Rail Accident Investigation Branch

Rail Accident Report

Autumn Adhesion Investigation
Part 1: Signals WK338 and WK336 Passed at Danger at Esher
25 November 2005

Department for Transport

Report 25 (Part 1)/2006
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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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Signals WK338 and WK336 Passed at Danger, Esher, 25 November 2005

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 This report contains the findings of the RAIB investigation into the incident that occurred at Esher on 25 November 2005 when a train passed two successive signals at danger, overrunning the first signal by a distance of approximately 1050 metres. It is Part 1 of an investigation into adhesion-related incidents during autumn 2005.

4 On 30 November 2005, a signal passed at danger (SPAD) incident occurred at Lewes in circumstances that bore some similarity to the SPAD at Esher. The drivers of both trains had alleged that severe adhesion problems had been the cause of the overruns. The RAIB has also undertaken an investigation into the SPAD at Lewes (reported in Part 2 of the autumn adhesion investigation).

5 During the early stages of the investigation into the two SPAD incidents, it became apparent that there had been a higher number of adhesion-related SPADs and station overrun incidents in autumn 2005 than had occurred during autumn 2004. A separate report, Part 3 of the autumn adhesion investigation, has been prepared to address the causes of the high number of adhesion-related incidents in autumn 2005. Some of the issues identified in the investigation of the incident at Esher have much wider relevance than for that incident alone. Where appropriate, this Part 1 report into the incident at Esher contains references to the analysis of performance during autumn 2005 reported in Part 3.

6 Access was freely given to staff, data and records by Network Rail and South West Trains in connection with this investigation.

7 Appendices at the rear of this report contain:

- explanation of acronyms and abbreviations (Appendix A);
- explanation of technical terms (shown in italics the first time they appear within the body of this report) (Appendix B);
- a list of relevant *Railway Group Standards* (RGS), current at the time the incident occurred (Appendix C).

8 Reference is made in the report to levels of adhesion between wheel and rail. This is normally expressed as a coefficient of friction (symbol μ). The lower the value of μ, the lower the adhesion between wheel and rail. Typical values for μ for dry rail would be at least 0.20. In wet weather, this can fall to 0.10. Under severe low adhesion conditions, the value of μ can drop below 0.03. As trains rely on the coefficient of friction between wheel and rail to stop, the level of adhesion available is critical to the rate at which the train can decelerate. Many modern trains have four or five fixed braking rates available to the driver, the lowest of which will normally achieve a deceleration rate of 0.3 m/s^2 and the highest a rate of at least 1.2 m/s^2. A braking rate of 0.3 m/s^2 can only be achieved if the value of μ is at least 0.03. The value of μ would need to be at least 0.12 to sustain an emergency braking rate of 1.2 m/s^2

Summary

9 The RAIB investigation into the SPAD at Esher on 25 November 2005 has been undertaken in parallel with the investigation into the SPAD that occurred at Lewes on 30 November 2005 and a general investigation into the causes of adhesion-related station overrun and SPAD incidents during autumn 2005. This report focuses on the results of the investigation into the Esher incident alone.

10 At approximately 06:30 hrs on Friday 25 November 2005, train 1A12, the 05:44 hrs South West Trains (SWT) service from Alton to Waterloo passed signals WK338 and WK336 at danger on the *up fast line* between Esher and Hampton Court Junction. Train 1A12 stopped under the Hampton Court Junction flyover, having passed signal WK338 by a distance of approximately 1050 metres and signal WK336 by a distance of approximately 200 metres. After passing signal WK336 at danger, train 1A12 approached to within 200 metres of train 2F08, a service from Woking to Waterloo, which had crossed from the *up slow* to the up fast line at Hampton Court Junction.

11 Nobody was injured in the incident and there was no damage to the infrastructure or rolling stock. After a conversation between the signaller and the driver of train 1A12, the train was moved into Surbiton station platform and the driver relieved of duty as part of SWT's routine response to serious incidents. A replacement driver drove train 1A12 to Clapham Junction where it terminated. Passengers were conveyed to Waterloo by alternative services and the train was taken empty into Clapham Yard.

12 The driver of train 1A12 was driving in accordance with the *professional driving policy* in force at the time within SWT. The actions of the driver were neither causal nor contributory to the incident. The professional driving policy was based on SWT's understanding of the braking and *sanding* characteristics of its rolling stock. However, a different approach to braking under low adhesion conditions would have reduced the stopping distance of train 1A12.

13 Post-incident testing by Siemens of the unit involved in the SPAD at Esher indicated that the key systems on the train, braking, *wheelslide prevention* (WSP) and sanding had performed in accordance with the specification for those items of equipment. The standards that apply to these systems, the *Train Operating Company's* (TOC) involvement with their specification, their optimisation for low adhesion conditions and the way in which they are tested to demonstrate that they are fit for purpose are issues that are considered in detail in the Part 3 report.

14 The railhead on the up fast line at Esher had not been included within Network Rail's autumn adhesion treatment programme. This location was not a known low adhesion site and there had been no history of adhesion incidents on the up fast line. *Railhead swabbing* undertaken after the incident found no evidence of contamination. However, data gathered from the *On-Train Monitoring and Recording* (OTMR) equipment of the unit involved indicated that train 1A12 experienced severe low adhesion conditions for a distance of approximately 2500 metres. It is likely that available levels of adhesion were less than 0.03, whereas normal dry rail would offer at least 0.20 (see paragraph 8). The phenomenon of severe low adhesion conditions is discussed in the Part 3 report as is the industry's process for investigating adhesion incidents.

15 The actions of the signaller involved in the Esher incident were instrumental in avoiding a much more serious incident and the signaller is commended. The driver of train 1A12 advised the signaller that the train was sliding at an early stage and this enabled the signaller to manage the incident effectively. The driver is also commended.

16 The movement of train 1A12 into Surbiton station after the incident was not fully in accordance with procedures. There was also confusion in the aftermath of the incident regarding the effectiveness of the braking system on the unit involved, which resulted in the initial decision to allow train 1A12 to continue to Waterloo being changed, but not until the train had already left Surbiton.

17 Three recommendations specific to the incident at Esher are made to improve safety, all relating to procedures that govern the movement of trains after a serious incident. The Part 3 report contains a number of recommendations that are relevant to the causal and contributory factors associated with the Esher incident.

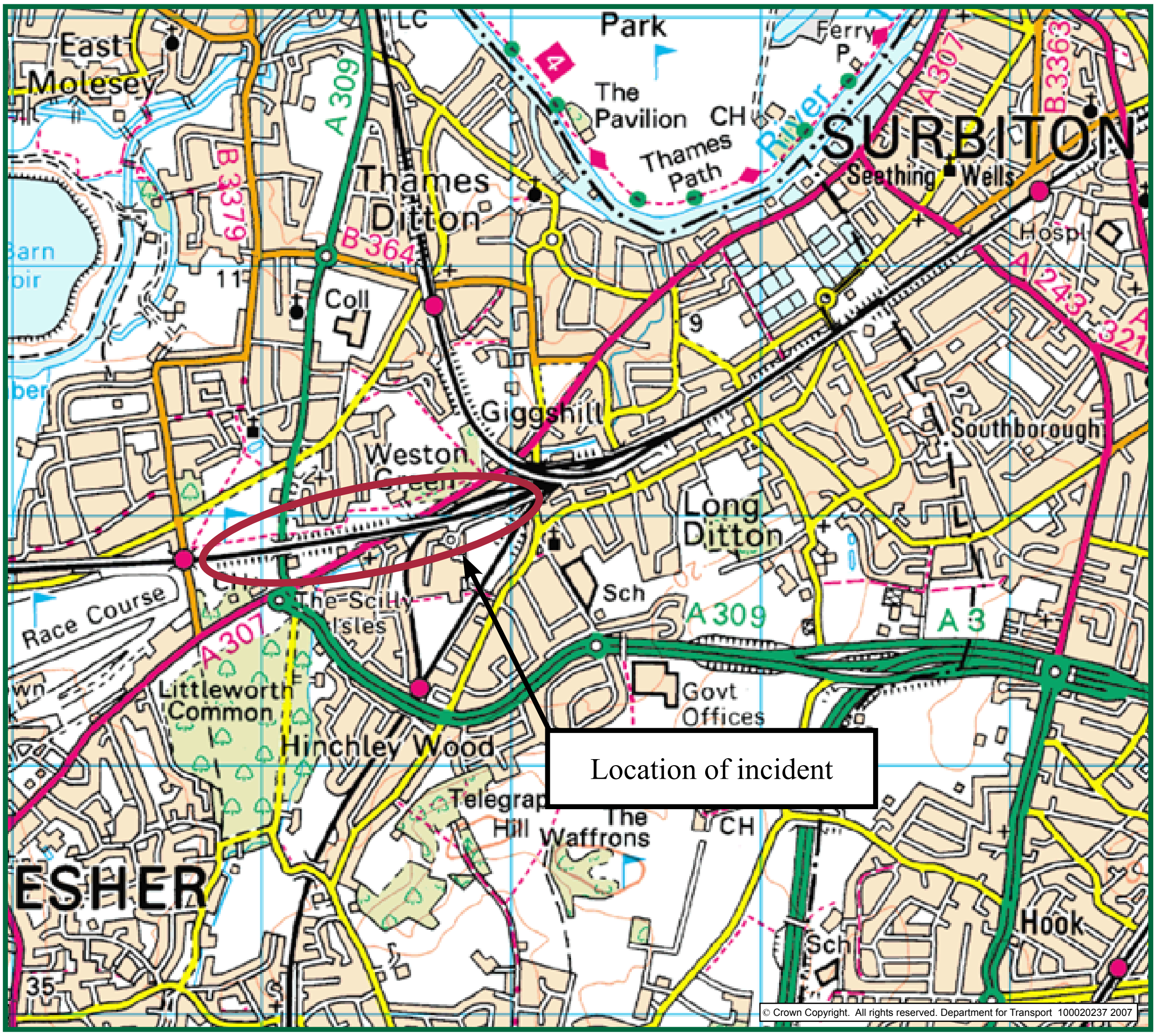

Figure 1: Extract from Ordnance Survey map showing location of incident.

The Investigation

Summary of the incident

18 At approximately 06:30 hrs on Friday 25 November 2005, train 1A12 passed signals WK338 and WK336 on the up fast line at Esher at danger.

19 As train 1A12 approached signal WK336, it came within 200 metres of train 2F08 which was crossing from the up slow line to the up fast line at Hampton Court Junction.

20 Nobody was injured in the incident and there was no damage to infrastructure.

Background

21 Esher is located 14 miles and 31 chains from London Waterloo on the south western main line that runs between Waterloo and Weymouth. At Esher there are four tracks designated down slow, down fast, up fast and up slow. Approximately one mile to the east of Esher is Hampton Court Junction, where, in the up direction, trains from the Cobham line converge on the up slow line, closely followed by another junction where trains from Hampton Court also converge onto the up slow line. Trains are signalled in accordance with the *Track Circuit Block Regulations*, controlled by Woking Area Signalling Centre (ASC). *Four aspect signalling* is provided and line speed on the up fast line is 90 mph (144 km/h). Figure 2 shows key features of the railway in the area where the incident occurred.

22 The train involved in the incident was the 05:44 hrs SWT service from Alton to London Waterloo, which carried the *train reporting number,* 1A12. Train 1A12 comprised a Class 450 four-car *'Desiro'* Electric Multiple Unit (EMU) No. 450 022.

23 Class 450 EMUs are equipped with a '*stepless' brake controller,* wheelslide prevention (WSP) system and equipment for depositing sand to assist in braking or traction. The WSP system is software-driven. It detects when the train is experiencing wheel to rail adhesion difficulties and controls the braking effort on sliding wheels in an attempt to match the braking rate to the available adhesion. The WSP system also triggers sanding, providing that the level of brake demanded by the driver exceeds a predetermined threshold.

24 At 06:30 hrs on 25 November the temperature in the area was around 0°C following a clear and frosty night.

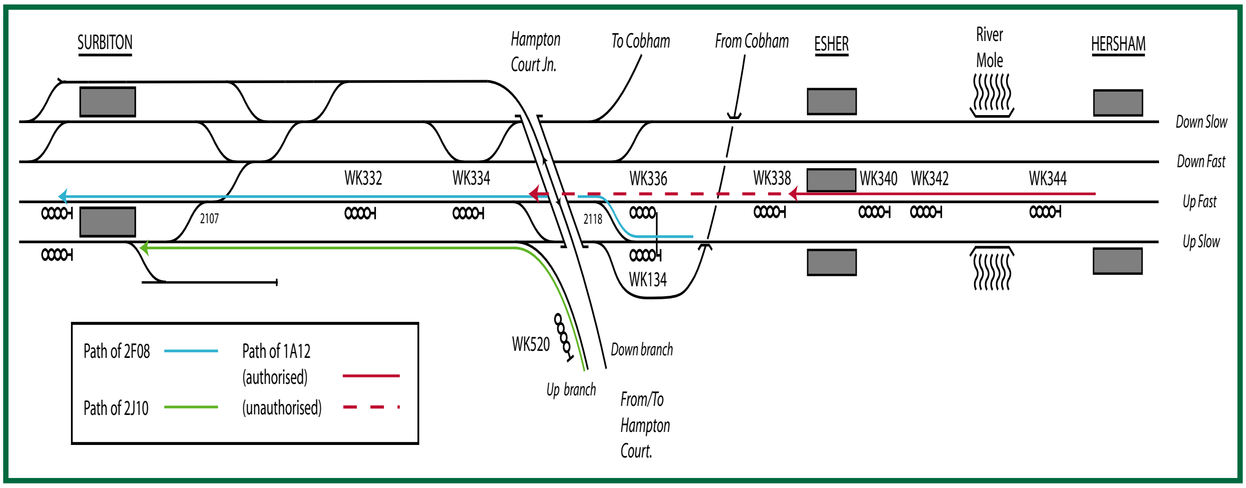

Figure 2: Key features of the track layout between Hersham and Surbiton.

Events preceding the incident

25 At around 06:30 hrs on the morning of 25 November, the signaller on duty at Woking ASC with responsibility for trains in the Esher/Surbiton area had two trains converging on the up slow line at Hampton Court Junction:

- Train 2F08, the 06:04 hrs service from Woking to Waterloo approaching on the up slow line from the Esher direction
- Train 2J10, the 06:24 hrs service from Hampton Court to Waterloo, approaching on the up branch line.

26 Both trains were timetabled to use the up slow line between Hampton Court Junction and Surbiton and both were scheduled to call at Surbiton. Train 2F08 was timetabled to precede train 2J10 and no conflict would normally have occurred. However, train 2F08 was running a few minutes late. To avoid creating further delay, the signaller routed train 2F08 from the up slow line to the up fast line at Hampton Court Junction, thus allowing train 2J10 a clear run on the up slow line.

27 The movement of train 2F08 onto the up fast line was protected by Signal WK336 being placed to danger. Signal WK338 was also placed to danger because 2118 points (over which train 2F08 was routed) lie within the *overlap* of Signal WK336. Working back towards Woking on the up fast line, Signal WK340 displayed a single yellow aspect and WK342 a double yellow aspect. Figure 2 shows the general layout including the location of the relevant signals.

28 Approaching the area on the up fast line at this time was train 1A12, running at line speed of 90 mph (144 km/h). It was scheduled to run non-stop between Woking and Surbiton over the up fast line. Shortly after it passed signal WK344 displaying a green aspect the driver sighted the next signal, WK342, displaying a double yellow aspect.

Events during the incident

29 From evidence provided by the OTMR download the events described in paragraphs 30 to 35 can be established or inferred.

30 The driver shut off power approximately 600 metres from signal WK342 and made an initial brake application approximately 300 metres from the signal. Almost immediately, the ‘sanding’ light on the driver’s desk illuminated. This provided an indication that the WSP system on the unit had become active. Noticing that there was no obvious reduction in speed, the driver increased the brake to 50% approximately seven seconds after the initial brake application. By this stage, train 1A12 was approaching Signal WK342 (double yellow), which was passed at a speed of approximately 85 mph (136 km/h)

31 The driver was immediately aware that increasing the braking effort had made little difference to the speed of the train and thus initiated *full service (100%) braking* after a further 6 seconds. The rate at which the train was slowing was still far below the driver’s expectations and after another eight seconds the brake controller was placed into the *emergency* position. By this stage, train 1A12 was approximately 400 metres from signal WK340, which was displaying a single yellow aspect. Signal WK340 was passed at a speed of approximately 80 mph (128 km/h).

32 The driver of train 1A12 made an emergency call via the *cab secure radio* (CSR) to advise the signaller that the train was not going to stop at signal WK338. At this stage, train 2F08 was approaching 2118 crossover which would take it onto the up fast line and into conflict with train 1A12. Train 1A12 was approximately 1200 metres from the conflict point and still running at approximately 70 mph (112 km/h). The signaller's actions under these circumstances are governed by the *Rule Book*[1]. The relevant section indicates that when a signaller becomes aware that a train is 'proceeding without authority' (a train passing a signal at danger is defined as a train proceeding without authority) he/she should place signals to danger against any other train which could be put in danger and send a radio message to the relevant trains. However, the signaller realised that if those rules were applied exactly, it would probably result in train 2F08 stopping in the path of train 1A12. The signaller therefore permitted train 2F08 to continue through 2118 crossover and onto the up fast line towards Surbiton.

33 In the meantime train 1A12 continued through Esher towards Hampton Court Junction. It passed signal WK338 at danger travelling at approximately 70 mph (112 km/h). On the approach to the signal, a *Train Protection & Warning System* (TPWS) overspeed intervention occurred, but with no effect on the rate at which the train was decelerating. Train 1A12 now proceeded towards signal WK336, slowing, but not at a rate commensurate with emergency braking. As train 1A12 approached signal WK336, the driver was able to see train 2F08 crossing onto the fast line ahead. Around this time, the braking performance of train 1A12 improved and having passed signal WK336 at danger at approximately 40 mph (64 km/h), it stopped under the Hampton Court Junction flyover. In the short time between train 2F08 passing over 2118 points and train 1A12 approaching them, the signaller managed to *normalise* the points, thereby avoiding the damage that would have occurred if train 1A12 had *run through* them.

34 Although it is not possible to be precise, based on information from the signalling equipment and evidence from those involved, it is likely that the minimum distance between train 1A12 and train 2F08 during the incident was in the order of 200 metres.

35 From the time that the driver first applied the brakes to the time that the train stopped, 112 seconds had elapsed. During this period, train 1A12 had travelled approximately 3000 metres. In normal circumstances, the train would have stopped before reaching the first red signal (WK338) with the driver only having to use a maximum of 50% braking. The length of the overrun beyond signal WK338 was approximately 1050 metres and the length of the overrun beyond signal WK336 was approximately 200 metres.

Events after the incident

36 After train 1A12 had stopped the driver and signaller conversed and the driver agreed to take the train into Surbiton station. The train was routed past signals WK334 and WK332 and over 2107 crossover (see Figure 2) into the up slow platform at Surbiton where the *RT3189 'Signal Passed at Danger' form* was completed as required by the Rule Book. A driver who had been travelling as a passenger on train 1A12 then took over from the driver who had been in charge at the time of the incident (in accordance with SWT's policy for dealing with serious incidents) and train 1A12 went on to Clapham Junction where it terminated.

[1] RSSB, *Rule Book GE/RT 8000, Module TS2, Track Circuit Block Regulations*, Clause 6.1, Issue 1, June 2003.

37 The original intention had been to allow the train to continue to Waterloo because the driver had made no allegation against the train brakes. After train 1A12 left Surbiton, confusion arose in the *Wessex Integrated Control Centre* (WICC) over the involvement of the train's braking system in the incident and the decision was taken to terminate the train at Clapham Junction and transfer passengers to other services for their onward journey to Waterloo.

38 Railhead swabbing of the up fast line in the vicinity of signals WK338 and WK336 was carried out by Network Rail in the immediate aftermath of the incident. Later on that day, Network Rail decided to undertake railhead swabbing in the vicinity of Signal WK340 on the basis that the train had been sliding in this area and it would be useful to gather data on railhead conditions at this location.

39 Unit 450 022 was taken out of service after train 1A12 terminated at Clapham Junction and the OTMR equipment downloaded. Subsequently, the unit was moved to Strawberry Hill depot where the braking and sanding equipment on the unit was tested by Siemens (the train manufacturer and maintainer). SWT, Siemens and Knorr Bremse (the braking equipment manufacturer) conducted a review of the OTMR download and the performance of the train during the incident. No relevant faults were found with the unit, which had performed in accordance with its specification.

40 The driver of train 1A12 underwent routine drugs and alcohol screening after the incident, the results of which were negative.

Evidence

41 Evidence was obtained from the following sources:

- OTMR download from unit 450 022;
- voice tapes of the communications between the driver of train 1A12 and the signaller;
- staff involved in the incident;
- SWT, the operator of train 1A12;
- Siemens AG, who manufactured unit 450 022;
- Knorr Bremse, who supplied the braking, WSP and sanding equipment fitted to 450 022;
- the investigation report prepared by Network Rail into the incident.

Analysis – events during the incident

42 The RAIB determined that there were four principal issues to be investigated relating to this specific incident:

a) The actions of the signaller;

b) The actions of the driver;

c) The condition of the railhead;

d) The performance of the rolling stock;

43 General issues and those with a wider application than this incident alone are covered in the Part 3 report.

Actions of the signaller

44 Signals WK338 and WK336 were at danger because the signaller had decided to cross train 2F08 from the up slow line to the up fast line at Hampton Court Junction. This decision was made when train 1A12 was in the Weybridge area, approximately 6 miles from Hampton Court Junction. This was a standard *regulating* decision, taken to avoid delay or further delay to trains 2J10 and 2F08 respectively.

45 The signaller was unaware of any problem with train 1A12 until the driver sent an emergency CSR message. At this stage, train 1A12 was no more than 60 seconds running time (at its then current speed) from the point of conflict with train 2F08, which was approaching 2118 points and about to cross onto the up fast line. The signaller took the following critical actions in a very short space of time:

a) decided not to send an emergency radio message to stop train 2F08, instead allowing it to continue through 2118 points onto the up fast line ahead of train 1A12;

b) normalised 2118 points after the passage of train 2F08 just in time to prevent them being run through by train 1A12, thereby preventing damage to the points;

c) maintained contact with the driver of train 1A12 while the train was slowing.

46 The decision not to stop train 2F08 almost certainly prevented a collision between train 1A12 and train 2F08. Had the driver of train 2F08 been instructed to stop, it is likely that the train would have passed over 2118 points before coming to a stand, which would have left it in a position of conflict with the approaching train 1A12. If train 2F08 had stopped anywhere in the vicinity of 2118 points, a collision between train 1A12 and train 2F08 would have been inevitable. The action of the signaller in normalising 2118 points behind train 2F08 to avoid the points being run through by train 1A12 showed remarkable presence of mind. In maintaining contact with the driver of train 1A12, the signaller was able to evaluate the need for further action in order to maintain safe separation between trains.

Actions of the driver and SWT

47 At an early stage in the investigation, SWT indicated that the driver had handled the train in accordance with the company's professional driving policy. In reviewing the download from the OTMR, it is clear that the driver had responded appropriately to the double yellow aspect displayed in Signal WK342. At the time of the incident, SWT advised drivers to brake 'light and early', in other words to respond immediately a double yellow signal was seen, but with a gentle brake application. The driver of train 1A12 followed this guidance. It is also apparent that the driver acted quickly and appropriately to the lack of response from the brakes. Within 21 seconds of making an initial brake application, the driver placed the brake controller into the emergency position, having progressively increased braking effort and observed the effect in the interim.

48 Having realised that the train was not going to stop at signal WK338, the driver, showing presence of mind in stressful circumstances, made an emergency call to the signaller thereby playing a significant part in the avoidance of damage to the infrastructure.

49 Given that the driver of train 1A12 had handled the train in accordance with SWT's professional driving policy, the investigation has considered the contents of that policy. As stated in paragraph 47, SWT's policy emphasised the need for drivers to brake their trains 'light and early'. However, in situations where the WSP system was active (ie low adhesion was present), it was not until the driver selected a braking effort of 75% or greater that sand was dispensed on the Class 450 EMU. Sand, one of the principal aids to stopping under low adhesion conditions, was not available in the early stages of a 'light

and early' brake application. During the incident, train 1A12 travelled for 13 seconds with brakes applied but sanding not taking place. During those 13 seconds, the train travelled approximately 500 metres.

50 On 9 December 2005, SWT issued a bulletin to its drivers with revised guidance on stopping in low adhesion conditions. The new guidance indicated that full service (100%) braking should be selected if a train was not slowing in accordance with the driver's expectations during initial braking. During February 2006, SWT undertook a series of tests involving a Class 450 EMU at Wildenrath in Germany. The purpose of the tests was to examine different sanding parameters and low adhesion conditions were created to facilitate the exercise. Following its review of the results from the tests, SWT commenced a programme to adjust the sanding parameters on the Class 444 and 450 EMUs so that sanding is initiated when the driver selects 40% braking (with the WSP system active).

51 Had current advice been in place at the time of the Esher incident, 100% braking (and sanding) would have been initiated at least 6 seconds earlier, allowing an additional 200 metres of sanding. This would probably have reduced the length of the overrun although it would not have prevented it.

52 It is apparent that there was some confusion among SWT's driver managers (and therefore drivers) regarding the meaning of the illumination of the yellow light labelled 'sanding' on the driver's desk. Illumination of the light indicates that WSP is active. It does not indicate that sand is being laid, although this view was held by some SWT driver managers and drivers. A driver could be misled into thinking that sanding was taking place as soon as WSP activity commences. In the incident at Esher, 13 seconds elapsed between the 'sanding' light becoming illuminated and sand actually being laid.

Condition of the railhead

53 The up fast line between Woking and Hampton Court Junction is not a known low adhesion area. Neither up nor down fast lines were included within Network Rail's autumn 2005 railhead treatment programme, although the up and down slow lines were subject to water jetting. The difference in treatment policy between the slow and fast lines existed because trains on the slow lines are required to stop at and start from some or all of the six intermediate stations between Woking and Surbiton and are thus susceptible to slipping during acceleration or sliding during braking. On the fast lines, unless there is a requirement to brake for signals or temporary speed restrictions, trains will not brake at any intermediate point between Woking and Hampton Court Junction.

54 While not relevant to the SPAD at Esher, it occasionally happens that lines scheduled for rail head treatment do not receive it. To address this, Network Rail and the TOCs operate a system that provides a warning to drivers when they sign on duty if scheduled rail head treatment has not been undertaken.

55 During the autumn period, Network Rail operates a predictive system for railhead conditions throughout the country, based on information supplied by the specialist environmental and weather organisation, ADAS UK Ltd. The prediction takes account of the likely influence of weather conditions (rain, frost, high winds) on leaf fall and the extent of leaf fall is used as the means for predicting railhead conditions. The network is divided into 16 areas and the prediction is area-specific. Network Rail takes further precautions such as providing additional railhead treatment in known problem areas when severe conditions are forecast.

56 For the area that includes Esher, severe conditions had been predicted for 25 November at the beginning of the week, but by 24 November the prediction had changed and indicated only slight problems for the following day.

57 This is of limited relevance to the SPAD at Esher because the railhead on the up fast line is not treated. Neither Network Rail nor SWT had made a case for treatment because there had been no recorded instances of trains experiencing adhesion difficulties in this area. In itself, this is unsurprising because trains on the up fast line would normally only need to brake between Hersham and Esher if signal WK338 was at danger. This would only be the case if 2118 points were being used to cross a train from the up slow to the up fast line. There are few timetabled uses of this crossover and none in the morning peak. Adhesion difficulties on the up fast line would therefore go undetected.

58 Although extreme low adhesion conditions were not predicted for this area on 25 November, they were present on the up fast line, but not revealed until train 1A12 approached the area. It was the first train on the up fast line that morning that had been required to brake on the approach to Hampton Court Junction. WSP activity commenced as soon as the driver made an initial brake application, indicating that the level of adhesion available to the train was below 0.03. This is because the initial braking rate on a class 450 EMU is approximately $0.3 m/s^2$, which requires a level of adhesion of approximately 0.03 for this level of deceleration to be realised (paragraph 8). The rate at which train 1A12 slowed on 25 November indicates that it encountered low adhesion conditions over a distance of at least 2500 metres.

59 Railhead swabbing was undertaken by the Network Rail Mobile Operations Manager (MOM) who responded to the incident when notified by the WICC. A total of 29 swabs were taken over a distance of 1800 metres, starting with a location approximately 130 metres on the approach to signal WK340 (which had been displaying a single yellow aspect as train 1A12 approached) and ending in the vicinity of the second signal passed at danger (WK336). In order to avoid the need to close the up fast line during the morning peak period, the swabbing on the approach to signal WK340 was undertaken much later in the day by the late turn MOM.

60 No contamination was found on any of the swabs, but there was evidence of sand between signals WK340 and WK336, which is likely to have been deposited by train 1A12 (see paragraph 74). The way in which swabs were taken and the results showing lack of contamination are inconclusive because:

- No swabs were taken where the slide commenced (on the approach to signal WK342, which was displaying a double yellow aspect).
- The swabs that were taken on the approach to signal WK340 (which was displaying a single yellow aspect) were taken several hours after the incident. The conditions that give rise to low adhesion can be transient in nature because they are affected by temperature and humidity which vary throughout the day. The delay in railhead swabbing would almost certainly have resulted in evidence of contamination vanishing.
- The swabs that were taken on the approach to signal WK338 showed no evidence of contamination. However, they were taken an hour after the incident and at least three trains passed over the up fast line before the swabs were taken. Both the delay in swabbing and the operation of other trains may have had an effect on the contaminant. The analysis report for the swabs taken in this location states that the lack of contamination found indicates that the railhead was 'either exceptionally clean or that ineffective swabbing had been performed'.

- The swabs that were taken on the approach to signal WK336 showed no evidence of contamination. However, it was in this vicinity that the braking performance of train 1A12 began to improve markedly, indicating that the area of severe contamination had been passed.

61 The presence of ice on the rail head is unlikely to have affected the results from the swabbing because by the time swabbing took place (around 07:30 – 08:00 hrs) the temperature is likely to have risen above freezing.

62 There are two other factors relating to events on 25 November that indicate that low adhesion conditions were prevalent that morning:

a) In the immediate aftermath of the incident, there was a further incident of a train experiencing severe adhesion difficulties on the up fast line between Woking and Surbiton. Having become aware of the adhesion problems encountered by train 1A12 in the vicinity of Esher, the signaller spoke to the driver of the next train travelling over the up fast line, train 1P96, a service from Portsmouth to Waterloo. The driver misinterpreted the message from the signaller as a request to stop and attempted to do so. Train 1P96 went into a slide as soon as braking was initiated. The WSP failed to control the slide and this resulted in the wheels locking up and severe wheel flats on the unit. Train 1P96 was formed of a Class 444 unit, which is similar in design characteristics to the Class 450.

b) The SPAD at Esher occurred on the worst day for adhesion-related incidents during autumn 2005, with 42 incidents being recorded nationally. Taking the period 05:30 hrs – 08:30 hrs on 25 November, apart from the Esher SPAD, there were adhesion-related station overruns at 15 other locations within a 25 mile radius of Esher. Two of the incidents (at Carshalton (06:20 hrs) and Ewell East (07:02 hrs)) were in close proximity and around the same time, but involved different type of rolling stock from that involved in the SPAD at Esher.

63 Taking all of these factors into account, the condition of the rail head is considered causal to the incident at Esher on 25 November.

<u>Performance of the rolling stock</u>

64 The Class 450 EMU is equipped with *dynamic* and *friction* brakes, a WSP system and sanding. The two types of braking are *blended*; the dynamic brake acting through the traction motors applies initially, with friction brakes being blended in as the train slows down. If *wheelslide* activity is detected, the dynamic brake is disabled and the train continues on friction braking alone.

65 The WSP system operates on all wheels, detecting wheelslide through changes in wheel speed that are not consistent with normal train braking. Once active, the WSP system fitted to the Class 450 EMU seeks to monitor the continued presence of wheelslide by releasing the brakes on a 'test' or 'reference' wheelset periodically when wheelside is present. Using measurements of speed and acceleration derived from this wheel, the WSP system is able to estimate the true speed of the train, which is then compared with the speed of the other wheels. In this way, the degree of wheelslide can be measured.

66 When wheelslide activity is detected, the WSP system endeavours to maximise and influence the adhesion available to the train by applying and releasing the train brakes. Wheel rotational speed is not permitted to drop below the estimated 'real' speed of the train by more than 20% before the brakes are released and the wheel rotational speed allowed to climb back towards 'real' speed, at which point the brakes are applied again.

The process of applying and releasing the brakes has the effect of limiting wheelslide while permitting a degree of *conditioning of* the railhead, thereby providing a slightly cleaner rail surface for later vehicles on the same train.

67 The OTMR download for unit 450 022 indicates that WSP activity commenced from the moment the brake was applied and continued throughout the duration of the slide until the train stopped. The OTMR download does not identify how many of the four vehicles on the train experienced WSP activity, but confirms that it happened continuously on at least one of the four vehicles.

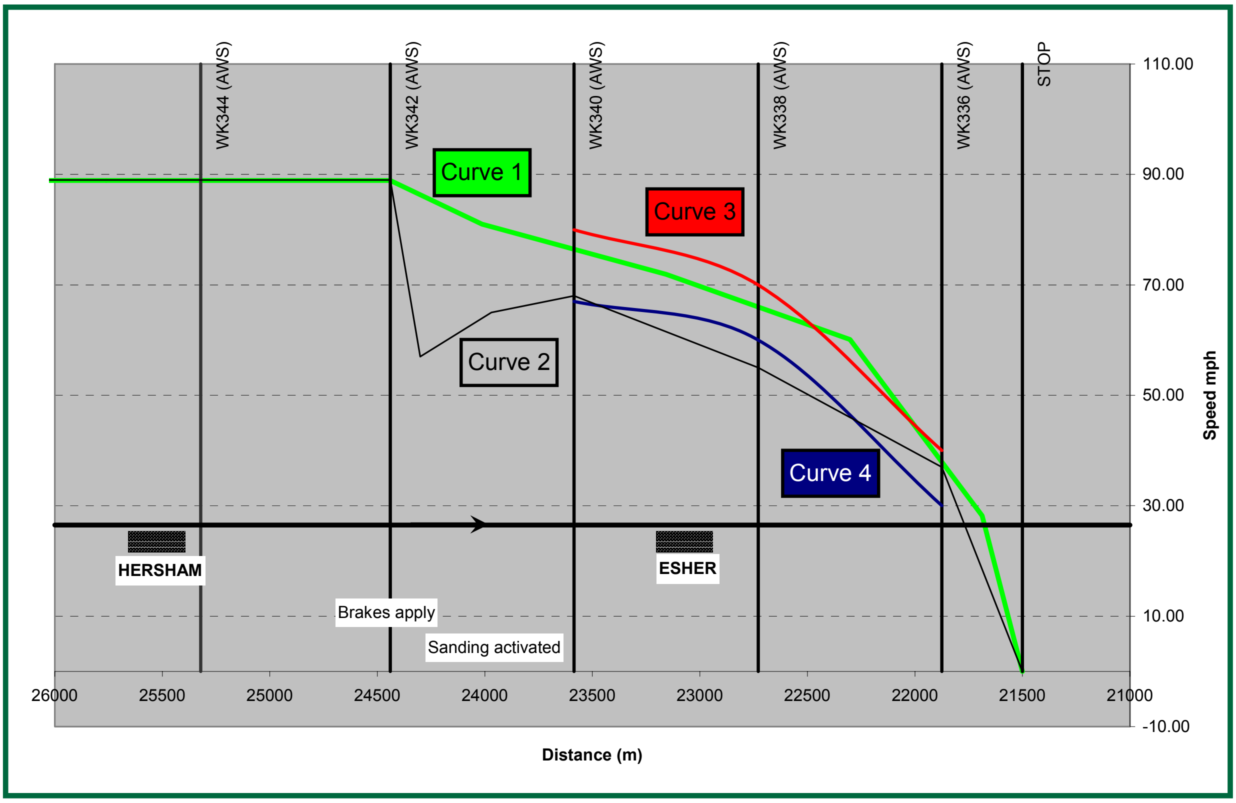

Figure 3: Distance speed graph depicting the events at Esher on 25 November 2005.

68 Figure 3 shows train and wheel rotational speeds derived from the following sources:

- Calculated speeds based on the times at which the train passed the Automatic Warning System (AWS) magnets, which are normally located 183 metres on the approach to the signal (Curve 1, green). This has been used as a measure of train speed that is independent of the figures estimated by the WSP system and reflected in the OTMR data.
- Speed data taken from the OTMR (Curve 2, black).
- Curve derived from the driver's estimate at certain locations (Curve 3, red)
- Network Rail estimate derived from data obtained from the signalling system which records times at which key activities occur such as trains passing signals. As such, it is also independent of the figures estimated by the WSP system, but only accurate to plus or minus a few seconds because the system monitors changes of state on the basis of sampling every few seconds rather than continuously (Curve 4, blue).

69 Figure 3 shows that:

- At the point that the brakes are applied the train encountered very low levels of adhesion. As a consequence the rotational velocity of the wheels drops very rapidly. However, within a distance of around 100 metres the rotational velocity of the wheels increases. This is consistent with the controlled release of the brakes as the WSP system intervenes.
- After this initial period of compensation the WSP is able to control the speed of each of the wheels such that they are never more than 20% below estimated train speed. This represents a controlled level of slip and is fully consistent with the design intent of the WSP system.
- By the time the train reaches signal WK336 the velocity of the wheelset and the actual speed of the train have converged. This is consistent with the train encountering improved adhesion.
- It appears that the activation of the sanding was initially insufficient to compensate for the very low levels of adhesion encountered. This is discussed further in paragraphs 73 to 75.

70 Given that the train appears to have performed in line with its design specification it is possible to use the data obtained from the OTMR to estimate the levels of adhesion that the train was encountering. This is summarised in Figure 4 below.

Section of route	**Average deceleration**	**Adhesion levels present** *(allowing for the benefit of sanding)*
WK344 to WK342	n/a (no braking)	unknown
Double Yellow displayed by WK342		
WK342 to WK340	$0.25 m/s^2$	<0.03
Single Yellow displayed by WK340		
WK340 to WK338	$0.17 m/s^2$	<0.02
Red displayed by WK338		
WK338 to WK336	$0.42 m/s^2$	<0.045
Red displayed by WK336		
WK336 to STOP	$0.6 m/s^2$	~0.06

Figure 4: Estimated deceleration and associated adhesion levels encountered by train 1A12 at Esher on 25 November 2005.

71 The levels of adhesion in the vicinity of Esher were no higher than 0.03 for a distance of approximately 2000 metres. The manufacturers of the WSP system and the rolling stock have also calculated the available adhesion levels to be in the region of 0.02 to 0.03, based on the initial speed and stopping distance of the train.

72 Sanding equipment is provided on the leading and trailing vehicles of the Class 450 EMU. However, sand is only applied by the equipment on the leading vehicle in direction of travel, irrespective of the number of vehicles in the train. Sand is deposited in front of the third wheelset on the front coach (ie immediately in front of the second bogie). At the time of the SPAD at Esher, sanding on the Class 450 EMU was initiated when three conditions were met:

- WSP active
- 75% brake demand (or greater)
- Train speed greater than 18 mph (30 km/h).

Once active, sanding continued until one or more of the three conditions was lost.

73 The OTMR download indicates that there was little apparent effect on speed when 75% braking was employed, at which point sanding should have commenced. This raises the question as to whether sand was actually applied. There are two possible reasons why sand might not have been delivered at the time that the conditions for sanding were satisfied:

- A system fault, which resulted in the sanding message not being received by the sanding equipment initially.
- A local failure that prevented sand being delivered, such as blockage of the delivery nozzle, possibly caused by freezing weather on the morning of 25 November.

74 The following evidence suggests that sanding did take place:

- Railhead swabbing of the up fast line at various locations in the vicinity of signals WK338 and WK336 found evidence of sand. Given that train 1A12 was the first train of the day to encounter restrictive signal aspects in this area on the up fast line, it is likely that the sand came from this unit. The lack of sand on the swabs taken on the approach to signal WK340 is inconclusive because at least six hours had elapsed between the incident and the swabs being taken, during which time many trains had travelled over the up fast line (see paragraph 60).
- Checking and static testing of the sanders was undertaken after the incident. The sand boxes were found to contain sand and the functioning of the sanding equipment was satisfactory. There was no procedure for dynamic testing of sanders to be undertaken.

75 Two other possibilities were also considered:

- Insufficient sand was dispensed. When unit 450 022 was examined after the incident, the sanding flow rate was tested. The maximum flow rate from the sanders was 1.32 kg/minute, which is lower than the limit of 2 kg/minute permitted by the relevant RGS GM/RT2461[2].

[2] Railway Safety (now Rail Safety & Standards Board) GM/RT2461, 'Sanding Equipment Fitted to Multiple Units and On-Track Machines'. Issue One, Railway Safety (now Rail Safety & Standards Board), August 2001. Available at www.rgsonline.co.uk

- The sand that was dispensed did not reach the critical point of interface between the wheel and the rail, i.e. it was blown off course by aerodynamic effects. Tests performed at Wildenrath in February 2006 by SWT indicated that sand dispensed at high speed on the Class 450 EMU did reach the wheel/rail interface. On this basis, the possibility that insufficient sand had reached the critical point of interface between wheel and rail was considered unlikely.

76 Sand is dispensed at a standard rate on the Class 450 EMU. The amount of sand applied per metre of rail is therefore lower when the train is travelling at higher speed. A sanding rate of 1.32kg/minute is equivalent to a sand density of 0.5 grammes/metre of track at a speed of 90 mph (144 km/h).

77 Following the incident, unit 450 022 was subject to testing by the manufacturer (Siemens). This took place on Sunday 27 November at Strawberry Hill depot before the RAIB had decided to undertake an investigation into the incident. Siemens used their own procedure for testing a train after a brake-related incident (BZR002) which includes:

- functional test of brakes and sanding equipment;
- test of gauges, governors and safety valves;
- brake pad apply/release test and inspection;
- examination of vehicle underframe and brake discs;
- examination of wheel treads;
- test of AWS;
- test of speedometer.

78 No relevant faults were found in the testing.

79 Siemens also reviewed downloads from the *Brake Control Unit* (BCU) and downloads from the BCU were sent to the braking supplier, Knorr Bremse for their review. Both Siemens and Knorr Bremse produced reports into the SPAD and concluded that the unit had performed in accordance with its design specification.

80 In the absence of any serious faults being found on the unit despite the severity of the overrun, it has been necessary to consider the more fundamental issue of the characteristics and configuration of some of the systems within the unit. The questions below, which all have wider application than the Esher SPAD alone, are addressed in the Part 3 report:

- Are RGS which govern WSP systems and braking and sanding equipment conducive to minimising stopping distances under low adhesion conditions?
- Is the figure of 20% for maximum permissible wheelslide used in the configuration of modern WSP systems the optimum for minimising stopping distance under severe low adhesion conditions?

Analysis – events following the incident

81 After the train had stopped at Hampton Court Junction, the driver and signaller discussed the steps to be taken. Some aspects of this process and the ensuing actions give cause for concern:

- The driver, despite being shaken by the incident, may have felt pressured into taking the train into Surbiton.

- The movement of train 1A12 into Surbiton station was in contravention of the rule book which requires that the signaller obtains permission from Operations Control before permitting a train involved in a SPAD to proceed past another stop signal (even one showing a proceed aspect).[3] The signaller did not have permission from WICC, but still permitted the train to pass two further signals (both showing a proceed aspect) into Surbiton station. However, the signaller's actions were governed by the understandable desire to get train 1A12 and its passengers into Surbiton station as quickly as possible.
- Confusion arose in the WICC (where Network Rail and SWT Operations Control staff are co-located) over whether an allegation had been made by the driver of train 1A12 regarding the functionality of the train's brakes , which resulted in a decision to terminate the train at Clapham Junction instead of Waterloo. The RT3189 form requires that the signaller asks the driver whether he or she considers the train fit to continue. The response to this question on 25 November from the driver of train 1A12 was, 'I think so', which was interpreted initially as an affirmation that there were no problems with the train.
- The Class 444 and 450 units have a brake test facility that can be used to check the braking system from the driver's desk. Had SWT's procedures required a brake test to be undertaken by the relieving driver, the decision to take the train forward could have been made in the knowledge that the integrity of the braking system was not in doubt. The functionality of the brakes is clearly a key concern and could have been addressed before the train was allowed to depart from Surbiton.

82 While railhead swabbing was undertaken after the incident, wheel swabbing was not. A potentially valuable source of information was therefore lost as the possibility of determining whether contamination had been transferred into the Esher area by the unit was not available. The RAIB considers that wheel contamination is unlikely to have been a cause of the incident because:

- the following train also suffered adhesion difficulties on the up fast line between Woking and Surbiton, suggesting that the source of the contamination was the rails rather than train wheels;
- if the source of contamination had been the wheels alone, the wheelside that occurred would probably have cleaned the wheels over a distance shorter than the length of slide experienced by train 1A12 on 25 November.

83 Paragraph 59 makes reference to the railhead swabbing that was undertaken after the incident at Esher. The value of the swabbing undertaken in the vicinity of signals WK336 and WK338 was diminished by allowing at least three trains to run over the up fast line before it took place. The value of railhead swabbing in the vicinity of signal WK340 was compromised by the extensive delay between the incident and the swabs being taken. No swabs were taken on the approach to Signal WK 342 which is where train 1A12 started to slide and further evidence was lost. There was no procedure in place at the time that governed post-incident data gathering. This issue is addressed in the Part 3 report.

[3] RSSB, Rule Book GE/RT 8000, Module TS1, Signalling general instruction, Clause 15.2.2, Issue 2, November 2004. Available at www.rgsonline.co.uk

Conclusions

84 The immediate cause of the incident was low adhesion on the up fast line between Hersham station and Hampton Court Junction.

85 Causal factors were:

- The presence of contaminants on the rail head of the up fast line which resulted in a level of adhesion no higher than 0.03 being available over a distance of approximately 2000 metres where train 1A12 was braking for signal WK338 at danger (paragraph 71). The issue of sustained low adhesion conditions is addressed in the Part 3 report.
- No rail head treatment of the up fast line between Woking and Surbiton (paragraph 53). This factor has already been satisfactorily addressed by Network Rail (paragraph 92).

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

- Neither Network Rail nor SWT had any knowledge of the low adhesion conditions on the up fast line between Hersham and Esher until train 1A12 was required to slow in the area (paragraph 57). The Part 3 report addresses the issue of monitoring for low adhesion conditions.
- The professional driving policy of SWT was not optimal for low adhesion conditions, given the characteristics of the sanding equipment on the Class 450 EMU (paragraph 49). The Part 3 report addresses professional driving in low adhesion conditions
- The configuration of the sanding equipment on the Class 450 EMU required the driver to select 75% braking effort before sand was dispensed (paragraph 72). In addition, unit 450 022 was dispensing sand at a relatively low rate in relation to the maximum flow rates contained in the relevant RGS (paragraph 75). The Part 3 report addresses the issue of sanding parameters for minimising stopping distances under low adhesion conditions.

87 The systems on board the Class 450 EMU appear to have functioned according to specification (paragraphs 77-79). Wider issues relating to the design and performance of braking and WSP systems are addressed in the Part 3 report.

88 While neither causal nor contributory to the incident, the following factors were identified during the course of this investigation:

- Potentially valuable information was not gathered after the incident because there was no procedure governing the investigation of low adhesion incidents (paragraph 83). The Part 3 report addresses this issue.
- The actions of the signaller after the incident had taken place were not in accordance with the rules and procedures that govern such a situation (paragraph 81, see Recommendation 1).
- Train 1A12 should not have been allowed to proceed beyond Surbiton at line speed with passengers on board on the morning of 25 November until it had been confirmed that the integrity of the braking system was not in doubt (paragraph 81, see Recommendations 2 and 3).

Actions already taken or in progress relevant to this report

89 SWT has amended its professional driving policy to require drivers to immediately place the train into full service braking (100%) if the level of deceleration on initial application of the brake is not in accordance with the driver's expectations.

90 SWT has reconfigured the sanding characteristics of Class 444 and Class 450 EMUs. Sand will be applied if the WSP system is active because of low adhesion and 40% braking effort is requested. Although not relevant to the circumstances of the Esher incident, SWT has also altered the lower speed threshold for sanding from 18 mph (30 km/h) to 10 mph (15 km/h).

91 Network Rail and SWT have jointly developed a risk assessment tool for adhesion-related risk at conflict points and other vulnerable locations such as level crossings. It is being used to determine priority locations for additional measures to prevent or mitigate the risk of low adhesion incidents and has resulted in the application of the additional measures described in paragraphs 92 and 93.

92 Network Rail has treated the rail head on the up fast line between Hersham and Hampton Court Junction using water jetting and Sandite for the low adhesion period in autumn 2006.

93 Network Rail has changed the signalling parameters affecting the operation of 2118 points for the duration of the autumn low adhesion period in 2006. Signal WK340 will also be held at danger if trains are crossing from the up slow to the up fast line over 2118 points at Hampton Court Junction. This means that trains approaching the area on the up fast line will receive their first cautionary (double yellow) aspect at Signal WK344, located on the London side of Hersham station, thus allowing an additional 900 metres of braking before the conflict point at Hampton Court Junction is reached. This measure was also implemented after the SPAD at Esher on 25 November 2005, for the remainder of the autumn low adhesion period.

94 Southern Railway arranged for a series of tests to be undertaken between Dorking and Horsham on 6 August 2006 to test the effect of increasing the maximum sanding rate from 2 kg/minute to 3 kg/minute. SWT representatives attended the tests. As a result, SWT is considering, in consultation with Network Rail, whether to increase the sanding rate on their Class 444 and 450 EMUs to 3 kg/minute.

Recommendations

95 The following safety recommendations are made[4].

Recommendations to address causal and contributory factors

96 The Part 3 investigation report contains recommendations that are relevant to causal and contributory factors associated with the incident at Esher on 25 November 2005, but have a wider applicability than the Esher incident alone.

97 Network Rail has added the up fast line between Hersham and Hampton Court Junction to their rail head treatment programme for the autumn low adhesion season (paragraph 92). This would otherwise have been the subject of a recommendation.

Recommendations to address other matters observed during the investigation

1 **Network Rail** to review the adequacy of their system for periodic briefing of signallers on Section 15.2.2 of the signalling general instructions and the procedures for dealing with a driver following the occurrence of a SPAD to ensure that they take account of the infrequency with which signallers have to deal with such incidents (paragraph 88). Depending on the outcome from the review, the procedures should be modified and changes implemented as necessary.

2 **Network Rail and South West Trains** to review jointly the adequacy of their Control Room procedures for dealing with trains that have been involved in severe overrun incidents to ensure that it is explicitly established whether any allegation has been made about the involvement of the train braking system in the incident before a decision is made on whether to allow the train to remain in service (paragraph 88). Depending on the outcome from the review, the procedures should be modified and changes implemented as necessary.

3 **South West Trains** to ensure that a brake test is undertaken on Class 444 and Class 450 units as a precondition for allowing a train to proceed after any SPAD and after any incident where the stopping performance of the train has fallen significantly below a driver's expectations (paragraph 88).

[4] 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 www.raib.gov.uk

Appendices

Glossary of abbreviations and acronyms — Appendix A

ASC	Area Signalling Centre
AWS magnet	Automatic Warning System magnet
BCU	Brake Control Unit
CSR	Cab Secure Radio
EMU	Electric Multiple Unit
MOM	Mobile Operations Manager
OTMR equipment	On Train Monitoring and Recording equipment
RAIB	Rail Accident Investigation Branch
RGS	Railway Group Standard
SPAD	Signal Passed At Danger
SWT	South West Trains
TOC	Train Operating Company
TPWS	Train Protection and Warning System
WICC	Wessex Integrated Control Centre
WSP system	Wheelslide Prevention system

Glossary of terms **Appendix B**

Automatic Warning System (AWS) magnet	Part of the equipment associated with the Automatic Warning System which, inter alia, provides information to a driver on whether the next signal is showing a clear (green) or restrictive (double yellow, single yellow or red) aspect.
Blended braking	The simultaneous use of two types of train brake (dynamic and friction) for the purposes of slowing or stopping the train. The contribution from each type of brake can be varied to achieve the demanded level of retardation.
Brake Control Unit	Interface between the driver's brake controller and the train brakes, WSP equipment and sanding, converting brake demands from the driver into brake cylinder pressures (via an analogue control unit). The BCU also contains a microprocessor which manages the brake blending process and logs any faults that have occurred within the braking, WSP and sanding systems.
Braking(Full Service and Emergency)	The rate at which a train slows, equating to at least $0.9 m/s^2$ for a full service brake application and $1.2 m/s^2$ for an emergency brake application on the Class 450 EMU.
Cab Secure Radio	A radio system allowing direct and one-to-one communication between a signaller and a train driver.
Conditioning (the railhead)	The process by which a contaminated railhead may be cleaned by the friction caused by train wheels passing over. WSP systems promote conditioning of the railhead by release and application of train brakes, which causes rapid changes in wheel rotational speed.
Desiro	Generic name for a family of diesel and electric multiple units manufactured by Siemens AG of Germany.
Dynamic Brake	A brake which operates by using the traction motors as electrical generators to slow down a train.
Emergency (braking)	See Braking Rate (Full Service and Emergency).
Four Aspect Signal	A signal that is capable of displaying red, single yellow, double yellow and green lights.
Friction Brake	A brake which operates by using friction to slow down a train, eg tread brakes which involve a metal block making contact with the tread of the wheel or disc brakes which involve contact between a pad and a disc located on the axle.
Full Service Braking	See Braking Rate (Full Service and Emergency).
Normalise (points)	The process of returning points to the main route that had previously been set for the converging or diverging route .
On Train Monitoring and Recording Equipment	An on-board computer that records the status of different items of equipment in real time and enables a plot of train performance and driver actions to be downloaded.

Overlap	The distance beyond a stop signal which must be clear before a train can normally be allowed to approach the signal.
Professional driving policy	A policy prepared by TOCs that describes, inter alia, train driving practices that the company expects its drivers to adopt in order to ensure safe and efficient train operations.
Railhead Swabbing	A process of wiping the rail surface with cotton wool pads to gather evidence regarding the presence or otherwise of contamination. Swabs taken from the rail head are analysed in specially equipped laboratories.
Railway Group Standard	Mandatory technical or operational document which sets out what is required to meet system safety responsibilities on Network Rail's infrastructure.
Regulating	Determining the order in which trains will be run to minimise delay.
RT3189 'Signal Passed at Danger' Form	A form completed by a signaller in collaboration with a driver after a train has passed a signal at danger without the authority of the signaller.
Rule Book	A book which incorporates most of the rules to be observed by general railway staff for the safe operation of the railway.
Run Through (Points)	The movement of a train through a set of points in the trailing direction which are not set for the passage of the train.
Sanding	The application of sand either automatically or manually to assist with adhesion during traction or braking.
'Stepless' brake controller	A brake controller that allows the driver to make fine adjustments (from 1% to 100%) in the amount of braking demanded.
Track Circuit Block Regulations	A set of rules that apply to the operation of trains over a section of line that is signalled using the occupation of track circuits as the means, inter alia, for determining the signal aspects displayed to drivers.
Train Operating Company	A company that is franchised to run train services over a designated area of the national rail network.
Train Protection & Warning System	A system fitted at some signals that intervenes to stop the train if a driver passes a signal at danger or if a driver approaches a signal at such a speed that it is inevitable that it will be passed at danger.
Train Reporting Number	A unique code that identifies each specific train, made up of four characters, the first of which designates its class, the second its destination and the third and fourth comprise a sequential number.
Up fast/slow line	Designations given to the two lines between Woking and Hampton Court Junction, one of which (up slow) serves intermediate stations and the other of which (up fast) does not.
Wessex Integrated Control Centre	Railway control centre staffed by personnel from Network Rail and South West Trains with responsibility for overseeing the operation of trains on the south western main line out of Waterloo.

Wheelslide	Condition where the rotational speed of the wheel is lower than the actual speed of the train.
Wheelslide Prevention (WSP) system	A system which, when active during braking, identifies when train wheels have started to slide and releases and reapplies brakes to: ● optimise braking rate to the level of adhesion available; ● condition the rail head (see separate definition).

Key standards current at the time — Appendix C

GM/RT 2044	Braking System Requirements and Performance for Multiple Units
GM/RT2045	Braking Principles For Rail Vehicles
GM/RT2461	Sanding equipment fitted to multiple units and on-track machines
GE/RT8000	Rule Book (Modules TS1, Signalling General Instructions and TS2, Track Circuit Block Regulations)

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