

Independent Inquiry Report

Coal Train Collision

Beresfield NSW

23 October 1997



**New South Wales Department of Transport
Transport Safety Bureau**

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Mr Jock Murray
Director General
NSW Department of Transport

Dear Mr Murray,

In accordance with Section 58(4) of the NSW Rail Safety Act 1993 we are pleased to provide you with the results of an independent inquiry into the railway accident at Beresfield, NSW, on Thursday 23 October 1997.

The report is intended to enhance safety and includes a description of the accident, an analysis of the factual information pertaining to the event, findings, significant contributing factors, and the identification of a number of safety deficiencies. It was not the intention of this report to attribute blame or apportion liability.

During the inquiry we were provided with invaluable cooperation by the NSW Transport Safety Bureau, FreightCorp, State Rail Authority, The Rail Access Corporation, Railway Services Authority of NSW, and the Public Transport Union.

Yours sincerely,

Barry A. Sargeant
Investigator in Charge
Bureau of Air Safety Investigation

Alan Hobbs
Human Performance Investigator
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Note 1. All times shown are in 24 hour format (hhmm or hhmm:ss), Eastern Standard Time, referenced to recorded data from locomotive No. 8246, unless otherwise indicated.

Note 2. Up, in the context of the up coal road, or up main line, signifies travel towards Sydney. Down signifies away from Sydney.

EXECUTIVE SUMMARY

On 23 October 1997, at 0632 hours, coal train DR396 collided with the rear of another coal train, MT304 standing at Tarro, en-route to Port Waratah. The collision occurred in clear conditions on the up coal road, adjacent to the western end of Beresfield railway station. Both trains were operated by FreightCorp.

The driver and observer of DR396 suffered serious injuries, as did a person standing on the station platform. The Stationmaster also suffered minor injuries.

The three locomotives and first ten coal wagons of DR396 were derailed, as were the three rear wagons of MT304. Wreckage blocked both coal roads and adjacent main lines. Beresfield station and associated structures also suffered extensive damage. Considerable disruption to passenger and freight operations resulted from the accident.

The response to the emergency by local services, and rail organisations, was carried out with speed and efficiency, substantially in accordance with established procedures. Restoration of services was largely accomplished by 27 October, without further injury.

The investigation found the circumstances of the accident were consistent with the crew of DR396 failing to comply with caution and stop signal indications protecting the stationary MT304. Reduced driver alertness, associated with work related fatigue, was found to be a significant factor in the events leading to the collision, together with a system intolerant of human error, and inadequate safety defences.

During the investigation a number of safety deficiencies were identified for further study by the NSW Department of Transport.

INTRODUCTION

Following a railway accident at Beresfield NSW, on 23 October 1997, the NSW Minister for Transport directed the Director General of the NSW Department of Transport to establish an independent inquiry into the accident, in accordance with the NSW Rail Safety Act 1993.

Section 58. (4) of that Act states;

The Minister may require the Director-General or a person or body nominated by the Minister to inquire into and report to the Minister on any railway accident or incident that may affect the safe construction, operation or maintenance of a railway.

The Director General subsequently authorised two investigators from the Bureau of Air Safety Investigation (BASI) to conduct the investigation, in accordance with the terms of reference specified below.

- 1. Examine the systems, procedures and processes which were in place prior to the incident occurring to determine whether the potential risk of an incident of this type occurring had been properly identified and appropriate measures introduced to minimise the risk of occurrence. In addressing this term of reference consideration should be given to existing risk management strategies, associated safety management systems, appropriate standards contained in the safety accreditation, other management decisions which may have directly or indirectly affected the risk, and previous history of any other incidents similar in nature.*
- 2. Examine all factors, both direct and indirect, technical and human, which contributed to the occurrence of this incident and, in particular, whether there was any deviation from the accredited safety performance standards.*
- 3. Examine the nature of the response to the incident to determine its efficiency and effectiveness in dealing with the incident. Consideration should be given to at least the emergency response and adherence to emergency management plans and the implementation of, if any, short, medium or long term strategies to minimise the potential for a similar incident to recur.*
- 4. Report on any matters arising from the investigation which have implications for identifying weaknesses which required rectification in other associated or unrelated safety management systems.*

The provision of investigators by BASI resulted from an Inter-Government Agreement concerning the investigation of rail safety occurrences within Australia. The investigators were provided with technical assistance by FreightCorp, State Rail Authority, The Rail Access Corporation, and the Railway Services Authority of NSW.

It was not the purpose of this investigation to attribute blame or apportion liability to any person or organisation.

INVESTIGATION METHODOLOGY

The purpose of this investigation is to enhance rail safety. A primary objective was to determine what happened, and why the accident occurred. Of equal 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 for adversely affecting safety.

Experience has shown that a significant proportion of safety occurrences result from an often complex interaction of factors, rather than from a simple error or violation on the part of operational personnel. Many of these factors, including task and workplace conditions, can have an immediate effect on the operation being performed, whilst other factors relating to organisational or systemic processes may remain unnoticed for considerable periods.

Individually, these factors are generally insufficient to cause a breakdown in safety. However, a combination of organisational and task factors may promote an environment conducive to human error, leading to a safety hazard. Should defences designed to warn and protect against those hazards be absent or inadequate then a safety breakdown is inevitable. It was therefore necessary for the investigation 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 from a number of sources, including;

- visits to the accident site and other locations associated with the occurrence
- observation of coal train operations and recorded video footage
- a review of operating procedures and practices
- commissioning and evaluation of specialist reports
- a study of track layouts and limitations
- an examination of signalling equipment and procedures.
- a review of reported signalling events
- analysis of recorded data
- personnel interviews
- a study of the NSW rail safety database
- research into the effects of crew rostering procedures

1. FACTUAL INFORMATION

1.1 Sequence of events

On the morning of 23 October 1997 coal train DR396 was returning to Port Waratah, Newcastle, after taking on a full load of coal from the Drayton loading terminal in the Hunter Valley.

The overall length of DR396 was 1,320 m, with a total laden weight of 7,596 t, consisting of three 82 class locomotives operating in tandem, hauling 72 NHVF coal wagons. The lead locomotive was No. 8246, followed by No's. 8219 and 8247. The train was crewed by a driver and an observer. The driver was seated at the driver's control position on the left side of the cabin, while an assistant driver occupied the observer's position on the right side of the cabin.

The journey from Port Waratah to Drayton, and subsequent loading, was completed without incident. During the return journey the crew reported observing clear signals throughout. Near Thornton the driver of passenger train 715, travelling in the opposite direction, waved to the driver of DR396, who waved back. Passing Thornton, on the up coal road, the train entered a section of track within which the signals were automatically controlled by the movement of trains. The reported weather in the area at the time was fine, earlier areas of fog had mainly dissipated, and the sun was about 16.5° above the horizon, some 42° left of the direction of travel.

Four parallel rail tracks, comprising the dual coal roads and the main northern line, run in a constant direction for about 3.9 km between Thornton to the WNW of Beresfield, and Tarro, located ESE of Beresfield (see figure 1). The overall gradient is downhill from Thornton to Tarro, apart from a small rise at Beresfield. The maximum speed limit for DR396 was 80 km/h.

Analysis of recorded data from the lead locomotive indicated that the train passed signal C113.0, just east of Thornton, at 0630:15, at 45 km/h with dynamic braking selected. It then continued for a further 1,404 m on a predominantly downhill gradient, gradually increasing speed to 63 km/h until it passed signal C112.2 at 0631:46, where the gradient was generally level. Vigilance control acknowledgments were made at 0630:54 and 0631:20.

At 0632:02, some 308 m beyond C112.2, at a speed of 62 km/h, with dynamic braking still engaged, the air brake pipe pressure began to decrease from 490 kPa, consistent with the application of emergency braking. However, at 0632:25 the lead locomotive collided with the rear wagon of a stationary coal train, MT304, standing at signal C110.8, near Tarro. The distance travelled from the application of air brakes to the point of impact was some 370 m.

The point of impact was located 678 m beyond signal C112.2, at position 179.770 km (from Sydney Central), adjacent to the western end of Beresfield station (see figures 2 and 3). About 115 m prior to impact the crew of DR396 jumped from the locomotive, sustaining serious injuries. The recorded speed of the locomotive at impact was 50 km/h.

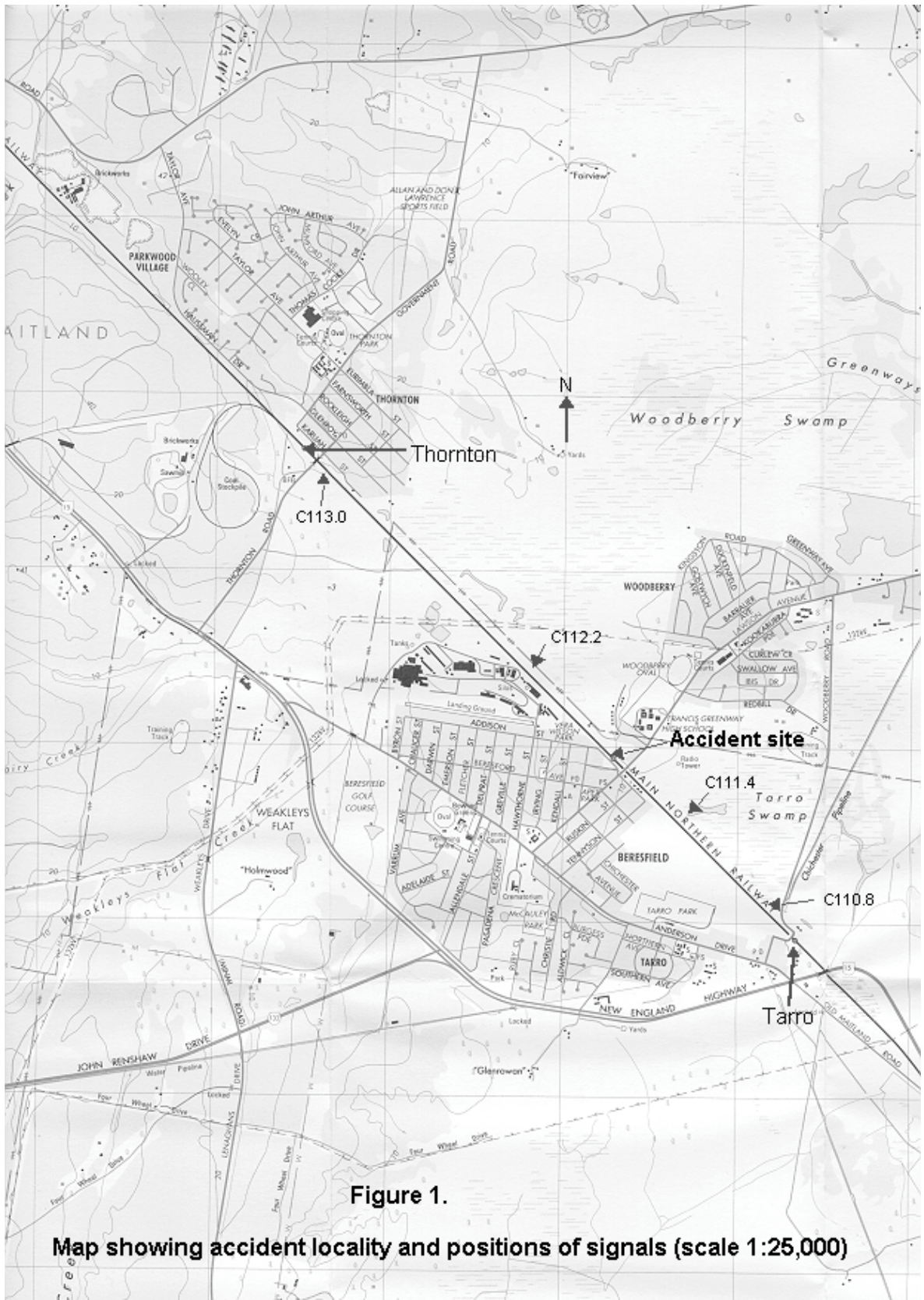


Figure 1.

Map showing accident locality and positions of signals (scale 1:25,000)



Figure 2
View of Beresfield Station looking
in direction of travel. DR396 in foreground.



Figure 3
MT305 standing at signal C110.8
Beresfield Station in distance.

MT304 was en-route from the Mount Thorley loading facility to Port Waratah and consisted of two 90 class locomotives operating in tandem, hauling 66 NHKF coal wagons. The lead locomotive was No. 9005, followed by No. 9026. The overall length of MT304 was 1,194 m, with a total laden weight of 6,920 t. The end of the train carried a standard battery operated red light. The train was crewed by a driver and an observer. The driver was seated at the driver's control position at the time of the accident.

Following the initial impact the lead locomotive of DR396 derailed and came to rest on top of the 64th wagon of MT304, laying across both coal roads and extending to the edge of the adjacent street (see figures 4 and 5). Locomotive 8219 derailed and came to rest inverted, across both coal roads, and the main down line. The third locomotive, No. 8247, also derailed, crossing the main down line and station platform before coming to rest across both main lines and the platform. The first 10 wagons of DR396 concertinaed into the locomotives and derailed, blocking both coal roads and the down main line.



Figures 4 and 5 showing wreckage distribution. Overhead bridge is located at eastern end of platform.

The three rear coal wagons of MT304 were also derailed. Damage to locomotives and rolling stock was extensive, and typical of this type of collision (see figures 6 and 7). Both trains were operated by FreightCorp.

The collision was first reported by the crew of passenger train 717, en-route from Newcastle to Telarah. As that train was travelling along the main down line between Tarro and Beresfield, about three minutes behind timetable, the driver saw what appeared to be smoke in the vicinity of Beresfield station. As he approached Beresfield the driver saw a locomotive laying on its side across the main down line.

The passenger train was stopped at signal C111.4 where the driver unsuccessfully attempted to contact the Broadmeadow signalling complex by two-way radio. He then contacted the driver of MT304 and advised him that his train had been struck by another train.

The driver of MT304 had already sent his observer towards the rear of the train to investigate a loss of brake pipe pressure, following what appeared to have been a slight impact. The guard of train 717 was then able to use the telephone at signal C111.4 to advise the train controller of the accident, to call out the emergency services, and to stop all trains operating in the area. The observer of MT304 made contact with North-West Control by two way radio and also reported the collision. As soon as he had been advised of the collision the driver of MT304 placed a track circuit shorting clip on the down coal road, then confirmed that the down coal road signal was displaying a stop indication.

The wreckage of both trains, and associated coal spillage, lay spread over both coal roads, both main lines, and Beresfield Station for a distance of about 130 m. The permanent way, the station platform and associated structures, together with surrounding areas were all extensively damaged (see figures 8 and 9). The Stationmaster at Beresfield suffered minor injuries, while a passenger waiting on the platform suffered more serious injuries. They were subsequently transported to hospital by ambulance, together with both injured drivers.

Although the actual impact was seen by bystanders, there were no witnesses to the accident who could provide information regarding the indications of the signals at C113.0 and C112.2.



Figures 6 and 7 showing massive disruption to locomotives and rolling stock.



Figures 8 and 9. Both coal roads and main northern lines were completely blocked. Extensive damage to the Beresfield station booking office and platform is evident

1.2 Train characteristics and serviceability – DR396

1.2.1 General

Coal service DR396 comprised three Clyde/General Motors Model JT42C diesel-electric 82 class locomotives hauling a 72 wagon unit train (unit train 8). Each locomotive is equipped with a 12 cylinder turbo-charged two-stroke diesel engine driving an electrical generator. Electrical power from that generator is distributed to six traction motors, each directly geared to a pair of driving wheels. The traction motors can also be utilised to provide dynamic braking. A Westinghouse 26L air braking system is fitted, controlled from the driving position.

A major element of the locomotive control system involves the interrelated functions of the throttle, governor and load regulator, most of which is computer controlled. The driver is able to initiate throttle, dynamic braking, and reverser functions through operating handles located on the locomotive controller console .

An examination of a predicted stopping distance table for DR396 indicated the train could have been stopped from 63 km/h on a level gradient in 579 m, using emergency braking. This distance included an allowance of +10%. The predicted stopping time was 47 seconds. The calculated distance from signal C112.2 to the point of impact was 678 m.

The maintenance history of all three locomotives was examined, together with recorded data. No evidence was found to indicate that each locomotive was other than capable of normal operation immediately prior to the accident, and that all scheduled maintenance had been carried out.

A unit train consists of a number of linked freight vehicles operated as a single element between scheduled maintenance cycles. This procedure provides operational and maintenance advantages. Unit train 8 consisted of 72 NHVF wagons operating on an approved 56 day maintenance cycle, with intermediate inspections every 14 days. Records indicated that the unit train was serviceable, and all scheduled maintenance, including braking tests, had been carried out.

1.2.2 Vigilance control system

Each locomotive was equipped with a vigilance control system as an aid for monitoring driver alertness, and as a defence against driver incapacity. The system utilised reset buttons located at the driver and observer positions. When operating in tandem the system is suppressed on the trailing locomotives. The vigilance timer commences after the locomotive's brakes are released. Following a period of 60 seconds without resetting, or operating the brakes to give a brake cylinder pressure in excess of 300 kPa, a warning indicator light will commence flashing on the drivers console. Failure to operate a reset button will cause a bell to commence ringing after 17 seconds, in conjunction with the flashing light. Should the driver or observer fail to acknowledge this condition within the next 17 seconds, the vigilance control system will apply all locomotive and wagon air brakes. Recorded data indicates the vigilance control system was serviceable prior to impact.

Both the driver and observer of DR396 indicated there was no set procedure for operating the vigilance control system. Either one would press the button, but usually this action was undertaken by the person occupying the driver's control seat.

1.2.3 Automatic defence systems

There was no form of warning system fitted to this train to alert the crew if a stop indication was passed. Nor was there any device provided to automatically halt the train if it passed a stop indication.

1.2.4 Visibility of coal trains

Observations of coal trains travelling east through Beresfield indicated that the rear of a train would be seen against a background of sky and should be clearly visible significantly well before the point at which the brakes were applied. However, because of the straight track, only the rear of the stationary train would have been visible, and the crew of the approaching train would have been presented with a relatively small target until close to the rear wagon.

The stationary train was equipped with a battery operated flashing rear light. However, this light is designed to only illuminate in the hours of darkness. In daylight it would be of virtually no value, even if it had been activated. Research has indicated that flashing lights or strobes have little attention getting value in daylight conditions, however, where lights are used, white unfiltered lights will be of greater value than lights with a red filter.

1.3 Serviceability of track and associated infrastructure

There was no evidence found to indicate that the condition of the coal road, and its associated infrastructure, contributed to this accident.

1.4 Signalling system

The progress of trains on the up coal road between signal C113.0, just east of Thornton, and C110.8 at Tarro, is dependent on a series of automatically controlled signals. The normal operation of those signals is solely triggered by the passage of trains through a succession of track circuits. A schematic of signal locations and overlaps for the area concerned is shown at figure 10.

Each automatic signal provides one of three indications; CLEAR (Green), CAUTION (Yellow), or STOP (Red). The normal position of an automatic signal is green. When a train occupies the first track circuit past a signal, the signal changes to red, and will remain red by the subsequent occupation of the following track circuits, until the rear of the train has proceeded a safe distance beyond the next signal ahead (called the overlap), at which time the first signal concerned will change to a proceed (caution) indication, then to clear when the signal ahead changes to a proceed indication. Should a fault develop within the signal circuitry the system is designed to default to a stop indication.

Signal C113.0 is suspended from an overhead gantry. Signals C112.2, 111.4 and C110.8 are positioned on stands to the left of the coal road (see figures 11 and 12).

Comprehensive testing was carried out by technical experts, utilising established industry standards, on the track circuitry associated with the operation of the signals between C113.0 and C110.8. Those examinations failed to reveal any defect prior to the collision that could have resulted in incorrect signal indications.

Train crew who had travelled along the up coal on the morning of the accident were interviewed regarding the operation of the automatic signals between Thornton and Tarro. All reported that the signalling equipment had functioned normally.

At 0400 on the morning of 22 October 1996, the driver of a coal train standing at C113.0 reported an apparent malfunction of signals C112.2 and C111.4. Subsequent testing failed to reveal any fault. That particular incident was reviewed during the course of this investigation to determine if there was a latent defect in the signalling system. A specialist analysis concluded that the signals had been functioning normally. Due to a combination of dark conditions, and the proximity of another unseen train in advance, the driver saw a combination of signal indications ahead that led him to believe the signals were malfunctioning.

A similar incident to the above was also reported to have occurred during the early morning of 13 November 1997, apparently affecting signal C112.2. Extensive testing failed to find any defect. A subsequent investigation again concluded that the driver who reported the apparent malfunction was not aware of the presence of a train in advance, and had misinterpreted the existing situation. In each case safety was not compromised as the train was already stopped at a red signal.

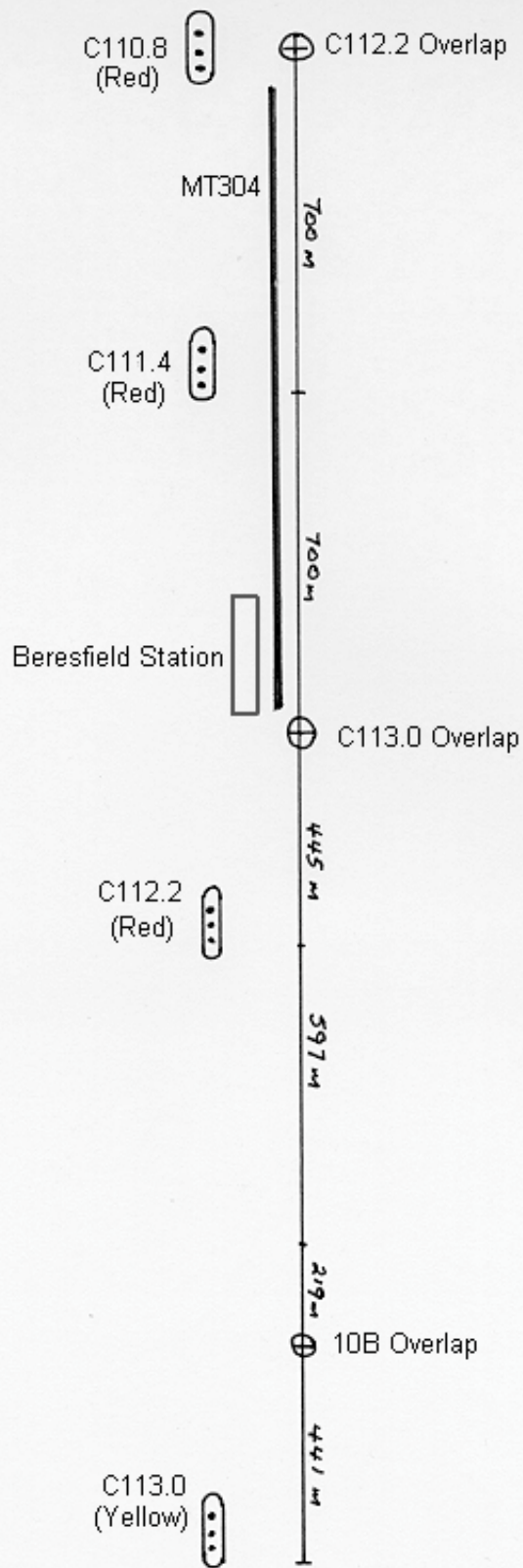


Figure 10.

Schematic of signal indications immediately prior to the collision.



Figures 11 and 12 showing signals C113.0 and C112.2.

1.5 Personnel

1.5.1 Train crew details – DR396

	Driver	Observer
Sex:	Male	Male
Age:	44 years	34 years
Classification:	Train Driver	Assistant Train Driver
Last assessment type:	Periodic/Progressive	Periodic/Progressive
Date:	9/10/97	12/8/97
Certification:	Competent	Competent
Medical status:	Group 1	Group 1
Date:	20/8/93	19/8/97
Limitations:	Nil	Nil

The driver and observer had worked together as a crew for the past 5-6 years. Both remembered few details of the events leading to the collision. They were unable to recall the signal indications as the train approached Beresfield, particularly those of C113.0 and C112.2. Although the observer could not remember, the driver said that both he and his assistant saw a train on top of the hill immediately ahead. The driver placed the brake handle in the emergency braking position, but when he realised a collision was inevitable he told the observer to get out, then followed him via the right side door of the locomotive. Emergency braking continued until impact.

Both the driver and observer reported having no difficulties in sleeping during previous rest periods, nor did they consider they were affected by any stressful life events. Vision correcting lenses were not required to be worn by either driver, and at the time of the accident sunglasses were not being worn.

The results of post accident blood alcohol tests conducted on the driver and observer proved negative. A number of 'Tilcotil' tablets were found in the driver's bag, located in the lead locomotive. The tablets were an anti-inflammatory medication, which the driver said he was taking to relieve symptoms associated with an elbow injury, although the drug was not prescribed to him. Eleven per cent of patients taking this drug experience side effects. In rare cases (less than 2%) these side effects may include headache, tiredness, and visual disturbances. (Reference MIMS 1997)

Recorded data from coal trains operated by the driver of DR396, in the 17 days prior to the accident, was compared with his operation of DR396. Although there were some variations noticed in powering and dynamic braking techniques, in general the journeys were somewhat similar. The specialist who conducted the comparison concluded that no fault was observed in driving technique.

1.5.2 Fatigue and driver alertness

Train crews operating from Broadmeadow can be rostered to work for up to 11 consecutive days.

A specialist analysis was conducted by the University of South Australia Centre for Sleep Research on the level of fatigue attributable to the work schedule of the train crew of DR396. That analysis examined the hours of work for the nine days prior to the accident, based on the roster shown below (figure 13.).

During the previous 15 days both men worked the following shifts;

Date	Sign On	Job	Sign Off	Hours worked
8.10.97	1000	Local	1810	8:10
9.10.97	1000	SF543	1900	9:00
10.10.97	1100	RV347	1930	8:30
11.10.97	1000	DR343	1800	8:00
12.10.97	0745	Local	1545	8:00
13.10.97	0400	Local	1240	8:40
14.10.97	0400	Local	1300	9:00
15.10.97		Off		
16.10.97		Off		
17.10.97		Off		
18.10.97	0930	TB438	1630	7:00
19.10.97	2210	Enfield	0550	7:40
20.10.97	1750	Return	0000	6:10
21.10.97	2330	DR301	0850	9:20
22.10.97	2300	DR395		

Figure 13.

A computer model developed by the Centre for Sleep Research returned a fatigue score for the driver and observer of 83-84, compared to a recommended maximum fatigue score of 80 for high risk activities such as train driving.

The analysis concluded that both crew members, at the time of the accident, would have been experiencing significant work-related fatigue. Not only would this have resulted in impaired hand-eye coordination and reaction/response times, but would have also resulted in reduced alertness and a heightened risk of involuntary sleep.

The level of fatigue experienced by the train crew was directly related to the structure of their shifts in the five days prior to the accident, reducing the amount of sleep they would get during the intervening break periods. That combination of night and afternoon shifts would have produced a limited opportunity to recover, particularly when having to sleep during the day. Shiftworkers who are required to work at night and sleep during the day typically build up increasing sleep debts with each successive night of work. This is because shiftworkers experience day sleep which is generally shorter in duration and poorer in quality than nocturnal sleep (Tilley 1982). A recent study of truck drivers in North America found that drivers who were required to sleep during daytime had an average of 3.8 hours of sleep each day, even though they reported that 7.2 hours of sleep was their ideal sleep time. (Vespa, Wylie, Mitler and Scutz, *Study of Commercial Vehicle Driver Rest Periods and Recovery of Performance in an Operational Environment*).

The Australian Railways Shiftwork and Workload Study 1997, Half Yearly Interim Report, contains an evaluation of the sleep and work patterns of 24 drivers at the Broadmeadow Locomotive Depot. The report indicates that although the work is relatively evenly distributed across the 24 hour day, drivers did not tend to obtain significant sleep during daylight hours, even when they were required to work at night. These results suggest that drivers at Broadmeadow are accumulating significant sleep debts when working at night.

There are various forms of sleep on the sleep-wakefulness continuum, ranging from a state of drowsiness (stage 1 sleep) as a person transitions from wakefulness to sleep, through to deep sleep. Generally, a person woken from stage 1 sleep will not be aware that they have been asleep. Stage 1 sleep can occur as 'microsleeps', or may involve longer episodes of lowered alertness, referred to as Automatic Behaviour Syndrome (ABS). The Transportation Safety Board of Canada defines Automatic Behaviour Syndrome as:

'A state of fatigue in which we are essentially sleeping with our eyes open. While able to perform simple or familiar tasks, we are unable to respond quickly to more critical tasks and situations. In sleep lab studies, participants experiencing ABS show brain waves characteristic of sleep'.

(A Guide For Investigating For Fatigue May 1997, p. A-1)

The potential for vehicle drivers to 'sleep with the eyes open' was referred to as long ago as 1929 (Miles W. Scientific American June 1929, pp. 489-492). Recent scientific studies have confirmed that fatigued drivers can continue to drive while being asleep with the eyes open (Horne and Reyner 1998). In a US study, truck drivers were monitored for signs of sleep while driving normal deliveries on US public roads. Electroencephalogram (EEG) readings indicated that some drivers were continuing to drive while in stage 1 sleep for periods of up to 20 seconds (Mittler 1998).

In recent years, many road and rail transport organisations have recognised the need to actively manage driver fatigue. For example, the Western Australian Government is introducing a Fatigue Management Code of Practice for commercial vehicle drivers in that state (Draft Code of Practice, January 1998). In the rail industry, Queensland Rail is currently developing a fatigue management program for train crew (Featherstone and McDonnell 1998).

Unless people are extremely sleep deprived, involuntary sleep generally will not occur in environments that are stimulating, uncomfortable or challenging. In normal circumstances, the task of driving a locomotive is not likely to be challenging to an experienced driver, and the environment in the cab of an 82 class locomotive is relatively quiet and comfortable. In such environments, a sleep deprived person can find it physically impossible to remain awake, even if they are trying hard to stay awake by willpower.

The train crew commented on the difficulty of remaining alert in the relaxed environment of the locomotive cabin, although they both felt they were well rested prior to commencing duty. The driver said he usually slept for about 5-6 hours after finishing work. Later he would have a further two hours sleep before returning to work.

The observer said he was able to sleep during the day. Each crewmember spoke about disruptions caused by roster changes, often at short notice. In general, start times were usually moved forward, rather than delayed.

1.5.3 Crew operating procedures

The basic duties of all train crews operating in NSW are described in the Safe Working Units (SWU) issued by the State Rail Authority. That document states:

This unit presents a compilation of basic duties of train crews. The list of duties is not intended to be exhaustive and must be read in conjunction with relevant instructions in other safe working documents. (SWU 141)

The basic listed duties of drivers cover such matters as;

- driver qualifications
- operating trains efficiently and safely
- controlling the movement of the train
- maintaining on-time running
- maintaining equipment and rolling stock

Drivers are required to pay strict attention to and obey all fixed signal indications, and adjust the speed of the train in accordance with the signal indication displayed. In addition, when a fixed signal is at stop, the driver shall bring the train to a stand as close as possible to the signal in order to keep the signal in clear view at all times, and be ready to proceed when the signal indication changes.

The basic listed duties of observers (freight trains) cover such matters as;

- qualifications
- obeying instructions
- checking the train before departure
- assisting the driver
- maintaining on-time running
- ensuring the safety of the train
- keeping records
- having all necessary equipment

Assisting the driver requires the observer to;

- unless otherwise engaged, operate the vigilance control in conjunction with the driver
- watch the track and assist the driver by observing signals, speed boards and track maintenance work
- warn the driver about any problem that needs attention

The listed safe working items do not provide drivers/observers with specific guidance as to how a particular duty is to be performed. Such guidance is normally acquired during initial training.

The observer of DR396 indicated that he would not call all signals except when changing lines, etc. Then he might call the signals or make some pertinent comment, but not always, whereas the driver said that the observer would normally call caution and stop signals.

Both driver and observer were asked about their use of the two-way radio equipment fitted to the locomotive. In general they were not frequent users of the radio, limiting its use to determining the length of delays, clearing signals after loading, or similar. They would not normally communicate with other trains. The driver commented that the performance of the two-way radios, as supplied, "was lacking in all areas".

When interviewing the driver and observer of DR396 it was evident that they appeared to get on well together and had been successfully operating as a crew for the past 5-6 years.

1.6 Recorded data – DR396

Each locomotive was equipped with a data logger that automatically recorded data, including;

- time
- speed in km/h
- brake pipe pressure (kPa)
- dynamic braking (on/off)
- vigilance control system activation (not by position)
- throttle notch setting

The recorded data from each of the three locomotives was successfully printed out in both tabular and graphical formats.

A comparison was made of each data set, corrected to lead locomotive time. All values recorded were consistent between locomotives. No braking abnormalities were observed.

1.7 Safety history

Signals passed at danger (SPAD's) are one of the most serious rail occurrences. It can be expected that for each accident involving a signal passed at danger there will be many incidents which did not result in injury or damage. Thorough investigation of such incidents may help to prevent accidents.

The NSW Transport Safety Bureau and FreightCorp each maintain a database of rail safety incidents. In the period January-December 1997, the NSW TSB database lists 43 SPAD's in NSW. Many of these involved suburban passenger trains or track machines.

Since 1 January 1995, the FreightCorp safety database records five incidents in which coal trains have passed signals at danger in the Hunter Valley region. Four of these

incidents were classified as 'slip pasts' in which the train was stopped a short distance beyond the signal. The remaining incident occurred during electrical work on the signalling system. No SPAD reports were received last year where signals were automatically controlled.

1.8 Emergency response

The collision triggered an emergency response involving personnel from police, ambulance, fire brigade, the State Emergency Service (SES) and Environment Protection Authority (EPA), as well as the relevant rail organisations and contractors.

Initial notification of the accident was made by local residents and by the crew of passenger train 717. Within five minutes of the accident, two ambulances were on the scene. Within ten minutes a total of six ambulances had arrived.

After the injured had been taken to hospital, the focus of the emergency response turned to ensuring the safety of the site, protecting the environment from contamination, removing wreckage and restoring infrastructure.

The response was carried out with speed and efficiency. However, as in most emergency responses of this magnitude, there were some problems.

In the first few hours of the operation, some emergency services personnel were initially unsure who was in charge of the site. In particular, Fire Brigade, EPA and SES personnel commented that upon arrival at the site, it was difficult to know who they should report to. The problem was compounded by the large number of personnel from various organisations wearing similar safety vests, which made it difficult to identify which organisation they represented.

Co-ordination between the various agencies was facilitated by regular site meetings. Although the meetings worked well, once the system was established, the initial meetings were not attended by all relevant personnel, due to a communication breakdown.

Considering the nature of the task, restoration work was completed with remarkable speed, without injury to personnel. In an atmosphere of cooperation and goodwill, assistance and resources were provided across organisational boundaries. Resumption of freight and passenger services, and restoration of the site, was largely complete by Monday 27 October.

The efficiency of the recovery operation can be partly attributed to the established working relations between personnel from the various rail organisations which, until 1996, had been units of the NSW State Rail Authority (SRA). New rail operators, with no historical connection with the SRA, are entering the industry in NSW. If future recovery operations involving such an operator are to proceed smoothly, a formal agreement on the provision of recovery assistance may be required.

2. ANALYSIS

2.1 Introduction

The circumstances of this accident were consistent with the crew of DR396 failing to halt their train at a stop signal protecting the stationary MT304. The investigation has established that MT304 had been correctly standing at signal C110.8 in accordance with safe working procedures.

The investigation has also determined that DR396 was capable of normal operation at the time of the accident. The train was being operated by the driver, who was seated in the left control seat, while the observer occupied the right control seat. Both crewmembers were qualified to undertake their assigned tasks. As a result of their injuries, both were only able to recall very limited details of the events leading to the collision.

2.2 Crew performance

At first glance this accident appeared to involve a simple error by the crew of DR396 when they passed a caution indication at signal C113.0, then failed to halt the train at the next signal, C112.2, which was showing a stop indication. There has been no evidence found to suggest that the crew deliberately ignored the track signals displayed as their train approached Beresfield. Moreover, an examination of the operational history of each crew member indicated that such a violation would be entirely out of character with past performances.

Recorded data showed that the train was being operated normally, consistent with previous similar journeys undertaken by the driver. The first indication of any abnormal event was when emergency braking was applied, some 370m before the lead locomotive of DR396 collided with the rear wagon of MT304. The position at which emergency braking was applied corresponded to the time when the train standing ahead was sighted by the driver.

The weather was fine, the sun was positioned well above the horizon to the left of the direction of travel, and earlier patches of fog had mainly dissipated. There were no restrictions to visibility along the track between Thornton and Beresfield. Observations made during the course of the investigation indicated that the rear of a train stopped on the up coal road at Beresfield should have been clearly visible, significantly well before the point at which emergency braking was applied.

Driver fatigue was examined during the investigation, although the train crew had been rostered in accordance with existing practices which supposedly provided adequate rest breaks and appropriate duty time limits. A specialist analysis was conducted on the level of fatigue attributable to the work schedule of the crew of DR396. It was considered that both driver and observer would have been experiencing a significant level of work-related fatigue, at the time of the accident. Although that level of fatigue would somewhat impair a drivers' hand-eye coordination and response/reaction times, the more serious consequences of such

fatigue would be a reduction of alertness, and an increased likelihood of involuntary sleep. Recent Australian research has indicated that the performance impairment resulting from fatigue can be equated with the impairment which results from alcohol consumption (Dawson and Reid, Nature 17 July 1997, vol 338).

Driver alertness immediately prior to the accident was considered as a possible contributing factor. Recorded data indicates that the train vigilance control was acknowledged twice between signals C113.0 and C112.2. Nevertheless, the recorded data does not discriminate between vigilance control acknowledgments by the driver or his observer, although both said that the person occupying the driving position would normally operate the vigilance control. It was also reported that the driver of a passing passenger train waved to the driver of DR396 near Thornton, and received an acknowledging wave, indicating at that time at least, the driver of DR396 was responding to outside events.

It is unlikely the driver of DR396 was asleep immediately prior to the accident, as evidenced by recorded data and the observation of another driver. But it is probable that the driver had been experiencing some form of Automatic Behaviour Syndrome, as defined by the Transportation Safety Board of Canada. This would have allowed simple or familiar tasks to be performed, such as operating the vigilance control, dynamic braking, etc, but rendered the driver incapable of responding quickly to more critical tasks and situations.

From what is known of the journey from the Drayton loading terminal to Thornton, the crew observed clear signals throughout. If the driver was experiencing some form of reduced alertness, the change in signal indications at C113.0 and C112.2 may have gone unrecognised, particularly when the track ahead would have appeared unoccupied as the train passed Thornton. This could also explain the delay in the application of air braking. Although the train ahead should have been visible well before, it would have been unlikely that the crew were expecting to see a train.

It is also quite likely that this condition of reduced alertness could go unnoticed by the observer for short periods. Unless he specifically requested some form of positive response, the observer would have relatively few cues to assist him to assess the state of alertness of the driver. However, once the train passed a caution signal, without any apparent reaction by the driver, it is almost inconceivable that the observer would not have warned the driver of impending danger, if he (the observer) had been aware of the developing situation.

As discussed previously, unless people are extremely sleep deprived, involuntary sleep will generally not occur in environments that are stimulating, uncomfortable or challenging. In normal circumstances, the task of driving an 82 class locomotive is not likely to be challenging to an experienced driver. The environment in the cab of that class of locomotive is relatively quiet and comfortable, and both driver and observer commented to this effect. This becomes even more apparent when the role of the observer is examined. On a journey such as the one undertaken by DR396, the observer has, in the main, relatively little to do, yet is required to stay alert to assist the driver. In such an environment, a person significantly affected by work related fatigue could find it difficult to remain fully awake.

The driver of DR396 was taking anti-inflammatory medication to relieve symptoms associated with an elbow injury. Research was carried out to try and establish the likelihood of that medication adversely affecting the performance of the driver. It is known that in rare cases (less than 2%) side effects may include headache, tiredness, and visual disturbances. However, after interviewing both the driver and observer, it is considered unlikely that the driver was adversely affected to any significant degree. Nevertheless, it is possible that this self medication may have resulted in a subtle lowering of alertness, unnoticed by the driver or his observer.

2.3 Train crew pairing

The driver and observer of DR396 had been working together for the past 5-6 years. It would appear that this was a typical rostering arrangement for coal train crews based at Broadmeadow. This crew got on well together and were apparently quite satisfied with this arrangement.

The problem with such a long term pairing can be that each becomes very familiar with the behaviour of the other, and adapts their own behaviour to avoid conflict. While this might be highly desirable in other circumstances, such familiarity over time, when operating complex equipment, may result in idiosyncratic or unsafe work practices.

Although there is no evidence of it happening in this accident, a diffusion of responsibility could occur in which each crewmember accepts less than full responsibility for remaining vigilant, aware that the other person is present.

This issue has been recognised by world airline operators, who are required to conduct their operations in a high hazard, high speed environment, at low risk. Rather than maintain long term crew pairings, it is not uncommon to find flight crew members paired with other crew members whom they had seldom or never worked with.

To successfully operate such a system relies entirely on each crew member complying with standard operating procedures. These procedures are of necessity very comprehensive and include specific guidance as to how and when a task is to be performed, standard phraseologies, the division of responsibility between crew members, and the management of crew resources. The advantages for the airline operator include, significant savings by the optimum operation of aircraft, the efficient use of operating crews, and the minimisation of risk due to human error.

Likewise, the potential exists for the safety and efficiency of rail operations to be enhanced by adopting operating principles similar to those used in the airline industry.

2.4 Serviceability of signals

During the early stages of the investigation the recorded data from DR396 was analysed, relative to the progress of the train from Thornton. The data indicated there had been no apparent reaction from the driver as the train passed signal C113.0 at caution, and no attempt to comply with a stop indication at C112.2. However, if one assumed that both signals had been giving a clear indication, then the passage of the

train would have been consistent with normal operations. Testing of the automatic signalling equipment shortly after the accident did not reveal any malfunction that could have contributed to the accident.

After examining the recorded data, reviewing Trackwatch reports, and considering the circumstances of the accident, more comprehensive testing was considered necessary to determine what role, if any, the functioning of the automatic signals played in the events leading to the collision.

The results of that additional testing revealed no evidence to support the argument that the signals displayed at C113.0 and C112.2, indicated other than caution and stop respectively for the passage of DR396.

2.5 Failed or absent defences

2.5.1 Introduction

Research has shown that any system involving the interaction of people and complex equipment may be subject to failure, due to human error and/or technical malfunction. Much time and effort can be expended in designing, building, operating and maintaining such systems, yet despite this, latent defects can exist within a system that may go unnoticed for long periods, only becoming apparent when coupled with other more immediate factors. Such a combination of factors can result in a safety hazard. Should defences designed to warn and protect from such hazards be absent from the system, or be inadequate, then a safety failure is inevitable.

Ideally, defences should be multi-layered to provide for such elements as hazard identification and alerting, standardised countermeasures, protection of equipment and personnel, and where necessary, escape and survival.

The operation of DR396 prior to the collision was unremarkable. The intended journey could be said to be typical of coal train operations in the Hunter Valley conducted by FreightCorp. The safety history of such operations appeared to indicate a system that worked well.

However, on closer examination it became clear that there was little room for human error, particularly when a train was being operated on a section of track where signal indications relied entirely on the passage of trains. If the train crew, for whatever reason, passed a stop signal, then there was no defence to warn the crew of that transgression, or provide some other form of mechanical intervention. It simply became a matter of luck as to whether that event resulted in an accident.

2.5.2 Role of observer

It could be argued that the observer was the defence to warn the driver if a signal was missed or ignored. But it was evident in this accident that both the driver and observer were completely unaware that their train was in danger, despite passing two warning signals which should have been clearly visible to both. In other words, the factors that were affecting the driver were also likely to have had a similar impact on the observer.

2.5.3 Vigilance control

The vigilance control system provided no defence against passing a stop signal, nor was it intended to do so. Although, by its very name, the system is intended to monitor driver alertness when the train is moving, in reality it is only effective in detecting a significant reduction in the level of consciousness.

Research has shown that people who are in a state of involuntary sleepiness, while able to perform simple familiar tasks, may be incapable of responding quickly to more critical tasks and situations. Operating a train vigilance control was a task that would have been simple and automatic to the crew of DR396. Although it is likely that the driver of DR396 was operating the vigilance control, it may have been operated by the observer for the same outcome.

It would seem that a more effective vigilance control system would require one of a range of specific responses from the driver, at random, yet not be sufficiently onerous to divert attention away from operating the train. Even more effective would be a system that recognised caution and stop signals, requiring an explicit acknowledgment from the driver to avoid a penalty brake application .

2.5.4 Other warning systems

- There was no system fitted to this train, or to the infrastructure associated with the operation of the train, which could have provided a warning to the crew that a stop signal had been passed, or a caution indication had not been acknowledged. Such a 'safety net', if fitted, would have almost certainly prevented the accident, acting as a final line of defence.
- Because the accident occurred on a section of track equipped with automatic signals, the progress of the train was not under the direction of an external controller, hence no warning could have been provided. However, even if a controller had been able to observe the train pass the stop signal, there would have been insufficient time to warn the crew of the impending collision.
- There was no system installed to automatically apply the train brakes upon passing a stop signal, such as found on parts of the CityRail network.
- The crew of DR396 made limited use of the two-way radio communications system installed on the locomotive. This was partly due to reported poor radio performance. Currently it is standard practice for drivers to operate from signal to signal, without the assistance of radio communications.

However, if the train had been equipped with a more functional radio system, and drivers had been required to make standardised position reports, particularly when standing at an automatically controlled stop signal, it is likely that the situational awareness of the crew of DR396, regarding the status of other trains ahead, would have been significantly enhanced. This could have acted as a trigger for the driver and observer to exercise greater vigilance.

3. CONCLUSIONS

3.1 Findings

1. The driver and observer of coal train DR396 were qualified for their assigned tasks.
2. Both complied with required medical standards to drive trains, and were fit to carry out their assigned tasks. There was no evidence found to indicate that the performance of the driver or observer might have been affected by abnormal pre-existing physiological or psychological factors.
3. The driver and observer were working their fifth rostered shift, following three days clear of duty.
4. During the events leading to the collision the operation of DR396 was under the direct control of the driver.
5. The collision occurred during daylight, in conditions of good visibility.
6. DR396 was capable of normal operation.
7. The driver of MT304 was complying with a stop indication at signal C110.8.
8. At the time of the collision signal C113.0 was showing a caution indication, and signal C112.2 was showing stop. There was no evidence found to indicate any signal malfunction that could have contributed to the accident.
9. Recorded data from DR396 showed no significant change to the progress of the train as it passed signals C113.0 and C112.2.
10. Emergency braking was applied by the driver of DR396 some 370m prior to impact, consistent with first sighting the rear wagon of MT304. The predicted stopping distance required by DR396 was 579m.
11. There were no defences in place with the capability to warn the crew of DR396 of signals missed, or to arrest the progress of the train on passing a stop signal.
12. The vigilance control system was ineffective in detecting reduced levels of alertness, and could be operated by either the driver or observer.
13. Other deficiencies identified that related to the safe operation of trains included;
 - a. shift patterns
 - b. standard operating procedures and crew pairing

- c. SPAD reporting and investigation
- d. The use of two-way radio

3.2 Significant factors

1. The shift pattern worked by the driver and observer of DR396 resulted in a level of work related fatigue, due to sleep deprivation, of sufficient dimension to impair hand-eye coordination and reaction/response times, and to adversely affect alertness.
2. The task of operating DR396 on the morning of the accident was routine and relatively undemanding, conducive to also reducing the alertness of both driver and observer.
3. The vigilance control system did not adequately protect against reduced driver alertness.
4. The safe progress of the train relied on a system intolerant of human error, depending entirely on the crew observing and correctly responding to track signal indications.
5. Defences to protect the train from human error had not been established or were inadequate.

4. SAFETY DEFICIENCIES

The following safety deficiencies were identified during the course of the investigation. It is recommended that the NSW Transport Safety Bureau, as the rail safety regulator, ensure these deficiencies are reviewed, with a view to determining what corrective action, if any, need be taken.

1. The shift pattern worked by the crew of DR396 is considered to have had an adverse impact on their work performance. A Shiftwork and Workload study at 14 rail depots across Australia was conducted during 1997, including the Hunter Valley. The data from that study could provide valuable information concerning the suitability of the current rostering practices employed by FreightCorp, particularly with regard to the question of sleep deprivation and driver alertness. Consideration should also be given to the introduction of a fatigue management program.
2. The vigilance control system was found to be ineffective in protecting against reduced driver alertness. Additionally, the system can be reset by either the driver or observer, yet the observer is unable to drive the train from his duty station. There appears to be no compelling reason why the system should allow dual operation. It is also considered that the vigilance reset function should require specific, random responses from the driver, to provide greater protection against reduced driver alertness.

3. It is difficult to accept that a simple, low cost, electronic device could not be found or designed, to provide some form of warning to train crews of signals at caution or stop. If that warning could be incorporated into the vigilance control system, so much the better.
4. The lack of specific, standard operating procedures for train crews can encourage deviations from desirable safe working practices, leading to a reduced safety performance. Considerable information is available from the aviation industry on the benefits of such standard practices.
5. The desirability of permanent crew pairings was questioned during the investigation. If well designed standard operating procedures are in place, and are complied with, then long term pairings are not necessary. Constant change to crew pairings, if properly managed, should have the effect of ensuring full compliance with standard procedures, with consequent positive implications for safety and operating efficiencies.
6. Ineffective functioning and use of radio communications was a factor in this accident. Effective radio communications have a positive effect on safety by enhancing situational awareness, particularly with regard to the position of trains ahead. This could be further improved upon by equipping locomotives with low cost, satellite sensing, Global Positioning Systems, to provide for very accurate position fixing of trains.
7. Although there were few reports received by FreightCorp of SPAD's, it would appear that those reports came from locations where signals were controlled by signal boxes. No SPAD reports were received last year where signals were automatically controlled. This could suggest an area that needs further study to determine what the true position is.

System safety authorities estimate that for each accident, there may be between thirty and a hundred safety incidents. It is conceivable that SPAD incidents involving FreightCorp trains are being under-reported, and that this may serve to distort the actual safety performance.

Most transport accidents involve human factors, however, many transport safety incident databases focus on technical malfunctions rather than the human factors which underlie many accidents and incidents. Effective accident prevention depends on the identification of potential human and system weaknesses. This is likely to require new methods of incident data collection, such as a no-blame mandatory incident reporting system, a confidential reporting system, and specific incident report forms.

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