Boiler Water Treatment

Guidance for shell boilers, coil boilers, steam generators and hot water boilers

Ref: BG04

ICOM Energy Association

CEA Combustion Engineering Association

This page is intentionally blank

Table of Contents   Page

ABOUT THIS GUIDE

This comprehensive guide deals with all aspects of water treatment for steam boilers, steam generators and hot water boilers. This document applies to industrial and commercial steam and hot water boiler plant, including steam generators, operating at a working pressure of between 0.5 and 32bar gauge (except where stated) and a working temperature between 110°C and 239°C. We trust that by studying the contents and following the freely given advice your boiler plant will operate safely and more efficiently, and provide you with a trouble-free system. If in any doubt, contact your boiler water treatment expert for further advice.

Having considered who is responsible for looking after steam boilers, steam generators and hot water boilers and also who is responsible for managing the safe operation of this type of equipment, the Combustion Engineering Association (CEA) and ICOM Energy Association agreed to write this guide, with the help of our respective Members.

It is aimed as a document that can be read and understood by boiler operators, engineers and personnel with limited or no knowledge of water treatment chemistry. It is also intended to help them understand what effect any water and its subsequent treatment will have on their boiler plant.

Naturally, we cannot accept any liability for the information provided in this guide; however, be assured that we have consulted widely with our member companies during the compilation of the guide.

ACKNOWLEDGEMENTS

Specific thanks are due to David Young of Cochran Ltd who, as Chairman of the ICOM Industrial Boiler Group and the Technical Committee, as well as a Member of CEA and the chairman of this working group, has been responsible for the revision of the information which was previously in booklet format. Also, thanks go to Mick Casey of Deep Water Blue Ltd for the boiler water treatment chemistry information used when compiling the final document, and to all of those who have given their time freely and contributed to this guide.

Contributors to BG04 are:

- Deep Water Blue Ltd
- Industrial Boiler House Safety, and Chairman of the CEA
- GEMchem Ltd
- Fernox Ltd
- Aquanet International Limited
- ICOM Energy Association (ICOM)
- Combustion Engineering Association (CEA)
- Cochran Ltd
- Air and Water Consultants Limited
- Fulton Boiler Works (GB) Ltd
- Cochran Ltd

And thanks are given to the other members of both ICOM and the CEA who have been consulted.

The pictures, tables and diagrams in this guide are courtesy of*:*

- Deep Water Blue Ltd
- GEMchem Ltd
- ICOM Energy Association
- Cochran Ltd
- M&M Training
- Byworth Boilers Ltd
- Babcock Wanson UK Ltd
- SAACKE Combustion Services Ltd

SCOPE

This document applies to those industrial & commercial steam and hot water boiler plants, including steam generators, operating at a working pressure of between 0.5 and 32bar gauge and a working temperature between 110°C and 239°C.

The following boilers are specifically excluded from the scope of this Guidance Document:

- Water tube boilers such as would be found at an energy producer;
- Process Boilers with a capacity exceeding:
  - 70 tonnes steam per hour;
  - 46 MW thermal input;
  - 32 bar gauge working pressure;
- Domestic and commercial boilers smaller than 70kW thermal input;
- Manually operated boilers (i.e. those requiring constant human intervention).

This document also excludes from its scope any consequences arising from incorrect steam pressure delivery from the boiler.

THE PURPOSE OF THIS GUIDE

Boiler failures can, and do, occur more frequently than are reported. The common reasons for failures are:

- Non-operation of controls due to sludge accumulation;
- Perforation of smoke tubes due to corrosion;
- Less frequently, but even more serious, overheating, distortion and even collapse of the furnace caused by scale or other deposits.

All of the above can be avoided by correct boiler water treatment. Poor or inadequate water treatment has been shown to be the cause of more than 95% of all boiler failures. Often this is as a result of poor management of the water treatment regime by whoever is collectively deemed responsible.

All sources of water contain impurities which are harmful to steam and hot water boilers. All waters therefore need to be pre-treated and then chemically treated, either to remove these impurities or to minimise any adverse effects.

The Combustion Engineering Association and ICOM Energy Association are very pleased to be able, thanks to member input, to provide this publication relating to water treatment for shell boilers, coil boilers, steam generators and hot water boilers.

Routes to BG04 Compliance – End user Flowchart

EXISTING STEAM BOILER OR STEAM GENERATOR SYSTEM

END USER COMPANY MUST APPOINT STATUTORY DUTY HOLDER FOR THE BOILER.

USUALLY IT IS A COMPANY DIRECTOR OR SIMILAR

SDH APPOINTS A RESPONSIBLE PERSON (RP).

SDH CAN ALSO ASSUME RP POSITION FOR ANNUAL LEAVE OR SICKNESS ETC.

RP MANAGES SYSTEM

THE STATUTORY DUTY HOLDER (SDH) and the RESPONSIBLE PERSON (RP)

Please read the notes below explaining their responsibilities.

- CARRY OUT BOILER WATER TREATMENT RISK ASSESSMENT TO BG04.
- USE A SPECIALIST IN BOILER WATER TREATMENT TO HELP.
- STATUTORY DUTY HOLDER IS NORMALLY RESPONSIBLE FOR THIS TASK BUT IT CAN BE DELEGATED TO THE RESPONSIBLE PERSON

BOILER WATER TREATMENT RISK ASSESSMENT MUST BE COMPLETED IN ORDER TO PRODUCE BOILER WATER TREATMENT WRITTEN CONTROL SCHEME

ASSIGN OR VALIDATE BOILER WATER TREATMENT WRITTEN CONTROL SCHEME

NEW STEAM BOILER OR STEAM GENERATOR SYSTEM (WHICH MUST BE ONLINE AND OPERATIONAL TO CARRY OUT A VALID BG04 RISK ASSESSMENT)

- The Statutory Duty Holder (SDH) has to initiate the "Boiler Water Treatment Risk Assessment" and may then pass responsibility for the "Boiler Water Treatment Written Control Scheme" to the Responsible Person (RP) in order to carry this out.
- The SDH has to be in overall control of the boiler water and steam system operation. But the SDH can delegate the management of the system to the RP, who can in turn, pass parts of that responsibility to other employees or contractors as long as it is clearly written and noted in the "Boiler Water Treatment Written Control Scheme" and BG04 Boiler Water Treatment Risk Assessment documents.
- The management and recording of the boiler data for both the waterside and the steam side are critical within your programme. Only personnel who have been formally trained and who are deemed competent in boiler water treatment are to be involved in any and all changes that affect the water chemistry.

GENERAL NOTES

1. **PSSR 2000**

Regulation 11 of the Pressure Systems Safety Regulations 2000 requires boiler users to provide operators with adequate and suitable instructions for the safe operation of the boiler, and to ensure that the boiler is not operated, except in accordance with these instructions. Pressure Systems Safety Regulations 2000 Approved Code of Practice (L122) specifically para 152 (a) refers to the feed water treatment.

Summary (not part of the ACoP) – Steam Boiler Water Treatment Training

95% of significant or catastrophic failures in steam boilers can be traced back to poor or inadequate management of the water used to make the steam.

If you have a steam boiler on your premises it must be operated in accordance with PSSR. The duty is a corporate responsibility (clause 46), usually resting with the most senior person on site. The Regulations are concerned with steam at any pressure (clause 6). Once a pressure system is installed, the primary duty for compliance rests with the user (clause 26).

The PSSR ACoP has a special legal status. If you are prosecuted for breach of health and safety law, and it is proved that you did not follow the relevant provisions of the ACoP, you will need to show that you have complied with the law in some other way or a Court will find you at fault.

The user must five operational employees adequate instruction so that the boiler can be operated safely (clause 145 ACoP). These must include, for a steam boiler, instructions covering feed water treatment (clause 152a).

All reports which contain information relevant to the assessment of matters of safety in relation to the operation of the pressure system must be kept (clause 179 ACoP). This will include reports of water quality that should be used to assess whether the boiler is operating under the correct waterside conditions.

Under PUWER, all employees required to use equipment at work must be trained and competent to do so (clause 144). This will therefore extend to their training and competence to operate and manage feed water treatment plant for steam boilers.

As the user of the pressure system, if the Competent Person you engage says the boiler is not fit for service because of a defect (e.g. excessive scale caused by incorrect water treatment procedures being followed), you must not use the boiler until the defect and the cause of the defect is repaired (clause 138), and the Competent Person will report this finding to the HSE (clause 141).

The ACoP will be used in any prosecution, and this may be for failure to meet the requirements of the ACoP or supporting guidance, not waiting until there is a fatality. Training for operatives in how to assess the effectiveness of steam boiler water treatment is therefore a legal requirement.

Note: Please see item 1.4 which are extracts copied from PSSR ACoP

2. **COSHH 2002**

The Control of Substances Hazardous to Health (COSHH) Regulations 2002 requires an assessment of the risk of exposure to substances hazardous to health and implication of the control measures needed to prevent, or if that is not reasonably practicable, adequately control such exposure. All sources of exposure in the workplace are covered, including releases resulting from explosion or venting. For further information, users are advised to consult the Control of Substances Hazardous to Health 2002 (Available from hse.gov.uk)

3. Whilst every care has been taken in the preparation of this guidance, please note that this should only be considered as general guidance. The user is directed to follow any mandatory local, national or international laws or statutes that are in force in the place of use of the boiler. Additionally, any guidance or operational instructions given by the equipment manufacturer should be followed closely. Where there are any doubts, the guidance of a boiler water treatment specialist should be sought.

4. MHSWR 1999

The Management of Health and Safety at Work Regulations 1999 places a duty on employers to assess and manage risks to their employees and others arising from work activities.

Employers must also make arrangements to ensure the health and safety of the workplace. This includes making arrangements for emergencies, availability of adequate information and provision of training for employees. Health surveillance of employees should also be provided, where appropriate.

Employees must work safely in accordance with the training and instructions given to them. Employees must also notify the employer or the person responsible for health and safety of any serious or immediate danger to health and safety or any shortcoming in health and safety arrangements.

5. BS EN 12953

The BS EN 12953 series of standards applies to the design, construction, testing, inspection and operation of electrically heated and directly fired shell boilers (including low pressure and heat recovery boilers) intended for land use with volumes in excess of 2litres, used for the generation of steam and/or hot water at a maximum allowable pressure greater than 0.5bar and with a temperature in excess of 110°C. It applies to the generator from the feed-water or water inlet connection to the steam or water outlet connection and to all other connections, including the valves and steam and water fittings.

The purpose of the BS EN 12953 series is to ensure that the hazards associated with the operation of shell boilers are reduced to a minimum and that adequate protection is provided to contain the hazards that still prevail when the shell boiler is put into service. The BS EN 12953 Shell boilers series supersedes BS 2790:1992 and BS 1894:1992. You may obtain all parts of BS EN 12953 separately but they are inter-dependent and the design and manufacture of a shell boiler may require the application of more than one part of the standard to ensure that all the necessary requirements are met.

6. BS EN 12953 – Part 10

This part of the European Standard applies to all shell boilers as defined in EN 12953-1 which are heated by combustion of one or more fuels or by hot gases for the generation of steam and/or hot water.

It applies to those components between the feed water inlet and the steam outlet of the steam generator. The quality of the steam produced is outside the scope of this standard.

It aims to ensure that the boiler is able to be operated to minimise risks to personnel, the boiler and associated plant components located near it.

Note: This part of the European Standard does not aim to achieve optimum economic operation. For certain purposes it will be more appropriate to optimize the chemical characteristics in order to:

- Increase the thermal efficiency;
- Increase the availability and reliability of the plant;
- Increase the steam purity;
- Reduce the maintenance costs - repair, chemical cleaning, etc.

It sets out minimum requirements for the specific types of water to reduce the risk of corrosion, sludge precipitation or formation of deposits that may lead to any damage or other operating problems.

Note: This part of the European Standard has been prepared on the assumption that the user of this European Standard possesses a sufficient knowledge of the construction and operation of the boiler as well as an adequate appreciation of water and steam chemistry.

7. **RIDDOR**

The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013, often known by the acronym RIDDOR, is a UK Statutory Instrument. It regulates the statutory obligation to report deaths, injuries, diseases and "dangerous occurrences", including near misses, that take place at work or in connection with work.

The regulations require "Responsible Persons" to report deaths at work, major injuries caused by accidents at work, injuries to persons not at work that require hospital treatment, injuries arising from accidents in hospitals, and dangerous occurrences (reg.3 (1)). Additionally, the law requires registered gas fitters to report poor and dangerous gas installations (reg.6).

Responsible Persons are generally employers but also include various managers and occupiers of premises (reg. 2). Though the regulations do not impose a specific obligation on employees, they have a general obligation under section 7 of the Health and Safety at Work etc. Act 1974 to take care of safety. The Health and Safety Executive recommends that they report incidents to their employer and encourages voluntary notification to the relevant regulating authority.

Note: In 2015 a person was killed by a boiler explosion in Belgium whilst in the vicinity of the boilerhouse. They were not working in or on the boiler at the time of the explosion, but were the innocent victim of the explosion. As a result, this multinational company introduced a complete review of all boilerhouse systems across Europe, unearthing some worrying facts.

In 2014 a boiler explosion at Immingham destroyed a boiler after a process component failure contaminated the boiler’s condensate recovery, which then affected the boiler safety systems; fortunately there were no fatalities but the situation could easily have resulted in loss of life.

In 2015 several boiler furnaces have been close to collapse, witnessed by the bulging that takes place as the metal softens and it can no longer withstand the boiler pressure (see fig 8). These instances could have easily resulted in a boiler explosion and should be reported, but are often overlooked and mistakenly not reported under RIDDOR.

It is the legal duty of the Competent Person under the PSSR 2000 ACoP (L122) 2014 to report any faults or dangerous situations they witness when carrying out annual inspections.

Figure 2 – Cut away section of a standard Shell Steam Boiler

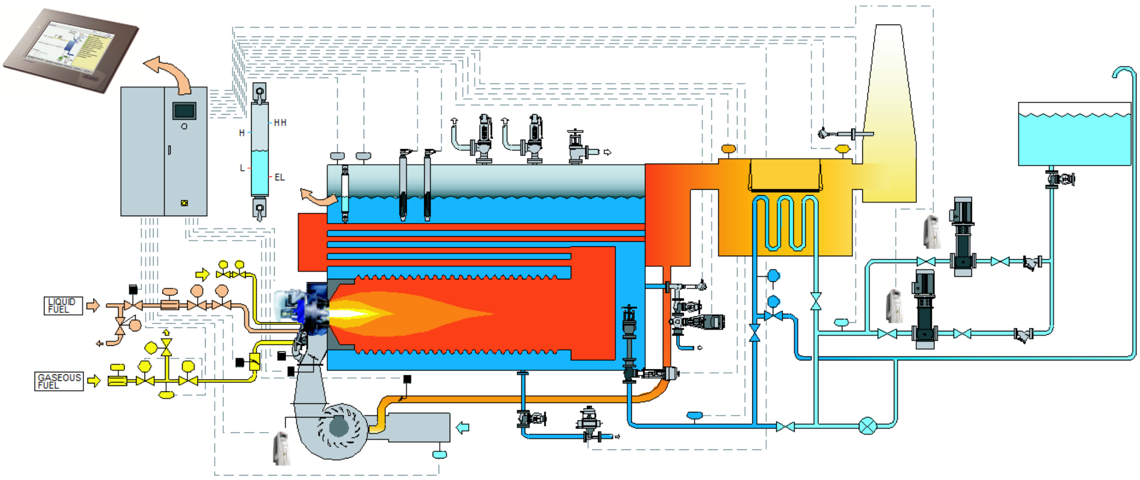
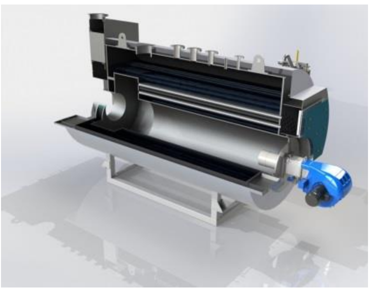


Figure 3 – Example - sectional diagram of a standard Shell Boiler system and controls



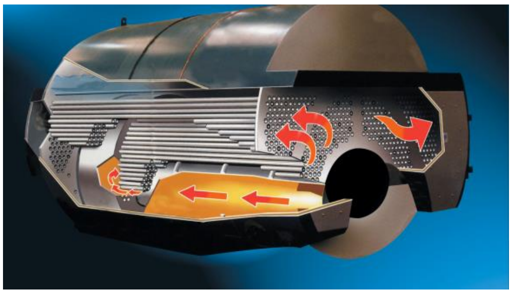


Figure 4 - Cut away image of standard shell boilers and a boiler under construction

1 INTRODUCTION TO…

1.1 Scale

Many waters when heated cause scale to form on the heated surfaces. Scaling of a domestic kettle in hard water areas is a typical example. If heat transferred from the burner through the furnace tube to the water in a steam boiler, or from the burner to the coil in a coil boiler or steam generator, were to be impeded by scale, the result could be serious; for example, the temperature of the metal of the furnace tube in a shell boiler would rise and could reach softening point. At this stage, it would become unable to bear the stress upon it and it would fail by distortion or fatigue.

A steam generator coil would eventually block, raising the safety valve initially and eventually shutting down. Such failures and shut downs occur, even today, as a result of using water of unsuitable composition. Some failures can be catastrophic in nature and may lead to significant damage, including possible loss of life.

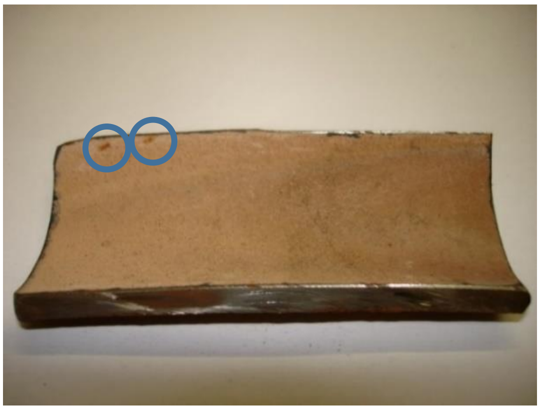


Figure 5 - Scaling of the internal surfaces of a coil boiler with corrosion underneath the scale as highlighted.

Figure 6 - Scaling of the external surface of a tube in a shell boiler

Waters containing salts of calcium and magnesium are described as hard. Hard waters are potentially scale-forming, especially when heated. To avoid scale formation, these salts can be removed and the waters are then described as soft. Softened waters do not deposit calcium carbonate scale but, of course, still contain dissolved solids. Even with suitable, sufficient and effective pre-treatment plant however, softened or otherwise treated water requires further conditioning to avoid scale, corrosion and precipitation leading to sludge and deposit formation.

Boilers and steam generators that contain scale require more heat input to achieve the same steam output, resulting in higher energy consumption and overall loss of efficiency. The thicker the layer of scale, the higher the loss in efficiency and the more it will cost to operate.

Get it right…

Inspection and monitoring

Get it wrong…

Figure 7: In the three images above the one on the left indicates what a very good boilerhouse should look like when you get it right. In the centre is a typical but large dual furnace shell boiler showing the internal complexity and the need for regular statutory inspection by a competent authority. On the right the aftermath of a boiler explosion and the devastation that can be caused when you get it wrong. Steam boilers are safe if well managed and maintained; steam or hot water boilers will give decades of good reliable service, but water treatment is a key component in that longevity. Poor water treatment can give rise to a failed boiler in a matter of months.

Figure 8 - Boiler Furnace Deformation.
This could have been a complete catastrophe

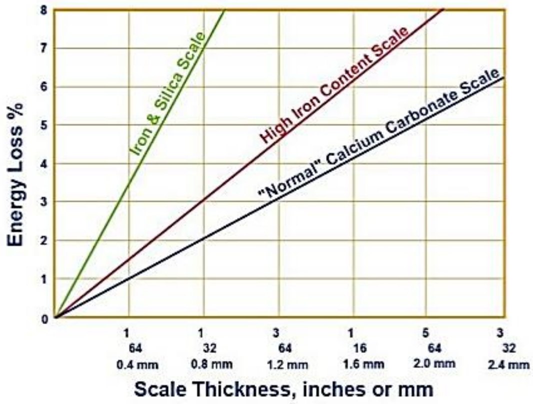


Figure 9 – Energy loss from scale deposits.

Whatever system of water treatment is used, it is essential to blow down sufficient boiler water (or in the case of a steam generator the feed water/boiler water) to maintain the total dissolved solids (TDS) at the level recommended by the boiler manufacturer or water treatment consultant (Ref. Table 2; see page 26). This is particularly the case with steam boilers. It should be borne in mind that in the case of shell boilers, this type of surface blowdown is specifically carried out to control TDS levels and is for a different purpose to bottom blowdown that should be performed to control mobile sludge accumulation. Bottom blowdown is best carried out as a pulsed blowdown as this sets up a wave action in the bottom of the boiler, moving the mobile sludge towards the blowdown valve and ultimately out of the boiler. This is also discussed in Section 1 (see page 18) and a formula given for determining the percentage blowdown needed.

1.2 Corrosion

Corrosion is electro-chemical in nature and any, or all, of four basic reactions may proceed according to prevailing conditions. Generally in boiler water treatment the most well-known form of corrosion is called pitting attack, and for this to take place oxygen must be present, sometimes in a non-alkaline environment. By eliminating this substance and ensuring that the correct alkalinities are maintained at all times, corrosion in the boiler will be controlled and the metal life extended substantially. For example, there are now many shell or coil boilers which have been in daily use for 15 years or more which have not been re-tubed or had the coil replaced; others, due to corrosion, can fail within a year.

Another type of corrosion involves copper, sometimes as a result of corroding condensate return pipework (when piped in copper, often found to be the case in hospitals) or a corroded heat exchanger, for example. This can lead to copper returning to the boiler and plating out within it.

De-aeration (oxygen removal) is normally a combination of physical and chemical processes. It should be remembered that effective chemical de-aeration can only take place when the steam system and the management of it are correctly operated.

The water chemistry should never be held accountable for system and/or site management failures. In the case of investigation of boiler failures due to suspected corrosion, it is prudent to engage a specialist in this matter in order to ascertain the true mechanism of failure. Also, see glossary of terms related to corrosion.

Figure 10 - Historic corrosion pit covered by a new magnetite layer after an acid clean

1.3 Foaming and Priming

Foaming is the release of foam bubbles out to the steam main, and **priming** is the release of water droplets carried over into the steam main.

There is always a degree of carry-over of water with the steam generated from a shell boiler and this is referred to as “steam dryness”, far less so with steam generators. Shell boilers tend to be far more susceptible to carry over than coil boilers. Under certain conditions when contaminants are present the boiler water may foam or prime badly, and this can cause a number of difficulties:

a) Gross carry-over of boiler water into the steam main can occur. Traps may be overloaded and pipes flooded, leading to dangerous water hammer. Water hammer occurs when slugs of water travelling at speeds between 90kph and 145kph enter the steam main and can cause serious damage.

Note: A well-designed steam system will have steam velocities at 25m/sec (90kph) and up to 40m/sec (145kph). Anything above 40m/sec is deemed “bad practice”.

b) Water level controls are designed to operate in water, not in foam, and lockout of the boiler may result.
c) Foam in contact with heated surfaces does not conduct heat away from them as effectively as water. As a result, the boiler metal may overheat, perhaps dangerously.
d) Carryover as a result of foaming can precipitate out and dry within the steam system, resulting in a subsequent reduction in heat transfer and operational issues with equipment, such as blocked steam traps and valves.

Substances that can cause foam to form include detergents, oils, fats and solids suspended in the boiler water. General guideline parameters to the propensity of the boiler water to form foam, or to carry over, are the Total Dissolved Solids (TDS) content and the Suspended Solids content, both of which increase the tendency to foam as their concentrations rise.

This tendency to foam may also be enhanced by the presence of high caustic alkalinity levels. This can be due to overdosing of chemical, high TDS, or process contamination. Carryover, if left unchecked, can cause serious system damage downstream of the boiler.

Note: There are other factors that can affect shell boilers and the way that the water inside the boiler reacts to certain load conditions. These cannot be covered in this guide as the loads, site conditions and boiler configuration may be unique to that site, creating unusual effects.

2 SCALE AND DEPOSIT FORMATION

Deposition on heat transfer surfaces can occur by a variety of processes. The main cause of deposition is scaling, but corrosion products and organic fouling can also lead to deposit formation.

2.1 Scale formation

A simplified explanation of scale formation:

Calcium, magnesium and silicon are the main types of deposit formers. Calcium and magnesium behave similarly, so only the classic explanation of scale formation for calcium is described. Dissolved compounds of silicon are discussed separately below.

In nature, rain falling through the atmosphere dissolves carbon dioxide (among other impurities) to form carbonic acid.

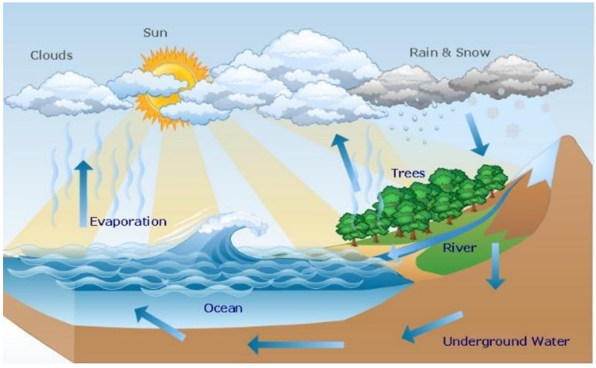


Figure 11 – Natural Water Cycle

H_2O rain	+	CO_2 carbon dioxide	=	H_2CO_3 carbonic acid

Depending on the geographical location, this acid dissolves calcium carbonate (chalk) (amongst other impurities and at atmospheric temperature) from the rocks over which it passes to form calcium bicarbonate.

H_2CO_3 carbonic acid	+	$CaCO_3$ calcium carbonate	=	$Ca(HCO_3)_2$ calcium bicarbonate

Subjected to high temperatures, such as occur in boilers, the bicarbonate breaks down with liberation of the original carbon dioxide to deposit chalk scale.

$Ca(HCO_3)_2$ calcium bicarbonate	+	heat	=	$CaCO_3$ chalk scale	+	H_2O water	+	CO_2 carbon dioxide

In a steam boiler, the lime scale deposits out on the heat transfer surfaces and the carbon dioxide gas, evolved from the breakdown of bicarbonate alkalinity under temperature and pressure in the boiler, then passes out with the steam.

The traditional term referred to as "temporary" hardness derives from this process. Modern nomenclature uses the term "alkaline" hardness.

In a similar manner, rain dissolves sulphurous gases from the atmosphere to form an acid that reacts with rocks etc. to produce calcium and magnesium sulphates. Other calcium and magnesium salts are commonly found in water, these being calcium and magnesium chloride and nitrate. These sulphur, chloride and nitrate salts do not break down under the conditions found in boilers or steam generators. Because of this, the process was described as "permanent" hardness, nowadays referred to as "non-alkaline" hardness.

"Permanent" or "non-alkaline" hardness salts precipitate when concentrated beyond their solubilities. The solubility of calcium sulphate decreases with increasing temperature and thus scale is likely to form if water containing calcium sulphate (gypsum) is heated.

The compounds of silicon associated with boiler operation are generally described as silica, and these can form particularly hard-to-remove scales of very low thermal conductivity. Protection against these very troublesome scales is by either correct pre-treatment such as reverse osmosis (the preferred option) or by keeping the silica in solution and at a safe level. To do this, the recommended caustic alkalinity to silica ratio must be maintained in the boiler water and/or a maximum level of silica, consistent with the boiler operating pressure, must be maintained and kept within the parameters set by the relevant standards. Control is by regular and frequent chemical testing, coupled with the suitable pre-treatment and operational standards. Silica levels should be monitored on a very regular basis.

Silica can combine with traces of metals to form complex silicates that are extremely difficult to remove.

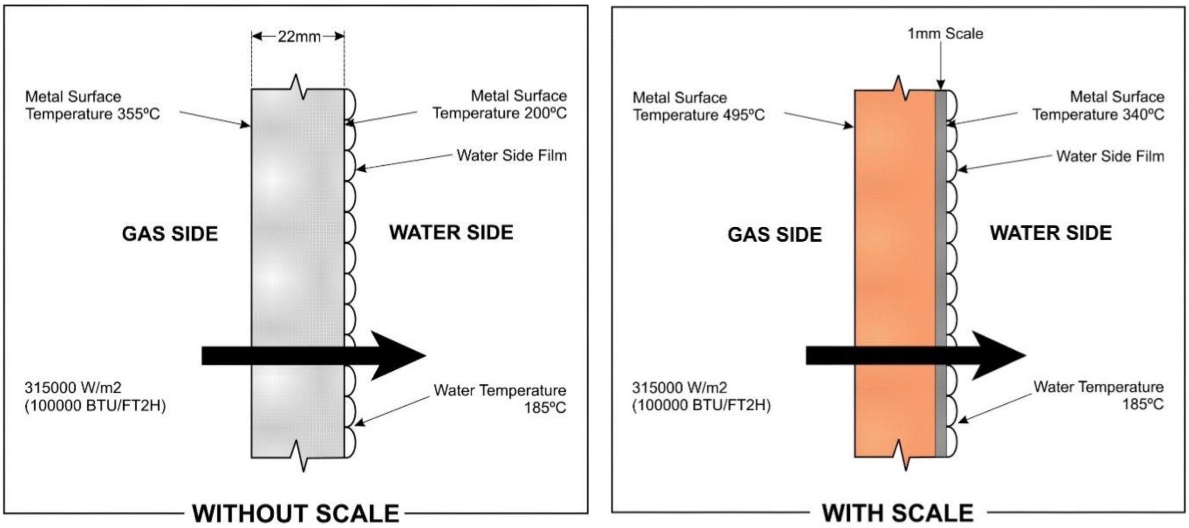


Figure 12 – Metal temperatures in boiler plate with and without scale

If, in spite of adhering to all the recommendations given in Table 2 (see page 23) it is suspected that silica-bearing scales are present, advice must be sought at once. Initially, advice should be sought from the boiler water treatment specialist, the boiler maker and the competent person for the WSE. Failure to control silica scaling can lead to severe overheating and to very expensive repairs.

Figure 12 illustrates how the metal temperature in a boiler furnace plate increases, under the conditions indicated, as a result of the thermal impedance of a layer of average boiler scale on the waterside surface. For a given heat flux, the metal temperature will increase as the thickness of the scale increases. If the temperature of the steel exceeds that at which creep begins to dominate, elasticity or deformation may occur. This can result in leaking tube-plate joints, cracked tube and furnace ends, cracked ligaments and in extreme cases, furnace collapse.

Typical Boiler Scales and their Thermal Conductivities		
Scale Substances	**Conductivity**	
	Btu in/ h ft^2 °F	W/mK
Calcium Carbonate	6.0 - 18.0	0.9 - 2.6
Calcium Sulphate	12.0 – 23.9	1.7 – 3.4
Complex Silicates	1.5 -5.0	0.2 – 0.7
Average Boiler Scales	15.6	2.2

Where:

Btu = British thermal unit – a traditional unit of work equal to about 1055 joules. It is the amount of work needed to raise the temperature of one pound of water by one degree Fahrenheit

in/h ft^2 °F = inch per hour per square foot per degree Fahrenheit

W/mK = Watts per metre per degree Kelvin

Table 1 - the thermal conductivities of various scales.

Note: The very low thermal conductivities of silicate scales.

Different types of scale have different thermal conductivities and therefore thickness alone is not a true measure of potential danger.

Note: A damaged leaking tube in a boiler can often be observed by a plume of steam at the stack, and the result if not addressed quickly (as in this case below) can result in:

- Excessive scale build-up around tube end plates and on the inner surface of the tubes;
- The bottom of the smoke box becoming filled with solid deposits, from where the boiler water had been flashing off to steam for an extended period;
- The boiler itself starting to overheat, thereby becoming extremely dangerous!

Figure 13 - A plume of steam from the stack

Figure 14 – Deposition caused by a leaking boiler tube

To avoid scale formation and to improve water quality entering the boiler or steam generator, one of several pre-treatment methods (described as follows) is normally used. Even after pre-treatment, the water will always require further conditioning to protect against, for example, traces of hardness passing through the softener, transient mal-operation and corrosion.

For shell or coil boilers, such conditioning typically takes the form of:

- calculated additions to the pre-treated feed water of a sludge conditioner to precipitate remaining traces of hardness salts, and
- an alkali booster to ensure that the pH is correct in order to avoid corrosion in the pre-boiler system and in the boiler itself, and
- a suitable oxygen scavenger in order to remove any final traces of oxygen after some form of physical de-aeration, such as the use of a steam sparge at its most basic level.

Note: if you look into the furnace and see white deposits accumulating on the surface of the furnace it indicates a possible tube leak and hence deposition of previously dissolved solids.

Please note that there are many types of water treatment products available on the market and it is the end user's responsibility to ensure that the treatment programme that is going to be applied to their coil or shell boiler is correct both for the unit itself and for its intended operation.

It is not correct simply to assume that one style of chemical treatment programme suits all types of steam boilers or steam generators and perhaps more importantly, the chemical programme must also take into account what the steam is likely to be used for.

Not all chemical programmes are suitable for all industries and some products are strictly controlled in terms of acceptable levels within steam or their application banned altogether in, for example, milk or in the production of milk products.

If in any doubt, you should contact a boiler water treatment specialist who has a proven track record in water treatment for steam systems.

2.2 Pre-Treatment Methods

The main types of pre-treatment processes are:

a) Those based on ion exchange, principally simple base exchange but sometimes de-alkalisation and occasionally demineralisation, and
b) Those based on reverse osmosis.

2.3 Filtration

It is extremely important that when utilising boiler pre-treatment plant of any type the water supply to it is clear and free from large amounts of contaminates, such as suspended solids, iron and manganese, since all of these items have the ability to reduce the efficiency of, and/or damage, downstream plant.

This is not usually a problem when using a town mains supply, but can be a significant issue when utilising a natural water source such as a spring or well.

In cases such as these, a multi-stage treatment and filtration plant in advance of the boiler pre-treatment plant may be required.

It is prudent to contact a specialist before utilising any water source, including town mains, so it can be analysed and a suitable and correct treatment system be proposed.

2.4 Base Exchange Softening

Ion exchange is widely used in many kinds of industrial processes for water softening. Boiler feed Base Exchange plant is the cheapest to buy and simplest to run.

This type of plant consists of a vessel(s) containing a specially prepared resin through which water is passed. In this vessel, calcium and magnesium ions are exchanged for sodium ions, the products being sodium bicarbonate from the alkaline hardness salts and sodium nitrate, chloride and sulphates from the non-alkaline hardness salts. These sodium salts are very soluble and do not form scales when the boiler water T.D.S. (Total Dissolved Solids) is maintained at or below the recommended level. When the ion exchange capacity of the resin is exhausted, it is regenerated with brine solution, produced from granular, pellet or pure dried vacuum salt, the calcium and magnesium ions being flushed to drain and replaced by sodium.

Figure 15 – Typical softener

It is important to ensure that your softener is filled with the correct type of salt, as recommended by the unit manufacturer, otherwise blockages and plant failure can occur.

Figure 16 below shows the general arrangement of an automatic base exchange plant. Regenerated with brine and given annual maintenance and a regular resin change every five years, such plant will produce soft water cheaply and reliably. Maintenance and resin changes may need to be carried out more often if, for example, the quantity of soft water produced between regenerations falls off significantly. Water softeners can be used successfully even in high alkaline hardness districts, such as the South East of England, provided that there is a reasonable amount of condensate return. However, in cases where there is little or no condensate return, reverse osmosis or dealkalisation/base exchange may be necessary.

2.5 Base exchange softener – cycle

1. Water passes downward through the resin in its regenerated condition until the resin becomes exhausted, as shown by hardness breakthrough.

2. Unit is taken out of service - where two units are run as a duplex system, the standby unit goes into service as the unit previously in service goes into regeneration.

3. Resin bed is backwashed to remove debris and loosen the bed.

4. Saturated brine is run through the resin bed to regenerate it. Calcium and magnesium chlorides and excess sodium chloride runs to drain, followed by rinse water.

5. Unit is ready for service.

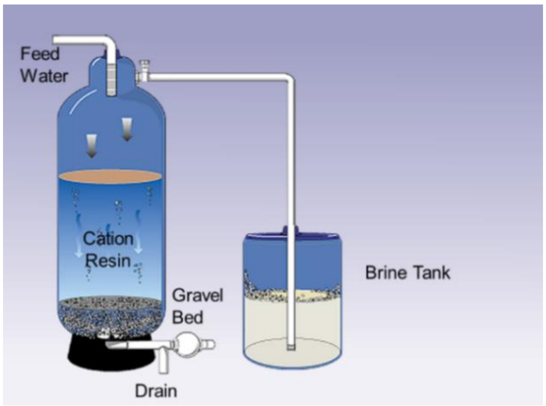


Figure 16 – Base Exchange Softener

2.6 Reverse Osmosis (RO)

Introduction

Reverse Osmosis (RO) is a process finding increased applications for boiler feed make up and offers a safer and more reliable method (over historical methods) of producing high purity water for boiler feed.

Reverse Osmosis has become the main source of corrective pre-treatment after softening, overtaking dealkalisation and demineralisation in eliminating the major components of make-up water contamination.

Figure 17 - RO & Water Softening installation

With improved technology and higher recovery rates, the cost of production and the COSHH benefits make it the technology of choice for producing high purity water.

Osmosis is a natural process involving fluid flow across a semi-permeable membrane barrier. If a solution of salts is separated from pure water using a basic thin semi-permeable membrane, the pure water passes through the membrane and tries to dilute the salt solution.

The osmotic pressure can be measured and is shown diagrammatically below:

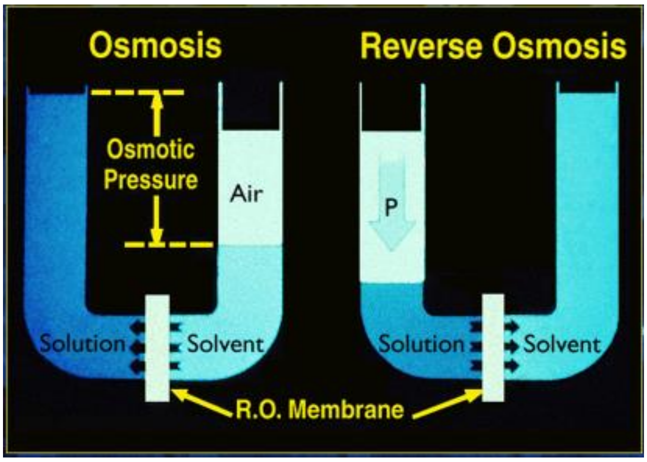


Figure 18 – Diagram of Osmosis and Reverse Osmosis Process

This process can be reversed - hence 'Reverse Osmosis' - by applying a counter pressure to the salt solution. Pure water will then pass the other way through the membrane in a process that is easy to visualise as 'pico filtration', where the membrane will only let through the small water molecules and retain almost all of the other molecules.

2.7 Membrane Construction

The semi-permeable membrane for reverse osmosis applications consists of a thin film of polymeric material, a fraction of a millimetre thick, cast on a fabric support.

Commercial grade membranes have high water permeability and a high degree of semi-permeability; that is, the rate of water transport is much higher than the rate of transport of dissolved ions. The membranes are stable over a wide range of pH and temperatures. These membranes have good mechanical integrity, often giving a useful life of between 3 to 5 years, or even up to 10 years if the incoming water to the RO unit is base-exchange softened in advance.

There are a number of different materials used for membranes and several ways of constructing them. Often, the membrane is sited in a high-pressure housing with seals at each end. Water under pressure is introduced into one end of the housing/membrane assembly so that it runs between the feed channel spacer, concentrate being either discharged or recirculated and permeate output collected and stored or transferred directly into the boiler or steam generator hotwell, with suitable heat sink and non-return valve precautions.

2.8 High Pressure Pump

In order to develop sufficient water pressure to overcome the osmotic pressure of the feed water and produce an acceptable volume of permeate, a high pressure pump is used to boost the system to a pressure that will overcome the osmotic pressure and any mechanical characteristics of the system.

2.9 Recirculation

Membranes will normally each 'recover' only 10-15% permeate (pure water) from the raw water without fouling. However, by returning a proportion of the concentrate (reject water) exiting from the final membrane to the inlet of the high pressure pump the flow across the surface of the membrane is dramatically increased, allowing a recovery ratio of between 75% and 85% to be achieved without significant fouling, especially when softened water feed is utilised. Recirculation also allows a higher flow of water through the pump, reducing the load on its bearings and helping the pump to run cooler. Many RO plants are now controlled using variable speed drive pumps that respond to changes in water quality and also temperature and flow variations.

2.10 Recovery

The 'recovery' of a Reverse Osmosis System is a measure of the proportion of the total input water that is converted to high quality permeate. At high recovery ratios, the amount of solids in the concentrate water as it exits the membrane will be high which will result in a higher level of solids in the permeate. However, by reducing the recovery, the operating pressure in the system can sometimes be reduced, which in turn can also result in a raised level of dissolved solids in the permeate since rejection rates can be better at higher pressures.

A balance of the optimum water quality and volume is usually found at recovery ratios of between 75% and 80% when pre-softening is used. Recovery rates are lower when only anti-scalant dosing is used.

2.11 Rejection

The rejection ratio is a measure of the dissolved solids content of the raw water that is 'rejected' by the membrane. At 99% rejection on a raw water supply of 400ppm, it would be feasible to expect a permeate quality of 4ppm. However, by running single membranes at high recovery levels with considerable recirculation, it would mean that the membrane actually 'sees' a raw water of 1000-1500ppm which could give a product water quality of 10-15ppm.

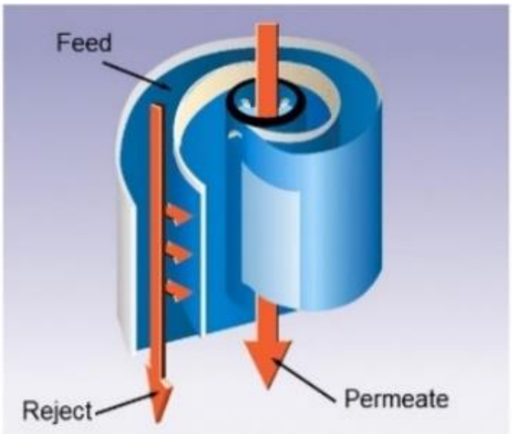


Figure 19 - Reverse Osmosis Process

2.12 Flush

In order to remove fouling that accumulates during service it is essential to periodically flush the membrane, normally at a high water flow rate. Modern membrane design aids the cleaning of contact surfaces by the design of the spacers incorporated into the spirally wound membranes.

2.13 Pre-Treatment for a Reverse osmosis plant

For a Reverse Osmosis plant to function as efficiently as possible, the raw water feeding the system needs to have its hardness reduced by a water softener or inhibited with special chemicals that are dosed into the supply, upstream of the system.

Often duty/standby 'duplex' softening is preferred since it is very cost effective and contributes to the longevity of the membranes. The majority of RO membranes are intolerant to oxidising chemicals such as chlorine, and also to iron and manganese as well as other metal ions.

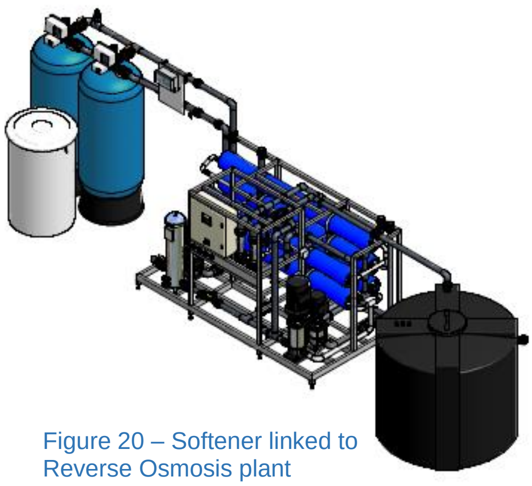


Figure 20 – Softener linked to Reverse Osmosis plant

It is good practice when fitting RO units to remove the chlorine often present in town mains water supply. The chlorine can be removed by using either a backwashing filter filled with granular activated carbon or, if the unit is small, a disposable cartridge. On larger systems dechlorinating chemicals are very often used. Certain metal ions should also be removed by pre-treatment.

Figure 21- Examples of Reverse Osmosis treatment plants

2.14 Dealkalisation

The disadvantage of the base exchange process is that there is no reduction in TDS and alkalinity. This may be overcome by prior removal of the alkalinity by preceding the base exchange softener by a dealkalising ion exchange process. This ion exchange process differs from base exchange in that the resin exchanges hydrogen for calcium and magnesium thus removing the calcium and magnesium, leaving a solution of carbon dioxide in water, normally known as carbonic acid. After dealkalising ion exchange treatment the water is passed through a degassing system where the carbon dioxide is removed. After this stage, a sodium hydroxide solution is added to raise the pH value to at least 8.5.

The water that now contains little alkaline hardness is passed through a normal base exchanger where the non-alkaline hardness is removed. The dealkalising stage is regenerated with acid and the base exchange stage with salt brine in the normal manner. The total dissolved solids content and the alkalinity of the treated water are reduced by an amount below the alkaline hardness content of the raw water.

2.15 Demineralisation

For packaged steam raising shell boilers demineralisation can seldom be justified, since both capital and running costs are many times higher than simple base exchange. However, for very high pressure boilers this type of treatment may be justified as being essential.

Demineralisation works by removing the cations of dissolved salts in one part of the process and the anions in another, thus producing water of a very high quality that contains virtually no dissolved solids.

An increasingly common method of producing very pure water without the need for acid and caustic regenerants is to use Continuous Electrodeionisation that involves the use of reverse osmosis and potentially degassing as pre-treatment.

For hot water boilers using only a small amount of make-up, demineralisation or reverse osmosis can sometimes be economic and is an option, albeit that significant numbers of systems in the UK operate with no pre-treatment, using towns mains supply.

2.16 Blowdown

Steam raising inevitably results in the concentration of dissolved and suspended solids in the boiler water. These can promote foaming and overheating if left unchecked. It is therefore necessary to control their level in the boiler by blowing down. The minimum amount of blowdown required is calculated as a percentage of the evaporation rate by using the following formula:

$$\text{Blowdown Rate} = \frac{F \times 100}{B - F}$$

F = The total dissolved solids content of the feed in parts per million

Surface (or in the case of coil boilers, carrier fluid) blowdown should be carried out continuously, using automatic TDS monitoring and control. Bottom blowdown only is used to control sludge deposition for shell boilers, this method being most effective in removing sludge particularly when applied in short sharp bursts, setting up a wave action in the bottom of the boiler.

Boiler blowdown may be carried out manually, in the case of bottom blowdown only, but must be fully automatic in the case of surface blowdown or coil feed water blowdown. There are two main types of blowdown regime commonly in use, and these can be used individually or in combination to suit each particular application.

With the potential for personal injury that may occur due to incorrect blowdown procedures, reference should be made to the relevant national standards and Health & Safety Regulations to ensure the system used is safe and fully compliant with these requirements.

In the UK, reference should be made to the following as a minimum:

- Health & Safety at Work etc. Act 1974
- Factories Act
- Management of Health and Safety at Work Regulations (MHSWR) 1999
- Control of Substances Hazardous to Health (COSHH) 2002
- Pressure Systems Safety Regulations (PSSR)
- Public Health Act
- Provision and Use of Work Equipment Regulations (PUWER) 1998
- HSE Industrial Guidance Note INDG 436 & BG01. (Also CEA guide BG03 replacing PM60 for boiler blowdown).

These and other guidance are available at www.hse.gov.uk.

Each boiler should be fitted with a main bottom blowdown or drain valve (either manual or automatic). Additionally, for intermittent/automatic TDS control a side mounted control system must be fitted. The following figures give a number of different examples of common types of valve and blowdown arrangements in use.

The important safety consideration to take into account on any blowdown system is to ensure that only one boiler can be blown down into the blowdown vessel at any one time. For multi-boiler installations utilising manual blowdown systems, there must only be one blowdown valve handle in the boiler house.

Where automatic and timed blowdown systems are fitted these must be arranged to ensure that only one valve can be opened at one time either by electrical interlocks or by use of timed control units.

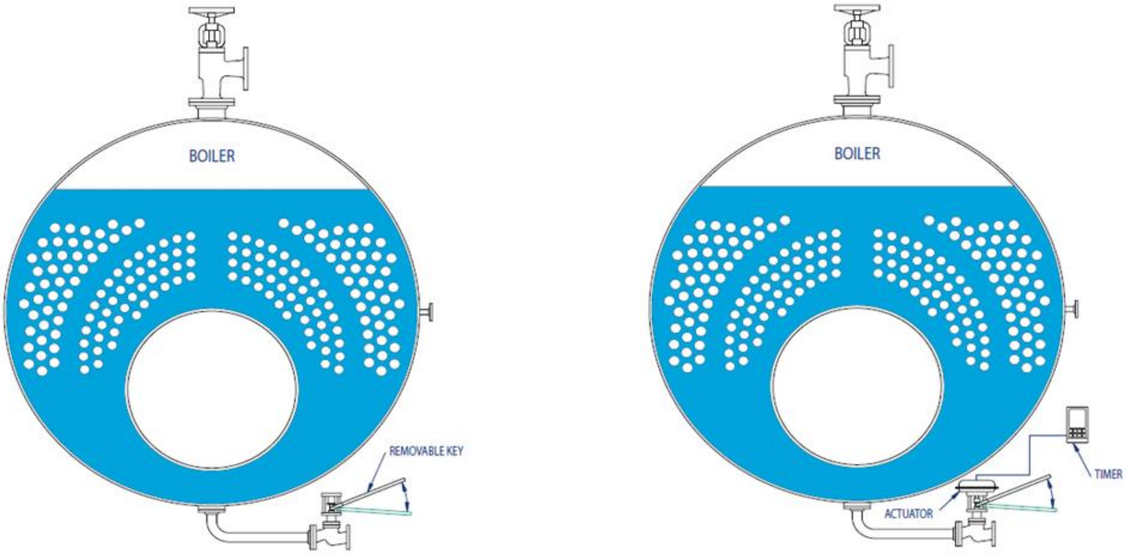


Figure 23 – Automatic actuated Bottom Blowdown System

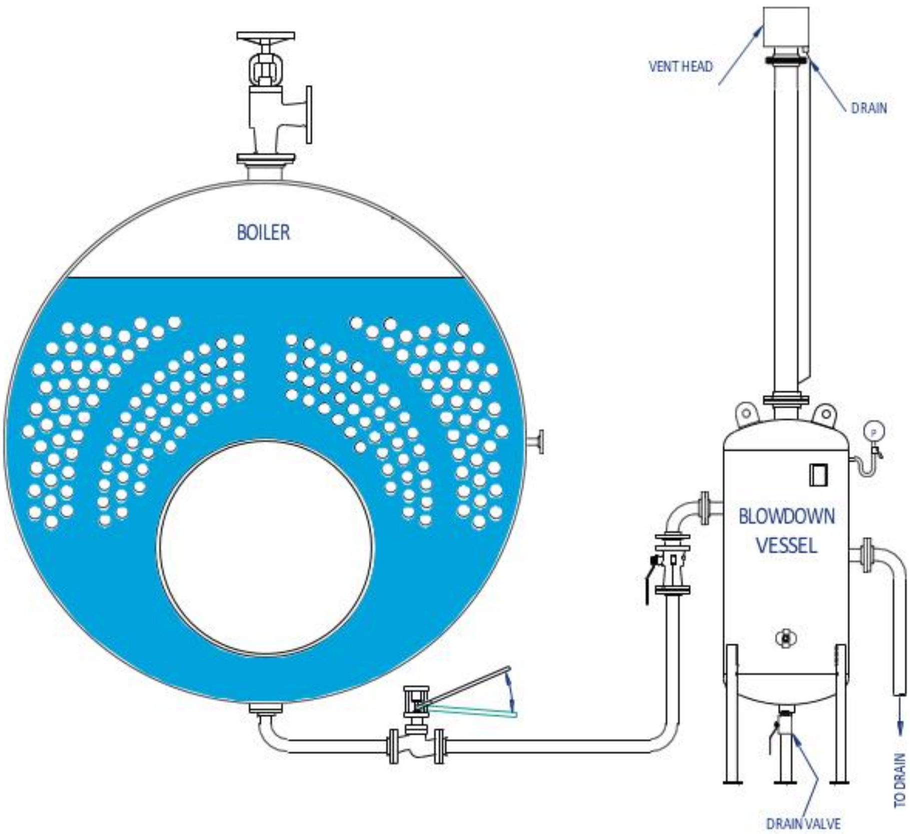


Figure 24 – Simple single boiler blowdown arrangement to Blowdown Vessel

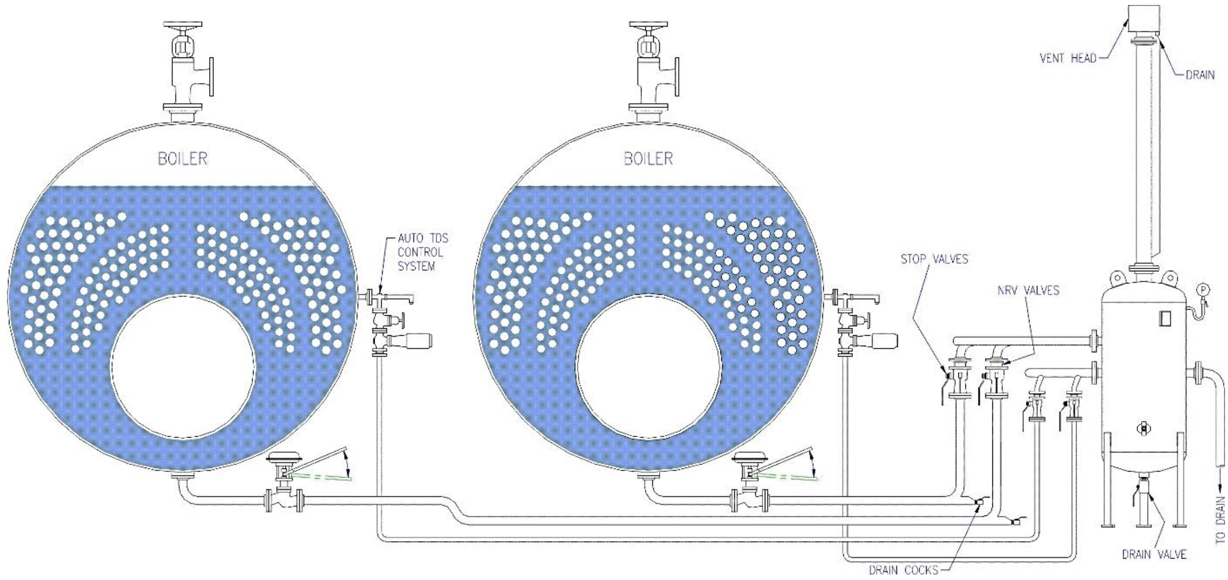


Figure 25 – Multi-boiler Blowdown System (Incorporating Automatic Side TDS Control)

Note: Additional connection manifolds to the blowdown vessel are required to accommodate the drain connections for level gauge glasses and water level control chambers as appropriate.

Note: Discharge temperatures from boiler blowdown to drain should not exceed permissible limits, usually a maximum of 43ºC, but check with your local water authority and/or bylaws.

3 CORROSION

Corrosion may occur in all parts of boiler plant, in the feed system, in the boiler itself and in the steam and condensate pipework.

3.1 Pre-boiler Systems

Oxygen is the main cause of corrosion in hot wells, feed lines and feed pumps, but if carbon dioxide is present then the pH will be low (i.e. the water will tend to be acidic) and the rate of corrosion will be increased, due to low pH attack.

Typically, corrosion is of the oxygen pitting type where, although the loss of metal may not be great, deep penetration and perforation of tubes can occur within a few months.

The essential requirements for prevention of corrosion are to keep the pH of the feed water correct and to eliminate oxygen. Very high levels of pH should be avoided as they lead to foaming, carry-over, and to attack and/or deposition on the gauge glasses and condensate system.

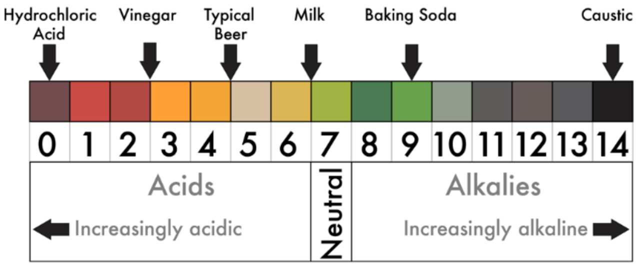


Figure 26 - The pH Scale

Note: The pH scale is a logarithmic one and so a reading of pH4 is a factor of 10 times more acidic than a reading of pH5 and 100 times more acidic than a reading of pH6.

Note: If pH is totally neutral and the water pure, certain electronic instruments will not read correctly. For reliable and consistent pH readings that can be trended therefore, the use of accurate 3 or 4-point pH papers is preferred.

3.2 Deaeration

Elimination of oxygen is normally carried out by a combination of both chemical and physical methods. Water exposed to air is always saturated with oxygen, according to the water temperature. At 0°C the oxygen content is 14ppm and this gradually reduces to effectively zero at 100°C. The addition of a sufficient and suitable oxygen scavenger will chemically neutralise the available oxygen and remove its corrosive effect. Physical deaeration by preheating the feed water followed by chemical neutralisation of residual oxygen is strongly recommended, as this provides for a more successful solution.

The more successful the mechanical deaeration, then the less oxygen scavenger required.

For the applications relevant to this document, the most commonly encountered deaerator would be the simple steam sparge pipe, typically heating the hotwell by injection of live steam to keep the feed water temperature at approximately 85°C. Anything less than 70°C would be considered to be inefficient and likely to cause other problems in the boiler.

Note: If the feed water from the hotwell is too cold going into the boiler, this can lead to thermal shock and cracking at the intersection of the feed nozzle and the boiler shell.

Note: If the feed water temperature is too high it is one factor that can lead to cavitation in the feed pump, damaging the pump.

Note: Always locate the hotwell as high above the feed pumps as reasonably practical to avoid cavitation unless a booster pump is employed, such as in a floor level installation.

Note: If an economiser is fitted, extra care needs to be taken with the water treatment. Please speak to your boiler water treatment specialist for advice. Reference BS2486 para 5.7.4.

The atmospheric deaerating head (normally fitted to the top of a hotwell) with a recirculation pump is a more advanced form of deaerator that relies on the feeds to the head itself being capable of carrying out the deaeration process efficiently.

It is strongly advised that if this type of system is to be considered then a specialist in this area is sought, since incorrect application of these types of units can result in rapid boiler failure.

Whatever form of deaeration is to be used, chemical treatment is always required, since complete system deaeration at all times is impossible due to oxygen ingress downstream of the steam header.

Figure 27 – Coil Boiler General Corrosion Attack

Figure 28 – Coil Boiler Tubes Cut Away View showing Oxygen Pitting Corrosion Attack

3.3 Boiler

The process of boiling causes any carbon dioxide and oxygen present to 'flash off' into the steam lines. Even so, corrosion within the boiler itself may take place unless the water is conditioned to avoid this. Corrosion may be particularly severe in idle boilers. The precautions necessary are detailed in Section 7.

Figure 29 - Oxygen Pitting Corrosion Attack External View

Figure 30 - Carbonic Acid Corrosion

3.4 Condensate Return System

In condensate lines some carbon dioxide is always present, even when the majority of the available alkalinity has been removed from the feed by, for example, reverse osmosis. The return of good quality condensate, where possible, is very important in order to conserve/recover primarily energy, but also water and treatment chemicals. It is possible to convert poor quality returning condensate into good quality condensate suitable for re-use in the boiler by means of a condensate polisher or similar. These systems normally require a considerable financial investment and are only therefore suited to larger installations with large volumes of poor quality returning water.

Where condensate is of poor quality and cannot be reclaimed for particular operational or commercial reasons then it would need to be dumped, usually involving an automatic condensate monitoring system controlling typically on pH and/or TDS content.

Note: Discharge temperature to drain should not exceed permissible limits, typically 43^{o}C.

Oxygen can also be present due to natural ingress from atmosphere, especially so in batch processes where condensate is allowed to cool. The concentration of carbon dioxide or oxygen in water varies with temperature and pressure; at steam condensing temperatures above atmospheric pressure it is virtually nil, even though the atmosphere above it is rich in the gas. Thus the temperature of the condensate, not the concentration of carbon dioxide in the steam, determines the corrosion potential. Similarly, the hotter the condensate, the lower is the propensity for oxygen from atmosphere to re-enter.

Figure 31 - Condensate Pipework Corrosion Attack

The severity of corrosion in condensate lines increases as the temperature falls; it will generally be found to be most severe at the end of the condensate line where it is coolest. Where use of boiler plant is intermittent, it should be remembered that copious amounts of oxygen and carbon dioxide are available from the atmosphere, and wherever these have access to pockets of undrained cold condensate, corrosion of the containing vessel, usually pipelines, will be very severe.

Where condensate lines are too small, a corrosion/erosion mechanism may be found where any protective oxide film formed under favourable conditions is subsequently destroyed by water droplets carried by flash steam at high velocity, say 45m/s (150ft/s). Carry-over from the boiler will aggravate the conditions by varying the pH. Incorrect sizing of condensate lines is quite common and advice on this subject is available from technical literature.

Condensate line corrosion can be alleviated by simply piping the return system in stainless steel, an approach found in food factories for example. If this is not practicable, then levels can also be reduced by using either neutralising or filming amines; neutralising amines when the carbon dioxide content of the steam is only a few ppm and filming amines when it is high, e.g. after simple base exchange in high alkalinity water areas.

Amine based treatment chemicals can however be toxic and are not acceptable in the manufacture of milk/milk products and may not be acceptable in other food production or critical process industries, such as steam sterilisation in hospitals. These types of products must also not be used in the manufacture or packaging of organic food products. Where a single steam system is used in a factory to supply both organic and non-organic lines, amine based treatment chemicals must not be used unless the whole steam system is subject to a fully monitored and tested “bleed run” between organic and non-organic loads.

Amine based treatment programmes do have considerable benefits when used in the correct circumstances. As they contain very little TDS, the requirement for boiler blowdown is lowered and this leads to energy savings (due to the reduced loss of hot, treated water to drain). This form of treatment can also dramatically lower the occurrence of corrosion in the condensate system.

Some traditional boiler water treatment programmes, such as straight phosphate for hardness conditioning, also have some limitations. However, these types of programmes are rarely used nowadays and are not covered in the scope of this document as they are more suited to applications in the power generation industry.

In steam systems for humidification, some volatile products may be deemed to be unacceptable unless the site specific risk assessment deems otherwise. These types of products, being volatile, may also interfere with or damage finished product in certain manufacturing processes; careful consideration, including consultation with a steam chemistry specialist, is advisable.

Note: Reference to a Boiler Water Treatment Risk Assessment in the context of this BG04 document relates specifically to your boiler and steam system. You are also required to conduct risk assessments specifically related to other water and associated systems at your site. For example, cooling water treatment, Legionella risk, discharge to drain, or emissions to atmosphere through evaporative cooling towers etc. all need to be considered by formal and specific risk assessments carried out in each area.

Although there are specified United States Food and Drug Administration (USFDA) limits for some of the raw materials found in these types of amine products, both the testing of these and their subsequent control are considered to be specialist and as such these types of treatments should only be applied after careful consideration and extremely thorough training.

Note: The USFDA does not provide approvals for finished water treatment products and has no official standing in the UK and Europe, albeit those chemicals containing FDA approved raw materials are widely used in the food and beverage industry throughout Europe.

Automatic measurement or control of some amine treatments can also be an issue, due to their filming properties interfering with probes, potentially causing levels to be misread.

Historically, steam quality checks were rarely put in place on sites and so treatment chemicals, (whether or not containing USFDA listed raw materials) and their subsequent levels of concentration were rarely known.

It is therefore deemed essential to carry out testing of condensate for TDS and pH as a minimum. This will give an indication as to the quality of the steam being provided.

Certain critical industries may require far more detailed steam and condensate quality testing and control.

The simplest solution to reduce condensate line corrosion is to pipe condensate lines in stainless steel, thus rendering them far more resistant to corrosion attack.

Some steam systems, such as typical closed loop type or high pressure steam systems (for example, space heating via a heat exchanger and a fan, or power production via a turbine) can however benefit from these types of amine based treatments and so they do have applications in industry. They are used in, for example, power stations/nuclear reactors and the petroleum industry. Care should be exercised in the food industry to ensure that the best and most appropriate product is selected for any particular application. Application of these types of amine products in the petroleum and power industries however lies outside the scope of this document.

The **Boiler Water Treatment Risk Assessment** needs to be a part of the **Technical Boiler House Risk Assessment (TBRA)** required under BG01; adherence to both documents is required for all sites.

The Boiler Water Treatment Risk Assessment should clearly describe the chemical treatment programme in place and its effect on both the feed water and steam provided to the plant. It is essential to include the Boiler Water Treatment Risk Assessment and the input from the boiler water treatment specialist as a part of the TBRA. It is also essential to have a small team of staff contributing to the TBRA rather than a single individual person being given the job to create the TBRA.

Note: All boilerhouses must have a **site and system specific** "Boiler Water Treatment Risk Assessment" in place.

A risk assessment should be considered to be a live document and as such requires regular review, ideally taking account of any changes. For example, the "pre-contract" risk assessment for a new boiler installation must be performed before commissioning, but the actual "Boiler Water Treatment Risk Assessment" required here under BG04 must be carried out immediately after commissioning and reviewed again when the system has been operational for several weeks or months.

It is the responsibility of the "Statutory Duty Holder" (typically a director of the company) to ensure that the Boiler Water Treatment Risk Assessment is carried out to identify and assess the risk arising with respect to the water treatment plant and systems employed and the steam created. The Statutory Duty Holder must then appoint a person to take day-to-day responsibility for controlling any identified risk from the steam boiler system. This person is termed the "Responsible Person" and they need to have:

a) Sufficient standing and authority within the organisation (e.g. a senior manager) and competence and knowledge of the steam system to ensure that all operational procedures are carried out in a timely and effective manner; and

b) A clear understanding of their duties and the overall health and safety management structure and policy in their organisation.

If the Statutory Duty Holder is competent, they may appoint themselves as the Responsible Person.

A person must be appointed to carry out the risk assessment by The Statutory Duty Holder/Responsible Person and it may require input from more than one person to complete this process successfully. The appointed person can be an employee of the Statutory Duty Holder or an external contractor. It is considered that the appointed person must be a specialist in boiler water treatment, having a strong chemistry or scientific background, with extensive experience in steam systems. The Statutory Duty Holder remains accountable for implementing the recommendations arising from the Boiler Water Treatment Risk Assessment.

From the findings of the Boiler Water Treatment Risk Assessment, each site must then produce a "Boiler Water Treatment Written Control Scheme".

However, this must not be confused with the legal requirement under the PSSR to have a Written Scheme of Examination (WSE) for pressure plant. See item 16, Notes on table 2 (See page 28).

Both the Boiler Water Treatment Risk Assessment and The Boiler Water Treatment Written Control Scheme should be reviewed periodically and as and when there is any significant change e.g. a system variation, change in operating parameters or manning levels/ chance of contractor or site operator, responsible person etc. The outcome of any reviews should be recorded. Both the original documentation and any subsequent reviews should also stipulate when the next target date for system review is due.

In any event, both the Boiler Water Treatment Risk Assessment and The Boiler Water Treatment Written Control Scheme should be formally reviewed every two years, as an absolute minimum.

Recommended conditions for both feed and boiler waters are given in Table 2. It is emphasised that these are of a general nature only, and special conditions may apply to unusual waters and steam systems. Specialist boiler water treatment companies can advise in these circumstances.

Table 2 - Recommended Water characteristics for shell or coil boilers, including steam generators			
		Feed Water - Shell Boiler	**Feed Water - Coil Boiler**
Parameter	**Units**	**Values**	**Values**
Appearance		Clear, produces no stable foam	Clear, produces no stable foam
pH value at 25ºC		8.5 to 9.5 (note 1)	9.5 to 11
Total hardness	ppm	2 max. (note 2)	<2
Dissolved oxygen	ppm	(notes 3 and 4)	Nil
Caustic alkalinity (OH-alkalinity)	ppm	(note 5)	200 to 400ppm as OH Alk Note that this is the feedwater/boiler water level.
Oil and grease	ppm	(note 6)	(note 6)
		Boiler Water - Shell Boiler	
pH value at 25ºC	-	10.5 to 12.0 (note 7)	N/A
Total alkalinity (M-alkalinity)	ppm	1000 max.	N/A
Caustic alkalinity (OH- alkalinity)	ppm	10-15% of Dissolved Solids (note 8)	N/A
Oxygen scavenger (note 15 and 16)			
Sulphite	ppm	30 to 70	60 to 100
Tannin	ppm	120 to 160	N/A
Ascorbic acid	ppm	15 to 30	15 to 30
DEHA	ppm	0.1 to 1.0 in feed water	0.1 to 1.0
Film Forming Amines	ppm	0.2 to 1.0 in feed water	0.2 to 1.0
Phosphate	ppm	30 to 60 (note 9, 10 and 17)	30 to 70
Silica	ppm	150 max. (note 11)	<1
Suspended solids	ppm	200 max.	50 max.
Dissolved solids (notes 12 and 18)	ppm	3500 max. or manufacturer's standard (notes 13 and 14)	Manufacturer's Standard.

Table 2 – The recommended water characteristics for shell boilers and coil boilers up to 32bar.

Notes on Table 2

1. When copper alloys are present in the feed system, this value should not exceed pH 9.2 if corrosion of these materials is to be avoided. Copper is a serious boiler contaminant and results from the corrosion of steam/condensate system components. Incorrectly applied water treatment chemicals can also break down to form ammonia and accentuate corrosion attack of copper components. Copper corrosion attack can also result from inadequate acid cleaning procedures. In order for copper corrosion attack to take place oxygen must normally be present, so removal of oxygen is paramount. Systems that are regularly off and suffer from in-leakage of oxygen will be more prone to this type of attack. Where feed pumps are manufactured from cast iron the pH may have to be increased.

2. This value can be achieved only by the use of suitable external pre-treatment plant. It is essential that such plant should be properly maintained. It is also recommended that a suitable polymer dispersant be used to ensure clean heat transfer surfaces.

3. Dissolved oxygen should be reduced to the lowest practicable level, which will be achieved by the use of a properly designed feed tank or an atmospheric deaerating head/de-aerator.

4. An oxygen scavenger should be used and should be added to the storage section of the feed water tank or de-aerator in sufficient quantity to reduce the dissolved oxygen level to zero before the feed water enters the boiler or the economiser (where fitted).

5. It is recommended that feed water alkalinity be maintained below 25ppm. Alkalinity of 25ppm and above will result in 10ppm carbon dioxide in the steam. This level of carbon dioxide can be economically controlled by the use of a neutralising amine, if this is deemed to be allowable by the site and system specific Boiler Water Treatment Risk Assessment. If this feed water alkalinity level cannot be achieved, it is recommended that de-alkalisation of the make-up water be carried out, or that reverse osmosis pre-treatment is used.

6. If the possibility exists for these substances to enter the feed system then suitable detection equipment should be installed to activate an alarm if they are detected.

7. Corrosion of boiler internals can occur if the pH value is outside these limits.

8. It is recommended that the caustic alkalinity be maintained at 10-15% of the total dissolved solids concentration if phosphate conditioning is practised. If carbonate conditioning is used, see note 9.

9. Maintenance of a phosphate reserve is not essential provided either that a minimum carbonate alkalinity of 250ppm can be maintained (depending on the alkalinity of the feed water and the working pressure of the boiler) or that an appropriate programme of transporting polymers is employed. It is important to ensure that magnesium phosphate is not precipitated in the boiler water as it can cause sludge to adhere and form hard scales on heat transfer surfaces. This is unlikely if the phosphate does not exceed 10% of the minimum caustic alkalinity specified in the tables. As an additional safeguard, use an appropriate polymeric sludge conditioner which will maintain precipitates in suspension for removal with the blowdown.

10. The use of solubilising treatments using chelants (EDTA, NTA etc.) is permissible provided that a maximum of 10ppm is not exceeded at any time. Complete removal of oxygen should have been achieved prior to injection of the chelant.

11. Silicate scales can be formed readily in all boilers. Maintenance of a ratio of silica content to caustic alkalinity of less than 0.4:1 can prevent this.

12. Of these two parameters, conductivity and TDS, only one needs to be measured. In the UK it is normal practice to report TDS only when relating to waterside conditions in a boiler.

    Note: Be aware that all meters measure conductivity and then some convert to TDS. However, not all meters will read out only in TDS, some measure and read out in both conductivity and TDS. Therefore, it is imperative always to ensure you use the same method of measuring and readout.

13. These values are for guidance only. It might be found from experience that lower values are necessary to avoid priming or carryover, especially in modern package boilers with a small steam space.

14. These values are recommended for fully softened feed water in accordance with the table. If feed water with a significant hardness has to be used, then the TDS level should be reduced to achieve the suspended solids limit. At 20ppm feed water hardness, the upper limit should be reduced to 3000ppm and at 40ppm hardness it should be reduced to 2000ppm. If TDS is measured inside the boiler by the use of a conductivity device, care must be taken to ensure an accurate correction factor is applied for the dissolved solids and to take account of the sample being un-neutralised. When carrying out TDS testing, it should be made clear as to whether samples are neutralised or not.

15. Other oxygen scavengers are available. Control levels of these should be as recommended by the supplier of the treatment chemical. These include multifunctional products that can be used in consultation with the boiler manufacturer in so far as they follow the basic good practice defined in BS2486 or EN12953-10. These products can have significant advantages with respect to the application of treatment programmes.

16. Oxygen scavengers come in two general types, organic based or volatile (e.g. hydroxylamines and ketoximes) and non-volatile (Sulphite or ascorbate/erythorbate based). These different types give rise to many different styles and blends of oxygen scavenger, each one having its own benefits and drawbacks. It should be clearly noted that the Boiler Water Treatment Risk Assessment and the Boiler Water Treatment Written Control Scheme should denote which type of boiler water treatment and oxygen scavenger should be used, how it will be applied, and why. Clear reasoning for this choice should be stated in the document and implications for where and how the steam is to be used must be considered. Any local health and/or process implications must also be considered by the Boiler Water Treatment Risk Assessment.

17. Precipitation and alkalinity control programmes should also be given very careful consideration before deployment in any steam boiler system and it should be clearly noted in the Boiler Water Treatment Risk Assessment and the Boiler Water Treatment Written Control Scheme which type of programme is to be used, how it will be applied and why. Clear reasoning for this choice should be stated in the document and implications for where and how the steam is to be used must be considered. Any local health and/or process implications must also be considered by the Boiler Water Treatment Risk Assessment.

18. Under certain circumstances with high purity make-up water, such as RO or Demineralised waters, it may be necessary to control blowdown so as not to exceed the maximum levels of silica in the boiler.

4 FOAMING IN BOILERS

It is well known that the water level in a shell boiler can become unstable, the evidence being that the water in the gauge glasses surges and copious liquid trickles downwards from the steam connection. With automatic boilers the level controls may cause the burner to lock-out. Wet steam can also be produced, sometimes to an alarming extent. These phenomena are due to foaming of the boiler water.

The trend in shell boilers has been towards smaller shells for a given evaporation, thus leaving less space to accommodate any foam formed; modern boilers are likely to be more sensitive than older types. Having said that, foaming is a function of the nature of the boiler water and can only be treated by correcting the water conditions, which in turn will need to be examined to find out what waterside conditions or substances are likely to be the cause.

Foam, whether it be on a glass of beer, in the kitchen sink or in a sewage works, is a familiar sight and certain facts emerging from everyday experience are:

1. Pure water does not foam.
2. ‘Hard’ water, though it contains impurities such as the bicarbonates of calcium and magnesium, and calcium sulphate, will not foam.
3. The addition of common alkalis, soap, or domestic detergents can all cause foam to be formed. Some of these substances are used to soften water. Boiler water is softened to prevent scale formation and is therefore predisposed to foaming.
4. Violent agitation of a foamy liquid increases foam formation.
5. A powder introduced into an ebullient solution causes violent foaming e.g. pure ground ginger sprinkled onto a glass of sparkling mineral water.
6. Boiling of a colloidal suspension, e.g. milk, causes violent foaming. (Note: colloidal particles are less than 0.0001mm diameter and can pass through a normal filter. They remain in suspension in the liquid and never settle).

Foam in a glass of beer sits on the top of the liquid; what is not generally realised is that when foam is formed in a boiling liquid, the liquid surface disappears and the whole content of the containing vessel becomes a graduation of foam bubbles, small and relatively few at the bottom, large in size and number near the top. This can be studied by gently boiling milk in a glass boiling tube.

The last example simulates foaming in a boiler, and the level sensors may, under some circumstances, give false signals. A boiler may be severely foaming and in fact be short of water so that the heating surface may become overheated and collapse. Moreover, foam may occur in the locality of heated surfaces and this foam cannot conduct the heat away as quickly as water so the heated surfaces are at risk. The foaming potential of a boiler water can be roughly tested by withdrawing a sample from the boiler and shaking it in a bottle.

All level sensors, electrodes and floats must be protected against a foaming condition. This can be achieved by enclosing the sensor in a suitably designed tube, therefore minimising the effect of bubbles or foam.

The main substances which cause or assist foam formation are:

1. Alkaline Salts;
2. Total Dissolved Solids (TDS);
3. Detergents;
4. Suspended Solids.

In boiler waters, the amounts of the first two of these substances should be measured, preferably daily, and if found to be increasing beyond the normal satisfactory figure, blowdown should be increased. Excessive alkalinity can cause gauge glass failure.

The total dissolved solids content of a shell boiler should not typically exceed 3500ppm (a coil boiler being typically 2000ppm) **but this is a very rough guide**, as much depends on the nature of the dissolved solids and also the type of boiler and the available steam space. Modern package shell boilers with small steam spaces have a higher propensity to foam and as such, TDS control limits for these types of boilers are far lower, usually around 2500ppm or sometimes even lower. The same applies to suspended solids that should normally not exceed 200ppm, but it also depends on their nature. Solids which are distributed throughout the water stabilise foam; but if the particles are heavy, they sink out of harm's way to the bottom of the boiler. It all depends on what impurities are present in the feed water.

Coil boilers and steam generators do not typically exhibit issues with foaming due to their design and control parameters.

Detergents are another matter. They may be of natural origin (e.g. colloids resulting from decaying vegetable matter) or they may be of domestic or industrial origin. The occurrence of the latter substances is tending to increase markedly in boiler water supplies, particularly when these are derived from streams or rivers into which the outflow from sewage works is directed; sewage purification processes do not break down many of the substances. The estimation of detergent concentration will require rather special techniques and should only be undertaken by an expert if, and when, their presence is suspected. A detergent content of only 1ppm in the boiler feed can cause severe foaming as it concentrates in the boiler; in such cases, a change to towns mains supply is advised, inconvenient and expensive though it may be. The use of specialist bespoke pre-treatment plant may be considered as an alternative to a change of supply, as these can remove many types of organic materials. Even though capital expenditure is incurred in providing the plant, it could prove cheaper in the long run than to use an expensive water supply.

Antifoams can be supplied by water treatment contractors. These are substances which are added to the boiler water and break down the foam bubbles. In the majority of cases, they can be extremely effective, but in very poor quality boiler waters they may not have any beneficial effects. Such is the case when foams are caused by suspended solids which absorb the antifoams and render them ineffective.

It should always be remembered that the waterside chemistry in a boiler can only respond to what the steam load and boiler are asking of it, given the conditions prevailing in the system at that time.

Engineers should not view water chemistry as having the ability to alleviate or even negate poor external or system conditions and poor management control of the system itself.

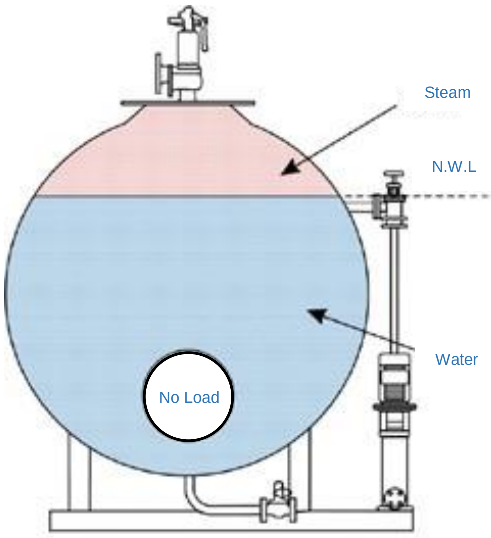
Water chemistry should be viewed as the final piece of achieving good system balance and longevity, with the correct engineering and management conditions already in place.

As the volume of steam increases with decreasing pressure it follows that the volume of foam will increase in a similar manner, and it will be noted that the volume increase is particularly sharp at pressures below 7barg. Anything that tends to reduce the boiler pressure, such as a sudden increase in steam demand, will therefore make a foaming condition worse. It also follows that boilers operating above 7barg are less sensitive than those working below.

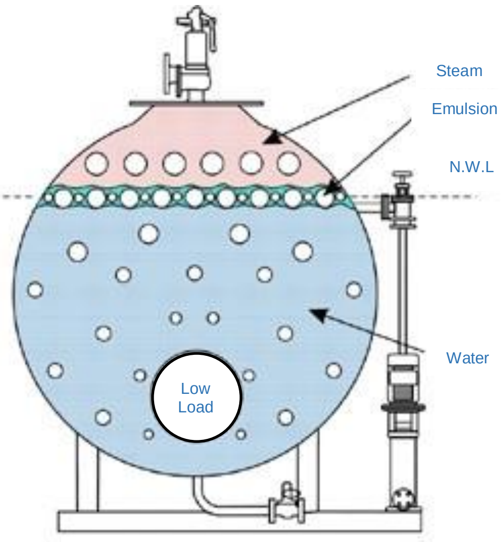
Figure 32 below shows diagrammatically the various stages of boiler foaming related to boiler load and how the foaming can adversely affect the boiler operation and performance.

It is recommended that where boilers are known to be subject to foaming they should be operated at the maximum design pressure, which is where the designer intended the boiler to work, and if low pressure steam is required, this should be obtained through the use of a reducing valve.

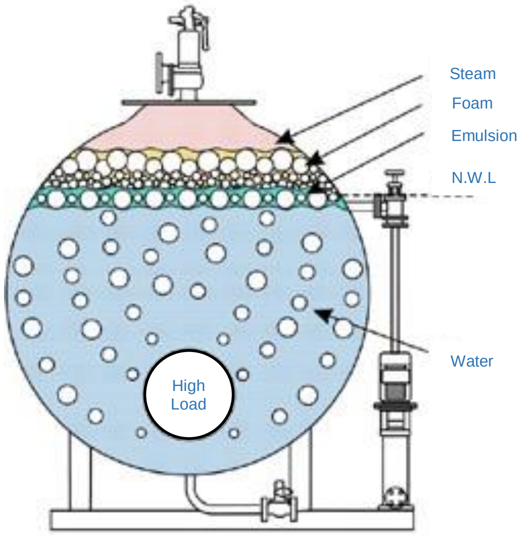
Care should be taken to ensure that the various steam users in any plant are phased in, rather than all coming on-line together which can create steam demands beyond the capacity of the boiler and/or the burner, and the boiler pressure would fall significantly, known as "flattening the boiler". This will also result in boiler water carry-over.



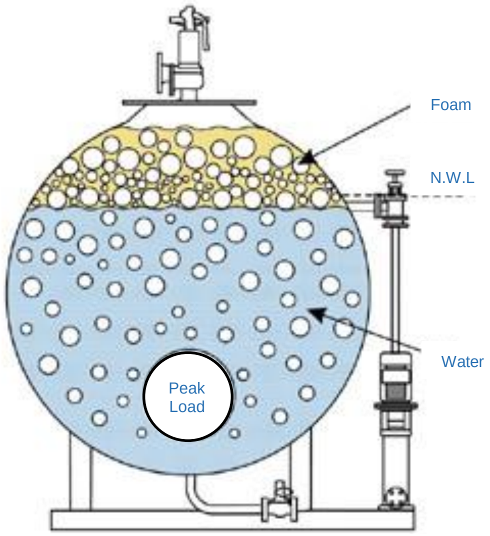
The feed pump is off



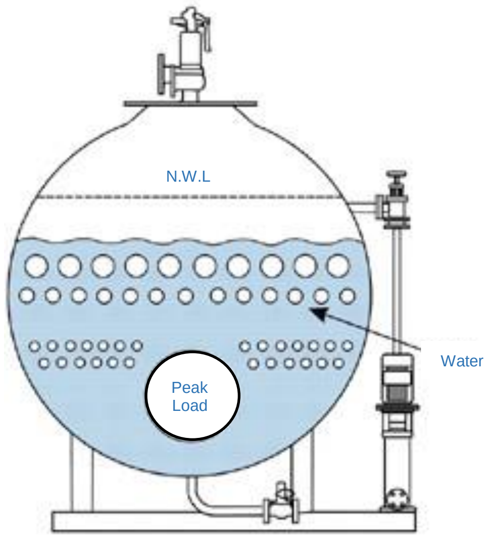
The feed pump is off



The feed pump is off



The feed pump is off
Sudden reduction of boiler pressure



Peak load comes off
Water level falls, pump runs, boiler locks out

Figure 32 – Different Boiling Conditions in a Boiler

5 CONDITIONING TREATMENT

No matter how efficient the prior treatment of feed water has been to remove scale forming minerals by softening and to remove corrosive oxygen and carbon dioxide by elevation of pH and mechanical de-aeration, sufficient of these impurities remain to cause scaling and corrosion in the long term. Additional chemical treatment must therefore be applied to the feed water to ensure that problems do not arise from these impurities. Such treatment is known as waterside conditioning, and it may either precipitate the scale forming impurities in a non-adherent and thus non-scaling condition or it may keep them in solution. Dissolved oxygen is removed by the addition of an oxygen scavenger. These processes are discussed in more detail below.

Table 2 gives guidance on the quality of both feed water and boiler water to be maintained to avoid scale and corrosion in the pre-boiler and boiler/steam generator systems. To ensure that the parameters are met, it is essential to carry out simple control tests generally as described in BS 1427: 2009. These control tests must be site specific and recorded in all cases. The recorded tests should be linked to some form of response procedure to ensure operational staff and management act upon the test results where appropriate.

Note: In all cases, a suitable and site specific system of documentation of test results and actions taken in response to all ‘out of specification’ results must be in place.

It should be clearly noted that waterside testing and protocols must be site specific in all cases, taking account not only of the specific pre-treatment plant and water treatment programme in place, but also the duty and purpose of the steam supply itself.

In all cases, basic condensate analysis must also be undertaken on a daily basis, in order to prove both steam quality and the health and efficiency of the system in place.

Site testing must only be undertaken by competent and fully trained personnel who can provide documentary evidence of having attended a recent and specific training course on boiler water treatment for steam systems and associated test procedures, data upload and analysis/interpretation.

This training should be site and process specific and must be proved by the completion of an appropriate written or electronic test that should then be recorded and held on the site and in a personnel file. (This helps you to prove competence).

Training should be refreshed:

- As a minimum every 5 years
- Or as and when there has been a change to the site personnel involved
- Or changes to the system
- **Or there has been a system or process failure,** such as scale build up or a corrosion failure of the system.

This is of particular importance in unmanned sites or sites where there may be a transient or contracted out workforce.

Note: It is not acceptable for one operator to pass on their training to another, since they are not considered to be at the level of the initial trainer and the information is at risk of being diluted or not correctly understood.

Sites and boiler operators must themselves ensure that the personnel training them can demonstrate a track record over a number of years specifically in water treatment for steam applications, along with suitable qualifications and experience.

A word of caution - It is not acceptable simply to engage a water treatment company whose specialty might be in a completely separate area of water treatment such as water hygiene or control of Legionellosis and who have limited or no experience of steam systems and their treatment.

5.1 Example – Typical Shell Boiler Daily Testing Log Sheet

Boiler water test sheet								
Parameter	Control Limits	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
	Enter date:							
Softener:								
Test 2 Total Hardness	Less than 2ppm							
Test 6	-							
TDS [ppm] DO NOT NEUTRALISE	-							
Test 4 M Alkalinity	-							
Test 5 pH	-							
Salt	2 weeks supply min.							
Feed water:								
Total Hardness	Less than 2ppm							
M Alkalinity	<25ppm							
pH	8.5 - 9.5							
TDS [ppm]	-							
Feed water temperature	Actual:							
	Gauge: 70°C Min.							
Boiler water:								
Test 1 Sulphite	30 - 70ppm							
Test 2 Total Hardness	Less than 2ppm							
Test 3 P Alkalinity	600 - 800ppm							
Test 4 M Alkalinity	800 - 1000ppm							
Test 5 pH	10-12							
Test 6 TDS [ppm] [Neutralised]	Max 3500							
Test 7 Phosphate	30 - 70ppm							
Condensate:								
Test 5 pH	6.5 - 7.0							
Test 6 TDS [ppm] DO NOT NEUTRALISE	<10ppm							
Chemicals:								
Chemical 1	Pump rate							
Chemical 2								
Chemical 3								

Figure 33 – Example of Typical Shell Boiler Daily Testing Log Sheet

Addition of conditioning chemicals may increase the TDS and in turn the blowdown, therefore overdosing is to be discouraged. Volatile products that can enter the steam phase are also prone to overdosing due to their more complex control and the testing procedures involved. Overdosing of these types of products can lead to formation of sticky deposits, commonly referred to as "gunk balls". If using these types of amine treatments a specific reserve must be maintained at all times in order to maintain the protective layer between water and metal interfaces.

Some types of amine based treatment chemicals can be toxic if incorrectly applied or managed and are not acceptable in the manufacture of milk/milk products and may not be acceptable in other food production or critical process industries due to possible interference with and/or damage to the finished goods.

These types of amine based products are also used in higher pressure boiler applications and closed loop steam systems, and as such are predominantly outside the scope of this guide. However, this does not preclude use of these types of products if the site and system specific “Boiler Water Treatment Risk Assessment” concludes that the risk is acceptable and adequately controlled.

The site and system specific “Boiler Water Treatment Risk Assessment” should only be carried out by a suitably competent person with significant experience and technical qualifications in boiler water treatment and steam chemistry. It is unlikely that anyone other than a boiler water treatment specialist will have the necessary technical expertise and experience in order to carry this out, and in the case of particular types of boilers such as coil boilers, only a specialist in that area should be used.

To avoid excessive blowdown losses and hence an increase in costs and loss of efficiency, the TDS should be kept as high as possible up to the limit suggested in Table 2 consistent with avoidance of foaming and protection of waterside balance. (Always follow manufacturer’s instructions and seek advice from a boiler water treatment specialist).

It may occasionally be found necessary (e.g., in areas of high alkalinity) to blow down the boiler to keep below the recommended maximum “Total Alkalinity” given in Table 2 instead of the TDS. In such a case, investigation of more comprehensive pre-treatment plant might prove cost effective.

The practical application of boiler water conditioning can be rather complicated and the advice of a specialist should always be sought. For example, several boilers working at different loads may be fed from a single feed pump. To provide accurate dosing proportional to the needs of each boiler would call for a multiplicity of chemical dosing pumps. An experienced, qualified field chemist can be engaged under a service contract from a water treatment company specialising in steam who can often provide an acceptable compromise in such a case. Specialty companies can provide suitable water treatment chemicals and prescribe conditioning programmes, including periodic visits, where laboratory resources and extensive water treatment knowledge are not readily available on site.

Notes:

1. It must be clearly noted that boiler water treatment and especially coil boiler water treatment are very specialist areas and consultancy in these disciplines should be regarded as a technical and scientific discipline.

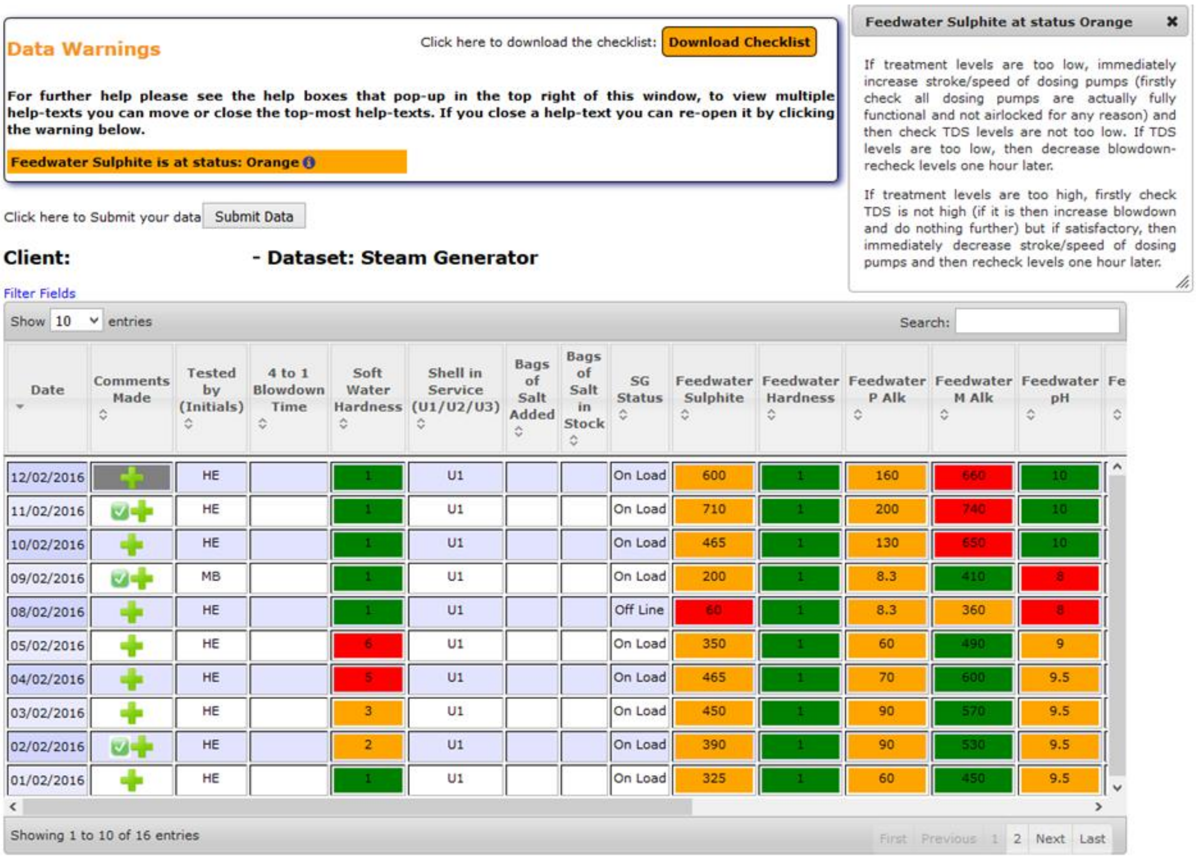
2. It is the quality of the boiler water treatment and the management of that process which you adopt that will make the difference in terms of safety and control of the boiler condition. It is highly recommended that you take into consideration all factors covered in this document when choosing the person to supply the expertise and specialist consultancy that you may require, thereby avoiding plant failure which could result in an accident and potentially loss of life.

3. To enhance the safe operation and life expectancy of your boiler plant, it is also necessary that periodic visits from a specialist **should only be in support of, and not to replace, site specific daily testing,** unless all testing is automatically monitored on your plant.

   Note: It can only take a matter of hours for your boiler water treatment to change significantly if something in the boiler, the treatment, or the condensate, changes; this could lead to a very serious situation. Therefore, it is highly recommended that you take your own boiler water treatment readings on a daily basis.

4. It is unrealistic to consider waterside conditions in a boiler to be under control if only carried out on a monthly visit from a boiler water treatment specialist. If left unchecked, waterside conditions in these types of situations could be out of specification for thirty days between specialist visits. This is clearly undesirable and could lead to a failure.

5. Where unattended operation is in place, or proposed as an option on a boiler, then the additional boiler and steam system monitoring and control equipment fitted to allow this unattended operation and the additional checks and balance necessary to facilitate this, must be clearly noted in the Boiler Water Treatment Risk Assessment and Boiler Water Treatment Written Control Scheme. If the Boiler Water Treatment Risk Assessment deems that this monitoring and control equipment and the additional checks and balances being applied are not suitable and sufficient for safe operation of the boiler and steam system, then this must be clearly stated in the assessment and appropriate remedial action be carried out, in order to immediately rectify this situation. Whilst these remedial actions are being carried out, the steam boiler and system should be regarded as not being in unattended operation mode, from a boiler water treatment perspective and so daily testing of pre-treatment plant, boiler waterside conditions and the associated condensate return system, must be undertaken and test results appropriately recorded. At the point that remedial works are completed and unattended boiler operation is reinstated, then the Boiler Water Treatment Risk Assessment and Written control scheme must be immediately reviewed and updated, in order to reflect any changes made and their effects on both system waterside conditions and safety of boiler operation.


Data Warnings

Click here to download the checklist: Download Checklist

For further help please see the help boxes that pop-up in the top right of this window, to view multiple help-texts you can move or close the top-most help-texts. If you close a help-text you can re-open it by clicking the warning below.

Feedwater Sulphite is at status: Orange

Feedwater Sulphite at status Orange

If treatment levels are too low, immediately increase stroke/speed of dosing pumps (firstly check all dosing pumps are actually fully functional and not airlocked for any reason) and then check TDS levels are not too low. If TDS levels are too low, then decrease blowdown-recheck levels one hour later.

If treatment levels are too high, firstly check TDS is not high (if it is then increase blowdown and do nothing further) but if satisfactory, then immediately decrease stroke/speed of dosing pumps and then recheck levels one hour later.

Click here to Submit your data Submit Data

Client: - Dataset: Steam Generator

Filter Fields

Show 10 entries Search:

Date	Comments Made	Tested by (Initials)	4 to 1 Blowdown Time	Soft Water Hardness	Shell in Service (U1/U2/U3)	Bags of Salt Added	Bags of Salt in Stock	SG Status	Feedwater Sulphite	Feedwater Hardness	Feedwater P Alk	Feedwater M Alk	Feedwater pH	Fe
12/02/2016		HE		1	U1			On Load	600	1	160	660	10	
11/02/2016		HE		1	U1			On Load	710	1	200	740	10	
10/02/2016		HE		1	U1			On Load	465	1	130	650	10	
09/02/2016		MB		1	U1			On Load	200	1	8.3	410	8	
08/02/2016		HE		1	U1			Off Line	60	1	8.3	360	8	
05/02/2016		HE		6	U1			On Load	350	1	60	490	9	
04/02/2016		HE		5	U1			On Load	465	1	70	600	9.5	
03/02/2016		HE		3	U1			On Load	450	1	90	570	9.5	
02/02/2016		HE		2	U1			On Load	390	1	90	530	9.5	
01/02/2016		HE		1	U1			On Load	325	1	60	450	9.5	

Showing 1 to 10 of 16 entries

First Previous 1 2 Next Last

Fig 34 - Typical Web Based Analytical Test Result Monitoring System

5.2 Analytical Site Testing and Chemistry Protocols

It is vital that all site testing is carried out specifically in relation to the site and system involved. Testing should only be carried out by suitably trained and competent personnel (ref-HSE INDG436 - Safe Management of Industrial steam and hot water boilers) and should follow specific laid down procedures, of which a typical representation is shown below. A record of these procedures should be kept on site, with clear instructions of how and when to carry out routine testing.

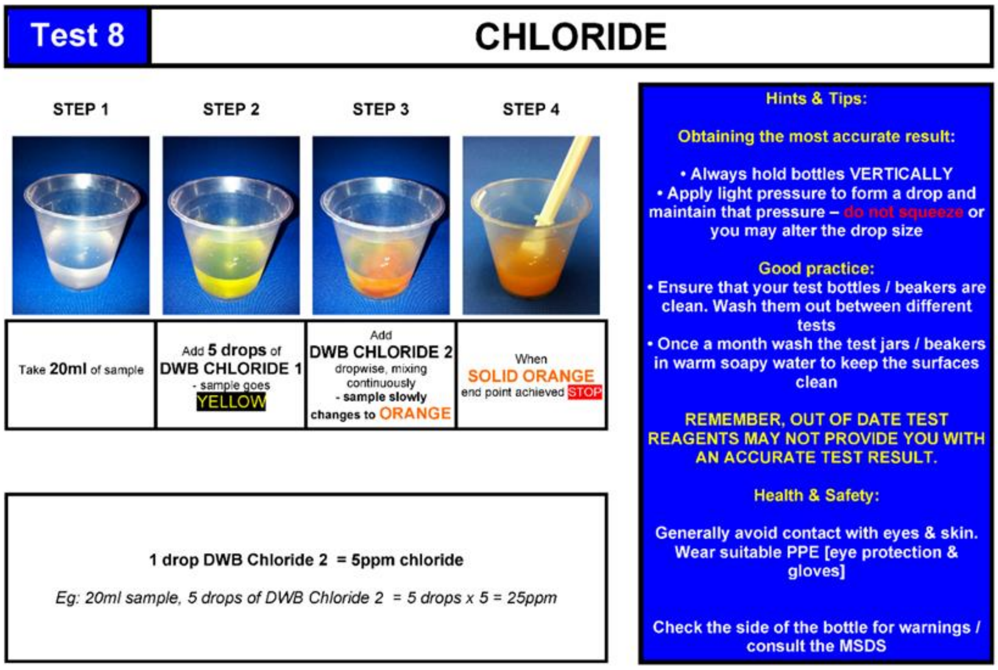


Figure 35 - Example of a site testing procedure shown above

Testing should be carried out in an area suitable for analysis and in an environment conducive to the collection of accurate and meaningful test data. For instance, it is not advised to take samples from a boiler house on one side of a factory and then transport them to the other side to be tested, as they are likely to have degraded.

A picture of a typical site testing area is at Figure 36. Following a risk assessment, suitable and sufficient PPE must be provided, along with facilities for washing test equipment etc.

Samples should be fresh and analysed immediately in order to reduce sample degradation and to produce high quality and meaningful results on a consistent and repeatable basis.

Test equipment should be suitable and sufficient for the application intended and have the necessary degree of accuracy, such as to meet the standards required.

As an example of this, the use of hardness "yes/no" or "stop/go" tablets are still widespread in the UK. Whilst these tablets are capable of indicating full failure of a softener, they do not provide the accuracy required for feed water or boiler water hardness analysis.

Figure 36 - Example of a site testing area

Similarly, test equipment that is out of date cannot be relied upon to produce accurate and representative results and as such should be not used for waterside analysis.

Figure 37 - Example of a suitable site test kit

Figure 38 - Example of a suitable site test point

The testing and results obtained should be recorded either manually or electronically, and should include as an absolute minimum include;

- The results of the tests taken and their comparison against target values;
- The name of the operator taking the tests;
- The date and time of the tests;
- The action taken in response to the results obtained and a suitable commentary as to the effectiveness of the action taken.

Where automatic monitoring systems are in place these must be checked regularly for calibration and the results of those checks recorded. It is never acceptable in boiler water treatment to rely completely on automatic monitoring and control since these items are subject to drift and if left unchecked can cause waterside conditions to fall completely out of control.

It should be noted that there must be a suitable auditing and checking system in place, such that the commentary and effectiveness of any action taken is checked by senior personnel in the management or operational chain and concluded to be a suitable and sufficient response. This is in order to close the loop of responsibility.

Site records of testing and actions taken should be retained for a minimum of 5 years and should be stored in a place that is readily accessible should they ever be required by enforcing authorities.

Note: Ideally these records should be kept with the boilerhouse daily logbook, or your site/web based electronic log book and monitoring system, in which you should record all boilerhouse activity, and if paper based, sign and date each entry in a hard backed book and have it countersigned by the Responsible Person on a daily or weekly basis. If site/web based, the system should be capable of tracking information sent, who received the information for review and when, plus date and time stamped. This forms part of your evidence in the event of an incident occurring.

Backup copies of records should be retained by site, or via a cloud based system or similar, in order to avert any issue in the event of loss.

In order to assist site testing and to provide a method of checking results and offering technical support, every steam boiler, coil boiler or steam generator must be subject to at least a monthly visit from a water treatment specialist who is experienced in boiler water treatment.

Site test results should be reviewed and discussed during this visit for each boiler and condensate system being tested. A complex system with more boilers will take longer to carry out the tests.

Electronic, cloud based or written reporting systems should have suitable security and encryption, such that no person could reasonably interfere with the data that they store, or change it in any way.

5.3 Water Treatment Dosing Arrangements - Typical Set Ups

The absolute minimum level of any steam boiler or generator water treatment dosing and control arrangement is fully automatic TDS control, used in conjunction with fully automatic dosing equipment. (Bottom blowdown for sludge control on shell boilers should be fully automatic where possible). This is the minimum acceptable standard for any new or existing steam installation in the UK, as shown in the following diagrams.

Manual control of TDS is not ideal as it tends to lead to adverse fluctuation of waterside conditions and does not allow waterside balance to take place.

It is of course possible to increase the level of automatic system monitoring and control by fitting condensate line contamination controls such as pH and TDS monitoring that pass condensate to drain in the event of contamination being sensed.

As with all treatment and control systems, these are only as good as the degree to which they are monitored and calibrated and the competence level of the person looking after them.

It is unreasonable to expect that any automatic control system will completely obviate the need for human intervention after a set period or in response to an alarm state being detected, either on-site or remotely. This should be noted in the risk assessment.

These types of systems should also be subject to regular maintenance such as probe cleaning/changes, by competent personnel and in line with manufacturer's recommendations.

Control and monitoring equipment that is left to run unattended and without regular checking by a competent person will eventually go out of calibration and/or fail, leaving waterside conditions to deteriorate, possibly catastrophically.

Figure 39 – Coil Style Steam Generator typical arrangement

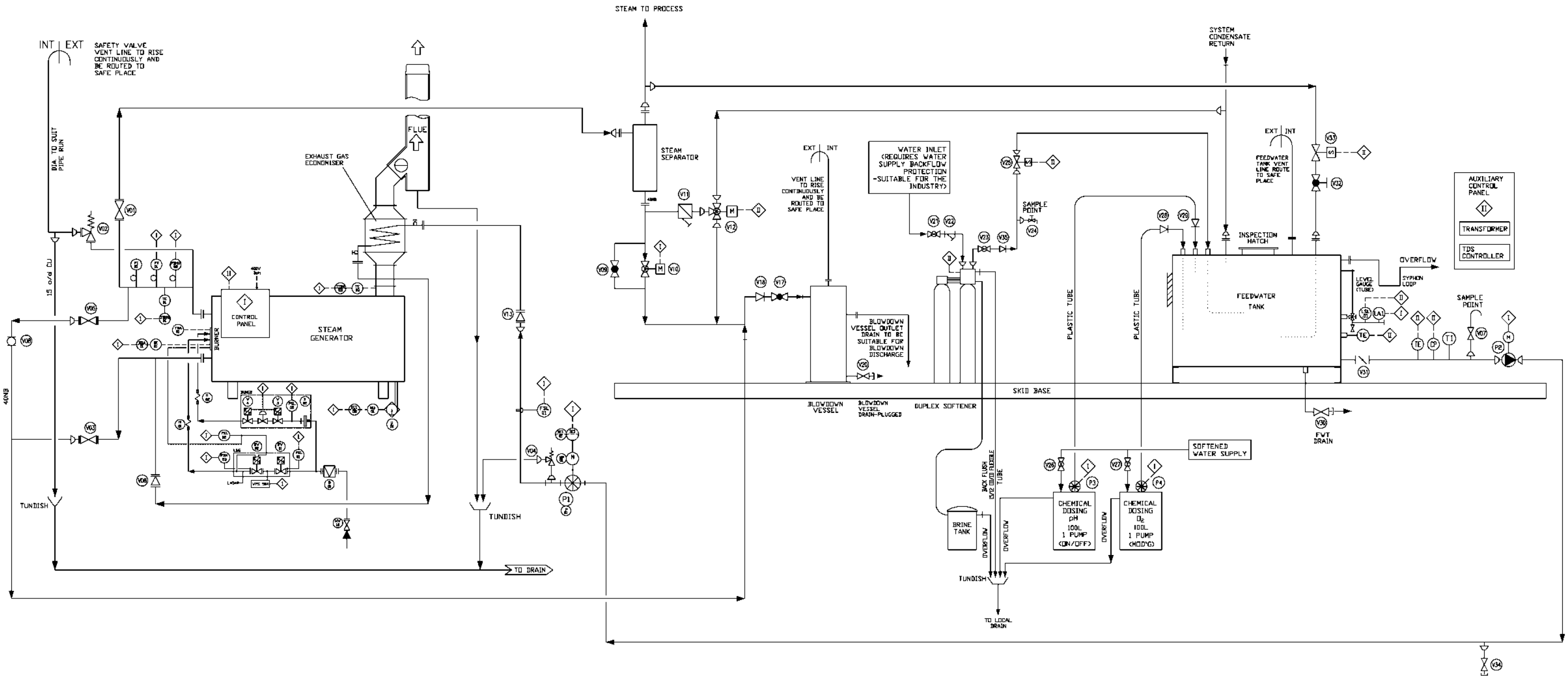
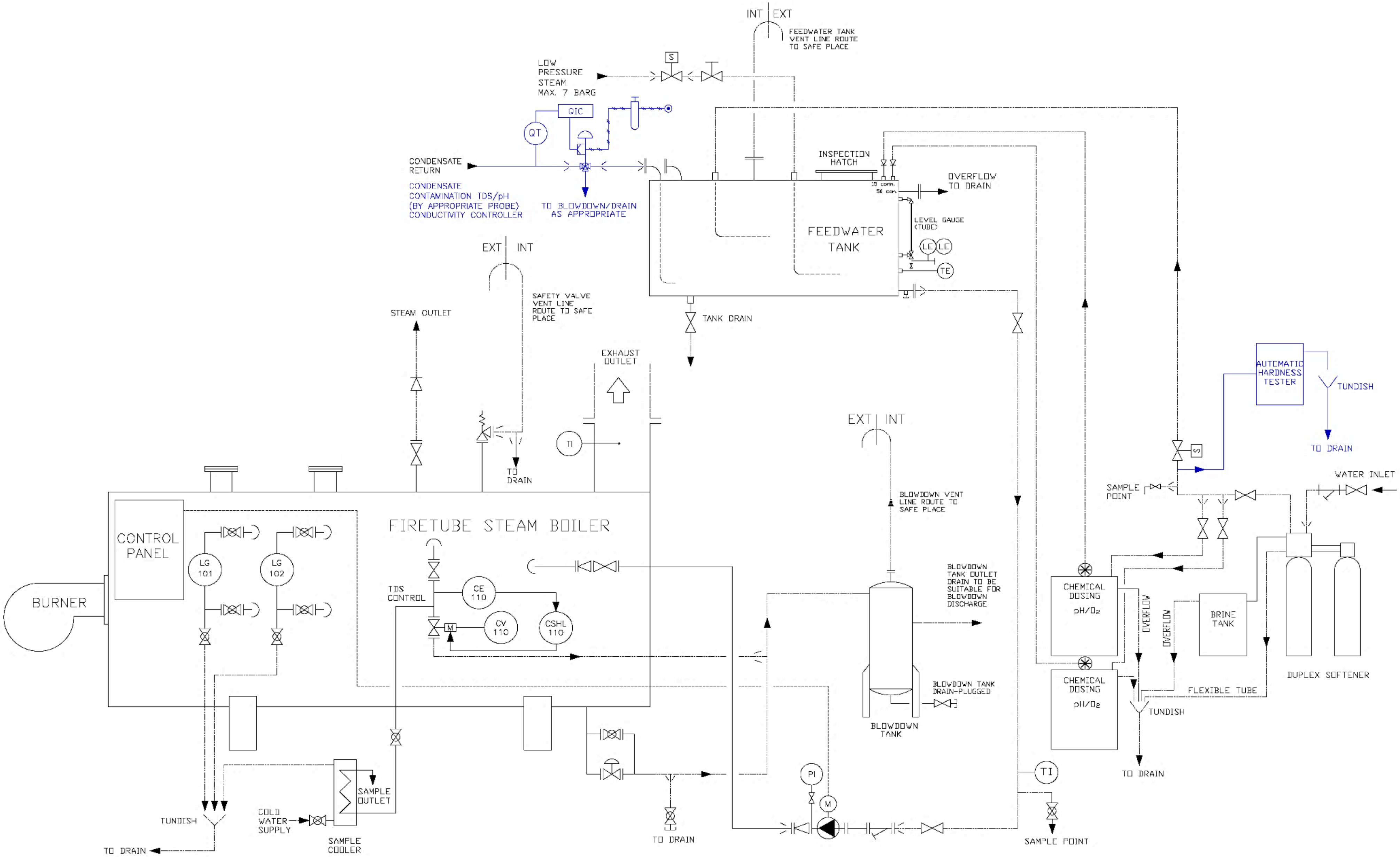


Figure 40 - Shell Boiler – Suitable automatic monitoring systems for condensate return and treated water hardness added



6 INDUSTRIAL HOT WATER BOILERS – CLOSED LOOP SYSTEMS

The need for water treatment applies to all boilers whether they are for steam or hot water. It is commonly assumed that because hot water boilers operate in a closed circuit no water treatment is necessary. This is far from the truth. Sometimes hot water is drawn-off from hot water systems either by accident, such as a system failure, or by loss during planned maintenance e.g. the changing of a radiator or valve. Any accidental loss must be made up with properly treated water.

Hot water boilers and their systems need to be initially charged with water, and that will normally contain the usual hardness salts and corrosive substances which, unless treated, can cause system damage. All hot water systems need to have arrangements made for the expansion of system water content and in many cases the expanded water will at some time be in contact with the atmosphere and so be able to absorb oxygen and carbon dioxide. Any arrangements which can be made to reduce or avoid such contact should be made, e.g. nitrogen blanketing of expansion tanks, the floating of an impermeable blanket on the water surface, or the use of diaphragm chambers or pressurisation vessels. Even when such measures are taken, it is wise to maintain correct reserves of boiler water treatment chemicals in the system.

A hot water system is rarely perfectly sealed. There will be losses from leakage and evaporation from the expansion tank that may jointly need make-up to restore the system capacity dependent upon circumstances and how well the system is being managed. The make-up water will therefore need to be treated for hardness, corrosion and bacteriological activity, otherwise scale deposition and corrosion in the boiler system can occur.

It is important that, particularly in hard water areas, the initial charge and all subsequent charges should be of softened, reverse osmosis or demineralised water and should contain a sufficient amount of oxygen scavenger and biocide. As stated, above all make-up water should be treated before addition to the system in order to avoid expensive failures later on.

There are however significant numbers of systems in the UK that are initially filled with town mains only which should not result in failure as long as losses are very low and the system is correctly treated and monitored.

Small inexpensive pre-treatment plant of sufficient capacity to handle the make-up should normally be installed. There are several approaches to filling systems with the appropriate quality water:

a) Mixed bed ion exchange vessels. These units contain a special resin that reduces the incoming mains water TDS to virtually zero, providing a single charge of demineralised quality water. Charging an empty system with such plant could take several days or more as resins will require changing, and this inconvenience has to be accepted. This approach is generally more cost effective for smaller systems but can of course be used as the basis of a blended water system fill, utilising the local town mains supply in conjunction with the packaged demineraliser.

b) Small packaged Reverse Osmosis systems that include a water softener to protect the membranes from fouling, either with or without oxygen removal systems in the form of a vacuum degassing membrane, are also a viable alternative as they require very little attention. The regenerant chemical is granular salt and there is no need to handle oversized regenerable ion exchange vessels or acid or caustic chemicals.

For larger systems, it is possible to rent a large output containerised Reverse Osmosis plant on a short-term basis or charge from a tanker loaded from a source of demineralised water e.g. a power station.

When a heating system is commissioned after installation or modification it is pressure tested. This should be done with water treated for cleansing. No system should be left drained; otherwise, rapid corrosion will take place from damp surfaces exposed to air.

The water conditions in a hot water system should correspond to the boiler water in Table 3 below, and should be kept under observation. Because in theory there is no evaporation, and therefore comparatively little make-up, the water analyses should remain stable over much longer periods than with steam boilers, but this does not mean that the subject can be neglected.

TEST PARAMETER	UNITS	TARGET CONTROL PARAMETER
pH value at 25ºC	pH Scale units	6.5 to 9.5 Steel 6.5 to 8.5 Aluminium
Sulphite	ppm	30 to 70
Nitrite	ppm	1000 min
or Tannin	ppm	120 to 160
or Ascorbic Acid	ppm	15 to 30
or Diethyl Hydroxylamine	ppm	0.1 to 1.0
Molybdate	ppm	200 min steel 300 min aluminium
Dissolved Iron	ppm	<1
Suspended solids	ppm	200 max.
Total Dissolved solids	ppm	3500 max Dependent on type of make-up water and system inhibitor used
Total microbiological activity	Cfu/ml	<1000
NRB's/SRB's/Pseudomonas(Sp)	Cfu/ml	Nil

Table 3 - Typical water treatment test parameters for hot water boiler systems

6.1 Points to consider about water quality

All heating systems are more efficient with clean, good quality system water. The most prevalent factors adversely influencing the quality of heating water are - oxygen content, total hardness, conductivity, suspended solids, total metals, chlorides, settled sludge, pH and microbiological activity.

Chemical analysis of the heating system water will determine the quality of the water by identifying the composition and concentration of the above factors. A plan to implement the appropriate corrective actions can then be formulated.

A detailed analysis of make-up water is essential prior to any cleaning/treatment programme, and a detailed assessment of system design and volume, materials of construction, and mode of operation must be carried out before a suitable programme can be developed.

Note: As the formative period of the heating system operation is dynamic, continual monitoring must be carried out until stable conditions are present, thus validating the condition of the heating system water quality.

When using non-metallic pipes these must be of the barrier type to prevent oxygen diffusion.

When an installation is regularly topped up with fresh water, more oxygen and other components (including calcium hardness) are introduced to the heating system, so adding significant quantities of fresh, hard, mains water should be avoided.

To monitor the volume of make-up water entering the system, a water meter must be fitted and readings recorded in a log book to be retained on site or in your site/web based electronic log book and monitoring system.

Note: pre-treatment of the make-up water may be required to achieve the desired system water quality, as previously noted.

6.2 Water treatment

Any boiler water treatment product must be appropriate for all materials used in the heating system. Consult with a boiler water treatment specialist for further details. Always comply strictly with the guidelines and operating instructions provided by the supplier of the water treatment product. This will involve periodic checks and possibly additional dosing to ensure chemical concentrations are maintained at a suitable level.

Note: Nitrite based inhibitors should not be used with aluminium boilers. Nitrite based inhibitors are often buffered to elevate their pH and can also encourage biological growth in systems during periods of no heat load, which can in turn affect system pH.

Consult the services of a boiler water treatment expert in relation to the following:

- The water quality of a heating installation must be checked regularly.
- The user of the installation is responsible for ensuring the installation water is always of a suitable quality. If the user wishes to obtain the required water quality by using water treatment products, they must take responsibility for the treatment.
- All records relating to water treatment products and dosing must be recorded in a site log book or web based monitoring and recording system. Any work started or completed on the heating installation should also be recorded in the log book or web based monitoring and recording system.
- It is considered best practice that records should include ‘pre-commission cleaning & flushing’ or existing system ‘remediation’ documents which evidence the efficacy of the cleaning process and final water quality on completion. They should also include details of flow rates achieved, sample locations and independent analysis of results together with ‘witnessing’ of water quality on completion.

WARNING

Applying water treatment requires great care and attention. If the instructions for the water treatment product are not followed in full, are interpreted incorrectly and/or if the product is not dosed properly, this may result in health risks or damage to the environment or the heating system.

6.3 Operating information

1. Commission the system step by step, starting with the lowest boiler output and a high heating water flow rate. This prevents a localised concentration of lime scale deposits on the boiler heating surfaces.
2. During expansion or repair work, only drain the necessary pipework sections.
3. Filters, dirt traps and other blow-down or separating facilities in the heating water circuit must be checked, cleaned and activated more frequently after commissioning or re-commissioning, and later on as required, subject to the water treatment applied (e.g. water softening).

The build-up of lime scale deposits on the heating surfaces will be minimised if these instructions are observed.

6.4 Prevention of damage due to corrosion on the water side

The corrosion resistance of ferrous materials on the heating water side of heating systems and boilers depends on the absence of oxygen in the heating water and on microbiological activity that could lead to microbiologically induced corrosion (MIC) being kept under close control.

Closed loop heating systems are often dosed with an electrochemical inhibitor only. This approach is incorrect and a microbiological control product must be added in all cases to control microbiologically induced corrosion.

The characteristic blackening of the water after some time in use indicates that free oxygen is no longer present.

The technical rules, and in particular this BG04 guide, therefore, recommend that heating systems are designed and operated so that a constant ingress of oxygen into the heating water is prevented.

During operation, oxygen can normally only enter due to:

- Open expansion vessels receiving flow through the vessel;
- Negative pressure in the system;
- Gas-permeable components.

Sealed unvented systems (e.g. systems with a diaphragm expansion vessel) offer good protection against the ingress of airborne oxygen into the system if they are correctly sized and operated at the correct pressure.

At every part of the heating system, even at the suction side of the pump, and under all operating conditions, the system pressure should be above ambient atmospheric pressure.

The pre-charge pressure of the diaphragm expansion vessel should be checked, at least during the annual service.

For pressure maintaining systems or sealed systems, the use of permeable components (e.g. plastic pipes that are permeable to gas in underfloor heating systems) should be avoided. System separation should be utilised if such components are used. This must separate the water flowing through the plastic pipes from other heating circuits (e.g. from the boiler) by the provision of a corrosion-resistant heat exchanger.

However, additional precautions should be taken where there is a risk of oxygen ingress, for example by adding an appropriate inhibitor or oxygen scavenger. The pH value of the heating water should typically be between pH6.5 and 9.5.

Different conditions apply to systems that contain aluminium components. Where chemicals are used as part of the corrosion protection, we recommend that the manufacturer of the chemicals confirms that they are suitable for use with aluminium. We further recommend you refer questions regarding water quality/treatment to a boiler water treatment specialist.

6.5 Existing systems

Flush the heating system thoroughly to remove dirt and sludge deposits before connecting a boiler to an existing heating system, otherwise this dirt and sludge will be deposited inside the boiler and can lead to local overheating, noise and corrosion. Boiler damage caused by such deposits can lie outside of a manufacturer‘s warranty. Where necessary, install dirt traps.

6.6 Looping out sensitive equipment

Consideration must be given to looping out all sensitive equipment having small-bore pipework and/or low lift valves to ensure they do not become blocked during the flushing /cleaning procedures. It is important that the system equipment manufacturer's instructions be carefully followed prior to cleaning.

6.7 Flushing points

Before commencing cleaning, adequately sized flushing points must be installed (if not already available) on the flow and return pipe-work or headers to ensure the required flushing velocities are obtainable (see table 4 below).

6.8 Static flushing

The system should be filled with mains/treated water and where appropriate, suitable water treatment chemicals added, then briefly circulated and drained rapidly from the system low points/flushing points.

Best practice dictates that systems be designed and operated so that constant ingress of oxygen into the heating water is prevented. During operation, oxygen can normally only enter due to:

- Open expansion vessels receiving circuit flow;
- Negative system pressure;
- Gas-permeable components;
- Poor jointing (especially pump connections);
- Drain down for maintenance/service (section isolating valves can minimise loss of system water).

Sealed, unvented systems (for example those with a diaphragm expansion vessel) offer better protection against the ingress of airborne oxygen if they are correctly sized and operated at the correct pressure. In any case, throughout the system, even at the suction side of the pump and under all operating conditions, the pressure should be above ambient atmospheric pressure.

It is recommended that the pre-charge pressure of the diaphragm expansion vessel be checked at least during the annual service.

In pressure-maintaining or sealed systems, the use of permeable components such as gas permeable plastic piping commonly found in under-floor heating systems should be avoided.

Where the use of gas-permeable pipe is unavoidable, water flowing through them should be isolated from the main circuit by the insertion of a corrosion-resistant heat exchanger.

Where there is an unavoidable risk of oxygen ingress, extra precautionary measures should be considered such as adding suitable oxygen scavengers to the system water, or deoxygenating the water using a degassing system, along with suitable hardness conditioners and biocides. Residual levels of these products should be regularly monitored, in order to ensure that correct levels for protection are being maintained.

6.9 Determining system volumes in closed loop systems

System volume should be estimated from a consideration of pipe bore and length, together with nominal waterside volumes of all components. A very approximate minimum system volume may be estimated from:

Boiler kW (thermal input) x 12 = System volume (litres)

Alternative methods include accruing data from system drawings and fitting/reading an appropriate water meter.

6.10 Reverse Osmosis (RO) water for Initial System Fill and Top-Up

Reverse Osmosis water, as an initial fill and for minimal top-ups, is recommended for all kinds of heating system with all types of metals. In completely demineralised water, not only are all substances which may cause hardness removed from the fill and top up water, but also some corrosion agents such as chloride and sulphate.

Reverse Osmosis does not of course remove oxygen, a prime facilitator of corrosion in closed systems, so chemical treatment of the system is still required (even after deoxygenating the water using a degassing system, if fitted).

6.11 Monitoring and maintenance

The objectives of water treatment (and pre-treatment) are to minimise the corrosion of system metals, to inhibit the formation of mineral scale, and to inhibit the growth of microbiological organisms. In this way, not only the physical integrity of the system but its long-term efficiency and effectiveness are preserved. Major problems of corrosion, scale and microbiological fouling can be avoided by correct system design and installation which will minimise ingress of air into system water and reduce excessive requirement for make-up water, electro-galvanic couplings and use of municipal potable supply water.

Account should be taken of long-term static periods during times of heating shut down, as these conditions will promote corrosion, especially microbiologically induced corrosion.

Primary heating circuits should be thoroughly cleaned and flushed prior to commissioning, re-commissioning following major remedial works; this also applies if the system is known or suspected to be affected by corrosion, settled sludge, deposits, build-up of scale on heat transfer surfaces, gassing or cold spots.

The type and extent of debris, dirt and fouling commonly found inside heating circuits largely depends on the age and nature of the system and how well or poorly it has been maintained. New systems invariably contain contaminants and debris from component manufacture or from the system installation work itself, whilst older, even well maintained installations, may have accumulations of sludge and scale. Microbiological slimes and contamination may be found in all systems regardless of age.

A thorough system clean not only restores system efficiency and effectiveness, but is also critical in preparing interior surfaces for effective corrosion and scale inhibition.

Before cleaning, the system should be examined to determine the system configuration, the age and overall condition of components and the nature of the contamination that needs to be cleaned. This is done in order to decide the most appropriate cleaning agent and cleaning method.

6.12 Choice of Cleaning Chemical

There are many different cleaning and sanitising chemicals available. These range from mild, detergent cleaners, which may be designed for cleaning newly installed systems, through to cleaners formulated to penetrate, lift and remove sludge and accretions in older systems, and to strong acid based cleaners, specifically designed to remove high levels of hardened lime scale deposits and corrosion. Other cleaners are formulated with biocidal ingredients to target and destroy microbiological growths. The choice of cleaning agent should be appropriate for the materials of construction of the system, the type of contamination to be removed, the cleaning method employed and any discharge limitations.

Chemical cleaning of closed loop heating systems is a specialist discipline and only appropriately equipped and experienced providers should be considered.

Special consideration should be given to systems containing aluminium that are vulnerable to attack at low and high values of pH. Manufacturer’s recommendations and guidelines regarding the choice/use of chemicals and recommended operating parameters should ALWAYS be followed.

6.13 Cleaning Methodologies

The type of cleaning method adopted will depend on the system size and complexity, system materials and sensitivity, or obstruction of plant items (regulating valves, chillers etc.) to the cleaning process. In all cases, the technical requirements for the system cleaning protocol should be prescribed by the system designer and the protocol undertaken by trained and experienced personnel under the auspices of management procedures that ensure safe and effective working practices and adequate record keeping. The specification for cleaning of a system should at least include drawings of the system layout as installed in relation to the building, schedules of materials of construction, system equipment and system components, details of system sectional volumes, the main steps in the cleaning process to be employed and the method of achieving the required flushing velocities to effect an adequate removal of contaminants.

In larger systems, the larger-bore primary ring main should be isolated, bypass circuits closed off and the main ring dynamically flushed first. Where the bore diameter makes it difficult to obtain adequate flow velocity, the addition of a chemical dispersant may aid debris suspension or it may need to be accessed and physically cleaned. In systems served by a large bore ring, consideration should be given to providing full-flow filters, dirt traps/separators or scrubbers to protect system components.

The secondary main pipework sub-circuits should be isolated and cleaned after opening all valves and isolating sensitive equipment.

A typical cleaning programme for either the entire system or isolated sections of it will involve the following steps and may include temporary pumping facilities:

1. A biocide prewash in systems vulnerable to microbiological contamination or in systems left idle for several weeks after pressure testing.
2. A pre-chemical clean dynamic flush using potable municipal supply water/treated water.
3. A chemical-clean dynamic circulation, neutralisation procedure if applicable, and flush.
4. A post-chemical clean dynamic flush using potable municipal supply water/treated water.
5. A passivation regime should be considered for some systems.
6. A final fill with potable municipal supply water/treated water and addition of an appropriate corrosion and scale inhibitor.

To aid the cleaning process, filtration should be considered. This may be side stream or in line filtration using magnetic filters, dirt separators or strainers. This will aid the cleaning process by continually removing dirt particles during the cleaning programme.

A visual inspection of the water at the end of stages ii) and iv) is required to confirm cleanliness. Preferably, methods for on-site quantitative estimation of water clarity such as graduated turbidity tubes or similar should be employed. Filters and strainers should be cleaned at the end of each stage i) to iv). Stages ii), iii) and iv) may each have to be repeated several times to attain satisfactory conditions.

Extra stages may be required in special circumstances (e.g. to effect the removal of greases, neutralise acidic cleaner solution or pre-passivate system metal) and these should be incorporated into the cleaning programme in the appropriate sequence.

The water velocity for flushing and cleaning should be sufficient to penetrate, dislodge, suspend and transport insoluble debris and gas from the system. It should also ensure even temperature around the system for optimum effectiveness of the chemical cleaner. Flushing velocity should be based on the largest pipe diameter in the system or zone to be flushed. Effective minimum flush velocities for horizontal pipe provide sufficient turbulent flow (Reynolds number >4000) and are listed in Table 4.

Nominal Pipe Size (mm)	Flushing Velocity (m/s)	Flushing Volume (l/s)
20	1.00	0.37
30	1.05	0.96
40	1.08	1.50
50	1.11	2.45
80	1.17	6.00
100	1.22	10.50

Table 4 - The required minimum velocities for effective pipeline flushing.

It may be difficult to attain sufficient flushing velocities in primary circuits having pipe bores more than 100mm and in such circumstances it is advisable to adopt alternative cleaning protocols such as the addition of chemical dispersants to help suspend particulate debris or, as a last resort, direct access for physical cleaning.

The duration of chemical cleaner circulation in the system or system sub-circuit depends on several factors including the type and thickness of deposits, the temperature and concentration of the cleaning solution, the flow velocity and agitation and its compatibility with materials of construction. Water treatment chemical suppliers' instructions must be followed.

It is often possible to discharge spent cleaning solution directly to foul drain, but permission must be sought from the local municipal water authority, and must be within the requirements of prevailing legislation. Such effluent should never be discharged to surface drains.

6.14 Dynamic pre-clean flushing

An initial dynamic balanced flushing procedure may be performed by pumping in fresh water and, if required, using a suitable temporary pump and tank set. This initial flush, prior to a chemical dynamic flush, will remove significant amounts of loose corrosion or installation debris and thereby reduce subsequent system demand for cleaning chemical.

The system pumps should be operational during this procedure (where possible) to help achieve flushing velocities as noted in Table 4, or at least 10% above design flow rate. This procedure helps to remove larger particles of corrosion debris from the system. As noted above, in some cases due to the size of the primary pipework it may be difficult to achieve the flushing velocities required in this loop; therefore, advance use of a suitable chemical dispersant product prior to flushing can assist the dynamic flush process by encouraging suspension of the loose material. In this case, heating the system water to above 40ºC prior to the flush will further enhance the loosening and suspension of debris.

To help maximise flushing velocities, larger circuits should be divided into individual zones or sections and cleaned separately. Each section of the system being cleaned should be isolated from the rest of the circuit during the flushing process.

The duration of the dynamic flush depends on flush velocity, section size and initial extent and nature of deposits but should be sufficient to achieve an appropriate level of cleanliness. In any case, it should be followed immediately by drain down to ensure optimum removal of the suspended debris. System strainers or filters should be inspected and cleaned.

Flushing water clarity can be estimated by use of graduated turbidity tubes.

6.15 Dynamic chemical flushing

Following the initial dynamic flush, the procedure should be repeated with the inclusion of an appropriate chemical cleaner to the system water to dissolve or dislodge and remove adherent iron oxides, sludge, greases, fluxes and scales.

Water treatment chemical cleaning products should be added via a dosing vessel, a solid chemical feeder, pot feeder or flushing pump.

If possible, heating the circulating cleaner solution will enhance the effectiveness of the clean and may shorten the cleaning cycle. The duration of the dynamic chemical clean depends on temperature, flush velocity, section size and initial extent and nature of deposits, and the nature and concentration of the cleaning chemical employed. In all cases, the chemical cleaner supplier's instructions must be followed, especially with regard to material compatibility.

Monitoring of the progress of the dynamic chemical clean according to the supplier's instructions may be possible and will indicate when the chemical clean is complete.

Highly acidic or alkaline cleaning solutions must be adjusted to a neutral or near neutral pH (6.0 – 8.5) before discharge to drain. In any case, discharge to drain of the cleaning solution must occur immediately after dynamic chemical flushing in order that solid suspended matter is removed with the cleaning solution and not allowed to resettle in the system. System strainers and filters should be inspected and cleaned.

6.16 Final Full System Flush

Individual, isolated sections may be dynamically flushed with mains/treated supply water. To ensure adequate water quality throughout, the entire system should be finally flushed simultaneously until the quality of the effluent is acceptable.

System strainers or filters should be inspected and cleaned and any looped out equipment should be back flushed prior to reinstatement.

6.17 Final Water Treatment

After the final flushing is complete, a chemical corrosion and scale inhibitor product along with a suitable biocide should be dosed during, or immediately after, the final refilling of the system in order to prevent system deterioration. Inhibitors should be added via a dosing pot, a solid chemical feeder, dosing pump or flushing pump at a concentration recommended by the water treatment chemical supplier.

Corrosion control is most effectively achieved by the addition of water treatment chemicals to the system water. Their effectiveness relies on interior metal surfaces being clean and consequently on the thoroughness of pre-commission cleaning operations. Water treatment chemicals used in closed loop heating systems should have the following attributes;

- Soluble or easily dispersible in order that they can be evenly distributed and afford protection throughout the system.
- Stable and effective across the entire temperature range experienced in the system.
- Effective in the system fill water in regard to its quality or hardness. Where fill water is pre-treated by base-exchange softening or demineralisation, there is an increased potential for corrosion and it is critical that a corrosion inhibitor is added which has been specifically formulated for such waters.
- Inhibits corrosion of all the different metal types in the system.
- Non foaming.
- If the system contains aluminium components, it is critical that the water treatment chemical should buffer and stabilise the pH of the system water strictly between pH6.5 and 8.5.

- In the absence of aluminium components, the additive may buffer and stabilise the pH of the system water from pH6.5 up to pH9.5.
- Compatible with all water-facing materials in the system.
- Preferable to be able to perform on-site testing for concentration level in the system.
- Some water treatment chemical inhibitors may have discharge considerations subject to local constraints.

Water treatment chemicals should be added during the final fill of the system at a concentration recommended by the water treatment chemical supplier. It is important that full circulation and homogenous distribution of the water treatment chemicals are achieved before sampling system water to confirm the correct water treatment chemical concentration/waterside conditions, with subsequent adjustment if necessary.

The volume of system water make-up should be monitored, preferably by incorporation of a water meter on the system supply line so that water treatment chemical losses due to leaks or partial drainage for maintenance work can be replenished. In any case, the concentration of water treatment chemicals and general waterside conditions in the system should be checked periodically, at least quarterly, as an absolute minimum. This may need to be more often in systems deemed to be at risk, or requiring frequent make up due to losses.

If antifreeze is used, then compatible water treatment chemicals should be used and the concentration of these must be measured periodically, at least quarterly as previously stated.

Problems caused by mineral scale are minimal in sealed, closed circuit systems requiring little or no water make-up. Where the use of water pre-treated by base-exchange softening or reverse osmosis is chosen, only water treatment chemicals should be added which have been specifically formulated for such waters.

Scale control is most easily achieved using chemical scale inhibitors. It is common that chemical scale inhibitors and chemical corrosion inhibitors are formulated together in a single product. If added separately, similar precautions should be taken to maintain optimum concentration in the event of replenishment of water losses as noted above for corrosion inhibitors.

If conditions are favourable to their proliferation, microbiological organisms can thrive in closed circuit systems. If water temperatures in any part of the circuit never exceed temperatures of 60ºC, then given sufficient nutrients, micro-organisms can thrive.

Systems prone to microbiological fouling should first be cleaned and sanitised as part of a commissioning or periodic cleaning programme, followed by the application of an appropriate biocide to the system water for long-term protection. Similar precautions should be taken to maintain optimum concentration of biocide in the event of replenishment of water losses as noted above for corrosion and scale inhibitors.

The system should be commissioned stepwise, starting with the lowest boiler output and a high heating water flow rate. This helps prevent a localised concentration of lime scale deposits on the boiler heating surfaces.

Note: Filters, dirt traps and other blow down or separating facilities in the heating water circuit must be checked, cleaned and activated more frequently after commissioning or re-commissioning.

Each stage of the cleaning process should be witnessed by the client and signed off on a service/work sheet.

It is recommended that water samples be taken for full laboratory analyses following the flushing stages and after the addition of the inhibitor, together with the mains/fill water.

One copy of the service/work sheet should be presented to the client and one retained for reference.

A certificate to confirm the water condition should be attached to the work completion certificate, and accepted with a counter signature by the client.

Waterside condition monitoring after a suitable period (typically 2-4 weeks after completion of works), is strongly advised in order to ensure that full circulation and homogenous distribution of the water treatment chemicals has taken place and that treatment levels and waterside conditions are correct. Samples may be taken for laboratory analysis.

A further check should be performed after three months and levels adjusted as necessary.

A copy of the analyses and recommendations should be communicated to the customer.

Waterside condition monitoring should be considered as part of an on-going maintenance programme and must take place at least once every three months, as an absolute minimum – more often in systems deemed to be of critical importance, at risk, or requiring frequent fresh/treated water make-up due to losses.

In the special case of steam-pressurised high pressure hot water systems from which any steam is taken as such, the water treatment should be as for steam boilers with much more frequent checking of the water analysis than with hot water only.

6.18 Dosing Arrangements for Hot Water Boilers

Hot water boilers may be dosed in several different ways but are usually charged using either a dosing pot or a solid chemical feeder, either of which are typically piped across the flow and return of a system.

Solid chemical feeders have the advantage of being able to dose both solid and liquid water treatment chemicals.

Examples of each type of feeder are shown as follows:

Figure 41 - Typical Solid/Liquid Chemical Feeder

Figure 42 - Typical Liquid Chemical Dosing Pot

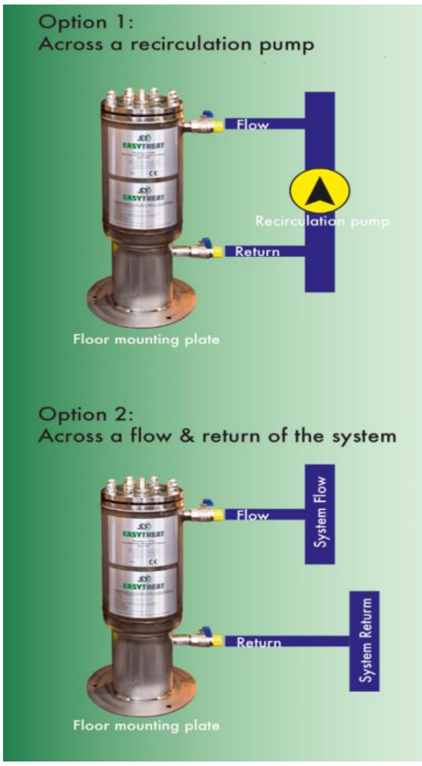


Figure 43 - Typical Solid/Liquid Chemical Feeder Installation

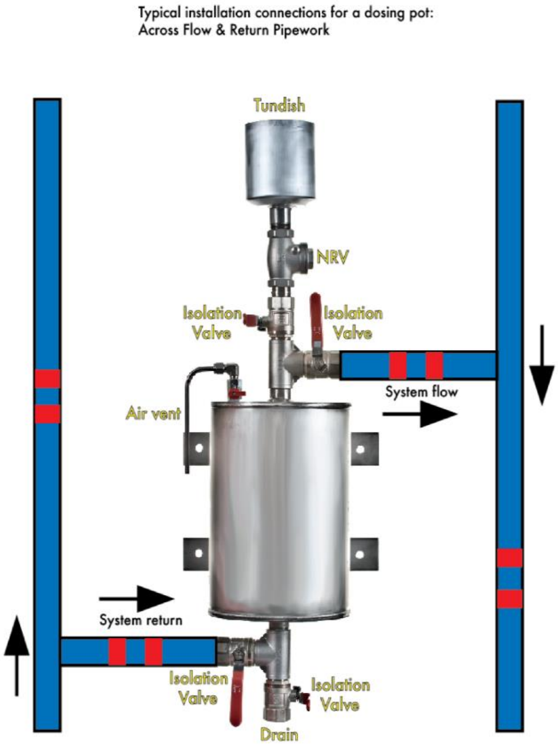


Figure 44 - Typical Liquid Chemical Dosing Pot

For systems experiencing significant water losses, or that require regular and frequent dosing, a further option is to utilise a dosing pump and chemical tank. This arrangement can be used in tandem with a water meter or count down timer.

7 COIL BOILERS AND STEAM GENERATORS

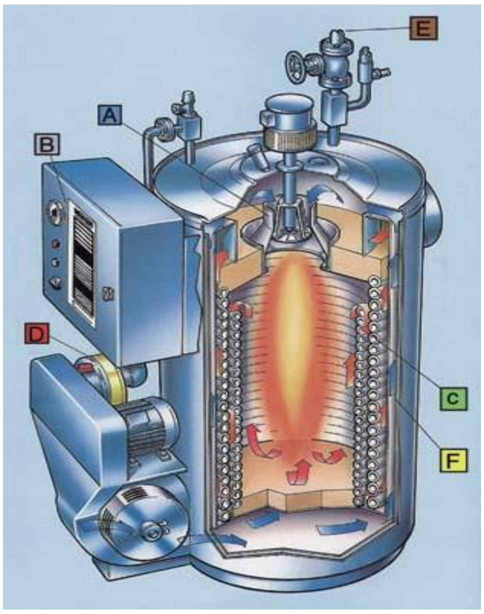
The need for correct water treatment applies equally to Coil Type Steam Boilers as Shell and Tube type. Coil boilers operate differently as they pass an excess of water through a heated coiled tube to produce the required quantity of steam, with the excess water (typically 10%) containing all the dissolved solids being re-circulated to the feed water system.

Some steam generators are shell type and these should be treated and managed in the same way as other steam generators.

The principles of water treatment for shell type boilers outlined in previous chapters are much the same for coil boilers or steam generators, albeit that the application and control of these principles and parameters are normally markedly different to shell boilers. When treating these types of coil boilers or steam generators it is strongly advised that only a specialist in these types of boilers is used. It is not possible (or desirable) to treat the water within the coil of a coil boiler and all treatment and tests are completed in the feed system. This means the set parameters are slightly different, even though the end result is the same. The requirements for feed water quality will also vary as the steam is produced under forced flow conditions.

It is therefore recommended that operators of coil boilers and steam generators refer to the manufacturer's literature to determine limits for feed water quality and recommended treatment methods. It is strongly advised that only a specialist in the treatment of these types of boilers is used.

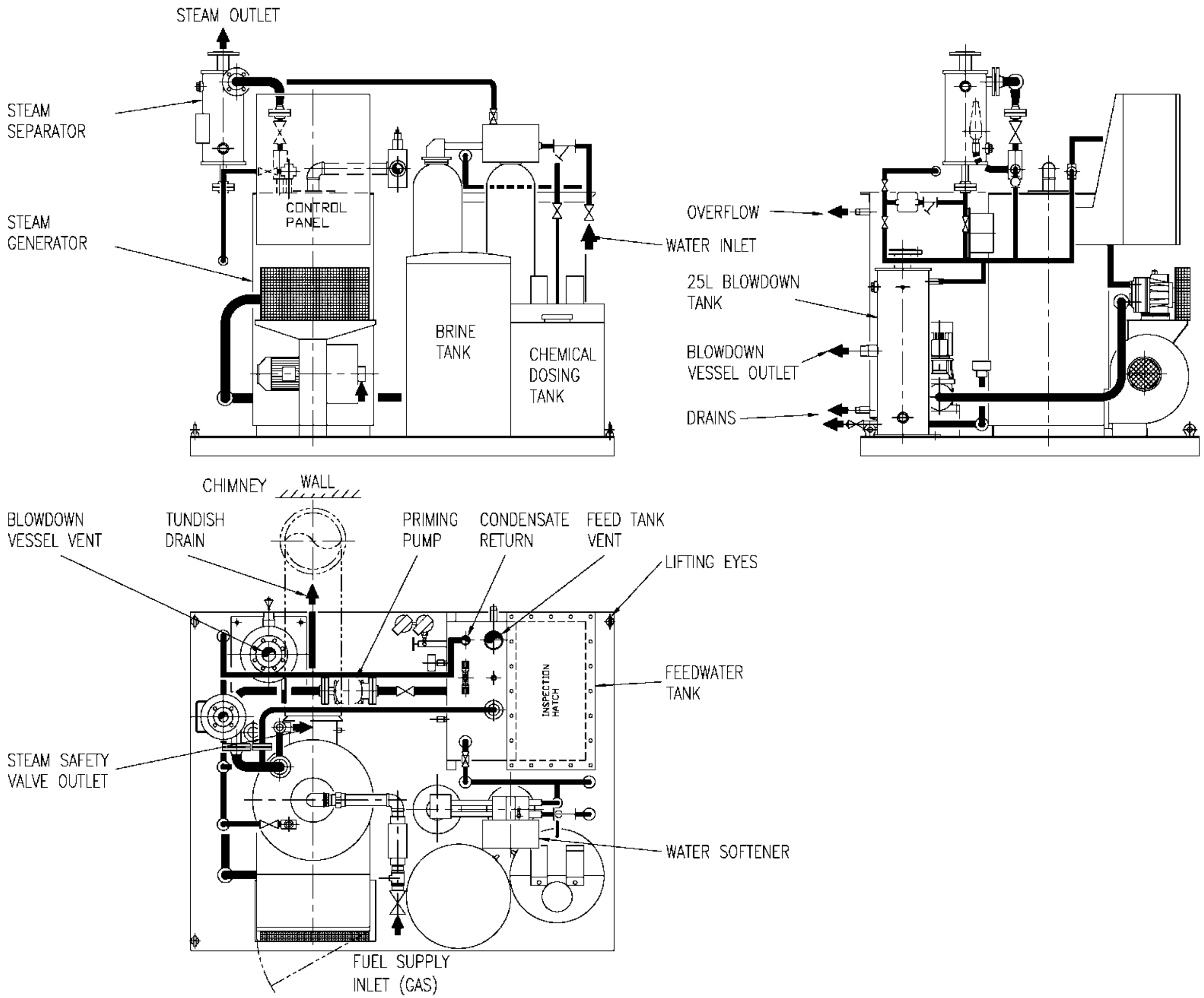
Figure 45 - Typical Skid Mounted Coil Boiler showing water treatment arrangement



A - Gas or oil integrated burner
B - Control Panel
C - Combustion gas passes
D - Feed water pump
E - Main steam outlet valve
F - Integral combustion air pre heat

Figure 46 – Coil Boiler Cut Away Section

Figure 47 - Typical skid mounted diagrammatic installation



8 IDLE BOILERS

Sometimes boilers are in full-time operation throughout the year, whilst in other cases they are 'laid up' for extended periods, e.g. space heating boilers during the summer months. The former case, where the boilers are in constant demand, is the best and simplest condition to control from a water treatment perspective, whereas the latter can cause severe difficulties with both water-side and gas-side corrosion unless precautions are planned.

8.1 Water-Side Corrosion

With hot water systems, the system and boiler should be left full of properly treated water, as described in Section 5 and Table 3, albeit that some inhibitors do not perform well in static conditions and are best deployed in systems where the recirculation pump is run regularly – ideally for an hour a day. With steam boilers, coil boilers or steam generators, the methods are more complex, and they depend both on the period of 'lay-up' and also the specific type of boiler involved. If this is only a few days it is sufficient merely to valve off, ensuring that the oxygen scavenger reserve and pH levels are adequate.

For periods up to one month, the boiler should be fully flooded and the water checked to give a pH of 10 - 11.5 and a sulphite reserve of at least 500ppm. The water analysis should be checked at weekly intervals and corrected if necessary. All air should remain excluded from the steam and water space of the boiler.

If the lay-up period is over one month a shell boiler should be drained, the man and mud holes should be knocked-in, and the inside completely dried out. A source of hot air, such as that from a small convection heater, is then ducted to a mud hole and the boiler inspected from time to time to ensure that it is kept dry. In the case of a coil boiler, the coil should be sealed and filled with an inert gas, such as nitrogen. These various methods are summarised below.

8.1.1 Steam Boilers (Shell and Tube Type)

Overnight Shutdown - no action normally required, assuming that treatment levels are in specification (30-70ppm as Sulphite).

Weekend Shutdown or for periods of up to 48 hours – boost Sulphite levels 1-2 hours before turning off the boiler by turning the dosing pump up to 100%. Aim to achieve 150ppm as Sulphite as a minimum. On start-up leave the pump at 100% for 1 hour to immediately boost treatment levels. After 1 hour reduce the dosing pump down to normal settings.

Shutdown for periods of greater than 48 hours and up to 7 days – boost Sulphite levels 3-4 hours before turning off the boiler by turning the dosing pump up to 100%. Aim to achieve greater than 250ppm as Sulphite as a minimum. On start-up leave the pump at 100% for 1 hour to immediately boost treatment levels. After 1 hour reduce the dosing pump down to normal settings. It is also important to maintain system alkalinities during prolonged shutdown periods.

Shutdown for periods greater than 7 days and up to one month - boost Sulphite levels 5-6 hours before turning off the boiler by turning the dosing pump up to 100% to immediately boost treatment levels. Aim to achieve greater than 500ppm as Sulphite as a minimum.

On start-up leave the pump at 100% and after 1 hour reduce the dosing pump down to normal settings. Consider running the unit on pump only or firing on low fire/blowing down every 3-4 days in order to keep treatment levels up and introduce fresh product into the system. Chemical treatment mixes should be kept as a minimum in dosing tanks in order to preserve freshness and mixed specifically according to usage requirements. It is also important to maintain system alkalinities during prolonged shutdown periods. Treatment levels should be tested at least weekly, even when boilers are off-line, in order to prevent against off-line corrosion attack.

For longer shutdown periods – Ensure the boiler is fully depressurised, drain the boiler and systems, open all manways and mud holes and allow natural ventilation throughout the boiler to dry the internal metal surfaces to prevent corrosion. Forced draught with the use of heaters can help dry out the boiler more quickly. Coil Boilers require a different approach; they need the coil fully draining, then filled with an inert gas such as Nitrogen, and then sealed.

8.1.2 Steam Generators

Overnight Shutdown - no action normally required, assuming that treatment levels are in specification (60-100ppm as Sulphite).

Weekend Shutdown or for periods of up to 48 hours – boost Sulphite levels 1-2 hours before turning off the generator by turning the dosing pump up to 100%. Aim to achieve 150ppm as Sulphite as a minimum. On start-up leave the pump at 100% for 1 hour to immediately boost treatment levels. After 1 hour reduce the dosing pump down to normal settings.

Shutdown for periods of greater than 48 hours and up to 7 days – boost Sulphite levels 3-4 hours before turning off the generator by turning the dosing pump up to 100%. Aim to achieve greater than 250ppm as Sulphite as a minimum. On start-up, leave the pump at 100% for 1 hour to immediately boost treatment levels. After 1 hour, reduce the dosing pump down to normal settings. It is also important to maintain system alkalinities during prolonged shutdown periods.

Shutdown for periods of greater than 7 days and up to one month – boost Sulphite levels 5-6 hours before turning off the generator by turning the dosing pump up to 100%. Aim to achieve greater than 500ppm as Sulphite as a minimum. On start-up leave the pump at 100% for 2 hours to immediately boost treatment levels. After 1 hour reduce the dosing pump down to normal settings. Consider running the unit on pump only, or firing on low fire every 3-4 days in order to keep treatment levels up and introduce fresh product into the system. Chemical treatment mixes should be kept at a minimum in dosing tanks in order to preserve freshness and mixed specifically according to usage requirements. It is also important to maintain system alkalinities during prolonged shutdown periods. Treatment levels should be tested at least weekly, even when boilers are off-line, in order to prevent against off-line corrosion attack.

Figure 48 - A well-treated steam generator coil-internal cut away view showing well-formed magnetite layer internally

8.2 Gas-Side Corrosion

More corrosion can take place on the gas-side of an idle boiler than when the boiler is in operation.

Gas-side corrosion results from attack on the metal of the boiler by sulphur compounds. These accumulate in soot deposits which may contain up to 30% sulphuric acid which is hygroscopic i.e. absorbs moisture from the atmosphere. The soot becomes wet and allows the acid otherwise absorbed on the particles to migrate to and attack the boiler metal.

When boilers are 'laid up' it is important that the gas-side is thoroughly cleaned and all soot removed. This is much more easily done with the boiler hot. The soot is then much drier and more readily removed than if the boiler is left to cool, even for a few hours.

Where the boilers are connected to separate chimneys it is best to leave the gas-side fully ventilated i.e. open up the burner or remove it, and leave the exit damper (if any) fully open. Where the boiler outlets are connected to a common chimney this cannot be done, otherwise flue gases may discharge back into the boiler house through the idle boiler. In these cases, the exit damper must be shut.

9 BIOMASS BOILERS

Boilers running on biomass (organic fuel such as wood chip) have become more popular in recent times due to government incentives and the availability of new designs and systems.

Although biomass boilers run on a different type of fuel, from a purely water treatment perspective they follow the guidance laid down in previous chapters of this document, whether they be steam or hot water in nature.

10 ELECTRIC/ELECTRODE BOILERS

These are steam or hot water boilers/generators that are powered by electricity instead of typical fossil fuels, such as gas. Although not very prevalent in the UK, these types of units have become marginally more popular in recent times due to the perception by some that electricity is a green fuel. There are of course arguments against this concept.

These types of boilers typically have small make-up water storage systems and are of low steam or hot water output, and are thus predominantly suited to smaller installations, albeit that larger output versions are available nowadays.

They often heat the make-up water from cold, converting it to steam or hot water and given their design, can be very difficult to treat effectively, with elements/electrodes often failing due to scale formation.

As such, extremely high water treatment standards are vital with respect to this style of steam or hot water boiler if failure is to be avoided.

11 GLOSSARY OF COMMONLY USED TERMS IN STEAM BOILER, STEAM GENERATOR AND HOT WATER BOILER WATER TREATMENT

Alarm Relay: An electric circuit, that when triggered will active an alarm – this could be internal or external to the boilerhouse, or at a remote monitoring station.

Alkalinity: An expression of the total basic anions, including hydroxyl, carbonate and bicarbonate in a solution.

Alkalinity Booster: A chemical used in water treatment to raise pH and alkalinity.

Allowable working pressure: The maximum pressure for which the boiler was designed and constructed; the maximum gauge pressure on a complete boiler and the basis for the setting on the pressure relieving devices protecting the boiler.

Amine: A type of chemical used to control corrosion generally in condensate systems, although under certain circumstances can be used throughout the steam system. They are generally classified as neutralising or filming.

Anion: A negatively charged ion.

Anode: The positive electrode of an electrochemical cell where electrons are donated and oxidation occurs.

Backwash: A stage in the regeneration cycle of a softener or other ion-exchange equipment, during which water flow through the unit is directed upwards through the resin bed. This is done to clean and reclassify the bed following exhaustion.

Balanced dynamic flush: A stage in the flushing of closed circuit systems, such as hot water boiler systems, whereby the incoming fresh water flushing flow rate is "balanced" against the dirty water leaving the system to drain.

Biocide: A solid or liquid water treatment chemical added to closed loop circuits, such as hot water boiler systems, to control bacteria levels and reduce the propensity for the set-up of microbiologically Induced Corrosion (MIC).

Biocide wash: A stage in a closed loop hot water boiler system clean whereby specific solid or liquid biocidal water treatment chemicals are added, recirculated and then flushed from the circuit in order to control initial bacteria levels and reduce the propensity for the set-up of microbiologically Induced Corrosion (MIC).

Bottom blowdown: A portion of the boiler water that is intermittently sent to drain to remove sludge and other suspended matter within the boiler.

Surface Blowdown: A portion of the boiler water that is intermittently sent to drain, in order to remove total dissolved solids (TDS) content.

Blowdown valve: The valve that opens to carry out blowdown – this could be automatic in the case of surface blowdown or manual/automatic in the case of bottom blowdown.

Boiler horsepower: A rate of heat generation equivalent to 33,479 BTU per hour. A boiler operating at one horsepower (HP) load evaporates 34.5 pounds of steam per hour.

Boil out: The removal of oils, greases, etc. at commissioning prior to normal operation or after major repairs by heating a highly alkaline solution in the boiler pressure parts. Not generally required for modern boilers due to the improvements made in quality of manufacture.

Boiler Water Treatment Risk Assessment: Site and system specific document, identifying and assessing the risk from the water treatment in relation to the steam boiler plant and total steam system, determining any necessary precautionary measures.

Boiler Water Treatment Written Control Scheme: This is a scheme arising from the findings of the Boiler Water Treatment Risk Assessment, that records the various control measures to be employed and how to use and carry out those measures. It should describe the water treatment regime in place and the correct operation of the water system plant. The scheme should be both site and boiler/steam specific, relating only to water treatment of the boiler plant and so therefore specifically tailored to the boiler plant covered by the Boiler Water Treatment Risk Assessment.

The following list summarises the information that must be included in a Boiler Water Treatment Written Control Scheme.

- Purpose;
- Scope;
- Boiler Water Treatment Risk Assessment;
- Management Structure:
  - Statutory Duty Holder;
  - Responsible Person(s) and communication pathways;
  - Training records;
  - Allocation of responsibilities;
- Up to date system schematic diagram from incoming water right through to condensate return;
- Correct and safe operation of the system;
- Precautions in place to prevent or minimise risks associated with the water treatment of the boiler;
- Analytical tests, other operational checks, inspections and calibrations to be carried out, their frequency and the resulting corrective actions;
- Remedial action to be taken in the event that the Boiler Water Treatment Written Control Scheme is shown not to be effective, including Written Control Scheme reviews and any changes made;
- Health and safety information, including details on storage, handling, use and disposal of any water treatment chemical products used in both the treatment of the system and its testing;
- Incident plan designed to cover the following situations:
  - Plant failure such as complete boiler failure or system explosion;
  - Dosing and control equipment failure;
  - Monitoring and data recording equipment or systems failure.

British Thermal Unit (BTU): The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.

Buffer Solution: A solution with a specific pH value, used as a control in calibrating sensors or hand held meters.

Calibration: A procedure to match the values read by sensors against a known standard.

Calorifier: An apparatus used for the transfer of heat to water in a vessel by indirect means, the source of heat being contained within a pipe or a coil immersed in the water.

Carbonic acid: A weak and unstable acid, H_2CO_3, existing only in solution. Carbonic acid is formed as carbon dioxide in steam dissolves in condensate. This is the primary cause of condensate system corrosion, otherwise known as "grooving" or "river rot".

Carry-over: The entrainment of liquid water along with dissolved impurities in steam leaving a boiler or steam generator. This results in loss of heat transfer, erosion, deposition in steam-using equipment and eventual blockage of key equipment and waterways.

Cathode: The negative electrode of an electrochemical cell where electrons are accepted and reduction occurs.

Cation: A positively charged ion.

Caustic: A concentrated alkali used in boiler water treatment to raise pH.

Caustic embrittlement: Cracking of stressed steel in contact with concentrated alkali.

Chelant: An organic compound that forms soluble complexes with certain metallic ions, especially calcium, magnesium, iron and copper.

Chemical Feed Pump: A relay or proportionally controlled pump that disperses chemical into the system.

Chloride: Soluble ionic form of the element chlorine, useful as a measure of cycles of concentration.

Closed loop system: A term used to describe any system that is closed to atmosphere (not airtight) and recirculates water on a continuous basis.

Condensate: The water that is formed when steam cools and changes from a gas to a liquid.

Commissioning: The process of initially setting up the water treatment plant, control equipment and chemical treatment programme for any steam boiler, generator or hot water boiler.

Concentration factor or **Cycles of Concentration**: This factor compares the TDS in the boiler water against that of the feed water, assuming a shell boiler. It can be measured using Chloride or TDS typically.

Conductivity: Represents the electrical current carrying capacity of a water. It is used as a means of indirectly measuring the total dissolved solids concentration of a water. Conductivity can be converted to TDS by a simple calculation.

Corrosion: The destructive disintegration of metals (e.g. steel or copper) by electrochemical means; measured in mils (mils = one thousandth of an inch) per year (mpy). See Oxygen attack or pitting corrosion.

Deaerator: A device that physically removes dissolved oxygen from boiler make-up water. A properly operating deaerator will reduce the make-up water dissolved oxygen level to 10 parts per billion (ppb) or less.

Dealkaliser: An ion exchange unit designed to remove alkalinity from water. Alkalinity removal is performed with either a cation resin using sulphuric acid as the regenerant or an anion resin using sodium chloride for regeneration.

Deionisation: The removal of all anions and cations from a water by ion exchange.

Demineralisation: Equivalent to deionisation.

Deposit: Accumulation of mineral or organic matter laid down on heat transfer surfaces.

Deposition/Deposit Formation: The process by which mineral or organic matter is laid down on heat transfer surfaces.

Desludging chemical: A liquid or solid water treatment chemical, specifically formulated to act as a mild system cleaner. These types of products are normally used to de-sludge existing hot water boiler systems where flows have reduced over time.

Dip slide: A simple and easy to use method of measuring general bacteria counts in closed loop hot water boiler systems. Dip slides are non-specific and can only read total viable counts of bacteria. They are useful in closed loop monitoring.

Dissolved gases: Gases that are in solution in water.

Dissolved solids: Solids in true solution in ionic form in water that cannot be removed by filtration (expressed as Total Dissolved Solids (TDS)). The presence is due to the solvent action of water in contact with minerals in the earth.

Dosing pot: An apparatus used to dose liquid water treatment chemical to a closed loop hot water boiler system.

Dry steam: Steam containing no moisture. Commercially dry steam for a shell boiler contains typically 2% moisture. Output from a steam generator is significantly drier.

Dynamic flush: A stage in the flushing of closed circuit systems, such as hot water boiler systems, whereby the incoming fresh water at high pressure is used to flush dirty system water to drain.

Electric or Electrode Boilers: These are steam or hot water boilers/generators that are powered by electricity, instead of typical fossil fuels, such as gas.

End-point: In water testing, the point at which titration reactions are completed and the indicator changes colour.

Erosion: The physical wearing of metal by the action of a liquid or gas.

Feed water: Water introduced into a boiler during operation. It includes make-up and returned condensate.

Feed water heater: An apparatus for raising the temperature of feed water by transferring some of the heat from exhaust steam to the feed water. This may be of the direct type, sometimes called a steam sparge, where steam is discharged directly into the feed water, or the indirect type that utilises a heat exchanger.

Filming amine: An organic chemical that forms a water repellent film on system metal. The film controls corrosion in the condensate system or sometimes in the whole steam system.

Fire tube boiler: A boiler in which the hot combustion gases pass through tubes that are surrounded by water. Heat is transferred from the combustion gases into the water to produce steam. (Also referred to as Shell Boiler or Smoke Tube Boiler).

Flash tank: A vented tank into which boiler blowdown is directed to allow latent heat to escape before the water is discharged to drain. Also known as a blowdown vessel.

Flashing: Steam produced by discharging water at a temperature greater than the saturation temperature corresponding to the pressure of the space into which it is discharged.

Foaming: The formation of bubbles that have sufficiently high surface tension to remain as bubbles beyond the disengaging surface. This interferes with the natural steam disengagement process and can result in carryover.

Fouling: The obstructing of the flow of water by matter that accumulates on pipe walls or in water-using equipment.

Galvanic corrosion: Generally results from the juxtaposition of two dissimilar metals, e.g. copper and steel, in an electrolyte. It is characterised by an electron movement from the metal of higher potential (anode) to the metal of lower potential (cathode) resulting in corrosion of the anodic metal.

Grains per gallon (gpg): A unit of concentration equivalent to 17.14 parts per million (ppm).

Grooving attack: The attack of condensate pipework by carbonic acid formed from carbon dioxide re-dissolving back into the condensate that is returning to the hotwell.

Handhole: An opening in a pressure part for access, usually not exceeding 6" in longest dimension.

Hardness: The total of a water's calcium and magnesium ion content. The total concentration is reported as calcium carbonate. Hardness is sometimes referred to as carbonate and non-carbonate hardness. Carbonate, also referred to as temporary hardness is that portion of the total hardness that combines with carbonate and bicarbonate ions. The remainder of the hardness is that which combines with sulphate or other anions and is known as non-carbonate or permanent hardness.

Incubator: An apparatus used to grow bacterial cultures on dip slides.

Independent set point: This is a controller feature that allows the user to independently set the high and low alarm levels.

Indicator: In water testing, a substance that undergoes a colour change when the end-point of a titration has been reached. The indicator does not enter into the reaction.

Inhibitor: A substance that selectively slows down a chemical action, such as scaling or corrosion.

Interval: The amount of time between blowdown events.

Ion: A negatively or positively charged atom or radical.

Ion exchange: A reversible process in which ions that are chemically attached to resin beads are exchanged for other ions that are in solution in a water. For example, in an ion exchange softener sodium ions on the resin beads are exchanged for calcium and magnesium ions in the water passing through the softener.

LPHW: Low pressure hot water - a term used to describe hot water boiler systems.

Magnetite: an impervious layer of fully formed iron oxide that is black in colour and cannot be oxidised any further. Formed within boilers or steam generators by allowing normal internal rusting to take place but in a pH controlled and oxygen negative environment. Requires an excess of hydroxyl ions to allow correct formation of this layer. The formation of magnetite prevents oxygen pitting or low pH corrosion attack taking place.

M-Alkalinity: Also called total alkalinity or methyl orange alkalinity. This is the measure of the total of bicarbonate, carbonate and hydroxyl ions in a water.

Make-up: The water added to a boiler system to compensate for that lost through steam used, blowdown, leakage to atmosphere, etc.

Manhole: The opening in a pressure vessel of sufficient size to permit a man to enter. Also called a manway.

Monitoring Tool: A monitoring tool is a system or process used to undertake the regular observation and recording of activities taking place in a system, project or programme. This tool could, for example, be web or paper based. The tool is used to implement and subsequently monitor the process of routinely gathering information on all aspects of the system, project or programme. To monitor is to check on how the system, project or programme activities are progressing. It is observation; systematic and purposeful observation. Monitoring also involves giving feedback about the progress of the project to the donors, implementers and beneficiaries of the project. Reporting enables the gathered information to be used in making decisions for improving system, project or programme performance.

Neutralising amine: An alkaline organic chemical that neutralises the acidity of condensate to control corrosion.

Oxygen attack: Corrosion or pitting in a boiler system caused by dissolved oxygen.

Oxygen scavenger: A chemical added to boiler feed water to remove dissolved oxygen.

P-Alkalinity: A measure of half the carbonate and all of the hydroxyl ions in a solution. It is determined through titration using phenolphthalein indicator.

pH: The hydrogen ion concentration of a water stated on a logarithmic scale from 0 to 14 used to indicate the water's relative acidity or alkalinity; pH7 is neutral - pH below 7 indicates an acidic solution and pH above 7 indicates an alkaline solution.

Phosphonate: An organic compound used to inhibit scale in boilers by distorting the crystalline structure of sludge particles, preventing them from agglomerating and forming a hard scale - also called organophosphonate.

Pitting: A concentration attack by oxygen or otherwise corrosive agents producing a localised depression in the metal surface.

Plate failure: A term used to describe when a heat exchanger plate fails.

Polymer: An organic compound used primarily to control scale and deposition in boilers by dispersing sludge particles, allowing for their removal from the boiler through blowdown.

ppm: Abbreviation of parts per million. It is used in chemical determinations as a measure of the concentration of dissolved impurities in water.

Precipitate: To separate materials from a solution through the formation of insoluble matter by chemical reaction.

Precipitation: The chemical process by which materials are separated from a solution through the formation of insoluble matter by chemical reaction.

Pre-treatment: Term frequently used to define mechanical treatment of water, e.g. softening, reverse osmosis or de-alkalisation, prior to its use in a process – also called external treatment.

Priming: The discharge of steam containing excessive quantities of entrained water due to sudden reductions in pressure or poor design of steam take-off.

Rated capacity: The manufacturer's stated capacity rating for mechanical equipment, e.g. the maximum continuous capacity in kg of steam per hour for which a boiler is designed.

Raw water: The water supplied to a plant or facility before external or internal treatment is applied.

Resin: Synthetic organic ion exchange material, such as the cation exchange resin used in water softeners. Formerly made of zeolite.

Responsible Person (RP): The Responsible Person is defined as the person who will take day-to-day responsibility for managing the control of any identified risk from the steam boiler or generator and associated steam system. Anyone can be appointed as the Responsible Person as long as they have sufficient authority, competence, skills and knowledge about their specific installation to ensure that all operational procedures are carried out in a timely and effective manner, and they implement the pre-defined control measures and strategies, i.e. they are suitably informed, instructed, trained and assessed. They should be able to ensure that tasks are carried out in a safe and technically competent manner.

If a Statutory Duty Holder is self-employed or a member of a partnership and is competent, they may appoint themselves as the Responsible Person. The Responsible Person should be suitably informed, instructed and trained and their suitability assessed. They should also have a clear understanding of their duties and the overall health and safety management structure and policy in the organisation.

Both the Statutory Duty Holder and the Responsible Person must have undertaken site-specific boiler water treatment training in order to effectively carry out their role, and this training needs to be refreshed at least once every five years.

Reynolds number: This is a dimensionless quantity that can be used on a predictive basis in order to assesses flow patterns, and is named after Osborne Reynolds**.** The Reynolds Number, the non-dimensional velocity, can be defined as the ratio of

- the inertia force *(ρ u L),* and
- the viscous or friction force *(μ).*

River Rot: Term used to describe the attack on condensate pipework by carbonic acid formed from carbon dioxide re-dissolving back into the condensate returning to the hotwell.

Safety valve: A spring-loaded valve that automatically opens when pressure reaches the valve setting. Used to prevent excessive pressure from building up in a boiler.

Sample point, **sample cock** or **sample valve**: A sample point allowing the user to draw off water for analysis.

Sample cooler: A small heat exchanger designed to cool a small flow of boiler water to a temperature where it can exist in its liquid state at standard atmospheric pressure.

Saturated steam: Steam at the pressure corresponding to its saturation temperature.

Saturation temperature: The temperature at which evaporation occurs at a particular pressure.

Scale: A dense, crystalline deposit form by precipitated material. It usually forms on boiler tube surfaces where heat transfer occurs.

Section failure: A term used to describe when a section of a hot water boiler fails.

Sequester: To separate and hold potential scale-forming materials in solution or suspension.

Set point: The user-determined value input to a controller that initiates action of the controller.

Set point differential or **hysteresis**: Also known as the “dead band” is the offset applied to a set point to stop the controller from “bouncing” too frequently around that point.

Sludge: A soft, water-formed sedimentary deposit that can usually be removed by bottom blowdown.

Sludge Deposition: The process by which a soft, water-formed sedimentary deposit is formed within a steam or hot water boiler that can usually be removed by either by bottom blowdown (if a steam boiler) or by dynamic/balanced flushing (if a hot water boiler).

Sulphite: The most commonly used oxygen scavenger in steam boiler systems. It comes in numerous forms and "Sulphite" is a generic term for this type of product.

Soft water: Water containing relatively low concentrations of calcium and magnesium ions (typically less than 5ppm).

Softener: A device for removing hardness from water. Ion exchange softeners operate by exchanging sodium ions (from salt) for calcium and magnesium ions. Ion exchange softeners do a very complete job of hardness removal and modern units are now very capable of producing a consistent supply of commercial zero hardness (less than 2ppm) water.

Solid Chemical Feeder: An apparatus used to dose liquid or solid water treatment chemical to a closed loop hot water boiler system.

Statutory Duty Holder/Duty Holder (SDH): The Statutory Duty Holder/Duty Holder is the person who has ultimate responsibility for all company/site Health and Safety related matters, including initiation of the Boiler Water Treatment Risk Assessment and completion of its findings. The Statutory Duty Holder would normally be a company director or similar and have sufficient authority and influence within the company such that the boiler water treatment regime and system could be correctly implemented and managed. The Statutory Duty Holder should appoint a Responsible Person (RP) to take over the operational management of this function for them. The Responsible Person (RP) would then normally action this by utilising input or assistance from various sources such as water treatment companies, specialising in boiler water treatment, boiler manufacturers and control system experts, or have the entire risk assessment carried out on his behalf by someone competent to do so. It is the responsibility of the RP to access and assure himself/herself of this competent help.

It is the responsibility of the Duty Holder to formally appoint the Responsible Person with, for example, a letter of appointment, including scope of role. This letter should be signed off by both parties as accepted. Similarly a deputy RP should also be appointed to cover periods of illness or annual leave, using the same formal process of engagement.

Both the Statutory Duty Holder and the Responsible Person must have undertaken site specific boiler water treatment training in order to effectively carry out their role, and this training needs to be refreshed at least once every five years.

Steam trap: An automatic valve designed to pass condensate while not allowing steam to escape. Used to discharge condensate from the steam side of a system to the condensate side, thus allowing for its return to the boiler.

Strainer: A coarse (usually in-line) filter used to protect vital components from gross debris.

Suspended solids: Solids not in true solution in water, rather in particulate from capable of being removed through filtration.

Test kit: A collection of test reagents, meters etc., usually contained in a bespoke case, used to test waterside balance in systems.

Test reagent: A specific indicator chemical used to test waterside balance in systems.

Threshold treatment: A technique of treating water by the addition of very low levels of chemicals, usually phosphonates and/or polymers that will temporarily inhibit the formation of scale.

Total Dissolved Solids (TDS): The total of all substances dissolved in ionic form in a water.

Tuberculation: Irregular, protruding mounds of corrosion product that form over corrosion sites on steel and cast iron that has been exposed to oxygenated water. The tubercle height may be as much as 30 times the metal loss depth below.

Turbidity: Cloudy appearance of water imparted by the presence of suspended or colloidal particles.

Under deposit corrosion: The destructive disintegration of metal by electrochemical means under a covering deposit of scale for example.

Volatile: Capable of being vaporised rapidly at relatively low temperatures.

Water column: A steam boiler fixture consisting of a cylindrical piece to which are attached the water gauge and the gauge cocks. The top and bottom have outlets that connect it with the boiler above and below the water level.

Water gauge: A glass tube mounted on the water column that will permit observation of the water level in a boiler, also called a gauge glass.

Water hammer: The banging and clanging of steam pipes and steam using equipment usually caused by live steam coming into contact with condensed steam that has not properly drained from the system. In higher pressure installations it is capable of rupturing fittings or pipes. The “shock pressure” caused by water hammer is considerably higher than that normally encountered in the system and can therefore readily cause damage.

Water tube boiler: A boiler in which water circulates through tubes between a “mud drum” and a “steam drum”. Hot combustion gases surround the water tubes heating the water inside to produce steam.

Web portal: A web portal is a specially designed internet web site that brings information together from diverse sources in a uniform way. The extent to which content is displayed in a "uniform way" may depend on the intended user and the intended purpose, as well as the diversity of the content. Very often design emphasis is on a certain "metaphor" for configuring and customising the presentation of the content and the chosen implementation framework and/or code libraries. In addition, the role of the user in an organisation may determine which content can be added to the portal or deleted from the portal configuration.

Wet steam: Steam containing entrained boiler water.

12 ANNEX 1

Legal Obligations

Boiler systems are required to comply with different legislation, including a number of health and safety regulations, which aim at ensuring that new and existing boiler systems are continually operated and maintained in a safe manner.

The principal sets of health and safety legislation that apply to the use of boiler systems covered by this guidance are:

- The Management of Health & Safety at Work Regulations 1999 (MHSWR).
- The Pressure Equipment Regulations 1999 (PER).
- The Pressure Systems Safety Regulations 2000 (PSSR).
- The Provision and Use of Work Equipment Regulations 1998 (PUWER).
- The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) (DSEAR may apply in some cases and will be briefly discussed with PER.)
- Safe management of industrial steam and hot water boilers - A guide for owners, managers and supervisors of boilers, boiler houses and boiler plant (INDG436)

With the exception of PER, all the regulations listed above are supported by Approved Codes of Practice (ACoP) and Guidance produced by the Health and Safety Executive (HSE), and available as free downloads from www.hse.gov.uk.

ANNEX 1.1 THE MANAGEMENT OF HEALTH AND SAFETY AT WORK REGULATIONS (MHSWR) 1999

MHSWR apply to every employer and self-employed person who carries out any work activity whether or not they own or control a pressure system (all future references to employers in this guidance should be read to include self-employed persons).

They impose a duty to manage all risks from any work activity, not only within the workplace itself but also any risks to all persons (including any non-employees) who may be affected by the activity in question.

Regulation 3 requires the completion of a suitable and sufficient risk assessment of the work activity in order to properly identify and adequately manage any risks. This is of central importance. The risk assessment should identify sensible measures to control identified risks that may otherwise result in injury or danger.

Risk assessments for water treatment of boiler systems are covered in more detail in this document and boilerhouse risk assessments are covered in BG01.

ANNEX 1.2 THE PRESSURE EQUIPMENT REGULATIONS 1999 (PER)

All new and substantially modified pressure equipment (including steam raising plant) comes within scope of PER and they must comply with its requirements before they may be supplied for use. PER applies to the design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with a maximum allowable pressure >0.5bar **and steam at any pressure**.

The Regulations do not apply to:

- Excluded pressure equipment and assemblies (specified in Schedule 1 to PER).
- Pressure equipment and assemblies placed on the market before 29 November 1999.
- Pressure equipment or assemblies placed on the market on or before 29 May 2002 if they comply with the safety provisions in force in the UK on 29 November 1999 and do not bear a CE marking (unless required by another Community Directive or any indication of compliance with PED).

Schedule 2 of PER details the essential safety requirements (ESR) that qualifying vessels must satisfy. Additionally, there are details of how the different products are classified, the technical requirements that must be satisfied, and the conformity assessment procedures that must be followed.

To comply with the ESRs the manufacturer must either produce a technical file that addresses each ESR in turn or manufacture the equipment using standards that have been listed in the EU's Official Journal which give a 'presumption of conformity' to specific ESRs.

The Department for Business, Innovation and Skills (BIS) has produced a very useful guide to PER. (www.bis.gov.uk/). There is an easy-to-use flow chart (Annex C) showing how equipment should be classified depending on, for example, what it is designed to contain and the operating pressure. This includes the conformity assessment procedure to be followed before placing the equipment on the market.

Equipment supplied for use in a potentially explosive atmosphere must also satisfy the relevant requirements of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996. The owner of the system may assist the manufacturer by providing information from an assessment of the probability of the presence and the likely persistence of a potentially explosive atmosphere in the proposed working environment as set out in the Dangerous Substances & Explosive Atmospheres Regulations 2002 (DSEAR) assessment.

ANNEX 1.3 PRESSURE SYSTEMS SAFETY REGULATIONS 2000 (PSSR)

PSSR set out the main legislative requirements to ensure the continued safety of the pressure systems (which includes steam boilers) in use. PSSR applies to two clearly defined categories of people (Duty Holders). These include:

- 'Owner' – This means an employer or self-employed person who owns a pressure system. Where the employer who owns the system does not have a place of business in Great Britain, or an agent in Great Britain who would take responsibility, then the user (see below) will be responsible.
- 'User' – This means the employer or self-employed person who has control of the operation of the pressure system.

The distinction between 'owner' and 'user' can be important in certain circumstances in determining the Duty Holder responsible for ensuring compliance with certain regulations under PSSR. However, in general owners carry more responsibility in relation to mobile systems while users have responsibilities in relation to installed systems. Package boilers are considered to be installed systems for the purposes of the regulations.

The owner/user of the boiler is responsible for complying with the following requirements of PSSR:

- Safe Operating Limits (SOL) have been set and are not adjusted without informing the Competent Person (CP) and manufacturer where appropriate.
- The system is never operated unless a current Written Scheme of Examination (WSE) is in place. Any requirements of this scheme (e.g. a report of the last examination) must also be satisfied (Regulations 8 & 9).
- The items identified in the WSE are examined by a CP in accordance with the requirements of the scheme.
- All repairs & modifications must be carried out by people suitably competent in such work (Regulation 13, PSSR, ACoP Para 180). The details of such work must be retained. The effects of modifications and repairs should also be assessed to determine whether the WSE needs review.
- The statutory technical documentation and other records must be kept and, where required, be made available for examination.
- Records must be transferred when the ownership of a system changes (Regulation14, PSSR).

The results of all tests and examinations should be recorded (see example BG01 - Log Sheets, section Appendix 4 - use a Hard backed logbook) and retained for a suitable period, or stored in a web based log book/monitoring system. A period of at least two years is recommended for records of routine tests and five years for water treatment tests. These may be kept on-site or at a designated central location, which may be electronic or otherwise, but wherever they are kept they should be secure and easily accessible (Regulation 14, PSSR). Examples of the type of records that should be kept and made available for scrutiny include:

- Manufacturer’s records and instructions.
- Examination reports.
- Record of periodic tests (e.g. Non Destructive Testing (NDT), Hydraulic test). Written Scheme of Examination (WSE).
- Certificates of thorough examination.
- Records of servicing & modifications and maintenance of controls.
- Training records for boiler operators, including site specific water treatment training. Audit reports for boiler operators.
- Test log.
- Water treatment records.
- Separate risk assessments relating to both BG01 and BG04

ANNEX 1.4 EXTRACTS COPIED FROM PSSR ACOP

Approved Code of Practice L122

This Code has been approved by the Health and Safety Executive, with the consent of the Secretary of State. It gives practical advice on how to comply with the law. If you follow the advice you will be doing enough to comply with the law in respect of those specific matters on which the Code gives advice. You may use alternative methods to those set out in the Code in order to comply with the law.

However, the Code has a special legal status. If you re prosecuted for breach of health and safety law, and it is proved that you did not follow the relevant provisions of the Code, you will need to show that you have complied with the law in some other way or a Court will find you at fault.

Guidance

This guidance is issued by the Health and Safety Executive. Following the guidance is not compulsory, unless specifically stated, and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Health and safety inspectors seek to secure compliance with the law and may refer to this guidance.

The ACoP describes preferred or recommended methods that can be used (or standards to be met) to comply with the Regulations and the duties imposed by the Health and Safety at Work Act. The accompanying guidance also provides advice on achieving compliance, or it may give information of a general nature, including explanation of the requirements of the law, more specific technical information or references to further sources of information.

Users of pressure systems

(46) The role of the user is generally a corporate responsibility. Often the user will be a firm or organisation in control of the operation of the system and therefore in the best position to comply with the Regulations.

Reg 10 (1) If the competent person carrying out an examination under the scheme of examination is of the opinion that the pressure system or party of the pressure system will give rise to imminent danger unless certain repairs or modifications have been carried out or unless suitable changes to the operating conditions have been made, then without prejudice to the requirements of regulation 9, he shall forthwith make a written report to that effect identifying the system and specifying the repairs, modifications or changes concerned and give it –

(a) In the case of an installed system, to the user;

(138) This regulation applies only to serious defects requiring immediate attention. That is, where there is a risk of imminent failure of the system if immediate repairs are not undertaken or other suitable modifications are not made to the operating conditions.

(141) Notification to the enforcing authority (i.e. HSE or the Environmental Health Department of the Local Authority) is also a separate action required of the competent person.

Reg 11 (1) The user of an installed system and the owner of a mobile system shall provide for any person operating the system, adequate and suitable instructions for;

(a) The safe operation of the system; and
(b) The action to be taken in the event of any emergency.

(144) Although the provision of training to people who use pressure systems is not covered by this regulation, it is required by regulation 9 of the Provision and Use of Work Equipment Regulations (PUWER). PUWER places a duty on the employer to ensure that anyone using work equipment, or supervising/managing its use, should have received adequate training for the purposes of health and safety.

(ACoP 11 – 145) The instructions provided to operators by the user/owner should cover:

(a) All procedures and information needed so that the system can be operated safely

(147) The operator should be familiar with and have ready access to all the instructions.

Steam and pressurised hot water plant

(151) Pre-firing and start-up instructions should include:

(a) Methods of establishing the proper water level in the boiler and maintaining adequate water supplies;
(b) Methods of carrying out any necessary flue gas side purging;
(c) Methods of establishing correct firing conditions so that pressure/ temperature are raised carefully, preventing undue thermal shock; and
(d) Procedures to avoid water hammer.

(152) There should also be instructions covering:

(a) Feed water treatment, if appropriate;

(Reg 12) The user of an installed system and the owner of a mobile system shall ensure that the system is properly maintained in good repair, so as to prevent danger.

Keeping of records

(178) Records retained should assist the competent person in the examination under the written scheme, the purpose being to assess whether the system is safe for continued use and/or if any planned repairs or modifications can be carried out safely.

(179) The user/owner should keep the following documents readily available:

(a) Any designer's/manufacturer's/supplier's documents relating to parts of the system included in the written scheme;
(b) Any documents required to be kept by PER;
(c) The most recent examination report produced by the competent person under the written scheme of examination;
(d) Any agreement or notification relating to postponement of the most recent examination under the written scheme; and
(e) All other reports which contain information relevant to the assessment of matters of safety.

(180) In deciding whether a report contains relevant information, the user/ owner should take account of the content of the report, the system's complexity, the operating conditions, previous history of repair and any significant modifications to the system.

ANNEX 1.5 PROVISION AND USE OF WORK EQUIPMENT REGULATIONS 1998 (PUWER)

Any employer who either provides equipment for use at work (including boiler systems) or has control over the way and manner in which equipment is used at work has a legal responsibility to comply with the relevant provisions of this regulation. An important and often overlooked requirement under PUWER is that a logbook, or data logging system when provided, must be kept up to date.

Other parts of PUWER of relevance to boiler systems cover such topics as equipment suitability, maintenance, inspection, information & instructions, training and control systems. This is not an exhaustive list.

13 ANNEX 2

Legal Obligations

ANNEX 2.1 RISK ASSESSMENTS – FOR NEW AND EXISTING SITES

Regulation 3 of MHSWR requires that a 'suitable and sufficient' risk assessment be carried out before the work activity commences. Its purpose is to determine whether any risks are present and whether these risks can be completely removed or not. If they cannot be completely removed, then they must be adequately managed, and so the risk assessment must then identify what further control measures are required in order to suitably manage this position. The significant findings of the separate risk assessments (including those relating to both BG01 and BG04) must be recorded where there are 5 or more employees.

The control measures must have the primary aim of eliminating the risks. Where elimination is not possible, the control measures should aim to reduce the risks to a level as low as is reasonably practical (ALARP). Regulation 4 and Schedule 1 of MHSWR sets out the principles of prevention.

The ultimate responsibility for Health and Safety related matters, including initiation of the risk assessment, lies with the employer's Duty Holder who should appoint a Responsible Person (RP) to manage this for them. The Responsible Person (RP) would then normally action this by utilising input or assistance from various sources such as boiler manufacturers, steam boiler water treatment specialists, and control system experts, or have the entire risk assessment carried out on his behalf by someone competent to do so. It is the responsibility of the RP to access and assure themselves of this competent help.

It is the responsibility of the Duty Holder to formally appoint the Responsible Person with, for example, a letter of appointment including scope of role. This letter should be signed off by both parties as accepted, and similarly a deputy RP should also be appointed to cover periods of illness or annual leave, using the same formal process of engagement.

It is of fundamental importance that the Statutory Duty Holder and all Responsible Persons are trained and competent such that they might be able to competently manage their respective positions. If they have not been formally trained by a suitably competent trainer, then they cannot themselves be deemed to be competent to manage any steam boiler system.

For a boiler, the boiler house (BG01) risk assessment should consider issues such as:

- The likelihood and severity of injuries from:
    - Burns from hot water, steam, burners and flues.
    - Electric shock.
    - Fuel escape.
    - Fire.
    - Asphyxiation, and toxic effects from combustion products.
- The location of the boiler with respect to:
    - Proximity to industrial premises/workers.
    - Proximity to the public, especially vulnerable populations such as in schools, hospitals, care homes etc.
    - The potential impact on neighbouring sites due to an incident.
- Capability of safety-related systems.
- Level of supervision.
- The positioning of alarms and the associated response times.
- The presence of other dangerous materials.
- The adequacy of boiler house ventilation and flue integrity.

- Environmental effects, e.g. noise, pollution, waste streams.
- Effect of chemicals on workers, environment and others, e.g. water treatment chemicals – this may be additionally covered in the BG04 risk assessment.
- Operational risks:
    - Mechanical or water damage to plant or equipment.
    - Water-side explosion due to catastrophic failure of the pressure envelope.
    - Combustion explosion caused by unburned fuel.

Since risk assessments must assess the existing control measures, they should also consider information regarding:

- Manning levels.
- Type and reliability of controls and the integrity of safety-related systems.
- Additional controls for remote or unsupervised boiler operation.

Thereafter, the Boiler Water Treatment Risk Assessment required under BG04 should typically consider such points as the type and effectiveness of the water treatment monitoring programme, waterside balance parameters, destination and use of the steam generated, and method of logging data and site actions in the event of any waterside control issues.

The BG04 Boiler Water Treatment Risk Assessment should be compiled by a boiler water treatment specialist proficient and competent in steam boiler chemistry; note that if your unit is a coil style steam generator the assessor must demonstrate competence in these types of units specifically.

The "pre-contract" water treatment risk assessment of an initial installation must not be confused with the requirement for the Boiler Water Treatment Risk Assessment under BG04 when the system is in full operation. These are two distinctly separate situations and must be therefore approached differently, since there may have been a number of changes in the process and/or system, since commissioning.

Before conducting the assessment, the assessor should be able to offer a summary of their qualifications and experience in steam boiler and steam generator water treatment, outlining their proficiency and specific suitability for these works.

The risk assessment should also specifically ask about site personnel competency and training and **must** also contain a schematic drawing of the whole steam system, from incoming water supply right through to steam users and condensate return.

Risk assessments must be reviewed periodically and when there is a significant change e.g. a system variation, change in operating parameters or manning levels/change of contractor or site operator etc. The outcome of any reviews should also be recorded. Any reviews should also stipulate when the next routine review is due.

As an example, an owner moving from a manned boiler to an unmanned boiler should, as a first step, review the boiler design and the current/recent risk assessment to take account of the planned change in manning levels. The results of the risk assessment will be used to determine any measures necessary to ensure that the boiler remains safe to use and operate. Such measures may include:

- The proper formulation and correct application of all modifications and installations to ensure they have sufficient safety integrity to adequately control the risk of a dangerous occurrence.
- Amendment of procedures where appropriate to ensure the plant continues to be operated safely.
- All personnel on-site & off-site and surrounding property remain safe.

2.2 WRITTEN SCHEME OF EXAMINATIONS (WSE)

The requirement for a WSE is set out in Regulation 8 of PSSR. The user/owner is ultimately responsible for ensuring that the scope of the WSE covers all relevant parts of the boiler system, and should select an organisation with sufficient knowledge and expertise on the systems in question to carry out the Competent Person (CP) duties on that system.

The Competent Person (CP) role and responsibilities are covered in the PSSR ACoP. (A brief summary is provided is provided below) .

The WSE should include the name of the CP who certified the scheme as suitable, the date of the certification, and the following information:

- All parts which require examination by the CP, with justification for excluding items from examination and including all protective devices.
- The nature and frequency of the examinations required.
- Details of any preparatory work required by the user/owner in order for the examinations to be completed.
- Details of any requirements for the initial examination.
- Details of any repairs and modifications where the CP needs to be involved.

Where there is more than one WSE for a single pressure system, (e.g. one for the boiler house and another covering the site) the respective responsibilities for each part of the pressure system should be clearly identified. The boundaries of each WSE should be adjacent to each other, with no physical gaps.

It must be clearly noted that the boiler water treatment written scheme arising out of the findings of the Boiler Water Treatment Risk Assessment is a completely separate document from the written scheme of examination mentioned in 2.2.

2.3 EXAMINATIONS IN ACCORDANCE WITH THE WSE (THOROUGH EXAMINATIONS)

Regulation 9 of PSSR requires that pressure systems (including boilers) be periodically examined by a CP in accordance with a WSE, itself being drawn up by a CP.

The owner/user is responsible for ensuring their boilers meet this requirement. Where the WSE specifies any preparatory work, they are also responsible for ensuring that this is completed before the examination.

As soon as possible following examination, the CP will prepare a report of examination for the owner/user. The report will also include, amongst other information, the following:

- Whether any repairs are required and the date by which they should be completed.
- The latest date by which the next examination should be carried out.
- Whether any modifications are required to the WSE.
- Note that the CP may also specify the manner which these modifications should take and procedures to be followed.

Note: The CP may also specify the nature of the required modifications to the scheme.

If any of these issues are raised in the report of examination, the user/owner must:

- Ensure that the boiler is not used or supplied if the date set for any repairs/ examinations passes without these being completed.
- Make the required modifications to the WSE and have it recertified by a CP.
- Ensure the boiler is not used or supplied if the date set for the modifications to the WSE passes without these being implemented and certified by a CP.

ANNEX 2.4 SUMMARY OF RESPONSIBILITIES

The owner/user of a boiler system is ultimately responsible for ensuring the system complies with all the relevant Health & Safety legislation (not just those responsibilities mentioned above).

While third parties (e.g. maintenance contractors) can be used to assist in achieving compliance with these legal obligations, the overall and legal responsibility remains on the Owner/User and cannot be contracted out, although there is scope for certain duties to be transferred (as set out in a written agreement) between the owner and user.

Useful help and advice on ensuring boiler systems remain safe to operate can be obtained from a number of sources, such as the CP carrying out the periodic examination of the boiler or the equipment manufacturer.

14 ANNEX 3

Personnel and Responsibilities

The roles and responsibilities are often not clearly defined when it comes to owning and operating boiler plant as very often there is a lack of focus and attention paid to it; many people think of it as just a large kettle. But if the boilers on your plant fail or do not deliver steam to your processes, what will be the outcome and cost?

A very simple organogram is all that is needed so that the managing director understands his responsibilities and risks as well as both the man managing the plant and the person responsible for operating and monitoring the plant on a daily basis. This can all be identified in the risk assessments required under BG01 and BG04 and the boiler water treatment written scheme arising from the findings of the BG04 risk assessment. The following subsections help clarify these responsibilities:

ANNEX 3.1 EMPLOYERS

Under the Health & Safety at Work etc Act 1974 (HSWA), employers have general duties to provide safe places of work and adequate training for staff. This general duty on employers is also required under other legislation such as such as MHSWR and PUWER.

ANNEX 3.2 USER/OWNERS

These legal terms have been defined earlier in Annex 1 Section 1.3. The distinction between these terms is important as it will determine the Duty Holder responsible for ensuring compliance with certain regulations under PSSR. Similarly, the duties have been outlined in Annex 2 Sections 2.3 and 2.4 above.

ANNEX 3.3 COMPETENT PERSON (CP)

A Competent Person (CP) is defined in Regulation 2, PSSR as "a competent individual person (other than an employee) or a competent body of persons corporate or unincorporated; and accordingly any reference in these Regulations to a CP performing a function includes a reference to his performing it through his employees."

From Paragraph 17 of the PSSR ACoP, this term refers to the organisation employing the person who carries out these duties. Therefore, the legal duty to comply rests with a CP's employer, and not with an individual, unless that person is self-employed.

A CP is required to undertake two distinct functions under PSSR:

1. To draw up, certify or review the written scheme of examination, (Also referred to in BG01).
2. To carry out the examinations in accordance with the scheme and to produce a report after each examination.

These roles may be undertaken by the same person or by more than one organisation. The owner/user remains responsible for selecting a CP who possesses sufficient expertise in the particular system and is capable of carrying out the duties in a proper manner. A CP is also able to act in an advisory role and advise on other aspects of PSSR such as the scope of the written scheme and establishing the safe operating limits of pressure systems.

In addition to the above legally defined personnel, there are also a number of other personnel involved in the day-to-day safe operation of boilers. These are discussed below, but it should be borne in mind these are not terms that have a legal definition.

ANNEX 3.4 BOILER OPERATOR

It is common practice for the user/owner or Statutory Duty Holder to appoint a sufficiently competent and experienced person to be responsible for the daily safe operation of the boiler system (the Responsible Person/RP). The legal responsibility however cannot be transferred. The boiler operator should be adequately trained to carry out all the duties they are expected to perform at each specific site, including site-specific water treatment training. The training should enable the operators to recognise when the limits of their own expertise are reached and when to call for assistance.

The duties of the boiler operator include:

- Implementing the boiler manufacturer's recommendations with regard to starting up from cold, and for all the other aspects of boiler operation, use, maintenance and cleaning etc.
- Carrying out all functional tests of limiters & controls where required, before the boiler is left unattended and at all specified frequencies and in the specified manner. Records of all these tests must be maintained.
- Checking burners and associated equipment. Responding to alarms and taking appropriate action.
- Carrying out the recommended daily water quality tests, routine water treatment, recording the results and making adjustments where necessary in accordance with established standards such as BS EN 12953-10 or the manufacturer's equipment specific standard.

Training should be carried out at commissioning of any new boiler plant and carried out again at least once every 5 years. In any event, the level of competence and training of site personnel must be reviewed when a system is modified and/or changed or there is a change in the operating personnel themselves.

Training courses should always contain a test at the end that trainees are required to take and pass as part of the competency process being demonstrated.

It is considered that at least a day should be set aside for adequate water treatment training to take place – any less and the level of information provided would be unlikely to have reached the levels required to achieve competency.

On sites with transient workforces, it is imperative that the correct level of training is carried out with every new employee and not just passed from one operator to another, potentially diluting the content and knowledge base.

3.5 PERSONNEL MONITORING BOILER ALARMS FROM ON-SITE AND OFF-SITE LOCATIONS

All such persons should possess sufficient training and information to take the appropriate action in the event of an alarm condition before calling for the assistance of a boiler operator. In some cases this may involve the emergency shutdown of the system.

Persons should not enter the boiler house unless there is a system in place to ensure that access and egress is safe and that there is a safe system of work in place.

ANNEX 3.6 MAINTENANCE PERSONNEL

All maintenance personnel should possess sufficient certificated and recorded training to be able to carry out the expected duties. Maintenance personnel should only carry out the maintenance work for which they have been trained and are deemed competent. Suitable training courses and maintenance services for maintenance personnel can usually be provided or recommended by manufacturers of boilers, fittings, control equipment or water treatment providers with specific expertise in steam and hot water systems.

15 ANNEX 4

Training

Employers must ensure that all personnel possess sufficient knowledge of the boiler systems on which they work to perform their duties properly. This is a legal requirement under MHSWR.

Any training should form part of a structured scheme taking into account the particular types of boiler on-site and the full range of maintenance tasks required for safe operation of the boiler. All training, (including that for boiler systems) should be a structured on-going process which is updated to keep pace with developing technology, equipment and legislation. The level of competence required (and corresponding training requirements) should be reviewed when a system is modified, e.g. increased automation/remote supervision. The training should be delivered by personnel possessing the appropriate practical experience, assessment skills, and knowledge of the working environment.

The employer should ensure that all operatives and other relevant personnel are regularly assessed through work audits. Training should also be reassessed periodically, or at least once every five years. All of these items should be recorded and records retained for at least 5 years.

The Boiler Operation Accreditation Scheme (BOAS) is recognised by the Health and Safety Executive, the UK Insurance industry, the Safety Assessment Federation (SAFed) and industry members through the Combustion Engineering Association. Training providers accredited under the Boiler Operation Accreditation Scheme (BOAS) are accredited to industry standards.

ANNEX 4.1 TRAINING COURSES

There are a number of courses available at various levels. It is recommended that operators and managers achieve the national industry standards in:

- Certified Industrial Boiler Operator (CertIBO) for operators.
- Diploma in Boiler Plant Operation Management (DipBOM) for managers.

These qualifications form part of the Boiler Operation Accreditation Scheme (BOAS) mentioned above.

The level of training for operatives and managers should be tailored to the equipment an individual is expected to operate and the duties that are expected to be performed while operating that equipment, either normally or under exceptional circumstances.

Generic boiler system training courses can be used to provide basic information at varying levels. All training courses should involve site-specific elements. Courses should include the following topics:

- Boiler operation including start-up and shut-down.
- Boiler & burner controls and failure modes, taking account of fuel/s used.
- Feed water/boiler water analysis.
- Condensate drainage and water-hammer.
- Actions to be taken in an emergency and the consequences of inappropriate action.
- Responsibilities of all parties involved and legal aspects.
- Site-specific training plus documented written and oral examination on completion of course.

For boiler systems operators and managers, the BOAS courses cover the following in more detail:

- Basic heat & heat transfer concepts.
- Draught & combustion.
- Feed water & boiler water analysis (not site-specific).
- Control & instrumentation.
- Safety & legal requirements.
- Energy efficiency.
- Environment.
- Boilers & auxiliaries.
- Operation.
- Fuel concepts.

CEA in conjunction with their training partners are able to provide a training course covering steam boiler water treatment and waterside system testing, as outlined in BG04. This course is designed for engineers who already have BOAS, or are working towards it, or who own or are responsible for a steam boiler system. This course will allow candidates to demonstrate proficiency with respect to steam boiler water treatment and control and is approved by the CEA, as an adjunct to BOAS.

4.2 TRAINING RECORDS

Employers should ensure that all relevant training and assessment records are maintained and kept securely, including details of content and results of courses and any re-assessments. Appropriate audit records should be maintained and kept securely. Such evidence of training may be required to be viewed by enforcing authorities.

You **MUST** be able to demonstrate that the people operating and maintaining your boiler are suitably trained and competent.

4.3 COMPETENCE AND HOW TO DEFINE AND ACHIEVE IT

Employers have a duty to ensure that any person who carries out a task as part of his employment is competent. If a person is being trained, a competent person must supervise that person until he can carry out his work effectively and safely.

This duty also extends to people who employ contractors. A Duty Holder must be able to show that his or her organisation has done enough to reassure itself that the contractors it has engaged are competent.

Definition of Competence

A person who is deemed competent requires three main attributes:

- The ability to carry out and complete tasks effectively;
- The ability to work safely alone and/or with others;
- The knowledge of his/her limitations.

For many positions in the water treatment industry and other related disciplines (risk assessors, consultants, water treatment chemists etc.), the person must also have the ability to communicate well.

Recognising Competence

The qualities sought when establishing an individual's competence (as defined above) include that the person:

- Has undergone appropriate training;
- Is sufficiently experienced to carry out the activity effectively and safely;
- Possesses the ability to communicate verbally and in writing;
- Has the ability to use his/her experience to work safely in unfamiliar situations (e.g. when carrying out risk assessments);
- Has demonstrated the ability to manage time (their own and perhaps other people's time);
- Is able to meet deadlines without compromising safety.

Competence is recognised in a practical way. This means that on-the-job assessment is required in order to show that the employee/sub-contractor has the ability to work in a safe manner.

Competence cannot be totally assessed in the classroom. Whilst training is a key part of being competent, not all of that training should be formal classroom training. On-the-job training can be of use as long as the person delivering that training is competent to do so. It is not suitable or sufficient to simply pass knowledge along from, for example, one operator to another. This typically results in parts of the required training or information being missed or forgotten and errors being made.

There are, however, many people who work effectively and safely and have no formal qualifications at all. However, it is most unlikely that water treatment consultants, risk assessors, engineers etc., will have no formal qualifications, and most will be professional people (most commonly scientists and engineers). They may be members of professional bodies or learned associations such as The Royal Society of Chemistry. Even these people, however, will need to be able to show they are able to work safely and effectively.

Proving Competence

A formal strategy must be put in place in order to demonstrate that individuals are competent, or that competent people are being employed. This will vary depending on whether the person is a contractor, or a direct employee.

Competence is defined in law as Education, Training and Experience.

This would also apply to a contractor who wished to be able to prove his/her competence to a client.

The basic requirements will be:

1. On site references from customers (for contractors). It is good practice to be able to offer site visits to existing customers, where a client can visit systems already working and gain a first-hand knowledge of both contractor performance and competence and how things might work in practice. A contractor should hold a portfolio of suitable site references to produce as an aid to prove competence. For direct employees of a contractor, line managers within that business should be able to provide reassurance of a person's ability to work safely. For the self-employed, their present customers could be used as verifiers.
2. On-the-job checking on a regular basis. When first employing a contractor their ability should be checked when introducing them to the site and ensuring they can work safely. For direct employees, a supervisor should check his/her work frequently and keep a record of the findings. In the case of a contractor, a site contact could be asked to do this if proof is required of ability or the ability of one of contractor's employees.

Recording Competence

Finally, it will be necessary to show that every person employed is competent to do the job they have been employed to do. Even though all of the above may have been carried out, the person may be involved in a lost time accident. Proof may be required to enforcing bodies that everything practicable had been done to allow managers to believe the person was competent. This means that records will need to be maintained of all actions and observations. Those records need to be kept up to date (dated and signed), so be prepared to readdress all these aspects on a regular basis, at least annually or better every 3-6 months and whenever there are changes to personnel or their work**. Formal refresher training, both classroom and practical, should take place every five years, as a minimum.**

Competence is a continuous process.

16 REFERENCES

The following is a list of applicable documents current at the time of preparation of this publication. The following should be noted:

- This is an indicative, not comprehensive list.
- Free copies of all legislation are available from www.legislation.gov.uk.
- Legislation marked with an asterisk is supported by Approved Codes of Practice and Guidance (ACoP) published by HSE.
- Legislation marked with a double asterisk is supported by more than a single ACoP.
- The Electricity at Work Regulations (EAW) 1989 are supported by Memorandum of Guidance published by the HSE.

1. Health and Safety at Work etc Act 1974
2. Management of Health and Safety at Work Regulations (MHSWR) 1998 SI 1999 No. 3242
3. Provision and Use of Work Equipment Regulations (PUWER) 1998* SI 1998 No. 2306
4. Electricity at Work Regulations 1989 SI 1989 No. 635
5. Confined Spaces Regulations 1997* SI 1997 No. 1713
6. Control of Substances Hazardous to Health Regulations (COSHH) 2002* SI 2002 No. 2667
7. Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)** SI 2002 No. 2776
8. Control of Noise at Work Regulations 2005 SI 2005 No. 1643
9. Construction Design and Management Regulations (CDM) 2015*
10. Supply of Machinery (Safety) Regulations (SMSR) 2008 SI 2008 No. 1597
11. Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 SI 2016 No. 1107
12. Pressure Equipment (Safety) Regulations 2016 SI 2016 No. 1105
13. Pressure System Safety Regulations (PSSR) 2000 SI 2000 No. 128
14. The Gas Safety (Installation and Use) Regulations (GSIUR) 1998* SI 1998 No. 2451
15. BS 799: Part 4:1991 Specifications for atomising burners (other than Monobloc type) together with associated equipment for single burner & multiburner installations
16. BS 5925:1991 Code of practice for Ventilation principles and designing for natural ventilation
17. BS 6644:2008 Specification for Installation of gas-fired hot water boilers of rated inputs between 70 kW (net) and 1.8 MW (net) (2nd and 3rd family gases)
18. BS 7671 Requirements for electrical installations. IEE Wiring Regulations
19. BS EN 298:1994 Automatic Gas Burners Control systems for gas burners and gas burning appliances with or without fans
20. BS EN 676:1997 Automatic Forced Draught Burners for Gaseous Fuels
21. BS EN 746:1997 Part 2 safety requirements for Combustion and Fuel Handling Systems
22. BS12953-10: Shell Boilers
23. BS 2486:1997 Recommendations for treatment of water for steam boilers and water heaters
24. EN 45510 Guide for procurement of power station equipment Part 3-2 Shell Boilers IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems
25. BS 1427:2009 Guide to on-site test methods for the analysis of waters.

26. BG01 2011 Guidance on safe operation of boilers
27. HSE INDG 436 Safe management of industrial steam and hot water boilers
28. BS 7593 - Code of practice for treatment of water in domestic central heating systems
29. BS 6798 - Specification for selection, installation, inspection, commissioning, servicing and maintenance of gas-fired boilers of rated input not exceeding 70kW net
30. BS EN 14743 - Water conditioning equipment inside buildings. Softeners. Requirements for performance, safety and testing
31. BSRIA Standards list for Water Treatment: Pre-Commission Cleaning of Pipework Systems (BG 29/2012) BSRIA Water Treatment for Closed Heating and Cooling Systems (BG 50/2013) BEAMA Code of Practice for Chemical Cleaning and Inhibiting of Domestic Hot Water Central Heating Systems.
32. Permit-to-work systems HSE INDG98 ISBN 0 7176 1331 3 www.hse.gov.uk/comah/sragtech/techmeaspermit.htm
33. Permit to work web address - www.hse.gov.uk/comah/sragtech/techmeaspermit.htm
34. vSteam www.vsteam.co.uk
35. Water Management Society guide to risk assessment
36. Carbon Trust - Biomass Heating - A practical guide for potential users
37. Institution of Gas Engineers and Managers Utilisation Procedure UP/10
38. Installation of gas appliances in industrial and commercial premises
39. Institution of Gas Engineers and Managers (IGEM) UP/12
40. HSE Pressure Systems website http://www.hse.gov.uk/pressure-systems/index.htm

This page is intentionally blank

Document Control – Amendments

Edition 2, First impression – May 2017 – Amended scope and typing errors

Edition 3, First impression – November 2017 – Amended General Note 1, additional Annex 1.4 PSSR

Edition 3, Second impression – May 2018 – Amended refresher training recommendation to every 5 years. New Note 5, section 4. New Training course, Annex 4.1

Edition 4, First impression – March 2019 – Amended alignment and typing errors

Edition 4, Second impression – May 2019 – New layout to match CEA Boiler Guidance Documents

Edition 4, Third impression – August 2019 – Amended acknowledgements section

This page is intentionally blank

ICOM Energy Association (ICOM)

Camden House

Warwick Road

Kenilworth

CV8 1TH

www.icom.org.uk

The Combustion Engineering Association (CEA)

NETPark

Thomas Wright Way

Sedgefield

County Durham

TS21 3FD

www.cea.org.uk

This document will be formally reviewed periodically, although amendments and revisions may be made more frequently as required.

Users of this document should ensure they are working to the latest edition of this document and the related legislation and guidance.

Guidance on Industrial Boiler Water Treatment

Ref: BG04 Edition 4 - Published August 2019 - © all rights reserved

RRP £40.00

CEA
Combustion Engineering Association