



Exploration & Production

GENERAL SPECIFICATION

CORROSION

GS EP COR 003

Boiler water treatment

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1. Scope

This General Specification defines minimal requirements relative to boiler water treatment to minimize the risks of corrosion and fouling, reduce cleaning, and thus increase the efficiency of boilers and steam-using equipment.

Two types of natural circulation boilers are considered in this document:

- Water-tube boilers
- Fire-tube boilers.

Steam generation water treatment is a sophisticated water chemistry area and requires an understanding of the fundamentals of boiler water chemistry.

The requirements given in this document apply to boilers operating continuously. This specification does not cover conditions relative to particular operations such as start up, shutdown or fast fluctuation steam production.

This specification doesn't cover:

- Boilers with copper tubing or other "exotic" materials
- Electric boilers
- Recovery steam generators of specific design.

The particular case of pressurized hot water loop is also considered in this document.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
NF EN 12952-12	Water-tube Boilers And Auxiliary Installations - Part 12: Requirements For Boiler Feedwater And Boiler Water Quality
NF EN 12953-10	
	Requirements for feedwater and boiler water quality.

Professional Documents

Reference	Title
	Consensus on operating practices for the control of feedwater and boiler water chemistry in modern industrial boilers. The American Society of Mechanical Engineers - 1994



Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS EP COR 002	Corrosion control on production facilities: Field operations

3. Definitions

Direct conductivity	Conductivity directly measured in water
Cationic conductivity	Water conductivity measured downstream a strong acid ion exchange resin
Makeup water	Water which compensates water and steam losses of the circuit
Demineralised water	Water with a cationic conductivity < 0.2 µS/cm and silica (SiO ₂) < 0.02 mg/l
T.D.S.	Total dissolved solids

4. Water treatment

An appropriate on-site treatment of the water is **always needed**. This treatment has two main objectives:

- The prevention of corrosion and fouling of the various elements of the boiler (economizer, vaporization tubes, superheater)
- The production of vapor of suitable quality following the main criteria below:
 - Silica concentration < 0.02 ppm
 - pH of condensates > 8.5 and < 9.2.

Whenever possible, a **pretreatment of the water external to the circuit must be privileged**.

5. Chemistry of boiler water

The philosophies of treatment to be implemented are (see Figure 4 in appendix):

- “Controlled phosphate” treatment for operating pressures < 40 bars
- “Low or very low phosphate” treatment for $40 < \text{operating pressures} < 110$ bars
- “All volatile” treatment for operating pressures > 110 bars.

6. Steam quality

For any boiler, the quality of the steam to be produced is directly dictated by the users. The criteria of purity of the vapor reflect the ultimate usage that is made: production of electricity (turbines), superheated steam, etc.

The quality of the vapor is directly related to the quality of the water and to the design of the boiler (drum, deheater, etc.).

7. Water chemistry

7.1 Dissolved oxygen

The recommended concentrations of oxygen in feedwater are given in appendix. In any case, an oxygen scavenger injection in the deaerated drum is required.

Measurement of dissolved oxygen can be carried out by means of a standardized method (**ISO 5814**) or by polarographic analysis.

Particular case of closed circuit hot water heating loops: Hot water loops are generally treated using an oxygen scavenger (sulfite) only.

7.2 Iron, copper, hardness and suspended solids

The suspended solids content in the feedwater must be as low as possible and it is important to take into account the high sensibility of boilers to fouling.

It is thus necessary to limit the concentration in products susceptible to precipitate by an pretreatment carried out before the introduction of the fluids in the circuit.

Specific circuit treatments (based on dispersing or chelating agents) can tolerate a higher concentration of iron, copper and hardness in boilers. In normal conditions, water treatment does not need dispersing agents. In certain cases however, the addition of dispersing or chelating agents may be necessary. In that case, a dedicated study shall be carried out and these specific treatments shall be qualified prior to their use.

Verification of the treatment efficiency may include (when fuel is used as combustible) the extraction of a sample of tube in the zone with high thermal transfer during inspection of the equipment to determine the on-surface mass of deposit. When the extraction of tubes is inappropriate, specific non-destructive methods of inspection can be used.

Recommended cleaning frequencies are generally:

- Once per 10 to 15 years for "low pressure" boilers
- Once per 5 to 10 years for "medium pressure" boilers
- Once per 5 years for "high pressure" boilers.

7.3 pH

A pH > 8.5 is recommended for the feedwater to protect preheaters against corrosion. This value is consistent with the water treatment of boiler. At high pressures, pH adjustment shall be made by means of alkaline volatile agents only.

7.4 Organic compounds

Organic species can be present in boilers' water with is extremely variable degrees. They can result from natural water makeup or from process contamination (return of condensates). It is thus practically impossible to define a best practice for all situations. The organic species susceptible to pollute condensates are however easily identified (hydrocarbons, organic salts, etc.).

Organic compounds could cause severe damages in generators as well as in turbines and facilitate foaming.

7.5 Silica

The limits for silica contents in boiler waters are given in appendix (Figures 3 and 4).

7.6 Alkalinity

The P- and M- alkalinity are selected as basic control criteria because they correlate well to the pH, corrosion inhibition, and foaming tendency.

7.7 Conductivity

The recommended values are presented in appendix (Figures 1 and 2).

8. Condensates

The quality of the recycled condensates shall be controlled.

At least three parameters shall be controlled: pH, cationic conductivity and a specific parameter related to the process (e.g. visual control if risk of pollution by hydrocarbons, evaluation of the quantity of Cl⁻, etc.).

9. Analytical control

The contents and frequencies of water analyses relative to boilers is presented in tables 1 to 3. Water samples shall be taken at representative locations of the circuit.

- Feedwater → downstream the admittance valve
- Boiler water → drain
- Makeup water → upstream and downstream the external water treatment
- Condensate → before mixing with treated makeup water.

The following parameters shall be controlled:

Table 1 - Content and frequency of feedwater analytical controls

Parameter	Feedwater		
Pressure (bar)	5 - 20	20 - 40	40 - 100
pH	Continuous ⁽¹⁾	Continuous ⁽¹⁾	Continuous ⁽¹⁾
Direct conduct. at 25°C	Continuous ⁽¹⁾	Continuous ⁽¹⁾	Continuous ⁽¹⁾
H(Ca+Mg)	once/shift	once/shift	once/shift
HCa	once/month	once/month	once/month
SiO ₂	once/week	once/week	Continuous
O ₂	once/quarter	once/quarter	once/quarter

(1) Continuous or once/shift

Table 2 - Content and frequency of condensate analytical controls

Parameter	Condensate return		
Pressure (bar)	5 - 20	20 - 40	40 - 100
pH	once/day	Continuous ⁽²⁾	Continuous ⁽²⁾
Cationic conduct. at 25°C	once/day	Continuous ⁽²⁾	Continuous ⁽²⁾
Specific control ⁽¹⁾	once/day	once/shift	once/shift

(1) Specific control connected to the process (visual control, COT, etc.)

(2) Continuous or once/shift

Table 3 - Content and frequency of boiler water analytical controls⁽¹⁾

Parameter	Boiler water		
Pressure (bar)	5 - 20	20 - 40	40 - 100
pH	once/shift	Continuous ⁽²⁾	Continuous ⁽²⁾
Conduct. at 25°C	once/shift	Continuous ⁽²⁾	Continuous ⁽²⁾
TA/TAC	once/shift	once/day	once/shift
SiO ₂	once/day	once/day	Continuous ⁽²⁾
PO ₄ ⁽³⁾	once/day	once/shift	once/shift
Réducteur d'O ₂	once/week	once/day	once/day
Fe	once/month	once/week	once/week
Cu	once/month	once/week	once/week
TAOH	2TA - TAC	2TA - TAC	2TA - TAC

(1) For P > 100 bars, analytical control program to be defined specifically

(2) Continuous or once/shift

(3) If phosphate based treatment

10. Hot water loop

A typical water treatment for closed pressurized hot water loops (< 20 bars) is presented in appendix (Table 5). In order to be efficient, the loop shall be closed (monthly makeup water < 5% the total volume).

Appendix 1

Table 4 - Feedwater and boiler water quality for natural circulation steam

	5-20 bars	20-40 bars	50-60 bars	60-100 bars
Feedwater	Soft	Soft/Demin.	Demineralized	Demin. + fin.
O ₂ dissolved (mg/l) ⁽²⁾	< 0.04	< 0.02	< 0.02	< 0.02
Fe total (mg/l)	< 0.2	< 0.2	< 0.05	< 0.02
Cu total (mg/l)	< 0.03	< 0.03	< 0.02	< 0.01
TH (°f)	< 0.5	< 0.2	< 0.05	ND
PH	8.5 - 10.0	8.5 - 10.0	8.5 - 10.0	8.8 - 9.5
COT (mg/l)	< 5	< 3	< 0.5	< 0.2
Boiler water				
pH	10.5 to 12	10.5 to 12	10 to 11	9.5 to 10.5
TAC (°f)	< 100	< 60	< 15	< 5
TA (°f)	TA = 0.7 TAC	TA = 0.7/0.5 TAC	TA = 0.5 TAC	TA = 0.5 TAC
SiO ₂ (mg/l)	see Figure 3	see Figure 3	see Figure 3	see Figure 4
NaOH free (mg/l)	< 100	< 50	< 20	< 5
PO ₄ ³⁻ (mg/l)	30 to 100	20 to 80	10 to 60	5 to 20
TDS	see Figures 1 & 2	see Figures 1 & 2	see Figures 1 & 2	see Figure 2

(1) For high heat flux (> 230 kW/m²), values of the upper pressure zone shall be used.

(2) After primary deaeration and before O₂ scavenger injection

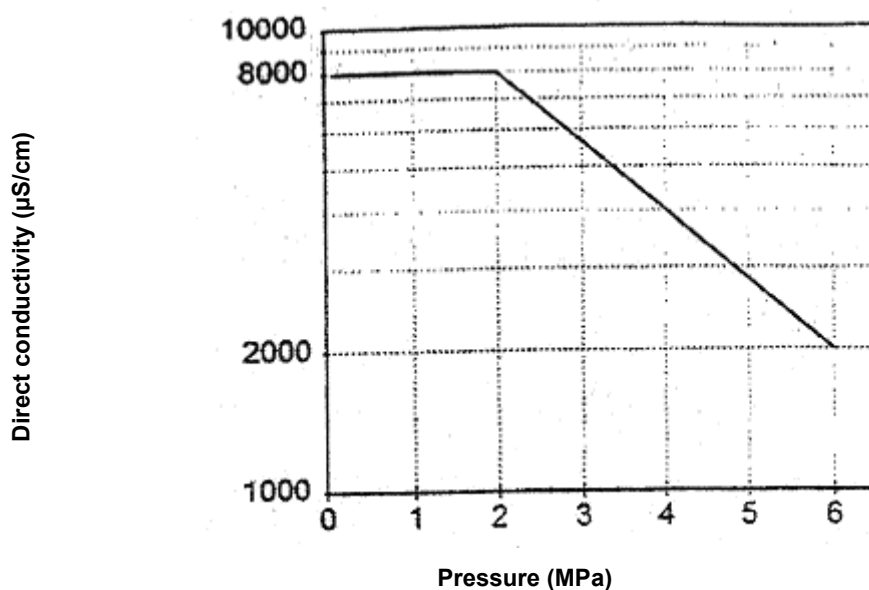


Figure 1 - Direct conductivity limit in boiler water; direct conductivity of feed water of feed > 30 µS/cm

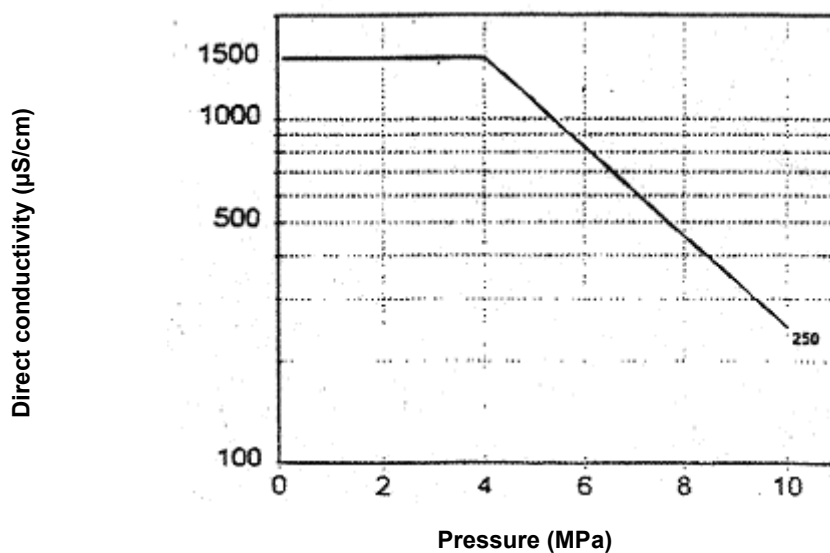


Figure 2 - Direct conductivity limit in the boiler water; direct conductivity of feed water of feed ≤ 30 µS/cm

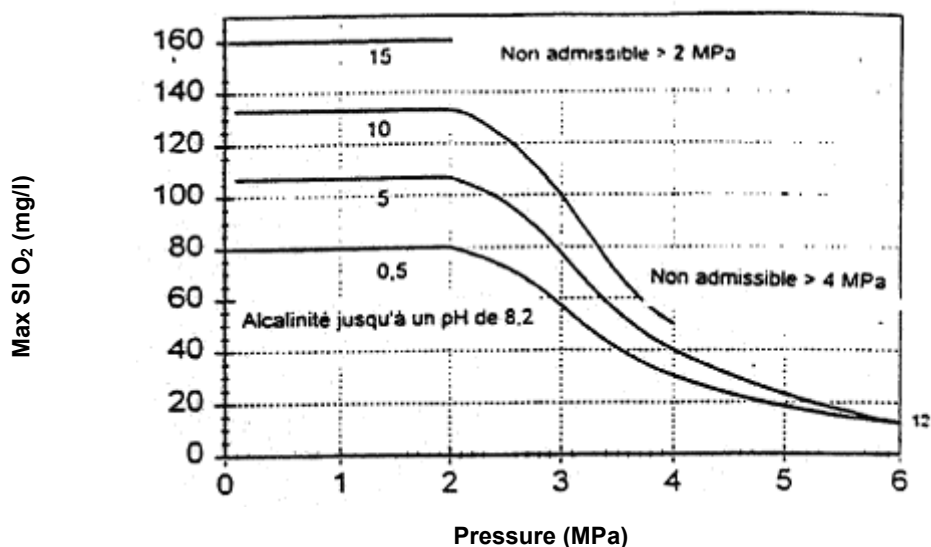


Figure 3 - Maximal (SiO_2) concentration in boiler water (between 0.05 and 6 MPa)

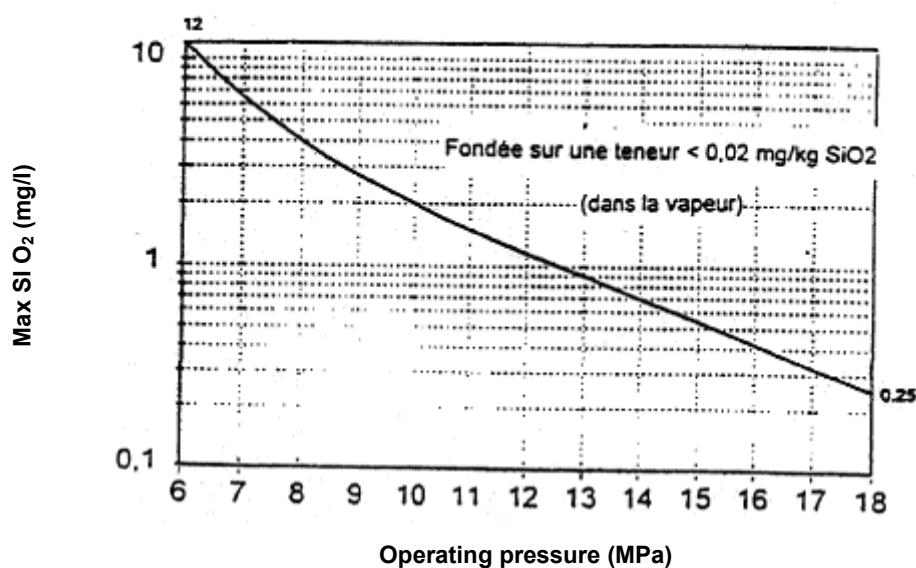


Figure 4 - Maximal (SiO_2) concentration in boiler water (between 6 and 18 MPa)



Table 5 - Hot water treatment for pressurized closed loops

Feedwater: Hardness < 10 mg/l (as CaCO₃)
[Cl⁻] < 25 ppm
TDS < 250 mg/l

Operating conditions: T < 150°C
Closed loop

Blanketing gas: Nitrogen (O₂ < 2%)

Typical conditioning product	Role	Injection mode	Typical dosage	Periodicity	Target monitoring values	Comments
Phosphate	pH control	Initial + top up in case of pH decrease	Calculated to reach an in situ pH > 9.5	Batch	pH > 9.5	No copper alloys
Sulfite	O ₂ scavenger	Initial + top up in case of [SO ₃ ²⁻] decrease	Calculated to reach an in situ excess sulfite concentration > 10 mg/l	Batch	[SO ₃ ²⁻] > 10 mg/l	