rail safety update

NEWS AND UPDATES FOR THE RAIL INDUSTRY AND SAFETY ASSESSORS

NZ TRANSPORT AGENCY
WAKA KOTAHI

Special edition October 2013

Special edition:

Dry pipe failures – steam locomotives

Two separate "dry pipe" failures have occurred recently at Glenbrook Vintage Railway and Weka Pass Railway. Dry pipe failures are a significant safety issue and can result in the locomotive being in an uncontrolled state.

The Transport Agency would like to thank both Glenbrook and Weka Pass Railways for giving the Transport Agency authorisation to share details of these incidents. Ian Tibbles from Shantytown is also sincerely thanked for his invaluable assistance and information. The Transport Agency will be distributing this information to all operators of steam locomotives. We trust you will find it useful and expect licence holders to take appropriate action to prevent a similar incident occurring.

How does the dry pipe work?

The steam travels from the regulator down the steam pipe to the engine unit or may pass into the wet header of a super-heater, the role of the latter being to eliminate water droplets suspended in the "saturated steam", the state in which it leaves the boiler (as well as increasing efficiency and reducing fuel consumption).

On leaving the super-heater, the "dried" steam exits the dry header of the super-heater and passing down a steam pipe enters the steam chests adjacent to the cylinders of a reciprocating engine.

Inside each steam chest is a sliding valve that distributes the steam via ports that connect the steam chest to the ends of the cylinder space. The role of the valves is two-fold: admission of steam into and exhaust of used steam from the cylinder.

Explanation

In the event of corrosion holes, steam will by-pass the regulator valve and the engine will be come to some extent uncontrolled (dependent on the size of the hole).

If in the case of the recent Glenbrook Vintage Railway dry pipe collapse, steam will enter the cylinders forcing the engine to lose traction in an uncontrolled manner. When this occurs the only way to control the engine is to centre the reversing lever thus minimising the amount of steam entering the cylinders and apply the loco brakes.

Shantytown and some other organisations have obtained an inexpensive ($30) USB camera for inspection of boilers and other internal components. This may be something your organisation would like to consider. Ian con be contacted for further information regarding this at **steam@shantytown.co.nz**.

Ultrasonic testing is another strategy that can be used to determine pipe wall thickness.

In this issue:

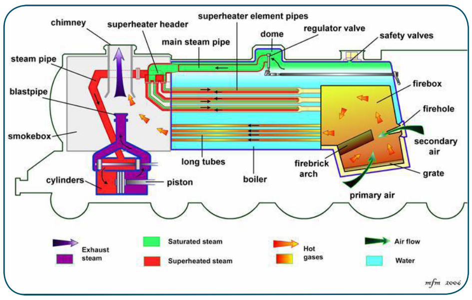


Diagram of a boiler – page 7 >>

Glenbrook Vintage Railway incident – 19 May 2013

On 19 May at 12.15pm, between Morley Road and Glenbrook, WW480 was leading a passenger service into Glenbrook when a mechanical failure resulted in loss of steam control by the regulator. Steam could still be shut off, however there was no gradation of control (ie full off/full on). This incident, which resulted in no damage or injury, is a serious failure. Had it occurred on train approaching Victoria Station with a crew member who was not able to act correctly and immediately there would be a potential to run into the stop block.

A senior mechanical engineer was in the charge of the train, the seriousness of the fault was recognised, and the train continued to it's destination at low speed using the cylinder cocks open and controlled with the reversing lever.

Cause

As the pictures show, the dry, or main, internal steam pipe of WW480 collapsed because it had been thinned by corrosion. This pipe carries steam from the regulator in the boiler dome to the cylinders via the super-heater. Because the pipe runs through the boiler, with the regulator shut, the pressure is external to the pipe and internal pressure would be zero. However, although called the "dry pipe", it is wet inside and out, whereas the tubes and flues are wet on the outer surface only, which may account for a higher rate of corrosion. When the pipe collapsed, steam bypassed the regulator valve and was able to pass directly, uncontrolled, to the cylinders, regardless of the setting of the regulator.

The locomotive went into a huge skid, and the solution was to bring the reversing gear into the mid-gear position (which took two of us), and to open the cylinder cocks. In the mid-gear position the valve travel is reduced to a minimum, allowing only a small quantity of steam to be admitted to each end of the cylinders ("lead" steam), and with the escape of steam via the cylinder cocks plus the train brakes the locomotive was able to be brought under control. An automobile analogy would be a jammed open accelerator. There was no explosive risk and the steam was contained – it was just a matter of controlling the locomotive.

As the pictures show, the top of the pipe collapsed just behind the front tube plate (where leaking problems usually occur), causing the end of the pipe to peel away from the end casting into which the tube is brazed. The brazed joint was not particularly sound, and the heat of the brazing process may have weakened the tube locally. The collapsed pipe was sawn into sections and it can be seen that the thickness (ie corrosion) is by no means uniform, being thickest at the regulator end thinnest about 400mm from the outlet end. Whether the corrosion was from the outside in or vice versa is hard to say.

The basic problem was that the dry pipe had been in the boiler too long, in this case over 20 years. These pipes are virtually inaccessible unless all the boiler tubes including super-heater flues are withdrawn, and the super-heater header is removed – a major job. Therefore the usual annual visual boiler inspection did not pick the problem, nor was there any prior indication by means of leaks, water running from cylinder cocks, etc. More common problems are leaking tubes, which can easily be noted by examining the tube plates. It was quite bad timing when the incident occurred as the locomotive WW480 was coming up for its 10 year survey and Glenbrook Vintage Railway (GVR) planned to replace the various tubes and dry pipe anyway.

Continued next page >>

Collapsed dry pipe – end view

Dry pipe – joint view

Dry pipe pieces

<< from page 2

GVR records don't show the specification of the tube used when the dry pipe was last replaced, but it may well have been to NZR Spec which called for (from memory) 1/4" wall thickness. This imperial size pipe is no longer readily available, but a fairly close metric equivalent in seamless line pipe is available, and we propose to do what Steam Incorporated and Weka Pass have done, and use Schedule 80 line pipe, which has a wall thickness of 9.25 mm, which being thicker should give a longer life than tube to NZR spec.

GVR are now proceeding with a complete re-tube of the boiler, and have found several tubes that would have soon developed pin holes anyway, so the re-tubing exercise is timely. Similar situations can occur if water is carried over through the regulator, known as "hydraulicing" and with the regulator closed the locomotive will keep steaming ahead powered by steam generated from water in the super-heater elements. The important thing is that drivers know what to do in such circumstances.

This emphasises the need for extreme care approaching Victoria Avenue Station, as is practice with the compulsory stop and notification of all drivers of this incident and the procedure to deal with it.

GVR has also advised the following points to the Transport Agency:

- All drivers have discussed the incident and aware of what to do in such a situation
- Reference to this will be included in future driver training modules
- GVR have advised other operators directly who may face a similar event
- This incident was discussed and promulgated information on this incident widely at the 2013 FRONZ conference.

Weka Pass Railway incident

A different type of dry pipe failure occurred at Weka Pass Railway on A428 in October 2012. A small hole developed in the dry pipe which made the locomotive more difficult to control and this was reported by the locomotive crew.

The locomotive was withdrawn from service and a picture of the corrosion damage is attached. It should be noted that the hole as pictured is slightly bigger as it had been poked and prodded as part of the incident investigation. Virtually all of the rest of the pipe in this case was found to be at, or close to, the original thickness.

A428 dry pipe – interior view

A428 dry pipe – exterior view

The "Blue Peter" over-full boiler incident

The Blue Peter article copied below involves an over-full boiler – a separate issue to the "dry pipe" issue. The water and steam enters the super-heaters flashing off into steam which overpowers the cylinders in a similar manner to a hole in the dry pipe. Although priming or water carry over is common to all steam locomotives, Ian Tibbles has never heard of one this serious in New Zealand or of an NZR regulator sticking open as described in the article.

Q&A *Special*

This issue we've expanded our usual column for an in-depth examination of priming

Rounding up the prime suspects

Expensive steam locomotives have suffered a sorry catalogue of serious damage over the past two or three years - and the blame is frequently put on the shoulders of traincrews 'playing to the gallery'. A former Nine Elms driver and founder of a leading footplate training company explains what causes the phenomenon of priming and warns that drivers and firemen must be vigilant to prevent it.

REPORT BY **CLIVE GROOME**

"I was the fireman who over-filled the boiler of an 'E6' Brighton radial that slipped uncontrollably for a very long 90 seconds outside West Croydon station in 1953. The driver, once he had regained control, told me never to forget the lesson - and I never have."

VALUABLE steam locomotives are increasingly suffering crippling damage on main line specials as a result of the carrying-over of water from the boiler to the cylinders. An experienced crew will avoid this by good management of the boiler and driving controls. If the problem arises despite good management - perhaps through dirty boiler water or a perforated internal main steam pipe - a skilled driver will act swiftly to prevent damage taking place.

Experienced crews are apparently becoming hard to find. An experienced driver will not respond to the 'gallery' of onlookers, enthusiastic passengers or influential footplate riders who encourage him to flog an engine over a bank in pursuit of some modern 'Blue Riband' or other. Especially if he has noticed that the water is out of sight at the top of the gauge glass and the safety valves are roaring off excess steam as his fireman displays his incompetence at boiler management!

Judging by most of the videos I have watched during the last three years of main line steam operation, the firemen involved are unable to control their boilers. Almost without exception, panning shots reveal plumes of steam gushing from safety valves uphill, downhill and during station stops. When the valves seat at last, the firemen probably panic as they realise they are making less steam than they were a moment or two before!

From a driver's point of view, the triumphant smile that is seen on some firemen's faces, as the valves lift halfway up a long bank, resembles nothing more than the grimace of a frightened monkey. It displays about as much 'engine sense' as one would expect from a dextrous animal. Drivers who ignore and allow such mismanagement are remiss in their duties, for they are in charge of events on the footplate and are likely to miss the signs that indicate imminent disaster from uncontrolled priming.

There are four main causes of priming, apart from the split internal main steam pipe:

■ **Cause 1** Boiler water carried too high in the glass. Belpaire boilers will carry an almost full glass with ease because ebullition (the process of boiling) takes place over a greater area and steam flow is not concentrated. Round-topped boilers are safer at half a glass because ebullition is under a narrower 'roof' and the steam flow is very concentrated. In both cases, high water is nearer the regulator valve (Figs 1 and 2).

■ **Cause 2** Dirty boiler water or unsuitable water supply. This is a difficult situation to cope with but fortunately not a common problem with the carefully maintained star performers of today. It happens if the boiler water is over-full of salts and other solids left behind as the pure water is boiled off over a period of days. The steam raised within the body of water now finds it difficult to get through to the surface. We can get an idea of what takes place by considering a saucepan of soup or porridge which, all the while we stir it, boils happily. But if we neglect to stir it for a moment, it boils over and messes up the stove!

Our spoon makes a space for steam to get out. We have no spoon in our boiler so the steam cannot get through and, just as porridge rises with the steam lifting it, so the water in our boiler rises as a foaming mass, until it is taken through the regulator valve and to the cylinders (fig 3).

This will even happen with a 'true' level of an inch or so in the bottom of the gauge glass. In bad situations the gauge glass will fill with foam to the top and bubbles of steam will be seen to wander up and down the glass, yet when the regulator is closed, a true level reappears that is barely enough to cover the firebox crown.

The third and fourth causes arise because water boils at different temperatures related to the pressure that surrounds it. In other words, at sea level and 14.7lb atmospheric pressure, water boils at 212°F; at the top of Everest it boils at far less than this. In a pressure cooker set for 15psi, it boils at 250°F, and so on. Our boilers on average are at around 200psi, so the water does not boil until we get it to 387.9°F.

What has this to do with priming? It's to do with the grinning monkey on the other side of the cab - and the clumsy driver who mishandles the regulator and reverser!

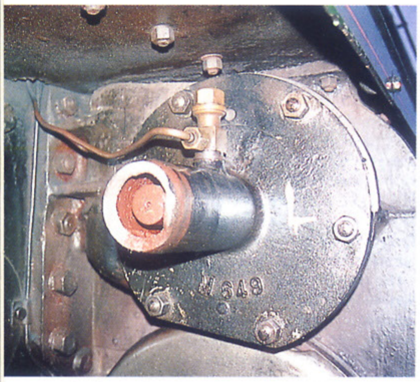
Imagine a boiler made of glass that allows us to see the firebox, the tubes, safety valves, regulator valve and so on. We see the raging mass of radiant heat within the firebox walls, the hot gases that are drawn through the fire tubes and superheat flues by the blast of the exhaust in the smoke box. We watch the boiler water in continuous turmoil as it moves from the hottest plates in great waves and swirls as it becomes less dense than the water that has yet to be so heated.

All the time, under heavy steaming conditions, veritable sheets of steam are forming against the top and top side surfaces of the firebox. They rise with difficulty against the pressure of steam already held within the boiler - rising out of the water in the form of an invisible gas that is hotter than the water it leaves behind because of its latent heat. We do not see this steam. The disturbed surface of the water is our only clue to the process taking place.

The regulator valve is open full first valve, the driver has the cut-off set at 25% and the train is racing along at 60mph. Everything is balanced nicely, the steam at 387.9°F is running through the superheat elements and arriving at the cylinders at around 650°F, hot enough to melt a block of lead. The gradient steepens sharply and our fireman, if he is skillful, will have deepened the firebed slightly in preparation for heavier work ahead. He keeps the pressure just below the red line, the water level will be in sight at the top of the glass and the steam entering the regulator will be as hot and dry as is possible at the pre-superheat stage.

Now let us look at how things can be made to go wrong. Our train is approaching the gradient but conditions within the boiler are rather different. The boiler water level has been above the top nut of the gauge glass for miles. The fireman overloaded the fire during the recent station stop, and in an effort to quieten the roar from the safety valves, he has driven the water level so high that he cannot 'pull it down' by opening and closing the drain cocks. For the moment, though, the valves are not lifting. He knows the gradient lies ahead and that his mate will try for the 'Blue Riband,' so he packs in a heavy charge of fuel and, shutting the firedoors, leans out of the cab to enjoy the stirring sound of an engine being 'opened up'.

The driver, either unaware of the water situation or ignorant of the danger, opens his regulator fully and advances the cut-off to produce the noise and speed that the 'gallery' expects. The draw on the firebed is now immense. Locomotive boilers are unique in their ability to produce steam out of all proportion to the size of the grate area because of the effect of the blast pipe. Our fireman has lingered too long, distracted from the observation of his pressure gauge, and once



The damage to *Blue Peter* saw much of the motion and valve gear wrecked. In addition to bent rods were many other damaged components. The piston valve tailrod over-travelled and punched a hole in the piston-valve cover. MAURICE BURNS.

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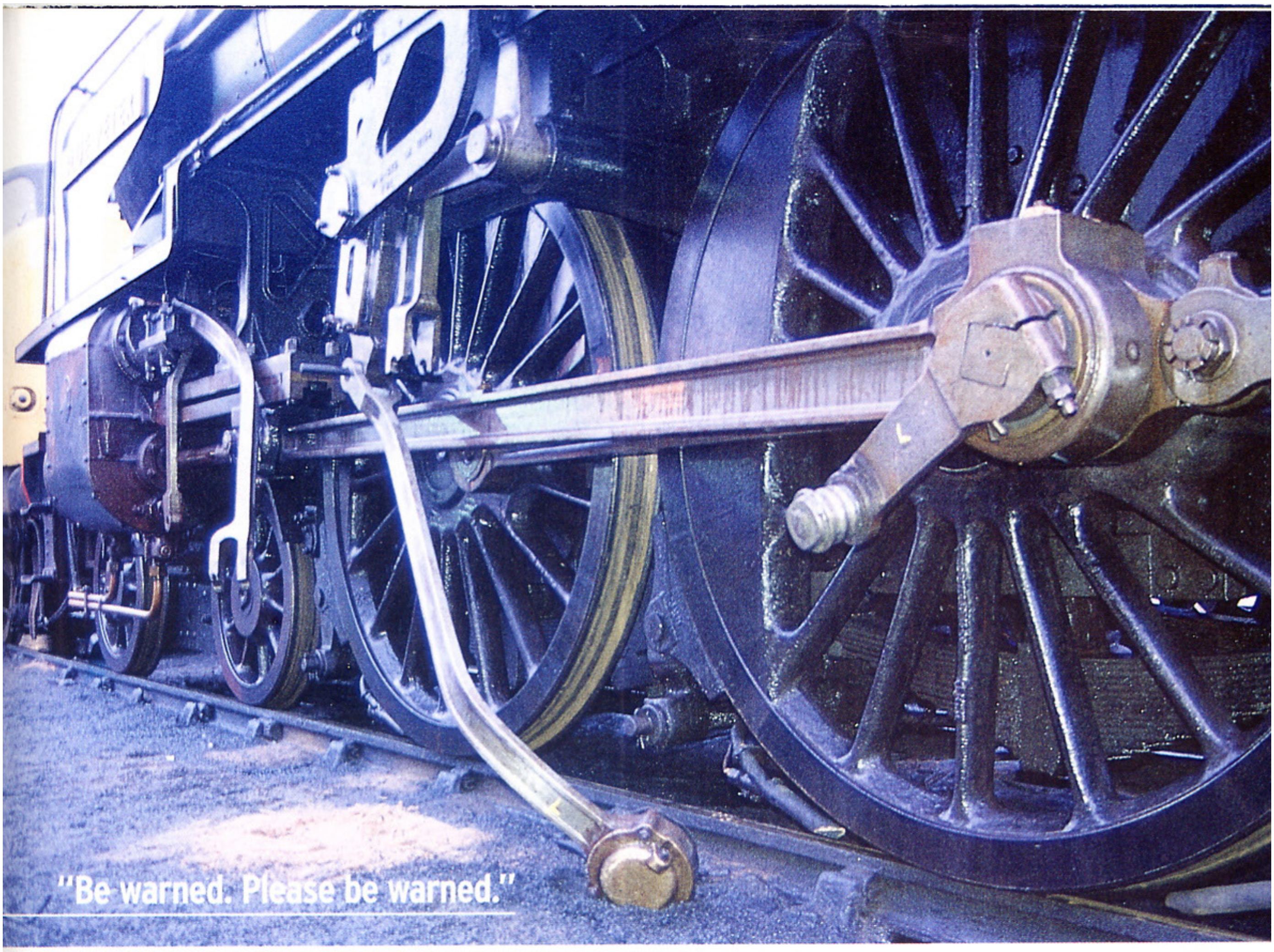
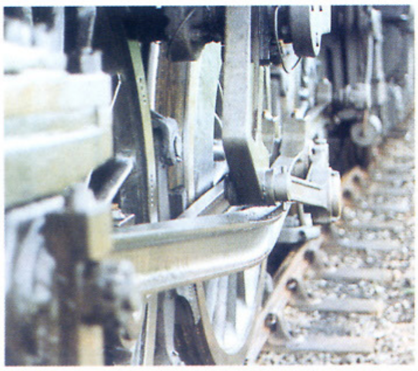


Whilst there have been a number of incidents over the years, none was as calamitous as that involving LNER 'Pacific' No. 60532 *Blue Peter* at Durham on October 1 1994. In a massive 36-second wheelslip, when *Blue Peter* would have reached 140mph if it had been moving, the locomotive literally thrashed itself to bits. The repair, which included extensive replacement of motion and valves, plus pioneering work to press a driving wheel onto the crank axle, cost £65,000. It also saw the engine lose nearly two years of its boiler ticket - it didn't steam again until April 28 1996. This view shows the broken radius rod and eccentric rod. MAURICE BURNS.



One of the latest incidents, at Fort William on July 13, left BR 'Standard 4' No. 75014 with a badly bent connecting rod and damage estimated to cost £15,000 to repair. This is a classic illustration of the damage that priming can cause.

again the safety valves lift. He does nothing. The boiler is already full and he imagines the onlookers are marvelling at the skill of a man who can provide so much steam when his engine is at full power at the head of such tonnage.

Cause 3 Within the boiler we'll notice the area of boiler water immediately beneath the roaring safety valves is behaving differently. Volumes of water will rise in a spout towards the valves, as the steam coming with difficulty out of the overall surface area (because of the pressure above it) now discovers an easier path. The release of steam - both valves, or three or four (depending on the locomotive in question) are releasing pressure in a very localised area. A lot of the steam that is pent-up within the body of water will now come out in one place and the water is carried up with it as a water spout. Some of it will hammer the fine edges of the safety valves and spoil them, the rest will follow the path of the steam flow into the regulator valve. Water-laden steam cools down the superheat, entering and leaving the cylinders in a fine spray of condensing steam that increases the blast on the fire as it goes out of the chimney with an increasingly muffled roar. The fire is drawn to fiercer heat and small pieces of unburned fuel will lift out of the firebed.

"Now our unobservant driver is in trouble: his engine is revving up on the spot with the pistons and valves hammering out the incompressible water."

Water is also entering the feed pipes that run within the boiler to auxiliary equipment on the footplate. One if these is the vacuum brake ejector. An observant driver would detect a change in the rattle of the limit valve in front of him as the train pipe needle begins to fall from 21in. But our driver merely pulls harder on the regulator and increases the cut-off to maintain speed for the crowd.

The cylinder relief valves are now blowing as they try to dump water that is being compressed at higher than boiler pressure at either end of the cylinders. The exhaust is now wrapped whitely around the chimney - no clear space of invisible steam. The safety valves roar harder as the fire responds to the increased blast (Fig. 4).

Cause 4 If the engine should slip as the curves drag on the flanges of the train, the fourth cause of priming comes into effect. If the regulator is opened violently or the cut-off is advanced greatly and suddenly, or if the engine slips under full power, a situation develops akin to the third cause.

The sudden increase in the volume of steam abstracted from the boiler through the regulator ▶

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Q&A Special

This issue we've expanded our usual column for an in-depth examination of priming

Q On a train journey in the 1960s, I remember noticing a 'B1' 4-6-0 in a yard with its left-hand piston connecting rod bent up in a great arc. I have often wondered what could have been responsible for the enormous force required to produce this effect. Can you explain?
Mr D.H. Taylor, Hendon.

A Water had occupied the clearance space between the cylinder end and an approaching piston nearing the end of its stroke.

Under normal conditions, if air or steam remains in the clearance space, the piston is able to compress those 'gases' and benefit from the 'bounce' they impart to the outward stroke. If water fills the space, however, this is impossible as water cannot be compressed, and the stroke of the piston ceases short of the full travel needed to bring the relevant big end to the fore or back limit of its circle of movement.

A hundred tons of metal is now stopped dead by a piston designed to transmit around two tons of push to the crankpin through the connecting rod. Something has to give. A locomotive moving slowly off the pit during shed work may stop dead at this point and, as long as its driver does not try to force the engine forward, little damage may result. If the speed is higher than a crawl, however, or the locomotive is coupled to a train, the moving weight will have to dissipate its energy by smashing out the restraint of a cylinder cover, by shattering a piston head or by bending the connecting rod in the way described. Any one of these events can take place in a fraction of a second.

At normal speed, when water is present in the cylinders, an alert crew will be warned by the start of a thump accompanying the rhythm of the engine. This initial thump may be enough to cause hidden damage to the piston and piston rods on older designs. This is despite the fact such machines have slide valves and are protected somewhat because the trapped water can force the valves off their face, allowing the water to escape up the exhaust to the chimney.

However, older designs often have piston heads that are tightened up on to a tapered piston rod end. The wall of water stops the piston but the taper of the rod is driven forcibly through the piston by a fraction, so that the nuts on the piston rod end can turn and gradually unwind. Ultimately, the nut will run so far off the rod that it strikes the cylinder cover on the outward stroke, which may then shatter the cover, days or even weeks after the initial entrapment of water took place.

An experienced driver or examining fitter could detect such a loosened piston head by the knock and thump that would result twice per wheel turn under steam as the piston was driven forward to the nut then backward on to the tapered piston rod.

"Judging by most of the videos I have watched during the last three years of main line steam operation, the firemen involved are unable to control their boilers."

▶ valve initiates a localised low-pressure area into which most of the available steam within the water will flow, carrying a water spout with it. Now our unobservant driver is in trouble: his engine is revving up on the spot with the pistons and valves hammering out the incompressible water. He flies to the regulator and cannot close it! Water pressure has locked the sliding plates solid. He is used to the feel of steam pressure against the valve, but this a new feeling. The regulator handle is solid and immovable despite the efforts of both men (Fig. 5).

The locomotive is totally out of control and can only be brought to heel by first applying the engine's brakes fully, then opening the cylinder drain cocks and attempting to put the reverser in mid-gear. Once the wheels are no longer able to turn, or the reverser is in mid-gear, the regulator will be docile again as the hydraulic pressure that locked it builds up on the superheat side of the valve and equalises with conditions on the waterside. But in the meantime, as we have seen all too often of late, the locomotive will have suffered a great deal of damage (see pictures).

I have experienced this situation several times. I was the fireman who over-filled the boiler of an 'E6' Brighton radial that slipped uncontrollably for a very long 90 seconds outside West Croydon station in 1953. The driver, once he had regained control, told me never to forget the lesson - and I never have. I have retrieved the situation subsequently myself while riding as an onlooker on the footplates of 'S15s' (twice) and North London tank No. 58850 (twice), and so narrowly prevented collisions made imminent by unskilful drivers. You will note that round-topped boilers feature in all these instances. Be warned. Please be warned. SR

Do you have a question? Write to *Steam Railway*, Apex House, Oundle Road, Peterborough PE2 9NP, or e-mail: steam.railway@ecm.emap.com Questions can only be answered through these pages. Technical questions on steam locomotives are answered by former Nine Elms driver CLIVE GROOME of training company Footplate Days & Ways.

Fig.1
Belpaire Firebox

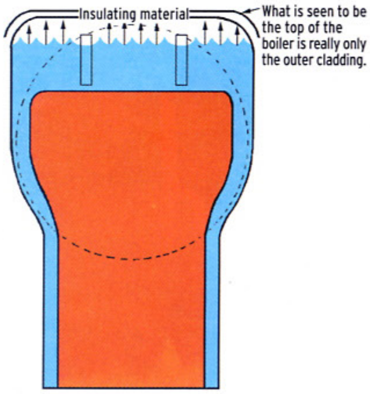


Fig.2
Round topped Firebox

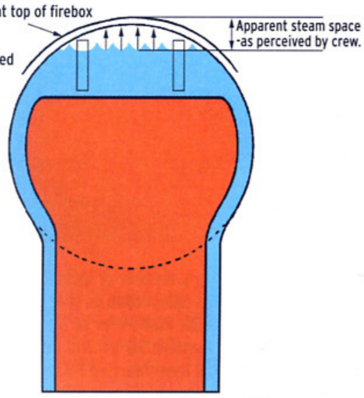
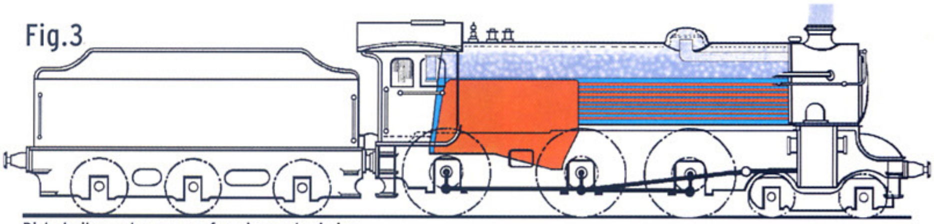
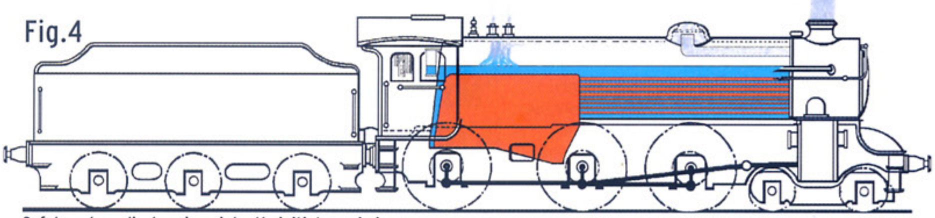


Fig.3



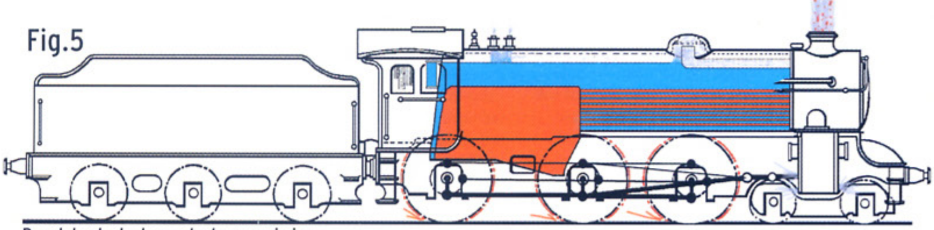
Dirty boiler water causes foaming and priming.

Fig.4



Safety valves discharging violently initiates priming.

Fig.5



Regulator locked open by heavy priming.

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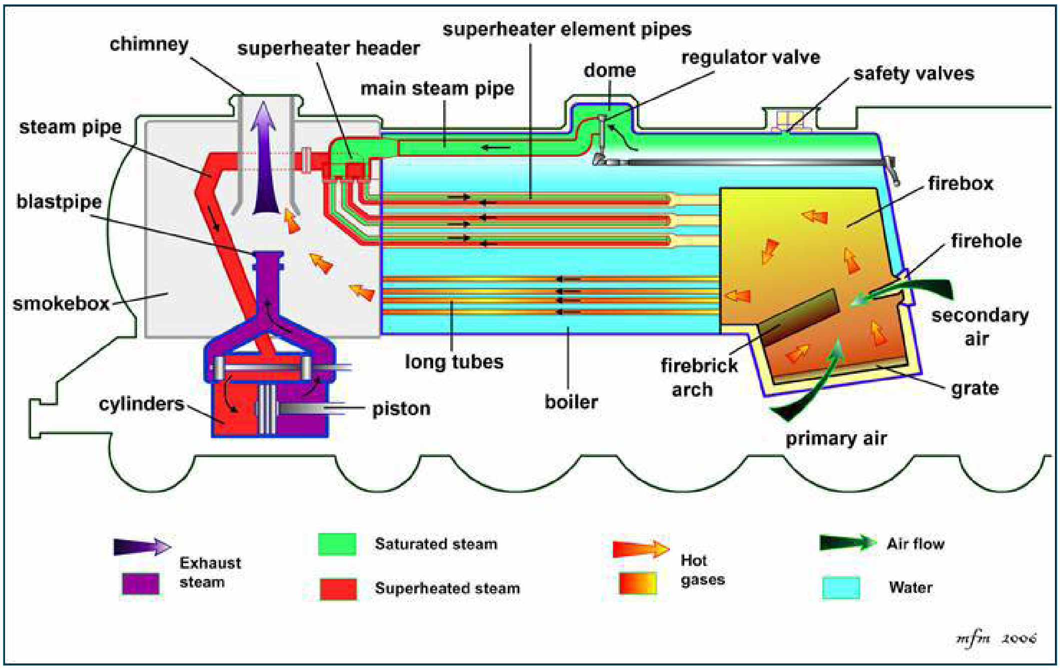
Diagram of a boiler



Correspondence to the Transport Agency

These days, all correspondence is filed in an electronic storage system here at the Transport Agency, so sending your letters, files or reports electronically saves us a bit of time.

Please send all of your electronic correspondence (except incident reports) to your client manager and please 'cc' our Manager Rail Systems – **john.freeman@nzta.govt.nz**. However, if electronic mail is not available for your organisation 'snail mail' will still be answered! For rail incident reports email us at **railregulation@nzta.govt.nz**.

Our contact details

For general enquiries or contact information about the Transport Agency please check our website ***www.nzta.govt.nz*** or email us at ***info@nzta.govt.nz***

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The Rail Systems team is located on level 3
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Rail Safety Notification Hotline

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Phone (04) 499 1858

Rail incident reports: email us at ***railregulation@nzta.govt.nz***

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