RAIB
Rail Accident Investigation Branch

Rail Accident Report

Collision at Badminton
31 October 2006

Department for Transport

Report 30/2007
August 2007

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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Contents

Introduction

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to prevent future accidents and incidents and improve railway safety.

2 The RAIB does not establish blame, liability or carry out prosecutions.

3 Access was freely given by First Engineering, Swietelsky Construction, Bridgeway Consulting and Network Rail 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; and
- technical terms (shown in *italics* the first time they appear in the report) are explained in Appendix B.

5 In this report, locations are referred to by their position, in the form of a distance in miles and chains from zero at London (Paddington), in accordance with standard practice on the UK national network. There are 80 chains in one mile.

Summary of the report

Key facts about the accident

6 At about 22:54 hrs on Tuesday 31 October 2006 two self-propelled track maintenance machines, a *tamper* and a *ballast regulator*, collided near the site of the former station at Badminton, Gloucestershire. The collision occurred on the *up line* of the railway between Bristol Parkway and Swindon stations, on a section of line that was closed to normal traffic for track renewal work.

7 The tamper was travelling at about 35 mph (56 km/h), and the ballast regulator was stationary. All four people on board the machines, the drivers and two machine operators, were injured, two of them seriously.

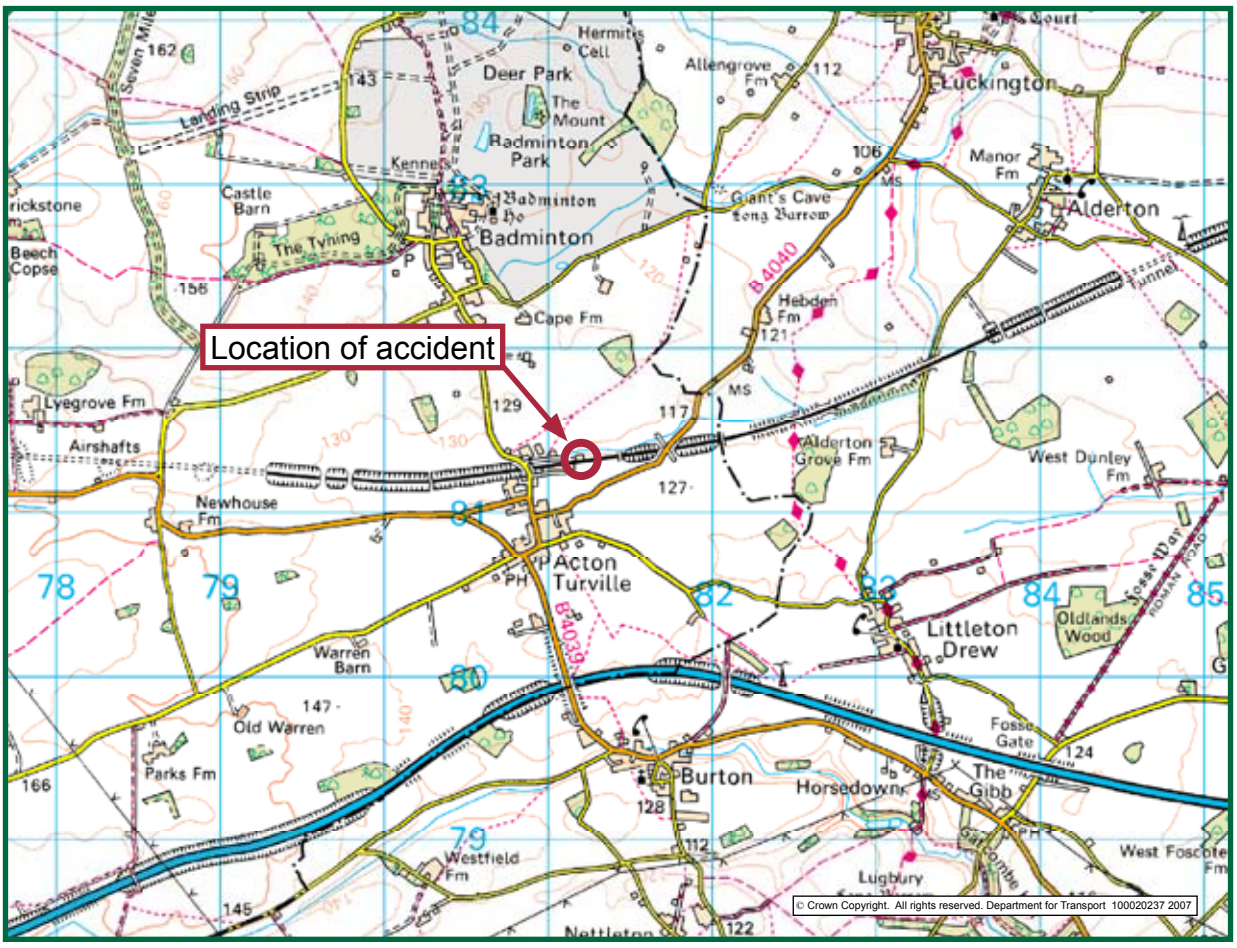

Figure 1: Extract from Ordnance Survey map showing location of accident

Immediate cause, causal and contributory factors, underlying causes

8 The immediate cause of the accident was that the driver of the tamper did not control his speed or react to the presence of the stationary regulator on the line ahead, so as to be able to stop short of it.

9 Causal factors were:

- the fatigue experienced by the driver, which may have made it difficult for him to remain alert; and
- running the tamper and regulator separately, rather than coupling them together.

10 In addition, the following factors were considered to be contributory to the severity of the accident:

- the custom of OTM drivers of driving at more than 20 mph (32 km/h) in *work sites*, and the failure of First Engineering's monitoring and assessment system to identify and correct this; and
- the lack of a defined speed limit for movements in work sites.

11 The investigation also observed that the extreme length of the work site resulted in an arrangement which permitted the two machines to travel long distances on the same section of line simultaneously, with neither the protection of the signalling system nor suitable operational measures to control the risk arising.

12 In addition to this, the lack of a definition of a work site in the rule book and the resulting ability to make the work site so long made it difficult for the *engineering supervisor* (ES) to comply with the Rule Book requirements and increased the risk to people working.

Recommendations

13 Recommendations can be found in paragraph 120. They relate to the following areas:

- the size and organisation of work sites, and the movement of machines within them;
- monitoring and assessment of drivers of on-track machines; and
- reduction of risk of injury to staff travelling on on-track machines by contact with internal fixtures and fittings.

The Accident

Summary of the accident

14 At about 22:54 hrs on Tuesday 31 October 2006 vehicle DR73112, a Plasser & Theurer 09-3x *plain line tamper*, collided with stationary vehicle 77209, a USP5000RT ballast regulator also manufactured by Plasser & Theurer, near the site of the former station at Badminton, Gloucestershire, on the up line of the railway between Bristol Parkway and Swindon stations.

15 The collision occurred at about 35 mph (56 km/h). The driver of the tamper, the only person on board, was seriously injured. There were three people on the ballast regulator, the driver and two machine operators: all of them were injured, one seriously.

16 The emergency services were called by staff and members of the public who saw or heard the collision, and arrived about twenty minutes later. First aid for the injured was provided by staff and local residents.

Figure 2: The tamper after the collision, showing damage to the front end

17 There was no damage to the track or signalling equipment. After inspection by First Engineering staff to confirm that they could be run safely, the damaged machines were removed by rail at slow speed to Chipping Sodbury sidings, and the line was re-opened for traffic at 14:55 hrs on 1 November 2006.

The parties involved

18 The railway is owned, operated and maintained by Network Rail (Western Route). The tamper and regulator, which were operating in a work site within a *possession*, were owned by Network Rail and operated by First Swietelsky, the operating name for the High Output division of First Engineering Ltd. The High Output project is a contract for delivery of track renewals work on Network Rail, and in the Western and London North Eastern territories it is a joint venture between First Engineering Ltd and Swietelsky Construction Co Ltd; the operational aspects are managed by First Engineering Ltd under the 'First Swietelsky' operating name.

19 The tamper and regulator drivers and the machine operators were employed by Swietelsky Construction, and managed by First Engineering. Staff involved in the management of the possession (the *person in charge of the possession* (PICOP), and the person operating the *ground frame* at Chipping Sodbury) were provided by Bridgeway Consulting Ltd. The engineering supervisor (ES) was provided by the New ISG staff agency.

Location

20 The accident occurred at a site known as Badminton Old Station, which is at the 100 milepost (from London) on the railway between Wootton Bassett Junction (west of Swindon) and Westerleigh Junction (east of Bristol Parkway). There was formerly a station at this point, from the opening of the railway in 1903 until 1968. The site of the station is now used for access to the railway for engineering works, and in connection with this a portable building where signing-on and briefing takes place has been provided. The site is close to the village of Acton Turville, Gloucestershire (Figure 1).

21 At this point the railway is double track, and in normal operation trains are permitted to run at up to 125 mph (200 km/h). The line from Chipping Sodbury (104 miles 31 chains) to Badminton (100 miles) is on a rising gradient of 1 in 300. Chipping Sodbury tunnel (which is 2 miles 926 yards (4.1 km) long) extends from 103 miles 48 chains to 101 miles 6 chains (Figure 3). The route is almost straight, with a slight left-hand curve approaching Badminton. Signalling on the line is by the *track circuit block* system, with two, three and four aspect colour light signals controlled from Bristol *panel signal box*. However, the signalling system was not being used to control the machines involved in the collision (paragraph 35).

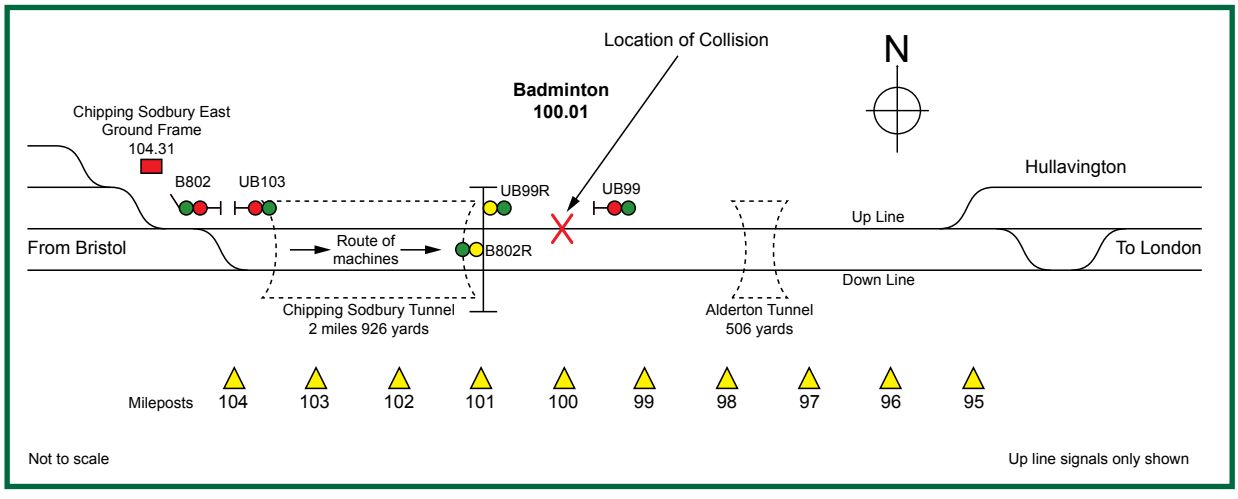

Figure 3: Schematic diagram

External circumstances

22 The night was clear, and there was no frost. Visibility was good. The area in which the accident occurred is rural, and there were few lights visible outside the railway boundary. The access point at Badminton was brightly lit, with at least one light pointing towards the track.

Rail equipment

23 The tamper involved in the collision, DR73112, was built in Austria in 2005 (works no. 3155). It was a Plasser & Theurer 09-3x plain line tamper with *dynamic track stabilising* equipment, weighing 129 tonnes, and with an overall length of 35 m. Its maximum speed was 60 mph (100 km/h). It could be driven to and from work sites from either end, but when working it could be operated from the 'A' end (the west end on the day of the accident) only (Figure 2).

24 The other machine, DR77902, was a Plasser & Theurer USP5000RT ballast regulator, 27 m long, weighing 89 tonnes, also with a maximum speed of 60 mph (97 km/h). It was built in 2004, also in Austria. It was also intended to be operated from the end which was facing west at the time of the accident. This end has a large operating area behind the driving controls, with seats for the operators from which they can observe the work the machine is doing, both via CCTV and directly through windows overlooking the belts and buckets of the machine.

The tamper driver

25 The tamper driver was 47 years old. He joined the railways in 2000 as a trainee driver with South West Trains (SWT), and went through that company's training process. He qualified as a driver in June 2001, and after completion of route learning he drove passenger trains out of Salisbury depot from November 2001 until he transferred to Freightliner Heavy Haul at Bristol in April 2003. While at Bristol he drove freight trains over a large area of the country.

26 The driver transferred to First Engineering in January 2006, to develop his career by working on a wider range of traction and routes. He was given training on driving on-track machines, and assessed on his competence to drive the 09-3x tamper on 7 March 2006. He then began work driving machines in connection with the High Output project. He already had *route knowledge* covering most of the routes on which the High Output project would work.

Events preceding the accident

27 The High Output (HO) project began in 2004. It involves the use of modern track relaying and ballast cleaning equipment, designed to perform these processes more quickly than has been possible in the past.

28 The work on the line between Wootton Bassett and Westerleigh had been in progress for six weeks. It involved renewal of the *down line* east of Badminton (with associated reballasting), and ballast cleaning and follow-up tamping on the up line near Hullavington (near the 95 milepost).

29 On the night of 31 October, work was planned to take place between 21:50 hrs and 05:45 hrs. Possession of the up and down lines was due to be taken once the high output ballast cleaning (HOBC) train (6Y11), had arrived, on the down line, at signal DB98 at Alderton, one and a half miles (2 km) east of Badminton. Within an engineering possession, locations where work will take place are known as work sites (Rule Book Module T3, sections 1.2 and 2.2). A single work site was set up, extending from 86 miles 75 chains to 104 miles 40 chains. Two pairs of machines, each pair comprising a tamper and a ballast regulator, then entered the possession: one pair from the sidings at Chipping Sodbury, directly into the possession/work site, and the other pair from Swindon into the east end of the possession.

30 The tamper driver had been on leave from 15 to 24 October. He then spent three days working 08:00 hrs to 15:30 hrs. In this period he spent two days route learning between Reading and West Ealing, and one day ferrying a tamper and regulator from Chipping Sodbury to Oxford.

31 After ceasing work at 15:30 hrs on Friday 27 October, he moved to night work, coming on duty at midnight on Saturday 28 October. He then worked until 12:00 hrs on Sunday 29 October driving a tamper in a track renewal site near Oxford. His next turn began at 19:30 hrs on Monday 30 October, ferrying the tamper from Oxford to Swindon then working with it in a possession between Little Somerford and Hullavington. He booked off at Swindon at 06:00 hrs on Tuesday 31 October. He drove home, a journey of about an hour, and went to bed. The details of his activities later in the day are unclear. He left home in mid-evening for the drive of one hour to Chipping Sodbury, arriving there about 21:00 hrs.

32 For operational reasons, on the evening of Tuesday 31 October First Engineering exchanged the tamper which had been stabled at Chipping Sodbury since the previous night's work (DR73111) with tamper DR73112, which had been at Swindon since 29 October. DR73112 was brought from Swindon to Chipping Sodbury by a First Engineering driver standards manager, who then returned immediately to Swindon with DR73111, arriving there by 21:50 hrs.

33 The drivers of the tamper and regulator arrived at Chipping Sodbury and contacted First Engineering control in Glasgow to confirm their presence and fitness for duty. The tamper driver used his mobile telephone to book both himself and the regulator driver on duty at 21:10 hrs.

34 Some shunting was necessary at Chipping Sodbury to release DR73111 and get the machines into the correct positions for the night's work. During this shunting the head and tail lights on DR73112 and the regulator DR77902 were observed to be working correctly.

35 The possession was taken slightly late, at 22:13 hrs. The ES instructed the *ground frame operator* at Chipping Sodbury, by telephone, to brief the drivers of the tamper and regulator. The ground frame operator passed on instructions to both drivers to run to milepost 100 at Badminton, to stop there to pick up the machine crews, and to wait at Badminton for further instructions. As they were running in a possession, the drivers were instructed to proceed at caution and pass all signals at danger. There was therefore no protection provided by the signalling system: this is the normal, authorised method of operation in possessions.

Events during the accident

36 The regulator departed from Chipping Sodbury at 22:39 hrs. It travelled to Badminton and stopped. Two members of Swietelsky staff boarded the rear cab of the machine and began to prepare it for the night's work. The regulator driver remained in the front cab, awaiting further instructions from the ES.

37 The tamper left Chipping Sodbury at 22:43 hrs, about four minutes after the regulator. The OTDR record shows that the driver accelerated to 29 mph (46 km/h) going into Sodbury tunnel, then reduced speed to 10 mph (16 km/h) in the middle of the tunnel. He then applied power again and the speed of the tamper had reached 35 mph (56 km/h) and was still increasing, when the tamper collided with the stationary regulator at Badminton at 22:54 hrs. A member of Swietelsky staff was standing by the line, waiting to board the tamper, and had to take evasive action to avoid being struck by debris from the collision.

38 The regulator, standing with its brakes on, was propelled violently forward. It came to rest 80 m beyond the point of impact, 17 m ahead of the tamper. Neither vehicle was derailed.

Consequences of the accident

39 The driver of the regulator and the two crew members in its rear cab were all injured in the collision. The regulator was badly damaged: the engine was shifted from its mountings, one bogie kingpin was fractured, the two rear buffers were knocked off, several windows were broken and much of the on-board electronic equipment was displaced from its mounting racks.

40 The tamper driver was seriously injured. The tamper was extensively damaged: the underframe was distorted and the articulation drawbar (which connects the two sections of the machine) was buckled. Both front buffers were knocked off, the bufferbeam was bent and the drawgear was distorted (Figure 2). Debris from the collision was spread along the line for about 28 m beyond the point of impact. One buffer was found near the yard access gate, about 13 m away from the line.

41 Both machines were subsequently declared to be beyond economic repair.

Events following the accident

42 The emergency services were called by First Swietelsky's manager of the site access point at Badminton. The location is remote. Ambulances arrived within twenty minutes and the injured were removed to Frenchay Hospital, Bristol and Bath Royal United Hospital. Local residents and railway staff gave first-aid assistance.

43 At 02:30 hrs, technical staff from First Engineering identified a misaligned and heavily compressed spring in one of the bogies of the regulator. Because of their evaluation of the potential for this spring to release suddenly, possibly projecting components violently into the air, residents were evacuated from some nearby houses. After the arrival of a recovery team from EWS at 05:15 hrs, the hazard was safely dealt with by 06:30 hrs.

44 The tamper and regulator were made fit to run at low speed, and were removed by rail to Chipping Sodbury sidings, arriving there by 14:55 hrs on 1 November, when the main lines were re-opened for normal traffic. Both machines were subsequently removed by road to the manufacturer's depot at West Ealing, where detailed examination took place.

The Investigation

Sources of evidence

45 The RAIB obtained evidence for this investigation from:

- on-site examination of the machines and the surrounding area;
- interviews with staff concerned;
- detailed examination and testing of the tamper and regulator at the manufacturer's depot; and
- analysis of the *on-train data recorders* (OTDR) from both machines.

46 The tamper driver was unable to recall the details of the journey, and up to the time of publication of this report it had not been possible, for medical reasons, for the RAIB to interview him about other aspects of the event. Information about his movements has therefore been obtained from other sources and may not be comprehensive.

Factual Information

The driving of the tamper

47 Events while the tamper was running from Chipping Sodbury to Badminton have been reconstructed entirely from analysis of the OTDR, because the driver of the tamper was unable to recall what had happened after entering the tunnel at Chipping Sodbury, until he became aware of finding the tamper stationary and himself inside the cab, injured.

48 The 4.4 mile (7.1 km) journey from Chipping Sodbury to Badminton took 11 minutes 15 seconds, an average speed of 23.5 mph (37.8 km/h). Line speed on this section is 125 mph (200 km/h), but the tamper is limited to a maximum speed of 60 mph (100 km/h). Analysis of the OTDR from the tamper shows that the driver applied 35 % throttle to move out of the siding at Chipping Sodbury, reaching 4 mph (6 km/h), and then shut off power to pass through the points onto the main line. He opened the throttle again and over the next 3 minutes 56 seconds the tamper accelerated to 29 mph (47 km/h) at about the mid-point of Chipping Sodbury tunnel. The driver shut off power for 1 minute 45 seconds, and speed dropped (on the rising gradient of 1 in 300) to 10 mph (16 km/h). The driver then applied power (48 % throttle), and the speed of the tamper rose steadily over the next 5 minutes 10 seconds, reaching 35 mph (56 km/h) when the collision occurred with power still applied.

49 Throughout the journey the driver was responding to the driver's safety device (DSD, sometimes known as the 'vigilance') on the tamper. This required him to keep a pedal depressed, and acknowledge an audible alarm by releasing and re-pressing the pedal. If he did not do this within three seconds the emergency brake would be applied and could not be released until the machine had come to a stop. The alarm would sound every 61 seconds if the driver did not move the pedal in that period, but the 61 second delay could be reset at any time by releasing and re-pressing the pedal.

50 On this journey, the driver acknowledged the DSD every 61 seconds for the first six minutes after leaving Chipping Sodbury. He then initiated a DSD input after 52 seconds, acknowledged the next warning 61 seconds later and then made a further series of inputs at irregular intervals (12, 24, 25 and 33 seconds). The last of these coincided with acknowledgment of an AWS warning horn for signal B802R (a signal for moves in the down direction on the up line, the AWS for which was not suppressed as it would be for trains in normal running because no route had been set by the signaller for the movement of the tamper), at about 100 m 75 ch.

51 Following this, the driver acknowledged the next DSD warning 61 seconds later, and 44 seconds after that, the AWS 'clear' bell sounded for signal UB99 (this is an automatic signal which was showing a green aspect at the time, because the regulator had not passed it). One second later, the driver released and reset the DSD, sounded the tamper's horn for 0.8 seconds (about one second before impact), and released the DSD as the collision occurred.

52 The OTDR shows that the brakes of the tamper were not applied before the impact. Witnesses on the ground at Badminton, who saw the tamper approaching, did not hear any sound of braking.

53 The tamper driver had a mobile telephone provided by his employers. At the time of the accident the SIM card from this phone was being used in the driver's personal phone. No calls were made or received on this number between the time the driver signed on duty at 21:10 hrs, and the time of the accident.

The condition of the machines

54 Following the collision, the braking system of the tamper could not be tested on-site because of damage to the shut-off valve at the front of the machine, but the information obtained from the OTDR showed no evidence of any attempt to apply the brakes before the collision. The braking system was subsequently tested by the manufacturers at their depot at West Ealing in the presence of an RAIB inspector. No defects were found.

55 The tail lights of the regulator, and the headlights of the tamper, were destroyed in the collision. Witness evidence indicates that they were all functioning normally and were alight before the collision, and subsequent testing of the control circuits under the supervision of the RAIB, and of the electronic control modules by the manufacturers in Austria, did not identify any defects.

56 The control system of the tamper was tested after the collision, and the functioning and calibration of the speedometer was checked under the supervision of the RAIB. No defects were found.

Driver competence, assessment and monitoring

57 The driver had some six years experience since joining the railways, beginning with his training by SWT at their Salisbury depot (paragraph 23). While he was based at Salisbury, the driver was involved in a signal passed at danger (SPAD) incident for which he was held responsible. He had not checked that a signal had been cleared before moving off, during shunting to transfer empty carriages from one platform to another at Salisbury station. As a result of this he was placed on SWT's list of specially monitored drivers and given special monitoring and assessment in accordance with the requirements of railway group standard GO/RT3251 'Train Driving'.

58 This standard requires train operators to have systems in place that will provide special monitoring and support of individual drivers when, among other things, a driver has caused or contributed to an incident. These systems should include processes for:

- developing, agreeing and implementing action plans that include practical interventions to minimise the potential risk;
- monitoring driver performance, either through obvious or unobtrusive means, but directly related to the level and nature of the risk present; and
- recognising when performance has improved sufficiently to allow, through the application of the relevant criteria, removal of the driver from special monitoring.

The standard permits train operators to exercise discretion over the length and nature of action plans, but all decisions are required to be documented.

59 In accordance with industry procedures, information about the driver's record, including the SPAD incident, was passed to Freightliner Heavy Haul when he transferred to that company, and then to First Engineering. The special monitoring and assessment therefore continued during his employment by these companies. During his service with First Engineering, he was assessed by a Driver Standards Manager for competence in carrying out driving duties on 10 May 2006, while driving from Reading to Chipping Sodbury, and again on 8 August 2006 while working in and out of an engineering possession at Wootton Bassett, as part of the monitoring required by GO/RT3251. The results of both these assessments were satisfactory.

Driving within work sites

60 At the time of the accident, the movement of on-track machines within engineering possessions was governed by the requirements of module T11 of the Rule Book (GE/RT8000). This module has since been amended.

61 Section 3.3 stipulated that only one movement at a time may take place within the area of the possession under the control of the PICOP. There was no comparable restriction relating to the areas (the work sites) under the control of an engineering supervisor. It was therefore permissible for the tamper and regulator to be moving at the same time in the work site that extended from Chipping Sodbury to the eastern limit of the possession at Wootton Bassett.

62 Section 8.4 of module T11, directed to the driver, read:

a) **Making the movement at caution**

You must:

- Make the movement at caution
- Be prepared to stop where required by a handsignal.

You must also carry out the instructions set out in module S5 *Passing a signal at danger* or TW7 *Wrong-direction movements* until your train is brought under the control of a signal.

b) **Passing a signal within the possession**

- You must not pass a signal **at danger** within the possession unless you are authorised to do so by the PICOP or the engineering supervisor
- You can pass **without authority** a signal showing a proceed aspect or indication but you must disregard the normal meaning of that signal.

63 This instruction applied to movements in both PICOP and ES controlled areas. The driver of the tamper had been authorised to pass signals at danger, but in the event after leaving Chipping Sodbury he did not encounter any signals at danger before the tamper reached Badminton.

64 An amendment to the Rule Book, which came into effect on 2 December 2006, added to section 8.4 a bullet point after "Make the movement at caution", reading:

- Not exceed 40 mph at any point in the journey when entering, making a movement within, or leaving the possession.

65 The purpose of this change was explained, in the amendments to the module issued by RSSB, as being to enable a safe system of work to be set up for people working outside work sites on lines controlled by the PICOP. However, Section 8.4 applies to the whole of a possession, including work sites.

66 The expression 'at caution' is not defined in the Rule Book. However, it is often linked to an instruction to 'be prepared to stop short of any obstruction'. It was therefore subject to interpretation by individual employers and drivers. Within First Engineering, drivers were instructed that within a possession, they should be travelling at a speed which would enable them to stop clear of any obstruction. As advice to help them interpret this instruction, drivers were told that, within a work site where people might be working on the track without lookout protection, speed should not exceed walking pace. If an ES advised the driver that the work site was not a green zone, the maximum speed should be 20 mph (32 km/h). This advice was passed on by driver instructors and standards managers and was not written down. It is in line with the Rule Book instructions to the COSS of work being carried out within a possession, in an ES's work site, after dark, under lookout protection. These instructions, which were in section 10.3 of module T7, required the ES and COSS to agree that all movements within the work site would be restricted to 20 mph (32 km/h). This module of the Rule Book was not issued to drivers as it only applies to staff working on the ground.

67 However, the drivers of both the regulator and the tamper drove at up to 35 mph (56 km/h) between Chipping Sodbury and Badminton, in an area that was designated a work site under the control of an ES. Examination of other OTDR records showed that this had occurred before, with both the tamper and the regulator in the four weeks before the accident.

Running machines separately

68 The tamper and regulator ran separately from Chipping Sodbury to Badminton. If they had been coupled together and run as a single train the accident would not have occurred.

69 Coupling OTMs together, with one towing the other, was once standard practice in the UK. However, the latest generation of machines were not designed with this in mind, and when, at the inception of the High Output project, it was suggested that the designs of tamper and regulator involved in the incident be used coupled together with the lead machine towing, the manufacturers expressed concern about the compatibility of the drive trains and the possibility of over-straining one machine when towing another. The machines were designed to be adaptable for *multiple working*, ie with both machines under power, controlled by a driver in the leading machine, but the necessary equipment for this was not fitted when they were built.

70 The objective of coupling machines together was considered by Network Rail to be worth pursuing, because of the potential benefits to both safety and efficiency, so in 2006 a programme of equipping Network Rail's fleet for multiple working was commenced. The necessary equipment was being fitted at the time the accident took place, and the fitting work has since been completed, and multiple working was implemented on 3 July 2007 (paragraph 118).

71 In the intervening period First Engineering investigated the possibility of tandem working, in which the two machines are coupled together and each has a driver on board and is under power. There are risks associated with this approach, particularly in ensuring that the driver of the rear machine, whose forward view is severely restricted, shuts off power when required, and it was not implemented in view of the multiple working programme described above.

Length of work sites within engineering possessions

72 Although the Rule Book specifies that locations within a possession where work will take place are known as work sites (module T3, section 1.2), there is no definition of what exactly a work site is in terms of the extent of the location or the nature of the work. Module T6 defines a work site as 'a portion of line within a possession where work is taking place', but is silent as to the relationship between the actual extent of the work and the work site limits. The engineering supervisor (ES) is responsible for the safety of the work and the control of train and vehicle movements within the work site (Module T3, section 10). The limits of work sites are defined by marker boards placed between the rails. Diagrams in module T3 show marker boards placed at least 100 m beyond an area shown as 'work site', which may be the area where work is actually taking place, or may be a much longer length of track.

73 However, if there is only one work site in the possession, and the only movements that will take place are those of on-track machines or on-track plant, marker boards do not have to be used (Module T3, section 10.1). If tampers are working at different locations then the T6 definition requires a work site to be set up for each and marker boards would be required.

74 In the possession between Wootton Bassett and Westerleigh, on 31 October, there was only one work site, and one ES. The possession itself was 24 miles (39 km) long, and the work site was 17.5 miles (28 km) long, extending from 86 miles 75 chains (near Brinkworth) to 104 miles 40 chains (Chipping Sodbury). Within the work site there were actually three separate locations where work was taking place:

- High Output ballast cleaning on the down line (95 miles 69 chains and 103 miles 62 chains, which on 31 October had reached around 99 miles, slightly east of Badminton).
- Follow-up tamping on the up line between Hullavington and Wootton Bassett (86 miles and 94 miles 32 chains). This extended outside the limits of the work site set up that night (this discrepancy was not noticed during the planning process or during the possession period). Marker boards were positioned at 86 miles 75 chains and 104 miles 40 chains.
- Remedial work to the retaining walls and the top of the cutting slope outside the eastern end of Chipping Sodbury tunnel (101 miles). This work was not mentioned in the WON because the work was not on or near the line, but the COSS in charge of the work had signed in to the railway work site because of the possibility that equipment, material or debris might fall from the retaining wall and obstruct the line.

75 There were also two items of work planned to take place within the possession, under 'red zone' arrangements extending beyond the limits of the work site. These were track inspection (ultrasonic rail examination) and cable works in connection with the GSM-R project, which could have been in progress anywhere between 84 miles 7 chains (Wootton Bassett West) and 106 miles 60 chains (Westerleigh Junction), virtually the whole length of the possession. These works would not have involved the use of on-track plant, and the staff engaged in them would have been protected from passing trains by look-outs. The COSS in charge of each activity would be responsible for putting the protection arrangements in place, with reference to the ES or PICOP in accordance with module T7 of the Rule Book. In the event, these activities did not take place on 31 October 2006.

Severity of consequences

76 Four people were injured in the accident. The drivers of the tamper and regulator were both sitting in the leading cabs of the machines and were thrown against the control desks. The operating crew of the regulator were preparing the rear cab, and were injured by being thrown against equipment cabinets in the operating area. There was no structural collapse or loss of integrity of the cabs and working spaces.

77 Prompt attention was given to the injured after the accident, by staff trained in first aid and by local residents. The emergency services were called immediately after the collision and, considering the remoteness of the site, their response was rapid and effective.

Previous occurrences of a similar character

78 The most recent accident in which engineering trains or on-track machines collided with standing vehicles in a possession occurred at Fosse Road near Leamington Spa on 24 April 2005, when a train consisting of a locomotive and 40 loaded ballast wagons collided with wagons standing in a work site.

79 The train had travelled just over one mile (1.6 km) from the work site marker boards, reaching speeds of up to 17 mph (27 km/h). There was no tail lamp on the standing vehicles at the time of the collision, and the locomotive driver did not see them until it was too late to stop. The collision occurred at 5 mph (8 km/h), and there were no injuries.

Analysis

Identification of the immediate cause

80 The sequence of actions recorded by the OTDR suggests that the driver may have been having difficulty keeping alert, and so may have lost concentration after the final routine DSD warning, until he was roused by the AWS bell, and so realised that the regulator was immediately ahead, too late to take any effective action. The tamper driver's lack of reaction to the presence of the regulator ahead was the immediate cause of the collision (paragraph 51).

81 The condition of the tamper and regulator did not contribute to the causes of the accident (paragraph 56).

82 Weather conditions, and potential confusion associated with extraneous lights, are not considered to have contributed to the causes of the accident (paragraph 22).

83 The standards of training, assessment and monitoring of the driver are not considered to have contributed to the causes of the accident (paragraph 58).

Identification of causal and contributory factors

Driver fatigue and sleepiness

84 The relationship between fatigue and sleep, with particular reference to train driving, is discussed in the RAIB report on the derailment of a freight train at Brentingby Junction on 9 February 2006[1]. That report describes some of the factors which may affect sleepiness, and distinguishes this from fatigue.

85 Fatigue can be defined as the impairment of mental activity associated with the pattern of work and rest. Sleepiness is the propensity of the individual to fall asleep. It is possible to be fatigued without being sleepy, and conversely a person can be sleepy without being mentally fatigued. Alertness is related to both of these and can be defined as a state of wakefulness when a person is best able to process information and be responsive to the external environment. It is possible to fall asleep quickly, and an individual may be very sleepy driving on a monotonous route, without feeling fatigued.

86 How alert a person is during the waking period is dependent on two basic mechanisms:

- the amount of sleep obtained and the time since last awakening; and
- the body's internal clock, known as the circadian rhythm.

If either of these mechanisms are disturbed, fatigue and alertness may both be affected.

[1] Report 01/2007, published January 2007: paragraphs 136 to 169.

87 The tamper driver's pattern of work and rest, going from day work to nights, working Saturday night until mid-day Sunday, then Monday and Tuesday nights, may not have assisted him in remaining alert at the time of the accident. The RAIB has used the HSE Fatigue and Risk Index[2] to quantify (in approximate terms) the likely effects of this work pattern on the performance of the driver. The development of the Fatigue Index, which was first published in 1999, arose from the requirement to assess the risks from fatigue associated with rotating shift patterns and, in particular, the requirement to provide guidance in support of the Railways (Safety Critical Work) Regulations. It is now expressed in terms of the average probability of a high score on the Karolinska Sleepiness Scale, which is a nine-point scale ranging from one (extremely alert) to nine (extremely sleepy). The Risk Index was developed in 2006 to represent the relative risk of the occurrence of an incident on a particular shift. For a detailed description of this technique, please see http://www.hse.gov.uk/research/rrhtm/rr446.htm. The change from day to night work produces a substantial increase in the Fatigue and Risk indices, but the pattern worked by the driver does not increase the fatigue index to a significant extent. This is a common pattern for shift work and one which the driver would have been accustomed to since moving to freight work in 2003. The accident occurred near the beginning of the shift, at a time of day when people are normally still awake and alert, if they have sufficient rest before the beginning of the shift. The driver's work pattern enabled him to take sufficient rest before beginning his shift. However, it is not known if he had sufficient sleep during the day prior to the start of his shift.

88 It is presumed that the driver was overcome by sleep on several occasions during the journey, because of the way in which he began to operate the DSD erratically, probably on waking from a series of short sleeps. On the last occasion his sleep was interrupted by the DSD alarm, and then immediately afterwards by the collision. It seems likely that he was more tired than he realised, and that the warm, enclosed cab and motion of the machine travelling at less than 40 mph made him drowsy (paragraph 51).

89 Fatigue was therefore a possible causal factor in the accident. No recommendation is made as the RAIB considers that this is of significance only in the context of the person concerned and does not have any wider implications.

Driving in possessions and work sites

90 The reasons why drivers of OTMs often exceed the stipulated speeds in work sites have been explored as part of the investigation. All such machines are fitted with OTDRs, which enables the details of each journey to be examined as part of the process of driver monitoring and assessment.

91 In the High Output project, the role of the tamper and regulator is to follow behind the ballast cleaner or track renewal train, and work to redistribute the ballast and lift and align the track for high speed running. They cannot begin this work until after the main work of the night has been done, and so there is no reason for the tamper and regulator drivers to be under pressure to reach the site of work in a hurry. When they get there, they are likely to have to wait some time before work can start.

92 There is sometimes pressure, at the end of a possession, for the tamper and regulator to clear the site quickly so that the line can be handed back punctually for normal operation. Drivers have claimed they have been instructed, by the PICOP or ES, to run as quickly as possible to the sidings. The risks in doing so may be seen as low, particularly if the *transit* is outside a work site, ie in an area controlled by the PICOP.

[2] MB Spencer, KA Robertson & S Folkard: 'The development of a fatigue/risk index for shiftworkers'. HSE research report 446, London, 2006.

93 The machines have powerful headlights and efficient brakes. The line between Westerleigh Junction and Wootton Bassett is laid out for 125 mph (200 km/h) running, and in good weather drivers can see far enough to be able to detect an obstruction at a point where they believe they will be able to stop short of it from quite a high speed. This may encourage them to run faster than the 20 mph that they have been advised is appropriate.

94 If the tamper had been travelling more slowly the accident could still have occurred; indeed the greater monotony of slower travel may have made it more difficult for the driver to remain alert. However, the consequences of the collision (paragraph 76) would have been less severe if it had taken place at a lower speed.

95 Driving the machines at more than 20 mph (32 km/h) in work sites, and the failure of First Engineering's monitoring and driver management system to act to correct this, is considered to be a contributing factor to the severity of the accident (paragraph 67, **Recommendation 2**).

96 If the machines had been coupled together, then clearly the collision would not have occurred. Running the machines separately, rather than coupled together, is considered to be a causal factor in the accident. The multiple working programme described at paragraph 70 will reduce the risk of a similar incident occurring, but it is necessary for the operators to ensure that multiple working facilities are made use of by staff in normal operation (paragraph 71, **Recommendation 3**).

Observations

97 The risk created by the use of only one, long, work site was that of a collision between two machines, not subject to the protection of either the normal signalling system or there being only one movement in the PICOP's controlled area. The control measures for this risk are driving at low speed (20 mph (32 km/h)), maintaining a separation distance between machines, and the actual movements being closely supervised by the ES.

98 The length of the work site, and in particular the inclusion of the section from Chipping Sodbury sidings to Badminton, is considered to have increased the difficulty of controlling movements within it. This is discussed further in paragraph 104 (paragraph 74, **Recommendation 1**).

Other factors for consideration

<u>The rules applicable to work sites in possessions</u>

99 The rules relating to setting up work sites and making movements within them are discussed in paragraphs 60 to 67, 72 to 75.

100 Clause 1.3 of Module T3 requires the contractor and the Network Rail area operations representative to keep the length of the possession as short as possible, as part of the planning process. There is no similar requirement relating to work sites.

101 If three work sites had been set up, marker boards would have been used to define each work site, and it would have been necessary to appoint three people to act as ES. The tamper travelling from Chipping Sodbury through Badminton to the crossovers at Hullavington would have had to stop at the entrance and exit of each site, the ES for the site would have had to attend to remove and replace the marker boards, and would have had to obtain permission from the PICOP for the tamper to leave each site and proceed through the PICOP's controlled area to the next site.

102 Only one movement at a time is permitted in each section of the PICOP's controlled area, so the tamper would have been unable to leave Chipping Sodbury until the regulator had passed into the first work site. All this would have slowed down the work, and increased the risk to staff who had to go on the line to place and remove marker boards. However, the way in which the work was actually carried out meant that it was difficult (because of the distances involved) for the ES and COSS of each group of workers to meet face to face to enable the ES to sign the form (RT 3199) authorising the group to start work. This is not in accordance with clause 10.7(a) of module T3 of the rule book, but it is acknowledged to be a common practice. It was not a causal factor in the collision. This was, however, a causal factor in the accident at Manor Park on 19 March 2006 (RAIB report number 26/2007).

103 The extent of the work site was published in the method statement for the renewal project dated 25 July 2006, and it had been set up in this form on many occasions before the accident. A decision on the work site limits could have been made at the PICOP/ES briefing meeting, but precedents and the complications and delays inherent in use of multiple work sites, as well as the extra appointments required (qualified ESs were available among the people due to be working on the night) provided a strong incentive to only set up a single work site, if all the parties agreed.

104 It is common for 'standard' possession limits to be used, to reduce the risk of miscommunications, enable the use of pre-prepared locations for detonators and PLBs, and avoid people having to go on the track at dangerous locations.

105 However, long possessions create risks from engineering trains and plant having to run long distances without the protection of the signalling system. If the work site is also unnecessarily long the risk is increased, because the rules permit more than one movement within it. This relaxation was intended to allow the necessary movements of trains and machines actually carrying out work. It is therefore not practicable to recommend that it be abolished. However, it would appear to be reasonably practicable to ensure that work sites are kept as short as possible so that movements between and within the actual locations of work may be better controlled (paragraph 72, **Recommendation 1**).

Crashworthiness of On-Track Machines

106 The design requirements for on-track machines are defined in railway group standard GM/RT2400 'Engineering Acceptance and Design of On-Track Machines'. This references requirements in GM/RT2100 'Structural Requirements for Rail Vehicles' which are relevant to the issue of crashworthiness.

107 GM/RT2100 requires vehicle body structures to withstand a longitudinal compressive force of 2000 kN. The force generated in the initial impact of this collision is calculated to be 1700 kN, and the structure of both vehicles withstood this without distortion in the areas occupied by people.

108 Energy dissipated in the initial impact is calculated to be 10.4 MJ. For comparison, the energy dissipated in the Ladbroke Grove collision of 1999 was approximately 400 MJ. Energy was absorbed in propelling the regulator along the line and in the distortion of the structural members of both vehicles, rather than in deformation of the occupied spaces.

109 The machine structures performed in accordance with the specifications laid down, and the design of them was effective in protecting the crews and reducing the severity of the consequences of the collision.

110 Most of the injuries sustained by the crews were due to contact with the internal fittings of the cabs and operating areas of the machines. These were not subject to any requirements relating to crashworthiness, unlike the interiors of passenger-carrying vehicles (covered by ATOC standard AV/ST9001 'Vehicle Interior Crashworthiness', which specifically excludes locomotive cabs and rail mounted maintenance vehicles).

111 The relatively low operational speeds of on-track machines mean that the risks to operators from impacts are very low: no collision involving a tamper of the severity of the one at Badminton had occurred before. It would be appropriate to consider whether protection for sharp edges and corners of internal fittings could be provided to reduce the risk of injury to people inside the machine in the event of rough riding or low-speed collisions (paragraph 76, **Recommendation 4**).

Conclusions

Immediate cause

112 The immediate cause of the accident was that the driver of the tamper did not control his speed or react to the presence of the stationary regulator on the line ahead, so as to be able to stop short of it (paragraph 80).

Causal and contributory factors

113 Causal factors were:

- the activities of the driver in the period before the accident, which may have made it difficult for him to remain alert (paragraph 88); and
- running the tamper and regulator separately, rather than coupling them together (paragraph 96, **Recommendation 3**).

114 In addition, the following factors were considered to be contributory:

- the custom of OTM drivers of driving at more than 20 mph (32 km/h) in work sites, and the failure of First Engineering's monitoring and assessment system to identify and correct this contributed to the severity of the collision (paragraph 95, **Recommendation 2**); and
- the lack of a defined speed limit for movements in work sites (paragraph 94).

Observations

115 The extreme length of the work site, resulted in an arrangement which permitted the two machines to travel long distances on the same section of line simultaneously, with neither the protection of the signalling system nor suitable operational measures to control the risk arising (paragraph 97).

116 The Rule Book is not explicit about the relationship between the limits of a work site and the actual area where work takes place. The resulting ability to make the work site so long made it difficult for the ES to comply with the Rule Book requirements and increased the risk to people working (paragraph 105, **Recommendation 1**).

Actions reported as already taken or in progress relevant to this report

117 First Engineering have taken action to require two people to be in the cab of machines making movements in worksites and possessions.

118 Network Rail have continued to implement the programme of fitting multiple working equipment to the existing high output support plant. Multiple working for the on-track machine fleet allocated to High Output track renewals work was implemented on 3 July 2007.

119 The Rule Book is to be amended from December 2007 to instruct the drivers of engineering trains or on-track machines that they must not exceed walking pace within a work site unless the engineering supervisor specifically authorises them to do so, in the absence of any 'green zone' working. This aligns with the instruction already published in the latest issue of module OTP for operators of on-track plant.

Recommendations

120 The following safety recommendations are made[3]:

Recommendations to address causal and contributory factors

1 RSSB should make a proposal, in accordance with the Railway Group Standards Code, to amend Module T3 of the Rule Book to require work sites to be kept as short as possible (paragraph 105).

2 First Engineering should review their driver monitoring and assessment system to ensure that incidents of overspeeding are, so far as is reasonably practicable, detected and effectively dealt with (paragraph 95).

3 RSSB should make a proposal, in accordance with the Railway Group Standards Code, to amend Module T11 of the Rule Book to require that on-track machines are operated in tandem/multiple within possessions and work sites where it is practicable to do so (paragraph 71).

Recommendation to address the severity of consequences

4 Operators and suppliers of on-track machines should assess the hazards to staff working in them from contact with sharp edges and corners, and take appropriate action to reduce the risk of injury (paragraph 111).

[3] 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

Appendices

Glossary of abbreviations and acronyms — Appendix A

ATOC	*Association of Train Operating Companies*
AWS	*Automatic warning system*
CCTV	Closed circuit television
COSS	*Controller of Site Safety*
DSD	*Driver's safety device*
ES	Engineering supervisor
EWS	English, Welsh & Scottish Railway
GSM-R	Global System for Mobile Communications – Railways
HO	High Output
HOBC	High output ballast cleaner
NR	Network Rail
OTDR	On-train data recorder
OTM	On-track machine
PICOP	Person in charge of possession
RSSB	*Rail Safety & Standards Board*
SPAD	Signal passed at danger
SWT	South West Trains
WON	*Weekly Operating Notice*

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

Association of Train Operating Companies	Umbrella organisation representing train companies to the government, regulatory bodies, the media and other opinion formers on transport policy issues and providing its members with a range of services that enable them to comply with conditions laid on them in their franchise agreements and operating licences.
Automatic Warning System	A fail-safe arrangement of permanent magnets and electro-magnets placed between the rails that convey information about the aspect of the associated signal to the train driver.*
Ballast regulator	An on-track machine (OTM) used for ballast regulation (the action of distributing ballast evenly along the track, and to the correct profile across it), using an arrangement of ballast ploughs and brushes. Some are equipped with a hopper to allow them to remove and relocate excess ballast.*
Controller of Site Safety (COSS)	A safety critical qualification demonstrating the holder's competence to arrange a safe system of work, ie protecting staff working on the line from approaching trains.*
Down line	A track on which the normal passage of trains is in the down direction, i.e. away from London, or towards the highest mileage (westbound at Badminton).
Driver's safety device	A system that halts the locomotive or train if the driver ceases to respond. Previously commonly known as a Dead Man's Handle, most examples are pedals that must be pressed in response to an audible reminder.*
Dynamic track stabiliser	An on-track machine (OTM) used to accelerate the consolidation of recently reballasted track by a combination of vertical load and vibration.*
Engineering Supervisor	The person nominated to manage the safe execution of works within an engineering work site. This includes arranging the marker boards, authorising movements of trains in and out of the work site and managing access to the site by Controllers of Site Safety (COSS).*
Ground Frame	A small group of signal and points levers located close to some isolated and infrequently used facility such as a crossover. These levers are locked by the controlling signal box, and only released when required.*
Ground Frame Operator	Person appointed to operate a ground frame to permit trains to move in or out of sidings.
Multiple working	The coupling of two motive power units together such that all the power and braking controls are managed by a driver in the leading end driving cab.*

On-track machine	Any piece of specialist railway plant which moves only on the rails and is normally self propelled.*
On-train data recorder	Device that continuously records selected parameters associated with the journey, including speed, throttle and brake control positions, activations of horn, DSD and AWS cancel button, etc.
Panel signal box	Western Route term for a power signal box (a large signal box which controls the points and signals over a large area by electrical means).
Person in charge of possession	The competent person nominated to manage the following: ● safe and correct establishment of the protection for the possession, and removal of protection at the end of the possession; ● managing access to the possession area by engineering supervisors (ES); ● managing the establishment of engineering work Sites within the Possession; ● liaising with the signaller regarding the passage of the train into and out of the possession; ● controlling the movement of trains between the Protection and Work Sites.*
Plain line tamper	A tamper that is only equipped to work on plain line, not switch and crossing layouts.*
Possession	A period of time during which one or more tracks are blocked to trains to permit work to be safely carried out on or near the line.*
Rail Safety & Standards Board	The pan-industry body responsible for producing and maintaining the suite of Railway Group Standards.
Route Knowledge	Before any driver can drive a train along a particular route, they must first learn the locations of junctions, stations, signals, permissible speeds, etc. This is Route Knowledge. The process of acquiring it is colloquially called Learning the Road.*
Tamper	An on-track machine that can (generally) lift and slew the track and simultaneously compact the ballast under the sleepers.*
Track circuit block	A signalling system where the line is proved clear to the end of the overlap beyond the next signal using track circuits.*
Transit	Movement of on-track machines between locations where they are required to work or stable.
Up line	A track on which the normal direction of trains is in the Up direction, i.e. towards London, or the lowest mileage (eastbound at Badminton).
Weekly Operating Notice (WON)	A Network Rail document published on a route basis, providing information about engineering work, speed restrictions, alterations to the network and other relevant information to train drivers.*
Work site	The subdivision of an engineering possession that is delimited by marker boards and managed by an Engineering Supervisor (ES).

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