Rail Accident Investigation Branch

Rail Accident Report

Broken Rails at Urchfont and Kennington following the passage of a freight train 5 January 2006

Department for Transport

Report 27/2006
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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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This report is published by the Rail Accident Investigation Branch, Department for Transport.

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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 to Network Rail, Freightliner Heavy Haul and Dartmoor Railway Company staff, data and records for the purpose of this investigation.

4 Appendices at the rear of this report contain Glossaries explaining the following:

- acronyms and abbreviations are explained in the glossary at Appendix A; and
- certain technical terms (shown in *italics* the first time they appear in the report) are explained in the glossary at Appendix B.

Summary of the report

Key facts

5 On 5 January 2006 at 11:40 hrs, train 6F95 comprising a Class 66 locomotive and 14 *JNA NLU 'Falcon'* wagons, left Meldon Quarry, near Okehampton in Devon, bound for Hinksey yard near Oxford.

6 At 16:00 hrs and 17:20 hrs *track circuit* failures occurred at Urchfont and Kennington respectively, in each case just after train 6F95 had passed by. Examination of the line to determine the cause of the track circuit failures, revealed that the rails had been broken at those locations, one break occurring at Urchfont and two at Kennington.

7 Subsequently, one of the loaded wagons, NLU 29553, was found to have severe *wheel flats* which measured approximately 120 mm in length, but which were 7-8 mm deep, indicating that the flat length had been even longer during the journey. Another wagon, NLU 29334, was found to have much smaller wheel flats, within the permissible tolerance of 60 mm, and was returned into service.

Conclusions

8 The immediate cause of the broken rails at Urchfont and Kennington was mechanical overload, resulting from the high vertical impact loads imposed on the running rails by train 6F95 as it passed those locations on the journey from Meldon Quarry.

9 The first causal factor was that wagon NLU 29553 had developed large wheel flats on both wheels of its third axle, which generated high vertical impact loads, sufficient to cause complete fracture of the three rails, each of which had small, normally occurring, pre-existing, manufacturing defects. These would not have caused premature failure under normal traffic loading. Contributory factors which are likely to have led to the formation of the wheel flats were:

- low rail head adhesion conditions on the Meldon branch line which increased the risk of wheelsets locking up under braking and generating flats on their running surfaces;
- the style of driving train 6F95, which would not normally have caused wheel flat problems, was not matched to the specific characteristics of the Meldon branch line given the low adhesion conditions at the time of the incident and the prolonged steep downhill gradients.

10 The second causal factor was that a roll-by test was not undertaken at the exit from the Meldon Branch line, where the flats were most likely to have been created. The likely contributory factor which led to this was:

- a Railtrack formal investigation recommendation for roll-by tests at Coleford Junction, issued in November 2000 to the quarry train operator at that time, following a previous wheel flat incident in December 1999, had not been implemented into the Sectional Appendix for the route, nor made known to the current operators of these quarry trains.

11 The third causal factor was that the wheel flats were not detected during the subsequent journey from Coleford Junction to Hinksey Yard. Likely contributory factors which led to this were:

- there was only one automatic *wheel impact load detector* system on the route taken by train 6F95, at Cholsey, near the train's final destination, and that system was not in operation at the time of the incident due to ballast cleaning and relaying work;
- there were no reports of flats on train 6F95, either from the driver or from railway staff, except for one report by an off-duty signaller at the end of the journey.

12 The underlying cause of the incident was that despite the history of wheel flat problems on the Meldon branch line, involving a variety of wagon types, and a spate of three incidents within the two months prior to the incident, knowledge of these had not been adequately disseminated between the different parties involved in the Meldon quarry train operations. This led to no collective assessment of the risk from the flats and no mitigation.

Recommendations

13 Recommendations can be found in paragraph 165. They relate to the following areas:

- development and implementation of a low adhesion management strategy for the Meldon line with the aim of improving rail head condition;
- development of an optimum driving policy specifically for the quarry trains on the Meldon branch line, briefed to relevant drivers and regular monitoring to check compliance;
- implementation of a robust *roll-by test*ing procedure to check trains from Meldon Quarry for wheel flats;
- ensuring the requirement for roll-by testing is captured in formal route documentation (eg the Sectional Appendix) so it remains in place irrespective of the companies involved;
- a review of the number and location of wheel impact load detectors on the Berks and Hants line and the availability of such detectors on the railway network generally;
- implementation of a joint system for alerting each relevant company, in the event of further incidents of wheel flats on that route, so that evidence collection and investigation can be undertaken quickly, and the effectiveness of mitigation measures can be reviewed and enhanced if necessary.

The Incident

Summary of the events

14 On 5 January 2006, train 6F95 comprising a Class 66 locomotive hauling 14 JNA NLU 'Falcon' wagons (Figure 2), left Meldon Quarry near Okehampton in Devon at 11:40 hrs bound for Hinksey yard near Oxford. One wagon in the train was empty, the remainder were fully loaded.

15 At 16:00 hrs and 17:20 hrs, track circuit failures occurred at Urchfont and Kennington respectively, in each case just after train 6F95 had passed by. Examination of the line to determine the cause of the track circuit failures, revealed broken rails at the those locations, one at Urchfont and two at Kennington.

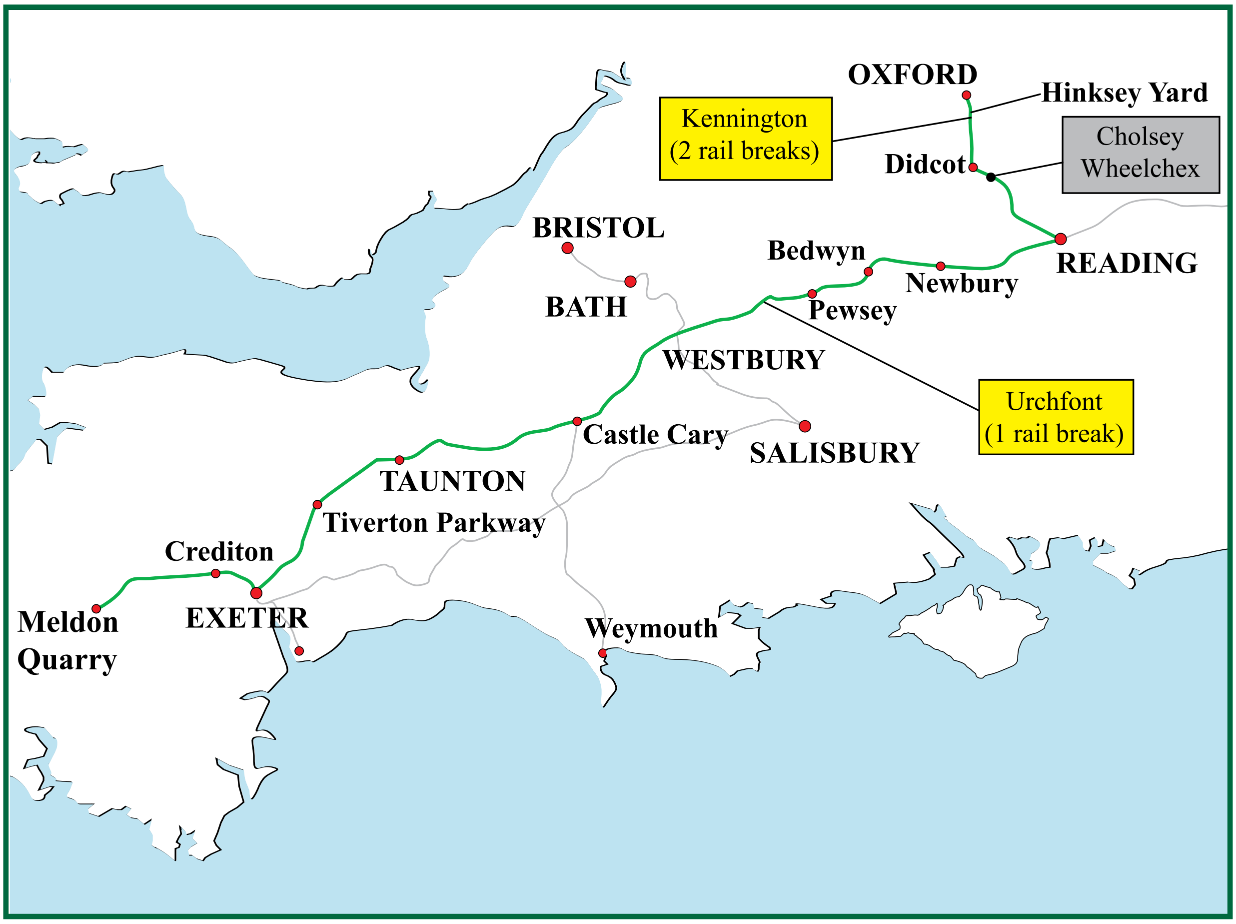

Figure 1: Location of rail breaks and the route of train 6F95.

16 Subsequently, one of the wheelsets on loaded wagon NLU 29553 was found to have severe wheel tread damage, with flats which measured approximately 120 mm in length within a damaged portion on each wheel which extended 255-285 mm. The depth of the flats at 7-8 mm indicated that the flat length had been even longer (160-170 mm) at some point in the journey. Another wagon, NLU 29334, was also found to have much smaller wheel flats, within permissible tolerances, and it was returned into service.

17 The incident caused disruption to operations on the affected lines for approximately 6 hours at Urchfont and 10 hours at Kennington, while Network Rail carried out repairs.

Incident location

18 The route taken by train 6F95 on 5 January 2006 is shown in Figure 1. Quarry trains run routinely four times a week from Meldon Quarry to Exeter Riverside yard where they reverse direction. The service then travels up the West of England main line initially to Cogload junction, east of Taunton, before it joins the Berks and Hants line to Reading West Junction via Castle Cary, Westbury, Urchfont and Pewsey. At Reading West Junction, the train travels in a northerly direction to Didcot East Junction and then on to Hinksey yard near Oxford, via Kennington. The total mileage from Meldon Quarry to Exeter Riverside is 26 miles (42 km) and from there to Hinksey is a further 175 miles (280 km).

19 The first rail break occurred at Urchfont on the *Up* main line at 81 miles 9 chains from London Paddington. The other two breaks were found, one on each rail, near Kennington Junction on the *Down* main line, at 60 miles 30.5 chains from Paddington.

The parties involved

20 The infrastructure between Meldon Quarry and Coleford Junction (Figure 4) is maintained and operated by the Dartmoor Railway Company (DRC), who have leased the line since 2000 from the owner, Aggregate Industries. DRC also run their own passenger trains. The signalling between Meldon Quarry and Okehampton is operated by DRC.

21 Network Rail own and operate the infrastructure on the route of train 6F95, between Coleford Junction and Hinksey, including all the signalling from Okehampton onwards.

22 The train was operated by Freightliner Heavy Haul (FLHH), who provide drivers, shunters and locomotives for the service. The service between Meldon Quarry and Hinksey is driven by a group of eight drivers, based at Bristol. A round trip is made up of 3 *turn*s. In the first turn, a light locomotive (without wagons) runs from Bristol to Hinksey, picks up the empty 'Falcon' wagons and brings them to Exeter Riverside as train 6F94. The second turn takes the train on to Meldon Quarry and returns to Exeter with the loaded wagons as train 6F95. The third turn takes train 6F95 from Exeter to Hinksey yard and brings the locomotive back to Bristol.

23 An FLHH shunter is responsible for train preparation at Meldon Quarry, operating the *ground frames* there and at Okehampton, and undertaking the train preparation after the *run-round* at Exeter.

24 The wagons are owned by Network Rail and maintained on their behalf by Wabtec Rail Ltd.

25 Loading at Meldon Quarry is carried out by Bardon Aggregates who are responsible for weighing and loading of the ballast stone onto the wagons. The FLHH driver shunts the train as required by the Bardon Aggregates loader.

Train(s) and plant

26 Train 6F95 comprised locomotive 66546, 13 loaded and 1 empty 'Falcon' wagons. Wagon NLU 29553 was the third wagon from the locomotive between Meldon and Exeter and was the third from the back on the subsequent journey to Hinksey. NLU 29334 was the eighth wagon in the train between Meldon and Exeter and seventh on the subsequent journey to Hinksey. The total weight of the train was 1224 tonnes.

27 The JNA NLU 'Falcon' wagon (Figure 2) is an open box bogied wagon used primarily to transport aggregates, either new ballast to engineering worksites or ballast spoil from worksites. There are 555 of these wagons in use with Network Rail. They have a tare weight of 26 tonnes and fully loaded weight of 90 tonnes. Based on the loaded ballast weights provided by Bardon Aggregates, all the wagons on train 6F95 were below this gross weight, the highest being 83.9 tonnes. Wagon NLU 29553 had a gross weight of 83.4 tonnes.

Figure 2: Wagon NLU 29553 at Hinksey Yard on 6 January 2006.

The orientation of wagon NLU 29553 with respect to the Meldon–Exeter and Exeter–Hinksey legs of the journey and the wheel and axle numbers referred to later in this report are shown in Figure 3.

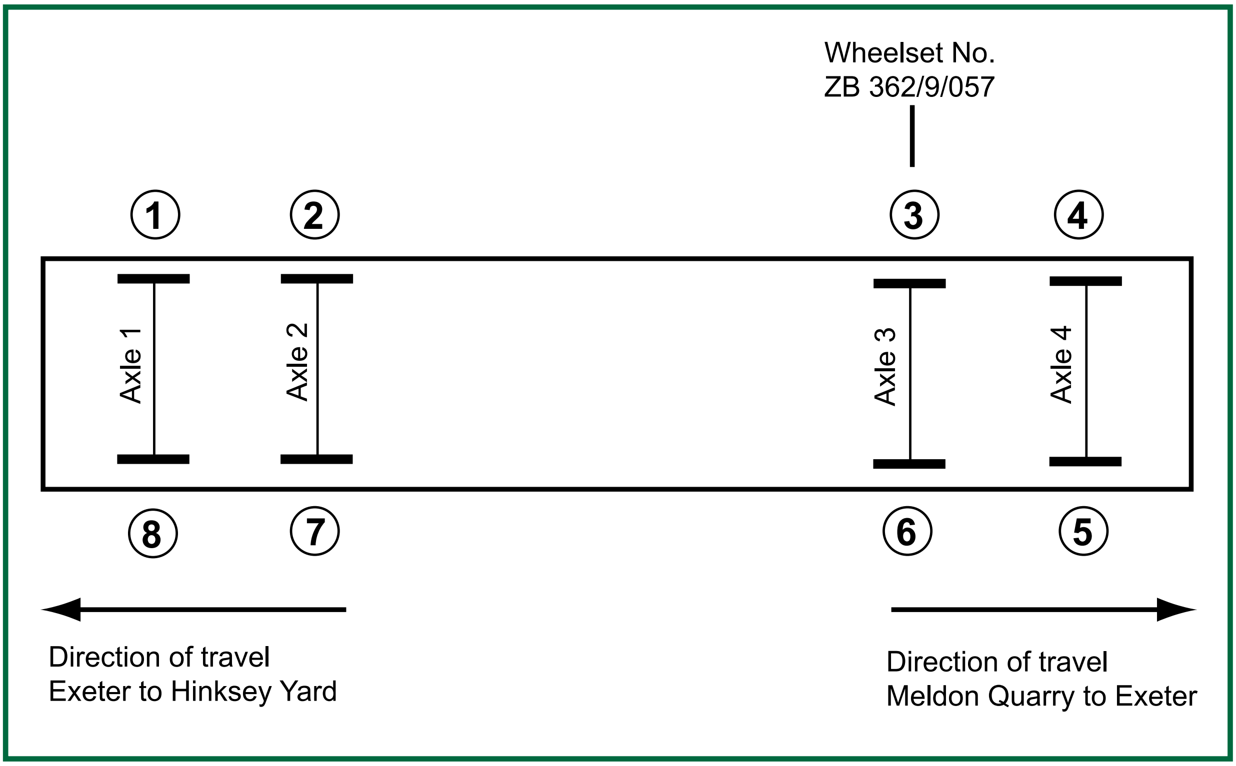

Figure 3: Wagon NLU 29553 directions of travel with respect to wheel and axle number

Infrastructure (including signalling system)

28 The first 15 miles of the journey from Meldon Quarry to Coleford Junction (Figure 4) is over a single *bi-directional line*. Trains must stop at Okehampton and Meldon Quarry where the shunter operates ground frames. Over most of this distance there is a relatively steep falling gradient, the maximum being 1 in 76. There are also some short sections of rising gradients at North Tawton (1 in 80) and Bow (1 in 120).

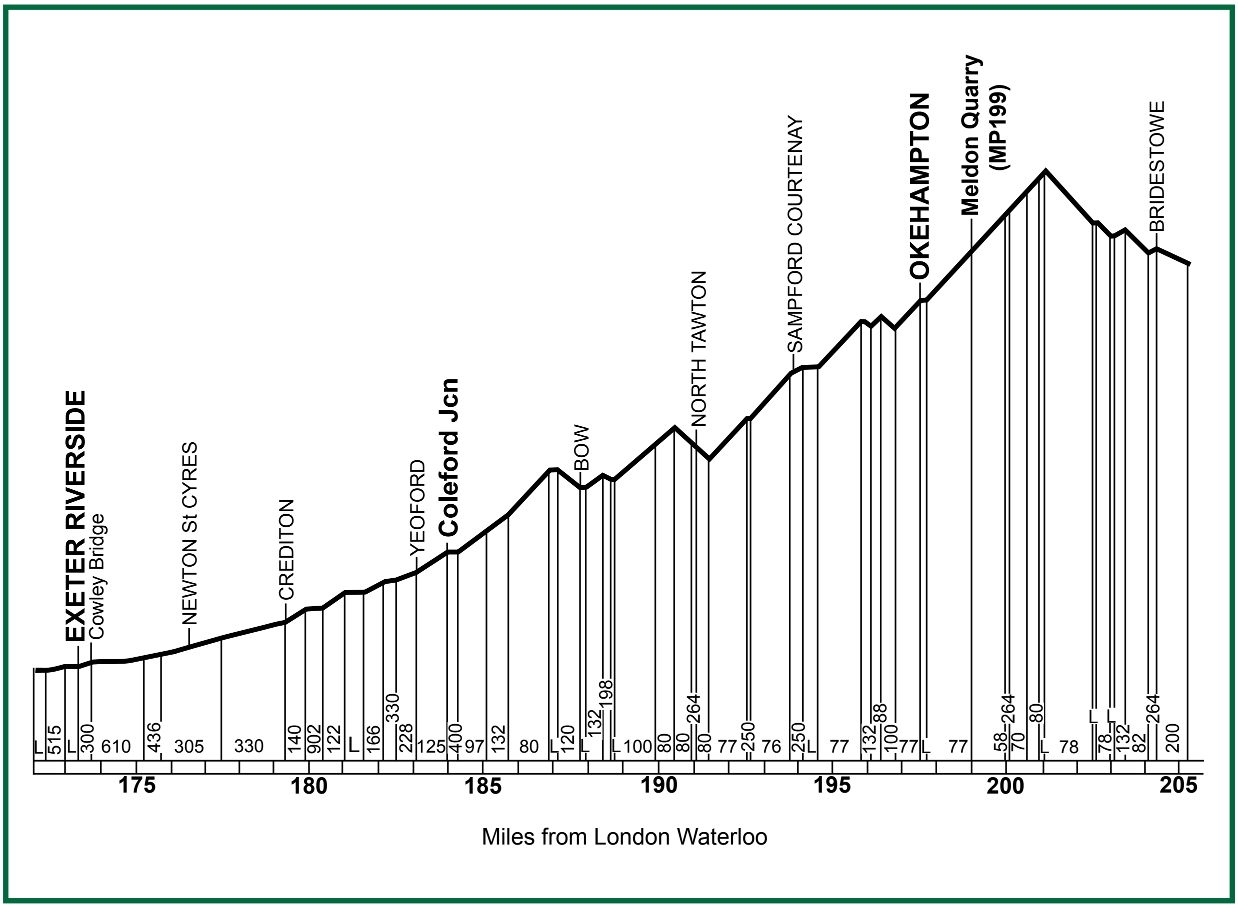

Figure 4: Gradient profile between Meldon Quarry and Exeter.

29 For loaded quarry trains, the maximum line speed from Meldon Quarry to Okehampton is 25 mph (40 km/h) and from Okehampton to Coleford Junction it is 40 mph (64 km/h), with one restriction down to 30 mph (48 km/h) for the bridge at Greenslade, located at 191 miles 55.5 chains from London Waterloo. The steep downhill gradients over these two sections of the route require the driver to make frequent brake applications to control train speed if running at the maximum line speed.

30 Between Coleford Junction, where the train enters Network Rail infrastructure, and Crediton the speed limit is 20 mph (32 km/h), with a restriction down to 10 mph (16 km/h) for a bridge at 182 miles 38 chains. From Crediton to Cowley Bridge Junction, on the approach to Exeter Riverside Yard, the maximum speed is 30 mph (48 km/h) with a restriction down to 20 mph (32 km/h) for a bridge at 177 miles and 21 chains. Drivers are given an 'advice to traincrew' form which contains details of the speed limits.

31 The only trains which run all the way up to Meldon Quarry are the ballast carrying services on behalf of Network Rail. DRC also operate their own daily passenger services between Okehampton and Sampford Courtney during the spring and summer school holidays and at weekends during the autumn and winter, with some longer excursions to Coleford Junction. First Great Western operate a Sunday service from Exeter to Okehampton between the end of May and the end of September for the tourist season.

32 For the remaining 175 miles (280 km) from Exeter to Hinksey, the gradient rises up to a summit at Whiteball Tunnel, located between Tiverton Parkway and Taunton, and then falls to Cogload junction. From there to Reading West Junction the gradient is undulating and thereafter to Hinksey it is generally level.

33 A combined *hot axlebox detector* (HABD) and a *hot wheel detector* (HWD) is located at Urchfont on the Berks and Hants Up main line. A wheel impact load detector is located on the Down relief line at Cholsey but this was inoperable at the time of the incident, because of ballast cleaning and relaying work.

External circumstances

34 The weather on the day of the incident is reported to have been damp and overcast.

35 The driver, who took train 6F94 to Meldon for loading on 5 January 2006, reported that the railhead condition was better than usual and he encountered no wheel slip on the locomotive during the journey to Okehampton.

Events preceding the incident

36 Train 6F94, which became train 6F95 on departure from Meldon Quarry, left Hinksey Yard with the 14 empty wagons at 01:40 hrs on 5 January and travelled to Exeter Riverside Yard with the first turn driver. On arrival at Exeter, the *brake timing* was changed from '*goods*' to '*passenger*' for the run-round, which is normal practice, in order to obtain a faster brake response. Following the run-round, the loco was coupled to the train and stabled with brake timings at the 'passenger' setting.

37 The second driver arrived at Exeter late (due to transport problems) at 07:40 hrs, to pick up the train. The train was prepared and a *brake overcharge* and *brake test* were carried out in accordance with normal practice. He left the locomotive brake timing at the 'passenger' setting and train 6F94 left Exeter at 08:05 hrs for Meldon Quarry, 153 minutes late.

38 Train 6F94 arrived at Meldon Quarry at 09:15 hrs; the loco was run-round and the wagons were loaded with ballast. A brake overcharge and brake test were carried out and the train left Meldon Quarry as train 6F95 at 11:40 hrs (50 minutes late) and proceeded to Exeter.

39 Train 6F95 arrived at Exeter Riverside Yard at 12:55 hrs without any reported incident. The third driver took over from the second driver and ran the locomotive round to the north end of the train. The brake was reset to 'goods' timings and a brake continuity test was carried out with the assistance of the second driver and the shunter.

40 Train 6F95 departed Exeter at 13:15 hrs, 40 minutes late. The second driver, who had brought the train from Meldon Quarry, reported that he stood at the back of the train and watched it depart but did not notice anything wrong.

Events during the incident

41 The driver working the third turn (paragraph 22) took train 6F95 from Exeter to Hinksey. During the journey, at approximately 16:00 hrs, the signaller at Reading signal box noted that a track circuit on the Up Westbury line at Urchfont was showing ‘occupied’ when it should have cleared after train 6F95 had left the section. He reported this to Network Rail fault control at Swindon. Meanwhile, the driver was unaware of any problem with his train.

42 Train 6F95 reached Hinksey yard at 17:22 hrs. Just prior to this, an off-duty signaller, living near the line, rang Oxford signal box and reported an abnormal noise as train 6F95 passed by. Shortly after, the signaller noticed a track circuit at Kennington, on the approach to Hinksey, as showing ‘occupied’ when it should have cleared after train 6F95 passed. He informed fault control at 17:25 hrs and operations control at 17:36 hrs.

43 On arrival at Hinksey yard, train 6F95 was unloaded and arrangements were made for the wagons to be held for examination, by which time the locomotive had been detached and returned to Bristol.

Events immediately following the incident

44 At 18:11 hrs, Network Rail technicians discovered the cause of the earlier track circuit failure at Urchfont was a broken left hand rail. At 18:29 hrs Network Rail staff responding to the fault at Kennington found both left and right hand rails broken at 60 miles 30.5 chains.

45 Following the discovery of the broken rail at Urchfont, the Up main line was blocked and trains were diverted via Melksham while repairs were undertaken. Normal working was resumed at 00:18 hrs.

46 At Kennington, the line was blocked and single line working was started between Kennington Junction and Didcot North junctions at 22:15 hrs while the rails were repaired. Normal working was resumed at 03:41 hrs.

47 Meanwhile, at Hinksey Yard an EWS shunter examined the wagons and discovered the large flats on wagon NLU 29553 and the damage to a wheelset on wagon NLU 29334. Both vehicles were removed from the train.

48 A download of the *on-train monitoring recorder* (OTMR) on locomotive 66546 was carried out by FLHH at Bristol; it was later returned to Hinksey for brake testing with the defective wagons.

49 On 6 January, the RAIB was informed and joined vehicle engineers from Network Rail and FLHH to examine wagon NLU 29553 at Hinksey. Arrangements were then made for wagon NLU 29553 to be moved by road to Derby for testing. A full brake test was also carried out with locomotive 66546 and wagons NLU 29553 and NLU 29334 at Hinksey yard.

50 Network Rail stopped further Meldon Quarry train movements until April 2006, while it undertook a formal investigation.

Consequences of the incident

51 There were no fatalities or injuries as a result of this accident.

52 Damage to the track was confined to single fracture of the plain left hand rail at 81 miles 9 chains on the Up Main line at Urchfont and fractures of left and right hand rails at welded joints at 60 miles 30.5 chains near Kennington. The damaged rail sections were removed and new closure rails were welded in place at these locations.

53 The only significant damage to wagon NLU 29553 was the wheel flats on axle 3. There was some minor damage to suspension components on the affected bogie and the wheel bearings had also lost some of their grease due to the harsh vibration caused by the wheel flats.

54 Wagon NLU 29334 was also found to have small flats which had rolled out and had possibly been created on a previous trip. These flats were examined by Network Rail vehicle engineers and found to be within the allowable tolerance of 60 mm and this wagon was subsequently returned to service.

The Investigation

Sources of evidence

55 Evidence was obtained from a variety of sources:

- information about the incident and the relevant background, provided by Network Rail, FLHH and DRC;
- statements of personnel involved;
- the locomotive's data recorder (OTMR);
- examination of wagon NLU 29553 and testing of its braking system;
- brake testing of a rake of three laden NLU wagons, 29488 (77.6 tonnes), 29435 (76.5 tonnes) and 29177 (75.1 tonnes) on the Meldon branch line;
- brake testing of wagon NLU 29553 at the Great Central Railway, in tare and laden (86 tonnes) conditions;
- examination of sections of the Meldon branch line to determine its condition;
- visit to Meldon Quarry and cab ride from Meldon Quarry to Exeter;
- review of the NLU wagon brake system, design calculations, test results and maintenance specifications.

Key evidence

Vehicles

56 Locomotive 66546 was attached to wagons NLU 29553 and 29334 at Hinksey yard on 6 January and a functional brake test was carried out. Further brake tests, in accordance with FLHH's current post incident test procedure for this locomotive type, were undertaken by them on 10 January. These tests confirmed that the braking system of the locomotive was working correctly.

57 Wagon NLU 29553 was subject to further examination at Derby on 17 & 18 January 2006 by Network Rail and the RAIB. The wheel flats were on axle 3 (wheel numbers 3 and 6), which was the trailing axle of the leading bogie from Meldon (Figure 3). The flats were well defined, indicating that they had been freshly created during the last journey.

58 Each wheel flat (Figure 5) measured approximately 120 mm in length, but the wheels were damaged over a greater portion of their circumference of between 255 and 285 mm in length (including the flatted portions). The majority of the deformation was above the upper edge of the flat as shown in Figure 5. Between Exeter and Hinksey the wheel would have been rotating as shown by arrow A in Figure 5. The depth of the flats were measured at 6.9 mm on wheel 3 and 8.1 mm on wheel 6. These depths are 3-4 mm greater than would be expected for a freshly slid flat 120 mm long, and correspond to a flat length of approximately 160-170 mm. This indicated that, at some point in the journey, the flat length had been longer than the final visible length of 120 mm. The forces generated by such severe flats is discussed later in paragraphs 77 and 122.

59 The fore and aft edges of the flat were battered, confirming that the wheel had been rotating for some considerable distance after the flats had been created. This battering of the edges also explains how a longer flat of the order of 160-170 mm had reduced in size to the final 120 mm length. There was also evidence of metal flow at the edges of the flat portions, as seen by the curved upper and lower edges of the flat in Figure 5. The shape of the edges indicated that the flat had formed first at some point in the journey from Meldon to Exeter, followed by rotation and further skidding in the Exeter - Hinksey direction of travel.

Figure 5: Flat on wheel 3 of axle 3 (serial no. ZB 362/9/057) on wagon NLU 29553

60 The brake blocks on the affected wheelset were intact except for damage at the top edge where they had been impacted by the wheel flat during braking. There was no evidence of abnormal brake application or brake forces either on the block or wheel treads on this wheelset.

61 The affected bogie showed evidence of severe vibration on primary suspension components. The wheel bearings were dismantled and examined by SKF, the bearing manufacturers, at Luton. This confirmed the bearings were in good condition, although some grease had been expelled through the bearing seals due to the severe vibration from running with flatted wheels.

62 Static brake tests were carried out on wagon NLU 29553, using a brake trolley, with the RAIB present. Brake cylinder pressures and brake block forces across all 4 axles were measured in a series of tests with initial and full service applications to check for variations in brake block forces which might have explained why axle 3 locked to form the flats.

63 There are two brake cylinders on the vehicle, each actuating the brake linkages on one bogie. The cylinder pressures were generally found to be consistent to within 2% of the design value. Each wheel has one brake block; the forces applied by these were found to be within tolerance at -8% and +4% of the design value. The block forces on the defective wheelset were among the lower readings. The tests did not reveal any fault with the brake system nor explain why axle 3 had locked preferentially to other axles on this vehicle.

64 The handbrake applies brake blocks on axles 3 and 4 on wagon NLU 29553. The handbrake interlock system was tested and found to be working correctly. Had the vehicle's handbrake been left on, the driver would not have been able to release the brakes on the train. There is an isolating valve which allows the system to be bypassed, but it's wire lock was sealed and had not been tampered with when the RAIB inspected the wagon.

65 The wheel loads on wagon NLU 29553 on the day of the incident, in the loaded condition, could not be determined, because the wagon had already been unloaded at Hinksey before the investigation started. Wagon NLU 29553 was weighed in the tare condition on 8 February to check the wheel and axle load distribution. The axle load on the affected wheelset was 6640 kg and was within 1% of the loads on other 3 axles. The wheel loads were also very similar; being within +/- 6% of the average wheel load.

66 On 15-16 March 2006, Network Rail undertook instrumented testing on the Meldon branch line with a Class 66 and three laden NLU wagons to try and understand the cause of the wheel flats and to determine what adjustments could be made to the brake performance and driving technique to minimise the probability of wheel flats. Wagon NLU 29553 was not included because it was being prepared for brake testing elsewhere (paragraph 67). In the event, the tests were abandoned early due to damage on the wheel treads of the instrumented wagon; however, this damage was not related to wheel slide or wheel flats. The tests did not provide any useful information regarding the cause of the wheel flats on 5 January 2006.

67 Further brake tests were undertaken by Network Rail on 8-10 March 2006 with wagon NLU 29553 in tare condition and on 22-24 March 2006 with the wagon fully loaded. This testing had been planned before the incident of 5 January, in order to understand the cause of uniform wheel tread damage (comprising a narrow circumferential band of overheated wheel tread, different to wheel flat damage) observed on some 'Falcon' wagons wheels. Tests were undertaken initially with the same type of brake block as fitted at the time of the incident and then with other types to evaluate improvements. Instrumentation to measure various brake pressures and stopping distance was fitted. The test results showed that the braking performance of wagon NLU 29553 with the original type of brake block was satisfactory and met the requirements of Railway Group Standard GM/RT 2141. There was no evidence of wheel slide during the tests.

68 Network Rail have informed the RAIB that there is no history of wheel flats on 'Falcon' wagons, other than those on the Meldon line, which are covered later in paragraphs 105 to 108.

Wagon maintenance

69 Maintenance of the 'Falcon' wagons is carried out by Wabtec Rail at various locations in the UK. Wagon NLU 29553 received a 6-monthly planned preventative maintenance (PPM) exam on 28 November 2005 and an annual vehicle inspection and brake test (VIBT) on 19 May 2005. This was in accordance with the maintenance plan. The maintenance records show that new brake blocks were fitted on 4 July 2005 and a functional brake test carried out. The maintenance record for wagon NLU 29553 over the previous 12 months did not indicate any braking problems.

Wagon loading

70 Ballast stone is loaded onto the wagons at Meldon Quarry by conveyor belt. The discharge hopper, located approximately 1.5 m above the top of the wagon, discharges the ballast into a series of 6-8 piles on each wagon as the driver moves the train forward. This distributes the load uniformly over the length of the vehicle. Each wagon is loaded in approximately 8 minutes. Therefore, the loading is gradual and does not subject the wagon suspension to any shock loading which could cause the load-weigh valves to stick in such a way as to increase brake effort unduly on a particular bogie.

The fractured rails

71 Each of the three broken rails had suffered complete brittle fracture, one in plain rail at Urchfont and the other two in rail welds at Kennington. This type of brittle fracture occurs when a rail is overloaded mechanically, rather than by a process of fatigue from normal service stresses. The usual cause of such overload is impact from wheels with significant flats or 'out of roundness'.

72 The track quality at the site of the rail breaks was assessed, because poor track quality can also cause high loading of rails. The track at both Urchfont and Kennington was last measured on 16 December 2005 by Network Rail's 'New Measurement Train', which measures track geometry and the results were recorded as 'Good' or 'Satisfactory'.

73 Detailed metallurgical examination of the broken rail from Urchfont (Figure 6) showed that it contained a rolled-in lack of fusion defect in the rail foot which had been there since the rail was manufactured circa 1970. The inclusion of such defects was inherent in the manufacturing process used at the time. The rail foot is in tension as rails bend under vertical loading. However, the size of the defect was too small to have been detected using the standard in-situ manual and train based ultrasonic scanning equipment used on the network. The fracture faces were consistent with mechanical overload and there was no evidence of any fatigue crack growth.

74 Examination of the broken left hand rail from Kennington (Figure 7a) revealed that it had fractured rapidly from the bottom of the rail foot at the edge of the weld collar, where there were three small fatigue cracks, the largest of which had a surface length of 4 mm and depth of 1 mm. The fatigue cracks had initiated at slag inclusions formed during the weld manufacture in 1968. The crown of the rail had been weld repaired at some unknown point in its history, leaving a horizontal defect.

75 The right hand rail from Kennington (Figure 7b) had also fractured rapidly from the edge of the weld collar, having initiated at 2 fatigue cracks, 1 mm deep and 3.5 mm deep at the bottom of the rail foot. The rail and weld were manufactured in 1968.

76 The pre-existing defects in both Kennington rail breaks were also too small to be detected by standard manual and train based ultrasonic equipment. Although there was evidence of fatigue crack growth, the age of the rails indicated that the rate of growth was extremely slow.

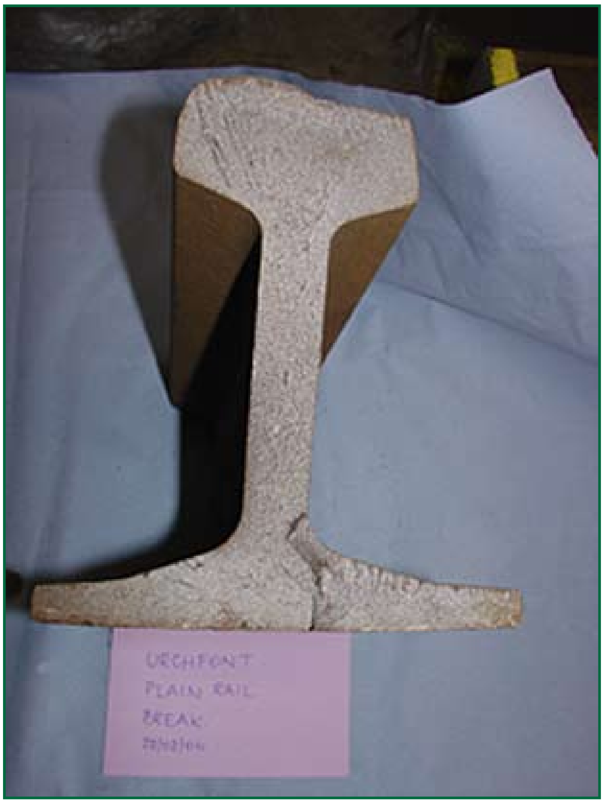

Figure 6: Broken left-hand rail from Urchfont

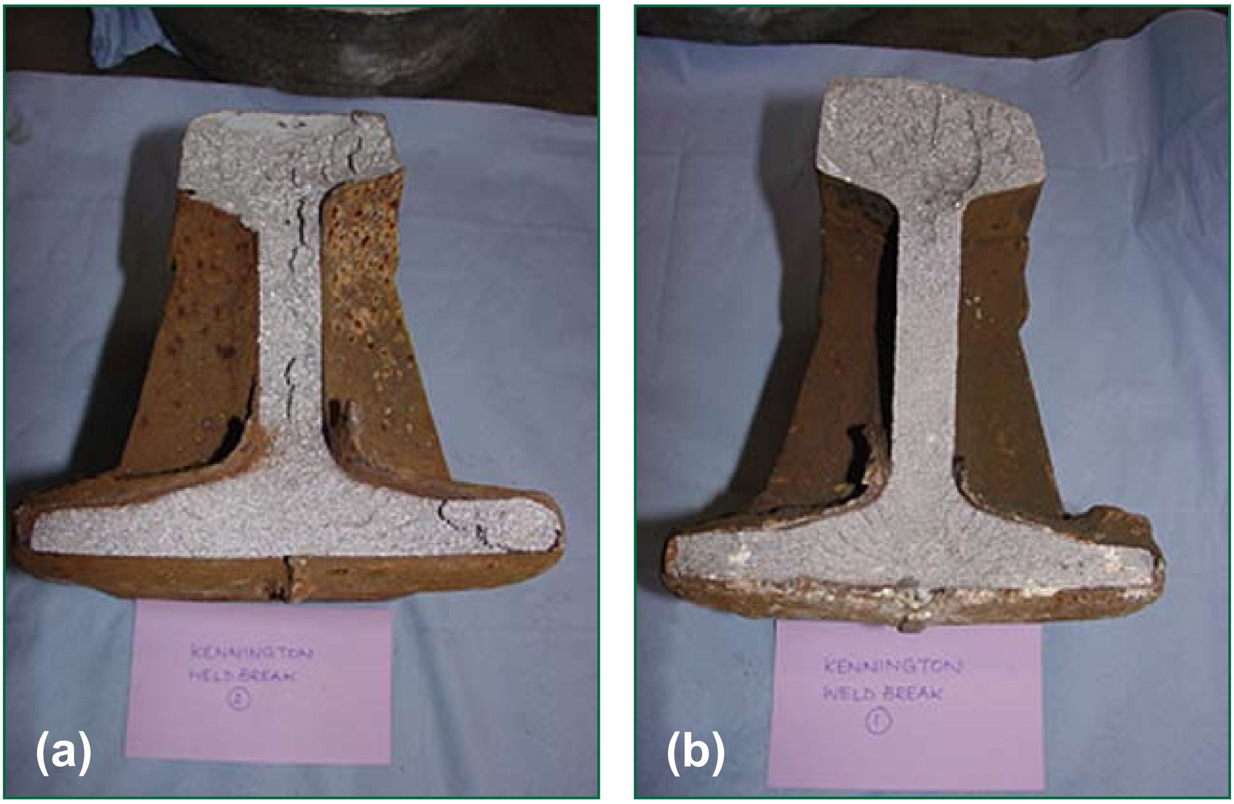

Figure 7: Broken left (a) *and right* (b) *rails from Kennington*

77 The maximum vertical impact force, which a vehicle is allowed apply to the track, is specified in Railway Group Standard GM/TT0088 as 322 kN, for a prescribed 'design' track irregularity. As the force rises above this level, the risk of rail breakage also increases. In April 1999, a series of seven rail breaks occurred after the passage of a Class 47 locomotive which was later found to have an 'out of round' wheel with a maximum defect depth of approximately 5 mm. AEA Technology subsequently calculated the resulting impact forces for Railtrack to be 570 kN (Appendix C - Reference 1) at a speed of 70 mph (112 km/h) for an axleload of 20 tonnes. This axleload is similar to the 20.8 tonne axleload of wagon NLU 29553.

Formation of wheel flats

78 Wheel flats occur when a rotating wheel locks and skids on the rail head. The resulting heating and wear causes a flat spot to appear on the running surface of the wheel tread. The longer the period of skidding, the longer will be the length of flat generated. Modern passenger vehicles usually have *wheel slide protection* (WSP) systems and therefore wheel flats are relatively uncommon on such vehicles. UK freight vehicles are not fitted with WSP and are therefore more susceptible to flats.

79 Wheels are more prone to skid and form flats if the friction between the wheel and rail is lower than the value assumed in the design of the brake system. The brake system on the 'Falcon' wagons is designed to a typical wheel/rail friction coefficient of 0.28 to ensure there is adequate braking effort in normal train operation. However in low adhesion conditions the value of friction coefficient can drop to well below 0.1, significantly increasing the risk of flats if WSP is not fitted.

80 Research was carried out in Sweden in 1996 (Appendix C - Reference 2) to understand the formation of wheel flats. A comprehensive series of instrumented track tests were carried out using a test train in which the brake on the test axle could be manually controlled to induce wheel locking. The results showed that wheel flats initially grow in length very quickly at the start of a wheel slide and then more slowly as the slide progresses. For example, it was found that 5 seconds of wheel skid, whilst travelling at 12.5 mph (20 km/h), was sufficient to create a flat of about 40 mm for an axle load of 10.1 tonnes. If skidding occurred for 25 seconds, the resulting flat would be only slightly longer at about 50-60 mm.

81 The size of wheel flat required to prevent a wheel from rotating, once the brakes have released, can be estimated mathematically. For a 762 mm diameter wheel, the critical flat sizes for wheel/rail friction coefficients of 0.05 and 0.1 are approximately 50 mm and 100 mm respectively. In conjunction with findings from the Swedish research (paragraph 80), this means that a relatively short duration slide can create a big enough flat that a wheel will tend to skid on the flat, increasing its size further, rather than rotate in low adhesion conditions. If the wheel/rail friction subsequently increases, the wheel will be forced to rotate again. Hence a flatted wheel can undergo a series of skids and rotations depending on the prevailing wheel/rail friction.

Detection of wheel flats

82 Wheel flats and 'out of round' wheels are both known to cause severe impact loading on the running rails (Appendix C - Reference 3). In order to protect the infrastructure, Network Rail have 25 automatic wheel impact load detectors or '*wheelchex*' sites on the network. Their location, when originally installed, was based on the following criteria:

- relatively high incidence of broken rails;
- high traffic loadings and heavy freight flows;
- maximised coverage across train operators;
- availability of suitable recess points (eg sidings) to enable defective trains to be moved out of the way.

If a train causes excessive wheel loads at a detector, it will automatically notify the local route control centre. Procedures exist for the train to be stopped and the driver informed. The train is then allowed to proceed, at reduced speed, to a suitable location to be taken out of service. The reduced speed is dependant on the class of the train and the severity of the impact forces measured.

83 There are four levels of alarm at 'wheelchex' sites, level 1 (200-350 kN), level 2 (350-400 kN), level 3 (400-500 kN), level 4 (> 500 kN). A level 1 alarm is advisory and the control centre do not need to stop the train. A level 2 alarm requires a 30 mph (48 km/h) speed restriction for a freight train until it reaches a suitable location where it can be taken out of service. Levels 3 and 4 require 20 mph (32 km/h) and 10 mph (16 km/h) speed restrictions respectively.

84 On 24 November 2005, Cholsey 'wheelchex' picked up the flatted wheels on one axle of another 'Falcon' wagon NLU 29350 (paragraph 108). This axle registered impact forces of 398 kN on the right wheel and 370 kN on the left wheel, for flat sizes of 90 mm and 70 mm respectively. The flats on NLU 29553 would be expected to have recorded even higher forces, had Cholsey 'wheelchex' been operable at the time.

85 Currently, the only other means of finding wheel flats on a moving train is detection by railway staff either on or off the train. Their general safety responsibilities include the reporting of any fault they notice on a passing train. Flatted wheels make a distinctive loud banging sound as the wheel rotates. If a flatted wheel skids, the sound is much less distinctive and can easily be missed. Therefore, if severe wheel flats had been heard by railway staff, they would almost certainly have reported it so that action could be taken to arrange for the train to be stopped at the earliest opportunity for inspection. On this occasion there were no reports of abnormal noises from train 6F95, except at the end of the journey when the train had nearly reached its destination.

86 There is a HWD at Urchfont. This system is designed to pick up the heat signature from dragging wheels or brakes and to complement conventional HABDs. Their performance is currently being assessed by Network Rail and therefore they are not yet set up to provide alarms at signal centres if dragging wheels or brakes are detected. Data from Urchfont HWD for the passage of train 6F95 on 5 January 2006 showed that there was no significant heat difference between the flatted axle and other axles, indicating that the flatted axle was rotating rather than skidding over this stretch of track. This is consistent with the rail breaks at Urchfont which required a rotating flatted wheel to have caused the damage.

Availability of wheel impact load detectors

87 Wheel impact load detectors form the final line of defence against significant infrastructure damage by vehicles with severe wheel flats, given that such defects will not always be detected by railway personnel. Hence the availability of these systems affects the risk from wheel flats.

88 The detectors on all four lines at Cholsey were taken out of service on 2 December 2005 for ballast cleaning and relaying track work. On 30 January 2006, three lines, including the route taken by train 6F95, became operational and the fourth line was commissioned by 24 February 2006.

89 Network Rail's daily control logs, which report on all incidents over the last 24 hours, include a summary of 'wheelchex' locations and lines that are inoperable and the date and reasons for their failure or disconnection. A brief review of the availability of 'wheelchex' systems over the 12 month period from July 2005 to June 2006 was carried out by taking a snapshot of overall availability on the first day of each month. Additional data on the availability of wheelchex on a line by line basis (most sites have multiple lines) was provided by Network Rail. The data indicated:

- The availability on a line by line basis varied from 64% (August 2005) to 89% (February 2006), the average being 81%.
- 15 of the 25 sites had at least one line inoperable at some time for various reasons such as power failure, awaiting re-calibration and awaiting reconnection following track renewal work.
- Some sites had not been fully operable from long before the analysis period and these periods of partial or no operability varied greatly from a few days to over 508 days, the average being 98 days.
- On the first day of any given month the number of inoperable sites varied from 1 (March 2006) to 8 (September, November 2005). The average number of inoperable sites per month improved from 6.5 for the first half of the analysis period to 3.5 in the second half.

Characteristics of the Meldon branch line

90 In addition to the relatively steep gradients on the branch line (paragraph 28), the other significant feature of the line is the condition of the rails, particularly during the leaf fall season.

91 It was apparent from discussions with Dartmoor Railway Company, that *low adhesion conditions* have been prevalent during autumn and winter since they took over operation of the line in 1994. Wheel flats have not been known to occur except during these seasons.

92 Additionally, flats were not considered a problem when quarry trains were hauled by earlier generations of locomotive such as Classes 31, 37 and 47. Incidents of wheel flats appeared to increase markedly when Class 66 locomotives were introduced to the route. The advanced traction control system on the Class 66 requires only small amounts of sand to be sprayed into the wheel/rail interface to improve adhesion, whereas the older locomotives used a greater quantity of sand. It has been suggested that the greater quantity of sand used by the older locomotives improved adhesion not only for the locomotive but also for the following wagons. The RAIB has separately conducted a comprehensive investigation into low adhesion incidents involving passenger trains (Appendix C - Reference 4). The findings from that investigation confirm that increasing the quantity of sand used in low adhesion conditions increases adhesion and reduces stopping distances.

93 In December 1998, DRC banned Class 66 locomotives from operating on their infrastructure, because of the association between these locomotives and wheel flats on DRC track. Subsequently, DRC allowed them back as older locomotives were phased out and replaced by Class 66s. No new risk mitigation measures regarding wheel flats were introduced.

94 During this investigation, evidence of *leaf mulch* and brake block debris was found at some of the locations examined south of Sampford Courtney in March 2006, particularly where the line lies in cuttings. During a subsequent visit in June 2006, in which the whole route was examined from the cab, it was noted that there was still a light residue of leaf mulch and staining of the rail head on many parts of the line. There was an abundance of overhanging trees, vegetation and fallen leaves. In some areas the vegetation forms a canopy which does not permit much sunlight and therefore the rail head tends to remain damp. The light traffic loadings also mean that any leaf mulch that does build up is not worn away quickly. Such conditions will likely lead to low adhesion levels in the leaf fall season.

<u>Operation of the train</u>

95 There were no reports of any problems on train 6F95 at any stage of the journey from either of the two drivers, shunter or the signaller at Crediton. During the journey from Meldon Quarry to Exeter on 5 January 2006, the driver reported no low adhesion problems. However, on the previous day, the same driver reported a significant amount of wheel slip. The OTMR record for 5 January 2006 shows that, whilst under power on the approach to Okehampton, the locomotive had automatically applied sand and adjusted traction power several times, in order to minimise wheel spin.

96 An estimate of the value of wheel/rail friction on the morning of 5 January 2006 was made from the OTMR record. On the approach to Okehampton, the driver had applied full power but the traction control system was matching the output power to what was sustainable at the wheel/rail interface. From this limiting traction power, the train speed and axleload, the friction coefficient was estimated to have been as low as 0.06-0.07. Whilst the OTMR only provides a record of wheel slip activity on the locomotive, it does indicate that the wagons, particularly those at the front of the train, would also have seen low adhesion conditions. Wagons further down the train usually benefit from rail head conditioning provided by the wheels of the first few wagons as they break through or wear away some of the leaf mulch.

97 It was noted from the OTMR record that the second driver on 5 January 2006 set the brake timing on his loco to the ‘passenger’ setting although the wagons were set to ‘goods’ timings. In ‘passenger’ mode the brake release time of the locomotive should be 9-12 seconds (in accordance with GM/RT2045), which is faster than the release times on the wagons in ‘goods’ timings (30-45 seconds). These settings were maintained on the return trip to Exeter where the locomotive brake timings were changed back to ‘goods’ setting by the third driver before he took the train on to Hinksey. This mismatch of brake timings is not approved practice by FLHH and can potentially lead to snatching between the locomotive and the wagons and brake drag on the wagons.

98 The second driver generally adhered to the speed limit of 40 mph (64 km/h) on the journey from Meldon Quarry to Coleford Junction, with two excursions up to 45 mph (72 km/h). Between Coleford junction and Crediton, the 20 mph (32 km/h) restriction (paragraph 30) was exceeded by 10 mph (16 km/h), except for the short 10 mph (16 km/h) stretch, which was complied with.

99 The OTMR record showed the second driver had made a series of brake applications as he controlled the train speed against the falling gradient. The driver made six brake applications during the 3 mile (4.8 km) journey from Meldon Quarry to Okehampton, covering a distance of approximately 0.9 miles (1.4 km) under braking. A further 20 brake applications were made during the 17 mile (27 km) journey between Okehampton and Crediton covering approximately 2.5 miles (4 km). The longest brake application during the journey covered 0.38 mile (0.6 km).

100 The driver's throttle applications generally occurred after the train brakes were fully released but there was one instance, at Okehampton ground frame, where power was applied from rest and the train started to move 22 seconds after brake release was demanded by the driver, with the attendant danger of creating wheel flats as explained later in paragraph 137.

101 The driver who took the train from Meldon to Exeter on 5 January 2006 entered service in 1987, joined FLHH in 2003 and was last assessed in April 2005. He was also the driver between Meldon and Exeter when the wheel flats of 4 January 2006 and 8 December 2005 occurred (paragraphs 106 & 107). Apart from these incidents, neither he nor the other driver who took the train from Exeter to Hinksey on 5 January 2006, have been involved with any previous safety incidents.

102 The steep gradients and low adhesion conditions on the Meldon branch require a careful driving technique to minimise brake use and the risk of wheel flats. Although the majority of the line is prone to low adhesion conditions, some areas are more suitable for braking than others.

103 Since commencement of the quarry train operations in April 2005, no specific driving technique for this service has been developed. FLHH undertake normal route learning procedures and provide an autumn safety briefing on poor rail head conditions for the eight drivers who are signed for that route. The drivers use their route knowledge to cope with the prevailing conditions. At the time of the incident, no regular monitoring of driving style or technique, by means of OTMR downloads, was carried out by FLHH for the Meldon line operations.

104 DRC and First Great Western carry out driver training exercises on the line for 6 weeks per year to optimise driving technique and avoid wheel flat problems. Although the majority of their journeys are made outside of the leaf fall season, DRC report there has been only one incident of a serious wheel flat to their knowledge on their rolling stock. Additionally DRC report they are not aware of any incidents of flats on First Great Western stock or their predecessors, Wessex trains, since circa 1997.

Previous occurrences of a similar character

105 Prior to the incident of 5 January 2006, there were four other wheel flat incidents involving 'Falcon' wagons operating from Meldon Quarry through to Hinksey during the winter of 2005/2006. In addition there have been a further five incidents going back as far as 1999, involving other types of wagons, which also originated at Meldon Quarry. These incidents are summarised in the following paragraphs.

Incidents involving JNA NLU wagons originating from Meldon Quarry

106 On 4 January 2006, the driver of train 6F95, comprising 15 loaded wagons hauled by Class 66 locomotive 66546 heard the sound of wheel flats as he approached Exeter from Meldon Quarry. A check revealed that wagon NLU 29166, the first wagon in the rake, had flats 180–190 mm long on the leading axle of the trailing bogie. The defective wagon was detached from the formation and the remainder of the train continued up to Hinksey.

107 On 8 December 2005, the signaller at Crediton heard wheel flats on wagon NLU 29130, the 4th wagon of loaded train 6F95 being hauled by a Class 66 locomotive. The leading axle of the leading bogie was found to have 120 mm flats.

108 On 24 November 2005, train 6F95, comprising 15 loaded wagons hauled by locomotive 66610 activated a level 2 alarm (paragraph 84) at Cholsey 'wheelchex'. Subsequent examination revealed 2 flats on each wheel of the leading wheelset on wagon NLU 29350, 50 mm and 70 mm long on the left wheel and 60 mm and 90 mm on the right wheel. The affected vehicle was the second wagon in the train from Meldon to Exeter.

Incidents involving other wagons originating from Meldon Quarry

109 In November 2004 an 'autoballaster' wagon, NLU 380222, was found at St Blazey with wheel flats after a trip from Meldon Quarry. The position of the wagon in the train is not known.

110 In September 2001, a JUA type 100 tonne bogied wagon, being hauled by a Class 66 locomotive, developed 200 mm long flats between Okehampton and Crediton. Its position in the train is not known.

111 On 3 December 1999, a 2 axle MEA 46 tonne box wagon 391234 from train 6Z81, hauled by a Class 66 locomotive, was stopped at Exeter having been found to have a 265 mm flat on each wheel of the trailing wheelset. Evidence was also found of smaller flats on the same wheels. This wagon was the first behind the locomotive and had caused three rail breaks due to the severe impact loading from its flatted wheels.

112 On 24 November 1999, another MEA wagon, 391267, which formed part of train 6Z81 and was being hauled by a Class 66 locomotive travelling from Meldon Quarry to Newton Abbot, was also stopped at Exeter and found to have a 235 mm flat on each wheel of the trailing wheelset. This wagon was also the first in the rake but no rail breaks were attributed to it.

113 A subsequent formal investigation into the incidents of 24 November and 3 December 1999 attributed the flats to handbrakes which were left on during train preparation at Meldon and then subsequently released at North Tawton by the shunter. However, it was generally acknowledged that there was a lack of clarity about exactly how the flats were formed.

114 On 8 November 1999, a class 66 locomotive from train 6Z81, Meldon to Hackney, had to be stopped for tyre turning due to wheel flats developed on the return trip from Meldon.

115 In all the above incidents, where the position of the affected wagon is known, it is invariably among the first four vehicles behind the locomotive.

Analysis

Summary of the causal chain

116 A summary of the causal chain is shown in Figure 8. Working downwards from the incident, each box contains the reason why the preceding event occurred or is considered to have occurred.

117 The reasoning behind the identified causal chain is explained in the following paragraphs.

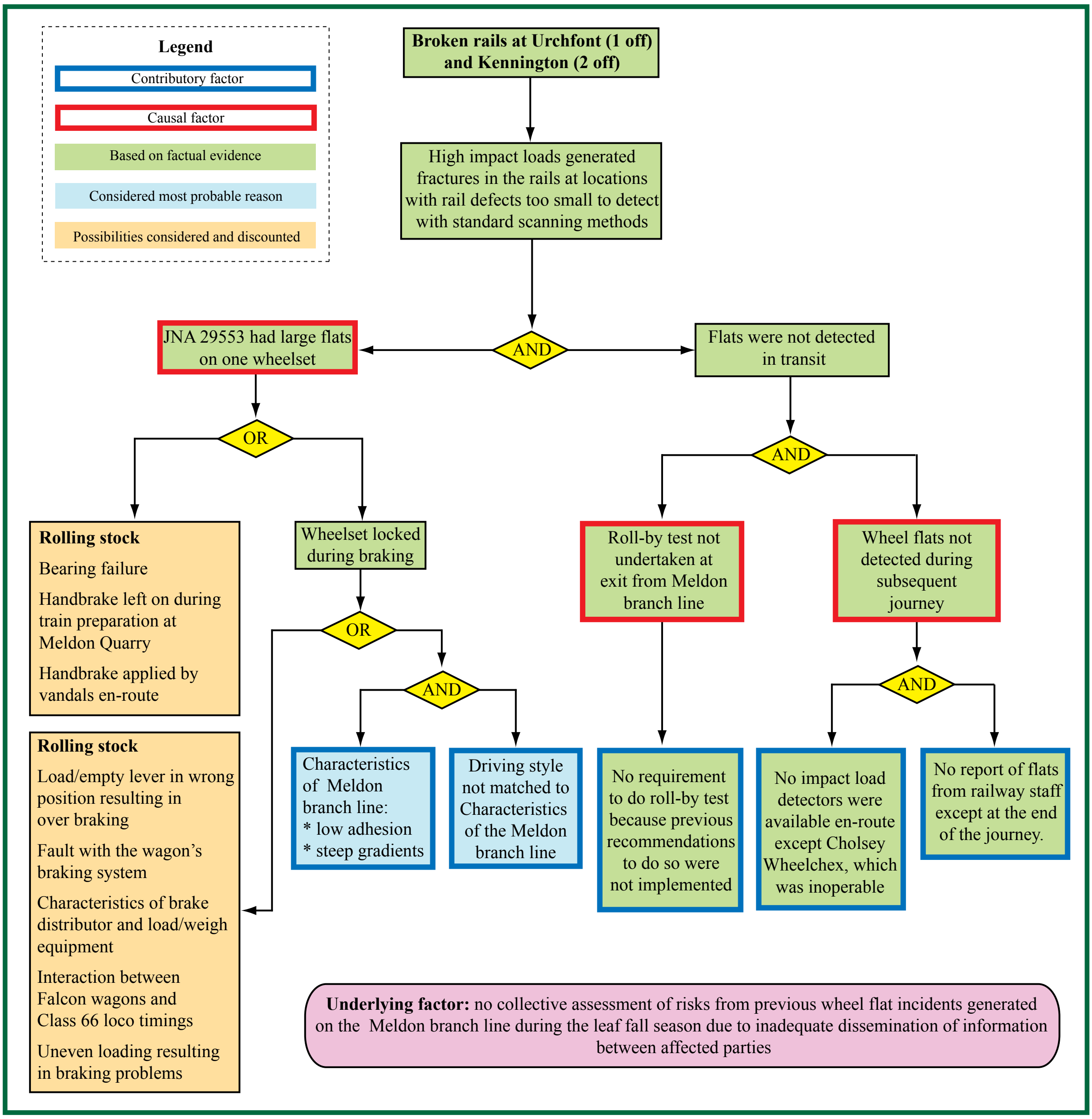

Figure 8: Summary of causal chain

Identification of the immediate cause

118 The immediate cause of the broken rails at Urchfont and Kennington was mechanical overload by forces acting in the vertical direction. This was revealed by the metallurgical examination of the broken rails (paragraphs 73-75).

119 Small pre-existing defects were also found at the fracture points but these were below the threshold of detectability for rail flaws using standard equipment and not of sufficient size to cause failure except under exceptional vertical impact loading.

Identification of causal and contributory factors

The cause of the high impact loads

120 There was no evidence of rail head irregularities which could have caused high impact loads under the normal passage of a train. The track quality data at both Urchfont and Kennington was within tolerance when the track was measured on 16 December 2005, indicating that it was unlikely the rail breaks resulted from a track fault.

121 Train 6F95 was the last train to pass through the site of the rail breaks before track circuit failures were noticed at Urchfont and Kennington, indicating that it was this train which had caused the rail breaks.

122 Examination of train 6F95, following its arrival at Hinksey yard, located 2 miles from the site of the rail breaks at Kennington, revealed large wheel flats measuring approximately 120 mm on both wheels of the third axle on wagon NLU 29553. However, their depth of 7-8 mm indicated that these flats had been longer at 160-170 mm earlier in the journey. The depth of these flats was significantly greater than those found on a Class 47 locomotive wheel in April 1999, which broke rails at seven locations (paragraph 77). Therefore it is not surprising, given the similar axleloads, that the flats on wagon NLU 29553 could have generated impact loads severe enough to have caused rail breaks at locations where small pre-existing defects existed. Therefore, the wheel flats are a causal factor.

The cause of the wheel flats

123 Wheel flats are caused when a wheel skids on the rail head. A wagon wheel will skid if the resistance to rotation either from applied brakes or a seized wheel bearing or mechanical wheel damage cannot be overcome by the driving frictional force between the wheel and rail.

124 Considering paragraphs 59, 68, 106-114, it is most likely that the wheel flats were developed on the Meldon branch line. A number of possible causes were considered:

- a fault with wagon NLU 29553 which gave rise to the locked wheels;
- low adhesion conditions on the Meldon line, combined with the driving style adopted on the day of the incident, leading to increased risk of generating wheel flats;
- uneven loading of the wagons.

Each of these possibilities is discussed in the following paragraphs.

Fault with wagon NLU 29553

125 Post-incident examination and testing of wagon NLU 29553 confirmed that the wheel bearing on axle 3 had not seized (paragraph 61) and that the air brake system was functioning correctly (paragraphs 62 & 63). Additionally wagon NLU 29553 had not had any reported braking problems over the 12 months before the incident (paragraph 69). Therefore, the possibilities of a seized wheel bearing or fault with the airbrake system causing the brake blocks to stick on axle 3 were discounted.

126 The handbrake interlock on the ‘Falcon’ wagons (paragraph 64) was found to be working correctly in the post incident tests and therefore the possibility of the handbrake being left on, either during train preparation or subsequently as a deliberate act of vandalism, was discounted. Had the handbrake being left on, the driver would not have been able to release the train brakes at the start of the journey.

127 The ‘Falcon’ wagons have an automatic load-weigh system which senses the amount of payload by monitoring the displacement of each bogie suspension and adjusts the pressure exerted by the brake blocks onto the wheels to suit. Therefore unlike some wagons, the ‘Falcon’ wagons cannot be over-braked by having an empty wagon with the brake system set to apply brake forces suited to the laden condition. Separate tests of the load-weigh system on wagon NLU 29553, confirmed that it was functioning correctly and therefore a malfunction of this system is discounted as a causal factor.

128 There have been no wheel flat problems with Class 66 locomotives hauling ‘Falcon’ wagons on other parts of the rail network. Additionally, extensive running brake tests on wagon NLU 29553 and review of the design of the braking system produced no evidence of a fault.

129 For the above reasons a fault with the braking system on wagon NLU 29553, due either to a design flaw or incorrect maintenance, was discounted.

130 In the previous occurrences of wheelflats on the Meldon Quarry line, the affected wheelset is always within the first four vehicles behind the locomotive and in most cases only one wheelset develops flats. Conditioning of the rail head by the locomotive and leading wagons is one factor which could explain why wagons further back in the train are unaffected. However, no explanation was found in this investigation as to why only one wheelset was affected. Factors such as uneven axle load, brake block forces, and weight transfer during braking were considered but do not fit the evidence.

Low adhesion conditions and driving style

131 The Meldon branch line has a long history of low adhesion conditions as explained in paragraph 91. Although the second driver did not report wheel slip problems on the ascent to Meldon Quarry on the early morning of 5 January 2006, the evidence of frequent sanding and low wheel/rail friction (paragraph 96) obtained from the OTMR data confirmed that rail conditions had been poor.

132 Therefore, it is very likely that train 6F95 also experienced low adhesion conditions (wheel/rail friction coefficients well below 0.1), during the descent, approximately 2.5 hours later, at least along some sections of the route. The wagon’s braking system is designed for a nominal friction coefficient of 0.28 and therefore, it is likely that even the relatively light brake applications made could have caused the wheelsets to lock. The low adhesion conditions were a contributory factor to the formation of the wheel flats.

133 The number and duration of the brake applications were greater on the descent than the ascent as would be expected and therefore it is more likely the flats were created on the journey back from the Quarry. Wheel flats of about 40 mm length can form in a matter of seconds even at half the axleload of wagon NLU 29553 (paragraph 80) and once formed there is scope for them to continue to grow as explained in paragraph 81. There was sufficient running distance between Meldon Quarry and Exeter for large flats to form as has been confirmed by previous incidents (paragraphs 106, 107).

134 The second driver maintained the train speed at 40 – 45 mph (64 – 72 km/h), slightly exceeding the 40 mph (64 km/h) line speed, against the steep falling gradient, possibly to try and recover some of the delay to the train, since 6F95 was running 50 minutes late on departure from Meldon Quarry. Between Coleford Junction and Crediton, he later drove through a 20 mph (32 km/h) speed restriction at 30 mph (48 km/h).

135 Drivers working the Meldon line are briefed on poor railhead conditions as part of their autumn safety brief. Beyond this there are no special instructions on how to drive the Meldon line to minimise the risk of wheel flats. The driving style shown by the OTMR data for 5 January 2006 was quite different to that adopted during the cab ride taken by the RAIB on 22 June 2006. Despite this journey being outside the leaf fall season, there was still some evidence of leaf mulch residue on the rail head and a more defensive driving style was used, with very gentle brake applications and no attempt to accelerate to and maintain the 40 mph (64 km/h) line speed over the first part of the journey. This journey, which included a stop of approximately 15 minutes at Okehampton station, took 25 minutes longer than the booked train timings for train 6F95 on 5 January 2006. Therefore, easing the booked train timings may help to reduce the risk of developing wheel flats and should be considered.

136 The driving style adopted on 5 January 2006, between Meldon Quarry and Exeter, was not suited to the special characteristics of the Meldon branch line at that time and is likely to have been a contributory factor in generating the wheel flats.

137 Where there is a mismatch in brake timings (refer paragraph 97), there is a danger that if the driver releases the train brake and applies power before the brakes have come off all the wagons, this could potentially lead to wheel flats because the wagon brakes at the back of the train would release later than those at the front. However, if this had happened on 5 January 2006, it is likely that several wheelsets towards the back of the train would have been affected; but this was not the case.

Wagon loading

138 If the load in each wagon is uniformly distributed, the output signal from the load/weigh sensing valves should be similar giving similar brake forces on each bogie. Even if the output from the load-weigh valves was not similar, giving rise to different brake cylinder pressures, it would be expected that a whole bogie would suffer flats, not just one wheelset. Therefore uneven loading was discounted as a factor.

The lack of detection of the flats on wagon NLU 29553

139 Once a train has been prepared, any faults which emerge subsequently are usually detected by:

- roll-by tests at the point of departure;
- automatic infrastructure mounted detectors;
- general vigilance of staff on duty around railway premises who may spot problems on passing trains.

140 The wheel flats on wagon NLU 29553 were not detected between Meldon and Hinksey Yard until after the rails had broken. No roll-by tests were undertaken at the exit from the Meldon branch line at Coleford Junction (such tests were not mandated at the time) and the wheel flats were not detected during the subsequent journey to Hinksey Yard. Both of these are considered causal factors.

Roll-by tests

141 Train preparation and departure instructions for Meldon Quarry sidings are contained in a joint method of working which involves one person each from FLHH, Dartmoor Railway and the Quarry company. This document does not specifically require any of the three people involved in the operation to carry out a roll-by test on departure or at any time along the journey.

142 If a wheelset had flats and was rotating on departure there would be two opportunities to detect the tell-tale hammer blow sound each revolution, as the train pulled up to and passed the ground frames at Meldon and Okehampton. However, in the absence of a prescribed roll-by test at the time of the incident, if a wheelset had a flat but was not rotating, it is quite possible that this would not have been picked up since staff were not specifically required to ensure that all wheels were rotating.

143 If a wheelset developed flats between Okehampton and Coleford Junction, a distance of 13.5 miles (21.6 km), the only possibility of it being detected would be if the driver or signaller at Crediton or other personnel heard the banging sound made by wheelflats.

144 The Railtrack formal investigation into the 1999 incidents of broken rails and wheelflats between Crediton and Cowley Bridge Junction recommended an examination of the vehicles at Coleford junction prior to entry onto Network Rail infrastructure. Had this recommendation been implemented into formal route documentation, such as the Sectional Appendix, roll-by tests would have been undertaken by the current operator and it is very likely that any wheel flats created between Meldon and Coleford Junction on 5 January 2006 would have been detected. Therefore not implementing the recommendation from the previous formal investigation is considered a contributory factor.

145 To prevent future recurrence, a roll-by test should be instigated, for Exeter bound quarry trains, at Coleford Junction. Account should be taken of the recommendations from a previous RAIB report (Appendix C - Reference 5) regarding supervision of roll-by tests and improving visibility of the rotation of wheels.

Automatic infrastructure mounted detectors

146 On the route taken by train 6F95 on 5 January 2006, there was only one ‘wheelchex’ site at Cholsey, located approximately 13 miles (20.8 km) south of Kennington. The detector had been inoperable since 2 December 2005 for ballast cleaning and relaying work and therefore on the day of the incident, it was not able to provide any warning of the defective vehicle.

147 Had it been operational, the large flat on wagon NLU 29553 should have set off an alarm at the remote reporting location and the signaller would have been alerted. He would then take action depending on the severity of the exceedance. In this case, the signaller would most likely have brought the train to a stand and instructed the driver to proceed at 5 mph (8 km/h). The time taken from first detection to stopping the train, would take approximately 10 minutes. In this time a train travelling at 60 mph (96 km/h) would cover 10 miles (16 km). Therefore, had the Cholsey 'wheelchex' been operational, the broken rails at Kennington, located 13 miles (20.8 km) further down the line, may have been averted. The inoperable status of Cholsey 'Wheelchex' is a contributory factor to the rail breaks at Kennington.

148 The number and availability of wheel impact load detectors ('wheelchex') sites on the network affects the risk from vehicles running in traffic with severe wheel flats. The Berks and Hants line is a key freight route in the UK but does not have any detectors and this incident has highlighted a degree of vulnerability to broken rails on that route. Additionally, a brief review of 'wheelchex' system availability across the UK, during this investigation, indicated that it can vary significantly from month to month (paragraph 89). The risk associated with the lack of detectors on the Berks and Hants line and the operational availability of existing systems should be reviewed to determine if it is acceptable.

General vigilance of railway staff

149 Flatted wheels make a loud banging sound once per revolution as they rotate. Railway staff are usually familiar with this distinctive sound and would normally assist with detection, if they are within earshot as the train passes, by contacting the signaller.

150 On this occasion, despite the time of the journey (11:40 hrs to 17:22 hrs), when railway staff are at their daytime stations, the only report of a defect on train 6F95 was made by an off-duty signaller who lived near Oxford signal box. He reported that train 6F95 was making an abnormal sound as it passed his property near the signal box. By this time, train 6F95 was close to its destination at Hinksey Yard. This could be because at the times the train passed manned stations en route, the wheelset was skidding and therefore not making a significant sound. However, it is clear from the broken rails and the readings of the HWD at Urchfont that, at least for some portions of the journey, the flatted wheels were rotating.

Underlying factors

151 Knowledge of the previous wheel flat incidents had not been immediately disseminated between all the parties currently involved in the Meldon quarry train operations. For instance, DRC state they were not made aware of any wheel flat occurrences since November 2001. They only became aware of the 5 January 2006 incident during a routine liaison meeting with Network Rail on 9 January 2006. FLHH state they were not made aware of the previous problems on the line when they started the quarry train operations in April 2005.

152 A previous recommendation from a Railtrack formal investigation into the wheel flat incidents and resulting broken rails of 1999, was that communications and incident reporting arrangements between involved parties should be 'reviewed with a view to ensuring that future communications are robust'.

153 It is clear that had there been arrangements for 'robust' communication between parties as previously recommended, the first flats of 24 November and 8 December 2005 would have alerted duty holders and should have led to investigation and an urgent review of risks and suitable mitigation measures. These did not happen. The lack of communication and co-ordination between relevant parties is therefore considered an underlying factor which contributed to the incident of 5 January 2006.

Conclusions

Immediate cause

154 The immediate cause of the broken rails at Urchfont and Kennington was mechanical overload resulting from the high vertical impact loads imposed on the running rails by train 6F95 as it passed those locations on the journey from Meldon Quarry.

Causal and contributory factors

155 The first causal factor was that wagon NLU 29553 had developed large wheel flats on both wheels of its third axle which generated high vertical impact loads, sufficient to cause complete fracture of the three rails, each of which had small, normally occurring, pre-existing manufacturing defects. These would not have caused failure under normal traffic loading. Contributory factors which are likely to have led to the formation of the wheel flats were:

- Low rail head adhesion conditions on the Meldon branch line, which increased the risk of wheelsets locking up under braking and generating flats on their running surfaces (Recommendation 1).
- The style of driving train 6F95, which would not normally have caused wheel flat problems, was not matched to the specific characteristics of the Meldon branch line, given the low adhesion conditions at the time of the incident and the prolonged steep downhill gradients (Recommendation 2).

156 The second causal factor is that a roll-by test was not undertaken at the exit from the Meldon Branch line, where the flats were most likely to have been created. The likely contributory factor which led to this was:

- A Railtrack formal investigation recommendation for a roll-by test at Coleford Junction, issued in November 2000 to the quarry train operator at that time, following a previous wheel flat incident in December 1999, had not been implemented into the Sectional Appendix for the route, nor made known to the current operators of these quarry trains (Recommendations 3 & 4).

157 The third causal factor was that the wheel flats were not detected during the subsequent journey from Coleford Junction to Hinksey Yard. Likely contributory factors which led to this were:

- There was only one automatic wheel impact load detector system on the route taken by train 6F95, at Cholsey, near the train's final destination and that system was not in operation at the time of the incident due to ballast cleaning and relaying work in that area. Had it been, it may have prevented the rail failures at Kennington but not at Urchfont (Recommendation 5).
- There were no reports of flats on that train, either from the driver or from railway staff, except for one report by an off-duty signaller at the end of the journey.

Underlying factor

158 Despite the history of wheel flat problems on the Meldon branch line, involving a variety of wagon types and a spate of 3 incidents within the two months prior to the incident, the knowledge of these had not been adequately disseminated between the different parties involved in the Meldon quarry train operations. This led to no collective assessment of the risk from the flats and no mitigation (Recommendation 6).

Additional observations

159 The OTMR data from the incident of 5 January showed that the driver for the Meldon – Exeter leg of the journey had set the locomotive brake timing to 'passenger' mode although the wagons were set to 'goods' mode, a practice which is not allowed by the operator. Although this is not considered to be causal, nor could it be ascertained that it could have been contributory to the incident, it is not good practice and emphasises the need for regular driver monitoring.

Actions already taken or in progress that affect this report

160 In April 2006, FLHH issued instructions, by means of an operating notice, to its Bristol based drivers and ground staff for roll-by rotational tests to be undertaken to check for wheel flats on trains to and from Meldon Quarry. Trains from Meldon Quarry must be examined at Coleford junction and the results of this test must be notified to the signaller at Crediton. Trains to Meldon Quarry must be examined at Exeter to ensure flats are detected before they travel to Meldon Quarry.

161 Network Rail have amended the Sectional Appendix to include a requirement for a roll-by test at Coleford Junction.

162 Network Rail have carried out tests with new brake blocks aimed at providing softer braking on NLU wagons. This development, which was planned before the broken rails at Urchfont and Kennington, is not for the purpose of reducing the risk of wheel flat development. However, the more gentle braking provided by the new blocks may also reduce the risk of wheel flats.

163 FLHH have instigated regular monitoring of OTMR downloads at their Bristol Depot as part of their company policy of driver assessment. Prior to the incident, FLHH did not have the requisite software installed at Bristol to enable this.

164 Dartmoor Railway have plans to undertake a number of measures to improve rail head adhesion on the Meldon branch line:

- rail head treatment using 'sandite' delivered by one of their modified vehicles, during the leaf fall season along the length of the line as necessary;
- to complete rail grinding, already started along the branch line in collaboration with Network Rail, to remove leaf mulch and surface pitting from the rail head; and
- accelerating vegetation management carried out on the line, in particular reducing the amount of overhanging branches, subject to securing the necessary funding.

Recommendations

165 The following safety recommendations are made[1].

1. DRC should develop and implement measures to improve the rail head condition on the Meldon Quarry line with the aim of minimising occurrences of wheel flats (paragraph 155).

2. FLHH should develop driving instructions specifically for the current quarry train operations on the Meldon branch line, with the aim of minimising the risk of wheel flats. Those instructions should take into account the measures resulting from the implementation of Recommendation 1 and include consideration of changes to the working timetable and permissible line speeds. All drivers signed for the Meldon branch line should be briefed on the instructions, including the appropriate setting for locomotive brake timings, and monitored accordingly (eg by using OTMR downloads) to ensure compliance (paragraph 155).

3. FLHH should ensure that all trains from Meldon Quarry are examined in a roll-by test to a robust approved procedure at Coleford Junction. To maximise the integrity of the roll-by tests, consideration should also be given to:
   - setting up a system of regular checks to ensure the test is being performed in accordance with procedures;
   - enhancing the visibility of rotating wheels to aid inspection (eg paint marks on the wheel rims).

   (paragraph 156)

4. Network Rail should ensure that the requirement for a roll-by test at Coleford Junction is recorded in formal operational documentation, such as the Sectional Appendix, so that the practice will always remain, irrespective of the operator of the quarry trains (paragraph 156).

5. Network Rail should assess the risks associated with:
   - not having any wheel impact load detectors on the Berks and Hants line and;
   - the current levels of operational unavailability of existing wheel impact load detector sites across the network;

   and determine whether they are as low as reasonably practicable. Where necessary, measures to address any identified shortcomings should then be implemented.

   (paragraph 157)

continued

[1] Responsibilities in regard 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 http://www.raib.gov.uk

6. Network Rail, FLHH and DRC should set up a joint system for alerting each other in the event of future wheel flat incidents on the Meldon branch line so that:

- relevant evidence collection and investigation can be undertaken quickly to ensure safety lessons are learned;
- existing mitigation measures are reviewed, and enhanced if necessary, to minimise the risk from broken rails on the wider network.

(paragraph 158)

Appendices

Glossary of abbreviations and acronyms — Appendix A

DRC	Dartmoor Railway Company
FLHH	Freightliner Heavy Haul
HABD	Hot Axlebox Detector
HWD	Hot Wheel Detector
OTMR	On-Train Monitoring Recorder
PPM	Planned Preventative Maintenance
VIBT	Vehicle Inspection and Brake Test
WSP	Wheel Slide Protection

Glossary of Terms **Appendix B**

Bi-directional line	Lines which are fully signalled to take trains in both directions.
Brake overcharge	An excess charging of the train brake system, when a locomotive is coupled up to a train in order to remove any pressure memory in the brake control gear left from the previous locomotive and prevent dragging brakes.
Brake test	A test which is performed when a locomotive is coupled up to a train, to ensure that the train brakes are working correctly.
Brake timings	The brake application and release timings which can usually be set to either 'passenger' or 'goods', the latter being slower in response.
Down (line)	Track with a normal direction of travel away from London (generally).
'Goods' timings	(see 'Brake timings').
Ground frames	A local control facility for operating points.
Hot axlebox detector	Infrastructure based devices which detect excess heat from axle bearings which may be symptomatic of a developing fault.
Hot wheel detector	An infrastructure based device which detects the heat signature from dragging wheels or brakes which may be symptomatic of a handbrake left on or brake fault.
JNA NLU 'Falcon' (wagon)	A bogied open freight wagon, owned by Network Rail, used to transport ballast to engineering work sites and ballast spoil from work sites.
Leaf fall season	The period, traditionally taken as being from 1 October to 31 December each year when leaves from lineside vegetation fall onto or near the line. In the winter of 2005/2006 the effects of this period were prolonged into early January 2006.
Leaf mulch	The residue formed on the rail head when leaves from lineside vegetation fall onto the running rails and are crushed by rail wheels, often reducing the available wheel/rail friction.
Low adhesion conditions	Conditions of low wheel/rail friction, caused by rail head contamination such as leaf mulch during the leaf fall season.
On Train Monitoring Recorder (OTMR)	On train monitoring recorder which captures and logs critical parameters of a train's journey, such as speed and use of train controls.
'Passenger' timing	(see 'Brake timings').
Ran light	Term used to describe a locomotive running on its own, ie not hauling any rolling stock.
Roll-by test	A planned visual check that the wheels of wagons passing at slow speed are all rotating.
Run-round	The term used when a locomotive changes ends before hauling a train in the reverse direction.

Sectional Appendix	A Network Rail document containing local rules, instructions and other details for a given part of the network.
Track circuit	An electrical device using rails in an electric circuit which detects the absence of trains on a defined section of line.
Turn (re: drivers schedules)	A part of a journey made up of two or more sectors, driven by different drivers.
Up (line)	Track with a normal direction of travel towards London (generally).
'Wheelchex'	A track-mounted monitoring system designed to measure the vertical wheel loads of passing trains and flag trains causing excessive damage due to wheel flats or 'out of round' wheels.
Wheel flats	A form of wheel damage caused by the wheel skidding on the rail instead of rotating.
Wheel impact load detector	The generic term for systems, such as 'Wheelchex', which measure wheel impact loads from rail wheels.
Wheel slide protection	A vehicle mounted system which identifies when train wheels have started to slide and releases and re-applies brakes to: ● optimise braking rate to the level of adhesion available; ● condition (or clean) the rail head.

References **Appendix C**

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