APPENDIX C

BOILER FEEDWATER CHARACTERISTICS

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Chemistry of Water Steam Cycles with Drum Type HRSG

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1. SCOPE OF APPLICATION

The specification is applicable for combined cycle power plants using heat recovery steam generators (HRSG) which consist of drum type evaporators.

The steam is superheated and used to drive a condensing steam turbine (ST). The steam at the outlet of the HP steam turbine ("cold reheat steam") is combined with the IP steam and reheated to drive the IP steam turbine. The condensing steam turbine may take steam production from multiple GT/HRSG units. The steam at the ST exhaust is condensed in a water or air cooled condenser.

The limits of operation and more detailed information are described in the general remarks in Chapter 9.

2. DEFINITIONS

Except where defined otherwise in the footnote of a table, the following definitions apply:

N **Normal value.** Values are consistent with long-term system reliability. A safety margin has been provided to avoid concentration of contaminants at surfaces.

A1 **Action Level 1.** There is a potential for the accumulation of contaminants and corrosion. Return to normal values within 1 week. Maximum exposure is 336 cumulative hours per year, excluding start-up conditions.

A2 **Action Level 2.** The accumulation of impurities and corrosion will occur. Return to normal levels within 24 hours. Maximum exposure is 48 cumulative hours per year, excluding start-up conditions.

S **Immediate Shutdown.** Immediate shutdown of the concerned system is required to avoid damage.

An=Analytical supervision. c=continuous (continuous instruments for one dedicated sample point may be shared with other sample points), m=manual (grab sample).

3. DEMINERALISED WATER (MAKE-UP FOR WATER/STEAM CYCLE)

Table 3.1: Purity requirements of demineralized water (at inlet to WSC, unless noted differently)

Parameter	Unit	N	A1 a)	A2	S b)	An
Specific conductivity c)	µS/cm	< 0.10	0.1 - <0.2	0.2 - <0.5	≥ 0.5	c
Degassed cation conductivity	µS/cm	< 0.15	0.15 - <0.3	0.3 - <0.5	≥ 0.5	c
Silica as SiO_2	ppb	< 10	10 - <20	20 - <50	≥ 50	c
Sodium as Na	ppb	< 5	-	-	-	c
Iron as Fe	ppb	< 20	-	-	-	m
Copper as Cu	ppb	< 3	-	-	-	m
TOC	ppb	< 100	-	-	-	c

a) A1 indicates that there is a problem. Action shall be taken to bring the values to normal. Operation can presume as long as feedwater / steam specification is not jeopardized.

b) Do not put this water in the demineralized water storage tank or into the water steam cycle

c) at demineralizer plant outlet (on-site demineralization plant or water from vendor)

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4. CONDENSATE

The condensate is the common condensed steam turbine exhaust and make-up water. The condensate is extracted from the hotwell and discharged with condensate pumps. Its required purity is shown in table 4.1.

Table 4.1: Condensate purity after condensate pumps

Parameter	Unit	N	A1	A2	S	An
Specific conductivity	µS/cm	3.5-11	-	-	-	c
Conductivity after cation exch.:						
- Water cooled condenser	µS/cm	< 0.30	0.3 - <0.6	0.6 - <1.3	≥1.3	c
- Air cooled condenser	µS/cm	< 0.40	0.4 - <0.7	0.7 - <1.3	≥1.3	c
Degassed cation conductivity	µS/cm	< 0.20	0.2 - <0.5	0.5 - <1.0	≥ 1.0	c
pH-value		9.1-9.6	-	-	-	m
Oxygen	ppb	< 10	-	-	-	m
Silica as SiO_2	ppb	< 20	-	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m

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5. WATER CHEMISTRY OF HRSG WHERE IP/HP FEEDWATER IS TAKEN FROM LP DRUM

5.1. LP Feedwater (at HRSG Inlet)

Parameter	Unit	N	A1	A2	S	An
Specific conductivity	µS/cm	5-18	-	-	-	c
Conductivity after cation exch.:						
- Water cooled condenser	µS/cm	< 0.30	0.3- <0.6	0.6- <1.3	≥ 1.3	c
- Air cooled condenser	µS/cm	< 0.40	0.4- <0.7	0.7- <1.3	≥ 1.3	c
Degassed Cation Conductivity	µS/cm	< 0.20	0.2- <0.5	0.5- <1.0	≥ 1.0	c
pH-value		9.3-9.8	<9.3, >9.8	<9.0, >10	≤7, ≥11	c
Sodium as Na	ppb	< 5	5 - <10	10 - <20	≥ 20	c
Silica as SiO_2	ppb	< 20	20 - <50	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m
Oxygen	ppb	< 10	≥ 100	-	-	c

5.2. IP and HP Feedwater (after LP drum)

Parameter	Unit	N	A1	A2	S	An
Specific conductivity	µS/cm	3.5-11	-	-	-	c
Conductivity after cation exch.						
- Water cooled condenser	µS/cm	< 0.30	0.3- <0.6	0.6- <1.3	≥ 1.3	c
- Air cooled condenser	µS/cm	< 0.40	0.4- <0.7	0.7- <1.3	≥ 1.3	c
Degassed Cation Conductivity	µS/cm	< 0.20	0.2- <0.5	0.5- <1.0	≥ 1.0	c
pH-value		9.1-9.6	≠ N [a)]	-	≤7, ≥11	c
Sodium as Na	ppb	< 5	5 - <10	10 - <20	≥ 20	c
Silica as SiO_2	ppb	< 20	20 - <50	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m
Oxygen	ppb	< 10	≥ 20	-	-	c

[a)] if outside Normal Value N

5.3. LP Drum Water

All Volatile Treatment

Parameter	Unit	N	A1	A2	S	An
Sodium as Na	ppb	< 5	5 - <10	10 - <20	-	m
Silica as SiO_2	ppb	< 20	20 - <50	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m

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5.4. IP /HP Drum Water

Parameter		Unit				An
Operating Pressure			≤10 MPa	10 - ≤16 MPa	>16 MPa	
Treatment			Phosphate	Phosphate	All Volatile	
Specific conductivity	N	µS/cm	< 40 a)	< 20 a)	3.5 - 11	c
	AL1		40 - <80	20 - <40	-	
	AL2		≥ 80	≥ 40	-	
	S		-	-	-	
Cation conductivity	N	µS/cm	-	-	< 1.0	c d)
	A1		-	-	1.0 – <2.5	
	A2		-	-	2.5 – <5.0	
	S		-	-	-	
pH	N		9.3 - 10.0 b)	9.2 - 9.8 b)	9.1 – 9.6	c
	A1		<9.3 / >10.0	<9.2 / >9.8	< 9	
	A2		-	-	-	
	S		< 8	< 8	< 8	
Phosphate as PO_4	N	ppm	2 - 6	1 - 3	-	m
Silica as SiO_2	N	ppm	c)	c)	c)	m

a) estimated value must be compatible with steam purity

b) within limits of Na/PO_4 :

≥ 3.0

≤ Na_3PO_4 + 1ppm NaOH

- min 0.1 pH above feedwater pH

c) see Table Chapter 7

d) for all volatile treatment (AVT) only

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6. WATER CHEMISTRY OF HRSG WHERE ALL FEEDWATER IS FED DIRECTLY FROM CONDENSATE SYSTEM (BOOSTER PUMP) OR FEEDWATER TANK

6.1. Feedwater (at HRSG Inlet)

Parameter	Unit	N	A1	A2	S	An
Specific conductivity	µS/cm	3.5-11	-	-	-	c
Conductivity after cation exch.						
- Water cooled condenser	µS/cm	< 0.30	0.3- <0.6	0.6- <1.3	≥ 1.3	c
- Air cooled condenser	µS/cm	< 0.40	0.4- <0.7	0.7- <1.3	≥ 1.3	c
Degassed Cation Conductivity	µS/cm	< 0.20	0.2- <0.5	0.5- <1.0	≥ 1.0	c
pH-value		9.1-9.6	≠ N [a)]	-	≤7, ≥11	c
Sodium as Na	ppb	< 5	5 - <10	10 - <20	≥ 20	c
Silica as SiO_2	ppb	< 20	20 - <50	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m
Oxygen	ppb	< 10	≥ 20	-	-	c

[a)] if outside Normal Value N

6.2. Drum Water

Parameter		Unit				An
Operating Pressure			≤10 MPa	10 - ≤16 MPa	>16 MPa	
Treatment			Phosphate	Phosphate	All Volatile	
Specific conductivity	N	µS/cm	< 40 [a)]	< 20 [a)]	3.5 - 11	c
	A1		40 - <80	20 - <40	-	
	A2		≥ 80	≥ 40	-	
	S		-	-	-	
Cation conductivity	N	µS/cm	-	-	< 1.0	c [d)]
	A1		-	-	1.0 – <2.5	
	A2		-	-	2.5 – <5.0	
	S		-	-	-	
pH	N		9.3 - 10.0 [b)]	9.2 - 9.8 [b)]	9.1 – 9.6	c
	A1		<9.3 / >10.0	<9.2 / >9.8	< 9.1	
	A2		-	-	-	
	S		< 8	< 8	< 8	
Phosphate as PO_4	N	ppm	2 - 6	1 - 3	-	m
Silica as SiO_2	N	ppm	[c)]	[c)]	[c)]	m

[a)] estimated value, must be compatible with steam purity
[b)] within limits of Na/PO_4 :
≥ 3.0
≤ Na_3PO_4 + 1ppm NaOH
- min 0.1 pH above feedwater pH
[c)] see Table Chapter 7
[d)] for all volatile treatment (AVT) only

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7. BOILER WATER CARRY-OVER AND NORMAL OPERATION LIMITS (N) FOR BOILER WATER SILICA

Drum pressure (MPa)	Carry-Over (%) [a]	SiO_2 (ppm)
≤ 6	≤ 0.1	≤ 7.5
7	≤ 0.1	≤ 4.8
8	≤ 0.1	≤ 3.4
9	≤ 0.1	≤ 2.5
10	≤ 0.1	≤ 2.0
11	≤ 0.1	≤ 1.6
12	≤ 0.1	≤1.2
13	≤ 0.2	≤ 0.9
14	≤ 0.2	≤ 0.6
15	≤ 0.2	≤ 0.4
16	≤ 0.2	≤ 0.2
17	≤ 0.33	≤ 0.1
18	≤ 0.33	≤ 0.1
19	≤ 0.33	≤ 0.1

[a] Carry-Over may be exceeded as long as steam purity is met

8. STEAM (SATURATED/SUPERHEATED)

Table 5.1 Steam purity requirements

Parameter	Unit	N	A1	A2	S	An
Specific conductivity	µS/cm	3.5-11 (7-28) [a]	-	-	-	m
Conductivity after cation exch:						
- Water cooled condenser	µS/cm	< 0.30	0.3 - <0.6	0.6 - <1.3	≥ 1.3	c
- Air cooled condenser	µS/cm	< 0.40	0.4 - <0.7	0.7 - <1.3	≥ 1.3	c
Degassed cation conductivity	µS/cm	< 0.20	0.2 - <0.5	0.5 - <1	≥ 1	c
pH-value		9.1-9.8 (9.4-10.0) [a]	-	-	-	m
Sodium as Na	ppb	< 5	5 - <10	10 - <20	≥ 20	c
Silica as SiO_2	ppb	< 20	20 - <50	-	-	m
Iron as Fe	ppb	< 20	-	-	-	m
Copper as Cu	ppb	< 3	-	-	-	m

a) The value in brackets refer to LP steam generated in an LP drum that is used for feedwater storage

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9. GENERAL REMARKS

9.1. Applicability

This is a general specification, valid for the plant type mentioned only. The criteria shall be reviewed for each specific application and at commissioning.

This specification is valid for normal plant operation. It is not applicable for commissioning (see 9.3) and the following operating period until final cleanliness of the water/steam cycle is achieved.

All conductivities and pH are referred to 25°C.

The specified values are maximum values. The actual values should be kept lower whenever possible, with the shortest and least frequent excursions.

The specification is related to the following conditions:

- There are neither copper nor aluminum nor their alloys in the system
- The drum type evaporators have blowdown for removal of impurities
- Losses of the water / steam inventory of the cycle are low and mainly caused by the boiler blowdown.
- The make-up water demand due to HRSG blow-down is < 3 % (depending on HRSG pressure) under normal conditions, up to 5 % maximum and intermittent based on total steam production. During start-up the demand may be higher (refer to project specific requirements).
- Conditioning is done exclusively with injection of ammonia into the condensate downstream of the condensate pump and of tri-sodium phosphate into the drums, if applicable.
- Oxygen scavenger dosing is not applied during normal operation. It may be provided as back-up for specific situations like standstill or short term control of elevated oxygen levels. It is not part of an automatic control for chemical conditioning.
- Only chemicals with defined impurity levels (batch analysis certificate) shall be used for chemical conditioning of HRSG and water steam cycle. The chemicals shall be generally reagent grade ACS at least.
- There are measures in place to minimize the ingress of air and impurities during shut-down
- Auxiliary steams or process return condensates from other sources that are fed into the water steam cycle shall comply with the chemical requirements and analytical supervision of the HRSG steams and main condensate, respectively.

9.2. Start-Up

Start-up Criteria for the steam turbine and allowable carbon dioxide contribution

Type of operation	Action Level	Type of condenser				Restrictions
		water cooling		air cooling		
		CC (a) [µS/cm]	DCC (b) [µS/cm]	CC (a) [µS/cm]	DCC (b) [µS/cm]	(c) / (d) / (e)
HRSG start		> 3	> 1	> 3	> 1	Do not start ST
ST release limit		≤ 3.0	≤ 1.0	≤ 3.0	≤ 1.0	
ST Operation during start up	A2	2 - 3	0.5 - 1	2 - 3	0.5 - 1	max 30 min per startup
	A1	0.5 - 2	0.2 – 0.5	0.5 - 2	0.2 – 0.5	• max 4 hours per startup for warm start with a

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						decreasing tendency after full load of ST • max 10 hours per startup for cold start with a decreasing tendency after full load of ST

Table 9.2 Maximum permissible tolerance for carbon dioxide (on-line instrument cation conductivity readings)

Note a) CC = Cation conductivity including carbon dioxide
Note b) DCC = Degassed cation conductivity (cation conductivity without carbon dioxide)
Note c) The time periods exceeding the permitted start up times for A1 and A2 will be added to the accumulated yearly impurities for the respective Action Level, see Chapter 2
Note d) The on-line monitoring system may not provide accurate readings at the very beginning, but the ST could already be released for a hot start. The steam turbine may be started up if :
- The previous operation was within normal chemistry control (stable N values) for the water / steam cycle
- there had been no upsets of the cooling water and demineralized make-up water system during previous operation and standstill period
- All chemical conditioning systems are functioning.
- The chemical monitoring system is reliable latest 30 min for the main steam after ST start to provide a monitoring control

Note e) Iron and silica are not measured on-line and degassed conductivities are not measured on-line for all sample streams. Therefore, it shall be verified by routine trace impurity measurements that the start-up and operation criteria for iron, sodium and silica are met and criteria for cation conductivities as mentioned in table 9.2 can be confirmed.

9.3. Commissioning Period and Long Term Cleanliness Considerations

During initial commissioning or after extensive WSC modifications it is usually difficult to respect the values given in this specification.
In order to obtain a satisfactory commissioning the boiler and steam lines shall be sufficiently cleaned prior to turbine operation. Please refer to the respective guidelines and specifications.
The turbine shall not be put into operation as long as the start-up values for the chemical parameters are not achieved.
The action level system shall not apply during commissioning.

The parameters shall show a declining tendency towards N-values during the commissioning. It shall be aimed to achieve at least AL1 values as quick as possible, latest at hand over of the plant (PAC). In case the normal operating values are not reached at PAC and if 1.5 x A1 time tolerance is used up before N values are reached a chemistry review shall be performed to identify the problem and to analyze for improvement.

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