA-type wagons in the general wagon fleet (not part of EG37) were also inspected at Jilalan Depot for the purpose of comparison with the wagons of EG37. Most of those wagon wheels showed signs of previous severe heating. Only a very small number of recently fitted wheels on those wagons did not also exhibit signs of previous severe wheel heating. Most wheels on wagons in the Depot showed signs of both wheel rim front-face and complete and near-complete wheel-web heating (see fig. 18 for schematic diagram of the parts of a typical wheel).

Wheel tread heating on wagons hauled from the derailment site was not evident. Any signs of heating on the wheel treads of the wagons on the front portion of EG37 were most likely removed by the action of the wheel tread against the rail as the loaded wagons were moved. The rear wagons at Hatfield, however, had only travelled a few kilometres, therefore, residual signs of heat stress on the wheel treads were more likely to be seen on those wagons though none was found. Some of those wagons, as for the general inspection of wagons that were not part of EG37, showed signs of severe wheel rim front-face and wheel-web heating.

Figure 18:
Schematic cross-sectional diagram showing the parts of a typical wheel



A selection of brake blocks from the lead locomotives and one from a remote locomotive, was dispatched to the University of Queensland in order for metallurgical examination to be carried out to determine the relative braking effort that the respective locomotives had undergone during the accident sequence. In spite of obvious external signs of significant heat on both the brake blocks and on the wheels of the lead locomotives, only one section of one brake block from a lead locomotive could definitely be identified as having been exposed to higher than normal temperatures. It appears that the type of analysis used in that examination is not a reliable indicator of brake temperature.

The brake blocks of those wagons that were inspected, were not considered to be outside wear tolerances. No other faults were found that could have contributed to the circumstances of the accident.

Static train tests

Preliminary brake tests were carried out on 3rd and 4th of July 2001 at the Jilalan Depot to determine the probable braking force of the train during the accident sequence. The command locomotive[35], (Lead Locomotive 3160), and the two other lead locomotives from EG37 were used in those tests. The remote locomotives and the ELRC wagons also used in those tests were not from EG37 as they had been damaged and were not available, however, ELRC119 was later recovered from the accident site for further examination and functional testing as referred to in various sections of this report.

The trains tested were the same size and make up as the derailed train. The same wagon sets were used for both days. Two different ELRC units were randomly chosen and deliberately changed for each day's testing. The brakes on wagons where brake force was measured were set to loaded braking. Note that testing of stationary trains is a valid method of checking the propagation of brake signals, and of determining how many wagons had brakes on and with what force.

The purpose of the tests was primarily to determine how many brakes ultimately applied when the Train Brake was applied by the Driver during the accident sequence as recorded by the Datalogger on Lead Locomotive 3160. Tests included the simulation of a Com Int situation.

Some individual tests were stopped after a Full Service application and the Train Brakes were inspected. That method was used to assist in determining the level of direct braking force and subsequent brake block fade at the point during the derailment when the Full Service brake application stabilised. Other tests were continued through to the Emergency application and thus found another point of reference during the Connors Range descent and prior to the derailment.

The results of those tests indicated that when the train was in a state of Com Int but there was no Remote Feed Valve flow fault at the ELRC, it took between 96 and 118 seconds to apply Train Brake on the entire train after an Emergency application.

The evidence and calculations at that point in the investigation did not strongly suggest that a defective Brake Pipe Control Valve in the ELRC was a factor in the accident. Consequently the tests on 3rd and 4th of July did not attempt to simulate such a problem but did deliberately change ELRC units between day one (3rd July) and day two (4th July) to see if there was any discernible operational differences between the two ELRC's Train Brake system performance.

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[35] Command Locomotive – the first locomotive in a lead group (consist) of locomotives that provides all the power and brake inputs which the other locomotives in that group mirror.

Brake fade

Brake fade is the loss of friction between the brake block and the wheel surface usually caused by high-energy dissipation demands on the brake block and wheel interface during braking. Elevated wheel surface temperatures, heavy brake applications, and high speed are the most significant contributing factors determining brake block fade. A train's kinetic energy (= ½ m v^2) is converted primarily to heat during braking by the brake blocks. The energy dissipation requirement of the brake block to wheel interface is proportional to the square of the train speed so that for a small increase in train speed there is large increase in kinetic energy to be dissipated. Brake fade is represented as a percentage (per cent Fade) and is the degree of reduction of braking effort. It should be noted that brake fade is not a constant and varies with time, speed and brake application force.

To assist in the estimation of the braking energy available to the Driver before and after the derailment, it was necessary to perform brake block fade tests. Those tests were conducted on a section of track between Hatfield and Bolingbroke.

During the fade testing, the Driver's braking actions and corresponding train speeds, derived from the Datalogger of Lead Locomotive 3160, were copied. That simulation resulted in a minimal loss of braking effort up to 60 km/h as the brake block to wheel interface was still heating (increasing in temperature) up to that speed. It was only at higher speeds that the brake block to wheel temperature nominally stabilised.

The results of those tests indicated that the wagons on EG37 would have expected to experience increasing brake fade as the speed increased during the accident sequence. The following brake fade values were determined:

No Brake Fade	up to 66 kph
21% Brake Fade	at 69 kph
33% Brake Fade	at 78 kph
47% Brake Fade	at 88 kph

The data from the fade and static train tests was used to calculate the number of wagons that would have had brakes operable on the derailed train. It was determined that nominally 46 to 55 wagons of EG37 would have had brakes fully applied during the emergency brake application.

Calculations were then made based on the actual performance of EG37 between 57 and 66 km/h. For those calculations, an assumption was made that no brake fade had occurred at those speeds and that the three locomotive automatic air brakes were fully applied in an emergency application (ie. no Dynamic Brake applied). It was then estimated that approximately 47 wagons would have been operating with brakes fully applied during the accident sequence under the conditions in which EG37 was operating at that time.

The fade tests conducted between Hatfield and Bolingbroke indicated that during the deceleration stage from a maximum speed of 88 km/h, 46 per cent brake fade was present at 70km/h. When the front part of the train separated, it would have had 28 wagons with brakes fully on (and which had been on for some time) and the Datalogger provides a good speed trace of this part of the event. Using that information for the front portion of EG37 at 70 km/hr, it was calculated that 43 per cent brake block fade should have been occurring during that part of the accident sequence.

The relative closeness of those results helped to substantiate and verify the relevance of the fade testing.

Note that fade tests on the locomotives were not performed but it was assumed that the brake blocks on the locomotives would suffer from brake fade to the same degree as had been experienced on the loaded wagons.

Brake Pipe Cock in OFF position

The possibility that a Brake Pipe Cock was in the OFF position was considered.

A closed Brake Pipe Cock in the *rear* portion of the train (behind ELRC), particularly one towards the front of the rear portion, would result in significant loss of braking performance under all conditions and should be noticed by a Driver even when Locotrol radio communications were available.

Where the closed cock was in the front portion of the train, the situation is quite different.

Provided Locotrol radio communications were operating normally, all Train Brake applications would appear to have pneumatic continuity[36] throughout the train. In such a case, the ELRC brake system would provide the Train Brake applications to the rear of the train.

The fault would only become apparent when a Driver applied Train Brakes during a period of communications interruption to the ELRC. A closed cock would be found by the Driver when making up a train[37] in accordance with the train make-up procedure. In fact, the Locotrol system will not ‘cut in’ the Remote Feed Valve until it detects a Brake Pipe rise as a result of a brake release from the lead locomotive.

However, a Driver would only be required to carry out those actions in cases such as making up a train as part of a Terminal Examination[38] or if defective wagons had to be removed from a train. A Driver would not normally require such actions while a train was en route.

As part of a Terminal Examination, trains at the Jilalan Depot are normally tested in two separate halves without Locotrol radio communications. A closed Brake Pipe Cock within the *lead* portion should be located as no Brake Pipe pressure or Train Brake applications would occur past the point of the closed Brake Pipe Cock. Therefore, the closed cock should be located at Terminal Examinations (every 15 days).

When a driver re-links the two halves of the train and ultimately achieves control of the radio-controlled braking at the ELRC, the system would indicate that there is pneumatic continuity through the lead portion of the train back to the ELRC. During that continuity test, a train examiner at the *rear* of the train observes whether the Brake Pipe is continuous through that portion of the train. If the Brake Pipe Cock at the rear of the lead portion of the train had been left in the OFF position following the earlier testing, the train examiner at the rear of the train would notice the problem as no Brake Pipe pressure or Train Brake applications would occur past the point of the closed Brake Pipe Cock.

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[36] Pneumatic continuity – complete and uninterrupted air pressure throughout the entire Train Brake Pipe. Train Brake applications and releases are therefore capable of being propagated through the entire length of the train.

[37] Making up a train – assembling the individual components of a train, for example, wagons and locomotives, by making all the appropriate mechanical, electrical and other connections.

[38] Terminal Examination – A periodical examination which checks the mechanical condition of all rollingstock on the train, confirms the presence and correct operation of equipment on the train, and confirms the correct operation of the braking system throughout the train. It also confirms that the make up of the train is consistent with the prescribed requirements for the safe and efficient operation of the train. The coal trains in the Goonyella Rail System undergo Terminal examinations at fortnightly intervals.

Therefore, unless a Terminal Examination was not conducted in the manner previously described, it is likely that if a Brake Pipe Cock closure had occurred, it would have happened after EG37's Terminal examination on 18 June 2001. Note that testing of electric locomotive-hauled trains fitted with Harris Locotrol II may undergo Terminal Examinations with Locotrol radio communications active and the brake applications sighted on each wagon by one or two train examiners who would inspect both halves of the train for brakes applied. However, that method of testing has always been strongly discouraged.

Staff at the Jilalan Depot advised that the Terminal Examination of train EG37 involved brake application, brake release, and leakage tests of the two separate halves of the train without Locotrol radio communications. EG37 was then assembled and checked for Brake Pipe continuity by a person with a Brake Pipe gauge at the rear of the train. That method of testing should have located closed Brake Pipe Cocks or one-way restrictions in both the front and rear portions of the train.

A train with a closed Brake Pipe Cock in the lead portion of a train would normally achieve unaffected Train Brake applications back to the closed Brake Pipe Cock. However, a flow from a defective Remote Feed Valve in the ELRC would result in variable train brake force for different sized Train Brake applications. The smaller the total Train Brake applications, the lesser the number of wagons brakes would be applied.

The information derived from Lead Locomotive 3160's Datalogger and the data collected from the static train tests, provided no evidence to suggest that there was a closed Brake Pipe Cock in the rear section of the front portion of EG37. Inspection at the derailment site of wheels on wagons 46 through to 55, did not display signs of severe heat stress, whilst wagons before that section of the train did display symptoms of recent severe heat stress. The Brake Engineer believed that a closed Brake Pipe Cock could not be categorically ruled out as a factor in the accident. However, he considered it was more likely that EG37's poor braking performance was due to other factors such as a defective Remote Feed Valve or a foreign object in the Train Brake Pipe causing a one-way restriction.

Wagon Main Reservoir cross flow

Cross flow of air at Main Reservoir pressure into the Train Brake Pipe, from one or more defective check valves in the wagon brake system, could have affected the braking performance of EG37 and was considered as part of the investigation.

Such flows would have attempted to reach full Main Reservoir pressure (750 – 950 kPa) and would have been observed by the Driver as a Train Brake Pipe pressure rise at the ELRC during Train Brake applications. There would also be noticeable evidence of continuous exhausting of air from the command locomotive Transmission Valve both during brake release and during prolonged applications. If those flows were of a sufficient level to affect the braking performance of the EG37 as it travelled down the Connors Range, it is likely that the Driver would have noticed that the brakes were less than effective when he made Train Brake applications prior to descending the range.

Nothing in the handover briefing to the Driver of EG37 suggested that there was any performance problems with the Train Brake of EG37. The Driver advised that EG37 responded normally when he made Train Brake applications prior to descending the Connors Range.

Such a defect would always manifest itself regardless of whether Locotrol radio communications were operating normally or if they were in a state of Com Int. The defect should be located during Terminal Examinations. It was therefore considered unlikely that the poor braking performance of EG37 was due to Main Reservoir cross flow into the Train Brake Pipe.

Defective Remote Feed Valve

Another possible defect that could have affected the level of braking performance on EG37, was an air flow to the Train Brake Pipe from a defective ELRC Remote Feed Valve.

The Remote Feed Valve is comprised of two pneumatic valves, a Relay Valve which controls the pressure at which the Train Brake Pipe is charged, and a Brake Pipe Control Valve which connects (or disconnects) the Brake Pipe to the Relay Valve. The combined Remote Feed Valve supplies the air to the Train Brake Pipe at the pressure demanded by the Driver during Train Brake applications and releases. Locotrol radio communications must be available for brake applications to occur at the ELRC.

During testing of the ELRC unit, an O-ring was found lodged in the seat of the cut off portion of the Brake Pipe Control Valve, and this was seen as the most probable cause of the poor braking performance evident on EG37. As this valve is open for much of the time that the train is in service, the only time the fault could be noticed is when the Driver selected Feed Valve OUT, and he then closely monitored the Remote Flow indicator during a Train Brake recharge. That function is normally only performed when making up a train and not carried out en route, and Drivers usually select either Brake Pipe or Equalising Reservoir indications and not Flow on the Locotrol control panel as a means of monitoring the brake system on the ELRC.

The only time such a defect could be detrimental to Train Brake performance, however, would be during a Train Brake application while the train was in a state of Com Int.

Trains could be assembled, disassembled, Remote Feed Valves could be ‘cut in’ and ‘cut out’ and, with Locotrol radio communications available, trains would brake normally. Trains could undergo Terminal Examinations in separate halves as previously described but such a defect may not be evident. Maintenance staff conducting routine functional tests on the ELRC as part of programmed maintenance are likely to be the only personnel expected to identify such a defect.

Tests with inoperative Brake Pipe Control Valve in ELRC

Following the finding of the O-ring in the ELRC119’s Brake Pipe Control Valve, tests were supervised by the Brake Engineer to determine the extent of the reduction in braking efficiency of EG37 at the time of the accident.

For the first test, a fully functional train including 120 bar-coupled[39] wagons, was tested using the Driver’s braking actions during a Com Int condition. The Remote Feed Valve on the ELRC promptly ‘cut out’ due to detection of Remote Feed Valve flow. The results of those tests indicated that the brakes on many of the wagons on the train would have started to apply during the initial application. All wagon brakes were at least 85 per cent fully applied before the Emergency application was initiated. In that instance, the Emergency application would have achieved very little improvement in application time or braking force as the Service brake applications were almost stabilised.

Had the brakes on EG37 reacted accordingly during the accident sequence, the train would have started to decelerate down the range from a maximum speed between

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[39] Bar-coupled wagons - wagons that are connected (usually in pairs) by means of a bar which can only be separated with difficulty in a workshop. The couplers on the other ends of the wagons are the usual automatic couplers.

48 and 52 km/h following Full Service brake application. As the speed reduced and the brake cylinders filled to 100 per cent, the deceleration rate would have increased. This clearly did not occur to EG37.

For the second test, the Brake Pipe Control Valve in the ELRC was forced to stay open. The test was conducted on the same 120 bar-coupled wagon train as before and revealed that Full Service application only resulted in brake applications on approximately the first 22 wagons, and with Emergency application, 30 wagons eventually applied.

The results of the static tests and the knowledge of brake fade determined from the fade tests, suggested that at the Datalogger time of 420 seconds, all (or near all) wagon brakes which were likely to apply under the circumstances, were applied at that time and with nominally no brake fade.

The Datalogger speed curve[40] indicated that the train maintained a slight deceleration rate until the Datalogger time of 300 seconds where it was considered that significant brake fade started to affect the available braking force of EG37.

The results of the tests in which the Brake Pipe Control Valve was placed in the fully open position were considered worse than for the effect of the Feed Valve flow which was probably experienced by EG37 due to the square section O-ring wedged in the Brake Pipe cut off portion of the Brake Pipe Control Valve. It was therefore suggested that for EG37, more than 30 wagons would have applied during the Driver's application of Train Brakes. It was also considered highly unlikely that any brake applications progressed past the ELRC Remote Feed Valve.

With and without bar-coupled wagons

Static tests, similar to those already described in a previous section of this report, were completed to determine whether the propagation rate of brakes through the train was affected as a result of having bar-couple wagons throughout the train. Bar-coupled wagons have a single triple-valve[41] per pair of wagons, rather than a series of separate wagons with triple valves on each wagon.

Those tests were conducted in the context of a Com Int situation and a simulated defective Remote Feed Valve.

The test involving the bar-coupled wagons revealed that the brakes of at least 22 wagons promptly applied but not more than 30 wagon brakes applied in total as the test progressed. In the case of the test involving individual wagons (each with triple valves), the brakes of at least 51 wagons promptly applied, but not more than 56 wagon brakes applied in total as the test progressed.

1.13.4 Com Int tests

Radio fade

The Network Services Officer for QR (Radio) conducted several tests to determine the extent and location of areas where Locotrol radio communications would be prone to failure (radio fade) on the Connors range.

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[40] Speed curve – the actual speed profile of the train throughout the sequence of events as indicated by the speed data captured and recorded on the Datalogger.

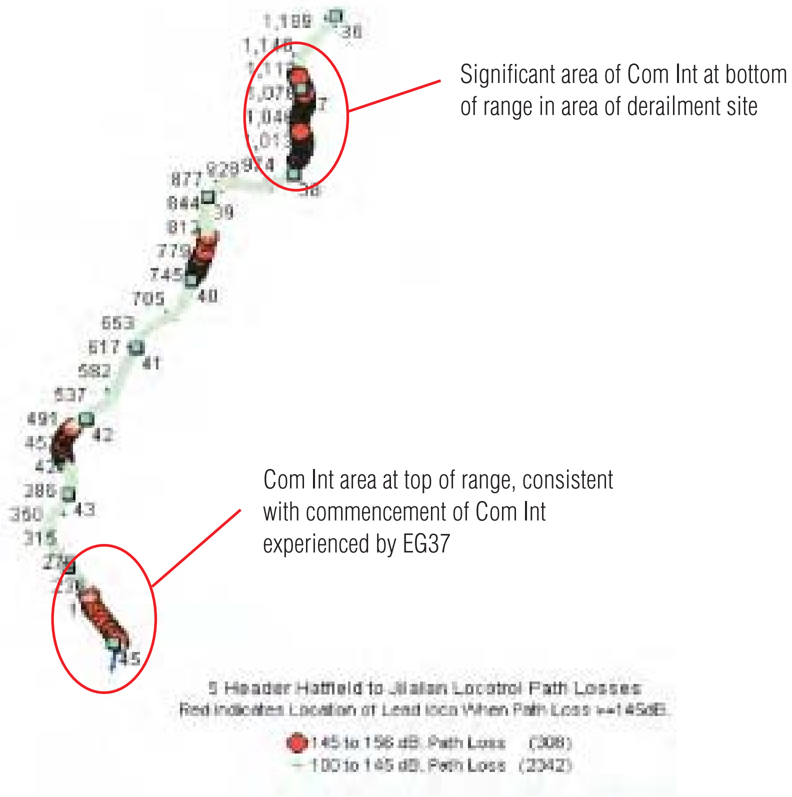
[41] Triple valve - a valve which is normally fitted on each vehicle of a train and which has three functions: to release the brake, to apply it and to hold it at the current level of application. It does this by use of valves which detect changes in air pressure and rearranges the connections inside the valve accordingly to:

- control the flow of air from the Train Brake Pipe to charge the Auxiliary Reservoir (local air storage);
- control the flow of air from the Auxiliary Reservoir to the brake cylinder to apply the Train Brake; and
- control the flow of air from the brake cylinder to atmosphere to release the Train Brake.

Those tests were carried out using the radio frequency 408.8 Mhz, a frequency sufficiently separate from the Locotrol frequencies in use so as not to cause interference to normal train operations. The radio frequencies normally used by Locotrol are 472.0 Mhz and 472.2 Mhz.

The results of those tests indicated that there were two significant areas of communications interruptions of varying duration and some other smaller areas (see fig. 19). The reason for the loss of radio signal was considered to be terrain shielding. Note that the tests were completed following the accident on trains travelling at modified speeds (maximum 35 km/h). It was therefore considered more likely that longer and more frequent communication interruptions would be evident during those tests.

Figure 19:
Locotrol 'Path Loss' Black Mountain 45 to 36 Km. 5-Header train travelling down the range



Significant area of Com Int at bottom of range in area of derailment site

Com Int area at top of range, consistent with commencement of Com Int experienced by EG37

One of the significant communications interruption areas identified during the tests was consistent with the area reported by the Driver of EG37 as being the location where the Com Int commenced. That location was also consistent with reports from other Drivers.

The tests also revealed that 5-header trains were more likely to experience longer Com Ints than 4-header trains, simply due to the greater distance between the aerial on the lead locomotive and that on the ELRC of 5-header trains.

Overhead wiring system

It was determined that EG37 lost the radio signal to ELRC119 shortly after passing the AutoTransformer at the top of the Connors Range. As such, checks were subsequently carried out to determine if there was evidence of radio signal interference such as corona discharge[42], radio 'noise'[43], or any other faults present that might have contributed to the extended loss of communications at the time of the accident. Tests using an ultrasonic detector were used to check for radio interference from AutoTransformers and the overhead power lines. Those tests were conducted on the 20th July along the Goonyella rail line from Hatfield to the Black Mountain area.

High frequency noise was detected on nearly all electrical masts along that section of track. The electrical engineers who conducted those tests considered that the noise was caused by the potential difference between side-tie wires, which grip the aluminium feeder wire to the feeder insulator, and the feeder wire. However, they advised that feeder insulators that are attached with clamps and not side-ties, do not generate such noise.

Side-ties are used extensively throughout both the Goonyella and Blackwater Rail Systems. The side-tie is a helical-shaped aluminium coated steel wire. The aluminium is used to prevent the steel from corroding, but over a period of time the aluminium oxidises. That oxide layer of a few microns is non-conductive and creates a potential difference between the aluminium feeder wire and the side-tie. High frequency noise is then generated which can interfere with communication equipment such as television and radio.

The electrical engineers advised that the high frequency noise generated by the side-ties has been known to be in existence for at least ten years, however, general consensus is that only VHF bands are affected.

While the tests completed in the Black Mountain area confirmed that low-level high frequency noise was generated by the overhead wiring system, it did not conclude what radio frequencies might have been affected.

No evidence of corona discharge or other faults was found.

Slip detector system

The slip detector telemetry system's primary function is to provide remote monitoring of geotechnical stability between positions 44.670 km and 37.856 km on the Connors Range, the purpose being to provide early warning of a ground movement before an embankment slips onto the track.

Tests were conducted on four of the five slip detector radio telemetry sites on the range. Those detectors transmit on a UHF frequency band of 471.250 Mhz. The fifth site was unable to be tested as it was destroyed as a result of the derailment of EG37. While not all radio sites appeared to be operating in accordance with Australian Communications Authority guidelines, no spurious emissions outside the frequency band of the radio telemetry equipment were detected that may have contributed to the extended loss of Locotrol radio communications.

Radio desensing

Radio technicians were asked to conduct tests to determine if there was evidence of desensing[44] of the UHF radio signal on the Connors Range. Desensing of a radio signal may be the result of radio interference caused by such things as radio 'noise' or corona discharge from the overhead wiring system, or an external radio signal of appropriate frequency interfering with the ELRC radio signal.

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[42] Corona discharge – a faint glow enveloping the high-field electrode is a corona discharge, often accompanied by streamers directed toward the low-field electrode. Another way of describing corona discharge is that it is a low current continuous discharge of High Voltage electricity which often cannot be seen or heard, or may be seen as a bluish haze.

[43] Radio 'noise' – noise in the radio frequency band, which can mask the presence of a genuine signal.

[44] Radio desensing – the reduction of the sensitivity of a radio receiver due to such things as radio 'noise' or corona discharge.

A measurable desense that could affect Locotrol data to some degree, was detected on the Connors Range, particularly in the areas of marginal signal. Whilst that finding might explain the existence of and, to some extent, the duration of the short-duration Locotrol communication interruptions, it did not explain the long-duration loss of Locotrol radio communications as was experienced by EG37. It was therefore considered that radio desensing as a result of interference from overhead wiring, could not disrupt Locotrol communications on the entire length of track between the 45 km and 36 km mark as there were substantial lengths of track where the radio signal was determined to be more than adequate for reliable Locotrol radio signals.

A check was made to determine if any radio repeating transmitters, operating on similar frequencies to those used in Locotrol, had recently been commissioned near the Connors Range. The Australian Communications Authority advised that no transmitters had been registered and commissioned within a 40 km radius of that area.

It may have also been possible that someone was travelling through the Mackay area at about the time of the accident and was transmitting on the same or similar UHF frequency as that of Locotrol. It was not possible to determine whether radio desensing had occurred at the time of the accident due to such transmissions.

1.13.5 Other

Point of no return (PNR)[45]

The investigation team sought to determine whether it was possible at any time during the accident sequence for the speed of EG37 to be controlled or brought to a halt.

Engineering train performance computer simulations were conducted to determine the latest point at which the train could have been brought to a halt on the range by the Driver’s actions. With the train located at the 44.50 km mark at 20 km/h, a Train Brake application was made and the train came to a halt in about 500 m. The same conditions were then used but the train was relocated at the 44.48 km mark. The result of that simulation was that the train initially decelerated to near zero speed, but then commenced to accelerate to a maximum speed of 80 km/h and did not stop until the bottom of the range.

Therefore, a Point of No Return was estimated to have occurred at approximately the 44.5 km mark.

Note that the sequence of brake application used for those simulations, was that suggested by the results of the Train Brake testing by the Brake Engineer and by the Driver’s actions as recorded on the Datalogger.

EG37 had been accelerating slowly for about 40 seconds from its lowest speed of 17 km/h and had reached a speed of 20 km/h. The Com Int occurred at approximately that location and the Driver had not yet applied full Dynamic Brake. In addition, Train Brake had not been applied, nor would it have been required at that time in normal circumstances because the complete train was still not on the downgrade of the range.

The Driver reported that he was not alerted to the developing problem till much later in the sequence of events.

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[45] Point of no return – it is possible for trains to attain speeds, particularly on a steep descent, which exceed the ability of a train to stop. In such cases, the train normally continues to be ‘unstoppable’ until such time as the gradient reduces so that the retarding (braking) forces available are sufficient to slow the train to a stop.

Speed indications of Lead Locomotive 3160

Lead Locomotive 3160 was checked to determine whether it was displaying accurate speed indications. This was achieved by comparing the speed indication of the Driver's speedometer with that of a Global Positioning System (GPS) unit and the Datalogger extractor. The indications were compared at 10 km/h, then every 10 km/h up to 80 km/h. All three speed indicating devices recorded the same speed throughout that test, confirming the accuracy of the locomotive speedometer and the Datalogger indication.

1.14 Organisational Context

Under the then new national co-regulatory arrangements, Queensland Transport, through the Rail Safety Accreditation Unit, accredited QR as a railway manager and railway operator in 1997. QR is a vertically integrated Government owned enterprise (GOE) with its own board and two principal shareholding Government Ministers.

Most of the rail corridor land in Queensland is owned by the State and leased to accredited railway managers such as QR.

QR is a business-led railway. Following a recent restructuring strategy, the organisation is now divided into seven business groups which were formally activated on 1 July 2001, though transitional arrangements were in place since March 2001. Those seven business groups are:

- *Passenger services* – including both CityTrain and TravelTrain.
- *Coal & Freight Services* – including Coal, Mainline & Regional Freight, Qlink, Service Delivery, Rollingstock, National Development and Business Services.
- *Infrastucture Services* – including Infrastructure North, Infrastructure South, Plant & Equipment, Programmed Maintenance Services, Infrastructure Construction, Infrastructure Business, Trackside Systems and Facilities.
- *Workshops* – including Redbank, Rockhampton and Townsville workshops, Business Services and QES & Staff Development.
- *Network Access* – including Network Infrastructure, Business Development, Network Operations and Integrated Management Systems.
- *Corporate Services* – including Human Resources, Information Services, Property, Corporate Counsel, Supply, Fleet Services, Appeal Board and two Chief Executive Representatives.
- *Technical Services* – including Projects, Civil Engineering, Rollingstock Engineering, Signal and Operational Systems, Electrical Engineering, Telecommunications, Spatial and Information Systems and Consulting Services.

QR staff employed to work in the Goonyella Rail System are managed in four functional areas, including the following:

- *Rollingstock maintenance staff* maintain all rollingstock in the Goonyella Rail System and report through their local managers to the Group General Manager *Coal & Freight Services.* Staff also work closely with the Rollingstock Engineering division of the *Technical Services* business group.
- *Traincrew, Station and Yard* staff are responsible for driving trains and managing and/or working at a variety of locations within the Goonyella Rail System. Those personnel are part of the Service Delivery Division and are responsible to the Group General Manager *Coal and Freight Services.*

- *Infrastructure staff* are responsible for the maintenance and upgrade of rail track and related infrastructure such as signals and telecommunications. Those personnel are part of the Infrastructure North and Trackside Systems Divisions and are responsible to the Group General Manager *Infrastructure Services*.
- *Train Control Centre staff* at Mackay control the safe movement of trains throughout the Goonyella Rail System. Those personnel are part of the Network Operations Division and are responsible to the Group General Manager *Network Access*.

Regular meetings are conducted between all of the above functional groups. Those meetings deal with short-term planning, communication of changes, and problem solving.

1.15 Risk identification

The Rail Safety Accreditation Unit of Queensland Transport assesses an organisation's Safety Management System against relevant safety management standards, generally Australian Standard AS 4292 – Railway Safety Management. QR demonstrated to the satisfaction of the Rail Safety Accreditation Unit during the accreditation process that the Safety Management System it had in place was acceptable.

Risk management[46] is the systemic application of appropriate management policies, procedures and practices to the tasks of identifying, evaluating, treating and monitoring risk. Section 3 of AS 4292 Part 1, refers to risk and incident management. Organisations are required to identify risks by establishing:

> procedures for analysing processes, work operations, activities of contractors and business premises lessees, railways safety records, reports and customer complaints to detect potential causes of accidents and incidents.
>
> The procedures shall include-
>
> (a) the analysis and monitoring of incidents to determine problem areas and adverse trends; and
>
> (b) a method of quantitatively identifying the probability and consequences of incidents associated with identified failure modes of safety systems and processes.

Organisations are also required to control risk by establishing:

> procedures for initiating preventative action in relation to problems or potential problems identified, by eliminating the hazards or controlling them to an acceptable level of risk, preventing the potential incidents from occurring or by controlling the consequences. In determining the action to be taken, the organisation shall take into account the likely frequency of an occurrence and its potential consequences (ie. use risk management techniques). This should be established with a full appreciation of the need to balance costs, benefits and opportunities.

1.15.1 QR's Safety Management System

QR's current Safety Management System was developed in the late 1990s in recognition of the fact that the organisation needed a more robust system that was not based simply on quality processes but 'whole of business' processes.

A hierarchy of documentation supports the Safety Management System:

- Policies – twenty policies form the framework of QR's Safety Management System

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[46] Risk management – The relevant standard is AS/NZS 4360 -1999 *Risk Management*, released by Standards Australia and Standards New Zealand. An earlier version was released in 1995.

- Standards – describe the safety objectives and the minimum standards that should be met to achieve those objectives
- Specifications – detail how those minimum standards may be achieved.

All policies, standards and specifications are mandatory for individuals, work groups and business groups to which they are relevant.

At a local level, line managers may issue Group Business Instructions, often based on Specifications, which provide further detail of how standards may be met, or exceeded, and which may also recognise safety aspects that are unique to a particular location or type of operation. For example, a specific Business Instruction may be issued to detail how a Driver should manage trains at a particular location or maintain a particular item of equipment.

There are 30 rollingstock Standards, including Standard STD/0064/TEC *Rollingstock Brake System Requirements* and STD/0065/TEC *Rollingstock Brake System Maintenance Requirements*. Both those Standards were issued on 26 February 2001 and became effective on 9 April 2001. Those standards clearly recognise and communicate the safety critical need to maintain a fully operational Train Brake system.

The purpose of STD/0064/TEC *Rollingstock Brake System Requirements* is to set the minimum requirements for the braking performance of rollingstock used on QR track to prevent derailment, collision or accelerated degradation of the track and rollingstock equipment. Further procedures and systems are currently being developed with a view to fully implementing those standards by the end of 2001.

The purpose of STD/0065/TEC R*ollingstock Brake System Maintenance Requirements* is to define the brake system maintenance/overhaul and test requirements for all rollingstock brake systems to ensure safe operation for vehicles re-entering traffic after service/overhaul or unscheduled repair to brake equipment, and for those remaining in traffic.

With respect to the management of rollingstock, much of the information in the Safety Management System is based on long established and recommended practices that were formulated as a result of both manufacturer's requirements and operational experience with the equipment gained over many years.

Proposed changes, such as the introduction of new equipment or procedures, require a formal, documented and auditable hazard analysis process to be undertaken. For example, in preparation for the recommencement of operations on the Connors Range following the derailment of EG37, a group of QR employees comprising Tutor Drivers and area and corporate rollingstock managers, conducted a hazard analysis of proposed amended procedures for driving trains down the range. Operational Instruction OI.JIL.OM.059 (06/07/2001) was then issued, detailing those amended procedures.

Existing equipment and procedures, which have demonstrated an acceptable level of safety through extensive operational experience, have not generally required such a formal process. Locotrol II, which was developed in the late 1970s and introduced into QR in 1985, was not subject to a formal hazard analysis, as described above, by either the manufacturer or QR. At that time, the concept of structured risk assessment and safety management had not been fully developed either nationally or internationally.

The manufacturer advised QR that it had not considered the possibility of a defect in Locotrol II such as was found in ELRC119 following the derailment of EG37.

The more recently introduced Locotrol technology, Locotrol-Electronic Brake (L-EB), was subject to an extensive formal and documented Failure Mode Effect and Criticality

Analysis (FMECA) and a hazard assessment by the manufacturer before it was commissioned. A similar fault to that which occurred on ELRC119 was considered in that analysis, but the secondary fault of a continued loss of radio continuity was not considered in conjunction with the primary fault in the Brake Pipe Cut-Off Valve. More recent advice received from the manufacturer has confirmed that the result would be the same for the LEB system as for the Locotrol II system. However, since the LEB system does not use O-rings but rather a gasket, the possibility of that type of failure has been removed. In addition, the risk of failure due to contamination or foreign objects is much lower due to its system design.

Part of the Safety Management System also includes procedures for accident and incident reporting, which enables staff to provide details of any operational or Occupational Health and Safety occurrences that they were involved in or observed. That reporting system applies a no-blame principle to those who voluntarily and promptly report accidents and incidents. This, in turn, provides QR and the Rail Safety Accreditation Unit, with an opportunity to monitor occurrence trends and to develop appropriate prevention strategies. QR also provides opportunities for operational staff to participate in safety committees and other safety-related activities in order to voice their safety concerns and to provide valuable information, derived from their experiences within the organisation that may contribute to improvements in safety.

Safety management oversight

Safety management oversight is achieved at various levels, as described by the Safety Management System, both from within QR and external to the organisation, principally through a variety of audit and other monitoring processes. Audit reports identify corrective actions and opportunities for learning. Progress on corrective actions is monitored until the issue is considered to have been satisfactorily addressed.

Individuals and line supervisors/managers are responsible for their own safety and for the continued safe operation of trains in their area of responsibility.

At a local level, internal audits may be conducted periodically. To enable greater objectivity, staff from one depot may audit an operation or area from another depot.

At a corporate level, internal audits are normally conducted on a 12-monthly basis. With respect to rollingstock, a five-year audit plan has been established. All QR Safety Management System standards, including rollingstock standards, must be audited once every five years.

QR has recently been accredited by the International Safety Rating System (ISRS) and is subject to audits on a 12–18 month basis. The ISRS system audits generic safety processes and provides a method of quantifying the progress of an organisation at an international level. There are 10 levels of safety in the ISRS system. QRs coal and freight rollingstock maintenance, for example, has achieved Level 4, two years ahead of its predictions for achieving that level. An ISRS audit of the then Coal and Mainline Freight Rollingstock Division was conducted on 13–29 March 2001. QR's Safety and Audit Compliance Officer performed that audit at four major depots/sites including Rockhampton, Gladstone, Jilalan and Townsville. The results of that audit indicated that QR was entering a level of maturity in its approach to and processes for safety management with many commendable safety initiatives being sited in the ISRS audit report. A notable area for improvement identified by that audit was the need to develop more comprehensive performance standards. It was noted that for a given period, only one 'near-miss' was recorded while in that same period, 40 accidents had been reported. The audit report suggested that there was a need for an improved system to capture 'near-misses' but acknowledged that the proposed introduction of a new accident/incident report form (10607) may go some way to address that concern.

QR is audited every six months by an external auditor called Sci-Qual. That external audit requirement arose during the mid 1990s when Japan, a major coal customer of QR, demanded that its coal suppliers be 'quality certified'. As a result, the maintenance facilities at Jilalan and Callemondah became the only maintenance workshops in QR to be 'quality certified' at that time. QR is now ISO 9000 accredited.

The Rail Safety Accreditation Unit audits QR on a 12-monthly basis. The purpose of those audits is to determine whether QR is compliant with its own Safety Management System and is therefore aware of its operational risks and adequately controls those risks. That system forms the basis for QR's accreditation as a railway manager and railway operator. Those audits are conducted through a desktop document review and an on-site inspection. Desktop exercises confirm that procedures exist and are in place to address risk as determined by QR and confirmed by Queensland Transport. On-site inspections are conducted to confirm whether a policy or standard has been implemented.

The audits conducted by the Rail Safety Accreditation Unit are a targeted 'snap-shot' of QR's compliance with its Safety Management System, with not all locations or organisational aspects being audited at any one time. Audits have been conducted in 1996, 1998, 1999 and 2000. Results of those audits indicate that QR's Safety Management System has been undergoing a process of continuous improvement in such aspects as document control, roles and responsibilities and operational procedures. The most recent audit in 2000 identified areas for improvement including a need for an improved understanding of safety validation and safety case processes and to review the requirements for internal auditing. The Rail Safety Accreditation Unit has not conducted any desktop or on-site inspection audits at Mackay (Jilalan).

QR also monitors its accident and incident trends and uses the information from that monitoring process as a basis for developing prevention strategies. The Corporate Safety Report covering the period May - June of 2001, rates safety performance against four main indicators, those being:

- Passenger safety
- Public Safety
- Operations
- Employee health and safety

Within the Operations category, QR's 5-year objective to decrease derailments by 20 per cent indicate that this target has been significantly exceeded, however, since the total number of derailments is generally low, any small change in that raw number can significantly affect overall rates. To help drive further improvement in accident and incident rates, QR has developed new evaluation criteria based on its own tolerability rates, for its 2001/2002 Corporate Safety Plan which will apply both on a network-wide and location specific basis.

1.15.2 History of similar occurrences

Western Australia and Queensland are currently the only two States in Australia that operate Locotrol-equipped trains. The Western Australia Rail Accreditation Authority advised there were no recorded occurrences in that State that had been triggered by similar technical failures as those involved in the derailment of EG37.

Discussions with the transport investigation agencies of the United States and Canada, revealed that whilst there had been some recorded cases of 'runaway trains' in Locotrol-equipped trains in those countries, the circumstances were, for the most part, different from the derailment of EG37. However, the findings of one accident report, stated, inter alia, that:

> Despite any questionable actions of the engineer regarding his train handling, he probably could not have prevented a runaway condition unless he kept the speed of the train at 15 mph or less which was significantly below his maximum authorised speed of 25 mph, and the requirement to stop at 30 mph.

A further finding of that report also stated that:

> Even though the Dynamic Braking System was critical to controlling the accident train, there was no requirement to test it and the engineer could not safely determine its real time condition.

The relevance of those findings to the investigation of the derailment of EG37, will be discussed in the *Analysis* section of this report.

The manufacture of Locotrol II, Harris, also advised that it was not aware of any similar cases to the derailment of EG37.

1.15.3 Management decisions affecting risk

Route down Connors Range

The route down the Connors Range, which forms part of the Goonyella Rail System, was commissioned in 1971 to service the coalfields of central Queensland. The most appropriate engineering alignment was determined with consideration given to local geography and the costs/benefits of alternative routes. At least two other routes were considered at that time including the possibility of connecting with the Netherdale branch line or a route down the Eton Range. In all cases, the track would have been required to negotiate similar gradients and curves as that of the Connors Range. The route down the Connors Range was seen as the most economical solution at that time.

When coal tonnage increased with a corresponding demand to haul more export coal to the ports, the single-line track was duplicated. In the process of accommodating the second track, the geometry of the alignment was improved with some curves eased. The track quality was also improved at that time.

In the early years of operation on the Goonyella Rail System, triple-header diesel trains (three locomotives at the front of the train) hauled loads of approximately 5,000 tonnes (1 km in length) down the Connors Range. By 1974, diesel trains hauling loads of up to 10,000 tonnes were in service on the Goonyella Rail System. Locotrol-equipped trains were operating at that time. Passing loops were extended to accommodate the longer trains.

In 1987, electrification of the Goonyella Rail System was completed. Today, predominantly electric locomotive Locotrol-equipped trains hauling loads of up to 12,000 tonnes (2 km in length) operate down the Connors Range. All Locotrol-equipped trains on the Goonyella Rail System are currently Locotrol II technology.

While there are other locations within the QR network with equivalent or steeper grades compared to that of the Connors Range, no other locations currently operate trains of similar length or tonnage.

The track quality had been upgraded to accommodate the changes in train operations over time and is now classified as Track Category 5. That category is the highest track quality category and relates to track geometry limits for maintenance purposes.

The Locomotive brake systems used have changed little during this time. The earlier Diesel Electric Locomotives used a WABCO 26 L system and the first generation LRC units used NYAB 26 L equipment. (26 L is an American standard system.)

The later Electric Locomotives use a D&M P85 brake system (which was specified and tested to be equivalent to the 26L system) Later ELRC units still used a NYAB 26 L system, but with additional features.

Change from VHF to UHF

Both VHF and UHF radio transmissions operate on line-of-sight principles and have corresponding short transmitting ranges. The transmitting range of UHF is shorter than VHF. UHF radio transmissions may be affected for many reasons including those that have previously been described in the *Overhead wiring system* section of this report.

Because of the line-of-sight properties of the signal, UHF radio transmissions may also be affected by terrain. Frequent curves on the route down the Connors Range can mean that line-of-sight is frequently lost between the aerial of the lead locomotive and that of the ELRC unit. However, on most occasions, the resulting loss of signal is momentary.

QR's Radio Engineer advised that there were predominantly three issues that led to the change of Locotrol operating frequencies from VHF to UHF:

- Locotrol-equipped trains in the Callemondah yard could not be reliably linked because of interference from the overhead wiring system in the yard.
- The Australian Communications Authority changed regulatory requirements that necessitated some users of VHF bands changing to UHF bands. QR was amongst those users who were required to make such a change. Train Control frequencies were also affected in that process.
- QR required an additional Locotrol frequency. With a changeover to the UHF band, QR was able to secure a second frequency.

In February 1997, tests similar to those described in the *Radio fade* section of this report, were conducted on the Connors Range in preparation for the imminent introduction of UHF frequencies. A report was prepared at the completion of those tests. The two areas of significant communications interruption referred to in the post-accident test report were also identified in the 1997 report. The 1997 report referred to the Com Int at the top of the range as a momentary interruption while the area at the bottom of the range near Black Mountain, coincident with the derailment site, was described as an interruption of a little more than one minute.

The changeover occurred in late 1997. The problems with linking trains in the Callemondah yard were resolved as a result of that change.

Drivers and other operational staff confirmed that they had experienced, or were aware of, Locotrol communications interruptions in the Black Mountain area ever since Locotrol-equipped trains commenced operating down the Connors Range. However, there was anecdotal evidence to suggest that those interruptions had been more predictable and frequent since the introduction of UHF for Locotrol. A number of Drivers also commented that they were more likely to experience communications interruptions while operating 5-header trains than while operating 4-header trains.

Locotrol communication interruptions on the Connors Range

The Network Services Officer QR (Radio) attributed the Com Int in the Black Mountain area of the Connors Range to a loss of signal due to terrain, adding that few surfaces were available to provide a reflected signal path between the transmitter and the receiver. No comment was made in the 1997 report as to the cause of the loss of Locotrol radio signal at other locations on the range. The Network Services Officer was not able to conclusively recommend that a transmitting repeater would address the problem as he had insufficient information to support that solution at the time. He recommended that tests be conducted in the near future. There was no evidence to indicate that such testing had been completed and no repeating transmitters had been installed by QR in the Black Mountain area at the time of the accident.

Drivers indicated that the loss of ELRC radio signal at the top of the range varied in length between 10-15 seconds up to as much as one minute, though the longer Com Ints were not common. On 26 April 2001, an e-mail between technical staff in the Goonyella Rail System referred to the receipt of a number of informal reports from Drivers that extended Com Ints (periods of about one minute) at the top of the range were being experienced more frequently. The loss of radio signal was allegedly affecting trains in both directions of travel and had been occurring for as long as 4–6 weeks.

In response to those concerns, a circular was posted at the Jilalan Depot requesting that Drivers formally report any experiences of extended Com Int. No guidance was provided in that circular as to what represented an extended Com Int. One report was received subsequent to the posting of that circular. When Drivers were questioned about why they didn't report their Com Int experiences, some Drivers responded that the problem had been in existence for a long time with, in their opinion, no action being taken to address the matter. Others did not consider that the loss of signal posed a problem as the Train Brake system was still capable of operating normally in those situations, albeit as a 'head-end-only' train.

Train handling techniques on the range were discussed with a number of Drivers. Some Drivers responded that they did not normally commence to apply Train Brake until the radio signal was re-established as it may have resulted in the train 'bogging down' because of Train Braking effort in excess of requirements following the return of the radio signal to the ELRC. Others indicated that they applied Train Brake in accordance with established procedures regardless of whether the train was in a state of Com Int or not.

Hazard identification – Locotrol II

As previously stated, the manufacturer advised QR that it had not considered the possibility of a defect in Locotrol II when developing the technology, such as was found in ELRC119 following the derailment of EG37. Nor was such a problem recognised by QR as a possible hazard when Locotrol II was commissioned for use within the organisation.

Although a formal hazard analysis had not been conducted for Locotrol II, many years of experience and knowledge of those involved led to both redundant and fail-safe systems being incorporated to ensure reliable and safe operation of Locotrol II under a wide variety of conditions. Many years of reliable operation have not subsequently provided the manufacturer, or Locotrol II operators, with any reason to believe that the defect found in ELRC119 was a potential safety hazard.

The Locotrol II system does not provide real-time information[47] to Drivers of a fault such as that found in ELRC119 following the derailment of EG37. The status of the Remote Feed Valve is determined by measuring air pressure in the '53A' pipe, which is upstream of the cut off portion of the Brake Pipe Control Valve. If the position of the valve could have been communicated to the Driver during the state of Com Int on

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[47] Real-time information – in relation to a Driver's awareness of any actual or developing fault, means information provided to the Driver at the time a fault occurs or develops while the train is in operation and not 'after the event' such as during subsequent periodical examinations. The real-time provision of such information in the form of warnings, messages, alarms etc., may enable the Driver to take any necessary action in a more timely.

EG37, he would have received a Feed Valve OUT indication. Such an indication would have confirmed to the Driver that the Train Brake Pipe had been sealed at the ELRC and that EG37 was simply a ‘head-end-only’ train. However, in the case of EG37, this was not the situation as the valve remained open and was feeding air into the Train Brake Pipe, opposing the Train Braking applications made by the Driver throughout the accident sequence.

1.16 Other factors relevant to the occurrence

1.16.1 Maintenance

Maintenance practices

Inspection and overhaul of rollingstock operating on the Goonyella Rail System is conducted in the rollingstock maintenance facilities at the Jilalan Depot.

Fitters and electricians in the Locomotive and Wagon Sheds participate in shift work. The Locomotive Shed workshop is a 7-day a week operation incorporating three shifts while the Wagon Shed is normally a Monday–Friday operation, also incorporating three shifts. Some weekend work is required in the Wagon Shed. As many as two mechanical and two electrical fitters as well as some cleaners or labourers may be rostered on any one shift.

The work program for any given day is determined by a Maintenance Planner and is posted on a Whiteboard, including which fitters, labourers and cleaners will be allocated to what tasks.

There are various types of inspections, which have corresponding levels of complexity. Those inspections are based on 12-week cycles with an ‘A’ inspection required after 12 weeks and so on, until a major inspection is required. The major inspection for Locomotives is referred to as an ‘E’ inspection, and is required at 288 weeks. The major inspection for ELRCs is referred to as a ‘D’ inspection, and is required at 144 weeks.

Maintenance planning is supported by a computer-based system. That system generates maintenance requests and related maintenance inspection sheets. Maintenance inspection sheets include the details of the mechanical and electrical inspection/test requirements for a particular type of inspection as referred to above.

In the Brake Room, there are three maintenance manuals that can be referred to – the Spare Parts Manual, the Overhaul Manual and the Test Manual. The Overhaul Manual is referenced to determine how a component is to be disassembled and assembled and how it is to be inspected or overhauled. It includes details of the parts required for a particular overhaul such as the Brake Pipe Control Valve, including the number and type of items such as O-rings, diaphragms and seals. The fitters would then normally refer to the Test Manual for bench test procedures. Some routine tasks would not generally necessitate reference to the manuals.

Twenty ELRCs are maintained in the Goonyella Rail System and, except for failures while in operation, Brake Pipe Control Valves are normally only overhauled every 144-weeks. There are about 5–6 spare Brake Pipe Control Valves kept at the Jilalan Depot. Based on the 144-week inspection cycle, this would mean that mechanical fitters overhaul Brake Pipe Control Valves about every 5–6 weeks.

A qualified mechanical fitter, working without direct supervision at a bench in the Brake Room, normally completes inspection and overhaul of the brake system components of ELRCs. Apprentices are usually directly supervised unless they have reached their 4th year of training.

Fitters may be stationed at a workbench for long periods while carrying out overhaul work so regular breaks from the tasks are normally taken.

The Brake Room is divided into three areas – an Office, the 'Dirty Room' where components are first brought in and are cleaned, and an air conditioned room, where overhauls and testing of components takes place. The Bench Test rack is separate to the workbenches where fitters complete the inspections and overhauls of the components.

There is a compactus at one end of the Brake Room, which has several drawers containing spare parts such as seals, diaphragms and O-rings. O-rings are usually supplied and stored in bulk as they are a standard stock item. Two storemen working on day shift, and the coordinator in charge of the Brake Room, supervise such things as ordering of parts, rotating stock and checking the service life of components.

A mechanical fitter could complete 2–3 overhauls of Brake Pipe Control Valves in one shift while some other jobs can take a couple of days. Fitters would normally work on one Brake Pipe Control Valve, or any other component, at a time.

There is generally a clean bench policy although this is not a written policy.

There is no parts reconciliation for individual overhaul tasks such as the overhaul of a Brake Pipe Control Valve, however, periodic inspection sheets identify components required and provide a section to note any additional items that may have been required for a particular task. A regular stocktake would generally pick up levels of stock and determine any need to order more stock but they are not used specifically to identify missing items.

It is standard practice for fitters to disassemble a component first before going to the compactus to obtain replacement parts. Throwaway items, which have been removed from components, are placed into bins provided inside the Brake Room.

If there is a need for a fitter to interrupt a task before it is completed, a yellow tag should be placed on the component, which indicates that work is still in progress. A red tag indicates that a component has failed a bench test and a green tag indicates that it passed a bench test. Discussions with staff at the Jilalan Depot indicated that they were only aware of one or two occasions when a Brake Pipe Control Valve had failed a bench test.

Rollingstock faults that become apparent while a train is in service, are required to be reported to the Rollingstock Defect Coordinator who is based at Rockhampton. The Rollingstock Defect Coordinator provides advice to staff in the field on how to manage rollingstock problems.

Maintenance history of EG37

Records of the recent maintenance history of the locomotives, wagons, and the ELRC of EG37, were reviewed. There was no evidence of any faults or anomalies that may have contributed to this accident.

The train was due for a routine Terminal Examination, having completed its last Terminal Examination on 18 June 2001. Since that time, two wagons were removed from the front portion of the train and replaced by two others. There had also been two changes of locomotives. Procedures that were followed in the Terminal Examination of EG37 have previously been referred to in the *Brake Pipe Cock in the OFF position* section of this report. Those procedures would normally have resulted in the detection of any Brake Pipe Cocks that may have been left in the OFF position as a result of the wagon or locomotive change-outs.

Assembly of the ELRC Brake Pipe Control Valve

As previously stated, Brake Pipe Control Valves undergo a 144-week cycle of overhaul and inspection including the replacement of certain items such as all O-rings. A sticker on the outside of the Brake Pipe Control Valve from ELRC119, indicated that the unit had been overhauled and 'Tested OK' on 19 January 2000 (see fig. 20).

Figure 20:
Brake Pipe Control Valve from ELRC119

Following an overhaul, the unit must undergo a bench test in accordance with Business Instruction DMM 09-020-03. The same fitter who has completed the overhaul normally conducts that bench test. There is currently no separate sign-off against each item of that test. Following the test, the fitter places a sticker on the unit with his initials and the date, as referred to above, and attaches a green tag. The unit is then wrapped in cling-film and stored on a shelf in the Store Room until required in an ELRC.

A Brake Pipe Control Valve with an obstruction to simulate the inoperative valve on ELRC119, was subjected to a bench test to determine if the fault should have been identified at the time of the bench test on 19 January 2000. That test was based on the assumption that the O-ring was already jammed in the seat of the valve at the time of the bench test. The Brake Pipe Control Valve failed the bench test in four separate areas of the test.

Functional testing of the Brake Pipe Control Valve in ELRC119

The Brake Pipe Control Valve shown in figure 20 was fitted onto ELRC119 on 5 May 2001 during its routine ELRC 144-week inspection. A functional test is normally carried out in accordance with Business Instruction DMM-010-33 as part of that inspection including a requirement to test the ELRC while in a state of Com Int. The functional test was conducted at that time and each section of that test was signed off as complete.

The investigation team arranged for a repeat test in accordance with DMM-010-33 to be conducted on ELRC119 using a valve with an O-ring arranged in the same configuration as that found in the inoperative Brake Pipe Control Valve on ELRC119 following the accident. The results of that test revealed that a fault such as this should have provided clues of its existence to the team carrying out the functional test procedure. In particular, the Flow light and an alarm should have been in evidence on the Driver's Locotrol console when the Emergency test was done. In addition, the Train Brake Pipe pressure and the Flow reading would not have been zero (if those indicators had been selected).

However, the then current procedure did not require a check of the specific function of the Brake Pipe cut off portion of the Brake Pipe Control Valve to be made, nor did those instructions provide guidance on what clues would have provided verification that the Brake Pipe Cut Off Valve was closed.

The then current train assembly procedure did not cover this scenario and hence it is likely that a Driver would not have identified that particular fault during Terminal Examinations and change-outs of wagons and locomotives.

1.16.2 Driver training and checking

Responsibilities of a Driver[48] include, but are not limited to:

- operating locomotives and trains in a manner which maximises efficiency and safety;
- monitoring the performance of equipment and rollingstock en route to identify faults or defects;
- using available resources including skills and knowledge to rectify locomotive or train fault situations.

A depot-specific training syllabus has been developed by QR for each Traincrew depot within the organisation. Each syllabus identifies the range of learning modules a Driver must demonstrate competency in to be fully productive at work. The core competencies for QR Locomotive Drivers are based on the *Transport and Distribution Training Australia – National Competency Standards.*

Trainee Drivers for the Goonyella Rail System complete a theory component of their Driver training in Rockhampton, including sessions in the Driver Training Simulator at that location. That training is of a generic nature and includes modules such as:

- Induction and workplace familiarisation;
- Signals, safeworking and traincrew support; and
- Air brakes, locomotives and train handling.

A qualification as a Traincrew Support Person is attained upon successful completion of that training. Trainee Drivers will then return to an appointed depot and work as a Traincrew Support Person for approximately two months. The Trainees then complete another theory portion of their training at Rockhampton. The purpose of that training is to equip Trainee Drivers with the necessary knowledge of train driving requirements relevant to the area in which they will be working such as the operation of electric locomotives and Locotrol-equipped trains.

Trainee Drivers are then placed with a Tutor Driver for approximately 100 shifts. That training is predominantly on-the-job training, however, Tutor Drivers are expected to provide briefings and debriefings as required before and after practical training sessions. When the Tutor Driver considers that the Trainee is competent, that Trainee will be assessed by another Tutor Driver to become a fully qualified Driver.

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[48] Driver responsibilities – Derived from *Curriculum Document-Train Management Program 1997*

Tutor Drivers are provided with significant training documentation, referred to in QR's *Competency Based Training Manual*, in order to assist a Tutor Driver to objectively assess the complete set of competencies required to be demonstrated by a Driver. Modules include, but are not limited to:

- Module 015 Remote Control Electric (RCE);
- Module 017 Train Management; and
- Module 019 Emergencies.

Both the theory modules and the on-the-job training modules refer to dealing with train faults and scenarios such as Train Brake problems and Com Ints on a descending grade.

A document titled *Locotrol Trouble-Shooting (helpful hints)*, which was revised and updated in November 1997, describes how various Locotrol problems may be handled by Drivers, including those times when the train is in a state of Com Int.

Route-specific instructions on how to handle trains whilst descending the Connors Range are also provided to Drivers. Those instructions have been referred to for comparative analysis of the Driver's actions and are contained in figure 4. Those instructions do not refer specifically to handling a train while in a state of Com Int on the range. However, amended procedures that were introduced following the derailment, provide directions to Drivers about what actions to take if a Com Int is experienced.

Drivers are exposed to some scenario-type exercises during their initial training, including simulator sessions where they may be required to deal with a variety of faults. Unless exposed to actual train faults while undergoing on-the-job training, Drivers are normally only required to verbalise what actions they would take in any given abnormal or critical situation. A train simulator, similar to the one that is used at the Rockhampton training facility, is available at the Jilalan depot. Although it is freely available to Drivers and Tutor Drivers, it is generally used in an ad-hoc fashion. There is no programmed periodical training or assessment undertaken in that simulator.

Once qualified, a Driver must be re-accredited every three years[49]. Re-accreditation involves a week of classroom sessions covering predominantly generic principles such as safeworking and train handling. It may also cover discussions about train faults but is not route-specific.

Drivers in the Goonyella Rail System are not currently required to undergo periodical en route assessments unless the Driver has not been over a particular route for over 12 months. Rostering on the Goonyella Rail System normally means that such en route assessments are unlikely to be required. It is expected, however, that Tutor Drivers should observe and assess any Driver they may be teamed with on any particular shift although this is an informal arrangement. Following an incident, a Driver may be required to be re-trained or observed by a Tutor Driver to ensure that the Driver has learnt from the experience.

A significant proportion of Drivers in the Goonyella Rail System work with a 'Permanent Mate'. This means that they are rostered with the same Driver for the majority of shifts and may result in some Drivers rarely being paired with a Tutor Driver.

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[49] Re-accreditation – A requirement of the QR Safety Management System as specified in Standard STD/0011/WHS *Safety Training and Accreditation* (17 April 2000).

On 2 December 1999, seven passengers on an urban passenger train lost their lives when the urban train collided with the rear of the Indian Pacific passenger train at Glenbrook, NSW. Following that accident, QR commissioned a study into its own training regime. The purpose of that study was to identify any gaps in the training of both Drivers and Train Controllers to ensure that QR was not exposed to the risk of a similar accident such as had occurred at Glenbrook. That study, conducted by an external consultant from the United Kingdom, Halcro Rail, made 21 recommendations. One of those recommendations flowed from the recognition that the rail industry needed to develop a better approach to critical incident (emergency) training. Halcro Rail considered that Drivers and Train Controllers needed more meaningful opportunities and better guidance on dealing with a variety of critical incidents. Halcro Rail also believed that better use could be made of Driver training simulators, which tended to focus more on train management skills rather than handling abnormal situations and other scenario-based training.

In order to implement the Halcro Rail recommendations, QR has formed an implementation team. One of the initiatives that has been partially progressed, is the introduction of a Skills Passport for Drivers and Train Controllers. There has been union support and involvement in the development of that scheme. The Skills Passport consists of a number of competencies, which must be subject to both an initial and annual on-the-job assessment. The purpose of the Skills Passport is to provide assessors and supervisors with a method of objectively measuring whether knowledge has been translated in a consistent and repeatable manner into on-the-job skills. To date, Train Controllers in the Passenger Business Group of QR are the only group of employees participating in that scheme.

2. ANALYSIS

2.1 Introduction

EG37 derailed due to excessive speed. This analysis will seek to explain the underlying reasons for that outcome.

The objective of this investigation was not to attribute blame or liability, but rather to learn from this occurrence how future accidents or incidents may be prevented.

The investigation team analysed this accident using the Reason model[50]. Hence, this analysis section begins with a consideration of active failures, then moves on to examine the local factors which were present at the time and place of the accident.

Following this, systemic weaknesses, which may have contributed to this accident, are considered. Systemic weaknesses may take the form of organisational factors, or absent or inadequate defences.

2.2 Active failures

Active failures are the result of either unsafe acts and/or technical failures. Both unsafe acts and technical failures can have a direct and immediate influence on the development and outcomes of an occurrence.

Unsafe acts (including acts of both commission and omission by humans) are active failures which can arise for a variety of reasons, including errors such as absent minded slips, memory lapses and mistaken intentions, or rule violations.

Technical failures may also result from acts committed or omitted by humans but which occurred or were triggered at a time far removed from the accident sequence. Therefore, the individuals directly involved in the sequence of events such as Train Drivers or Train Controllers may have little or no control over the existence or influence of the technical failure at that time. That is to say that the technical failure may have occurred under the circumstances regardless of what actions the operational staff had taken at the time.

The active failures that precipitated the derailment of EG37 are described below.

2.2.1 Extended communications interruption

The balance of evidence suggests that EG37 was in a state of Com Int throughout the entire accident sequence. It's commencement occurred at a time consistent with past experience. However, unlike with previous instances (in so far as those are known) Locotrol radio communications were not subsequently restored.

The Driver had reported that, following the activation of the Com Int warning light and alarm, he observed that the Dynamic Brake indication on the Locotrol console was flashing at value '8' and the green 'Feed Valve IN' light also continued to flash. Those indications simply informed the Driver about the degree of Dynamic Braking at the remote locomotives at the commencement of the Com Int and the status of the Remote Feed Valve at that time.

At worst, in accordance with the fail-safe design of the ELRC, the Driver should have expected the Remote Feed Valve to 'cut out', and the remote locomotives to reduce power to IDLE, after two minutes. Note that the remote locomotives were already at

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[50] REASON, J. 1990, Human Error, (Cambridge University Press: Cambridge)

IDLE at the time the Com Int commenced. However, as the Driver made Train Brake applications following the start of the Com Int period, the Remote Feed Valve should have 'cut out' before the 2-minute period, due to it sensing the air flow to the Train Brake Pipe.

In both cases, the outcome should have been that EG37 simply became a 'head-end-only' train. Train Brake propagation rates would have been somewhat slower due to all brake applications being propagated from the front of the train only, and not also from the centre of the train, via the ELRC. However, under those circumstances, the speed of EG37 should nevertheless have been able to be controlled.

2.2.2 Defective Remote Feed Valve

A supernumerary square section 'O' ring of a type used in both the Brake Pipe Control Valve and other components of ELRC119, was found to be lodged in a figure-8 shape across the seat of the Brake Pipe cut off portion of the Brake Pipe Control Valve. As a result, the Brake Pipe Cut Off Valve remained almost fully open throughout the accident sequence. This would have been the case even when Main Reservoir air through the '53A' pipe, was attempting to close the valve and thus 'cut out' the Remote Feed Valve at the ELRC. As stated above, the Driver's braking actions following the commencement of the Com Int, would have resulted in Main Reservoir air being redirected through the '53A' pipe. However, the obstruction meant that the required outcome of 'cutting out' the Remote Feed Valve could not be achieved.

With the Remote Feed Valve 'cut in' throughout the entire accident sequence, the propagation of Train Brake from the front of the EG37 would have been opposed to a variable degree because of air continuing to be fed into the Train Brake Pipe at the ELRC (in response to any reduction in Brake Pipe pressure sensed locally).

To have been able to 'Balance the Grade', EG37 would have needed at least 60 wagon brakes fully applied. Extensive Train Brake testing, which was completed following the derailment, concluded that EG37 would have had somewhere in the vicinity of between 47 and 55 wagon brakes applied with some of the brakes toward the rear of that group only lightly applied.

2.2.3 Driver did not recognise problem until after Point of No Return

The Driver did not recognise that the train was not responding appropriately to Train Braking until a point during the accident sequence when the speed of the train could no longer be controlled.

The Point of No Return was estimated to have occurred at a location 44.5 km from Hay Point. That location is right at the top of the range and would have been very shortly after the loss of radio continuity occurred, and before any normal brake application would have been made.

EG37 had been accelerating slowly for about 40 seconds from its lowest speed of 17 km/h and had reached a speed of 20 km/h. The Com Int occurred at about that location and the Driver had not yet applied full Dynamic Brake. In addition, Train Brake had not been applied, nor would it have been required at that time in normal circumstances.

Until the events on the Connors Range, the Driver reported that Train Braking performance had been normal. As this particular fault does not manifest itself unless a Driver applies Train Brake during an extended period of Com Int, the Driver of EG37 had no prior opportunity to detect the fault.

It is also unlikely that a Driver would have detected the fault on earlier journeys down the range as previous Com Ints had generally been of much shorter duration. If the Remote Feed Valve had been defective during any of those previous journeys, the shorter duration of the Com Int would generally have meant that Train Brake was not required to be applied until after Locotrol Communications had been restored. Alternatively, if Train Brake had been applied within the period of Com Int, Locotrol communications would have been restored shortly after and the control of the Train Brake, including the Remote Feed Valve, would have reverted to its primary controlling method of UHF Data Radio. In the latter case, any degradation in the Train Brake performance would have been momentary and unlikely to be noticed by the Driver.

With no knowledge of the existence of the fault in EG37, the Driver could not have been expected to commence taking action in a more timely manner. The Driver's actions were therefore not considered a direct factor in triggering the development of the sequence of events.

Even in circumstances with no other faults present that could influence Train Braking performance, Drivers expose trains to greater risks whenever they allow the speed of trains to exceed the maximum posted speed for the location. Such delayed actions result in higher wheel temperatures and possible significant brake fade at higher than normal speeds. If those added stresses on the Train Brake system were then complicated by another system failure, the risk of an accident or incident could be significant. Interviews with other Drivers confirmed that it was not uncommon to allow trains to exceed maximum posted speeds by a small amount providing that they considered the Train Brake was operating effectively. Further discussion about those behaviours is referred to in the *Driver expectations* and *Safety culture* sections of this analysis.

Analysis of the Datalogger of EG37 indicated that the Driver did not apply full Train Brake until the speed of the train had exceeded the maximum posted speed of 40 km/h. Nor did the Driver apply Emergency Train Brake until the speed of the train was accelerating through 52 km/h, 12 km/h above that maximum speed. It has been noted that in order to have controlled the speed of EG37, the Driver would have been required to commence significant Train Braking before the then current procedures would have even called for any level of Train Brake. However, had the Driver made Train Brake applications earlier, in a manner consistent with the then standard procedures, it is possible that the train would not have reached 93 km/h before the bottom of the range and that EG37 may not have subsequently derailed or that a lesser number of wagons may have derailed.

2.3 Local factors

Active failures occur in the context of local factors. These are aspects of the local work environment, which increase the probability that a human will commit an unsafe act or that a technical failure will occur or be revealed. Local factors may also influence the consequences of those active failures.

2.3.1 Track

The alignment of rail track on the Connors Range is such that it contours the eastern side of the range between Hatfield and Yukan. The effect of contouring usually removes significant undulations but can mean that trains negotiate a number of curves. As the speed of EG37 accelerated throughout the accident sequence, the resulting lateral forces from negotiating those curves at higher than normal speeds, became considerable.

The alignment of the track also meant that in negotiating curves, the Locotrol radio communications are lost due to the line-of-site limitations of the UHF signal. Steep, heavily wooded terrain shielded the signal in at least two locations on the Connors Range, one area usually of short duration at the top of the range, and another of usually longer duration close to the bottom of the range in the area of the derailment site. The Com Int that EG37 experienced commenced at the top-of-the-range location, consistent with previous experience. Local factors that may have influenced the length of that signal interruption will be discussed in the following section of this analysis.

The average downgrade on the Connors Range is 1:50. While there are other locations within the QR network that have steeper grades, those locations do not currently operate Locotrol-equipped coal trains of a similar length to EG37 and hauling similar loads. The braking effort required to control the speed of trains on steep and extended downgrades is considerably higher than the braking effort required on lesser grades. As the Com Int and subsequent Train Brake problem occurred at the top of the range, the train accelerated for several minutes, reaching its top speed of 93 km/h before derailing.

At the point coincident with the derailment site, EG37 entered a left curve that had minor variations in both curvature and cant. Although those minor variations were within normal threshold limits for track maintenance purposes, they were sufficient to result in significant unloading of the inside wheels of wagons, hence the mechanism of derailment was dynamic overturning.

If the fault in the Remote Feed Valve of EG37 had not manifested itself until nearer to the bottom of the range in the second area of Com Int, the consequences would have been minor. Shortly after that location, the downgrade becomes less steep (1:100) and the track becomes relatively straight. The train may have also accelerated well above its maximum speed in that case but would not have reached 93 km/h. Any forces that may have had an adverse impact on the stability of wagons at that location would have been negligible and the train would not have subsequently derailed.

2.3.2 Unknown factor regarding extended Com Int

The investigation has been unable to establish why Locotrol radio communications were not restored at any time during the accident sequence.

Tests on the radio systems of both ELRC119 and Lead Locomotive 3160 did not reveal any evidence of a fault that may have contributed to the extended Com Int though a transient condition or some associated equipment failure cannot be entirely ruled out. Subsequent in-service use of Lead Locomotive 3160 since the derailment has not revealed any related radio problems. Damage to the Multiple Unit cable on ELRC119 as a result of both the accident and the recovery operation precluded any determination being made as to whether a problem had developed with the cable. If the Multiple Unit cable on ELRC119 had ‘dropped out’, the Locotrol signal would have been lost between Lead locomotive 3160 and ELRC119 and the indications received by the Driver would have been identical to a Com Int resulting from any other factor such as terrain shielding.

Localised radio desensing, which may have been the result of interference due to corona discharge or radio ‘noise’ from overhead wiring, has been ruled out as a plausible reason for the extended loss of Locotrol radio communications as was experienced by EG37. In addition, no repeating transmitters of similar frequencies to that used by Locotrol, which may have had an adverse impact on the Locotrol radio signal at the time of the derailment, have recently been commissioned in the Connors Range area.

If any of the factors referred to above had been present and were affecting the Locotrol radio signals at the time of the derailment of EG37, it is also likely that other Locotrol-equipped trains would have been affected at that time. Such factors were also likely to be present prior to, or subsequent to, the derailment. In the absence of any reports from Drivers, apart from loss of signal due to known terrain shielding, those factors are considered not likely to have been present at the time of the accident.

Any remote possibility that someone may have been travelling through the Mackay area at the time of the accident and was transmitting on the same UHF frequency to Locotrol, cannot be determined. The unpredictable nature of that scenario would make it difficult to rule out such a factor unless an extended period of Locotrol signal monitoring was conducted in the area to identify any further instances of that form of radio signal interference.

2.3.3 Driver expectations

Interruption of Locotrol radio communications on the Connors Range have been experienced by Drivers ever since Locotrol-equipped trains started operating in the Goonyella Rail System in 1974. Whilst anecdotal evidence appears to suggest that the frequency of signal interruptions has increased since the changeover to UHF for Locotrol radio communications, many Drivers have a relaxed attitude about the issue. Years of past experience has resulted in Drivers having an expectation that the length of the signal interruption will be short-lived and that operations will be returned to normal without any resultant degradation in Train Braking performance.

That expectation has been further reinforced by the fact that no similar technical failures have occurred, which resulted in an otherwise routine period of Com Int developing into a serious unsafe situation, as was experienced by the Driver of EG37.

Years of reliable operation of the Train Brake system, including safety improvements to that system, also appear to have led many Drivers to have complete ‘faith’ in the Train Brake system under a wide variety of challenging conditions.

Those factors may have had some influence on the time during the accident sequence at which the Driver recognised that a serious problem was developing. Past experience has generally meant the Train Brake was capable of controlling the train, even if the Driver allowed it to attain a speed well in excess of the maximum posted speed for the area. As noted earlier, the Driver of EG37 did not apply full Train Brake until the speed of the train had reached 48 km/h and Emergency Brake was not applied until the speed of the train was accelerating through 52 km/h.

2.4 Absent or inadequate defences

Using the terminology of the Reason model, defences are safeguards built into a system to provide protection against identified hazards. Defences can serve a variety of functions, such as preventing an unsafe situation from arising, warning of an unsafe situation, or containing the consequences of an unsafe situation should all other measures fail.

In everyday situations, where hazards are generally low consequence, few defences may be necessary. However, it is generally expected that in complex technological systems, multiple lines of defence will be in place to protect against high-consequence hazards.

This accident highlighted two areas where defences were inadequate or absent.

2.4.1 Brake system

Had the Train Brake system operated as intended, that system would have prevented the speed of EG37 becoming excessive and the train would not have subsequently derailed. However, with the fault described in earlier sections of this report, the Train Brake system was operating at somewhat less than half its maximum braking effort. That, in turn, meant that the Point of No Return occurred very early in the development of the sequence of events and those wagon brakes that were applied under the circumstances, experienced significant brake fade.

The Remote Feed Valve 'cut out' procedure, a fail-safe feature of the ELRC system design, had been regularly exposed as the only defence in that part of the Train Brake system as a result of the frequent loss of Locotrol radio communications at the top of the Connors Range. No alternative mechanism is currently used by QR in the event that faults in the Train Brake system such as a Remote Feed Valve not 'cutting out', a closed Brake Pipe Cock or a one-way obstruction within the Brake Pipe, results in Train Brake applications not propagating through to the rear of the train.

2.4.2 No warning to Driver of real-time status of Remote Feed Valve during Com Int

While a train is in a state of Com Int, the Driver cannot be provided with any information about the real-time status of the Remote Feed Valve. He is left to assume that the Feed Valve 'cut out' has occurred, either as a direct response to Train Brake applications made by the Driver after the Com Int commenced or following the 2-minute timeout period if no Train Brake applications were made within that 2-minute period.

The status of the Remote Feed Valve is determined by measuring air pressure in the '53A' pipe, which is upstream from the cut off portion of the Brake Pipe Control Valve. Even if the status of the Remote Feed Valve could have been communicated to the Driver of EG37 during the Com Int, he would have received a 'Feed Valve OUT' indication within or just after the 2-minute period. Such an indication would have confirmed to the Driver that the Train Brake Pipe had been sealed at the ELRC and that EG37 was simply a 'head-end-only' train. However, this was not the situation with EG37 as the Remote Feed Valve remained open and was feeding air into the Train Brake Pipe, opposing the Train Braking applications made by the Driver throughout the accident sequence.

If the Driver was provided with information about the real-time status of the Remote Feed Valve at the time or very shortly after the Com Int occurred, he may have been able to take more timely action in order to control the speed of EG37. The case referred to in the *History of similar occurrences* section of this report, makes a similar observation with regard to the Driver's lack of awareness of the real-time status of the train's Dynamic Brake system during that occurrence.

If the Driver had been able to select and receive information about Flow or Brake Pipe pressure during the Com Int, he may have been able to identify the fault and take action in a more timely manner. A Flow indication, for example, would have alerted the Driver that there was something wrong. Although he may not have been able to do much about the situation from within the train, he may have been able to contact Train Control and request that the overhead power supply be shut down. This would have meant that the compressors on the locomotives no longer continued to supply air to the Main Reservoir and that the air being supplied, in turn, to the Remote Feed Valve would have eventually depleted. In that case, it is possible that more brakes would have then applied along the train and it may not have reached a speed sufficient to derail. However, consideration of such an action should be balanced with the potential to expose other trains in the vicinity to increased risks resulting from the power supply also being withdrawn from those services.

Another possible method of informing the Driver of potential degraded Train Brake performance, would be to have a hot/cold wheel detector located near the top of the range. Information derived from hot/cold wheel detectors is radioed to the Driver. In the case of EG37, it would have informed him that about half of the wagons on his train had cold wheels, when he should be receiving information that all wheels were at the same or similar temperature.

An End-of-Train device, a device that is commonly used in the United States, may have been an additional defence, which could have assisted the Driver of EG37 in this occurrence. An End-of-Train device has the capacity to apply Train Brake from the rear of the Train in emergency situations. In the case of EG37, this would have meant that additional braking could have been propagated from the rear of the train, which may have been sufficient, together with those brakes that applied on the front portion of the train, to have controlled the speed of EG37. However, for such a device to provide additional braking, radio communications with that device must be established.

2.5 Organisational factors

The investigation team considered that most of the local factors and inadequate or absent defences referred to above reflected wider organisational issues. Those issues are dealt with below.

Note that although a separate heading of *Risk Management* has been selected as a discrete organisational issue for the purpose of this analysis, it could be argued that all organisational issues relating to a particular occurrence are linked intrinsically to the management of risk.

It must also be stressed that any discussion about particular organisational factors should not be read to reflect criticism. Those discussions seek simply to explain why the local conditions were present or why safety defences were absent or inadequate.

2.5.1 Risk management

Short of bulldozing the range or tunnelling through it, the requirement to provide a rail service between the Central Queensland coalfields and the ports at Dalrymple Bay and Hay Point, meant that trains had to negotiate a significant descent at some point in their journey. This would have been the case even if other routes had been chosen at the time. Whilst duplication of the track and other projects such as electrification, resulted in significant upgrading of track quality, the route down the Connors Range is nevertheless a continuous steep downgrade for several kilometres including numerous curves. Consequently, the braking effort required for any given train is significant compared to other locations and, in turn, any degradation in braking performance has a much greater adverse affect on the ability of a Driver to control the speed of a train. The introduction of longer, heavier trains on the range in order to meet the increasing demands of clients, also meant that potential consequences could be more significant.

Due to terrain shielding, Com Ints were inevitable with the advent of Locotrol-equipped trains on the range in 1974, particularly with ever increasing train lengths. Many years of experience with those trains highlighted the existence of at least two areas where Locotrol radio signals are temporarily interrupted.

QR had appropriately conducted tests to determine if there were any further detrimental effects on Locotrol radio communications with the change from VHF to

UHF radio in 1997. Those tests simply confirmed the two locations that Drivers had experienced Com Ints on previous occasions. A recommendation made at that time to explore the possibility of installing a repeating transmitter in the area to prevent the occurrence of Com Ints, was not followed through.

The absence of evidence to suggest that a technical fault similar to that found on EG37 had ever existed or was likely to exist, probably increased the confidence both Drivers and management had in the Locotrol system to do its task in a wide variety of conditions. There is no denying that the probability of such a fault would be calculated as extremely low, even if it had been considered at the time of its design by the manufacturer or commissioning within QR. However, the potential consequences, as seen in the case of the accident involving EG37, may have been given insufficient consideration when developing strategies to ensure the safe operation of trains down the range.

2.5.2 Design of Electric Locomotive Remote Control unit

Locotrol technology has been designed to cope with periods of communications interruption. Both redundant and fail-safe systems have been incorporated to compensate regardless of what is the underlying cause of the loss of radio signal. Locotrol II has demonstrated itself to be very reliable and capable of operating safely in a wide variety of conditions.

Regardless of whether a train is a state of Com Int or not, the only mechanism that a Driver has to control a train safely is an adequate Train Brake system and to follow recommended procedures for handling that train. The Driver must be assured that there are adequate defences within the Train Brake system in order to continue to be able to control a train in abnormal situations. While the reason for the extended loss of Locotrol radio signal has not yet been established, this accident highlighted the fact that the Feed Valve ‘cut out’ mechanism is not entirely fail-safe.

The principles of Reliability Centred Maintenance (Moubray, 1991) suggest that if it is not possible to make a hidden fault visible, such as with the provision of a warning to Drivers, then a failure finding task will need to be scheduled or the system may need to be redesigned. The Locotrol II system cannot provide a Driver with the real-time status of the Remote Feed Valve. During a state of Com Int, no meaningful messages are provided to a Driver other than what configuration the remote locomotives were in at the time the radio signal was lost. Although the ELRC is designed to ‘cut out’ the Remote Feed Valve so that Brake applications made by the Driver at the front of the train are not opposed at the ELRC, the Driver is left to assume that this has occurred.

Even if the status of the Remote Feed Valve could be communicated to the Driver in such situations, it would not provide a reliable indication as that status is currently determined by sensing air pressure in the ‘53A’ pipe. As that location is upstream from the cut off portion of the Brake Pipe Control Valve, it can only be an ‘interpretation’ of the status of that valve.

It has already been noted that the manufacturer had not considered a fault such as was evidenced in the ELRC of EG37. It has also been noted that, through many years of experience with Locotrol II, there has been no evidence to suggest that this was a common or at least ‘known problem’. This may explain why the system has neither an alternative mechanism, which may effectively ‘bypass’ such a fault, nor any warning to Drivers that the Remote Feed Valve may be defective.

2.5.3 Maintenance procedures

Procedures are one of the least expensive forms of safety defence in industrial and transport contexts. Unfortunately, however, procedures are also one of the least effective forms of safety assurance as they rely on humans to understand and follow those procedures without committing errors or violations. In the absence of other defences, the integrity the Train Brake system of EG37 relied heavily on both adequate procedures and compliance with those procedures.

The then current overhaul bench test procedure for the ELRC Brake Pipe Control Valve, would have clearly identified the fault if it had been present at that time. If the fault had been present, it would suggest that the bench test procedure had been overlooked. There is no requirement for independent verification or sign-off of that procedure. In addition, the same fitter normally completes both the overhaul and the bench test. Though conclusions about this possibility could not be made, it was considered unlikely that the fault was present at the time of the bench test. However, it is recognised that quality control of safety-critical systems and components is essential. Processes such as independent verification, may be one method of achieving that outcome.

Functional tests of the Remote Feed Valve ‘cut out’ procedure, prescribed as part of an ELRC 144-week inspection, should have provided clues as to the existence of the fault if it had been present at the time of that inspection. However, those tests did not require a check of the specific function of the cut off portion of the Brake Pipe Control Valve to be made nor did those instructions include guidance on what clues would have provided verification that the Remote Feed Valve was actually ‘cutting out’. It is possible that, without a check on the specific function of the cut off portion of the Brake Pipe Control Valve or guidance on the ‘clues’ to be alert to, those involved in the test procedures could not have readily identified the fault.

The Terminal Examination that was conducted on 18 May 2001 may also have provided clues about the defective Remote Feed Valve if the fault had been present at that time. However, as previously stated, Drivers do not generally monitor Flow indications during that examination and any opportunity to detect the problem at that time may have been lost.

The time at which the square-section O-ring was introduced into the cut off portion of the Brake Pipe Control Valve could not be precisely determined. It is possible that when it was first introduced, it was not lodged across the seat of the Brake Pipe cut off portion of the valve and was therefore not affecting the functionality of that valve. It may have only manifested itself after bench tests and other related examinations had been conducted, with all those tests and examinations indicating at the time that the Remote Feed Valve was functioning normally.

NUCARS simulations calculated that the mechanism of derailment was dynamic overturning of one or more wagons at a speed of 93 km/h at the end of a transition to a left curve some 38 km from Hay Point. It was noted that minor variations in cant and curvature at that location were sufficient, together with the speed of the wagon, to cause complete ‘unloading’ of the wagon for a significant distance. It could reasonably be suggested that if the variations in the cant and curvature were not present, EG37 would not have derailed. However, though it provided an explanation for the derailment, the geometry of the track at that and other locations on the range was not designed on the basis of trains travelling down the range in excess of 90 km/h. Track maintenance procedures were therefore considered acceptable for the range of operations those procedures were designed to accommodate.

2.5.4 Safety culture

Efforts to improve the safety culture within QR have clearly paid dividends. Trend monitoring of safety occurrences has exceeded corporate targets and QR's Safety Management System has demonstrated a commitment to continuous improvement at all levels as evidenced through a variety of auditing and other safety oversight processes.

There is, however, a parallel emphasis on the throughput of coal trains and a significant pressure on the attainment of targets based on coal delivery demands from clients. This has the potential to lead to the acceptance of increased risk in an effort to keep trains serviceable and running on time.

There also appears to be an extraordinary faith in the Train Brake system, which may have led Drivers to have underestimated the increased risk exposure associated with the breakdown of related systems. Drivers, like other experienced professionals, have confidence in their ability to manage a train safely in a variety of conditions, including abnormal situations. Those attitudes are not unique to Drivers in QR, but more broadly reflect a similar attitude held throughout the industry. That attitude may help to explain why only one report was received from Drivers in the Goonyella Rail System in response to a request to notify local management about the possible existence of extended Com Ints at the top of the Connors Range.

It may have been appropriate to be more specific in the text of the circular that was issued in April 2001 as regards what constituted an 'extended Com Int'. However, responses from Drivers interviewed following the derailment of EG37, clearly indicated neither real concern about the problem nor any expectation that management would actually do something about the problem. Drivers were totally familiar with the route; they experienced Com Ints in that location almost every journey and they had experienced no operational problems resulting from those Com Ints. In addition, some Drivers articulated that they held no concerns about an extended Com Int as the Train Brake would 'always' be able to control the train.

Had more feedback been received from Drivers in response to the circular about Com Ints, it is possible that management may have further explored the issue at that time and identified underlying reasons for any extended loss of Locotrol radio signals.

The under reporting of 'near misses', as noted in the March 2001 ISRS report, may deny QR valuable opportunities to learn from its experiences and, in turn, pursue appropriate preventative strategies at both a local and organisational level. While mechanisms are in place to involve operational staff at all levels in the organisation in the process of hazard identification and the development of safety strategies to mitigate or eliminate those hazards, further efforts are needed to ensure that operational staff take full advantage of those opportunities and can contribute in a meaningful way

2.5.5 Training

While it was considered that training was not directly implicated in this accident, some training issues were highlighted following a review of training procedures and interviews with Drivers. It was considered appropriate to comment on those issues in this report because of the potential of those issues to impact on rail safety.

Drivers in the Goonyella Rail System are not normally required to undergo routine on-the-job re-assessment of their driving competencies. Though Tutor Drivers play a vital role in initial and ongoing Driver training and assessment, the protocol appears to be rather informal once a Trainee Driver has completed his Driver training and becomes a fully qualified Driver.

Competency-based training recognises the need for individuals to be able to consistently demonstrate the required competencies. Inherent in that principle is the need for regular on-the-job assessment. It is possible that some Drivers' previously learnt skills may become degraded over a period of time without the existence of any incentive to hone those skills through regular on-the-job assessment. Additionally, undesirable habits may be unintentionally developed which may, in turn, have an impact on safety. Drivers who were interviewed following the derailment of EG37, held different views as to how a train should be managed during a state of Com Int on the Connors range. While none of those views were considered alarming from a safety perspective, the element of inconsistency in train handling between Drivers may have the potential to impact on safety.

It also became apparent during the investigation that Driver initial and ongoing training currently concentrates primarily on train management with little emphasis on scenario-based training or training for critical incidents (emergencies). Little meaningful use is made of available simulators for this type of training. The ability to correctly verbalise intended actions in the case of an abnormal or emergency situation, does little to prepare a Driver to react in a timely and appropriate manner on those rare occasions when he is exposed to a real-time critical incident.

Training and assessment strategies in some other industries acknowledge the value of scenario-based and emergency training. Flight crew in the airline industry, for example, are required to demonstrate their competence annually to take appropriate action in a variety of abnormal and emergency situations. That training and assessment is conducted either in an aircraft or in a flight simulator and provides management, and the flight crew, with a realistic expectation about how flight crew will cope if faced with a real-time emergency.

Despite these observations about training, it is considered that QR is making significant progress on these issues with such initiatives as the development of a Skills Passport system for both Train Drivers and Controllers.

3. CONCLUSIONS

3.1 Findings

- The Driver of EG37 was appropriately qualified and was medically fit for duty.
- The Second Driver was overdue for Driver re-accreditation. He was medically fit for duty.
- Prior to arrival at the top of the range, there were no indications of Train Brake performance problems.
- The maximum posted speed for driving trains down the Connors Range was 40 km/h.
- Com Ints occur regularly at the top of the Connors Range, however, the period of Com Int at that location is generally of short duration (less than half a minute).
- A period of extended loss of Locotrol radio communications was experienced by EG37 at the top of the Connors Range when the train was travelling at a speed of 19 km/h.
- The reason for the extended Com Int has not been able to be determined.
- The Driver did not recognise and react to the developing situation until after EG37 had passed its Point of No Return, which was calculated to have occurred at a location coincident with the loss of Locotrol radio signal.
- The Driver applied progressive amounts of both Dynamic, then Train Brake, but EG37 continued to accelerate down the range.
- The Driver applied Full Service Train Brake when the speed of EG37 approached 48 km/h but the train continued to accelerate.
- The Driver applied Emergency Brake at 52 km/h, however, despite a short period of stabilisation, EG37 continued to accelerate.
- When EG37 reached a maximum speed of 93 km/h, the train separated at the 29th wagon when it derailed at the end of the transition to a left curve at approximately 38 km from Hay Point.
- The front part of EG37, including the first 28 wagons, remained on the track. It rapidly decelerated following the separation and stopped about two kilometres from the derailment site. The front part of EG37 was undamaged.
- A total of 74 wagons, the two remote locomotives and the ELRC were derailed during the accident sequence.
- The last 18 wagons of EG37 remained on the rails during the accident sequence and were undamaged.
- EG37 derailed due to dynamic overturning of one or more wagons as a result of excessive speed combined with the effects of minor variations in the cant and curvature of the track.
- The Driver's actions were not considered to have triggered the development of the sequence of events.
- The timing of the Driver's Train Brake applications were later than prescribed by the then current procedures for handling trains down the Connors Range.

- The Driver's somewhat delayed braking actions may have had some influence on the consequences of the accident. Had Train Brake applications been made earlier, consistent with the prescribed procedures, EG37 may not have reached a speed sufficient to have derailed or a lesser number of wagons may have derailed.
- Although outside the 2-hour time limit for persons to be required to submit for tests, both the Driver and the Second Driver submitted voluntarily to be tested for the presence of alcohol. The results of those tests were negative.
- The Locotrol II system cannot provide a Driver with information about the real-time status of the Remote Feed Valve during a period of Com Int.
- A supernumerary errant square section rubber O-ring was later found to be lodged in the seat of the cut off portion of the Brake Pipe Control Valve. That fault resulted in the Remote Feed Valve continuing to pump air into the Train Brake system at the ELRC, opposing efforts by the Driver to make Train Brake applications from the front of EG37.
- Bench tests following overhaul of the Brake Pipe Control Valve should have identified the fault if it had been present at that time.
- Functional tests following the replacement of the faulty Brake Pipe Control Valve during its ELRC 144-week inspection on 5 May 2001, should have provided clues as to the existence of the fault if it had been present at that time.
- Both the Terminal Examination completed EG37 on 18 June 2001 and tests following the change-out of locomotives and wagons which occurred after the Terminal Examination, may have provided clues to identify the fault if it had been present during any of those times.
- The time at which the errant O-ring was introduced into the cut off portion of the Brake Pipe Control Valve could not be precisely determined.
- Brake tests, inspections and calculations determined that EG37 would have had not more than between 47 and 55 wagon brakes applied during the accident sequence with some of the wagon brakes toward the rear of that section of the train being only lightly applied.
- To Balance the Grade, EG37 would have required at least 60 wagon brakes to be fully applied.
- The manufacturer had not foreseen a hazard of the type identified in this accident, when Locotrol II was designed.
- QR had not foreseen a hazard of the type identified in this accident, when Locotrol II was commissioned for operation in 1985.
- There was no evidence of previous occurrences which had been triggered by a similar fault in the ELRC as that which was found following the derailment of EG37.

3.2 Significant factors

- A period of extended loss of Locotrol radio communications was experienced by EG37 at the top of the Connors Range when the train was travelling at a speed of 19 km/h.
- The Locotrol II system cannot provide a Driver with information about the real-time status of the Remote Feed Valve during a period of Com Int.
- EG37 had insufficient wagon brakes applied during the accident sequence to Balance the Grade.

- As its speed reached 93 km/h EG37 entered a left curve near the bottom of the range. The resultant forces due to the speed of EG37, combined with minor variations in the cant and curvature of the track at that location, were sufficient to cause dynamic overturning of one or more wagons.
- The Driver's somewhat delayed timing of Train Brake applications may have had some influence on the consequences of the accident. Had Train Brake applications been made earlier, consistent with the then prescribed procedures, EG37 may not have reached a speed sufficient to derail. Alternatively, a lesser number of wagons may have derailed as the train may not have reached 93 km/h until a greater portion of the train had negotiated the curve.
- A supernumerary errant square-section rubber O-ring was later found to be lodged in the seat of the cut off portion of the Brake Pipe Control Valve. That fault resulted in the Remote Feed Valve continuing to pump air into the Train Brake system at the ELRC, opposing efforts by the Driver to make Train Brake applications from the front of EG37.
- The fault described above was not detected during previous periodic maintenance inspections though it could not be positively established whether it was present at those times.
- Neither the manufacturer nor QR had foreseen a hazard of the like which was identified in this accident, when Locotrol II was designed and later commissioned.

4. SAFETY ACTION

4.1 Safety action taken

- Amended procedures for operating trains down the Connors Range were instituted when services recommenced on 5 July 2001. Those procedures are being monitored and may be subject to further change in light of continued operational experience with those procedures, the findings of this report and any other relevant safety issues identified following the derailment of EG37.
- Changes to functional test procedures for ELRC's have been implemented, which provide for a specific and detailed test of the cut off function of the Remote Feed Valve. That functional test is now required to be conducted at each Terminal Examination, thus ensuring an opportunity to detect a fault, such as was found in EG37, every 15 days.

4.2 Safety action in progess

- QR is continuing to implement the Halcro Rail recommendations (Refer to the *Driver training and checking* section of this report). It is hoped that the implementation of those recommendations will address safety issues related to Driver ongoing re-assessment of skills, training for abnormal and critical incidents, improved utilisation of train simulator facilities, and safety culture, including improved hazard and incident reporting.

4.3 Safety action outstanding

4.3.1 Operational issues

- Continue to pursue and address the underlying reason/s for the extended loss of Locotrol radio communications on the Connors Range as was experienced by EG37. Evaluate whether there may be exposure to similar risks at other locations within the QR network.
- Consider the development of threshold limits for both frequency and length of Locotrol radio communication interruptions, in conjunction with requirements for braking in the particular area, as part of an overall strategy to address any unacceptable exposure to risk within the QR network.
- Explore options that will allow real-time information about the status of Train Brake continuity to be communicated to the Driver and/or will provide a Driver with other mechanisms or options that result in improved Train Braking efficiency in abnormal and emergency situations.
- A further review of train maintenance practices and procedures, taking into consideration human factors issues, to ensure safety-critical systems are subject to more rigorous quality control.
- Implement strategies that will reinforce the notion that Drivers should operate, as far as is practicable, in accordance with prescribed procedures in order to avoid unnecessary exposure to increased operational risks.

4.4 Investigation process

Aspects of the investigation process, though not specifically discussed in the Analysis section of this report, have been referred to within the *Factual Information* section. The following safety actions relate to potential improvements in the safety investigation process that, in turn, can directly impact on operational safety by ensuring that the investigation team is able to conduct a thorough, unimpeded and timely investigation.

- Clarify existing arrangements in relation to Authorised Persons to ensure that those personnel know their rights and obligations and that information about alcohol and drugs as a potential factor in an occurrence is collected in a timely fashion.
- Review the requirement of the 2-hour timeframe for the conduct of drug and alcohol tests, as prescribed by the *Transport Infrastructure Act 1994*, in light of practical constraints that are often posed by the circumstances of rail accidents and incidents.
- Consider an expanded program for the fitment of Dataloggers, or similar technology, to ELRC units and all locomotives in order to provide safety investigation personnel with additional and timely information about potentially safety-critical issues.
- Review the interface between accident investigation and recovery operations in order that all relevant evidence is collected and/or recorded in a systematic manner and that potentially safety-critical evidence is not damaged or destroyed as a result of the recovery operation.

APPENDIX A

Analysis of 3160 locolog data extraction-derailment of EG37-01 July 2001 37.550 km Goonyella System

Corrected time	Three second samples	Brake pipe	Brake cyl.	Throttle position	Dynamic brake	Train speed	Location km	Significant event
5:52:17 AM	0	0	310	F	0	0	34.950	**Stopped Position Lead Loco 3160**
5:52:14 AM	3	0	310	F	0	0	34.950	
5:52:11 AM	6	0	310	F	0	0	34.950	
5:52:08 AM	9	0	310	F	0	3	34.953	
5:52:05 AM	12	0	310	F	0	7	34.958	
5:52:02 AM	15	0	310	F	0	11	34.968	
5:51:59 AM	18	0	310	F	0	16	34.981	
5:51:56 AM	21	0	310	F	0	20	34.998	
5:51:53 AM	24	0	310	F	0	24	35.018	
5:51:50 AM	27	0	310	F	0	28	35.041	
5:51:47 AM	30	0	310	F	0	32	35.068	
5:51:44 AM	33	0	310	F	0	36	35.098	
5:51:41 AM	36	0	310	F	0	40	35.131	
5:51:38 AM	39	0	310	F	0	43	35.167	
5:51:35 AM	42	0	310	F	0	46	35.205	
5:51:32 AM	45	0	310	F	0	50	35.247	
5:51:29 AM	48	0	310	F	0	52	35.290	
5:51:26 AM	51	0	310	F	0	55	35.336	
5:51:23 AM	54	0	310	F	0	58	35.384	
5:51:20 AM	57	0	310	F	0	60	35.434	
5:51:17 AM	60	0	310	F	0	63	35.487	
5:51:14 AM	63	0	310	F	0	65	35.541	
5:51:11 AM	66	0	310	F	0	67	35.597	
5:51:08 AM	69	0	310	F	0	69	35.654	
5:51:05 AM	72	0	310	F	0	71	35.713	
5:51:02 AM	75	0	310	F	0	72	35.773	
5:50:59 AM	78	0	310	F	0	74	35.835	
5:50:56 AM	81	0	310	F	0	75	35.898	
5:50:53 AM	84	0	310	F	0	77	35.962	
5:50:50 AM	87	0	310	F	0	78	36.027	
5:50:47 AM	90	0	310	F	0	79	36.093	
5:50:44 AM	93	0	310	F	0	81	36.160	
5:50:41 AM	96	0	310	F	0	82	36.228	
5:50:38 AM	99	0	310	F	0	83	36.298	
5:50:35 AM	102	0	310	F	0	84	36.368	
5:50:32 AM	105	0	310	F	0	85	36.438	
5:50:29 AM	108	0	310	F	0	86	36.510	
5:50:26 AM	111	0	310	F	0	87	36.583	
5:50:23 AM	114	0	310	F	0	88	36.656	

5:50:20 AM	117	0	310	F	0	88	36.729	**Pantograph down**
5:50:17 AM	120	0	310	F	0	88	36.803	
5:50:14 AM	123	10	310	F	0	93	36.880	**Position of loco 3160 when lead portion of train separates-inferred from speed data**
5:50:11 AM	126	0	310	F	0	93	36.958	
5:50:08 AM	129	10	310	F	0	93	37.035	
5:50:05 AM	132	0	310	F	0	92	37.112	
5:50:02 AM	135	10	310	F	0	92	37.188	
5:49:59 AM	138	0	310	F	0	91	37.264	
5:49:56 AM	141	10	310	F	0	91	37.340	
5:49:53 AM	144	0	310	F	0	90	37.415	
5:49:50 AM	147	10	310	F	0	90	37.490	
5:49:47 AM	150	0	310	F	0	89	37.564	
5:49:44 AM	153	10	310	F	0	89	37.638	
5:49:41 AM	156	0	310	F	0	88	37.712	
5:49:38 AM	159	10	310	F	0	88	37.785	
5:49:35 AM	162	0	310	F	0	87	37.858	
5:49:32 AM	165	10	310	F	0	87	37.930	
5:49:29 AM	168	0	310	F	0	86	38.002	
5:49:26 AM	171	10	310	F	0	86	38.073	
5:49:23 AM	174	0	310	F	0	85	38.144	
5:49:20 AM	177	10	310	F	0	85	38.215	
5:49:17 AM	180	0	310	F	0	84	38.285	
5:49:14 AM	183	10	310	F	0	84	38.355	
5:49:11 AM	186	0	310	F	0	83	38.424	
5:49:08 AM	189	10	310	F	0	82	38.493	
5:49:05 AM	192	0	310	F	0	82	38.561	
5:49:02 AM	195	10	310	F	0	82	38.629	
5:48:59 AM	198	0	310	F	0	80	38.696	
5:48:56 AM	201	10	310	F	0	80	38.763	
5:48:53 AM	204	0	310	F	0	79	38.828	
5:48:50 AM	207	10	310	F	0	79	38.894	
5:48:47 AM	210	0	310	F	0	78	38.959	
5:48:44 AM	213	10	310	F	0	77	39.023	
5:48:41 AM	216	0	310	F	0	77	39.088	
5:48:38 AM	219	10	310	F	0	76	39.151	
5:48:35 AM	222	0	310	F	0	75	39.213	
5:48:32 AM	225	10	310	F	0	75	39.276	
5:48:29 AM	228	0	310	F	0	74	39.338	
5:48:26 AM	231	10	310	F	0	74	39.399	
5:48:23 AM	234	0	310	F	0	73	39.460	
5:48:20 AM	237	10	310	F	0	73	39.521	
5:48:17 AM	240	0	310	F	0	72	39.581	
5:48:14 AM	243	10	310	F	0	72	39.641	
5:48:11 AM	246	0	310	F	0	71	39.700	
5:48:08 AM	249	10	310	F	0	71	39.759	
5:48:05 AM	252	0	310	F	0	71	39.818	
5:48:02 AM	255	10	310	F	0	70	39.877	

5:47:59 AM	258	10	310	F	0	70	39.935	
5:47:56 AM	261	10	310	F	0	70	39.993	
5:47:53 AM	264	10	310	F	0	69	40.051	
5:47:50 AM	267	10	310	F	0	69	40.108	
5:47:47 AM	270	10	310	F	0	68	40.165	**Rate of acceleration increases**
5:47:44 AM	273	10	310	F	0	68	40.222	
5:47:41 AM	276	10	310	F	0	68	40.278	
5:47:38 AM	279	10	310	F	0	68	40.335	
5:47:35 AM	282	0	310	F	0	67	40.391	
5:47:32 AM	285	10	310	F	0	67	40.447	
5:47:29 AM	288	10	310	F	0	67	40.503	
5:47:26 AM	291	10	310	F	0	66	40.558	
5:47:23 AM	294	10	310	F	0	66	40.613	
5:47:20 AM	297	10	310	F	0	66	40.668	
5:47:17 AM	300	10	310	F	0	65	40.722	
5:47:14 AM	303	10	310	F	0	65	40.776	
5:47:11 AM	306	10	310	F	0	65	40.830	
5:47:08 AM	309	10	310	F	0	65	40.884	
5:47:05 AM	312	10	310	F	0	64	40.938	**Black Mountain**
5:47:02 AM	315	10	310	F	0	64	40.991	
5:46:59 AM	318	10	310	F	0	64	41.044	
5:46:56 AM	321	10	310	F	0	64	41.098	
5:46:53 AM	324	10	310	F	0	63	41.150	
5:46:50 AM	327	10	310	F	0	63	41.203	
5:46:47 AM	330	10	310	F	0	63	41.255	**Rate of acceleration increases**
5:46:44 AM	333	10	310	F	0	63	41.308	
5:46:41 AM	336	10	310	F	0	62	41.359	
5:46:38 AM	339	10	310	F	0	63	41.412	
5:46:35 AM	342	10	310	F	0	62	41.463	
5:46:32 AM	345	10	310	F	0	62	41.515	
5:46:29 AM	348	10	310	F	0	62	41.567	
5:46:26 AM	351	10	310	F	0	62	41.618	
5:46:23 AM	354	10	310	F	0	61	41.669	
5:46:20 AM	357	10	310	F	0	61	41.720	
5:46:17 AM	360	10	310	F	0	61	41.771	
5:46:14 AM	363	10	310	F	0	62	41.823	
5:46:11 AM	366	10	310	F	0	61	41.873	
5:46:08 AM	369	10	310	F	0	61	41.924	
5:46:05 AM	372	10	310	F	0	60	41.974	
5:46:02 AM	375	20	310	F	0	61	42.025	
5:45:59 AM	378	10	310	F	0	60	42.075	
5:45:56 AM	381	20	310	F	0	60	42.125	
5:45:53 AM	384	20	310	F	0	59	42.174	
5:45:50 AM	387	20	310	F	0	60	42.224	
5:45:47 AM	390	20	310	F	0	59	42.273	
5:45:44 AM	393	50	310	F	0	59	42.323	
5:45:41 AM	396	60	310	F	0	58	42.371	

5:45:38 AM	399	60	310	F	0	59	42.420	
5:45:35 AM	402	60	310	F	0	58	42.468	
5:45:32 AM	405	60	310	F	0	58	42.517	
5:45:29 AM	408	60	310	F	0	57	42.564	
5:45:26 AM	411	60	310	F	0	58	42.613	
5:45:23 AM	414	60	310	F	0	57	42.660	
5:45:20 AM	417	70	310	F	0	57	42.708	
5:45:17 AM	420	60	310	F	0	56	42.754	
5:45:14 AM	423	70	310	F	0	57	42.802	
5:45:11 AM	426	70	310	F	0	55	42.848	
5:45:08 AM	429	70	310	F	0	56	42.894	
5:45:05 AM	432	60	310	F	0	55	42.940	
5:45:02 AM	435	40	310	F	0	55	42.986	
5:44:59 AM	438	0	310	F	0	54	43.031	**Locomotive Brake at 310 kpa**
5:44:56 AM	441	0	270	F	0	53	43.075	**Rate of acceleration decreases**
5:44:53 AM	444	0	160	F	0	53	43.119	**Brake pipe at 0 kpa**
5:44:50 AM	447	270	0	F	0	52	43.163	**Emergency Application of Brakes**
5:44:47 AM	450	340	0	F	1	51	43.205	
5:44:44 AM	453	340	0	F	1	51	43.248	
5:44:41 AM	456	340	0	F	1	50	43.289	
5:44:38 AM	459	340	0	F	1	50	43.331	
5:44:35 AM	462	340	0	F	1	49	43.372	
5:44:32 AM	465	340	0	F	1	48	43.412	
5:44:29 AM	468	340	0	F	1	48	43.452	**Full Service – Brake Pipe equalises at 340kpa**
5:44:26 AM	471	350	0	F	1	47	43.491	
5:44:23 AM	474	360	0	F	1	46	43.529	**Further brake application**
5:44:20 AM	477	390	0	F	1	45	43.567	
5:44:17 AM	480	390	0	F	1	45	43.604	
5:44:14 AM	483	390	0	F	1	44	43.641	
5:44:11 AM	486	390	0	F	1	43	43.677	
5:44:08 AM	489	390	0	F	1	42	43.712	
5:44:05 AM	492	400	0	F	1	41	43.746	
5:44:02 AM	495	420	0	F	1	40	43.779	
5:43:59 AM	498	440	0	F	1	39	43.812	**Further brake application**
5:43:56 AM	501	450	0	F	1	39	43.844	**Entire train on downgrade**
5:43:53 AM	504	450	0	F	1	37	43.875	
5:43:50 AM	507	450	0	F	1	37	43.906	

5:43:47 AM	510	450	0	F	1	35	43.935	
5:43:44 AM	513	450	0	F	1	35	43.964	
5:43:41 AM	516	450	0	F	1	34	43.993	
5:43:38 AM	519	450	0	F	1	33	44.020	
5:43:35 AM	522	450	0	F	1	32	44.047	
5:43:32 AM	525	450	0	F	1	32	44.073	**Initial application of the Train Brakes**
5:43:29 AM	528	500	0	F	1	31	44.099	
5:43:26 AM	531	500	0	F	1	30	44.124	
5:43:23 AM	534	500	0	F	1	29	44.148	
5:43:20 AM	537	500	0	F	1	29	44.173	
5:43:17 AM	540	500	0	F	1	27	44.195	
5:43:14 AM	543	500	0	F	1	27	44.218	
5:43:11 AM	546	500	0	F	1	26	44.239	
5:43:08 AM	549	500	0	F	1	26	44.261	
5:43:05 AM	552	500	0	F	1	25	44.282	**Full Dynamic Brake**
5:43:02 AM	555	500	0	E	1	24	44.302	
5:42:59 AM	558	500	0	E	1	24	44.322	
5:42:56 AM	561	500	0	D	1	23	44.341	
5:42:53 AM	564	500	0	D	1	23	44.360	
5:42:50 AM	567	500	0	D	1	22	44.378	
5:42:47 AM	570	500	0	D	1	22	44.397	
5:42:44 AM	573	500	0	D	1	21	44.414	
5:42:41 AM	576	500	0	D	1	21	44.432	
5:42:38 AM	579	500	0	D	1	21	44.449	
5:42:35 AM	582	500	0	D	1	20	44.466	
5:42:32 AM	585	500	0	D	1	20	44.483	
5:42:29 AM	588	500	0	D	1	20	44.499	
5:42:26 AM	591	500	0	D	1	20	44.516	
5:42:23 AM	594	500	0	C	1	19	44.532	
5:42:20 AM	597	500	0	C	1	19	44.548	
5:42:17 AM	600	500	0	C	1	19	44.563	**Comm-Int (from Driver's statement- "short straight at the top of the range" - 44.430 to 44.750 km - "plus flashing DB 8")**
5:42:14 AM	603	500	0	F	1	19	44.579	
5:42:11 AM	606	500	0	C	1	19	44.595	
5:42:08 AM	609	500	0	9	1	19	44.611	
5:42:05 AM	612	500	0	8	1	18	44.626	
5:42:02 AM	615	500	0	8	1	18	44.641	
5:41:59 AM	618	500	0	6	1	18	44.656	
5:41:56 AM	621	500	0	5	1	18	44.671	
5:41:53 AM	624	500	0	5	1	18	44.686	
5:41:50 AM	627	500	0	4	1	18	44.701	
5:41:47 AM	630	500	0	4	1	17	44.715	
5:41:44 AM	633	500	0	2	1	17	44.729	

5:41:41 AM	636	500	0	2	1	17	44.743	
5:41:38 AM	639	500	0	1	1	17	44.758	
5:41:35 AM	642	500	0	1	1	17	44.772	
5:41:32 AM	645	500	0	1	1	17	44.786	**Driver engages Dynamic Brake**
5:41:29 AM	648	500	0	0	0	17	44.800	
5:41:26 AM	651	500	0	0	0	17	44.814	
5:41:23 AM	654	500	0	0	0	17	44.828	
5:41:20 AM	657	500	0	0	0	17	44.843	
5:41:17 AM	660	500	0	0	0	17	44.857	
5:41:14 AM	663	500	0	0	0	17	44.871	
5:41:11 AM	666	500	0	0	0	17	44.885	
5:41:08 AM	669	500	0	0	0	17	44.899	
5:41:05 AM	672	500	0	0	0	17	44.913	**Hold Point at Hatfield - train balanced**
5:41:02 AM	675	500	0	0	0	17	44.928	
5:40:59 AM	678	500	0	0	0	17	44.942	
5:40:56 AM	681	500	0	0	0	17	44.956	
5:40:53 AM	684	500	0	0	0	17	44.970	
5:40:50 AM	687	500	0	0	0	17	44.984	
5:40:47 AM	690	500	0	0	0	17	44.998	
5:40:44 AM	693	500	0	0	0	18	45.013	
5:40:41 AM	696	500	0	0	0	18	45.028	
5:40:38 AM	699	500	0	0	0	18	45.043	
5:40:35 AM	702	500	0	0	0	18	45.058	
5:40:32 AM	705	500	0	0	0	19	45.074	
5:40:29 AM	708	500	0	0	0	19	45.090	
5:40:26 AM	711	500	0	0	0	19	45.106	
5:40:23 AM	714	500	0	0	0	20	45.123	
5:40:20 AM	717	500	0	0	0	20	45.139	**Driver closes throttle**
5:40:17 AM	720	500	0	1	0	20	45.156	
5:40:14 AM	723	500	0	2	0	21	45.173	
5:40:11 AM	726	500	0	3	0	21	45.191	
5:40:08 AM	729	500	0	4	0	21	45.208	
5:40:05 AM	732	500	0	7	0	21	45.226	**Auto Transformer at 45.225km**
5:40:02 AM	735	500	0	7	0	22	45.244	
5:39:59 AM	738	500	0	7	0	22	45.263	
5:39:56 AM	741	500	0	7	0	22	45.281	
5:39:53 AM	744	500	0	7	0	22	45.299	
5:39:50 AM	747	500	0	7	0	23	45.318	
5:39:47 AM	750	500	0	7	0	23	45.338	
5:39:44 AM	753	500	0	7	0	23	45.357	
5:39:41 AM	756	500	0	7	0	24	45.377	
5:39:38 AM	759	500	0	7	0	24	45.397	
5:39:35 AM	762	500	0	7	0	24	45.417	
5:39:32 AM	765	500	0	7	0	25	45.438	
5:39:29 AM	768	500	0	7	0	25	45.458	
5:39:26 AM	771	500	0	7	0	27	45.481	

5:39:23 AM	774	500	0	7	0	27	45.503	
5:39:20 AM	777	500	0	7	0	28	45.527	
5:39:17 AM	780	500	0	7	0	28	45.550	
5:39:14 AM	783	500	0	7	0	30	45.575	
5:39:11 AM	786	500	0	7	0	29	45.599	
5:39:08 AM	789	500	0	7	0	31	45.625	
5:39:05 AM	792	500	0	7	0	32	45.652	
5:39:02 AM	795	500	0	7	0	33	45.679	
5:38:59 AM	798	500	0	7	0	33	45.707	
5:38:56 AM	801	500	0	7	0	34	45.735	
5:38:53 AM	804	500	0	8	0	35	45.764	**Top of Range**
5:38:50 AM	807	500	0	9	0	36	45.794	
5:38:47 AM	810	500	0	9	0	36	45.824	
5:38:44 AM	813	500	0	9	0	37	45.855	
5:38:41 AM	816	500	0	9	0	38	45.887	
5:38:38 AM	819	500	0	9	0	39	45.919	
5:38:35 AM	822	500	0	9	0	39	45.952	
5:38:32 AM	825	500	0	9	0	40	45.985	
5:38:29 AM	828	500	0	9	0	41	46.019	
5:38:26 AM	831	500	0	9	0	42	46.054	
5:38:23 AM	834	500	0	9	0	42	46.089	
5:38:20 AM	837	500	0	9	0	44	46.126	
5:38:17 AM	840	500	0	9	0	44	46.163	
5:38:14 AM	843	500	0	A	0	45	46.200	
5:38:11 AM	846	500	0	B	0	46	46.238	
5:38:08 AM	849	500	0	B	0	46	46.277	
5:38:05 AM	852	500	0	B	0	47	46.316	
5:38:02 AM	855	500	0	A	0	47	46.355	
5:37:59 AM	858	500	0	A	0	48	46.395	
5:37:56 AM	861	500	0	A	0	49	46.436	
5:37:53 AM	864	500	0	9	0	50	46.478	
5:37:50 AM	867	500	0	9	0	51	46.520	
5:37:47 AM	870	500	0	9	0	51	46.563	
5:37:44 AM	873	500	0	9	0	52	46.606	
5:37:41 AM	876	500	0	9	0	53	46.650	
5:37:38 AM	879	500	0	9	0	55	46.696	
5:37:35 AM	882	500	0	9	0	54	46.741	
5:37:32 AM	885	500	0	9	0	56	46.788	
5:37:29 AM	888	500	0	9	0	55	46.833	
5:37:26 AM	891	500	0	9	0	57	46.881	
5:37:23 AM	894	500	0	9	0	56	46.928	
5:37:20 AM	897	500	0	9	0	58	46.976	
5:37:17 AM	900	500	0	C	0	57	47.023	
5:37:14 AM	903	500	0	C	0	58	47.072	
5:37:11 AM	906	500	0	C	0	57	47.119	
5:37:08 AM	909	500	0	D	0	58	47.168	
5:37:05 AM	912	500	0	D	0	58	47.216	
5:37:02 AM	915	500	0	D	0	59	47.265	
5:36:59 AM	918	500	0	D	0	58	47.313	
5:36:56 AM	921	500	0	D	0	58	47.362	
5:36:53 AM	924	500	0	D	0	57	47.409	

5:36:50 AM	927	500	0	D	0	58	47.458	
5:36:47 AM	930	500	0	D	0	57	47.505	
5:36:44 AM	933	500	0	F	0	57	47.553	
5:36:41 AM	936	500	0	F	0	56	47.599	
5:36:38 AM	939	500	0	F	0	57	47.647	
5:36:35 AM	942	500	0	F	0	56	47.693	
5:36:32 AM	945	500	0	F	0	56	47.740	
5:36:29 AM	948	500	0	F	0	54	47.785	**Hatfield Departure Signals**
5:36:26 AM	951	500	0	F	0	54	47.830	
5:36:23 AM	954	500	0	F	0	53	47.874	
5:36:20 AM	957	500	0	F	0	53	47.918	
5:36:17 AM	960	500	0	E	0	51	47.961	
5:36:14 AM	963	500	0	D	0	50	48.003	
5:36:11 AM	966	500	0	D	0	49	48.043	
5:36:08 AM	969	500	0	D	0	49	48.084	
5:36:05 AM	972	500	0	D	0	48	48.124	
5:36:02 AM	975	500	0	C	0	48	48.164	
5:35:59 AM	978	500	0	C	0	47	48.203	
5:35:56 AM	981	500	0	B	0	47	48.243	
5:35:53 AM	984	500	0	A	0	46	48.281	
5:35:50 AM	987	500	0	A	0	46	48.319	
5:35:47 AM	990	500	0	9	0	45	48.357	
5:35:44 AM	993	500	0	9	0	45	48.394	
5:35:41 AM	996	500	0	8	0	44	48.431	
5:35:38 AM	999	500	0	8	0	44	48.468	
5:35:35 AM	1002	500	0	7	0	44	48.504	
5:35:32 AM	1005	500	0	6	0	43	48.540	
5:35:29 AM	1008	500	0			43	48.576	

Derailment of Coal Train EG37 — Conners Range 1 July 2001

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