



Rail Accident Investigation Branch

# Rail Accident Report



## **Derailment of a freight train at Maltby North 28 June 2006**

This investigation was carried out in accordance with:

- the Railway Safety Directive 2004/49/EC;
- the Railways and Transport Safety Act 2003; and
- the Railways (Accident Investigation and Reporting) Regulations 2005.

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This report is published by the Rail Accident Investigation Branch, Department for Transport.

# **Derailment of a freight train at Maltby North**

## **28 June 2006**

### **Contents**

<b>Introduction</b>	5
<b>Summary</b>	6
Key facts about the incident	6
Key conclusions	6
Recommendations	7
<b>The Accident</b>	8
Summary of the accident	8
The parties involved	10
The signalling	10
Events preceding the accident	11
Events during the accident	12
Events following the accident	15
Previous occurrences of a similar character	15
<b>Analysis</b>	17
Sources of evidence	17
Identification of immediate cause	17
Identification of causal and contributory factors	18
Severity of consequences	26
<b>Conclusions</b>	27
Immediate cause	27
Causal factors	27
Contributory factors	27
Observation	27

<b>Actions already taken or in progress that affect this report</b>	28
<b>Recommendations</b>	29
Recommendations arising from causal and contributory factors	29
Recommendations arising from observation	29
<b>Appendices</b>	30
Appendix A: Glossary of abbreviations and acronyms	30
Appendix B: Glossary of terms	31
Appendix C: Fatigue index	33

## Introduction

- 1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future incidents and accidents and improve railway safety.
- 2 The RAIB does not establish blame, liability or carry out prosecutions.
- 3 Access was freely given by Network Rail and Freightliner Heavy Haul to their staff, data and records in connection with the investigation.
- 4 Appendices at the rear of this report contain glossaries;
  - acronyms and abbreviations are explained in appendix A;
  - certain technical terms (shown in *italics* the first time they appear in the report) are explained in appendix B; and
  - appendix C describes the Health & Safety Executive (HSE) Fatigue Index (FI).

## Summary

### Key facts about the accident

- 5 On 28 June 2006 train 6C51, a Freightliner Heavy Haul coal train from Redcar to West Burton, was traversing the facing *turnout* in the *crossover* (points number 31B) from the single South Yorkshire Joint Line to the loop at Maltby North (Figure 1 shows a map of the area) when three of the wagons became derailed. The derailed wagons remained upright and did not spill their loads. The track was damaged for a distance of 80 m.
- 6 The train was travelling at 17 mph (27 km/h) at the time of the derailment and was quickly brought to a halt by the *automatic air brake*.
- 7 Nobody was injured in the accident.

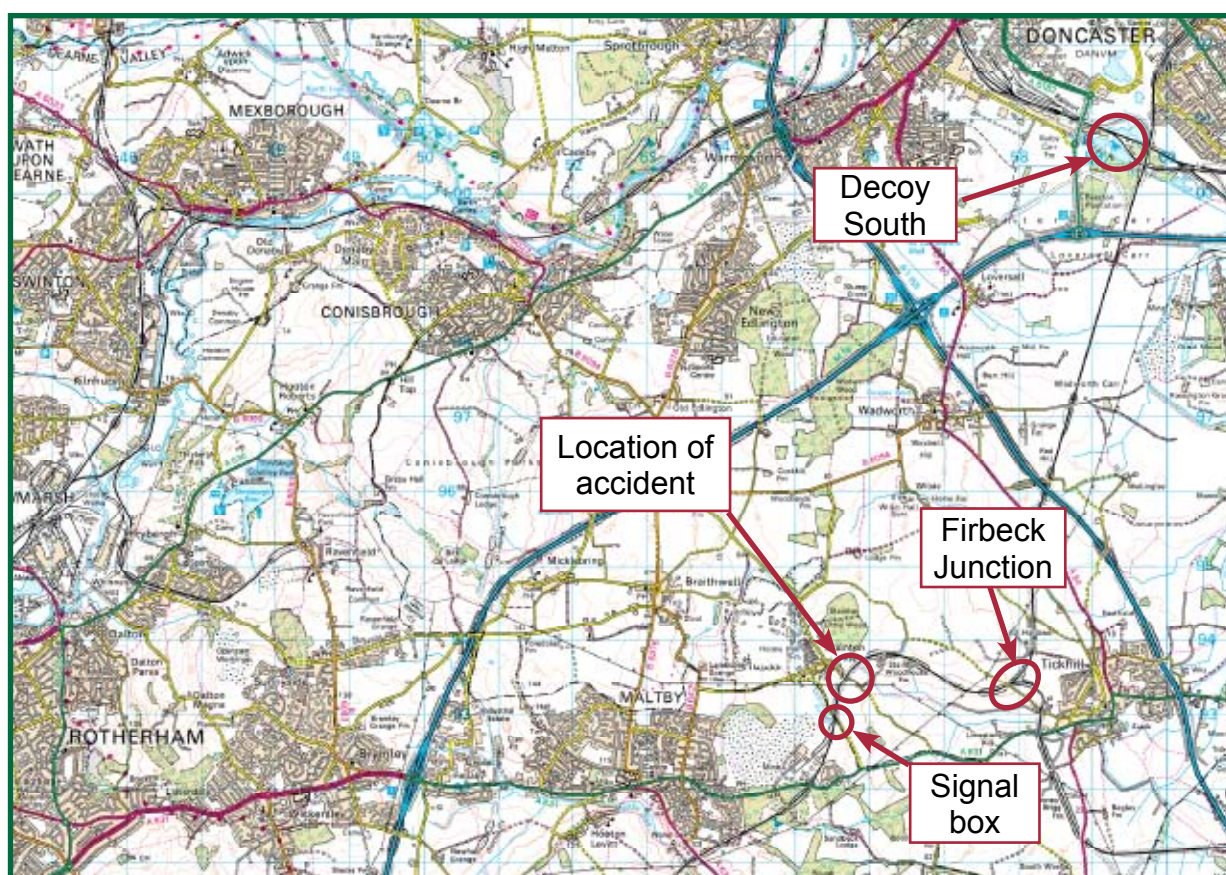


Figure 1: Extract from Ordnance Survey map showing location of accident

### Key conclusions

- 8 The immediate cause of the derailment was number 31B points moving from the normal position to the reverse position as the train traversed them.
- 9 The '*time of operation locking*' for these points, which is listed in the *control tables*, was not implemented. Had it been, the accident would have been prevented.
- 10 Though it cannot be proven positively, on the balance of probabilities given the evidence, it is likely that the driver of train 6C51 did not observe signal M36 and passed it at danger.

- 11 Signal M36 is poorly sited with only 3 m between it and 31B points. It does, however, have a sighting time, at the linespeed of 25 mph (40 km/h) of over 13 seconds, which adequately meets the requirements of Group Standard GE/RT8037.
- 12 Though it cannot be proven positively, on the balance of probabilities given the evidence, it is likely that the signaller pulled the lever for 31 points just as the locomotive reached signal M36. This action would not have caused an incident had the train not passed signal M36 at danger at the same time.
- 13 The length of the shifts being worked by the signallers at Maltby made them prone to fatigue during the night shift.

## **Recommendations**

- 14 Recommendations can be found in paragraph 126. They relate to the following areas:
  - implementation of a system to ensure that 31 points at Maltby can not move as a train is approaching them;
  - determination of whether a similar lack of point locking exists in other locations and formulation of a plan to control the resulting risk of derailment; and
  - fatigue to be taken into account when designing roster patterns for signallers at single-manned boxes.



## The Accident

### Summary of the accident

- 15 On 28 June 2006 train 6C51, a freight train operated by Freightliner Heavy Haul, was conveying coal from Redcar, near Middlesbrough, to West Burton power station, near Gainsborough. The train was travelling along the South Yorkshire Joint line between Doncaster and Worksop when it approached Maltby from the north at 03:00 hrs. The line is single track but there are two loops at Maltby which allow trains to pass. The train was being routed from the main line into one of these loops when it became derailed. Figure 2 shows the scene following the derailment.



Figure 2: Front part of train looking from 31B points towards locomotive

- 16 The train consisted of 17 bogie hopper wagons of type HHA. The wagons were fully loaded with coal to their maximum *gross laden weight* of 101.6 tonnes. The train was hauled by a class 66 locomotive, number 66 549. The train was coupled with *screw couplings* and they remained intact throughout the train during the derailment, though the *brake cocks* were broken off two of the wagons and the pipes parted. The loss of *brake pipe continuity* caused the brake to apply automatically which stopped the train.
- 17 The train was traversing number 31 crossover at the time of the derailment. The crossover is made up of two points numbered 31A and 31B (see Figure 3). The train was traversing 31B points in the facing direction when it derailed. The locomotive and leading bogie of the first wagon took the *normal* route through 31B points towards the *up* and *down* main line. The points then motored to the *reverse* route whilst the first wagon was passing. All four wheels of the rear bogie of the first wagon passed between the open *switch rails* and the *stock rails* and ran along the stock rails until the widening gauge caused them to drop between the rails into derailment.



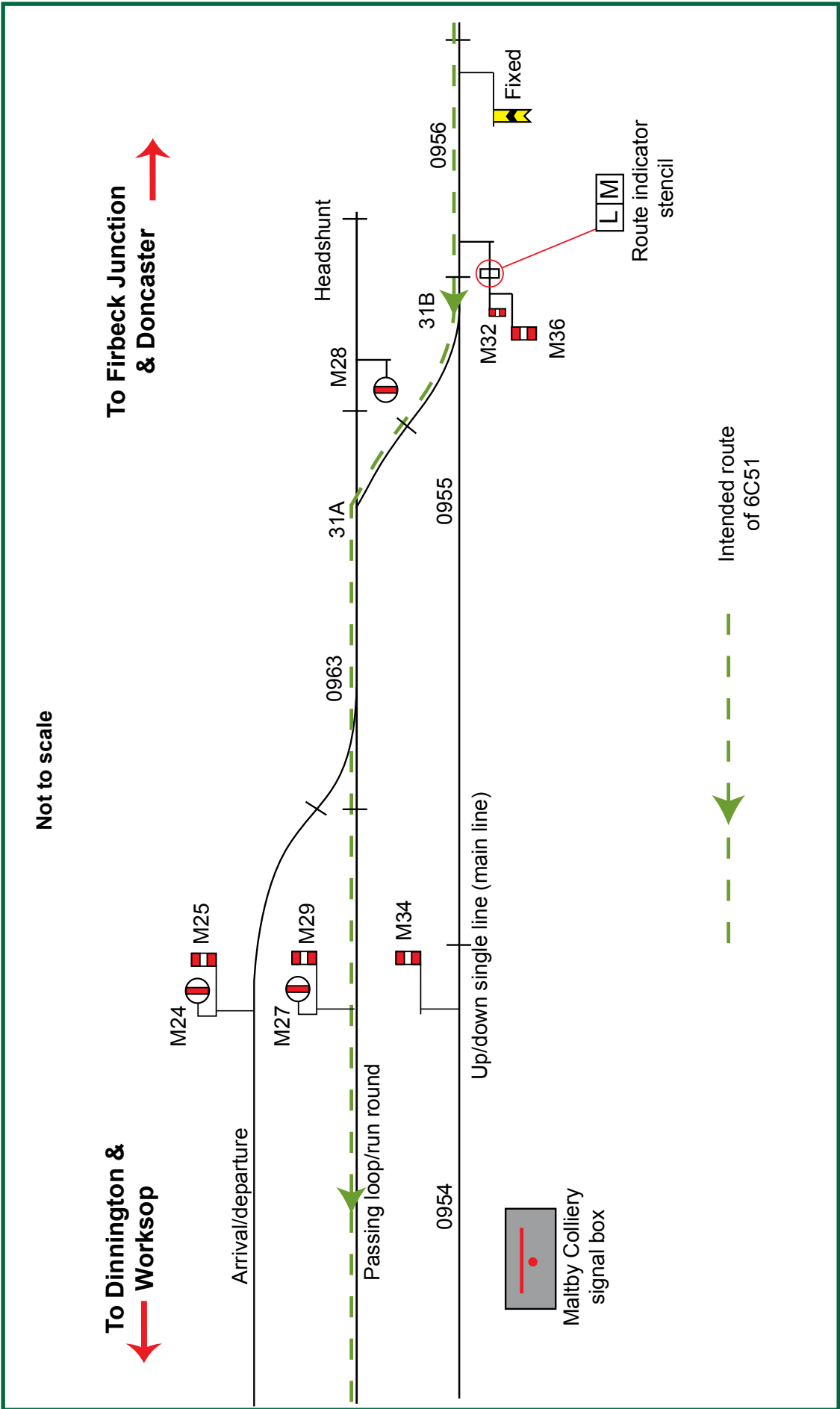


Figure 3: Plan of signalling at Malby North

- 18 The second and subsequent wagons took the reverse route through 31B points towards the loop. The derailed bogie of the first wagon dragged the following wagons into derailment as the gap between the diverging tracks widened.
- 19 Nobody was injured in the accident.

## The parties involved

- 20 The line is owned and operated by Network Rail and is part of the London North Eastern Territory.
- 21 The train was operated by the Heavy Haul division of Freightliner Ltd.
- 22 The track and signal equipment maintenance of the line is done by Network Rail.

## The signalling

- 23 The signalling on the line is *track circuit block* controlled from Maltby Colliery signal box. Maltby Colliery signal box is a mechanical box that has been modified to include control of the line towards Doncaster. These modifications were made in the mid 1980s and included the provision of a *relay interlocking* to control the former Maltby North and Firbeck Junction signal box areas. The points and signals at Maltby North are controlled from the lever frame at Maltby Colliery box. Firbeck Junction, along with the branch from there to Harworth Colliery, is controlled by a small electrical control panel in Maltby Colliery box. The former *block section* at Firbeck Junction is now an *intermediate block* between Maltby Colliery and the *power signal box* at Doncaster. Figure 3 shows a plan of the tracks and signalling at Maltby North.
- 24 The *linespeed* on the main line through Maltby is 25 mph (40 km/h). The linespeed through the crossover into the loops is 15 mph (24 km/h).
- 25 The signals at Firbeck Junction are colour light signals and the signals at Maltby are upper quadrant semaphore signals with electric lighting. There are also some mechanical disc ground signals to control shunt moves; these too are electrically lit. The *distant signals* on the approach to Maltby, from both directions, are *semaphore fixed distant signals*.
- 26 The running lines through Maltby form three parallel tracks which are denoted up and down main, passing loop and arrival/departure. The arrival/departure name is derived from the fact that it gives access to Maltby Colliery sidings. The arrival/departure line is not only used for trains requiring access to the colliery, it is also occasionally used for running round or as a passing loop as longer trains can be accommodated on this line than on the up and down main line due to the position of the *block joints* in the rails.
- 27 The Maltby up home signal ('up' at Maltby is from Doncaster towards Worksop) is a semaphore bracket signal with a main arm and a subsidiary arm. The main arm, signal M36, signals routes onto both the up and down main line and the passing loop. A stencil indicator shows 'M' or 'L' to indicate which route is set but both routes are set with the same lever in the box; the relay logic determines which letter to show according to the setting of the points. The subsidiary arm, signal M32, controls access to the arrival/departure line. Figure 4 shows the signals M32 and M36 along with the stencil route indicator box.



*Figure 4: Signals M32 (right) and M36 (left)*

- 28 Point numbers 31A and 31B, which make up the crossover on which the train derailed, are operated by Alstom style HW point machines, type HW1121. These are electrically powered and, at Maltby, operate on a supply voltage of 30 V DC. These machines are designed to be operated with a supply voltage of up to 110 V DC. Use of a 30 V supply causes the motors to operate more slowly than they would on the full 110 V DC.
- 29 The track approaching Maltby from the Doncaster direction is curved to the left and runs through an avenue of trees which close in on the line from both sides. The foliage combines with the curve to restrict the visibility of signals M32 and M36 during the summer. The sighting distance of the signals was measured by the RAIB and the minimum distance was 154 m to sight the spectacle glass of signal M36. The linespeed on the approach to the signals is 25 mph (40 km/h) giving a reading time of over 13 seconds. The minimum reading time specified in Group Standard GE/RT8037 is 8 seconds. Additionally, the distant signal for these signals is a fixed distant and so drivers must always expect signals M32 and M36 to be at danger as they approach.
- 30 The signal box at Maltby is manned by one signaller and is open 24 hours a day on weekdays and a shorter time at weekends. The signallers usually work 12 hour shifts with shift changes taking place at 05:30 hrs and 17:30 hrs. The traffic over the line is predominantly coal trains, both loaded and empty. There are typically between 20 and 30 trains per shift.

## **Events preceding the accident**

- 31 Train 6C51 left Redcar Ore Terminal at 18:36 hrs on 27 June and ran to Ferrybridge where the driver was to be relieved. On arrival at Ferrybridge, the driver leaving the train (driver 1) reported to the driver taking over the train (driver 2) that he had encountered a slight burning smell in the cab. He was unsure of whether this smell came from the locomotive or was due to a lineside fire.

- 32 Driver 2 had booked on at 20:00 hrs at Rother Valley depot at Kiveton Park, near Sheffield. He then drove by road to Ferrybridge. He relieved the incoming driver 1 at approximately 22:15 hrs. Shortly afterwards, within 5 minutes of leaving Ferrybridge, the locomotive failed completely at Knottingley. Driver 2 consulted his control and maintenance staff using his company mobile telephone. They were unable to diagnose the problem and a rescue locomotive was sent to assist.
- 33 The rescue locomotive, driven by driver 3, arrived at the rear of the train shortly before midnight and was coupled up. The train was drawn back to a suitable location to run round and the rescue locomotive was then coupled to the front of the train. Driver 3 left the train at Knottingley station to return to his booked duties by road transport. Driver 2 took the train forward to Doncaster arriving in the station there at 01:30 hrs. The plan was to drop the failed locomotive off in the sidings at Doncaster Decoy but there was not space to accommodate the train while this shunting move took place. Instead, the train was uncoupled and secured in Doncaster station and driver 2 took both locomotives to Decoy sidings.
- 34 The failed locomotive was shunted into a *cripple siding* with the help of a shunter who then rode back to the station with driver 2. The rescue locomotive was recoupled to the wagons and the shunter helped driver 2 to carry out the *brake continuity* test. The train finally departed Doncaster station at 02:24 hrs, running 220 minutes late. The train ran to Decoy South sidings to await a path over the South Yorkshire Joint line, having missed its timetabled path.
- 35 Train 6C51 was one of three trains bound for West Burton power station from Doncaster Decoy yard via the South Yorkshire Joint line. The first of these trains, 6C16, passed Maltby at 02:15 hrs. This was followed by train 6B74 which passed Maltby at 02:50 hrs. Train 6C51 left Doncaster at 02:46 hrs. These three trains ran from Doncaster to Maltby one after the other with no trains passing in the opposite direction in between them. Train 6C51 had to wait at Doncaster for the preceding train, 6B74, to clear the intermediate block section at Firbeck.
- 36 The line towards Worksop from Maltby is single track as far as Dinnington Junction but there is no intermediate block on this section of line. Since train 6C51 would have had to wait at Maltby for train 6B74 to reach Dinnington Junction, the signaller at Maltby decided to put it into one of the loops at Maltby in case a train needed to pass in the other direction.

## Events during the accident

- 37 The on-train monitoring recorder (OTMR) from the locomotive was analysed to provide information, about the running of the train.
- 38 Train 6C51 passed Firbeck Junction running under clear signals and, as the train approached the Maltby fixed distant signal, driver 2 shut the throttle and allowed the speed to fall. The gradient is rising throughout this section of line so driver 2 reapplied power to keep the train moving towards Maltby signal M36. The throttle was opened to notch 8, the maximum, for 22 seconds, then backed off gradually to notch 6. The speed rose slowly and had reached 17.4 mph (27.8 km/h) when the locomotive passed signal M36.
- 39 The locomotive and the first bogie of the first wagon passed through 31B points onto the up and down main line ('normal' setting for the points).
- 40 Immediately after passing signal M36 driver 2 quickly shut the throttle and applied the brake. Five seconds later he released the brake, with the throttle still closed.

- 41 The locomotive and first bogie of the first wagon passed over the points normally and ran onto the up/down single line. The second bogie of the first wagon ran between the stock and switch rails on both sides of 31B points. This is consistent with the points motoring across to the reverse position as the inter-bogie gap of the first wagon was passing. The right hand side switch tip was struck by a wheel flange (Figure 5).
- 42 The wheelsets of the second bogie of the first wagon ran along the stock rails of 31B points forcing the switch rails together which caused one of the stretcher bars to bend (Figure 6).



Figure 5: Damage to right hand switch tip of 31B points      Figure 6: Bent stretcher bar

- 43 As the stock rails diverged the gap between them became large enough for the wheelsets to drop into and they then struck the distance blocks and sleepers (Figure 7).



Figure 7: Point where wheelsets derailed



- 44 After the passage of the derailed bogie the switch tips continued their movement and subsequent wheelsets all took the reverse route. The point completed its movement and reverse detection was obtained.
- 45 The derailed bogie was drawn towards the *sixfoot* by the following wagons which were taking the route towards the loop. When the derailed bogie reached the crossing of 31B points it could no longer follow this path as it was constrained by the sixfoot rail of the up and down main line. This caused the leading end of the second wagon to be drawn towards the sixfoot breaking the rail fastenings on the sixfoot rail of the loop route and breaking a *fishplated rail joint*.
- 46 This rail, having broken free of its fastenings and its neighbour, was able to rotate and this allowed the leading bogie of the second wagon to derail to the sixfoot. The rail then sprung back sufficiently to allow the second bogie of the second wagon to pass without derailling, as evidenced by the fact that this bogie did not derail. The leading bogie of the third wagon had started to derail on passing the rail joint but the train came to rest before the second axle of this bogie had left contact with the rail (Figure 8).



Figure 8: Partially derailed bogie at front of 3rd wagon

- 47 The train was brought to rest at 03:00 hrs by an unsolicited brake application caused by loss of brake pipe continuity.
- 48 The wagons which derailed suffered damage to the derailed bogies and some underframe equipment.
- 49 The main damage that occurred was to the track, which required relaying before the line could be opened.



## Events following the accident

- 50 Driver 2 made five attempts to release the brakes before getting down from the cab to go and investigate the problem. He discovered that the train was derailed and called Maltby signalbox using his mobile phone at 03:04 hrs.
- 51 The signaller phoned Network Rail operations control to report the derailment, then phoned fault control to obtain a fault number for the derailment.
- 52 Driver 2 had a closer look at the derailed wagons then called the signaller again at 03:15 hrs to report more details of the damage. He discussed protection of the line with the signaller and the signaller confirmed that he had protected the site with fixed signals.

## Previous occurrences of a similar character

- 53 The derailment of 6C51 at Maltby was due to the points operating as the train passed over them. There have been several similar instances of this in recent years as described below.
- 54 At 09:22 hrs on 25 February 2003 at Hemel Hempstead on the West Coast Main Line, a class 321 electric multiple unit passenger train was derailed when number WJ343 B/C *switch diamond* operated under the train. Number WJ343 crossover had failed and the signaller locked the points normal and authorised the train to pass. Before the train had completely passed WJ343 B/C switch diamond the signaller unlocked WJ343 points in readiness to set a route for another train. This caused WJ343 B/C switch diamond to try and reverse as the train passed, derailling the rear vehicle. The Network Rail investigation recommended that Network Rail should arrange the signaller's roster to minimise fatigue. This recommendation was rejected by Network Rail because the recommendations review panel believed that a fatigue index was in existence and should be applied.
- 55 At 20:10 hrs on 21 October 2003 at Aberthaw in South Wales, the last vehicle of a coal train was derailed when number 27 points were returned to normal too quickly before the train had moved clear of them. The Network Rail investigation found the cause to be an error by the signaller.
- 56 Two vehicles of a coal train were derailed at Parcslip near Bridgend in South Wales at 11:20 hrs on 4 December 2003. The vehicles were derailed when a set of points operated from a ground frame were moved as the train passed. The Network Rail investigation reported the cause as incorrect operation of the ground frame.
- 57 On 14 January 2004 at Dunblane in Scotland a class 158 diesel multiple unit was crossing over between the main lines when the last bogie derailed. The Network Rail investigation found the cause to be due to the signaller returning the shunt signal to danger too soon and returning the points to normal while the train was still on them.
- 58 A derailment occurred at Westbury at 00:49 hrs on 4 May 2005 when a tamper was traversing number 828 points at Westbury North Junction. The enquiry found, on the balance of evidence, that the signaller moved the points from reverse to normal as the tamper passed over them. The signaller had completed 7 consecutive late evening/night shifts and fatigue was considered as a factor. The Network Rail report made a recommendation regarding reducing the risk of signaller fatigue. Network Rail rejected this recommendation as a number of fatigue studies had been undertaken along with the introduction of standard rostering principles and the report identified that the signaller was not considered to be fatigued at the time of the incident.

- 59 A class 66 locomotive was derailed at Ashburys in Manchester on 8 August 2005 while it was running round its train when number 1053A points moved under it. The driver and signaller both stated that the *ground position light* signal protecting the movement was clear at the time but testing by signalling engineers proved otherwise. The Network Rail investigation found the cause of the incident was that the driver passed the signal at danger and traversed the points before they had completed their movement.
- 60 A derailment occurred to a tram at Hillsborough in Sheffield on 18 September 2005. The Sheffield Supertram investigation found the derailment was caused by the tram failing to stop at a 'bar' indicator (signal) which showed that the points ahead were not set correctly. The points changed under the tram derailing the rear bogie.
- 61 An empty class 321 electric multiple unit was derailed at 05:30 hrs on 28 October 2005 in Watford Junction yard when a set of points operated from a ground frame was moved as the train passed over. The RAIB investigation into this incident (report ref. R02/2006) found that it was due to the ground frame operator misunderstanding the meaning of an indicator light and operating the points before the train had cleared them. Four recommendations were made; the first three covered training, competency and method of operation of the frame and the fourth called for consideration of provision of interlocking when the area is resignalled. The first three recommendations were implemented and the final one has not yet been implemented.

## Analysis

### Sources of evidence

- 62 There were no witnesses to the derailment. The driver of the train involved, driver 2, did not see or feel the derailment and his attention was only drawn to it by the unsolicited brake application (see paragraph 47).
- 63 The signaller was on duty in the box on his own and was only made aware of the derailment when driver 2 called him.
- 64 Evidence was obtained from:
- statements by Network Rail and Freightliner staff;
  - the locomotive OTMR;
  - the signal box train register;
  - signal box telephone voice recordings;
  - evidence gathered at site by the RAIB, shortly after the incident and during a special examination of the signalling equipment in November 2006;
  - photographs of the site taken by the Network Rail *Accredited Agent*;
  - reports on the testing to RAIB specification of the signalling equipment undertaken by the Atkins Rail signalling Technical Investigation Centre at Crewe;
  - the Network Rail report of the wrong side failure investigation of the signalling equipment, which was carried out by staff from a different area under the supervision of the RAIB.
- 65 The signal box was fitted with a data recorder which monitored the state of various sets of equipment at the Worksop end of the signal box area. There was no recorder fitted to monitor the points and signals at Maltby North. Following the derailment, such a data recorder was fitted. A few weeks after the derailment, when the same signaller was on duty, a download of this recorder was obtained and analysed as supporting evidence concerning the way in which the signaller worked the box. This analysis is described in paragraph 92.
- 66 The signaller and driver 2 were routinely tested for the presence of drugs and alcohol following the incident in accordance with normal industry practice and the tests showed that none was present.

### Identification of immediate cause

- 67 The marks on the rails around 31B points and the turnout itself consisted of a dent on the right hand side switch tip (Figure 5), drop in marks at the point where the distance between the diverging stock rails became greater than the distance over the wheel treads and wheel flange marks on the spacer blocks within the turnout (Figure 7). There was no evidence of flange climb on the switches which would have occurred if the switch profile had been worn. The switch rails were quite new and unworn, having been manufactured in 2005.

- 68 There were only two sets of derailment marks within the *switch lead* indicating that only two wheelsets were derailed prior to the crossing. Once the derailed bogie reached the crossing, the track damage became more severe and this led to the derailment of the following bogies.
- 69 Therefore the immediate cause of the derailment was the movement of 31B points as the train passed over them.

## Identification of causal and contributory factors

### Factors relating to signalling equipment

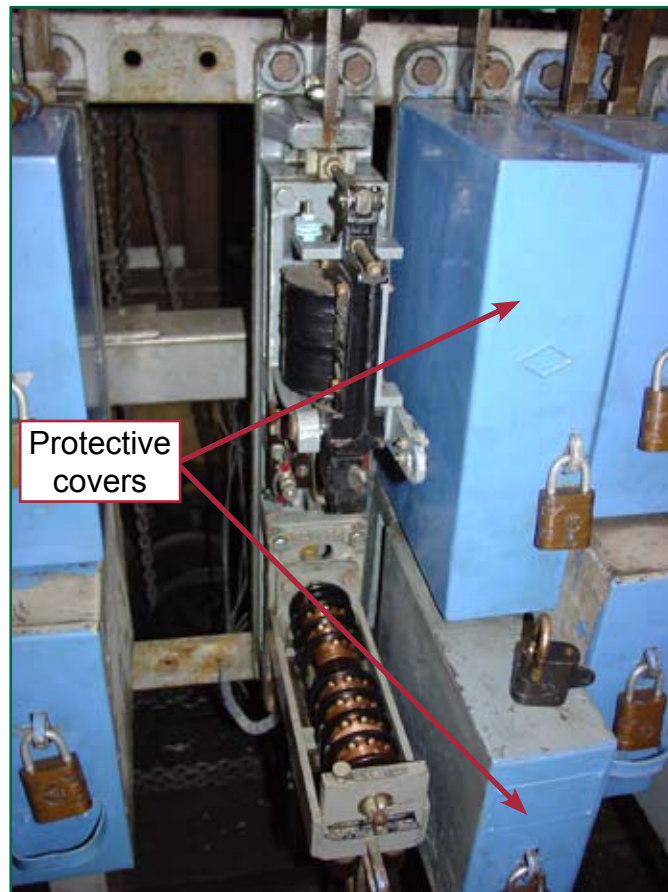
- 70 The signaller stated that he had set the route for the train to go into the passing loop as soon as the previous train, 6B74, had passed. He stated that he then cleared M36 signal when he saw train 6C51 approaching Maltby North. As the points had moved underneath the train (paragraph 41), initial investigations concentrated on finding how the signaller's command to move 31 points from normal to reverse might have been 'stored' by the signalling system and only acted upon when the train passed.
- 71 Network Rail signalling engineers conducted a wrong side failure investigation of the point operating equipment, following signal failure investigation (SFI) test plan T010 in the Network Rail Signalling Maintenance Testing Handbook (SMTH). The equipment tested included the point lever (no. 31) and the signal lever (no. 36) in the signal box, the *lever bands* and *lever locks* on these levers, the circuits that are connected to these levers, including the wires, cables and relays in the relay room and the location cabinets at the signal box and adjacent to the points. The point motors and their connecting cables to the location cabinets were also tested. This set of equipment comprised the entire chain from the lever in the box to the point blades themselves.
- 72 The Network Rail tests were observed by the RAIB at all stages and the RAIB also conducted additional tests of their own once the main testing was complete. The RAIB tests examined the wiring of the point operation circuit in the signal box and relay room.
- 73 Network Rail brought in a *signalling principles tester* to check independently the point operation and his report was also provided to the RAIB.
- 74 No fault was found with the signalling equipment that could have caused the incident. A data recorder was fitted to cover the Maltby North equipment and the interlocking was signed back into use by Network Rail. The RAIB conducted further detailed examination of the circuit for 31 points and the *track circuit* through them (no. 0955) in order to eliminate the signalling equipment from the investigation. This additional examination was conducted during a possession of the line 18/19 November 2006.
- 75 The Maltby up *home signal*, M36, is located very close to number 31B points. The RAIB measured the distance from the signal post to the tips of 31B points at 3.0 m. Within this distance there is an *insulated block joint* (IBJ) in the rails which forms the boundary between track circuits 0956 and 0955. This IBJ is 1.26 m from the signal post and 1.74 m from the switch tips. The close proximity of 31B points to signal M36 without the provision of time of operation locking is regarded as a contributory factor to this accident (paragraph 120).

- 76 The control tables for the signal *interlocking* in Maltby box were examined. The entry for 31 points lever shows the following:

Lever No.	Lever Lock	Released By	
		Arms or Aspects	Track Circuits
31	NR	24, 25, 27, 28, 29 on, 32, 34, 36 on	0955, 0963 (0956 or 0956 Occ 2 mins or routed away)

The 'arms or aspects' entry refers to signals that must be 'on' (i.e. at danger) before the points can be moved. The signals listed here all cover routes through 31 points. The 'track circuits' entry refers to track circuits that must not be occupied if the point is to be allowed to move. Track circuits 0955 and 0963 cover the tracks through the points themselves. Track circuit 0956 covers the track leading up to signal M36 from a point close to the fixed distant signal.

- 77 The purpose of the points being locked by the signals is to prevent the points from moving when a train is signalled over them. The requirement for track circuits 0955 and 0963 to be clear is to prevent the points from moving when a train is actually on them. The requirements involving 0956 track circuit cover three different cases:
- the first, that 0956 is clear, means that the points can be operated if there is no train approaching Maltby from this direction (track circuit 0956 is 743.5 m long);
  - the second requirement, that the track circuit is occupied for 2 minutes, is intended to allow time for the train to come to a stand at signal M36 before unlocking the points (called time of operation locking);
  - the last requirement, that the train is routed away, is to allow the points to be moved as soon as a train heading away from Maltby has cleared them.
- 78 It was found, during the testing of the signalling, that the time of operation locking on 31 points was not actually implemented, despite it being in the control tables. Train 6C51 had covered the length of track circuit 0956 in 1 minute 48 seconds so, if time of operation locking had been implemented, it would have prevented 31 points from being operated in this case. The lack of implementation of time of operation locking is regarded as a causal factor in this derailment.
- 79 The time taken for trains to cover the length of 0956 track circuit was examined for five trains that passed following the installation of the data logger at the box. It was found that typical times to cover this distance and pass signal M36 were between 1 minute 57 seconds and 2 minutes 34 seconds. The average time is longer than the 2 minute time of operation period specified in the control tables, so if time of operation locking were to be implemented here, the timing period would need to be longer than 2 minutes or the track circuit would need to be shortened.
- 80 The fact that Maltby signal box is a mechanical box that has been altered to include some relay interlocking means that there are two parallel interlocking systems in use. The levers in the box are mechanically interlocked with other levers and also electrically locked.
- 81 Where a lever works an electrical unit, such as a point machine, the electric circuit is made or broken via contacts which are driven by the lever. Levers which only operate electrical units do not require as much effort to move them as levers that work mechanical signals and points and these levers have had the handle section cut down to remind the signaller of this fact. Figure 9 shows the electrical lock and the lever contact bands that make up the electrical switch on number 31 lever. Figure 10 shows the operating floor of the box and lever frame with lever 31 in reverse and lever 36 normal.



*Figure 9: Lever lock (top) and lever bands (beneath) on lever 31 in Maltby Colliery signal box (protective covers removed from lever 31 units)*



*Figure 10: Interior of Maltby Colliery signal box*



- 82 Signal M36 signals routes through number 31 points in both directions, normal and reverse. Thus the signal lever 36 can be pulled with 31 points lever in either position. The mechanical interlocking prevents 31 lever from being moved from either position if M36 signal is clear. This interlocking was tested by both Network Rail and the RAIB and found to be fully effective.
- 83 When number 31 points are commanded to the opposite setting by moving 31 lever, the point machine is energised via a series of relays. One of these relays causes the indicator light on the shelf above the lever frame, which shows the setting of the points, to extinguish. When the points have completed their movement and detection is obtained, the indicator is lit with an 'N' or 'R' to show normal or reverse, as appropriate. The signaller did not clearly recall seeing this indicator light change when he set 31 points for 6C51.
- 84 Figure 11 shows the circuit which is operated by the switch on 31 lever. In normal operation, moving the lever from normal to reverse will cause switch 1 to open and switch 2 to close. The arrangement of the switches in this circuit ensures that only one of the relay coils can be energised at any one time. Other contacts on these relays (not shown in Figure 11) are used to operate the circuits which actually drive the point machines and cause the points to move.

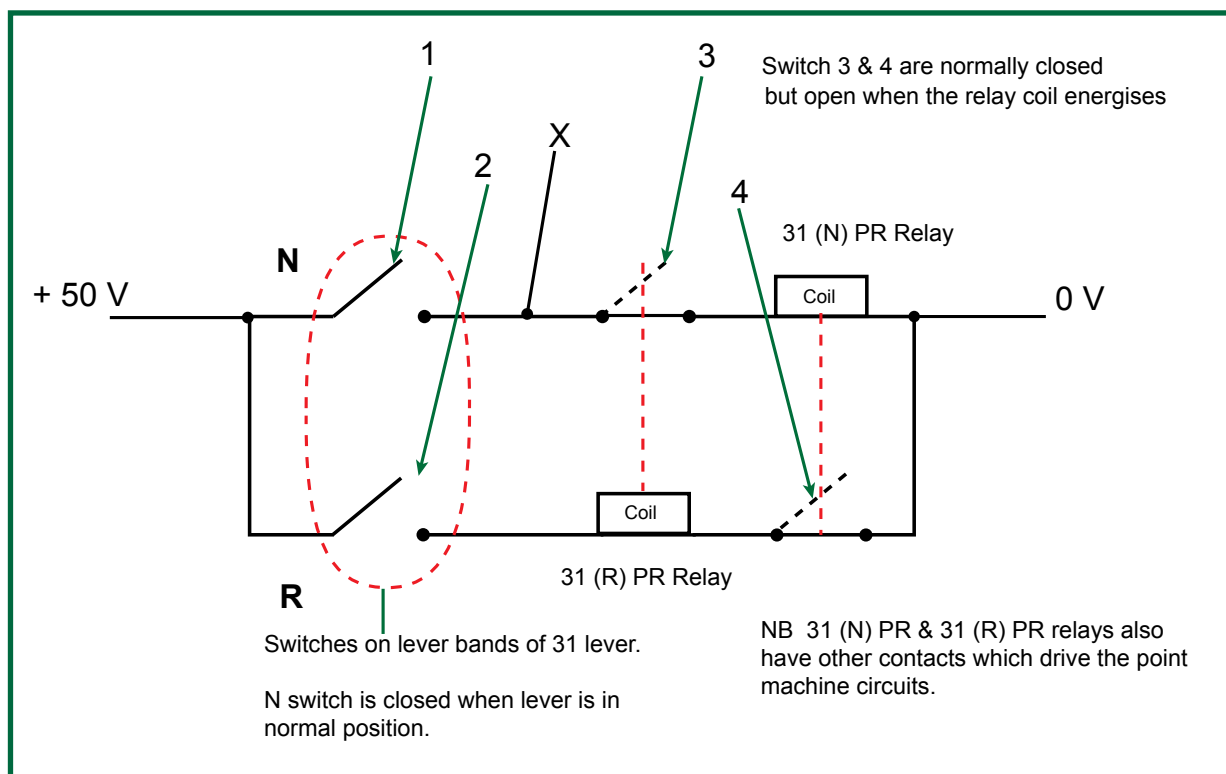


Figure 11: Lever band circuit on lever 36

- 85 The contacts which form switches 1 and 2 in Figure 11 are the only contacts connected to lever 31. This means that any part of the electrical interlocking which needs to know the position of lever 31 is reliant on contacts on relays 31 (N) PR and 31 (R) PR to do this. If there is a defect in one of these relays causing it to stick in the energised position, or there is a spurious electrical feed to wire 'X' in Figure 11, relay 31 (N) PR will remain in the energised position and prevent relay 31 (R) PR from operating, even though the lever has been moved and switches 1 and 2 have operated. In this state, the relay interlocking which displays the point position will continue to believe that lever 31 is in the normal position and will show normal detection for the points.

- 86 If the false feed is then removed, or the relay is jolted if it had stuck in the energised position, switch 4 will close making the circuit to 31 (R) PR relay. This will then operate the circuit powering the point machine and the points will motor over to reverse. They will motor over regardless of whether the track circuits that should lock them are occupied. This is because the interlocking between track circuits and lever 31 is done by means of the lever lock on lever 31. This lock remains in place preventing lever movement, but at this point in time lever 31 has already completed its movement, so the lock has no effect.
- 87 This potential failure mechanism was examined during the on-site testing of the signalling equipment. The wiring in the 31 lever circuit was traced and closely inspected for any signs of damage that might have led to spurious contact with another wire or any metalwork. The relays were removed and underwent detailed testing and examination of their mechanical and electrical performance. No fault was found in any of the relays. Further investigations consisting of close visual examination and electrical insulation and continuity testing were undertaken to examine the entire length of the wires that form the circuit shown in Figure 11. The wiring was found to be in good condition. It was concluded that this circuit could not have been accidentally false fed. The movement of the points just as the train approached must therefore have been due to the lever being pulled in the signal box at this time.
- 88 The design of the 31 lever circuit, whilst not proven to be causal to the derailment, is not in accordance with the design principles that would be used if the interlocking were to be designed today.

#### Factors relating to the signal box operation

- 89 The train register records that the previous train, 6B74, passed Maltby at 02:50 hrs running on the up and down main line. The train reporting number for 6C51 was transmitted from Doncaster at 02:21 hrs and the train register records that the train arrived at Maltby at 03:00 hrs on the passing loop line. The next item in the register is a note of the phone call from the driver of 6C51 saying that he is derailed. The note states that the derailment occurred at 03:00 hrs.
- 90 The signaller's evidence was analysed in conjunction with all the other information that was available. The analysis was carried out by answering several questions relevant to the incident using the evidence available. The key questions were:
1. When was 31 points' lever pulled?
  2. What was going on in the signalbox at the time the point lever was pulled?
  3. When was signal M36 cleared?
  4. When was the signal put back?
  5. Where was the signaller when the alarm for M28 signal (see below) went off?
- 91 Question 5 relates to the 'lamp out' alarm for signal M28. This signal is a ground disc signal which controls exit from the headshunt to the loop. The signal is in the sixfoot adjacent to 31B points and its cable was cut by a wheel as it derailed, setting off the audible alarm in the signalbox.
- 92 The signaller stated that 31 points were set for the loop as the previous train, 6B74, was passing the signal box at 02:50 hrs. Evidence from the signaller was that this was when he usually set the route and this is consistent with the way in which he was working the box on the data logger recording after the incident. There is no positive evidence that 31 points were set at this time.

- 93 The signaller was answering a telephone call from a train preparer at West Burton power station when the previous train, 6B74, was passing the box. During the voice recording of the call the signaller remarks to the train preparer that train 6B74 is passing and the sound of a passing train can be heard.
- 94 The signaller could not clearly recall his actions regarding train 6C51 that night. He was only able to recount his normal way of working the box. There is no positive evidence that train 6C51 was signalled in this way.
- 95 The signaller intended to set 31 points as soon as the previous train had passed. It is likely that he was distracted at some crucial point in his thought-action sequence by the phone call and did not pull the point lever at that time despite his intention to do so.
- 96 The signaller did not have a clear recollection of when he cleared signal M36 for 6C51 and it is likely that he never actually cleared it, but went to the frame as the train approached and pulled the point lever (31) at the moment that he originally intended to pull the signal lever (36). Operating the levers in this way is acceptable in terms of the interlocking, as the train should stop at signal M36, but the risk of a derailment is increased if a SPAD occurs. However, if the time of operation locking had been present, as designed, then this would have prevented the electric lock on lever 36 from releasing and this would have drawn the signaller's attention to the situation that he was attempting to operate the points just ahead of an approaching train.
- 97 A few seconds later, the 'lamp out' alarm sounded. The signaller had to carry out various actions to determine which lamp was out and established that it was signal 28.
- 98 When driver 2 called to say that he was derailed the signaller looked at the lever frame and track circuit display panel to determine point and signal settings. The display showed the track circuits into the loop as occupied and the signal lever was back in the frame. The signaller may have assumed that he had operated the controls as he normally did and therefore must have set the points when the train was at Firbeck and must have put the signal back as the train passed it.

## **Factors relating to train operation**

- 99 The signals at Maltby are not fitted with AWS or TPWS as this is a freight only line and these systems are not required, so there is no indication on the OTMR to show whether a signal is on or off.
- 100 The OTMR data showing the final approach to the stop at the derailment is shown in Figure 12. The data channels shown in Figure 12 are the train speed, brake pressure and throttle setting (shown as analogue traces) and the driver's brake handle (shown as digital indication at the bottom of the figure). The data has been plotted with distance as the horizontal axis. The distance from the locomotive to points 31B and signal M36 was measured on site and the signal and point location is indicated in Figure 12.
- 101 Figure 12 shows the train approaching signal M36 with the throttle in step 6 and the speed gradually rising. Driver 2 does not alter any control positions until a point 3.3m past the signal when he closes the throttle completely and applies the brakes. This throttle movement is very rapid, taking less than 0.5 seconds to accomplish. Previous instances in the shift when driver 2 had closed the throttle involved a gradual closure, typically 6 steps in 3 seconds. The fastest throttle closure on the OTMR prior to reaching Maltby was shortly into the journey over the South Yorkshire Joint Line when the throttle was moved from step 8 to step 4 in 1.0 second in response to the train reaching linespeed.

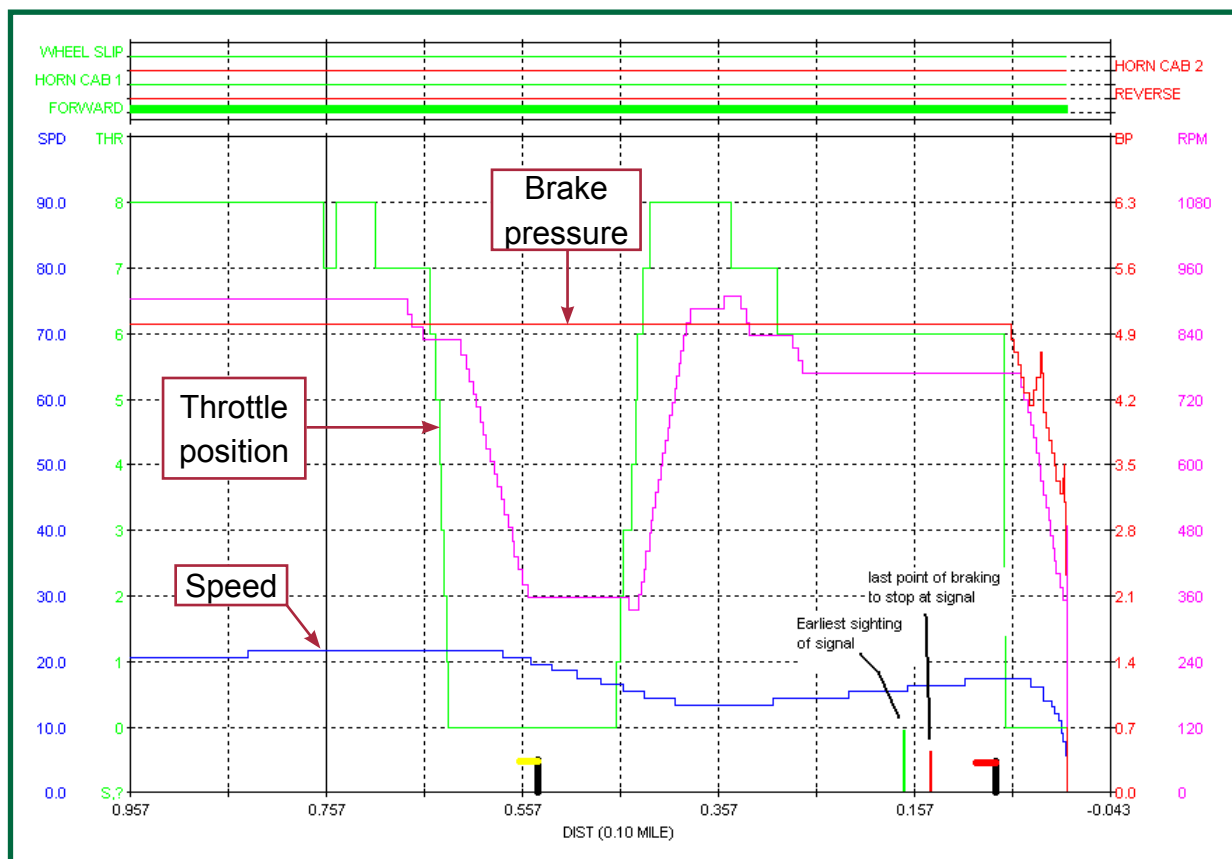


Figure 12: Annotated display from the OTMR

- 102 There was no positive evidence as to why driver 2 had shut the throttle so quickly. He stated that he had seen signal M36 at clear when he approached and passed it but he could not recall seeing the route indicator stencil. Analysis of the OTMR data suggests that either driver 2 did not notice signal M36 until after he had passed it or that he suddenly noticed that the speed of the train had risen too high for the turnout route and shut off to reduce it.
- 103 After the throttle closure and brake application, the brake was released and the train coasted for a further 13 m before an unsolicited brake application occurred, due to loss of brake pipe continuity. This loss of continuity occurred when the brake pipe was broken off the rear of the first wagon in the derailment. The train travelled a further 42 m before coming to rest.
- 104 When interviewed, driver 2 could not recall the reasons for his actions after passing the signal. It is likely that driver 2 passed signal M36 without observing its aspect. The testing of the signalling equipment (paragraphs 71 to 74) found no fault that would allow signal M36 to be cleared while 31 points were moving and so it is concluded that signal M36 must have been at danger when the train passed it.

#### Factors relating to the signaller

- 105 The signaller had worked for Railtrack since 1999 and had been a signaller since 2001. He was posted to Maltby box in October 2004. Prior to the accident, the signaller had not been involved in any accidents.
- 106 The signaller had undertaken assessments as part of the Network Rail signaller competence assessment programme and had obtained the required pass marks.

- 107 The signaller was working 12-hour shifts at the box. The box was manned on the basis of there being just two signallers to cover the full 24 hour period, so the need for a handover between outgoing and incoming signallers at each shift change made each signaller's time at the box slightly over 12 hours. The signaller on duty at the time of the derailment was working his second consecutive 12-hour night shift. Previous to these two night shifts, on Monday and Tuesday nights, he had had a rest day on Sunday and worked 12-hour day shifts the previous Thursday, Friday and Saturday. The first part of the previous week had consisted of three rest days.
- 108 The signaller reported that he had felt very tired during the hour leading up to the derailment but had managed to stay awake and reasonably alert as there had been a steady stream of trains passing. The signaller had rested during the previous day but had found it difficult to sleep.
- 109 In order to assess how fatigued signaller 2 may have been, his shift pattern was analysed using the Fatigue Index (FI), which is described in appendix C. The FI for the signaller for the turn of duty in which the accident occurred was 35, which is the level at which a night shift becomes prone to undue fatigue. As discussed in appendix C, the FI calculation does not take into account the amount of sleep obtained prior to the shift. He had had a rest day on the preceeding Sunday, followed by a full night's sleep. He did not sleep during the day on Monday and worked all that night. He went to bed on Tuesday morning, but had difficulty in sleeping, and was thus probably more fatigued on the Tuesday night, when the incident occurred, than the FI indicated. Fatigue of the signaller is regarded as a contributory factor to this accident.

#### Factors relating to the train driver

- 110 Driver 2 had started his career in 1982 with British Rail and became a *trainman* in 1989 and a driver in 1994. He transferred to Freightliner in 2002 and has driven class 66 locomotives since 1999.
- 111 Driver 2 had travelled over the South Yorkshire Joint line whilst a trainman and learnt the route again after joining Freightliner in 2002. Since then he had driven over the route an average of about 5 times a month, some in darkness and some in daylight.
- 112 During his driving career with BR, EWS and Freightliner driver 2 had not been involved in any incidents and had never passed a signal at danger.
- 113 In order to assess how fatigued driver 2 may have been, his shift pattern was analysed using the FI. Driver 2 had had a rest day the previous Saturday and worked a night shift starting at 22:05 hrs on Sunday night. The end of this shift had been delayed and he did not finish until 09:30 hrs Monday morning. This meant that his Monday night shift had to start later than planned at 21:30 hrs (rather than the intended 20:00 hrs). He worked until 04:30 hrs and got 6 hours sleep on Tuesday morning. He did not feel tired when he started work on Tuesday night at 20:00 hrs. The FI for this shift pattern is 30 if the task being undertaken by driver 2 is assumed not to be complex. If, however, the task is assumed to be complex, as it was earlier in the night while the locomotive failure was dealt with and the failed locomotive shunted off, the FI rises to 35. This is the level at which a night shift becomes prone to undue fatigue. Human factors research has shown that the highest risk of sleep-related accidents is in the early hours of the morning and that (road vehicle) drivers are about 50 times more likely to fall asleep at 02:00 hrs than at 10:00 hrs. Driver 2 is likely to have been starting to suffer from the affects of fatigue as he approached Maltby at 03:00 hrs.
- 114 It is likely that driver 2 passed signal M36 at danger and that fatigue may have been a contributory factor.

## **Severity of Consequences**

- 115 The linespeed through this area is only 25 mph (40 km/h) and this meant that the derailment occurred at a relatively low speed. The derailed wagons remained upright and did not spill their loads, further limiting the consequences of the derailment.



## Conclusions

### Immediate Cause

- 116 The derailment was caused by points 31B moving from normal to reverse as the first wagon in the train passed over them (paragraphs 67 to 69).

### Causal Factors

- 117 The time of operation locking for these points, which is listed in the control tables, was not implemented. Had it been, the accident would not have occurred (paragraph 78, **Recommendations 1 and 2**).
- 118 Though it cannot be proven positively, it is likely that the driver of train 6C51 did not observe signal M36 and passed it at danger (paragraphs 104 and 114).
- 119 Though it cannot be proven positively, it is likely that the signaller pulled the lever for 31 points just as the locomotive reached signal M36. This would not have caused an accident had the train not passed the signal at danger at the same time (paragraph 96, **Recommendation 1**).

### Contributory Factors

- 120 Signal M36 is poorly sited with a distance of only 3 m between it and 31B points (paragraphs 75 and 29).
- 121 The length of the shifts being worked by the signallers at Maltby may have made them prone to fatigue (paragraph 109, **Recommendation 3**).
- 122 The driver of train 6C51 may have been suffering the effects of fatigue following events associated with the locomotive failure earlier in his shift (paragraph 113).

### Observation

- 123 The design of the interlocking on 31 points is not in accordance with present-day design principles. The position of lever 31 is not proven directly from the lever bands, but from relays driven by these bands (paragraph 85). This makes it possible, under certain fault conditions, for the lever to be in reverse but the indicator to show the points set normal (paragraph 88, **Recommendation 4**).

## **Actions reported as already taken or in progress that affect this report**

124 Network Rail have installed a data logger to monitor points and signals at Maltby North.

This will not prevent a similar incident from occurring but may positively prove the cause.

125 Network Rail have implemented time of operation locking on 31 points at Maltby.

## Recommendations

126 The following safety recommendations are made<sup>1</sup>.

### **Recommendations arising from causal and contributory factors**

1. Network Rail should implement a system to prevent 31 points at Maltby from operating as a train is approaching or passing over them (paragraphs 117 and 119). Time of operation locking of 31 points was implemented in May 2007 (paragraph 125).
2. Network Rail should find out whether there are other similar installations where time of operation locking is specified but not implemented. Based on this, Network Rail should implement appropriate control measures to control the risk of a similar incident occurring at these locations (paragraph 117).
3. Network Rail should design roster patterns for signal boxes that are manned by a single person such that the signaller is not subjected to undue fatigue (paragraph 121).

### **Recommendations arising from observation**

4. Network Rail should alter the design of the interlocking at Maltby so that movement of lever 31 positively destroys detection on the points until they have moved to the new position (paragraph 123).

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<sup>1</sup> Responsibilities in respect of these recommendations are set out in the Railways (Accident Investigation and Reporting) Regulations 2005 and the accompanying guidance notes, which can be found on RAIB's web site at [www.raib.gov.uk](http://www.raib.gov.uk)

## Appendices

### Glossary of Abbreviations and Acronyms

### Appendix A

AWS	Automatic warning system
IBJ	Insulated block joint
LNET	(Network Rail) London North Eastern Territory
OTMR	On-train monitoring and recording (system)
TPWS	Train protection and warning system

## Glossary of terms

## Appendix B

All definitions marked with an asterisk, thus (\*), have been taken from Ellis' British Railway Engineering Encyclopaedia © Iain Ellis. [www.iainellis.com](http://www.iainellis.com)

Accredited Agent	A member of railway staff trained and appointed by the RAIB to gather perishable evidence pending the arrival of RAIB inspectors.
Automatic air brake	A brake system operated by compressed air which automatically applies the brake if air pressure is lost.
Block joint	An insulated joint between two lengths of rail that marks the boundary between adjacent track circuits.
Block section	A section of track divided by the signalling system in which only one train is permitted at a time.*
Brake cock	A valve fitted in the brake pipe at each end of a wagon which can be closed to prevent compressed air from leaking away when the wagon is at the end of the train.
Brake (pipe) continuity	The state where the train brake pipe system is intact and functional. Loss of brake pipe continuity causes the train brakes to apply.
Cripple siding	A siding used for the storage of defective rail vehicles awaiting repair.*
Control tables	The tables that contain information specifying how points and signals are interlocked.
Crossover	A route between two parallel tracks that allows a train to cross to the other track.
Distant (signal)	A signal only capable of displaying a proceed or caution aspect.*
Down	In a direction away from London or in the direction of increasing mileage.*
Fishplated rail joint	A mechanical joint between two rails made by means of plates and bolts.*
(Semaphore) Fixed distant (signal)	A distant signal only capable of displaying a caution aspect.*
Gross laden weight	The total weight of a vehicle including the load it is carrying.
Ground position light (signal)	A shunting signal consisting of a group of lights mounted at ground level.
Home signal	The first signal capable of displaying a stop aspect.*
Insulated block joint	A rail joint that incorporates insulating material to provide electrical isolation of the two rails joined.
Interlocking	The system of preventing signals and points from being set so as to produce a dangerous condition.
Intermediate block	A section of track between two signal boxes controlled from one of those boxes.

Lever Band	A copper drum operated by a mechanical signal lever which makes or breaks a pair of contacts to indicate the lever position.
Lever Lock	An electrically operated bolt which is withdrawn from a notch to allow a mechanical lever to move.
Linespeed	The maximum permitted speed at which trains may run when not subject to any other instruction or restriction.
Normal	The position of a point when set for the most usual route through it.
Power signal box	A large signal box where points and signals over a wide area are controlled.
Relay Interlocking	A system of electrical switches that are designed to control points and signals to prevent conflicting routes being set.
Reverse	The position of a point when set for the opposite route to the normal route through it.
Signalling principles tester	A signalling engineer professionally qualified to undertake testing activities which are independent of the design; and provide suitable and sufficient evidence to confirm that the operational, technical, and safety principles demanded by the designated authorities have been validated.
Sixfoot	The space between one line and another. This distance may be less than six feet wide.
Screw couplings	A means of coupling vehicles together that involves a threaded bar for adjustment of the distance between the vehicles.
Stock rail	The fixed rail of a set of points.
Switch diamond	An intersection between two tracks which involves moving blades to minimise the gaps between the sections of rail.
Switch lead	The distance between the switch tips and the crossing of a turnout.
Switch rail	The movable rail of a set of points.
Time of operation locking	A means of preventing a signal, or other device, from being operated while another piece of equipment is changing state.
Track circuit	An item of electrical signalling equipment connected to the rails to detect the presence of a train.
Track circuit block	A system of operation of a railway line involving the division of the line into track circuited block sections.
Trainman	A member of train crew who is not qualified to drive the train but carries out other operational duties. This grade was created by British Rail in 1988 by amalgamating the roles of guard and secondman.
Turnout	A piece of track which is designed to allow trains to be diverted to another track. Also referred to as a set of points.
Up	In a direction towards London, or in the direction of decreasing mileage.*



The Fatigue Index (FI) was developed by the Centre for Human Sciences at the Defence Evaluation and Research Agency (now known as QinetiQ) in a research project commissioned by the HSE. It was designed to provide a means to assess the short-term daily fatigue and cumulative fatigue risks associated with shift work. Both the start time of a shift and its duration will have an affect on alertness. The risk of fatigue is at its highest in the early hours, and as the duration of the shift increases, the likelihood of an accident increases.

The FI is based on the five main factors known to have an impact on fatigue: time of day, shift duration, rest periods, breaks within a shift, and cumulative fatigue. For each component a scoring system operates.

The FI takes account of day, night and early shifts and can be used to compare different shift patterns. It can also be used to identify peaks of fatigue within a shift pattern so that suitable control measures can be put in place. If the FI is 30 or more for day or evening shifts, or 35 or more for night shifts, then steps should be taken to reduce it.

However, the FI has some shortcomings in that it deals with averages only and takes no account of individual factors such as age and fitness etc. Significantly, it also takes no account of an individual's lifestyle outside work, including the amount of sleep obtained preceding a shift. The FI does enable effective comparisons to be made between different shift roster patterns.

If fatigue levels are assessed as being high, it is incumbent upon employers to introduce suitable control measures. These are likely to include shift-work education and a shift system that conforms to good practice guidelines so far as is reasonably practicable. The following are examples of good practice:

- restricting the number of nightshifts to no more than four in a row if possible;
- allowing no additional overtime if 12-hour shifts are worked;
- planning a minimum of 12 hours between shifts;
- using forward rotation (morning/afternoon/night);
- taking travelling time into account.

The FI calculation allows for the complexity of the task being done to be taken into account by means of a simple 4 step scale, with 1 being a simple task and 4 being the most complex.

This report is published by the Rail Accident Investigation Branch,  
Department for Transport.

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