Federation of Model Engineering Societies

Boiler scale and descaling

This document was written by Mike Wheelwright and was originally published by Worthing and District SME in their newsletter in the Spring of 2013.

Quite coincidentally two matters related to water have arisen recently: a club locomotive was found to have its boiler furred-up to the extent that fittings were blocked and injectors very unreliable then ME ran an article about water for model boilers. This latter mentioned ways of testing water and descaling boilers but focussed mainly on installations for rainwater storage. Those of us living in SE England, particularly near the Downs, don't need to test our water to see if it is hard, its effect at home on things used for heating it and on our boilers leaves no doubt. The railways of course had the same problem in the days when boiler water quality concerned them more than leaves on the line. Quite simply the water coming out of our taps contains various types of dissolved solids which interfere with industrial and domestic processes, in our case it causes soap to form scum and deposits white crust in heaters and kettles, including the expensive kettles on our models. The measure for impurity is Total Dissolved Solids (TDS) expressed as parts per million and 200 ppm it is reckoned as very hard. I recently tested a sample of Worthing water which came out at about 750 ppm, although Brighton just beat it at about 1000 ppm, it's amazing that it still runs through pipes! We definitely have a problem.

Hardness is divided into two categories, temporary and permanent, each caused by different chemicals. Calcium and magnesium bicarbonates dissolved in water contribute to hardness but at boiling point they break down into simple carbonates (chalk) which are insoluble and precipitate out so the hardness is reduced: hence the term "temporary". Salts such as sulphates and chlorides are not affected by heating therefore their contribution to hardness is "permanent". So, what problems do they cause? In general, high levels of dissolved solids promote frothing at the water surface, which translates into priming (carry-over of water through the regulator) and water lift at safety valves; it also tends to produce instability in water gauges and injectors. For us the real problem lies with the temporary hardness because when the temperature of water is raised in the boiler the chalk comes out and sticks to the heating surfaces, gradually building up on tubes and plates where it forms an insulating layer. The heating surfaces work on the principle of a very hot fire on one side of the copper (which left to itself would soften) and water at about 320°F on the other, as the copper has high conductivity the water keeps the fire side cooled. Once a layer of insulation forms over the water side the conductivity reduces and the fire side temperature is allowed to increase significantly, this eventually damages the boiler. Furthermore, severe furring reduces the width of water spaces restricting circulation, which again causes overheating as well as reducing boiler efficiency, while bits of chalk can come loose and block valves, water gauges and injectors. Let's see what happens one afternoon between 2pm and 5pm: suppose the engine's boiler holds ¾ gallon of water at half-glass, tenders usually carry about a gallon so every time we top up the tender we put in about ¾ gallon, after topping up the tender 3 times each hour the boiler still contains ¾ gallon, so about 9 times this quantity of water has been evaporated. The steam that boils off is pure water leaving behind 9 boiler-loads of salts and suspended chalk: the total solids content is now 9 times higher than it was at 2pm. This is the problem we have to contend with. The effect of "bad water" on locomotive boilers was always a serious matter. Generally speaking, railways did not look closely at maintenance costs but the

new LMS management of 1926 made a point of gathering a lot of information and some results have been published, the interesting point is the lower cost in Scotland which was not due to innate Caledonian prudence but to the increased life of boilers (about double). This was of course due to water in Scotland being generally good with quality deteriorating further south. The GWR went to the trouble of taking water from Kemble and piping it 12 miles to the works and yards at Swindon.

The LMS tried water treatment in English depots and troughs but didn't seem to be able to apply it consistently and gained little benefit. The Southern was concerned enough to go to the extreme of fitting up water treatment equipment on tenders. The snag with treatment is that more chemicals are added to the water to soften it and steps have to be taken to limit the concentration and get rid of sludge. The only way is to blow down a proportion of the boiler water and this is done continuously through a special valve. Of course, heat is lost, the coal bill goes up and the fireman works harder.

All locomotives were given frequent boiler washouts, sometimes every few days, and boilers were provided with plugs for putting in hoses and passing rods to scrape the crown stays. Things don't sound too good for us.

So, what can we do? Obviously, we could buy demineralised water, a bit expensive but my club in Spain does it, this eliminates the problem and there is no sign of white marks round fittings. What about rain water as advocated in the magazine article? This is also an answer to the problem but there are two points to watch. First, in some areas with air pollution the rain can dissolve acid, here in Sussex the absence of coal fired power stations makes this unlikely, I recently checked a sample from my own roof which came out around pH7, this is neutral so plate corrosion is not a problem, however if water is acidic the boiler concentration after a few hours could be of concern (for comparison Worthing water had pH 7.5, slightly basic, good). The other point is the removal of organic matter from the water, the installations described in ME made provision for filtering out the large stuff and flushing through to discourage aquatic life. I have a water butt and at first glance the water comes out clean but when looked at closely in a tumbler there seems to be quite a bit of almost transparent suspended matter in it, some of it wriggles! This may well "bake" to the plates with I-know-not-what effect in the long term. Over the years I have developed my own way of handling the water problem, the best example I can give is my Hunslet which has now been running on Sussex water since 1996 and for 13 years it was the only locomotive I used for public running so it must have boiled a few gallons. Every 4 years (previously 2 years) I remove the dome to blank off the regulator for the hydraulic test and being a NG model the opening is big, so with the aid of a light a fair bit of the middle section of the innards is visible, there is no white (or other colour) deposit on tubes or plates, the copper has the heated black look to it. Of course, I cannot see the foundation ring and I am unaware of what may be deposited there. I am not certain why there is no visible build up but it may be due to the following conjecture. I always raise steam on rainwater so there is nothing to precipitate out when the water gets to the temperature at which temporary hardness salts would coat the hot surfaces. Thereafter boiler level is maintained using tap water and some precipitation takes place in the injector when the steam meets the feed water, so water passing out of the check valve has some fine solid in suspension, then when it shoots into the steam space there is a sudden temperature increase that releases the remainder of the chalk in fine particles. Effectively precipitation takes place away from heating surfaces. Of course, the suspended solids build up during the run and some may fall to the lowest level but I make a point of <u>always</u> completely blowing down to remove as much solid as possible, taking care to start with a full glass and full pressure so as to produce plenty of turbulence. It is interesting to note that the Great Western introduced top feeds in 1906 with water delivered through check valves that can be seen each side of the safety valve manhole. What can't be seen are the trays below, when the water enters the boiler and goes through the precipitation temperature it cascades over the trays depositing much of the solids on them, these of course have to be cleaned at boiler wash-out. In due course the idea passed to Ashford and Derby, eventually becoming BR standard practice.

If descaling has to be carried out it is quite a task, domestic agents can be used but I have heard of subsequent problems with bad priming. The ME article mentions using citric acid, if sufficiently concentrated this does attack the build-up of carbonate by forming calcium citrate, BUT unfortunately this itself is insoluble and builds up its own suspension in the water which tends to block passages. Valves (including blow down) should be removed and replaced by plugs and after the treatment prolonged flushing is required to remove loose scale which can play havoc with fittings if left in the boiler. I am keeping my fingers crossed and continuing with my system of firing up on soft water, delivering water from an injector into the steam space and blowing down rigorously. So far so good!