Steam Boiler Operation…'Is it Safe'

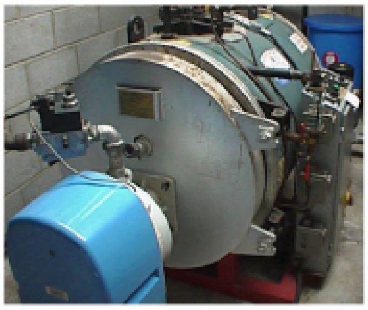
Beating Boiler Failure Part 2

It is the line of least resistance to do a job by rule of thumb or just follow instructions. But often things happen that cannot be put right by rules and require someone who knows "Why" as well as "How".

That statement is as relevant today as it was in 1945 when it appeared in "The Stoker's Manual" prepared under the directions of the Fuel Efficiency Committee of the Ministry of Fuel and Power.

The book contained information that would help the stoker 'operate the boiler plant in the best possible way', and recognised the important role the Stoker could play in saving coal.

Yet today, boiler water treatment is still based on a 'Rule of Thumb' that was conceived when the 'Lancashire Boiler' was at its peak. At that time it was recognised that controlling the pH value was sufficient to prevent corrosion on low-pressure boilers with low heat-flux and employing internal chemical treatment.



It made sense 60 years ago to test the water once a day, but today?

Modern 3-pass wet back boilers contain probably less than a third the amount of water for the equivalent steam generation capacity with the furnace tube having a considerably higher heat-flux rate.

Maintaining the combustion efficiency over the lifetime of any boiler is dependent upon the rate of heat transfer from flame to water; fouling of the furnace and boiler tubes retards boiler efficiency. With over 70% of all recorded boiler failures related to incorrect water treatment it is time to disregard the "Rule of Thumb" of a daily water test and give water treatment the prominence it deserves.

To maintain efficiency throughout the boilers working life we need to ensure that the heat transfer surfaces remain scale and corrosion free, accurately control the surface blowdown at the recommended TDS level and prevent sludge build up by regular operation of the bottom blowdown valve.

Good corrosion control requires a high boiler water pH, the formation of a dense thin magnetite layer on the metal surfaces and the total absence of oxygen in the feed water throughout the boilers working life. Relying on daily water tests and manually adjusting the dosing pumps cannot possibly be the most efficient and effective way to protect the boiler from damage.

Scale Formation

All scale deposits have a much lower thermal conductivity than the furnace and boiler tube heat transfer surfaces and must when present reduce the thermal efficiency of the boiler. A reduction of 2 – 3% in fuel efficiency is itself significant; with a monthly fuel bill of £30,000 the reduction in efficiency can be as much as £900/month. But more important than the monetary loss is the effect on the thermal conductivity of the metal parts.

Carbon steel begins to loose its strength at temperatures above 300^{O}C and BS 2790:1992 states that the maximum metal temperature shall not exceed 420^{O}C and in some cases it is limited to 380^{O}C. These temperatures are considerably less than the furnace temperature which will be in excess of 1200^{O}C during normal operation and relies on the boiler water to carry the heat away by natural convection and formation of steam bubbles. The scale, when present, forms an insulating barrier between the outer metal surfaces and the boiler water and as the layer increases in thickness the metal temperature increases forming hot spots weakening the metal. The metal will then be distorted by the boiler pressure and may collapse.

Also, it may well be the case that the insulating layer of scale is not thick enough to cause furnace tube problems but thick enough to unbalance the combustion process because insufficient heat is removed from the flame, this results in high metal temperatures at the entrance to the first tube pass which, according to BS 2790:1992 can cause cracking of the tube plate ligaments and cracking of welds and tube ends at the tube plate attachments.

Any company that has suffered boiler failure or has had to have their boiler retubed or chemically cleaned will appreciate the need to improve boiler feedwater chemical control.

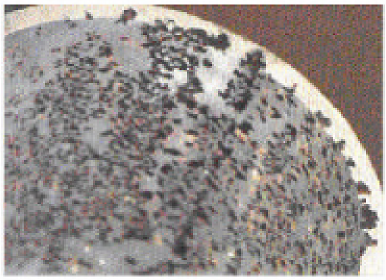
Oxygen Corrosion

If the actual temperature of the feedwater is unknown then 'How can you accurately treat the oxygen content'?

Water with a temperature below 100°C will absorb oxygen, which unless removed by suitable treatment reacts with the metal inside the boiler and steam system causing corrosion. The lower the feedwater temperature the greater the amount of dissolved oxygen it contains and therefore proportionally more oxygen scavenging chemicals are required to prevent damage.

The oxygen reacts with the iron in the boiler to form red oxide as Fe_2O_3, that is every 3 molecules of oxygen will react with 2 molecules of iron and be converted to rust.

The damage is not uniform however as oxygen damage is characterised as localised pitting so it does not take too much before a tube failure occurs or problems start to appear in the steam and condensate lines.



Neutralising the oxygen before it enters the boiler is obviously vital but this is not without its downside – as some oxygen scavengers raise the Total Dissolved Solids (TDS) of the boiler water for example, Sodium Sulphite, which is commonly used on land boilers requires approx 8mg of product to neutralise 1mg of dissolved oxygen thus raising the TDS of the feed water by at least 8mg/litre so if your philosophy to combat oxygen damage is to overdose the chemical for the worst case condition you introduce other problems like higher rate of surface blowdown with the attendant energy and water loss.

Whether you have a daily start-up or operate 24seven the feedwater temperature will vary throughout the course of the day each day and every day. Ascertaining the correct dosage of Oxygen Scavenging chemicals is based on calculation: on start-up or with an increase in load, the natural balance between steam flow and condensate return will change and the feedwater tank level will fall. Cold make-up water is required to correct the imbalance. The tank temperature will be depressed and dissolved gas content will increase.

Testing once a day, at about the same time will probably give you similar results. But the results are not representative of actual operating conditions and beg the questions:-

1. At what temperature do you set your chemical dosing regime?
2. How much reserve do you need to cater for the unknown?

At a temperature of 80°C there is 3mg/l of dissolved oxygen in the water being fed to the boiler. At 95°C the Oxygen content will be 1mg/l reducing the sulphite requirement by approx 2/3$^{rd.}$

As Sodium sulphite greatly contributes to the dissolved solids in the boiler; economies in operating costs can be expected as the reduction in dissolved solids means less blow down, saving energy and water.

Dosing chemicals based on an estimated temperature or one sample per day contributes considerably to problems in the boiler, which ultimately reduces efficiency and increases operating costs throughout the lifetime of the boiler.

Given, therefore, the uncertainty of the stored feedwater temperature and the boiler demand it makes sense to monitor the feed rate and the dissolved oxygen level (or feed water temperature) and to design your dosing algorithm based on these factors.

It would then be possible to accurately adjust the dosing rate in real time, according to the feed water demand. Not too much, not too little but just the right amount, saving chemicals and energy by reducing the need to blow down the boiler.

Dissolved & Suspended Solids Content

As we generate steam, the water in the boiler evaporates and the concentration of dissolved and suspended solids increases. How quickly they increase depends on the quality and condition of the feedwater. If we do nothing about this, the Dissolved Solids level will increase until we get foaming and priming with consequent problems within the boiler and the steam distribution system. It is essential therefore, that the dissolved solids level within steam boilers is not allowed to rise above a specified concentration.

The majority of boilers nowadays have automatic controls, which monitor and regulate the solids content to within the boiler manufacturers specified limits to prevent foaming and carry over. However, the majority of controllers installed rely on a fixed temperature input to calculate the solids level. Since conductivity varies with temperature at approximately 2% per °C accurate control can only be achieved when temperature compensation is automatically applied.

The suspended solids, which may otherwise form sludge, should be controlled by manual or automatic operation of the bottom blowdown valve. The most effective and economic way is to open the valve quickly but for short periods of 3 to 5 seconds duration. The object being to disturb the sludge at the bottom of the boiler and draw it out through the valve, short sharp operation has overtime proved the best method.

To be effective boiler feedwater control needs to be automatic and available 24seven

The Aquanet AQ300 series of boiler feedwater management systems offer precise and repeatable control of the chemical composition of boiler water with additional benefits of improved reliability and reduced maintenance.

The automatic "Boiler Water Management" system has been designed to maintain the quality of the feedwater inline with the boilers steaming rate: accurately maintaining the water at the ideal density for maximum chemical performance. Providing maximum protection whilst optimising chemical usage and minimising waste.

The microprocessor-controlled system continuously monitors and maintains the correct pH and conductivity levels of the boiler water by automatically adjusting the chemical dosing and blowdown rates according to the analysis of the measured samples. Oxygen scavenging chemicals are accurately controlled in response to the feedwater temperature and flow rate. Aquanet International have been manufacturing automated feed water management systems for marine steam boilers for 20 years and it is in use in cruise ships, Tankers, Gas Carriers, FPSO's chemical tankers world wide. It is now time for it to come ashore to protect land based boilers.

Customer List 2007 (In excess of 250 systems installed world wide)

AQ300LP System for feed and 2 boiler samples (up to 10 bar) with 4 chemical dosing pumps controlling oxygen scavenger, condensate treatment and a boiler product to each boiler., this unit also controls blowdown

AQ300HP System for feed, condensate and 2 boiler samples (up to 100 bar) shown with 4 high pressure chemical dosing pumps (flooded suction) controlling oxygen scavenger, condensate treatment and a boiler product to each boiler.
(External HP coolers not shown)
This unit also controls blowdown (up to 100 bar).

Industrial Customers

Aquality B.V.
InterBrew
Der Heel Hospital Amsterdam
Dowty (Cheltenham)
Glaxo Smith Kline UK
Intervet UK
Macau Central Power Station

Marine Customers

A P Moller
Barber Ship Management.
Bergesen Ship Management
British Gas Group
British Petroleum
Carnival Cruises
Celebrity Cruises
Cunard (QM2)
Ch' de L'Atlantique
Disney Cruises
Dynacom
Daewoo Shipping & Mechanical Eng.
Fincantieri Ship Building.
Frontier Drilling
Hapag Lloyd
Holland America Lines
Hyundai Heavy Industries
Kimman B.V.
Maersk Shipping
Maran Gas
Mitsubishi Heavy Industries
Mitsui Overseas Lines
Norfolk Line
Petrobras
Petronas
Phillips China
P & O
Princess Cruises.
Samsung Heavy Industries
Single Buoy Moorings
STASCO (Shell)
Vecom
Woodside Petroleum