

Recommendations for

Treatment of water for steam boilers and water heaters

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Committees responsible for this British Standard

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- Association of Circulator Manufacturers
- British Association for Chemical Specialities
- British Water
- Chemical Industries Association
- Chemical Industries Association (GOSIP)
- Electricity Association
- Health and Safety Executive
- Institute of Domestic Heating and Environmental Engineers
- Institute of Marine Engineers
- Institute of Plumbing
- Manufacturers Association of Radiators and Convectors Limited
- Power Generation Contractors Association PGCA (BEAMA Ltd.)
- Royal Society of Chemistry
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Foreword

This British Standard was prepared by Subcommittee EPC/37/8. It revises and supersedes BS 2486 : 1978, which is withdrawn. The responsibility for this standard has now been allocated to CII/62.

BS 2486 was first published in 1954 and last revised in 1978. This revision of the standard brings the technical content up to date, reflecting developments and experience gained in industrial boiler design and operation since 1978. The scope has been broadened to include water treatment for electrode boilers or evaporators, combined heat and power plant (CHP), combined cycle plant (CCP) and plant that produces hot water for heating or process purposes only.

Further information on the design and manufacture of water-tube steam generators and plant can be found in BS 1113 : 1992 and that of shell boilers in BS 2790 : 1992.

Further information on the maintenance of hot water systems of output >45 kW can be found in BS 6880 : Part 3 : 1988.

Given the range of knowledge and experience of the users of this standard, descriptive and introductory text cannot be entirely eliminated. It is also necessary to provide explanations for those applications which do not fall conveniently within the tables provided, or where there are risks if the treatment concerned is not adequately understood.

Values for levels of water treatment chemicals given in this standard are typical values given for information only. It is strongly recommended that, for specific applications, the advice of specialists in boiler water treatment be sought and followed.

Wherever a pressure is quoted in terms of bar, it refers to bar (gauge).

WARNING. Many of the chemicals referred to in this standard are hazardous to human health and or environment and should be handled with care. Attention is drawn to the provisions of the Control of Substances Hazardous to Health Regulations 1994 [1] and applicable environmental legislation. (See note 2 to 1.1.)

Attention is drawn to the fact that it is claimed that the use of methyl ethyl ketoxime is the subject of British patent No. 2 145 707, copies of which can be obtained from the Sale Branch, The Patent Office, Cwmfelinfach, Cross Keys, Newport NP1 7HZ. BSI takes no position as to the validity of the patent or whether it is still in force. The patent is endorsed 'licences of right' under Section 46 of the Patents Act 1977¹⁾, which states:

'(3) Where such an entry is made in respect of a patent —

- a) any person shall, at any time after the entry is made, be entitled as of right to a licence under the patent on such terms as may be settled by agreement or, in default of agreement, by the Comptroller on the application of the proprietor of the patent or the person requiring the licence.'

Licence details can be obtained from the registered proprietor of the patent.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

¹⁾ Or Section 35(2)(a) of the Patents Act 1949 if applicable.

Section 1. General

1.1 Scope

This British Standard gives recommendations for the control of water-side conditions of steam boilers and water heaters and also for the preparation of feed water for such plant. The following categories of water heating or steam-raising plant are covered:

- a) hot water systems as defined in 1.4;
- b) electrode boilers;
- c) shell (fire-tube) boilers operating at pressures up to 30 bar;²⁾
- d) water-tube boilers operating up to critical pressure;
- e) once-through boilers, including 'coil' and 'hairpin' types, operating up to, or above, the critical pressure.

NOTE 1. Regulation 11 of the Pressure Systems and Transportable Gas Containers Regulations, 1989 [2] came into effect on 1 July 1994 and 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. Guidance given in the Health and Safety Executive's Approved Code of Practice *Safety of Pressure Systems* [3] requires that instructions should cover, if appropriate, the feed water treatment.

NOTE 2. The Control of Substances Hazardous to Health (COSHH) Regulations 1994 [1] require 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 Approved Codes of Practice covering the control of substances hazardous to health and control of carcinogenic substances [4].

The recommendations are not applicable to:

- a) the treatment of water for most domestic heaters, which is covered by BS 7593 *Code of practice for treatment of water in domestic hot water central heating systems*;
- b) the treatment of water for marine boilers, which is covered by BS 1170 *Recommendations for treatment of water for marine boilers*;
- c) the treatment of water for nuclear-powered steam-generation plant.

The use of electronic, electrostatic or magnetic products is outside the scope of this standard. The preparation of a future British Standard covering such physical treatments of water for steam boilers and water heaters is being considered.

Methods for the analysis of water are not described in this standard.

Additional information on water and water treatment is given in annexes A to D.

1.2 Objectives

1.2.1 Objectives of water treatment

The objectives of water treatment are:

- a) to contribute to the overall safety of operation of the boiler or water heater;
- b) to assist in the maintenance of high heat-transfer efficiency in the boiler or water heater by:
 - 1) preventing deposition of precipitated scale or other debris;
 - 2) preventing corrosion or deterioration of surfaces in contact with water;
- c) to maintain the quality of any generated steam or hot water, appropriate to the particular application.

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

1.2.2 Factors influencing the quality of feed water required for steam boilers and water heaters

These are:

- a) the type and design of boiler or water heater, materials of construction and the operating conditions, particularly heat transfer rates and pressure;
- b) the desired steam or hot water quality and the requirements for any spray attenuators, desuperheaters or post-boiler plant, e.g. steam turbines.

Tables 1 to 7 fully reflect these criteria.

1.2.3 Factors influencing the type of water treatment necessary to meet the feed water quality requirements

These are:

- a) the characteristics, relative proportions and cost of make-up water, condensate and other process water that can comprise the feed water;
- b) the capacity and characteristics of any existing water treatment facilities and procedures;
- c) the balance between capital and operating costs of any proposed water treatment plant or procedure, including the effect of energy costs.

1.2.4 The water treatment process

The water treatment process, except for closed circuit water systems, usually involves two distinct elements:

- a) external treatment, which is concerned primarily with the removal of undesirable constituents;
- b) internal treatment, where chemical additions are made to the feed water, boiler water and steam in order to confer desirable attributes, or to react with traces of undesirable constituents which can remain after external treatment.

²⁾ 1 bar = 100 kPa.

1.3 References

1.3.1 Normative references

This British Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate points in the text and the cited publications are listed on the inside back cover. For dated references, only the edition cited applies; any subsequent amendments to or revisions of the cited publication apply to this standard only when incorporated in the reference by amendment or revision. For undated references, the latest edition of the cited publication applies, together with any amendments.

1.3.2 Informative references

This British Standard refers to other publications that provide information or guidance. Editions of these publications current at the time of issue of the standard are listed on the inside back cover, but reference should be made to the latest editions.

1.4 Definitions

For the purposes of this standard the following definitions apply:

1.4.1 boilers

Items of plant which heat water to its boiling point to produce saturated steam. This steam can subsequently be superheated.

1.4.2 hot water heaters

Items of plant which heat water to a temperature below its boiling point at the pressure of the system.

NOTE 1. The water so heated feeds a closed primary circuit utilizing some form of heat exchanger which allows the primary water to heat air, water or other process fluids. The primary circuit water is never used for potable or domestic purposes.

NOTE 2. Hot water heaters and their associated primary circuits are usually classified according to their operating temperature, as defined in 1.4.3, 1.4.4, and 1.4.5.

1.4.3 high temperature hot water (HTHW)

Water above 120 °C.

1.4.4 low temperature hot water (LTHW)

Water below 100 °C.

1.4.5 medium temperature hot water (MTHW)

Water at 100 °C to 120 °C inclusive.

Section 2. Water quality requirements for boilers

2.1 General

The recommendations and data presented in this section should be used as guidelines and reflect good operating and design experience from industry and from boiler manufacturers. It is important, however, that each application should be considered on its own merits. Boiler manufacturers' recommendations should be followed, especially when performance guarantees are given.

Good water treatment practice is dependent on a suitable treatment regime for the whole system. Planned, preventative maintenance of the steam boiler or water heater and all ancillary equipment will ensure the most efficient and safe operation.

2.2 Quality of water supply

Source water can vary considerably in quality and the effect of impurities can be detrimental to boiler operation (see annex D), so before a realistic attempt can be made to assess the treatment needed for any application it should be confirmed that reliable quality data, including variations, are available for the source water.

2.3 Hot water systems

2.3.1 General

Because more than one approach to water treatment exists for hot water systems, each of which gives varying degrees of protection to the system, the approach most suited to the system should be selected after consideration of its type, age and condition in order to provide the most cost-effective regime.

Consideration of existing systems should include an assessment of the quality of the water found in the system and it is particularly important to gauge the extent of any corrosion or scaling. This data should be augmented by determination of the concentrations of dissolved metals and the presence or absence of debris, e.g. iron oxides and/or lime scale. Comparison of the system performance with its design parameters in respect of flow rates, heat distribution, efficiency and response time should also indicate any problems. In addition, the operating history of the system should be ascertained, especially regarding occurrence of blockages and burst pipes, and the level of maintenance required, as this will help to determine the tolerance of the system to corrosion and scaling.

The flow diagram, figure 1, should be referred to for recommendations on water treatment plant selection.

Where the temperature in the system exceeds 100 °C pressurization is necessary to prevent the recirculating water from boiling. Medium temperature hot water systems (MTHW) operating below 3.5 bar generally are pressurized by the height of the expansion tanks above the system, but above 120 °C nitrogen-pressurizing should be used, when system pressures can go as high as 17 bar (177 °C).

2.3.2 Water treatment

Water treatment for hot water systems should be selected after consideration of the following parameters:

- materials of construction
- operating temperature and pressure
- water pre-treatment
- plant and system make-up water quality and quantity.

Two different approaches to chemical treatment for corrosion should be considered:

- a) the use of oxygen scavengers, such as sodium sulfite or tannins, buffered to provide the recommended pH range;
- b) the use of proprietary blends of corrosion inhibitors which can include nitrite and film-forming additives under appropriate pH conditions.

Where copper or its alloys are present a specific inhibitor against copper corrosion should be used; tannin and organic azoles are the most commonly used. Where aluminium is present specialist water treatment advice should be sought.

Standards of performance should be agreed with the chemical service company with the aim of maintaining plant performance and integrity. Corrosion monitoring can be carried out using direct measurement with corrosion coupons of suitable metallurgy or by routine monitoring of corrodible metal levels in the water. There are no generally acceptable levels and these should be agreed with the chemical service supplier.

Recommendations for suitable water treatment approaches are given in table 1.

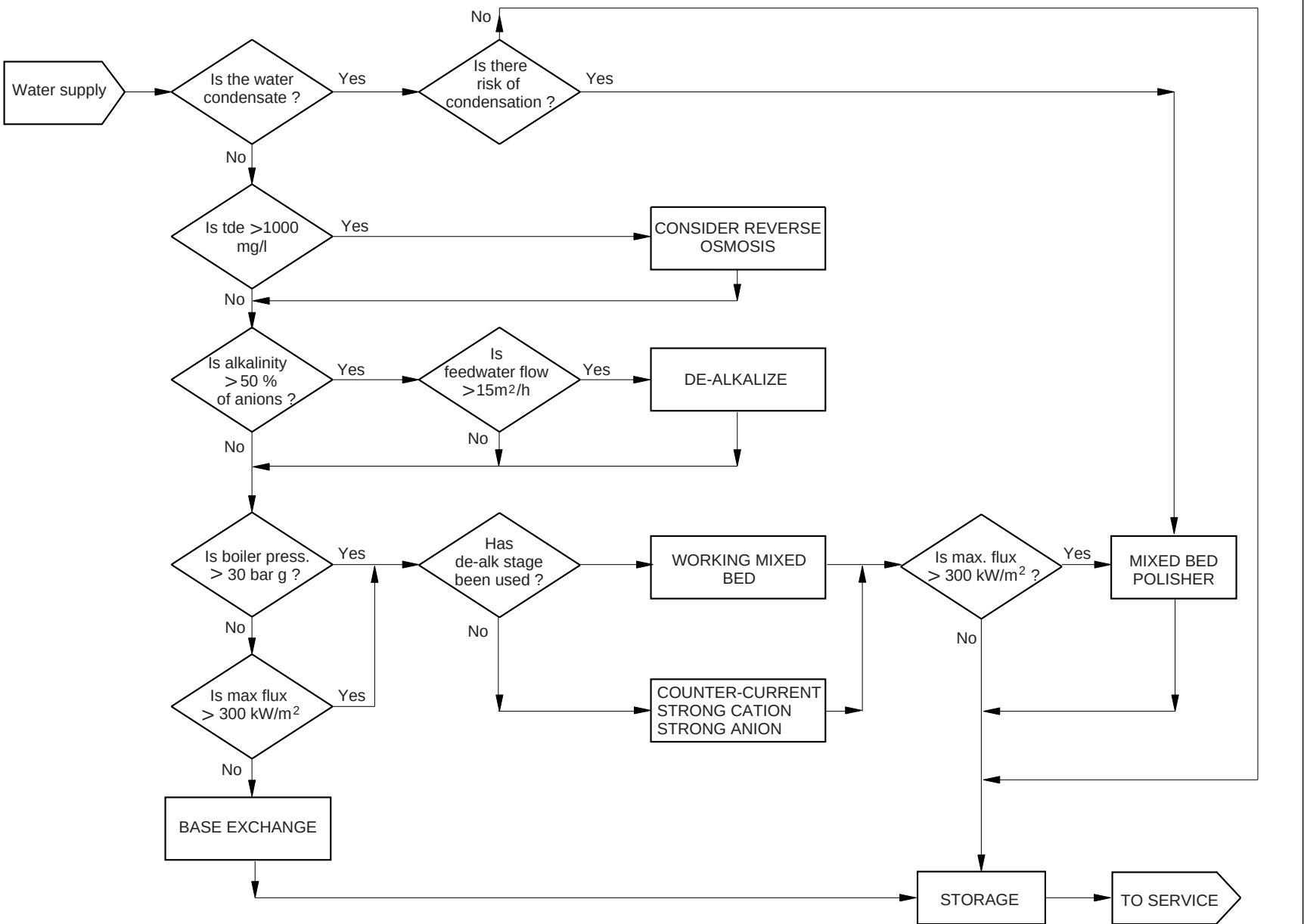


Figure 1. Steam boiler feed water pre-treatment options

Table 1. Water treatment for hot water systems

System type	Low and medium temperature hot water systems up to 120°C			High temperature hot water systems above 120°C		
Materials of construction (note 2)	Iron only	Iron with copper and copper alloys	Iron with copper, copper alloys and aluminium	Iron only	Iron with copper and copper alloys	Iron with copper, copper alloys and aluminium
Water quality (note 4)	Raw water	Raw water	Raw water (notes 5 and 6)	Raw water (note 7)	Raw water (note 7)	Raw water (notes 5, 6 and 7)
pH limits	8.0 to 10.5	7.5 to 9.2	7.0 to 8.0	8.0 to 10.5	7.5 to 9.2	7.0 to 8.0
Alkalinity control	Sodium hydroxide	Sodium hydroxide	Untreated or buffered	Sodium hydroxide or amines	Sodium hydroxide or amines	Amines
Copper corrosion inhibitor	None	Benzotriazole/tolyltriazole	Benzotriazole/tolyltriazole	None	Benzotriazole/tolyltriazole	Benzotriazole/tolyltriazole
Oxygen scavenger and/or	Sodium sulfite, tannin, hydrazine or DEHA	Sodium sulfite, tannin, hydrazine or DEHA	Sodium sulfite, tannin, hydrazine or DEHA	Volatile oxygen scavengers (see 5.3.2)	Volatile oxygen scavengers (see 5.3.2)	Volatile oxygen scavengers (see 5.3.2)
Corrosion inhibitor (note 3)	Suitable inhibitor blend (note 1)	Suitable inhibitor blend (note 1)	Suitable inhibitor blend (note 1)			
Sludge conditioner	Suitable organic polymer or blend	Suitable organic polymer or blend	Suitable organic polymer or blend	Suitable organic polymer or blend	Suitable organic polymer or blend	Suitable organic polymer or blend

NOTE 1. Chromate inhibitors should not be used because of their undesirable impact on the environment. It should also be noted that some treatment chemicals are microbiologically degraded in storage.

NOTE 2. Galvanized steel is not considered suitable for hot water systems.

NOTE 3. Alkaline oxygen scavengers can be used as an alternative treatment where toxicity restrictions prohibit proprietary blends.

NOTE 4. Raw water can be used, although in areas where the hardness exceeds 200 mg/kg as CaCO₃ and make-up exceeds 1 % of system capacity per week, a supplementary dispersant should be employed.

NOTE 5. Some naturally soft mains waters can be unsuitable because they contain dissolved copper ions which could lead to aluminium failure. Poor buffer control can also cause attack.

NOTE 6. Hard waters which have been fully softened should be avoided when aluminium is present.

NOTE 7. Anions such as chloride and sulfate should not exceed 10 mg/kg. Where the available water contains more than 10 mg/kg of each anion, demineralized water should be used.

2.4 Steam generating plant

2.4.1 Shell boilers (horizontal or vertical)

Shell or fire tube boilers produce steam by heat transfer from the heat source into water confined within a cylindrical vessel or shell, by passage of hot gases through a sequence of tubes. Modern shell boilers are designed to BS 2790.

From a combination of the boiler design and operating parameters it should be noted that solids entering the boiler with the feed water can rapidly concentrate at the metal water interface, especially at areas of high heat transfer. Such deposits can restrict heat transfer and consequently raise mean metal temperature, which can cause corrosion and reduce safety margins.

NOTE. Most shell boilers operate without de-aeration equipment (except feed tanks) and as a consequence high levels of oxygen and free carbon dioxide enter the boiler, both of which, without adequate internal treatment, cause severe corrosion.

As a result of experience gained since the last revision of this standard it is recommended that the operational parameters should not exceed the values given.

The recommendations in table 2 apply to high efficiency shell (fire-tube) boilers operated under design conditions. In view of the great variety of boiler designs in this category it is not possible to stipulate the precise feed water characteristics required for all boilers.

Whilst these recommendations should be generally applicable, there are some boilers, particularly of older and more conservative designs, where deviations from the recommendations of tables 2, 3 and 4 might be justifiable. The advice of the boiler manufacturer should be obtained particularly with regard to the maximum limits recommended for suspended solids and feed water hardness.

The following factors should be taken into consideration:

- a) boiler design;
- b) blowdown facilities including those of the water level controls;
- c) intermittent operation;
- d) operation of the boiler at less than the design pressure.

The levels of water treatment chemicals shown in table 2 are typical values only. It is strongly recommended that for a specific installation, the recommendations of the chemical service supplier should be followed.

Table 2. Recommended water characteristics for shell boilers up to 30 bar			
Feed water			
Parameter	Units	Values	
Appearance		Clear, produces no stable foam	
pH value at 25 °C		8.5 to 9.5 (note 1)	
Total hardness	mg/kg CaCO ₃	2 max. (note 2)	
Dissolved oxygen	mg/kg O ₂	(notes 3 and 4)	
Total alkalinity to pH 4.5 (M-alkalinity)	mg/kg CaCO ₃	(note 5)	
Oil and grease	mg/kg	1 max. (note 6)	
Boiler water			
Heat flux	kW/m ²	≤ 300	> 300 (note 7)
pH value at 25 °C	—	10.5 to 12.0 (note 8)	9.5 to 10.5 (note 8)
Total alkalinity (M-alkalinity)	mg/kg CaCO ₃	1000 max.	100 max.
Caustic alkalinity (O or P ₂ alkalinity)	mg/kg CaCO ₃	350 min. (note 9)	20 min (note 10)
Oxygen scavenger (note 18)			
Sodium sulfite	mg/kg	30 to 70	(note 12)
or Hydrazine	mg/kg	0.1 to 1.0	0.1 to 1.0
or Tannin	mg/kg	120 to 160	(note 12)
or Iso ascorbic acid	mg/kg	15 to 30	(note 12)
or Diethyl hydroxylamine (DEHA)	mg/kg	0.1 to 1.0 in feed water	0.1 to 1.0 in feed water
Phosphate	mg/kg PO ₄	30 to 60 (notes 11 and 13)	10 to 30 (notes 11 and 13)
Silica	mg/kg SiO ₂	150 max. (note 14)	5 max. (note 14)
Suspended solids	mg/kg	200 max.	20 max.
Dissolved solids (note 15)	mg/kg	3500 max. (notes 16 and 17)	1000 max. (notes 16 and 17)
Electrical conductivity at 25° C. on un-neutralized sample (note 15)	μS/cm	7000 max. (notes 16 and 17)	2000 max. (notes 16 and 17)

Table 2. Recommended water characteristics for shell boilers up to 30 bar (*continued*)

NOTE 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.

NOTE 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.

NOTE 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 a deaerator. (See 5.3 and figure 6.)

NOTE 4. An oxygen scavenger should be used (see 5.3.2) and should be added at the outlet of the feed tank or the deaerator in sufficient quantity to reduce the dissolved oxygen level to zero before the feed water enters the boiler or the economizer (where fitted).

NOTE 5. It is recommended that feed water alkalinity be maintained below 25 mg/kg. Alkalinity of 25 mg/kg and above will result in 10 mg/kg carbon dioxide in the steam. This level of carbon dioxide can be economically controlled by the use of a neutralizing amine (see 6.1). If this feed water alkalinity level cannot be achieved, it is recommended that dealkalization of the make-up water be carried out.

NOTE 6. As determined by the method given in BS 2690 : Part 11 : 1989. This standard has been withdrawn because it involves the use of chlorinated hydrocarbons and the replacement method is not yet available. Copies of the withdrawn standard are, however, obtainable from BSI on request.

NOTE 7. At these heat fluxes the use of demineralized water is essential.

NOTE 8. Corrosion of boiler internals can occur if the pH value is outside these limits.

NOTE 9. At these heat fluxes it is recommended that the caustic alkalinity be maintained at 10 % to 15 % of the total dissolved solids concentration if phosphate conditioning is practised. If carbonate conditioning is used, see note 11.

NOTE 10. This value will depend upon the silica concentration in the boiler water and also on the pH requirement.

NOTE 11. Maintenance of a phosphate reserve is not essential provided either that a minimum carbonate alkalinity of 250 mg/kg 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 sludges to adhere and form hard scales on heat transfer surfaces. Experience has shown that this is unlikely if the phosphate does not exceed 10 % of the minimum caustic alkalinity specified in the tables. As an additional safeguard it is common practice to use an appropriate polymeric sludge conditioner which will maintain precipitates in suspension for removal with the blowdown.

NOTE 12. These substances can, in some high heat flux and high pressure applications decompose to yield corrosive components. Applications should be individually assessed with the supplier concerned.

NOTE 13. The use of solubilizing treatments using chelants (EDTA, NTA etc.) is permissible provided that a maximum of 10 mg/kg is not exceeded at any time. Complete removal of oxygen should have been achieved prior to injection of the chelant. In boilers having heat fluxes greater than 300 kW/m², the use of chelants should be avoided since they can decompose to produce acidic residues.

NOTE 14. 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.

NOTE 15. Of these two parameters, conductivity and TDS, only one needs to be measured. See 5.1.

NOTE 16. These values are for guidance only. It might be found from experience that lower values are necessary to avoid priming or carryover. (See annex C.)

NOTE 17. These values are recommended for fully softened feed water in accordance with the table. If, for whatever reason, feed water with a significant hardness has to be used then TDS/conductivity level should be reduced to achieve the suspended solids limit. At 20 mg/kg feed water hardness the upper limit should be reduced to 6000 µS/cm* and at 40 mg/kg hardness it should be reduced to 4000 µS/cm*.

* Conductivity measured on un-neutralized sample.

NOTE 18. Other oxygen scavengers are referred to in 5.3.2. The control levels of these should be as recommended by the supplier of the treatment chemical.

2.4.2 Water tube boilers

2.4.2.1 Fired boilers

Water tube boilers produce steam by heat transfer from the heat source into water confined within a tube. Except at very high pressures, the thermal conductivity of steam is much lower than that of water and the lower cooling effect of a flow of a steam water mixture passing through a tube results in a higher metal temperature than that from water alone. The flow velocity of the steam water mixture through a tube will determine the phase distribution of the mixture. This mixture can take the form of a turbulent mousse which speeds up the fluid flow velocity or some form of phase separated flow which slows down the liquid phase velocity. These effects cause metal cooling problems and present corrosion risks.

Modern water tube boilers are designed to produce large amounts of steam from a relatively small boiler size and utilize a relatively high heat input. The heat distribution in a natural flow boiler can have major effects on the velocity of fluid flow in any particular area of the boiler and this should be taken into consideration when boilers are operated at pressures and steaming rates different from their designed optima.