Rail Accident Investigation Branch

Rail Accident Report

Boiler incident on the Kirklees Light Railway
3 July 2011

Department for Transport

Report 04/2012
March 2012

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.

Any enquiries about this publication should be sent to:

RAIB	Email: enquiries@raib.gov.uk
The Wharf	Telephone: 01332 253300
Stores Road	Fax: 01332 253301
Derby UK	Website: www.raib.gov.uk
DE21 4BA	

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

Boiler incident on the Kirklees Light Railway 3 July 2011

Contents

Summary

A steam locomotive hauling a passenger train on the Kirklees Light Railway on Sunday 3 July 2011 ran low on water in the boiler. The train crew did not take prompt action to deal with the situation and the boiler overheated, damaging the locomotive and giving rise to a risk of injury to the train crew if the overheated metal had ruptured.

The cause of the incident was that the driver did not ensure that sufficient water was put into the boiler during the journey and did not remove the fire from the locomotive when he realised the water had run low. The driver had just completed his training for driving steam locomotives. The underlying cause was that the Kirklees Light Railway's safety management system was inadequate to deal with the risks arising from operation of a steam railway.

Two recommendations have been made to the Kirklees Light Railway concerning their safety management system and operating procedures.

Introduction

Preface

1 The sole purpose of a Rail Accident Investigation Branch (RAIB) investigation is to improve railway safety by preventing future railway accidents or by mitigating their consequences.

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

Key definitions

3 All dimensions and speeds in this report are given in metric units, except speed and locations which are given in imperial units, in accordance with normal UK railway practice. Boiler pressure is given in imperial units (pounds per square inch (psi)), as this was what was shown on the locomotive pressure gauge. Where appropriate the equivalent metric value is also given.

4 The report contains abbreviations and technical terms (shown in *italics* the first time they appear in the report). These are explained in appendices A and B.

The incident

Summary of the incident

5 A steam locomotive was hauling a passenger train from Clayton West to Shelley on the Kirklees Light Railway on Sunday 3 July 2011 when the boiler water level dropped below the indicated minimum level and the minimum safe level. The driver called for assistance but the crew did not remove the fire from the firebox (a process known as *dropping the fire*) until after the *responsible officer* in charge of the railway had arrived.

6 By the time the fire was dropped the boiler water level was below the top of the firebox, and the steam pressure had fallen from its normal operating pressure of 160 – 170 psi (11 – 11.7 bar) to around 100 psi (6.9 bar). The firebox was exposed to the heat of the fire without water behind it and suffered extensive damage as a result. Had the heat-softened metal in the top of the firebox ruptured there would have been a risk of serious injury to the train crew.

7 Nobody was injured in the incident.

Context

Location

8 The incident occurred on the 15” (381 mm) gauge line between Clayton West and Shelley, near Huddersfield. The line is operated as a tourist railway and occupies the trackbed of the former standard gauge line from Clayton West Junction to Clayton West.

9 The train was running from Clayton West towards Shelley, which is close to the former Clayton West junction (figure 1). The train had just passed through Shelley Woodhouse tunnel, which is 511 yards (467 metres) long and was approaching the 3 mile post (distances are measured from Clayton West). The line climbs all the way from Clayton West to this point.

10 The train had run 3 miles (4.8 km) from the start of its journey and was ¼ mile (402 metres) from its destination at Shelley station.

Organisations involved

11 The railway is owned and operated by the Kirklees Light Railway (KLR), which is owned by Stately-Albion Ltd. The Kirklees Light Railway has some paid staff, but many of the trains are staffed by volunteers.

12 Kirklees Light Railway leases the trackbed of the line from Kirklees Council.

13 Kirklees Light Railway and Stately-Albion freely co-operated with the investigation.

Train involved

14 The train involved was the 11:40 hrs departure from Clayton West to Shelley. This was the second passenger train of the day, but was the first to be hauled by the locomotive named ‘Hawk’ (figure 2). The train consisted of five passenger coaches and there were two train crew and between 25 and 30 passengers on board.

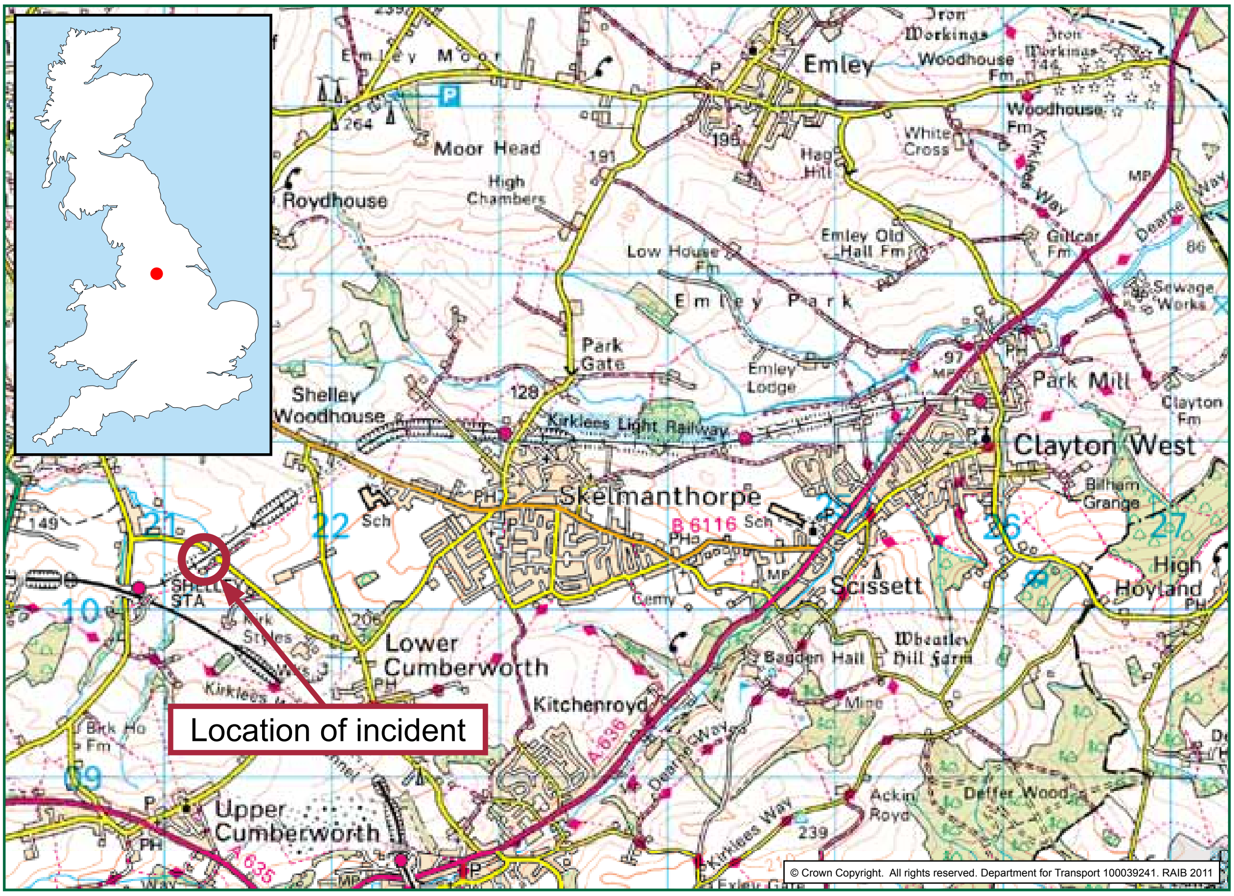

Figure 1: Extract from Ordnance Survey map showing location of incident

Figure 2: Locomotive 'Hawk' which was involved in the incident

15 The locomotive involved is a '*Kitson-Meyer*' type locomotive with two 4-wheel bogies. Each bogie is powered by a pair of cylinders which are fed with steam from the boiler. It is a *tank locomotive* and has three water tanks; one each side of the boiler at the front of the locomotive (the front tanks), and one to the rear of the cab (the back tank). The two front tanks are connected by a pipe to balance the water levels between them and function as a single tank.

16 The locomotive was built in 1997 for the railway and entered service in 1998. It is coal fired. A description of the boiler construction and operation is presented in paragraphs 36 to 43.

Staff involved

17 The train was being driven by a volunteer driver who was alone in the cab. The driver had been a volunteer at the KLR since July 2009 and had been passed as competent to be a guard by the KLR in January 2010 and to drive diesel trains in February 2010. He commenced training on steam locomotives in October 2010 and was passed as competent to drive them on 19 June 2011. The driving duty on 3 July was the second shift he had performed since being passed as competent as a steam locomotive driver, though he had previously been a volunteer in various roles (not as a driver) at other *heritage railways* and was familiar with steam locomotives, having driven his own miniature (7 ¼ inch (184 mm) gauge) locomotives.

18 The guard was also a volunteer and had started on the KLR in September 2010. He was passed as competent by the KLR as a guard on 12 February 2011.

19 The responsible officer in charge of the railway on the day of the incident was a member of the KLR's paid staff. He started on the railway as a volunteer in 1998 and became a member of the paid staff in 2008. He was passed as competent by the KLR to drive steam and diesel trains in 2000 and passed as competent in the responsible officer role in 2006.

External circumstances

20 The weather at the time of the incident was dry and sunny. The weather played no part in the incident.

Note regarding witness evidence

21 Much of the evidence supporting the events described in the next three sections is taken from a single witness account and cannot be corroborated in every respect.

Events preceding the incident

22 The locomotive had worked four trains on Saturday 2 July and had been left in steam overnight at Clayton West with the fire built up with coal, the *dampers* closed, the firebox door vent closed and a cover plate placed on the chimney. When the locomotive cleaner arrived on the morning of 3 July he thought that the fire was out and started to clean ash from the boiler tubes.

23 The driver arrived at 08:55 hrs and found that there was actually a small part of the fire that was still burning. He worked on the fire and got it burning well by the time that the train was due to depart at 11:40 hrs. The boiler pressure when the driver arrived was between 20 and 30 psi (1.4 and 2.1 bar), but had risen to the point where the safety valves operated prior to departure of the train. The safety valves operate when the boiler reaches its maximum *working pressure* which is 185 psi (12.7 bar). The locomotive moved around the station area whilst preparing for departure and the safety valves operated for part of this time, so water would have been used from the boiler.

24 During the journey from Clayton West one of the two *injectors* (paragraph 42) was operated to put water into the boiler. The injector was not used continuously, but was operated as the train approached the two intermediate stations, so as to reduce the boiler pressure and prevent steam escaping noisily from the safety valves while the train was in the station. The driver was concerned that the locomotive was not steaming as well as normal and made adjustments to the opening of the *firehole* door to get the fire to burn better.

25 On departure from the second intermediate station, Skelmanthorpe, the driver was still concerned about the rate of steaming and the way that the fire was burning. The boiler pressure was between 150 and 160 psi (10.3 and 11.0 bar), which the KLR says is normal, and the fire appeared to be burning well.

Events during the incident

26 During the journey from Skelmanthorpe to Shelley the driver became concerned about the water level in the boiler. He slowed the train down so as to concentrate on getting water into the boiler. The boiler pressure had dropped to 140 psi (9.6 bar) and the water level was by now at the bottom of the glass so the driver stopped the train. The driver thought there was a problem with the locomotive and he called the guard to the front of the train and used the KLR mobile telephone carried on the train by the guard to contact the responsible officer for advice on what to do.

27 The responsible officer talked the driver through various tests and observations in an attempt to diagnose the problem. They were unable to solve the problem during the phone call and the responsible officer said that he would come to site to assist. The driver added more coal to the fire during the phone call; it is unclear who suggested this action.

28 The responsible officer came to site in another locomotive which was stopped a short distance from the back of the train, as required by the KLR rules for a locomotive assisting a failed train. The responsible officer walked to the front of the train and saw that the locomotive was overheating, with paint on the *boiler cladding* blistering off. The water level was below the bottom of the glasses and when the responsible officer opened the *gauge glass blow down valve*, no water came out, only steam. He then decided to drop the fire.

Events following the incident

29 The driver and guard assisted the responsible officer in dropping the fire, which involved using a metal bar to lift the *firebars* which form the grate beneath the burning coal. The burning coal then fell into the ashpan where the guard and driver pulled it out onto the track. They then opened the injector steam valves to reduce the boiler pressure and hence reduce the load on the overheated metal in the firebox.

30 Once the boiler had been made safe by reducing the pressure, the responsible officer brought the assisting locomotive to the rear of the train and coupled to it.

31 The passengers remained on the train throughout the time that the boiler was being made safe. The KLR did not have a procedure to deal with boiler emergencies.

32 The train, still with the passengers on board, was brought back to Skelmanthorpe station where some of the passengers alighted to continue their journey on another train. The train was then brought back to Clayton West.

33 The locomotive was removed from the train and taken to an inspection pit where the responsible officer examined it for leaks. None were found, but the *fusible plug* (paragraph 39) in the top of the firebox had melted. The responsible officer reported that the front tanks were full and the rear tank still had a significant volume of water in it. He checked the water supply system on the locomotive and found that a valve between the *clack valve* and the boiler (figure 3) on the large injector feed pipe was only open 1 ½ turns. The operations manager stated that this valve should have been fully open (12 turns).

34 The incident was not reported to the RAIB until the following day (4 July). An RAIB inspector visited the railway on 5 July to conduct a preliminary examination of the evidence.

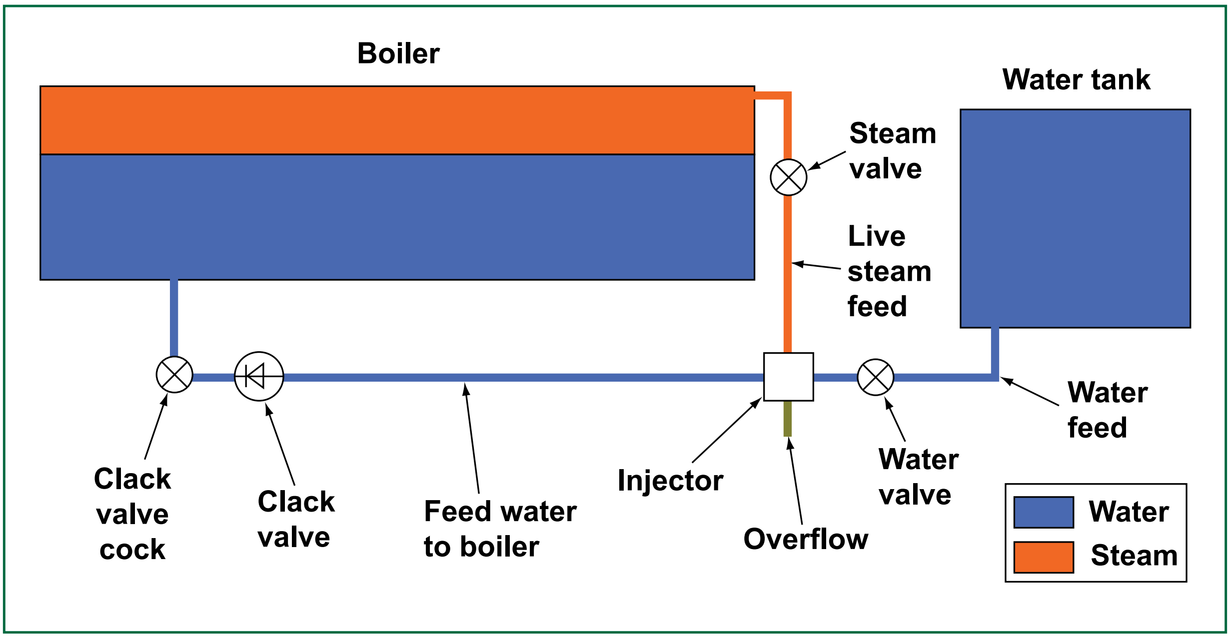

Figure 3: Schematic diagram of the water feed arrangements

The investigation

Sources of evidence

35 The following sources of evidence were used:

- witness statements;
- photographs taken after the incident;
- KLR training and personnel records;
- KLR safety management documents;
- examination and hydraulic testing of the boiler after the incident and prior to repair;
- examination of the boiler during repair;
- testing of the locomotive and reconstruction of the train's journey after repair (paragraphs 53 to 55); and
- guidance documents published by the Heritage Railway Association (HRA) (paragraph 80) and the Office of Rail Regulation (ORR).

Key facts and analysis

Background information

Steam locomotive boiler construction

36 A steam locomotive boiler consists of two main parts, the barrel and the firebox. The boiler barrel of 'Hawk' consisted of a length of 24" (610 mm) diameter tube and was manufactured in 1997. The boiler barrel contained 42 boiler tubes, which ran longitudinally from the firebox to the *smokebox* (figure 4). These tubes carry hot gas from the fire and, during its passage through the tubes, the gas gives up heat to the water.

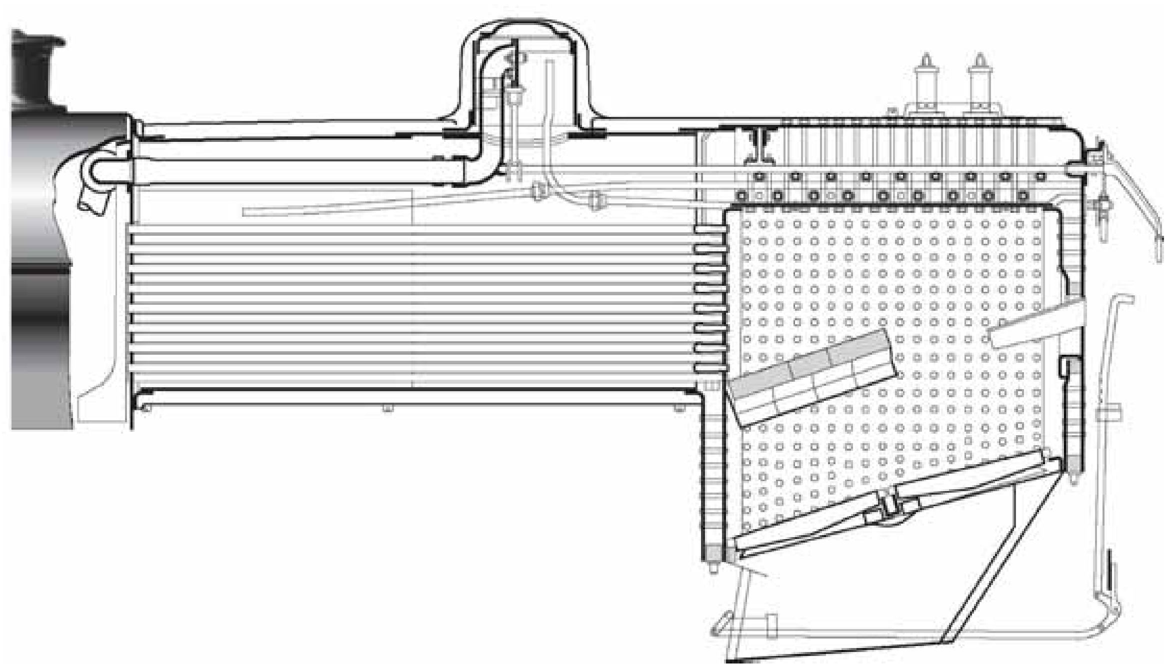

Figure 4: Diagram showing section through main line steam locomotive boiler (from ORR Railway Safety Publication 6, 'The Management of Steam Locomotive Boilers')

37 The firebox consisted of an outer casing and an inner box and was of welded steel construction. The inner box contained the fire which was supported by firebars over the ashpan. The gap between the inner and outer parts of the firebox contained water and the inner box and outer casing were connected by *stays* to resist the pressure in the boiler.

38 A pair of gauge glasses were fitted to the part of the outer firebox that projected into the cab to show the water level in the boiler (figure 5). They were arranged such that when the water level was at the bottom of the glass there was approximately 50 mm of water above the top of the firebox. This gave a safety margin between the minimum indicated level and the point at which the top of the firebox became dry.

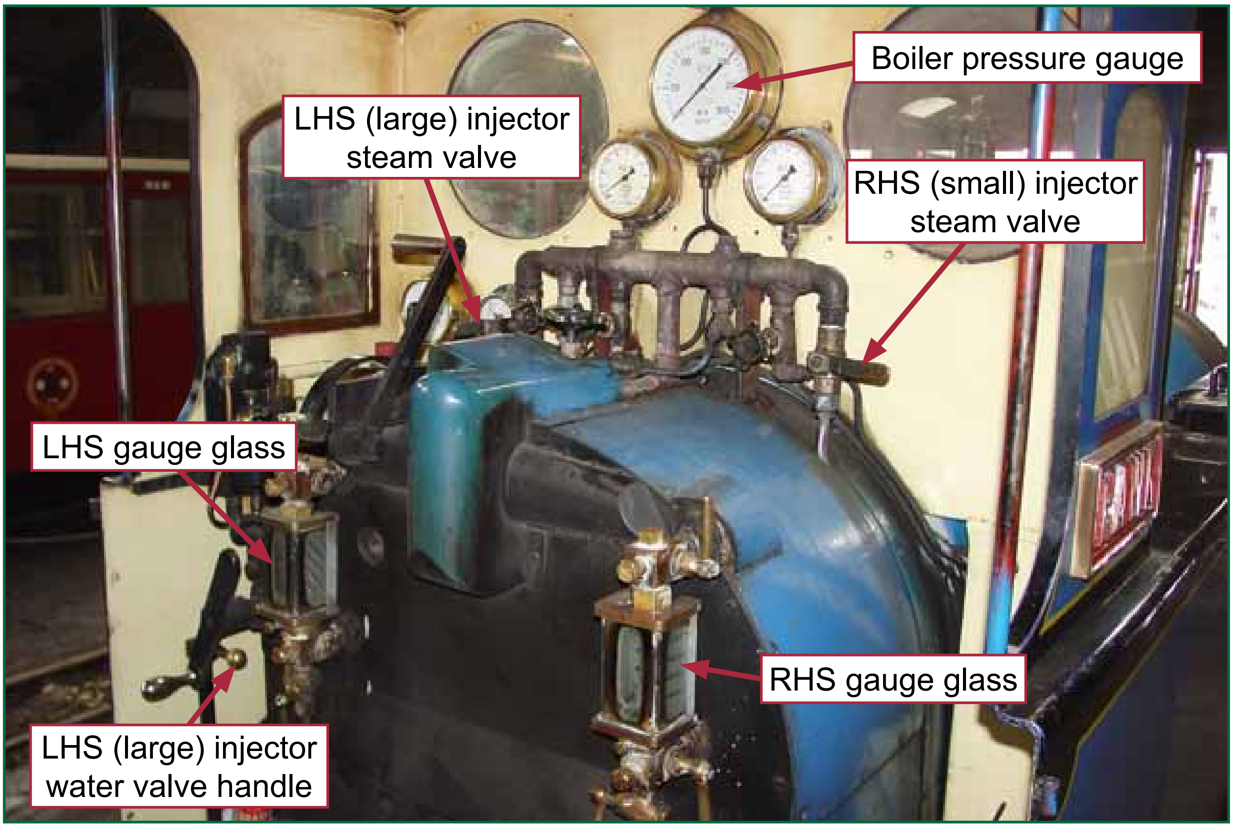

Figure 5: Cab interior showing key controls

39 A threaded boss in the inner firebox *crownsheet* was fitted with a fusible plug. A fusible plug is a hollow threaded steel plug containing a core of a low melting point metal, such as lead[1]. Its purpose is to provide a warning of overheating of the firebox crownsheet by the melting of the core of the plug and consequent release of steam into the firebox. It does not prevent the firebox overheating, but is intended to give a warning so that action can be taken by the crew to prevent further damage. The appropriate action is to drop the fire. Figure 6 shows the fusible plug that was removed from the locomotive after the incident. The location of the plug in the firebox crownsheet is indicated in figure 7. The fusible plug was manufactured by the KLR to its own design and was installed in April 2010.

40 The ORR published guidance on steam locomotive boilers, 'The Management of Steam Locomotive Boilers, Railway Safety Publication 6', in 2007. This was the latest revision of a document first published in 1986 as HS/G 29 by the Health and Safety Executive (HSE) (and that document was in turn a revision of a much earlier guidance note). This guide states that, for safety, at least two methods of determining water level in the boiler shall be provided, preferably as transparent gauges. It also states that there should be two independent means of supplying feed water to the boiler when it is under pressure. Locomotive Hawk was provided with two transparent gauge glasses and two injectors to provide feed water into the boiler. The two injectors were of differing sizes; the small one had a bore of 2.1 mm and a capacity of 7 litres/min with the boiler pressure at 160 psi (11 bar). The large injector had a bore of 3 mm and a capacity of 15 litres/min with the boiler pressure at 160 psi (11 bar).

[1] The Heritage Railway Association (HRA) published a guidance note on fusible plugs (HGR-B9008) in May 2009.

Figure 6: Fusible plug removed from 'Hawk'

Figure 7: Interior of firebox showing scorch marks and quilting of the crown (location of fusible plug arrowed)

Steam boiler operation

41 The crew of a steam locomotive must vary the rate at which fuel is added to the fire according to the rate of steam usage while at the same time ensuring that the water level is maintained. When the injectors are used to put water into the boiler, the incoming water lowers the temperature of the boiler water and hence lowers the boiler pressure. The KLR training encouraged their drivers to use this feature to prevent boiler pressure rising when stopped in stations to reduce the likelihood of the safety valves lifting, which can be noisy. However, the main purpose of the injectors is to maintain the water level in the boiler, and the KLR stated that their drivers were told to put water into the boiler whenever the level dropped regardless of where they were along the line.

42 Injectors work by taking steam at boiler pressure and combining it with cold water from the tanks in a nozzle arrangement. The steam and water combine to produce warm water at a pressure greater than the boiler pressure. This water is then fed into the boiler via a non-return valve (also known as the clack valve). The driver controls the operation of the injector by using valves in the steam and water supply pipes (figure 3).

43 The temperature of the fire can reach a level where the strength of the firebox metal would be compromised if there was no water behind to cool it. The first part of the firebox to be exposed by falling water level would be the crownsheet. If this becomes overheated, there is a risk of it failing, with the release of the boiler pressure into the firebox and ejection of the fire into the cab. This is why it is important to keep the water level above the top of the firebox.

44 The temperature at which water boils depends on its ambient pressure and, at the boiler pressure prior to dropping the fire (100 psi, 6.9 bar) water boils at 164ºC. The water in the boiler is therefore at this temperature and, if it were to be suddenly released to atmospheric pressure, at which water boils at 100ºC, the released water would turn instantly and explosively to steam.

Identification of the immediate cause[2]

45 **The supply of water to the boiler was less than the rate of usage.**

46 There is witness evidence to suggest that the locomotive started the day with the boiler and the water tanks full of water. By the time that the train was ready for departure, some of this water would have been used up due to the *blower* being used, the safety valves operating and the locomotive moving around the station preparing for departure. The locomotive was fitted with a steam driven air compressor for the braking system and this would also have used water from the boiler.

47 Following the incident the front tanks were still completely full and the back tank needed only 125 litres to fill it to overflowing. The capacity of the back tank is 325 litres.

48 The low level of the water in the boiler after the incident was evident from the damage to the tubes and firebox, as those parts exposed to the fire without water around them were scorched (figure 7).

[2] The condition, event or behaviour that directly resulted in the occurrence.

49 The locomotive had a sufficient supply of water on board, but the water in the boiler was being used at a rate which exceeded the fill rate. The possibility of leaks from the boiler or its pipework is discussed in paragraphs 57 to 59.

Identification of causal factors[3]

Management of the boiler water level

50 The water level in the boiler was allowed to fall so low that the fusible plug melted and the firebox crownsheet was damaged. This was a causal factor in this incident.

51 The possible scenarios that may have led to the water level being allowed to fall are:

- water could not be injected into the boiler at sufficient rate;
- water was leaking from the boiler or its fittings;
- the water level in the boiler was incorrectly indicated; or
- inadequate action by the driver to replenish the water in the boiler.

Each of these is discussed in turn below.

Rate of injection of water into the boiler

52 When examined by the KLR's responsible officer after the incident, the valve between the clack valve and the boiler was found to be open by only 1 ½ turns (paragraph 33). Following the incident, the RAIB tested an identical valve on another KLR locomotive and found that the injector worked with the valve open by any amount beyond ¼ turn. After locomotive Hawk's boiler had been repaired and the locomotive had been reconstructed, the RAIB conducted a test using the original large injector valve, refitted to locomotive Hawk. The test measured the rate of fill of the injector with the valve open by various amounts. The results showed that the injector started to work when open by ¼ turn and that the rate of fill was the same with the valve opened ¼ turn, 1 ½ turns and 12 turns (fully open). The limited opening of the valve on the day of the incident would therefore not have affected the rate at which the injector filled the boiler.

53 Following repair of the locomotive, the RAIB conducted a reconstruction of the incident journey. The water tanks were filled and the locomotive coupled to a train of six empty coaches. The sixth coach was added to the train to make it a similar weight to a five coach train with passengers on board. The valve between the clack valve and the boiler in the large injector pipe was set to the same position it was found in after the incident; open by 1 ½ turns. During the journey up the line from Clayton West the injectors were operated in accordance with the most likely pattern of usage during the incident journey, as determined from witness evidence. The water was drawn from the back tank, as on the incident journey. The boiler pressure and water level were recorded during the test run.

[3] Any condition, event or behaviour that was necessary for the occurrence. Avoiding or eliminating any one of these factors would have prevented it happening.

54 The train started from Clayton West with the water level at the top of the gauge glasses while the train was on level track. When the train was stopped at the site of the incident the water level in the boiler was at 1/3 of the gauge glass. The volume of water needed to refill the back tank was measured and was 125 litres. This was the same volume as was needed to refill the back tank after the incident. The RAIB have therefore concluded that the injector use during the reconstruction was similar to that on the day of the incident, and therefore that the rate of water input to the boiler was not impeded by the partly-closed valve.

55 The reconstruction run started with the gauge glasses full while the locomotive was on level track and ended with the water level at 1/3 of the glass with the locomotive on a gradient (which causes the water level at the cab end of the boiler to be higher than it would be on level track). Therefore a volume of water corresponding to over 2/3 of the difference in level represented by the whole glass was used during the run. The KLR stated that the driver would normally keep the water level towards the top of the glass. This would have required more use of the injectors.

56 For the water to have gone below the bottom of the glass on the day of the incident, either the locomotive started the journey with the water level below the top of the glass or there was leakage from the boiler during the journey.

Condition of the boiler and pipework

57 The locomotive was inspected by the responsible officer and another member of the KLR staff after the incident, looking for signs of water or steam leaks around the boiler and the pipework. None were found.

58 The RAIB witnessed a cold hydraulic test of the boiler after the incident and no leaks were found which could have caused the water level to drop during the journey. The damage to the boiler prevented a test being done at working temperature and pressure.

59 The fusible plug was found to have melted when examined after the incident (paragraph 33 and figure 6). It is possible that this plug may have been leaking before it melted completely. This would have caused a loss of water from the boiler during the journey. Any such loss of water would have caused the water level in the gauge glasses to fall, if it were not compensated for by use of the injectors.

Indications of water level in the boiler

60 It may have been possible for the driver to have been misled by the water level in the gauge glasses if they were blocked by debris.

61 The driver stated that the left-hand gauge glass was showing a lower water level than the right-hand glass before the locomotive left the shed. He did not investigate the reason for this difference. The driver and the responsible officer checked that the gauges were clear by *blowing them down* while the train was standing at the incident site. No blockages were found at that time.

62 No evidence of blockage was found after the incident. However, the trauma undergone by the boiler and its fittings during the incident may have caused any such material to have become dislodged. When examined by the RAIB after the incident, there was a small amount of boiler scale on the *foundation ring* of the firebox but this may have been loosened by the overheating.

63 The two gauge glasses are completely independent of each other, and as such, it is unlikely that both glasses would become blocked at the same time.

Actions of the driver

64 The RAIB has concluded that the injectors were operational and capable of delivering sufficient water to the boiler. It has also concluded that there was sufficient water available for the journey, and it is likely that the water level indication was correct in at least one of the gauge glasses. The only remaining credible cause of the water level being allowed to fall was that the driver did not sufficiently replenish the boiler during the journey. Since he understood the need to maintain an adequate water level, the RAIB has concluded that the driver had not observed that the level indicated in the gauge glasses had fallen and consequently did not operate the injectors for sufficient time to replenish the boiler.

65 At the time of the incident the driver was on the first trip of his second turn of duty after qualifying as a driver and therefore was relatively inexperienced with KLR's locomotives. He stated that he was concerned with the condition of the fire and this may have distracted his attention from the water level.

Reaction to the melting of the fusible plug and the low water level

66 **The driver did not drop the fire following melting of the fusible plug or the water level falling below the gauge glass lower level. This was a causal factor.**

67 Witness evidence mentioned a 'high pitched whistling sound' from the locomotive after it had stopped. This is likely to have been the sound of the fusible plug operating. The fusible plug is provided to indicate to the crew the need to drop the fire.

68 If a steam locomotive boiler runs low on water it is normal practice for the locomotive crew to drop the fire. However, the decision to do this was only made after the responsible officer had arrived at the incident site. Witness evidence was that the paint on the dome was blistering shortly after the train stopped, and was certainly blistering by the time that the responsible officer arrived. This was a sign that the water level had been below the minimum level for long enough to allow the top of the boiler to overheat.

Training and competence of drivers

69 **The KLR training scheme for steam locomotive drivers did not have a documented syllabus and did not define the competencies that a driver was required to demonstrate. In particular, the driver did not appreciate the importance of dropping the fire as soon as the water level became too low. This was a causal factor.**

70 The KLR training scheme for drivers involved driving the locomotive under the supervision and instruction of an experienced member of staff. The number of driving turns which the trainee had to complete before being assessed as competent was not defined. The operations manager and general manager jointly decided when a trainee driver had achieved the necessary competence, following observation of them working trains. The driver of the incident train had completed 20 days of driving under supervision between October 2010 and June 2011 and was assessed as competent by the operations manager and general manager on 19 June 2011. They completed a KLR 'Assessment of Competency' form which described how the driver had performed during the assessment.

71 The assessment of competency form did not contain a checklist of the competencies that a driver was expected to show. The topics to be covered during training were left to the trainer to determine and the full list of topics actually covered was not recorded.

72 The delay in dropping the fire was a factor which increased the severity of this incident. The RAIB has been unable to establish whether the importance of prompt removal of the fire when there is a problem with boiler water level was included in the driver's training. The RAIB issued urgent safety advice on this to all heritage railways on 28 July 2011. The text of the urgent safety advice is in appendix C.

73 The KLR issued an instruction on 6 July 2011 to all drivers that the fire be dropped immediately if the water level drops below the bottom of the glass.

Identification of underlying factors[4]

KLR's Safety Management System

74 **The KLR's safety management system (SMS) was incomplete and there were no risk assessments for operation of the railway and therefore no mitigation measures or details of training and competency assessment of drivers or other safety critical staff. This was the underlying factor in this incident.**

75 The KLR's SMS was dated 21 March 2007 and was issue 1. It included risk assessments in an appendix. Six risks were listed, all related to risks arising to personnel from road vehicle movements around the Clayton West station site. There were no risks listed relating to operation of the railway or the use of steam locomotives.

76 There was a risk assessment document for school party visits. This was done by the general manager and dealt with the risks arising from steam locomotive use and train operations during school visits, for example the risk of children being scalded by escaping steam or hot water during normal operation. Risk mitigations were directed at minimising the risk to school children. This document did not appear to form part of the formal SMS.

77 The section of the SMS which dealt with training only covered the induction training of new volunteers and staff. It did not cover the training of drivers, or other safety critical staff.

---

[4] Any factors associated with the overall management systems, organisational arrangements or the regulatory structure.

78 The SMS stated that it would be subject to annual audit. No such audits had been carried out but the report of a safety inspection in May 2006 (prior to this version of the SMS) was appended. This incorrectly assumed that the railway had a safety case and recommended that risk assessments should be done for all activities '*not included within the safety case assessment*'. The KLR has never held a railway safety case, and would have been granted exemption from the Railway Safety Case Regulations, 1994, had it applied for one, as railways with a maximum speed of 25 mph (40 km/h), isolated from the national network, were generally granted exemption by the HSE.

79 The Railways and Other Guided Transport Systems Regulations, 2006, (ROGS) replaced the Railway Safety Case Regulations and the ORR issued guidance on ROGS to heritage railways. The guidance restated the need for heritage railways to have a SMS. ROGS applied to main line railways from October 2006, but heritage railways were given a further two years to comply with its requirements. The ORR wrote to the KLR in November 2009 to remind it that ROGS applied to them and of the need to have a SMS.

80 Two documents of relevance to this incident are guidance notes HGA-S0001 'Risk Assessment' and HGA-S0003 'Safety Management System', published by the HRA for its members. The KLR is a member of the HRA and was aware of these documents but, although the SMS document broadly followed the template suggested by HGA-S0003, many sections of it were missing. The HRA is a trade association which publishes guidance for its members on various matters associated with operation of heritage railways. It has no audit or enforcement role with regard to its members.

81 The KLR's SMS was incomplete at the time of the incident and there were no risk assessments for the operation of steam locomotives on the railway, apart from during school visits. In particular, the KLR had no procedure for dealing with boiler emergencies (paragraph 31) and had not documented the competence requirements for drivers (paragraph 69). The KLR had recognised the need to complete its SMS and risk assessments and staff had attended an ORR seminar on the subject in October 2009, but had not prioritised the time and resources to complete this work. Witness evidence was that this work had not been completed due to time pressures from other work. The lack of consideration of the risks of steam locomotive operation arising from the KLR's incomplete SMS was the underlying factor in this incident.

Observations

82 The KLR had a 'Locomotive Daily Inspection' sheet which its drivers were required to complete and sign before commencement of the days running. This sheet consisted of a table of items to be checked, with the item description in the left column and space for the driver to record that he had checked it in the right column. The driver was required to sign that the checks had been completed. The item dealing with the injectors stated 'injector operation, including clack valves, shut offs and filters' (paragraph 52).

83 The driver of the locomotive on 3 July understood this to mean that he should check the first item, that the injectors worked, and only if this check failed should he check the other items. When he tested the injectors on the day of the incident they both worked correctly and so he did not check the other items. The locomotive daily inspection form was written by the operations manager. His intention was that drivers should check all of the items in each box. This was not made clear on the form.

Heritage railway safety management systems

84 In 12 previous investigations into accidents on heritage and minor railways the RAIB has found one or more of the following factors:

- the absence of an adequate SMS; and/or
- the management arrangements described in the SMS were not translated into the day to day operation of the railway; and/or
- an inadequate understanding of the risks associated with its assets.

Details of these investigations are included as appendix D.

85 During the course of this investigation the ORR has explained that it does not systematically check that all heritage railways have documented and implemented an appropriate SMS. This is because of the large number of such railways, over 200, and the disproportionate level of intervention this would require. However, ORR has provided guidance to the sector (paragraph 79) and delivered a series of training seminars to minor railways in conjunction with the HRA (paragraph 81). When ORR visits railways in the course of other investigations it reviews relevant aspects of the SMS and urges improvements when appropriate, and if necessary takes action to enforce improvements.

86 In the last 12 months ORR has issued eight enforcement notices on heritage railways requiring improvements to their SMS[5].

87 The ORR delivery plan for its corporate strategy during 2011-12 includes inspection of elements of the SMS of five heritage railways in addition to the reactive work, investigation and approvals.

88 The ORR has indicated to the RAIB that its delivery plan for 2012-13 will include greater emphasis on safety management on heritage railways and it will be more likely to bring prosecutions where there are serious shortcomings.

Previous occurrences of a similar character

89 There have been no recent incidents in the UK where low water in a steam locomotive has led to failure of the boiler or firebox. There have been several cases where a fusible plug has melted, but in almost all such cases the crew noticed the failure and acted promptly to drop the fire and bring the situation under control.

[5] http://www.rail-reg.gov.uk/server/show/nav.1847

90 There was an incident on the East Lancashire Railway on 25 May 2009 in which the boiler water level on a steam locomotive hauling a passenger train ran low due to problems with the injectors. One of the fusible plugs melted but the crew did not notice it. The crew got the injectors working again and the train continued its journey. It was only when the locomotive had returned to the shed at the end of the day that the failure was noticed. The incident was not reported to the RAIB at the time but was investigated by the ORR who made four recommendations to the railway. The recommendations included reminding drivers of their responsibilities for safety of the locomotive, consideration of replacement of one of the injectors with a more reliable type, reminding staff responsible for operational safety of their role and reminding locomotive crews of the need to report faults promptly. The ORR required the East Lancashire Railway to implement these recommendations within one month.

91 There was an explosion of a steam locomotive firebox on the Gettysburg Railroad in Pennsylvania, USA, on 16 June 1995 which was investigated by the US National Transportation Safety Board (special investigation report NTSB/SIR-96/05 available at http://www.ntsb.gov/doclib/safetystudies/sir9605.pdf). The explosion was caused by the failure of the firebox crownsheet due to overheating caused by the water level in the boiler getting too low. This locomotive was not equipped with a fusible plug. All three members of the locomotive crew were seriously injured. The report identified deficiencies in the maintenance of the locomotive and in the training of the railway's staff.

Summary of conclusions

Immediate cause

92 The supply of water to the boiler was less than the rate of usage (**paragraph 45**).

Factors

93 The following were causal factors:

a. The driver did not ensure that sufficient water was put into the boiler during the journey **(paragraphs 50 to 64 and 99**).

b. The driver did not drop the fire following melting of the fusible plug or as soon as the water level had fallen below the minimum (**paragraphs 66 and 99**).

c. The KLR training scheme for drivers did not emphasise the importance of immediately dropping the fire if the water level became too low (**paragraph 69 and Recommendation 1**).

d. The driver was inexperienced and may have been distracted from attending to the water level by dealing with problems with the fire (**paragraph 65 and Recommendation 1**).

Underlying factors

94 The underlying factor was that the KLR's SMS did not identify the risks arising from the operation of the railway with steam locomotives, and therefore did not include any measures to mitigate such risks (**paragraph 74 and Recommendation 1**).

Observations

95 The locomotive daily inspection check sheet, which all drivers were required to complete at the start of the day, did not make clear the full extent of the checks that the driver was required to perform (**paragraph 83 and Recommendation 3**).

96 The KLR did not have an emergency procedure to deal with boiler emergencies (**paragraph 31 and Recommendation 1**).

97 Guidance on the management of safety on heritage railways is provided by the ORR and the HRA. Furthermore, enforcement action is taken by the ORR when it becomes aware of a significant safety concern. Despite this, in 12 previous investigations into accidents on heritage railways the RAIB has identified issues with the safety management regime. This does not mean that all such railways are deficient in this respect but does suggest that the problem may apply to a significant number of railways. The ORR is planning to increase its level of supervision of heritage railways in 2012-13 (**paragraphs 84 and 100**).

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

98 The KLR has drawn up a training syllabus for steam driver, diesel driver, guard and trackside worker competencies. Written examination papers have been introduced for these roles. The new training arrangements were introduced from 31 August 2011 and one new steam driver had qualified under the revised regime at the time of publication of this report.

Actions reported that address factors which otherwise would have resulted in a RAIB recommendation

99 The KLR issued an instruction to all of its drivers shortly after the incident stating that, if the water level drops below the bottom of the gauge glasses, the fire should be dropped immediately.

100 The ORR has indicated to the RAIB that it recognises that there are issues with the establishment and operation of SMSs in some heritage railways. The ORR is planning to make available an increased resource for the oversight of safety, and take enforcement action where serious shortcomings are exposed, on heritage and other minor railways. This additional resource will be reflected in the ORR delivery plan for its safety regulation activities in 2012-13 and will be publicised to the heritage sector at seminars jointly organised by the ORR and the HRA. Since the impact of the above actions will take time to become apparent the RAIB makes no recommendation at this stage. However, the RAIB and ORR have agreed to meet later in 2012 to review the extent to which the issues identified in this report are being addressed by the sector.

Recommendations

101 The following recommendations are made[6]:

Recommendation to address the underlying factor

1 *The purpose of this recommendation is to complete the Kirklees Light Railway Safety Management System and implement it by a defined date. This may also be applicable to other heritage railways.*

Kirklees Light Railway should, within a timescale agreed with the Office of Rail Regulation, complete and fully implement a safety management system that is comparable with good practice in the heritage sector, and relevant standards and guidance. This should include the identification of risks, determination of safety critical elements of competence and the training and assessment to deliver it (paragraph 94). The Kirklees Light Railway should confirm that the recently-introduced training syllabus and competency arrangements (paragraph 98) are consistent with this.

Recommendation to address observation

2 *The purpose of this recommendation is to make clear to staff preparing locomotives which items must always be checked and provide positive indication that they have done this.*

Kirklees Light Railway should revise its locomotive preparation checklist to make clear which items must always be checked and which are dependent on the outcome of other checks (paragraph 95).

[6] Those identified in the recommendations, have a general and ongoing obligation to comply with health and safety legislation and need to take these recommendations into account in ensuring the safety of their employees and others.

Additionally, for the purposes of regulation 12(1) of the Railways (Accident Investigation and Reporting) Regulations 2005, these recommendations are addressed to the Office of Rail Regulation to enable it to carry out its duties under regulation 12(2) to:

(a) ensure that recommendations are duly considered and where appropriate acted upon; and

(b) report back to RAIB details of any implementation measures, or the reasons why no implementation measures are being taken.

Copies of both the regulations and the accompanying guidance notes (paragraphs 167 to 171) can be found on RAIB's website www.raib.gov.uk.

Appendices

Appendix A - Glossary of abbreviations and acronyms

HRA	Heritage Railway Association
HSE	Health and Safety Executive
KLR	Kirklees Light Railway
ORR	Office of Rail Regulation
psi	Pounds per square inch
ROGS	The Railways and Other Guided Transport Systems Regulations, 2006
SMS	Safety Management System

Appendix B - Glossary of terms

Blow down valve	A tap provided to allow water and steam to escape when required.
Blower	A device provided on a steam locomotive which discharges steam up the chimney so as to draw the fire.
Blowing down (gauge glasses)	The process of opening a valve at the bottom of the gauge glass so as to cause steam and water from the boiler to be ejected. This ensures that the pipes leading to the gauge are not blocked.
Boiler cladding	Thin metal sheeting surrounding a boiler which holds the thermal insulation in place.
Clack valve	A valve which only allows flow in one direction, also known as a check valve.
Crownsheet	The name given to the plate which forms the top of the firebox.
Damper	A movable flap which can be operated to restrict the flow of air to the fire.
Dropping the fire	The process of removing the fire from a steam locomotive firebox.
Firebars	Removable metal bars in the firebox which support the fire.
Firehole	The opening in the firebox through which the fire is accessed.
Foundation ring	The base on which the firebox is built which seals the lower edges of the inner and outer firebox shells.
Fusible plug	A hollow threaded metal plug containing a core of a low melting point metal, such as lead.
Gauge glass	A clear glass tube arranged to show the level of water in the boiler.
Heritage railway	A railway which is not part of the national network whose main purpose is as a tourist attraction or museum. In this report the term is also used to include minor railways.
Injector	A device used for supplying water into a boiler.
Kitson-Meyer	A type of steam locomotive which has its powered axles arranged on two bogies.
Quilting	The type of damage sustained by the crownsheet of a firebox whereby it deforms in between stays.

Responsible officer	The member of KLR management who is in charge on a particular day. The individual must have been previously assessed by the KLR as competent to perform the role.
Smokebox	The part of a steam locomotive at the front of the boiler where the exhaust steam is combined with the exhaust gases from the fire before being ejected through the chimney.
Stay	A metal bar within the water space of a boiler to assist the boiler plates to withstand the internal pressure.
Tank locomotive	A type of steam locomotive where the water needed is carried on the locomotive itself, rather than in a separate vehicle.
Working pressure	The maximum pressure that a boiler is designed to work at. Safety valves are provided to prevent the pressure exceeding this value.

Appendix C - Urgent Safety Advice

1. Incident Description	
Incident Name	Kirklees Light Railway boiler incident
Type of Incident	Boiler of steam locomotive ran very low on water
Incident Description	At 12:09 hrs on 3 July 2011 the second passenger train of the day on the 15 inch gauge Kirklees Light Railway stopped a short distance from the terminus with low boiler water level. The injectors were unable to maintain boiler water level, likely as a consequence of a nearly closed valve between one of the injectors and the boiler. The level dropped below the bottom of the gauge glasses and the fusible plug melted. The train crew and the railway's responsible officer were unable to diagnose the problem and, after some delay, the fire was dropped. By the time that the decision was made to drop the fire, the firebox crownsheet and the top of the firebox walls and tubeplate had been exposed to the fire without water behind them for several minutes. During this time there was an increasing risk of a catastrophic accident. The melting of the fusible plug in the firebox was not noticed by the train crew.
Supporting References	None

2. Urgent Safety Advice	
USA Date:	28 July 2011
Title:	Safe management of steam locomotive boilers
System / Equipment:	Boilers fitted to narrow gauge and standard gauge steam locomotives
Safety Issue Description:	Operators of steam locomotives should ensure that they have identified the risks associated with operation of the boilers and have put in place suitable and sufficient management systems so that staff are aware of their responsibilities and actions to be taken. In particular, the staff should be familiar with the following: • the importance of maintaining the water level in the boiler; • what to do if it drops below the bottom of the gauge glass; and • the need to drop the fire as quickly as possible when the water level drops below the minimum. The system of boiler inspection and certification used on steam locomotives normally ensures that the boiler is maintained in good condition, but this may not cover the operation of the boiler.
Circumstances:	The boiler was built in 1997 and was of welded steel construction with a steel firebox. Before the incident the boiler was in good condition. The locomotive was coal fired and was being driven and fired by a volunteer driver who had undergone training and had been assessed by the railway as competent as a steam locomotive driver.
Consequences	When a boiler runs low on water and the top of the firebox is exposed the metal can overheat, weakening it significantly. The boiler is then at an enhanced risk of explosion if the strength of the metal falls below that necessary to contain the internal pressure.
Safety Advice:	1. Operators of steam locomotives should ensure that they have identified the risks associated with the operation of boilers and have suitable processes in place, and briefed, for managing them. 2. Operators should check that they have robust arrangements in place for the preparation and routine inspection of steam locomotives before entering service. Operators should assess the adequacy of their existing arrangements against guidance provided by the Office of Rail Regulation (Railway Safety Publication 6, available at www.rail-reg.gov.uk/upload/pdf/RSP6-locoblrs.pdf) with particular reference to checking the correct operation of methods of feeding the boiler with water (e.g. injectors). 3. Operators should review the adequacy of their arrangements for ensuring that train crew are competent to recognise signs of low water, including the melting of fusible plugs, and subsequent actions to be taken.

Appendix D - Safety management systems on heritage and other minor railways

A number of investigations involving accidents on heritage and minor railways have found:

- the absence of an adequate safety management system; and/or
- that the management arrangements described in the SMS were not translated into the day to day operation of the railway.

One such investigation concerned a derailment at Hampton Loade on the Severn Valley Railway. The RAIB investigation (report 07/2010) found that specific requirements of the SMS relating to the monitoring of track and the checking of rolling stock following maintenance had not been implemented.

Similar findings relating to non-compliance with documented engineering safety arrangements were also made following the derailment of a train at Gysgfa, on the Ffestiniog Railway, in May 2008 (report 18/2009).

An investigation into an accident at Lydney on the Dean Forest Railway (report 14/2008) identified the lack of an adequate documented safety management system and the absence of competent advice on matters related to safety. Similar concerns were also raised following the investigation into a fatal accident involving a guard on the Gwili Railway in July 2006 (report 22/2007).

A more recent investigation concerned an injury to a volunteer guard in October 2010 as he attempted to rejoin a moving train on the Foxfield Railway (bulletin B01/2011). The investigation found that the requirements of the railway's own SMS relating to issuing of the rule book and the competence of staff had not been met. In this instance the RAIB concluded that the accident had highlighted the need for railways that are reliant on the services of volunteers to ensure that there are suitable arrangements in place to encourage safe behaviour and compliance with published rules.

An investigation into a collision between a train and a car at a user worked level crossing on the Wensleydale Railway (bulletin B05/2011) found that the operating company had a deficient SMS, and a weak process for the management of risk at level crossings, that had been the subject of enforcement action by the ORR.

Investigations have also demonstrated the need for heritage, and other minor railways, to ensure that they have sufficient knowledge of their assets, and an understanding of the risks, to deliver reliable and safe operations, inspection and maintenance. Examples include:

- Blow back of fire on the North York Moors Railway (report 04/2007).
- Three derailments on the Ravenglass and Eskdale Railway (reports 07/2007 and 32/2007).
- Collision on the Great Orme Tramway in September 2009 (report 13/2010).
- Runaway and collision on the Welshpool and Llanfair Railway in March 2010 (bulletin B06/2010).
- Derailment on the Bure Valley Railway in August 2011 (bulletin B04/2010).

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

Any enquiries about this publication should be sent to:

RAIB
The Wharf
Stores Road
Derby UK
DE21 4BA

Telephone: 01332 253300
Fax: 01332 253301
Email: enquiries@raib.gov.uk
Website: www.raib.gov.uk