Beating Boiler Failure

Over 70% of all Steam Boiler failures are attributable to Water Treatment. Who is at fault?

The design and manufacture of shell boilers is covered in British standard BS 2790: 1992 and Water tube boilers by BS 1113 :1992 and the recommendations for 'Treatment of water for steam and hot water boilers' is covered in BS 2486 :1997.

If the boilers are built to the correct standard and water treatment is correct, then why do boilers still fail?

British Standard BS 2486 gives recommendations for the control of water side conditions of steam boilers and the preparation offeed water for such plant and states in section:- ***1.2.1*** *that the objectives of water treatment are:-*

a) To contribute to the overall safety of operation of the boiler or water heater.

b) To assist in the maintenance of high heat-transfer efficiency in the boiler or water heater by:

1. *Preventing deposition of precipitated scale or other debris:*
2. *Preventing corrosion or deterioration of surfaces in contact with water;*

c) To maintain the quality of any generated steam or hot water, appropriate to the particular application

Failure to maintain suitable water conditions could compromise the in-service integrity of pressure parts and lead to danger from the unintentional release of stored energy or scalding effect of hot water or steam.

The recommendations should be used as guidelines, and reflect good operating and design experience gained from industry and boiler manufacturers. Good water treatment practice is dependent on a suitable treatment regime for the whole system. Modern steam boilers are fitted with automatic controls to provide good quality steam whilst improving the reliability of the boiler plant operation and the efficient conversion of fuel into heat energy.

The basic efficiency of a boiler is around 80% of the gross calorific value of the fuel. The actual efficiency obtained will depend on the operating conditions, type of fuel and whether economisers or air heaters are installed.

Much is made of the need to ensure correct combustion, water feed and Total dissolved solid levels but little attention is paid to the chemical dosing and the cause and effect of under or over dosing.

Traditionally, custom and practice has stated that boiler water should be manually tested on a daily basis and corrective adjustments made based on the results.

However, BS 2486:1997 states under section 2.5 Sampling and Testing:

"As a minimum, boiler water, feed water and condensate should be tested once per day and the ion exchange plant should be tested three times a day"

If custom and practice is correct, have you ever considered why more than 70% of all recorded boiler failures are accredited to incorrect water treatment?

The rule of thumb that governs the testing of boiler water has its roots way back in the past when the 'Lancashire Boiler' reigned supreme.

The design and construction of boilers has changed considerably since then. For the same steam output, boiler size has reduced and the steam release rate increased. Originally creating difficulties with steam quality and boiler control but a better understanding of the dynamics of steam production and modern controls have overcome the problems experienced all those years ago.

Steam boilers are designed to deliver dry steam and are fully automatic in operation. With modern controls that comply with the Health & Safety Guidance Note PM5 or Safed Boiler Guidelines Document PSG2 Arrangement 3, they can operate without manual intervention save for the weekly evaporation test to ensure that the safety alarm systems operate correctly.

Yet, when it comes to water treatment, we rely on custom and practice established more than 60 years ago and carryout a daily water quality test. Don't We?

Why then are so many boiler failures attributable to water treatment?

The efficiency of any heat exchanger is governed by the cleanliness of the primary and secondary side heat exchange surfaces, whether that is a calorifier, plate heat exchanger or a steam boiler.

The maximum steam output from a boiler at any given pressure is governed by the rate at which heat can be supplied and transferred in the boiler.

If steam demand exceeds the rate of heat transfer the pressure will fall and if the fall is sufficient, carryover and instability will result.

Chemical deposits or scale inhibit or restrict heat transfer, boiler efficiency falls and the possibility of failure increases.

Boiler feedwater is treated to prevent scale forming on the heat transfer surfaces and to prevent water side corrosion. Excessive concentrations of dissolved and suspended solids must be avoided if foaming at the interface of water and steam is to be controlled and carryover and instability avoided.

Modern Steam Boilers have a high heat transfer rate: impurities in the feedwater can cause scale or chemical deposits to form and reduce the rate of heat transfer from the tube walls to the water, overheating the metal surfaces whilst reducing the steam output.

Given that over 70% of all recorded boiler failures are attributed to feedwater treatment, it is in the interest of the operator to ensure that water quality is correct and thereby ensuring the cleanliness of the heat transfer surfaces.

Over dosing can lead to a reduction in efficiency, an increase in blowdown and energy wastage, under dosing leads to premature failure.

How much does it cost to descale a boiler?

What is the average cost of a retube, with hire boiler costs and lost production?

What is the cost in fuel with an increased blowdown rate?

The three main criteria that require constant monitoring are:-

1. Boiler feedwater (temperature & flow rate)
2. Chemical composition of the boiler water
3. Dissolved and Suspended solids content

Boiler Feedwater Temperature

If the actual temperature 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 following table illustrates the quantity of oxygen dissolved in water in a hotwell for various temperatures.

Temperature	Dissolved Oxygen
60°C	5mg/litre
80°C	3mg/litre
95°C	1mg/litre

The oxygen reacts with the iron in the boiler to form red oxide as Fe2O3, that is every 3 molecules of oxygen will react with 2 molecules of iron and be converted to rust.

If this is considered in terms of atomic weights (using 16 for oxygen and 56 for iron) then every 3mg of Oxygen can remove approx 7mg of iron from the boiler system.

Think of the damage that 5,000 litres per hour of poorly treated feed water at 80°C can do to a boiler operating for 10 hours a day for say 200 days per year.

$$\mathbf{7 \times 10^{-3} \times 5000 \times 10 \times 200 = 70kg}$$

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.

The problem is that even with a high proportion of hot condensate being returned to the feedwater tank, fitted with a direct steam injection heating system, it is difficult to achieve an even feedwater temperature.

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.

The feedwater tank is part of a very dynamic system with a number of variables all of which have an impact on the stored water temperature. Consider for a moment a typical system:-

On start up there is a natural time delay between steam flowing out of the boiler house and condensate returning during which time cold water is used to make up the contents of the feed tank. The temperature drops.

Initially, at start up, the returning condensate would be cooler than normal as the steam warms the plant through, but is at a higher temperature than the cold make up water, again affecting the temperature inside the tank.

After a couple of hours the system settles down and with a combination of cold water, returning condensate and direct steam injection heating system, a steady tank temperature is achieved. If it is a closed loop system with no vents, then all is well.

But most systems collect condensate in vented receivers and pump it back to the feed tank. On a system were all steam traps are working correctly, there will be a flash steam loss of between 10– 15%, based on operating steam pressure.

This 10– 15% loss has to be made up by cold water, the flow rate of which is controlled by an on/off control system supplying a relatively high volume of cold water in a very short time. This intermittent cold water addition depresses the temperature of the tank.

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:-

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

Too low a temperature and you will be under dosing for long periods throughout the day, risking oxygen attack. Too high a temperature and you will be over dosing, raising the TDS level inside the boiler, increasing the blowdown rate and wasting money.

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 reduced to 1mg/l reducing the sulphite requirement by approx 2/3rd.

Furthermore 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 reduce efficiency and increase operating costs throughout the lifetime of the boiler.

BS 2486:1997 Section 5.7.2 'Oxygen Scavenging Chemicals' states:-

"These should always be dosed continuously. The feed point should be selected so that it gives the maximum possible time for reaction. This will normally mean dosing the storage section of a De-Aerator or, where there is no De-Aerator, to the outlet of the boiler feed tank/hot well".

Given, therefore, the uncertainty of the stored feedwater temperature and the boiler demand wouldn't it make 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.

Chemical composition of the boiler water

Chemicals are added to boiler feedwater to protect the boiler shell and heat transfer surfaces from scale deposits and corrosion and in some cases to protect the process and condensate systems.

The rate of steam generation varies with time of day and production requirements yet we are apparently happy to test a sample of boiler water once a day or even twice a week and base all the chemical protection requirements on those test results.

Can we be absolutely sure that we are doing our best to protect the boiler? Over 70% of all recorded boiler failures are attributable in one way or another to the chemical treatment.

The function of a boiler is to transfer the energy in fuel into steam: it can do this efficiently only if the heat transfer surfaces within the boiler are maintained in a clean condition by the correct pre-treatment of the feedwater and boiler water.

It is generally acknowledged that the most satisfactory method of boiler water conditioning consists in accurate control of preliminary softening/demineralisation process, followed by the addition of suitable reagents in controlled proportions based on the composition of the water and the operating pressure of the boiler.

The composition of the reagents and the quantities added can only be determined by expert chemical analysis of the water supply but once determined it is essential that they are accurately applied.

Accurate chemical dosing cannot be achieved without knowing the rate at which the feedwater enters the boiler.

Testing boiler water daily and adjusting the feed rate of the chemicals based on these results presupposes that the hourly steam generation rate is constant. No matter how large or small your boiler plant, steaming rate will vary hour to hour day to day.

If you don't know how much water is being fed into your boiler how can you accurately protect it?

Wouldn't it be beneficial to all companies operating steam boiler plant to measure the boiler feedwater flow rate, automatically sample the boiler water and adjust the chemical dosing according to the results?

Aquanet International has been supplying automatic control systems to the marine industry for a number of years and many of the gas tankers, FPSO's and large cruise vessels such as QM2, Princess Cruises, Holland America Lines, install the equipment as standard so why has the land based industrial sector missed out?

Dissolved and 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%/Deg.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.

Conclusion

Well then, there it is, nobody's fault, it is just the way things are done? The fact that the way we deal with the subject of 'Treating Boiler Feedwater' has changed little over the last 60 years or so doesn't seem to matter, it's not really important is it?

After all statistically it is only 70% of all recorded boiler failures that are attributable, in one way or another, to chemical treatment. But it is not the chemicals to blame more the way they are applied. Just because it is so, doesn't mean it has to be so in the future. There is a better way.

This is the age of the computer. With modern instrumentation anything is possible even reducing the failure rate of boilers. Or does the cost of repair not concern you?

If you would like to compare your present dosing regime against an automatic system go to www.controls4steam.co.uk and click on the 'TDS & Oxy' Calculator link.