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**Boiler feed water, boiler water and steam
quality**

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Foreword

This Japanese Industrial Standard has been revised by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee as the result of proposal for revision of Japanese Industrial Standard submitted by Thermal and Nuclear Power Engineering Society (TENPES)/Japanese Standards Association (JSA) with a draft being attached, based on the provision of Article 12, paragraph (1) of the Industrial Standardization Act applied mutatis mutandis pursuant to the provision of Article 16 of the said Act. This edition replaces the previous edition (**JIS B 8223** : 2015), which has been technically revised.

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Boiler feed water, boiler water and steam quality

1 Scope

This Japanese Industrial Standard specifies the requirements for the quality of feed water, boiler water and steam of boilers for land use and boilers for marine steam use.

2 Normative references

Part or all of the provisions of the following standards, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS B 0126 *Glossary of terms for thermal power plants — Boilers and auxiliary equipment*

JIS B 0127 *Glossary of terms for thermal power plant — Steam turbines and auxiliary equipment of thermal and geothermal power plant*

JIS B 8224 *Boiler feed water and boiler water — Testing methods*

JIS K 0410-3-7 *Water quality — Sampling — Part 7 : Guidance on sampling of water and steam in boiler plants*

JIS K 0556 *Testing methods for determination of anions in highly purified water*

3 Terms and definitions

For the purpose of this Standard, the following terms and definitions, and those given in JIS B 0126, JIS B 0127, JIS B 8224, JIS K 0410-3-7 and JIS K 0556 apply.

3.1 Common terms

3.1.1

normal operating pressure

maximum pressure applicable in practical operation

3.1.2

water conditioning at normal operation

quality of water stabilized after the plant start and shift to the power operation (except the start-up and suspension)

3.1.3

evaporation rate of heating surface

evaporation amount per hour in the unit area of evaporation [kg/(m²·h)]

3.2 Terms for land boilers

3.2.1 Common terms for boiler for industrial plant and boiler for power plant

3.2.1.1

water tube boiler, circulation boiler

natural circulation or forced circulation boiler and once-through boiler of which the heating surface is made up of water tubes

3.2.1.2

once-through boiler

boiler in which water is fed from one end of tube in forced flow by a pump and steam is taken out from the other end of tube

3.2.2 Boiler for industrial plant

3.2.2.1

boiler for industrial plant

boiler which supplies generated steam mainly for buildings (for hot water supply and air conditioning), manufacturing, waste incineration plants and in-house power generation

Note 1 to entry A cylindrical boiler, special circulation boiler, water tube boiler for industrial plant, once-through boiler for industrial plant of 15 MPa or under in normal operating pressure, waste heat boiler and heat recovery steam generator are generically called boilers for industrial plant.

3.2.2.2

cylindrical boiler

boiler of which the shell is the main body, provided with a flue tube, fire box, smoke tube etc.

Note 1 to entry A vertical boiler, flue tube boiler, smoke tube boiler, flue and smoke tube boiler are included.

3.2.2.3

mono-tube special circulation boiler

once-through boiler consisting of single or several tubes spirally wound, which feeds water from one end in forced flow, evaporates it by heating, takes out the steam-water vapour mixture from the other end, separates it into saturated steam and saturated water by a steam separator, returns separated saturated water to a deaeration tank open to the atmosphere, and again supplies it to the heating water tube after mixing with makeup water

3.2.2.4

multi-tubular special circulation boiler

water tube boiler, consisting of multiple heating tubes (riser tubes) and a header, which feeds water from one end, takes out the mixture of steam and water from the other end, and makes the amount of hot water returning to heating tubes 50 % or un-

der of that of steam-and-water mixture after the separation by steam separator

Note 1 to entry Among the special circulation boilers in **3.2.2.3** and **3.2.2.4**, a boiler of over 5 m² up to and including 10 m² in heating surface area and of 1 MPa or under in a maximum allowable working pressure is generally called a “small once-through boiler”, which corresponds to a “small boiler” in “Ordinance on Safety of Boilers and Pressure Vessels” based on the Industrial Safety and Health Act. Also, a boiler of over 10 m² up to and including 30 m² in heating surface area is generally called a “small-size boiler”.

3.2.2.5

water tube boiler for industrial plant

water tube boiler used for industries other than power plants

Note 1 to entry It is also called a circulation boiler for industrial plant.

3.2.2.6

once-through boiler for industrial plant

once-through boiler which generates steam to be supplied mainly to manufacturing and in-house power generation

3.2.2.7

waste heat boiler

boiler which generates steam by recovering the residual heat of exhaust gas from furnace etc.

Note 1 to entry The water conditioning for waste heat boilers of waste incineration plants etc. shall be controlled in accordance with the water conditioning control of water tube boiler for industrial plant.

3.2.2.8

heat recovery steam generator

boiler which generates steam by recovering the heat from exhaust air and process gas of gas turbine

3.2.3 Boiler for power plant

3.2.3.1

boiler for power plant

boiler which supplies generated steam mainly to the steam turbine for power generation and power plant facility

Note 1 to entry General term for circulation boiler for power plant, heat recovery steam generator for power plants and once-through boiler for power plant of over 15 MPa in normal operating pressure, in general.

3.2.3.2

circulation boiler for power plant

circulation boiler which supplies generated steam mainly to the steam turbine for power generation and the power plant facility

Note 1 to entry It is also called a water tube boiler for power plant.

3.2.3.3**heat recovery steam generator for power plant**

heat recovery steam generator which supplies generated steam mainly to the steam turbine for power generation and power plant facility

Note 1 to entry Consists of multi-pressure drums and many heating water tubes, which uses exhaust heat from the gas turbine for power generation as the heat source of a recovery steam generator.

3.2.3.4**once-through boiler for power plant**

once-through boiler which supplies generated steam mainly to the steam turbine for power generation and power plant facility

3.3 Terms for boilers for marine use**3.3.1****main boiler for marine use**

boiler which generates steam necessary for driving the main engine

Note 1 to entry Mounted on a steam turbine-powered ship.

3.3.2**auxiliary boiler for marine use**

boiler which generates steam necessary for driving the auxiliary engine other than the main engine drive, oil tank heating, inboard air conditioner etc.

Note 1 to entry Mounted on a diesel-powered ship.

3.3.3**fresh water generator**

apparatus which produces distilled water used on board from seawater

3.4 Terms for water type**3.4.1****raw water**

water on which a feed-water treatment has not yet performed, such as city water, industrial water, underground water, river water and lake water

3.4.2**makeup water**

water supplied to a boiler

Note 1 to entry Softened water, ion-exchanged water and distilled water are included.

3.4.3

softened water

water with hardness of CaCO_3 : 1 mg/L or under obtained from raw water treated by a softening equipment filled with cation-exchange resin

3.4.4

ion-exchanged water

water purified by ion-exchange equipment using cation-exchange resin and anion-exchange resin

3.4.5

condensed water

water which is condensed in a cooling system after the usage (at a steam turbine etc.) of steam generated from a boiler, and returned to the cycle

3.4.6

feed water

mixed water of condensed water and makeup water supplied to the inlet of boiler (inlet of economizer, if provided) by a feed water pump

3.4.7

boiler water

water concentrated in the boiler inside

Note 1 to entry Generally, this water is represented by water in the drum.

3.4.8

desuperheater spray water

water for cooling, injected to suppress/prevent overheat of steam

Note 1 to entry Boiler feed water is often used.

3.5 Terms for type of water treatment method of boiler

3.5.1

caustic treatment

treatment method to adjust the pH of boiler water mainly with sodium hydroxide, and also to adjust the phosphate ion concentration with phosphate (mainly sodium salts)

Note 1 to entry Trisodium phosphate is normally used as phosphate.

3.5.2

phosphate treatment

treatment method to adjust the pH and the phosphate ion concentration of boiler water with sodium phosphate salts

Note 1 to entry Sodium phosphate salts are prepared so that Na/PO₄ molar ratio generally becomes 2.6 to 2.8 by mixing trisodium phosphate and sodium dihydrogen phosphate.

3.5.3

all volatile treatment

treatment method by the use of volatile substances only, in which the pH of feed water, or feed water and boiler water is adjusted with volatile ammonia or amine, and the dissolved oxygen is removed by using deaerator and oxygen scavenger such as volatile hydrazine, or deaerator only

Note 1 to entry According to with/without the use of oxygen scavenger such as hydrazine, and the degree of oxidation-reduction atmosphere, this method is classified into the following three treatment types : reducing type, low oxidizing type and oxidizing type.

3.5.4

oxygenated treatment

water treatment method intended for corrosion control by adding oxygen and alkaline agents such as ammonia in high-purity water

Note 1 to entry Oxygenated Treatment (OT) is also called Combined Water Treatment (CWT). The water treatment method in which only oxygen is added in high-purity water is called Neutral Water Treatment (NWT), and is used only under the special condition in which alkaline agents cannot be used, or the like.

3.5.5

low-concentration sodium hydroxide treatment

treatment method in which the pH of boiler water is adjusted with trace amount sodium hydroxide

3.6 Terms for boiler corrosion event

3.6.1

ammonia attack

grooved or pinhole-shaped corrosion produced when copper alloy is exposed to condensate water containing ammonia and oxygen

Note 1 to entry Ammonia attack occurs a part or the like near the baffle of air cooling zone of a condenser made of copper alloy.

3.6.2

carryover

phenomenon in which the dissolved substances and suspended solid substances in boiler water contaminate into steam in the process of steam generation from a boiler

Note 1 to entry Carryover includes mechanical carryover and chemical carryover.

Note 2 to entry Mechanical carryover is caused by airborne droplets of boiler-water accompanied in steam which are generated mainly by foaming and priming. Chemical carryover is caused by a part of component in boiler water accompanied in steam due to volatility specific to the component in boiler water.

3.6.3

Flow Accelerated Corrosion (FAC)

phenomenon in which the dissolution reaction of the protective film (magnetite etc.) of metal material surface is accelerated by the turbulence of flow in a water tube, and as a result, the base metal is thinned

3.6.4

hideout

phenomenon in which the phosphate concentration in boiler water decreases by its deposit on the tube wall at the time of high load from that at injection; on the other hand, the phosphate deposited on tube wall redissolves at the time of low load, and the phosphate concentration in boiler water increases

Note 1 to entry Depending on the molar ratio of Na/PO₄ on the phosphating treatment, at the time of high load, water conditioning for the heating surface of water-cooled tube becomes alkaline by the phosphate deposits and then free alkali occurrence in the liquid phase. On the other hand, at the time of low load, phosphate redissolves and pH of boiler water decreases. The deposition of phosphate in this case is sometimes called hideout, and redissolving of phosphate is called hideout return.

3.6.5

boiler scale

impurities of calcium etc. carried in from the feed water system and the condensed water system, deposits of metal ions and metal oxides etc., and also the corrosive oxides produced on the inner wall of boiler tube

3.6.6

foaming

phenomenon in which boiler water foams, and bubbles and airborne droplets of boiler water are produced inside the steam drum by the contamination in boiler water of organic substances such as oils and fats, and total evaporation residues

3.6.7

priming

phenomenon in which the water level of boiler rises while a lot of steam bubbles are generated in boiler water when boiler pressure declines rapidly due to the rapid increase of steam consumption etc.

4 General matters on water conditioning for feed water and boiler water

4.1 Water conditioning for feed water

General matters on the water conditioning for feed water are as follows.

- a) From a viewpoint of the corrosion prevention of carbon steels which constitute the system (see **B.7**), the concentration of dissolved oxygen should be maintained at 500 µg/L or under. The means of reducing dissolved oxygen include the installation of a deaerator or membrane type deaerator and the feed water temperature raise in the open part of feed water tank etc.
- b) The content of fats and oils (hexane extract substances, see **JIS B 8224**) should be maintained low in concentration from the viewpoint that a boiler should not be contaminated with fats and oils in order to prevent the boiler water foaming and the scale deposition.
- c) When galvanized steel pipes (commonly, white gas pipes) are used for the feed water piping or the drain recovery piping (condensed water piping), zinc may be eluted and contained in feed water. Normally, although zinc serves as a sacrificial electrode to iron and forms a precipitated film on it showing a corrosion prevention function, the zinc concentration should be maintained low, since it causes zinc-based scale deposits in a boiler.
- d) The water conditioning control parameters of feed water are given in Annex B.

4.2 Water conditioning for boiler water

General matters on the water conditioning for boiler water are as follows.

- a) When sulfite is used as an oxygen scavenger and the deoxygenated treatment of boiler water is insufficient (when sulfite ions do not remain), the lower limit of the sulfite ion concentration shall be set, because the corrosion of carbon steels due to dissolved oxygen is accelerated by the sulfate ions generated as reaction products. The lower limit of the sulfite ion concentration shall be 10 mg/L for the case of 2 MPa or under in normal operating pressure and 5 mg/L for the case of over 2 MPa up to and including 5 MPa in normal operating pressure.

The upper limit of the sulfite ion concentration is not specified herein; however, as a guide, it should be 50 mg/L or under in the case where a deaerator is not fitted, 20 mg/L or under in the case where a deaerator is fitted and the normal operating pressure is 2 MPa or under, and 10 mg/L or under in the case where a deaerator is fitted and the normal operating pressure is over 2 MPa up to and including 5 MPa. Also, due to the pyrolysis of sulfite at high temperature by the generation of sulfur dioxide (SO₂), hydrogen sulfide (H₂S) etc., care should be taken for the use of sulfite, because the corrosion in the vapour system and the boiler inside may be promoted. For the practical additive amount of sulfite, see **B.9**.

- b) When using hydrazine as an oxygen scavenger and controlling the hydrazine injection amount based on the residual hydrazine concentration of boiler water, the upper limit of hydrazine concentration is not specified herein; however, it should be maintained at low concentration, in consideration of the possibility of the corrosion of the copper alloy material due to ammonia generated by the autolysis of hydrazine and the hazardous property of hydrazine. Especially, when using steam for the use such as food processing and indoor humidification in which a human body directly takes in or touches, it is necessary to control the residual hydrazine concentration of boiler water strictly in the range in which hydrazine is not detected in steam; if it is difficult to control, oxygen scavengers other than hydrazine shall be used (see **B.8**).
- c) When raw water or softened water is used as makeup water, scale whose content rate of silica is high tends to be deposited because the silica concentration in boiler water increases. In order to prevent the scale formation due to silica in a boiler, not only hard components are made not to coexist but also the silica concentration in boiler water is restricted, and the acid consumption (pH 8.3) of boiler water shall be controlled by a blow-down so that it does not exceed the value obtained by multiplying the upper value of this value by 1/1.7 [the amount equivalent to the acid consumption (pH 8.3) necessary for making silica metasilicate-ion form] (see **B.14**). When silica is maintained at high concentration, the acid consumption (pH 8.3) that prevents the deposition of silica shall be maintained, and attention should be paid to the silicate scale produced due to the inflow of hard components. When the silica concentration in feed water is high, since the pH of boiler water becomes difficult to rise, the blow-down shall be adjusted, boiler compounds shall be used, or the water treatment apparatus etc. that can remove silica (such as a reverse osmosis membrane apparatus) shall be used in combination. When air is sent to a turbine, the silica concentration should be maintained low in order to prevent the reduction of turbine efficiency due to silica scale produced in the turbine.
- d) Since sulfate ions have corrosion acceleration function, the concentration should be maintained as low as possible.
- e) The concentrations of iron, copper and zinc in boiler water should be maintained low for the purpose of preventing scale deposition, sludge accumulation in boiler, heating surface pollution and secondary corrosion by oxygen concentration cell.
- f) The water conditioning control parameters of boiler water are given in Annex B.

4.3 Water conditioning for all volatile treatment

According to with/without the use of oxygen scavenger such as hydrazine, and the degree of oxidation-reduction atmosphere, this method is classified into the following three treatment types.

- a) **All volatile treatment (reducing type) [AVT(R) : All Volatile Treatment (Reducing)]**
Treatment for feed water and boiler water, in which oxygen scavenger such as hydrazine is added and the condition is positively made to reducing atmosphere.
- b) **All volatile treatment (low oxidizing type) [AVT(LO) : All Volatile Treatment (Low**

Oxidizing)] Treatment for feed water and boiler water, in which oxygen scavenger such as hydrazine is not added and the concentration of dissolved oxygen is 7 µg/L or under.

- c) **All volatile treatment (oxidizing type) [AVT(O) : All Volatile Treatment (Oxidizing)]** Treatment for feed water and boiler water, in which oxygen scavenger such as hydrazine is not added and the concentration of dissolved oxygen is over 7 µg/L up to and including 20 µg/L. See Annex A for details.

4.4 Quality of steam

The control parameters of steam conditioning are given in Annex E.

4.5 Water conditioning for makeup water

The general matters concerning the water conditioning for makeup water are given in Annex C.

4.6 Case when measured value of water conditioning control parameter deviates from control value

General handling methods when measured value of water conditioning control parameter deviates from the control value are given in Annex D.

4.7 Water conditioning control at start-up or during suspension

As the water conditioning control of boiler at start-up or during suspension, handling different from that at normal operation is necessary in order to control corrosion.

5 Types of boiler and types of water treatment method for boiler for industrial plant

The types of boiler and general types of water treatment method for boiler for industrial plant are as given in Table 1. The practical water treatment methods of feed water and boiler water are given in Annex A. For the water treatment of waste heat boilers of waste incineration plants etc., see the relevant pressure division of water tube boiler for industrial plant.

Table 1 Types of boiler and general types of water treatment method for boiler for industrial plant

Boiler type	Makeup water	Feed water treatment method	Boiler water treatment method
Cylindrical boiler	Raw water	Not specified ^{a)}	Caustic treatment
	Softened water		
Mono-tube special circulation boiler	Softened water	Caustic treatment	
Multi-tubular special circulation boiler	Softened water	Not specified ^{a)}	Caustic treatment
	Ion-exchanged water		
Water tube boiler for industrial plant	Softened water	Not specified ^{a)}	Caustic treatment
	Ion-exchanged water	All volatile treatment ^{b)}	Caustic treatment
			Low-concentration sodium hydroxide treatment
			Phosphate treatment
			All volatile treatment
	Oxygenated treatment		
Once-through boiler for industrial plant	Ion-exchanged water	All volatile treatment ^{c)}	
		Oxygenated treatment ^{c)}	
Note ^{a)} The condensed water recovery rate of these boilers is not uniform and softened water is sometimes used for the whole feed water; therefore, it is difficult to specify a feed water treatment method (depending on water conditioning for makeup water and condensed water). Water conditioning is classified into normal operating pressure, evaporation rate of heating surface, type of makeup water etc.			
Note ^{b)} It is generally all volatile treatment; however, concerning the use of generated steam, greater importance to safety and purity is given, and when the use of a volatile oxygen scavenger, ammonia, amine etc. are restricted, sodium hydroxide etc. which are non-volatile base are used.			
Note ^{c)} Control values of water conditioning corresponding to the division specified in Table 16 shall apply.			

6 Water conditioning for cylindrical boiler

6.1 Water conditioning for feed water for cylindrical boiler

6.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for cylindrical boiler at normal operation shall be classified by the normal operating pressure, evaporation rate of heating surface and type of makeup water, and shall be as given in Table 2 and as follows.

- When ion-exchanged water is used for makeup water for cylindrical boiler, the water conditioning in the pressure division of 2 MPa or under in normal operating pressure in Table 9 shall apply.
- When a flue and smoke tube boiler is used at the pressure over 2 MPa in normal operating pressure, water conditioning for feed water in the corresponding pressure division in Table 9 shall apply.

Table 2 Control parameters and control values of water conditioning for feed water for cylindrical boiler

Division	Normal operating pressure MPa	1 or under		Over 1 up to and incl. 2
	Evaporation rate of heating surface kg/(m ² ·h)	30 or under ^{a)}	Over 30	—
	Type of makeup water	Raw water	Softened water	
Feed water	pH (at 25 °C)	5.8 to 9.0	5.8 to 9.0	5.8 to 9.0
	Hardness CaCO ₃ : mg/L	60 or under	1 or under	1 or under
Note ^{a)} Applicable to a cast iron boiler when steam is directly used for indoor humidification, food processing, film manufacturing, hospital facilities etc. and also makeup water is always used.				

6.1.2 Notes on water conditioning

In terms of the water conditioning for feed water for cylindrical boiler, the following should be noted.

- When raw water or softened water is used as feed water, and drain (condensed water) is recovered, since the feed water temperature rise serves as a contributory factor of the corrosion increase in the feed water system, in order to control the corrosion, the pH shall be raised to 7 or over (control at slightly high) by adding ammonia, amine (morpholine, cyclohexylamine, 2-aminoethanol, 2-amino-2-methyl-1-propanol, 3-methoxypropylamine, 2-diethylaminoethanol etc.) etc.
- When using softened water as makeup water, in order to prevent scale formation due to hard components and silica, attention should be paid to unexpected leakage of hard components (calcium and magnesium).
- Although iron concentration is not specified in feed water for a cylindrical boiler, it should be kept as low as possible. As a cause of much iron content in feed water, a case where iron is contained in raw water, a case where a feedwater system has been corroded and a case where a drain recovery system has been corroded by drain recovery are considered, and the measures for corrosion reduction such as use of iron removal equipment, change to corrosion-resistant material and use of condensate treatment agent shall be taken.
- When the silica concentration in feed water is high, since the pH of boiler water is less likely to rise, the blow-down shall be adjusted, boiler compounds shall be used, or the water treatment apparatus etc. that can remove silica (such as a reverse osmosis membrane apparatus) shall be used in combination.

6.2 Water conditioning for boiler water for cylindrical boiler

6.2.1 Control parameters and control values of water conditioning

The water conditioning for boiler water for cylindrical boiler at normal operation shall be the caustic treatment, and classified by the normal operating pressure, evaporation rate of heating surface and type of makeup water, and shall be as given in Table 3 and as follows.

- a) When ion-exchanged water is used for makeup water for cylindrical boiler, the water conditioning in the pressure division of 2 MPa or under in normal operating pressure in Table 10 shall apply.
- b) When a flue and smoke tube boiler is used at the pressure over 2 MPa in normal operating pressure, water conditioning for boiler water in the corresponding pressure division in Table 10 shall apply.

Table 3 Control parameters and control values of water conditioning for boiler water for cylindrical boiler

Division	Normal operating pressure	MPa	1 or under			Over 1 up to and incl. 2
	Evaporation rate of heating surface	kg/(m ² ·h)	30 or under ^{a)}	Over 30 up to and incl. 60	Over 60	—
	Type of makeup water		Raw water	Softened water		
	Treatment method		Caustic treatment			
Boiler water	pH (at 25 °C)		11.0 to 11.8	11.0 to 11.8	11.0 to 11.8	11.0 to 11.8
	Acid consumption (pH 8.3)	CaCO ₃ : mg/L	80 to 600	80 to 600	80 to 600	500 max.
	Electrical conductivity (at 25 °C)	mS/m (μS/cm)	600 max. (6 000 max.)	450 max. (4 500 max.)	400 max. (4 000 max.)	350 max. (3 500 max.)
	Chloride ion	Cl : mg/L	600 max.	500 max.	400 max.	350 max.
	Phosphate ion ^{b)}	PO ₄ : mg/L	20 to 40	20 to 40	20 to 40	20 to 40
	Sulfite ion ^{c)}	SO ₃ : mg/L	10 min.	10 min.	10 min.	10 min.
	Hydrazine ^{d)}	N ₂ H ₄ : mg/L	0.1 min.	0.1 min.	0.1 min.	0.1 min.
Note ^{a)} Applicable to a cast iron boiler when steam is directly used for indoor humidification, food processing, film manufacturing, hospital facilities etc. and also makeup water is always used.						
Note ^{b)} Applicable when phosphate is added.						
Note ^{c)} Applicable when sulfite is added.						
Note ^{d)} Applicable when hydrazine is added.						

6.2.2 Notes on water conditioning

In terms of the water conditioning for boiler water for cylindrical boiler, the following should be noted.

- a) When raw water or softened water is used as makeup water, in order to prevent scale formation due to hard components and silica, the phosphate ion concentration in boiler water shall be maintained high enough, and the pH shall be controlled at 11 or over. Also, when softened water is used as makeup water, attention should be paid to an unexpected leakage of hard components (calcium and magnesium).
- b) Phosphate ions in boiler water shall be controlled near the upper limit of a control value in order to handle an unexpected leakage of hard components and the usage of raw water as makeup water. It is possible to prevent scale and sludge due to

hard components by carboxylate polymers (polyacrylate, polymaleate etc.), phosphonates (hydroxyethylidenediphosphite, phosphonobutane tricarboxylate etc.) and/or chelating agents (ethylenediaminetetraacetate etc.) in addition to phosphate ions. When using these methods, it is advisable to consult with the pharmaceutical manufacturer as a supplier about the retention concentration of phosphate ions.

7 Water conditioning for special circulation boiler

7.1 Water conditioning for mono-tube special circulation boiler

7.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for mono-tube special circulation boiler at normal operation shall be classified by the normal operating pressure, and shall be as given in Table 4 and as follows.

- The feed water for mono-tube special circulation boiler refers to the makeup water to which recovery water is added and moreover chemicals are added. Practically, since this feed water is water to which recovery water is added, it is equivalent to the boiler water used for a cylindrical boiler etc. The hardness shall apply to the makeup water before the addition of recovery water.
- When ion-exchanged water is used as makeup water, the water conditioning in the case of using ion-exchanged water as makeup water of the corresponding pressure division in Table 6 shall apply.
- For auxiliary boiler for marine use, the water conditioning given in Table 4 shall apply both when softened water is used as makeup water and when distilled water purified by fresh water generator is used as makeup water.

Table 4 Control parameters and control values of water conditioning for feed water for mono-tube special circulation boiler

Division	Normal operating pressure	MPa	1 or under	Over 1 up to and incl. 3
	Type of makeup water		Softened water	
	Treatment method		Caustic treatment ^{a)}	
Feed water	pH (at 25 °C)		11.0 to 11.8	10.5 to 11.0
	Hardness	CaCO ₃ : mg/L	1 max.	1 max.
	Electrical conductivity (at 25 °C)	mS/m (μS/cm)	450 max. (4 500 max.)	400 max. (4 000 max.)
	Acid consumption (pH 8.3)	CaCO ₃ : mg/L	200 to 600	500 max.
	Hydrazine ^{b)}	N ₂ H ₄ : mg/L	0.1 min.	0.1 min.
	Chloride ion	Cl : mg/L	600 max.	400 max.
	Phosphate ion ^{c)}	PO ₄ : mg/L	20 to 60	20 to 60
Note ^{a)} Including the water treatment method in which chemicals are not added to feed water.				
Note ^{b)} Applicable when hydrazine is added.				
Note ^{c)} Applicable when phosphate is added.				

7.1.2 Notes on water conditioning

In terms of the water conditioning for feed water, the following should be noted.

- a) When softened water or ion-exchanged water is used as makeup water, and drain (condensed water) is recovered, since the feed water temperature rise serves as a contributory factor of the corrosion increase in the feed water system, in order to control the corrosion, the makeup water pH shall be raised to 7 or over.
- b) For a mono-tube special circulation boiler in which softened water is used as makeup water, in order to prevent the increase in hardness due to an unexpected leakage of hard components and scale formation of silica, the concentration of phosphate ions in a water tube shall be maintained within a control value, and the pH shall be controlled at 11.0 to 11.8 for the case of 1 MPa or under in normal operating pressure and at 10.5 to 11.0 for the case of over 1 MPa up to and including 3 MPa in normal operating pressure.
- c) For a mono-tube special circulation boiler, since it is difficult to prevent scale hindrance due to hard components only by the blow-down control for the treatment inside a boiler, softened water or ion-exchanged water shall be surely used as makeup water.
- d) The acid consumption of feed water shall be controlled for the purpose of preventing scale deposition due to silica, while the feed water pH is indirectly controlled. For a mono-tube special circulation boiler in which softened water is used as makeup water, although the silica concentration in feed water is not specified herein, it should be adjusted by the blow-down so as not to exceed the value obtained by multiplying the upper limit value of the acid consumption (pH 8.3) of boiler water by 1/1.7, that is, the concentration of SiO_2 : 350 mg/L at a normal operating pressure of 1 MPa or under and the concentration of SiO_2 : 300 mg/L at a normal operating pressure of over 1 MPa up to and including 3 MPa (see **B.14**).
- e) The hydrazine in feed water shall be controlled for the purpose of preventing the corrosion of boiler. Although the hydrazine concentration in feed water is specified to be N_2H_4 : 0.1 mg/L or over, it is necessary to control it at the value of not less than the equivalent amount to the concentration of dissolved oxygen in outlet water of deaeration tank or in outlet water of hot-well tank.
- f) The concentration of chloride ions in feed water shall be controlled for the purpose of the corrosion control, while the concentration multiple shall be estimated. For a mono-tube special circulation boiler, an indirect control of the concentration of total evaporation residues is focused, and the upper limit of concentration of chloride ions in feed water shall be specified in consideration of the corrosion prevention.
- g) The phosphate ion concentration in feed water shall be controlled for the purpose of preventing scale formation due to calcium brought in by makeup water. The phosphate ions required per CaCO_3 : 1 mg as calcium is PO_4 : 0.57 mg in the reaction of calcium and phosphate ions in a water tube. For the control value, the concentration of phosphate ions in feed water is taken as PO_4 : 20 mg/L to 60 mg/L ; however, in order to handle an unexpected leakage of hard components, the control should be

performed slightly high near the upper limit. Also for auxiliary boiler for marine use, the concentration of phosphate ions shall be controlled near the upper limit of control value in consideration of contamination with seawater.

7.2 Water conditioning for multi-tubular special circulation boiler

7.2.1 Water conditioning for feed water

7.2.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for multi-tubular special circulation boiler at normal operation shall be classified by the normal operating pressure and type of makeup water, and shall be as given in Table 5 and as follows.

- a) When ion-exchanged water is used and the normal operating pressure exceeds 3 MPa, the water conditioning in the case of using ion-exchanged water as makeup water of the corresponding pressure division in Table 9 shall apply.
- b) For auxiliary boiler for marine use, the water conditioning in the case of using softened water or ion-exchanged water as makeup water of the corresponding pressure division in Table 5 shall apply.
- c) For makeup water for auxiliary boiler for marine use, the water conditioning similar to that of ion-exchanged water shall apply to distilled water purified by fresh water generator.

Table 5 Control parameters and control values of water conditioning for feed water for multi-tubular special circulation boiler

Division	Normal operating pressure MPa	3 or under	
	Type of makeup water	Softened water	Ion-exchanged water
Feed water	pH (at 25 °C)	5.8 to 9.0	5.8 to 9.7
	Hardness CaCO ₃ : mg/L	1 max.	a)
	Iron Fe : mg/L	0.3 max.	0.1 max.
Note a) When hardness is calculated from the determination lower limit value specified in the applied test method for calcium and magnesium (see JIS B 8224), this value shall be lower than the calculated value.			

7.2.1.2 Notes on water conditioning

In terms of the water conditioning for feed water, the following should be noted.

- a) When softened water or ion-exchanged water is used as feed water, and drain is recovered, since the feed water temperature rise serves as a contributory factor of the corrosion increase in the feed water system, in order to control the corrosion, the pH shall be raised to 7 or over (control at slightly high) by adding alkaline, amine (morpholine, cyclohexylamine, 2-aminoethanol, 2-amino-2-methyl-1-propanol, 3-methoxypropylamine, 2-diethylaminoethanol etc.) etc.

For auxiliary boiler for marine use, the pH shall be 7.0 to 9.2.

- b) In order to prevent scale formation due to hard components and silica, attention should be paid to unexpected leakage of hard components (calcium and magnesium).
- c) A large amount of iron contained in feed water is considered that it is caused in the case where iron is contained in raw water, the case where a feed water system is corroded or the case where a drain recovery system is corroded when drain is recovered, and the measures for reducing iron such as the use of iron removal equipment, change to corrosion-resistant material and use of condensed water treatment agent shall be taken.
- d) When the silica concentration in feed water is high, since the pH of boiler water is less likely to rise, the blow-down shall be adjusted, boiler compounds shall be used, or the water treatment apparatus etc. that can remove silica (such as a reverse osmosis membrane apparatus) shall be used in combination.

7.2.2 Water conditioning for boiler water

7.2.2.1 Control parameters and control values of water conditioning

The water conditioning for boiler water for multi-tubular special circulation boiler at normal operation shall be classified by the normal operating pressure and type of makeup water, and shall be as given in Table 6 and as follows.

- a) When ion-exchanged water is used, if the normal operating pressure exceeds 3 MPa or if the phosphate treatment is performed, the water conditioning in the case of using ion-exchanged water as makeup water of the corresponding pressure division in Table 10 shall apply.
- b) For auxiliary boiler for marine use, the water conditioning in the case of using softened water or ion-exchanged water as makeup water of the corresponding pressure division in Table 6 shall apply.
- c) For makeup water for auxiliary boiler for marine use, the water conditioning similar to that of ion-exchanged water shall apply to distilled water purified by fresh water generator.

Table 6 Control parameters and control values of water conditioning for boiler water for multi-tubular special circulation boiler

Division	Normal operating pressure	MPa	1 or under	Over 1 up to and incl. 3	2 or under	Over 2 up to and incl. 3
	Type of makeup water		Softened water		Ion-exchanged water	
	Treatment method		Caustic treatment ^{a)}			
Boiler water	pH (at 25 °C)		11.0 to 11.8	11.0 to 11.8	10.5 to 11.5	10.0 to 11.0
	Acid consumption (pH 8.3)	CaCO ₃ : mg/L	80 to 600	500 max.	200 max.	120 max.
	Electrical conductivity (at 25 °C)	mS/m (μS/cm)	400 max. (4 000 max.)	300 max. (3 000 max.)	150 max. (1 500 max.)	100 max. (1 000 max.)
	Chloride ion	Cl : mg/L	400 max.	300 max.	150 max.	100 max.
	Phosphate ion ^{b)}	PO ₄ : mg/L	20 to 40	20 to 40	10 to 30	5 to 15
	Sulfite ion ^{c)}	SO ₃ : mg/L	10 min.	10 min.	10 min.	5 min.
	Hydrazine ^{d)}	N ₂ H ₄ : mg/L	0.1 min.	0.1 min.	0.1 min.	0.1 min.
Note ^{a)} Including the water treatment method in which chemicals are not added to feed water.						
Note ^{b)} Applicable when phosphate is added.						
Note ^{c)} Applicable when sulfite is added.						
Note ^{d)} Applicable when hydrazine is added.						

7.2.2.2 Notes on water conditioning

In terms of the water conditioning for boiler water, the following should be noted.

- In order to prevent scale formation due to hard components and silica, attention should be paid to unexpected leakage of hard components (calcium and magnesium).
- Chloride ions in boiler water shall be controlled for the purpose of corrosion control, while the degree of concentration of boiler water shall be known. For auxiliary boiler for marine use, the electrical conductivity and the concentration of chloride ions shall be maintained as low as possible in consideration of the concentration rate of boiler water.
- The phosphate ions in boiler water shall be controlled near the upper limit of a control value in order to handle an unexpected leakage of hard components. Also for auxiliary boiler for marine use, the concentration of phosphate ions shall be controlled near the upper limit of control value in consideration of contamination with seawater. It is possible to prevent scale and sludge due to hard components by carboxylate polymers (polyacrylate, polymaleate etc.), phosphonates (hydroxyethylidenediphosphite, phosphonobutane tricarboxylate etc.) and/or chelating agents (ethylenediaminetetraacetate etc.) in addition to phosphate ions. When using these methods, it is advisable to consult with the pharmaceutical manufacturer as a supplier about the retention concentration of phosphate ions.
- When sodium sulfite is used as an oxygen scavenger for auxiliary boiler for marine use, it shall be injected continuously.

8 Water conditioning for water tube boiler for industrial plant

8.1 Water conditioning for water tube boiler for industrial plant (when softened water is used)

8.1.1 Water conditioning for feed water

8.1.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for water tube boiler for industrial plant using softened water at normal operation shall be classified by the normal operating pressure, and shall be as given in Table 7.

Table 7 Control parameters and control values of water conditioning for feed water for water tube boiler for industrial plant (when softened water is used)

Division	Normal operating pressure	MPa	2 or under
	Type of makeup water		Softened water
Feed water	pH (at 25 °C)		5.8 to 9.0
	Hardness	CaCO ₃ : mg/L	1 max.
	Iron	Fe : µg/L	300 max.

8.1.1.2 Notes on water conditioning

In terms of the water conditioning for feed water, the following should be noted.

- Although softened water is used as feed water for the water tube boiler of 2 MPa or under in normal operating pressure, when drain is recovered or when feed water heat-exchange type continuous blow-down device is installed, the feed water temperature rises and serves as a contributory factor of corrosion rate increase of these feed water systems; therefore, in order to control the corrosion as much as possible, the pH shall be raised to 7 or over (control at slightly high) by adding ammonia, amine (morpholine, cyclohexylamine, 2-aminoethanol, 2-amino-2-methyl-1-propanol, 3-methoxypropylamine, 2-diethylaminoethanol etc.) etc.
- When hydrazine is injected as an oxygen scavenger, to control the corrosion of the system after the injection point, hydrazine should be injected in the upstream side as much as possible of the system in which feed water is not in contact with air, and if there is a deaerator, in the upstream side of it. However, it shall be noted that the deoxidation effect is hardly expectable, since the reaction rate is slow at a temperature of 100 °C or under.
- In order to prevent scale formation due to hard components and silica, attention should be paid to unexpected leakage of hard components (calcium and magnesium).
- A large amount of iron contained in feed water is considered that it is caused in the case where iron is contained in raw water, in the case where a feed water system is corroded or in the case where a drain recovery system is corroded when drain is recovered, and the measures for reducing iron such as the use of iron removal

equipment, change to corrosion-resistant material and use of condensed water treatment agent shall be taken.

- e) When the silica concentration in feed water is high, since the pH of boiler water becomes difficult to rise, the blow-down shall be adjusted, boiler compounds shall be used, or the water treatment apparatus etc. that can remove silica such as a reverse osmosis membrane apparatus shall be used in combination.

8.1.2 Water conditioning for boiler water

8.1.2.1 Control parameters and control values of water conditioning

The water conditioning for boiler water for water tube boiler for industrial plant using softened water at normal operation shall be the caustic treatment and classified by the normal operating pressure, and shall be as given in Table 8.

Table 8 Control parameters and control values of water conditioning for boiler water for water tube boiler for industrial plant (when softened water is used)

Division	Normal operating pressure MPa	1 or under	Over 1 up to and incl. 2
	Type of makeup water	Softened water	
	Treatment method	Caustic treatment	
Boiler water	pH (at 25 °C)	11.0 to 11.8	11.0 to 11.8
	Acid consumption (pH 8.3) CaCO ₃ : mg/L	80 to 600	500 max.
	Electrical conductivity (at 25 °C) mS/m (μS/cm)	400 max. (4 000 max.)	300 max. (3 000 max.)
	Chloride ion Cl : mg/L	400 max.	300 max.
	Phosphate ion ^{a)} PO ₄ : mg/L	20 to 40	20 to 40
	Sulfite ion ^{b)} SO ₃ : mg/L	10 min.	10 min.
	Hydrazine ^{c)} N ₂ H ₄ : mg/L	0.1 min.	0.1 min.
Note ^{a)} Applicable when phosphate is added.			
Note ^{b)} Applicable when sulfite is added.			
Note ^{c)} Applicable when hydrazine is added.			

8.1.2.2 Notes on water conditioning

In terms of the water conditioning for boiler water for water tube boiler for industrial plant using softened water, the following should be noted.

- a) When softened water is used as makeup water, in order to prevent scale formation due to hard components and silica, the phosphate ion concentration in boiler water shall be maintained high enough, and the pH shall be controlled at 11 or over. Also, for the water tube boiler for industrial plant in which softened water is used, attention should be paid to an unexpected leakage of hard components (calcium and magnesium).
- b) The concentration of chloride ions shall be maintained as low as possible because the stability of the corrosion-resistant film of iron oxides on steel surface is disturbed.

- c) The phosphate ions in boiler water shall be controlled near the upper limit of a control value in order to handle an unexpected leakage of hard components. It is possible to prevent scale and sludge due to hard components also by carboxylate polymers (polyacrylate, polymaleate etc.), phosphonates (hydroxyethylidenedi-phosphite, phosphonobutane tricarboxylate etc.) and/or chelating agents (ethylene-diaminetetraacetate etc.) in addition to phosphate ions. When using these methods, it is advisable to consult with the pharmaceutical manufacturer as a supplier about the retention concentration of phosphate ions.
- d) If an oxygen scavenger other than hydrazine is used, the concentration of dissolved oxygen at the outlet of deaerator or the residual concentration of oxygen scavenger should be controlled. However, attention should be paid that the control value of residual concentration varies depending on the type of oxygen scavenger. See **B.8** for details.

8.2 Water conditioning for water tube boiler for industrial plant (when ion-exchanged water is used)

8.2.1 Water conditioning for feed water

8.2.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for water tube boiler for industrial plant using ion-exchanged water at normal operation shall be classified by the normal operating pressure and treatment method of boiler water, and shall be as given in Table 9 and as follows.

- a) In the boilers of over 15 MPa in normal operating pressure, the water conditioning of the relevant pressure division for circulation boiler for power plant shall apply. Also, for the water tube boiler for industrial plant, there are the cases where the volume to bring in air becomes large due to the large amount of makeup water and where air leakage due to the seal deterioration of a condenser cannot be suppressed and the corrosion of a condenser tube made of copper and copper alloy may be generated. Therefore, when using the condenser tube made of copper and copper alloy, the feed water pH shall be controlled at 9.4 or under.
- b) When used for the main boiler for marine use, the water conditioning in the case where same water treatment method in the corresponding pressure division in Table 9 is used shall apply.
- c) When distilled water purified in a fresh water generator is used as makeup water for a main boiler for marine use, the water conditioning in Table 9 shall apply.

**Table 9 Control parameters and control values of water conditioning for feed water for water tube boiler for industrial plant
(when ion-exchanged water is used)**

Division	Normal operating pres- sure	MPa	2 or un- der	Over 2 up to and incl. 3	Over 3 up to and incl. 5	Over 5 up to and incl. 7.5	Over 7.5 up to and incl. 10	Over 10 up to and incl. 15			
	Type of makeup water	Ion-exchanged water									
	Treatment method	—				All volatile treatment				Oxygenated treatment	
	Reducing agent	—				yes		no		no	
	Redox property	—				Reducing type [AVT(R)]		Low oxidizing type [AVT(LO)]	Oxidizing type [AVT(O)]	Oxidizing type (OT)	
Feed water	pH (at 25 °C)	8.5 to 10.3 ^{b) c)}	8.5 to 10.3 ^{b) c)}	8.5 to 10.3 ^{b) c)}	8.5 to 10.3 ^{b) c) d)}	8.5 to 10.3 ^{b) c) d)}	8.5 to 10.3 ^{b) c) d)}	8.5 to 10.3 ^{b) c) d)}	8.5 to 10.3 ^{b) c) d)}	8.0 to 10.3 ^{c)}	
	Electrical conductivi- ty after cation ex- changer (at 25 °C)	mS/m (μS/cm)	— —	— —	— —	— —	0.05 max. (0.5 max.)	0.05 max. (0.5 max.)	0.02 max. (0.2 max.)	0.02 max. (0.2 max.)	
	Hardness	CaCO ₃ : mg/L	^{e)}	^{e)}	^{e)}	^{e)}	^{e)}	^{e)}	^{e)}	^{e)}	
	Dissolved oxygen	O : μg/L	—	100 max.	30 max.	7 max.	7 max.	7 max.	Over 7 up to and incl. 20	Over 20 up to and incl. 50	
	Iron	Fe : μg/L	100 max.	100 max.	100 max.	50 max.	30 max.	30 max.	30 max.	10 max.	5 max.
	Copper	Cu : μg/L	—	—	50 max.	30 max.	20 max.	10 max.	10 max.	10 max.	10 max.
	Hydrazine ^{a)}	N ₂ H ₄ : μg/L	—	200 min.	60 min.	10 min.	10 min.	10 min.	—	—	—
Note ^{a)} Applicable when hydrazine is added.											
Note ^{b)} In the case of all the total iron system units, the pH lower limit should be adjusted and controlled to 9.3 or over.											
Note ^{c)} When the tubing material of the low-pressure feed water heater is made of copper alloy, the pH upper limit should be adjusted and controlled to 9.5 or under, when the high-pressure feed water heater is made of copper alloy, to 9.0 or under, and when the condenser is made of copper alloy, to 9.4 or under.											
Note ^{d)} When all volatile treatment is adopted for boiler water, the feed water pH shall be controlled so that the boiler water pH can be maintained within the control value.											
Note ^{e)} When hardness is calculated from the determination lower limit value specified in the applied test method for calcium and magnesium (see JIS B 8224), this value shall be lower than the calculated value.											

8.2.1.2 Notes on water conditioning

The water conditioning for feed water shall be as given in Table 9, and the following should be noted.

- a) **Feed water treatment when water treatment method of boiler is caustic treatment, low-concentration sodium hydroxide treatment, phosphate treatment or all volatile treatment**

The combination of feed water treatment method and boiler water treatment method for water tube boiler for industrial plant are given in Table 1 in Clause 5.

- 1) For the feed water pH adjustment, the volatile base such as ammonia and amine (morpholine, cyclohexylamine, 2-aminoethanol, 2-amino-2-methyl-1-propanol, 3-methoxypropylamine, 2-diethylaminoethanol etc.), or the non-volatile base such as sodium hydroxide shall be used. If the use of volatile oxygen scavenger, ammonia, amine etc. is restricted due to safety and purity concerns in the application of the generated vapor, a non-volatile base such as sodium hydroxide should be used.

In a boiler for power generation, since steam desuperheater spray water is branched from a feed water system, attention should be paid to an injection position so that hindrance does not occur by spraying the non-volatile base such as sodium hydroxide to a steam superheater or steam turbine. Also, when amine is used as the pH adjuster of feed water, it is necessary to maintain the pyrolysis amount of amine at a low level by selecting amine of which the decomposition rate is low in the temperature/pressure range to be used.

- 2) Although the sampling point of feed water should be a place of downstream side from the injection point of the base that adjusts the feed water pH, if the base such as non-volatile phosphate and sodium hydroxide as a treatment agent for boiler water is injected into feed water, a place of upstream side from the injection point shall be selected in order to avoid the influence by phosphate and base.
- 3) The upper limit value of feed water pH when the copper material is not used should be slightly high as the measures for the flow accelerated corrosion (FAC).

Although the upper limit of feed water pH when a condenser is made of copper alloy is set to 9.6 for the power plants, for the industrial plants, since a large amount of makeup water may bring in a large amount of air or the leakage of air due to the deterioration of sealing property of a condenser cannot be suppressed, which may result in the corrosion of the condenser tube, the pH is set to 9.4. On the other hand, as given in 1), when the use of volatile oxygen scavenger, ammonia, amine etc. is restricted due to safety and purity concerns in the application of the generated vapor, and if the pH is not adjusted or it is below the lower limit value of the control value, the measures for corrosion prevention such as the use of a feed water system made of corrosion-resistant materials should be taken.

- 4) In the boilers of over 10 MPa in normal operating pressure, the electrical conductivity after cation exchanger of feed water shall be measured. In the practical

control, the value of electrical conductivity after cation exchanger [normally, 0.02 mS/m to 0.03 mS/m (0.2 μ S/cm to 0.3 μ S/cm) or under at 25 °C] in a normal water conditioning state shall be grasped, and also against the fluctuation in the range of a control value, appropriate measures such as an improvement in water conditioning by chemical injection and blowing should be taken by checking the presence of trace amount leakage of cooling water from condenser, degradation in water conditioning for makeup water etc. which are the variation factor of the fluctuation.

- 5) In the boilers of over 2 MPa in normal operating pressure, the upper limit concentration of dissolved oxygen in feed water for each pressure division should be set and controlled empirically or based on the latest performance assurance value etc. of deaerator.
- 6) It is effective to control the corrosion of the system after the injection point by injecting hydrazine in the upstream side as much as possible of the system in which feed water is not in contact with air, and if there is a deaerator, by injecting it in the upstream side of it. The concentration of hydrazine in feed water for the water tube boiler for industrial plant of over 1 MPa in normal operating pressure in which the large portion of dissolved oxygen is removed by a deaerator should be larger than 1.5 times the concentration of dissolved oxygen after de-airing. For the feed water for the water tube boiler for industrial plant of 5 MPa or under in normal operating pressure, when the concentration of dissolved oxygen after de-airing exceeds $O : 7 \mu\text{g/L}$, the lower limit value should be controlled so that the hydrazine concentration of feed water is larger than twice the concentration of dissolved oxygen after de-airing. Generally, the concentration of hydrazine in feed water is a lower limit value necessary for water feeding at the inlet of boiler (if economiser is used, at the inlet of economiser), and it is necessary to adjust the injection amount of hydrazine so that this lower limit value is maintained. Although the upper limit value of the concentration of hydrazine in feed water is not set, if the injection amount of hydrazine is excessive, the amount of ammonia produced by the pyrolysis of hydrazine in the boiler increases and the amount of dissolution of ammonia to steam increases, and the pH of condensed water of condenser may rise. Therefore, in the case of the condenser using copper alloy, the injection amount of hydrazine shall be adjusted while monitoring the pH and the concentration of copper of feed water.
- 7) If an oxygen scavenger other than hydrazine is used, the concentration of dissolved oxygen at the outlet of deaerator and/or the residual concentration of oxygen scavenger should be controlled. However, attention should be paid that the control value of residual concentration varies depending on the type of oxygen scavenger. See **B.8** for details.
- 8) For iron, in the case of volatile matter treatment (reducing type) [AVT(R)] and volatile matter treatment (low oxidizing type) [AVT(LO)] of over 7.5 MPa up to and including 15 MPa in normal operating pressure, $\text{Fe} : 20 \mu\text{g/L}$ or under should be kept.

- 9) In the boilers of 3 MPa or under in normal operating pressure, although the concentration of copper in feed water is not specified, it should be maintained low. As a guideline, Cu : 50 µg/L or under should be kept as the boilers of over 3 MPa up to and including 5 MPa in normal operating pressure.
- 10) In the boilers of over 10 MPa in normal operating pressure, Cu : 5 µg/L or under should be kept .

b) Oxygenated treatment

- 1) In a water tube boiler for industrial plant, the pH should be 9.4 or over where necessary as a measure for iron suppression for a drain system in which oxygen is not supplied enough.
- 2) In order to maintain the corrosion control effect by dissolved oxygen, the electrical conductivity after cation exchanger should be 0.01 mS/m or under in contrast to the control value 0.02 mS/m or under.
- 3) When the steady operation continues by forming the protective film, since even if the concentration of dissolved oxygen is slightly low, the protective film can be retained, the value of dissolved oxygen suitable for the concentration of iron, copper etc. in feed water that becomes the minimum in the range of a control value should be set.
- 4) Since the concentration of iron of each system decreases with the reduction of solubility of iron oxides, considering that the concentration of iron in feed water can be suppressed as compared with the conventional water treatment, the iron concentration should be maintained at Fe : 2 µg/L or under as the practical control.
- 5) In the facilities in which oxygenated treatment is applied, in order to avoid the occurrence of the corrosion and pitting accident due to oxygen and ammonia, it is preferable that copper alloy should not be used for a condenser fine tube and a feed water-heater heating tube.

8.2.2 Water conditioning for boiler water

8.2.2.1 Control parameters and control values of water conditioning

The water conditioning for boiler water for water tube boiler for industrial plant using ion-exchanged water at normal operation shall be classified by the caustic treatment, low-concentration sodium hydroxide treatment, phosphate treatment, all volatile treatment and oxygenated treatment, and the normal operating pressure, and shall be as given in Table 10 and as follows.

- a) In the boilers of over 15 MPa in normal operating pressure, the water conditioning of the relevant pressure division for circulation boiler for power plant shall apply.
- b) When used for the main boiler for marine use, the water conditioning in the case where same water treatment method in the corresponding pressure division in Table 10 is used shall apply.
- c) When distilled water produced in a fresh water generator is used as makeup water

for a main boiler for marine use, the water conditioning in Table 10 shall apply.

For the makeup water for boilers of over 10 MPa in normal operating pressure, water obtained by treating distilled water by a polisher (deionizer) should be used.

**Table 10 Control parameters and control values of water conditioning for boiler water for water tube boiler for industrial plant
(when ion-exchanged water is used)**

Division	Normal operating pressure	MPa	2 or under		Over 2 up to and incl. 3		Over 3 up to and incl. 5		
	Type of makeup water		Ion-exchanged water						
	Treatment method		Caustic treatment	Phosphate treatment	Caustic treatment	Phosphate treatment	Caustic treatment	Low-concentration sodium hydroxide treatment	Phosphate treatment
	Reducing agent		—						
	Redox property		—						
Boiler water	pH (at 25 °C)		10.5 to 11.5	9.8 to 10.8	10.0 to 11.0	9.4 to 10.5	9.6 to 10.8	9.4 to 10.0	9.4 to 10.5
	Acid consumption	CaCO ₃ : mg/L (pH 8.3)	200 max.	100 max.	120 max.	80 max.	—	—	—
	Electrical conductivity (at 25 °C)	mS/m (μS/cm)	150 max. (1 500 max.)	120 max. (1 200 max.)	100 max. (1 000 max.)	80 max. (800 max.)	80 max. (800 max.)	3 max. (30 max.)	60 max. (600 max.)
	Electrical conductivity after cation exchanger (at 25 °C)	mS/m (μS/cm)	— (—)	— (—)	— (—)	— (—)	— (—)	6 max. (60 max.)	— (—)
	Chloride ion	Cl : mg/L	150 max.	150 max.	100 max.	100 max.	80 max.	2 max.	80 max.
	Phosphate ion ^{a)}	PO ₄ : mg/L	10 to 30	10 to 30	5 to 15	5 to 15	5 to 15	— ^{g)}	5 to 15
	Sodium	Na : mg/L	—	—	—	—	—	2.8 max.	—
	Sulfite ion ^{b)}	SO ₃ : mg/L	10 min.	10 min.	5 min.	5 min.	5 min.	— ^{e)}	5 min.
	Hydrazine ^{c)}	N ₂ H ₄ : mg/L	0.1 min. ^{k)}	0.1 min. ^{k)}	—	—	—	—	—
	Silica ^{d)}	SiO ₂ : mg/L	50 max.	50 max.	50 max.	50 max.	20 max.	20 max.	20 max.

Table 10 (continued)

Division	Normal operating pres- sure	MPa	Over 5 up to and incl. 7.5				Over 7.5 up to and incl. 10		
	Type of makeup water	Ion-exchanged water							
	Treatment method	Caustic treat- ment	Low-concentration sodium hydroxide treatment	Phosphate treatment	All volatile treat- ment	Low-concentration sodium hydroxide treatment	Phosphate treatment	All volatile treat- ment	
	Reducing agent	—				yes	—		yes
	Redox property	—				Reducing type [AVT(R)]	—		Reducing type [AVT(R)]
Boiler water	pH (at 25 °C)		9.6 to 10.5	9.4 to 10.0	9.2 to 10.2	8.5 to 10.0	9.4 to 10.0	9.0 to 10.0	8.5 to 10.0
	Acid consumption CaCO ₃ : mg/L (pH 8.3)		—	—	—	—	—	—	—
	Electrical conductivity (at 25 °C)	mS/m (μS/cm)	50 max. (500 max.)	3 max. (30 max.)	40 max. (400 max.)	— (—)	3 max. (30 max.)	15 max. (150 max.)	— (—)
	Electrical conductivity after cation exchanger (at 25 °C)	mS/m (μS/cm)	— (—)	6 max. (60 max.)	— (—)	6 max. (60 max.)	6 max. (60 max.)	— (—)	6 max. (60 max.)
	Chloride ion	Cl : mg/L	50 max.	2 max. ^{f)}	50 max.	2 max.	2 max. ^{f)}	10 max.	2 max.
	Phosphate ion ^{a)}	PO ₄ : mg/L	3 to 10	— ^{g)}	10 max. ^{h)}	— ^{h)}	— ^{g)}	6 max.	— ^{h)}
	Sodium	Na : mg/L	—	2.8 max.	—	—	2.8 max.	—	—
	Sulfite ion ^{b)}	SO ₃ : mg/L	—	—	—	—	—	—	—
	Hydrazine ^{c)}	N ₂ H ₄ : mg/L	—	—	—	—	—	—	—
	Silica ^{d)}	SiO ₂ : mg/L	3 max.	3 max.	3 max.	3 max.	1 max.	1 max.	1 max.

Table 10 (continued)

Division	Normal operating pressure	MPa	Over 10 up to and incl. 15				
	Type of makeup water		Ion-exchanged water				
	Treatment method	Low-concentration sodium hydroxide treatment	Phosphate treatment	All volatile treatment			Oxygenated treatment ⁱ⁾
	Reducing agent	—		yes	no		no
	Redox property	—		Reducing type [AVT(R)]	Low oxidizing type [AVT(LO)]	Oxidizing type [AVT(O)]	Oxidizing type (OT)
Boiler water	pH (at 25 °C)	9.1 to 9.5	8.5 to 9.8	8.5 to 10.0	8.5 to 10.0	8.5 to 10.0	8.0 to 10.0 ⁱ⁾
	Acid consumption (pH 8.3) CaCO ₃ : mg/L	—	—	—	—	—	—
	Electrical conductivity (at 25 °C) mS/m (μS/cm)	1 max. (10 max.)	6 max. (60 max.)	— (—)	— (—)	— (—)	— (—)
	Electrical conductivity after cation exchanger (at 25 °C) mS/m (μS/cm)	2 max. (20 max.)	— (—)	2 max. (20 max.)	2 max. (20 max.)	0.3 max. (3 max.)	0.3 max. (3 max.)
	Chloride ion Cl : mg/L	1 max. ^{f)}	2 max.	1 max.	1 max.	0.1 max.	0.05 max. ⁱ⁾
	Phosphate ion ^{a)} PO ₄ : mg/L	— ^{g)}	3 max.	— ^{h)}	— ^{h)}	— ^{h)}	—
	Sodium Na : mg/L	0.9 max.	—	—	—	—	—
	Sulfite ion ^{b)} SO ₃ : mg/L	—	—	—	—	—	—
	Hydrazine ^{c)} N ₂ H ₄ : mg/L	—	—	—	—	—	—
	Silica ^{d)} SiO ₂ : mg/L	0.3 max.	0.3 max.	0.3 max.	0.3 max.	0.3 max.	0.3 max.

Table 10 (concluded)

Note ^{a)}	Applicable when phosphate is added.
Note ^{b)}	Applicable when sulfite is added.
Note ^{c)}	Applicable when hydrazine is added.
Note ^{d)}	From the relation between the concentration of silica in boiler water and the concentration of silica in steam, the concentration of silica in boiler water shall be maintained low so that the silica concentration in steam is $\text{SiO}_2 : 0.02 \text{ mg/L}$ or under.
Note ^{e)}	In the low-concentration sodium hydroxide treatment, since the control of corrosive anions in boiler water is important, sulfite, which is one of the sources of sulfate ion generation, is not used as a oxygen scavenger.
Note ^{f)}	The concentration of chloride ions is set to the same as that for all volatile treatment (reducing) [AVT(R)].
Note ^{g)}	In the low-concentration sodium hydroxide treatment, since phosphate is not used, the concentration of phosphate ions is not specified.
Note ^{h)}	Phosphate or sodium hydroxide shall be added, which is required for the emergency treatment sufficient for the amount of components that contaminate and lower the amounts of calcium and magnesium and the pH value due to the leakage etc. of seawater from a condenser.
Note ⁱ⁾	The concentration of dissolved oxygen in boiler water reduces. For the pH adjustment, volatile substance (ammonia or volatile amine) shall be used.
Note ^{j)}	Tested in accordance with Clause 5 and Note (e) to this, specified in JIS K 0556 .
Note ^{k)}	The excessive addition leads to the pH rise of feed water and condensed water due to ammonia generation, when a copper tube or copper alloy tube is used, the concentration shall be 0.5 mg/L or under.

8.2.2.2 Notes on water conditioning

The water conditioning for boiler water shall be as given in Table 10, and the following should be noted.

a) Common matter

- 1) The higher the operating pressure of a boiler, the more significant the concentration of boiler water on the heating surface; therefore, the pH range for each pressure division shall be observed.
- 2) From the relation between the silica concentration in boiler water and that in steam, the silica concentration in boiler water should be maintained low so that the silica concentration in steam is SiO_2 : 0.02 mg/L or under.

b) Caustic treatment phosphate treatment

While the pH of boiler water is indirectly controlled through the acid consumption, and the acid consumption of boiler water is controlled for the purpose of preventing the scale deposition due to silica, it should also be controlled so that the upper limit is not exceeded in consideration of the following points.

- In the boiler of 3 MPa or under in normal operating pressure, when ion-exchanged water is used as makeup water, since the acid consumption of boiler water mainly derives from a water conditioner, it can be easily maintained low.
- In the boiler of over 3 MPa in normal operating pressure, when ion-exchanged water or water with at least water conditioning equivalent to this is used as makeup water, since the concentration of silica in boiler water is maintained at low, the control of acid consumption is excluded from control parameters because it is unnecessary to directly control the acid consumption as far as the pH of boiler water is controlled.

9 Boiler types and water treatment methods for boiler for power plant

The boiler types and general water treatment methods for boiler for power plant are as given in Table 11.

Table 11 Boiler types and general water treatment methods for boiler for power plant

Boiler type	Makeup water	Feed water treatment method	Boiler water treatment method
(Steam power plant method) Circulation boiler for power plant ^{a)}	Ion-exchanged water	All volatile treatment ^{b)} (Oxygenated treatment) ^{c)}	Phosphate treatment
			All volatile treatment ^{b)} (Oxygenated treatment, low-concentration sodium hydroxide treatment) ^{c)}
(Combined power generation) Heat recovery steam generator for power plant		All volatile treatment ^{b)}	Phosphate treatment
			All volatile treatment ^{b)} (Low-concentration sodium hydroxide treatment) ^{c)}
(Steam power plant method) Once-through boiler for power plant		All volatile treatment ^{b)} Oxygenated treatment	
Note ^{a)} For the boilers of 15 MPa or under in normal operating pressure, the water conditioning of feed water and boiler water of the relevant pressure division specified in Table 9 and Table 10 for the water tube boiler for industrial plant (when ion-exchanged water is used) shall apply.			
Note ^{b)} Three types for the all volatile matter treatment, Reducing type [AVT(R) : All-volatile Treatment (Reducing)], Low oxidizing type [AVT(LO) : All-volatile Treatment (Low Oxidizing)] and Oxidizing type [AVT(O) : All-volatile Treatment (Oxidizing)].			
Note ^{c)} There is no usage record in Japanese plants for the water treatment in parentheses; therefore, sufficient trial operation is necessary for practical application.			

10 Water conditioning for circulation boiler for power plant

10.1 Water conditioning for feed water

10.1.1 Control parameters and control values of water conditioning

The water conditioning for feed water for circulation boiler for power plant at normal operation shall be classified by the normal operating pressure, and shall be as given in Table 12.

In the boilers of 15 MPa or under in normal operating pressure, the water conditioning of the relevant pressure division of water conditioning for feed water for water tube boiler for industrial plant (when ion-exchanged water is used) shall apply.

Table 12 Control parameters and control values of water conditioning for feed water for circulation boiler for power plant

Division	Normal operating pressure MPa	Over 15 up to and incl. 20			
	Type of makeup water	Ion-exchanged water			
	Treatment method	All volatile treatment			Oxygenated treatment
	Reducing agent	yes	no		no
	Redox property	Reducing type [AVT(R)]	Low oxidizing type [AVT(LO)]	Oxidizing type [AVT(O)]	Oxidizing type (OT)
Feed water	pH (at 25 °C)	8.5 to 10.3 ^{a) b)}	8.5 to 10.3 ^{a) b)}	8.5 to 10.3 ^{a) b)}	8.0 to 10.3 ^{b)}
	Electrical conductivity after cation exchanger (at 25 °C)				
	mS/m (μS/cm)	0.05 max. (0.5 max.)	0.05 max. (0.5 max.)	0.02 max. (0.2 max.)	0.02 max. (0.2 max.)
	Dissolved oxygen O : μg/L	7 max. ^{c)}	7 max. ^{c)}	Over 7 up to and incl. 20	Over 20 up to and incl. 50
	Iron Fe : μg/L	20 max.	20 max.	10 max.	5 max.
	Copper Cu : μg/L	5 max.	5 max.	5 max.	5 max.
	Hydrazine N ₂ H ₄ : μg/L	10 min. ^{d)}	—	—	—
Note ^{a)} In the case of the total iron system units, the pH lower limit should be adjusted and controlled to 9.3 or over. Note ^{b)} When the tubing material of low-pressure feed water heater is made of copper alloy, the pH upper limit should be adjusted and controlled to 9.5 or under, when the high-pressure feed water heater is made of copper alloy, to 9.0 or under and when the condenser is made of copper alloy, to 9.6 or under. Note ^{c)} Determined as 7 μg/L or under based on the deaerator performance. Note ^{d)} Hydrazine reacts with equivalent amount of dissolved oxygen; therefore, the residual hydrazine value shall be controlled to be 10 μg/L or over at a boiler (economizer) inlet so that the dissolved oxygen shall be fully consumed during the time of water feed. When the concentration of dissolved oxygen after de-airing exceeds O : 7 μg/L, a further likelihood should be established and the lower limit value should be controlled so that the hydrazine concentration of feed water is larger than twice the concentration of dissolved oxygen after de-airing.					

10.1.2 Notes on water conditioning

In terms of the water conditioning for feed water for circulation boiler for power plant, the following should be noted.

a) **All volatile treatment (reducing type) [AVT(R)] and all volatile treatment (low oxidizing type) [AVT(LO)]**

- 1) The feed water pH should be maintained slightly high as the countermeasure for FAC.
- 2) Since iron brought in the boiler should be reduced as much as possible, the concentration of iron, Fe : 10 μg/L or under should be maintained.

- 3) In the case of AVT(R), the hydrazine concentration shall be the lower limit value necessary for water feeding at the inlet of boiler (if economiser is used, at the inlet of economiser). The injection amount of hydrazine should be adjusted so that this lower limit value is maintained. However, in recent years, there are also plants in which the concentration of dissolved oxygen at an inlet of deaerator can be maintained at 1 µg/L or under owing to the improvement in performance of a condenser, even if the injection of hydrazine is suspended at normal operation, and the concentration reduction of hydrazine is practically possible.
- 4) In the case of AVT(R), the environment of feed water surely becomes reductive by injecting hydrazine, and the control value of concentration of dissolved oxygen shall be O : 7 µg/L or under, which is the performance assurance value of a deaerator.
- 5) Since the nozzle of steam desuperheater spray water is often clogged due to the suspension of the injection of reducing agent (hydrazine), in such a case, return to AVT(R) is preferable.
- 6) Since the circulation boiler using the treatment method of AVT(LO) has not been practically introduced in Japan, in the case of the introduction, the iron concentration of the whole system should be monitored.

b) **All volatile treatment (oxidizing type) [AVT(O)]**

- 1) The feed water pH should be maintained slightly high as the countermeasure for corrosion prevention.
- 2) Since the nozzle of steam desuperheater spray water is often clogged due to the suspension of the injection of reducing agent (hydrazine), in such a case, return to AVT(R) is preferable.
- 3) The circulation boiler using the treatment method of AVT(O) has not been practically introduced in Japan; therefore, in the case of the introduction, the iron concentration of the whole system should be monitored.
- 4) When AVT(O) is adopted in a plant in which copper material is used, care should be especially taken for copper elution. When the control value of copper specified in Table 12 cannot be kept, or when faults such as corrosion are detected at the time of inspection etc. of the part in which copper material is used, change to AVT(R) or AVT(LO) is preferable.

c) **Oxygenated treatment** In the circulation boilers for power plant of over 10 MPa in normal operating pressure, the introduction of oxygenated treatment by securing the high-purity water conditioning through the condensate demineralizer installation is possible; however no circulation boiler for power plant is practically introduced in Japan. When the oxygenated treatment is introduced, the following should be noted.

- 1) In the plants in which iron elution is large in the drain system to which oxygen is not sufficiently supplied, the lower limit value of feed water pH control should be raised. In some plants, the pH is raised to about 9.4. However, care should be

taken that the corrosion due to ammonia in a high pH area occurs in the plant where copper alloy is used for the system according to the increase of the regeneration frequency of a condensate demineralizer. In addition, the ammonia injection to a steam extraction system, adoption of stainless steel etc. should be considered. For the regeneration frequency of a condensate demineralizer, the ammonia type ($\text{NH}_4\text{-OH}$ type) operation is adopted, the regeneration frequency can be decreased by increasing the yield and it is practically applied also in some plants; however, care should be taken for the leakage of sodium ion of which the resin selectivity is lower than that of ammonium ion. Concerning the sodium ion leakage derived from sodium hydroxide as a regenerant, for the electrical conductivity after cation exchanger, sodium ions are replaced by hydrogen ions by cation-exchange resin, one equivalent of these hydrogen ions reacts to one equivalent of hydroxide ions producing water (H_2O), and the electrical conductivity due to these ions disappears; therefore, it is impossible to monitor and the leakage situation should be checked by performing the measurement of sodium.

- 2) The electrical conductivity after cation exchanger, since the iron oxide film formed on the surface of steel products of boiler is broken by the increase in anions such as chloride ions in water, should be 0.01 mS/m or under that is lower than the conductivity equivalent to those total amounts.
- 3) When the steady operation continues by forming the protective film, since even if the concentration of dissolved oxygen is slightly low, the protective film can be retained, the value of dissolved oxygen suitable for the concentration of iron, copper etc. in feed water that becomes the minimum in the range of a control value should be set.
- 4) Since the iron concentration of each system decreases with the reduction of solubility of iron oxides, considering that the concentration of iron in feed water can be suppressed as compared with the conventional water treatment, the concentration of iron should be maintained at $\text{Fe} : 2 \mu\text{g/L}$ or under as the practical control.

10.2 Water conditioning for boiler water

10.2.1 Control parameters and control values of water conditioning

The water conditioning for boiler water for circulation boiler for power plant at normal operation shall be classified by the normal operating pressure, and shall be as given in Table 13.

In the boilers of 15 MPa or under in normal operating pressure, the water conditioning of the relevant pressure division of water conditioning for boiler water for water tube boiler for industrial plant (when ion-exchanged water is used) shall apply.

Table 13 Control parameters and control values of water conditioning for boiler water for circulation boiler for power plant

Division	Normal operating pressure MPa	Over 15 up to and incl. 20					
	Type of makeup water	Ion-exchanged water					
	Treatment method	Phosphate treatment	All volatile treatment			Oxygenated treatment	Low-concentration sodium hydroxide treatment ^{a)}
	Reducing agent		yes	no		Oxidizing type (OT)	
	Redox property		Reducing type [AVT(R)]	Low oxidizing type [AVT(LO)]	Oxidizing type [AVT(O)]		
Boiler water	pH (at 25 °C)	8.5 to 9.8	8.5 to 10.0	8.5 to 10.0	8.5 to 10.0	8.0 to 10.0 ^{b)}	9.1 to 9.5
	Electrical conductivity (at 25 °C) mS/m (μS/cm)	6 max. (60 max.)	— (—)	— (—)	— (—)	— (—)	1 max. (10 max.)
	Electrical conductivity after cation exchanger (at 25 °C) mS/m (μS/cm)	— (—)	2 max. (20 max.)	2 max. (20 max.)	0.3 max. (3 max.)	0.3 max. (3 max.)	2 max. (20 max.)
	Sodium Na : mg/L	—	—	—	—	—	0.9 max.
	Chloride Cl : mg/L ion	2 max.	1 max.	1 max.	0.1 max.	0.05 max. ^{c)}	1 max.
	Phosphate PO ₄ : mg/L ion	3 max.	^{d)}	^{d)}	—	—	—
	Silica SiO ₂ : mg/L	0.2 max.	0.2 max.	0.2 max.	0.2 max.	0.2 max.	0.2 max.
	Note ^{a)} The division of normal operating pressure for a boiler in which low-concentration sodium hydroxide treatment is applied shall be 16.5 MPa or under.						
Note ^{b)} For the pH adjustment, volatile substance (ammonia or volatile amine) shall be used.							
Note ^{c)} Tested in accordance with Clause 5 and Note ⁽⁶⁾ to this, specified in JIS K 0556 .							
Note ^{d)} In the case where components that lower the amounts of calcium and magnesium and the pH value are contaminated due to the leakage etc. of seawater from a condenser, phosphate or sodium hydroxide which is required for the emergency treatment sufficient for the amount of components that contaminate and lower the amount of calcium and magnesium and the pH value shall be added.							

10.2.2 Notes on water conditioning

In terms of the water conditioning for boiler water for circulation boiler for power plant, the following should be noted.

- Common matter** From the relation between the silica concentration in boiler water and that in steam, the silica concentration in boiler water should be maintained low so that the silica concentration in steam is SiO₂ : 0.02 mg/L or under.
- All volatile treatment (reducing type) [AVT(R)] and all volatile treatment (low ox-**

dizing type) [AVT(LO)] The pH of boiler water should be maintained slightly high as the countermeasure for corrosion prevention. Also, the pH of boiler water by all volatile treatment is maintained only by volatile bases such as ammonium ion that remains in boiler water. For this reason, if ammonia volatilizes to the steam side, the pH of boiler water decreases, and the difference of pH between feed water and boiler water is not constant according to the operating condition and other influences of a boiler; therefore, the pH of boiler water should be controlled aiming at the same range as the pH of feed water.

- c) **All volatile treatment (oxidizing type) [AVT(O)]** The pH of boiler water should be maintained slightly high as the countermeasure for corrosion prevention.
- d) **Oxygenated treatment** The electrical conductivity after cation exchanger, since the iron oxide film formed on the surface of steel products of boiler is broken by the increase in anions such as chloride ions in water, should be 0.01 mS/m or under, which is lower than the electrical conductivity equivalent to those total amounts.

11 Water conditioning for heat recovery steam generator for power plant

11.1 General

The water conditioning for general heat recovery steam generator for power plant which consists of multi-pressure drums is specified. In the case of the heat recovery steam generator for power plant including the element of an once-through boiler in which drums are not installed in the high-pressure system and so forth, the water conditioning for the once-through boiler in Table 16 shall apply only to the parts of that element concerned.

11.2 Water conditioning for feed water

11.2.1 Control parameters and control values of water conditioning

In the heat recovery steam generator for power plant, ion-exchanged water is used as makeup water, and the same water shall be fed to the multi-pressure drums. The water conditioning for feed water for heat recovery steam generator for power plant at normal operation shall be controlled using the division of the highest normal operating pressure among the constituent multi-pressure drums as given in Table 14.

11.2.2 Notes on water conditioning

In terms of the water conditioning for feed water for heat recovery steam generator for power plant, the following should be noted.

- a) **All volatile treatment (reducing type) [AVT(R)]**
 - 1) When all volatile treatment is applied to boiler water, the pH of feed water shall be the value at which the pH of boiler water can be maintained, and the pH of feed water when the copper material is not used should be maintained slightly high as the countermeasure for FAC.
 - 2) Since the hydrazine concentration is the lower limit value necessary for water feeding at the inlet of boiler (if economiser is used, at the inlet of economiser), the

injection amount of hydrazine should be adjusted so that this lower limit value is maintained. However, there are also plants in which the concentration of dissolved oxygen at an inlet of deaerator can be maintained at $O : 1 \mu\text{g/L}$ or under owing to the improvement in performance of a condenser in recent years, even if the injection of hydrazine is suspended at normal operation, and the concentration reduction of hydrazine is practically possible.

- 3) Since the environment of feed water surely becomes reductive by injecting hydrazine, the control value of concentration of dissolved oxygen shall be $O : 7 \mu\text{g/L}$ or under, which is the performance assurance value of a deaerator.
- 4) The iron concentration in the case of the normal operating pressure of 15 MPa or under should be controlled at $\text{Fe} : 20 \mu\text{g/L}$ or under, and at $\text{Fe} : 10 \mu\text{g/L}$ or under in the case of over 15 MPa.

b) All volatile treatment (low oxidizing type) [AVT(LO)]

- 1) The feed water pH when a copper material is not used should be maintained slightly high as the countermeasure for FAC.
- 2) The iron concentration in the case of the normal operating pressure of 15 MPa or under should be controlled at $\text{Fe} : 20 \mu\text{g/L}$ or under, and at $\text{Fe} : 10 \mu\text{g/L}$ or under in the case of over 15 MPa.
- 3) Since the nozzle of steam desuperheater spray water is often clogged due to the suspension of the injection of reducing agent (hydrazine), in such a case, return to AVT(R) is preferable.

c) All volatile treatment (oxidizing type) [AVT(O)]

- 1) The feed water pH should be maintained slightly high as the countermeasure for corrosion prevention.
- 2) Since the nozzle of steam desuperheater spray water is often clogged due to the suspension of the injection of reducing agent (hydrazine), in such a case, return to AVT(R) is preferable.
- 3) When AVT(O) is adopted in a plant in which copper material is used, care should be especially taken for copper elution. When the control value of copper specified in Table 14 cannot be kept, or when faults such as corrosion are detected at the time of inspection etc. of the part in which copper material is used, change to AVT(R) or AVT(LO) is preferable.

Table 14 Control parameters and control values of water conditioning for feed water for heat recovery steam generator for power plant

Division	Normal operating pressure MPa	10 or under			Over 10 up to and incl. 15			Over 15 up to and incl. 20		
	Type of makeup water	Ion-exchanged water								
	Treatment method	All volatile treatment			All volatile treatment			All volatile treatment		
	Reducing agent	yes	no		yes	no		yes	no	
	Redox property	Reducing type [AVT(R)]	Low oxidiz- ing type [AVT(LO)]	Oxidizing type [AVT(O)]	Reducing type [AVT(R)]	Low oxidiz- ing type [AVT(LO)]	Oxidizing type [AVT(O)]	Reducing type [AVT(R)]	Low oxidiz- ing type [AVT(LO)]	Oxidizing type [AVT(O)]
Feed water	pH (at 25 °C) ^{a) b)}	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3	9.0 to 10.3
	Electrical conductivity af- ter cation exchanger (at 25 °C)									
	mS/m (μS/cm)	0.05 max. (0.5 max.)	0.05 max. (0.5 max.)	0.02 max. (0.2 max.)	0.05 max. (0.5 max.)	0.05 max. (0.5 max.)	0.02 max. (0.2 max.)	0.05 max. (0.5 max.)	0.05 max. (0.5 max.)	0.02 max. (0.2 max.)
	Dissolved O : μg/L oxygen	7 max. ^{c)}	7 max. ^{c)}	Over 7 up to and incl. 20	7 max. ^{c)}	7 max. ^{c)}	Over 7 up to and incl. 20	7 max. ^{c)}	7 max. ^{c)}	Over 7 up to and incl. 20
	Iron Fe : μg/L	30 max.	30 max.	20 max.	30 max.	30 max.	10 max.	20 max.	20 max.	5 max.
	Copper Cu : μg/L	20 max.	20 max.	10 max.	10 max.	10 max.	10 max.	5 max.	5 max.	5 max.
	Hydrazine N ₂ H ₄ : μg/L	10 min. ^{d)}	—	—	10 min. ^{d)}	—	—	10 min. ^{d)}	—	—
Note ^{a)} For the total iron system units, the pH lower limit should be adjusted and controlled to 9.3 or over, and for the condenser made of copper alloy, the pH upper limit should be adjusted and controlled to 9.6.										
Note ^{b)} When all volatile treatment is adopted for boiler water, the feed water pH shall be controlled so that the boiler water pH can be maintained within the control value.										
Note ^{c)} Determined as 7 μg/L or under based on the deaerator performance.										
Note ^{d)} Hydrazine reacts with equivalent amount of dissolved oxygen; therefore, the residual hydrazine value shall be controlled to be 10 μg/L or over at a boiler (economizer) inlet so that the dissolved oxygen shall be fully consumed during the time of water feed. For a combined cycle plant on which a deaerator is not installed, when the concentration of dissolved oxygen after de-airing exceeds O : 7 μg/L, a further likelihood should be established and the lower limit value should be controlled so that the hydrazine concentration of feed water is larger than twice the concentration of dissolved oxygen after de-airing.										

11.3 Water conditioning for boiler water

11.3.1 Control parameters and control values of water conditioning

In the heat recovery steam generator for power plant, ion-exchanged water is used as makeup water, and the same water shall be fed to the multi-pressure drums. The water conditioning for boiler water at normal operation of heat recovery steam generator for power plant shall be as given in Table 15, and shall be controlled based on the control value of water conditioning according to the normal operating pressure of the constituent drum.

11.3.2 Notes on water conditioning

In terms of the common matters for water conditioning for boiler water for heat recovery steam generator for power plant, the following should be noted.

- a) Especially, the temperature of a low-pressure drum enters the temperature range in which FAC may occur; therefore, the pH of boiler water should be maintained at a higher value for the FAC prevention measures.
- b) From the relation between the silica concentration in boiler water and that in steam, the silica concentration in boiler water should be maintained low so that the silica concentration in steam is SiO_2 : 0.02 mg/L or under.