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Boilers and feed water

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I have, at home, a few vintage engineers' handbooks inherited from a variety of sources. In my experience, the older the book, the more useful data is contained and, since it is nearly fifty years since I left school, the archaic units are easy enough to live with. Recently, Charles gave me another little gem to add to my collection; Fowler's Mechanical Engineer's Pocket Book dated 1943, which has a useful section covering boiler feed-water, hardness and treatment. Being very small print on old yellowed paper, rather than scan it in I have summarised the contents here as they relate to us. Much of what it says reminds me of my chemistry lessons back in the 1950s but I must say that it makes more sense to me now than it did then.

Hardness

The first point to understand is what causes hardness. Salts, mainly of calcium and magnesium, are absorbed by water flowing over and through the ground. The noticeable domestic effect of these dissolved salts is to increase the amount of soap needed to form lather, and so the evaluation of hardness using standard soap solution used to be the way that hardness was measured (remembered from my school chemistry lessons). These dissolved salts are principally carbonates and sulphates of magnesium and calcium.

Temporary Hardness

Carbonates will come out of solution when water is heated and boiled and this is thus called 'temporary hardness'. In addition, these deposits of carbonates can be dissolved using 'weak' acids such as formic, phosphoric, citric and acetic (vinegar). Domestic kettle descaler is usually formic or phosphoric acid. ('Weak acid' here does not mean dilute, but is a measure of the chemical reactivity).

Permanent Hardness

Sulphates, on the other hand, remain in solution when the water is boiled but when the water is continuously evaporated, as in a boiler supplying a steam engine, the dissolved salts become increasingly concentrated. Eventually the concentration is sufficient for the salts to come out of solution as a very hard scale. These sulphate deposits also have the characteristic of binding with the carbonates already deposited which renders them much more resistant to removal with weak acid.

One other factor, new to me, which we need to take into account, is the effect of temperature on the solubility of magnesium and calcium sulphates. At 90 psi, when the water temperature is approximately 160 deg C, the solubility of the sulphates is reduced to almost one fifth of that at atmospheric pressure and at boiling point, 100 deg C. Because of this, the recommendation in the Engineer's Pocket Book is to allow a boiler to cool somewhat before blowing down so that some of the precipitated salts may re-dissolve. This sounds like a case for allowing the boiler to cool gradually and blowing down using the air line when cool. This would be a long process at the end of a running session. However, it gives further justification to my usual practice of, at the end of a run before blowing down, filling up the boiler using the injectors. This both cools everything down and dilutes the solution of salts.

Descaling

The way that the carbonates and sulphates combine to form a persistent hard deposit explains why 'weak acid' treatment is of limited effectiveness in steam generating boilers. The use of Hydrochloric or Sulphamic acid, with suitable inhibitors, as discussed previously, gives us a treatment that has the capability of dealing with this hard scale.

Injectors

Finally, as very little water evaporates at an injector, the scale deposits are of 'temporary hardness' due to the cold water being heated; i.e. carbonates, which may be removed using ordinary kettle descalers and other weak acids.