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Guidance on water conservation techniques of circulating cooling water in thermal power plants

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Foreword

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Introduction

Water plays an important role in transferring energy, cooling and cleaning in the process of thermal power generation. According to the statistics of the International Energy Agency (IEA) and China Water Resources Bulletin, fossil fuel power generation used approximately 189,6 billion cubic metres of freshwater in 2021, accounting for almost 50 % of global energy system freshwater withdrawals and 5 % of total global freshwater withdrawals. In China, water withdrawal for thermal power generation in 2021 accounted for approximately 17,7 % of the industrial water withdrawal, of which cooling water in thermal power plants accounted for approximately 50 %. To save water resources, improve circulating cooling water use efficiency and help thermal power plants to enhance water conservation, work efficiently and orderly, and thus improve the economic and social benefits of thermal power plants, it is important to formulate guidance for the conservation of water used as circulating cooling water in thermal power plants.

The quantity of circulating cooling water used in thermal power plants ranges from tens to hundreds of thousands of cubic metres based on their operating capacity. The reduction of circulating cooling water use should consider the water quality, pipe materials, water treatment, chemicals and other factors. Meanwhile, to achieve water conservation purposes, the use of residual heat of high temperature circulating water to reduce the temperature of circulating water in the cooling tower should be considered. Cycles of concentration is an important index for evaluating water conservation of circulating cooling water, while the amount of make-up water is closely related to the cycles of concentration of circulating cooling water. The higher the concentration, the better water conservation efficiency. However, with higher concentrations, the cost and difficulty of water treatment also increase exponentially.

Circulating cooling water quality control index and water conservation processes differ based on the quality of make-up water. Researchers and engineers should standardize the water conservation process of circulating cooling water in thermal power plants by fully considering the cycles of concentration and other relevant influencing factors, to provide standardized technical guidance for the targeted stake holders (policy makers, managers, technical consultants, designers, operators of water treatment systems, etc.).

Through analysis and research on the circulating cooling water conservation technology in thermal power plants, this document sets up a scientific and objective technical control index, management guidance and implementation methods that are helpful to improve the efficiency of circulating cooling water conservation and the standardization of technical transformation of thermal power plants.

Starting from the perspective of water conservation management and technology, this document provides acceptable operation control specifications for common processes of circulating cooling water conservation for most stakeholders, to improve the operation efficiency and management level of circulating cooling water conservation, which is conducive to guiding the development of specialization, normalization and standardization of circulating cooling water conservation.

This document establishes the technical guidance and recommendations for circulating cooling water conservation technology, provides research direction of circulating cooling water conservation technology, improves the water conservation efficiency, and promotes the transformation of circulating cooling water conservation technology to higher efficiency, lower energy consumption, environment friendly and resource saving, in the end realizing sustainable development.

Guidance on water conservation techniques of circulating cooling water in thermal power plants

1 Scope

This document provides technical and management guidance for water conservation of indirect open recirculating cooling water systems in thermal power plants. It is applicable to circulating cooling systems that use surface water, underground water, reclaimed water, and treated domestic sewage from thermal power plant as the make-up water and use physicochemical treatment methods to increase cycles of concentration, thus realizing water conservation and increasing water use efficiency.

This document is applicable to recirculating cooling in thermal power plants fuelled by coal, oil, natural gas, and biomass.

2 Normative references

There are no normative references in this document.

3 Terms, definitions and abbreviated terms

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 Terms and definitions

3.1.1
water conservation of circulating cooling water
process to increase *cycles of concentration* (3.1.2) thus increasing water use efficiency

3.1.2
cycles of concentration
ratio of the concentration of specific ions in the circulating cooling water to the concentration of the same ions in the make-up water

[SOURCE: ISO 16784-2:2006, 3.6]

3.2 Abbreviated terms

BOD_5	biochemical oxygen demand at five days
CFU	colony forming unit
COD	chemical oxygen demand
NH_3-N	ammonia-nitrogen
NTU	nephelometric turbidity unit

TDS total dissolved solids

TSS total suspended solids

4 General

The following principles should be followed for water conservation of circulating cooling water in thermal power plants:

— Users should develop efficient circulating cooling water treatment technology, improve the cycles of concentration under the premise of ensuring system safety and energy saving.

— Users should be aware of the requirements of local environment protection regulation.

— Water treatment chemicals with high efficiency, low toxicity and good chemical stability should be used; biodegradable water treatment chemicals should be given priority; toxic and harmful water treatment chemicals should be strictly restricted.

5 Circulating cooling water quality recommendations

5.1 Water quality recommendations of make-up water

When surface water, underground water, seawater, reclaimed water, and treated domestic sewage from thermal power plants are used as make-up water for circulating cooling water system in power plants, the quality of the source water and of the circulating cooling water and the working conditions should be analysed, and technical and economic comparison should be made to select the appropriate cycles of concentration. Table B.1 in Annex B contains water quality recommendations when surface water, underground water is used as make-up water for circulating cooling water system after pre-treatment. Table B.2 in Annex B contains water quality recommendations when reclaimed water is used as make-up water for circulating cooling water system after pre-treatment. When treated domestic sewage from thermal power plant is used as make-up water for circulating cooling water system, the water quality after treatment should not be lower than the recommendations in Table B.2 in Annex B. Table B.3 in Annex B contains water quality recommendations when seawater is used as make-up water of circulating cooling water system.

5.2 Water quality recommendations of circulating cooling water system

The water quality of circulating cooling water systems using surface water, underground water, reclaimed water, and domestic sewage from thermal power plants as make-up water should meet the recommendations of Table 1.

Table 1 — Water quality recommendations of circulating cooling water systems using surface water, underground water, reclaimed water, and domestic sewage from thermal power plants as make-up water

Parameters	Units	Recommended values
pH (25 °C)	—	7,5 to 8,8
TSS	mg/l	≤ 100
$(CO_3^{2-}) + (HCO_3^{-})$ [a]	mg/l	400 to 500
SiO_2	mg/l	150 to 200
$(Mg^{2+}) \cdot (SiO_2)$ [a]	mg/l	≤ 60 000

[a] Ca^{2+}, Mg^{2+}, HCO_3^- and CO_3^{2-} are calculated by $CaCO_3$(mg/l).

[b] Conductivity and TDS are non-binding parameters, only for reference. Common parameters having great effect on corrosion and scaling in water have been listed in this table. Although other dissolved ions contribute to the conductivity and TDS, they generally have little effect on corrosion and scaling, so these two parameters are only given as reference indicators for water quality.

Table 1 *(continued)*

Parameters	Units	Recommended values
$(Ca^{2+}) \cdot (SO_4^{2-})$ [a]	mg/l	≤ 2,5 × 10^6
$(Ca^{2+} + Mg^{2+}) \cdot (CO_3^{2-})$ [a]	mg/l	2 × 10^6 to 4 × 10^6
Cl^-	mg/l	According to the material of heat exchange
COD_{Cr}	mg/l	≤ 100
NH_3-N	mg/l	≤ 10 (≤ 5 for copper tube condenser)
TDS [b]	mg/l	≤ 5 000
Conductivity [b]	µS/cm	≤ 8 500

[a] Ca^{2+}, Mg^{2+}, HCO_3^- and CO_3^{2-} are calculated by $CaCO_3$(mg/l).

[b] Conductivity and TDS are non-binding parameters, only for reference. Common parameters having great effect on corrosion and scaling in water have been listed in this table. Although other dissolved ions contribute to the conductivity and TDS, they generally have little effect on corrosion and scaling, so these two parameters are only given as reference indicators for water quality.

The water quality of circulating cooling water systems using seawater as make-up water should be determined through the dynamic simulation test of scale and corrosion inhibitor (Annex A), or it should be controlled according to the recommendations of Table 2.

Table 2 — Water quality recommendations of circulating cooling water systems using seawater as make-up water

Parameters	Units	Recommended values
TSS	mg/l	≤ 30
Turbidity	NTU	≤ 20
pH (25 °C)	—	8,0 to 9,0
M alkalinity (calculated by $CaCO_3$)	mg/l	≤ 350
Ca^{2+}	mg/l	≤ 1 000
Mg^{2+}	mg/l	≤ 3 200
Total Fe	mg/l	< 1,0
Cl^-	mg/l	≤ 45 000
SO_4^{2-}	mg/l	≤ 6 000
(Cu^{2+}) [a]	mg/l	≤ 0,1
Oils	mg/l	< 5
Residual chlorine [b]	mg/l	0,1 to 1,0 (or lower, meet environmental requirements)
TDS [c]	mg/l	100 000
Conductivity [c]	mS/cm	≤ 150

[a] The copper ion concentration in seawater circulating cooling water systems containing copper materials should be monitored.

[b] The concentration of free residual chlorine should be controlled when adding oxidizing biocides.

[c] Conductivity and TDS are non-binding parameter, only for reference. Common parameters having great effect on corrosion and scaling in water have been listed in this table. Although other dissolved ions contribute to TDS, they generally have little effect on corrosion and scaling, so these two parameters are only given as reference indicators for water quality.

The total number of heterotrophic bacteria in circulating cooling water should not be more than 1 × 10^5 CFU/ml, and the amount of biological slime should not be more than 3 ml/m^3.

6 Technical guidance for water conservation of circulating cooling tower

6.1 Basic guidance

6.1.1 The selection of cycles of concentration in circulating cooling water system should comprehensively consider the water source conditions, water quantity and water quality balance, environmental protection requirements, circulating cooling water system material and other factors. Scale and corrosion inhibition test (Annex C) should be performed, and technical and economic comparisons should be made; dynamic simulation test of scale and corrosion inhibitor should be used when necessary. Within the safe range of scale and corrosion inhibition, the cycles of concentration should be increased as much as possible. The calculation of cycles of concentration should refer to Annex D.

6.1.2 A side-stream treatment system should be set up if key indexes such as TSS, NH_3-N and salt content significantly exceed the water quality recommendations of the circulating cooling water system after increasing cycles of concentration, leading to potential risks of system corrosion, blockage and scaling.

6.1.3 The side-stream treatment of circulating cooling water includes side-stream filtration, softening or desalination process. The selection of a side-stream treatment process should be determined by a comprehensive comparison of the circulating cooling water quality, the type and volume of pollutants to be removed and other factors. The calculation of side-stream treatment volume should refer to Annex F.

6.1.4 Side-stream filtration treatment should be set up after technical and economic comparison when there are more than 5 cycles of concentration of circulating cooling water system, or if there is severe seasonal sandstorm.

6.1.5 When reclaimed water is used as make-up water for circulating cooling water, if the water quality does not meet the recommendations of Table B.2 in Annex B, then the treatment process and operation control scheme of circulating cooling water should be determined by scale and corrosion inhibition test and dynamic simulation test of scale and corrosion inhibitor.

6.1.6 When a clarification tank is used to treat circulating cooling water blowdown, the influence of temperature fluctuation on the treatment effect should be taken into account. Automatic temperature regulation device and air separation device should be installed. The influent temperature variations of the clarification tank should not be more than 2 °C/h.

6.2 Guidance for treatment of circulating cooling with water quality stabilizer

6.2.1 General

Water quality stabilization treatment is essential to circulating cooling water treatment, whether it is to adopt natural balance of pH treatment or other treatments such as softening, adding acid, desalting or partial desalting. Water quality stabilization treatments includes scale and corrosion inhibition, microbial control and other technologies.

6.2.2 Scale and corrosion inhibition technology

6.2.2.1 The performance and evaluation of scale and corrosion inhibitor for circulating cooling water should be determined according to the volume of make-up water and the material of circulating cooling water system. The test for selecting and performance evaluation of scale and corrosion inhibitors for circulating cooling water should include the following:

a) The carbonate hardness limit selection test, cycles of concentration limit selection test (Annex E) and scale and corrosion inhibitor concentration selection test (Annex C).

b) The effect of bactericide and its effect on the performance of scale and corrosion inhibitor.

c) Corrosion inhibition performance test (when the material is stainless steel, electrochemical corrosion performance test should be conducted).

d) Analysis items of operation control (chloride ion, hardness, alkalinity, conductivity, pH, etc.) and its control recommendations.

6.2.2.2 The formula of scale and corrosion inhibitor for circulating cooling water should be determined by the dynamic simulation test of scale and corrosion inhibitor and by technical and economic comparison. The following factors should be considered in dynamic simulation test:

a) make-up water quality;

b) thermal resistance value of fouling;

c) corrosion rate;

d) cycles of concentration;

e) material of heat exchange equipment;

f) condenser approach temperature of heat exchange equipment;

g) inlet and outlet water temperature of heat exchanger;

h) water flow rate in heat exchange equipment;

i) the stability of chemicals and their influence on the environment.

6.2.3 Microbial control technology

6.2.3.1 The selection of biocide or other control technology should be based on the type of microorganism, such as heterotrophic bacteria, iron bacteria, sulfate reducing bacteria, nitrifying bacteria etc.

6.2.3.2 The selection of bactericide for circulating cooling water should consider cooling water quantity, water quality conditions, biological species, heat exchange equipment material and other factors.

6.2.3.3 If the proposed microbiological control program is suspected to have a possible positive or negative influence on the effectiveness of the inhibitor program being tested, then the dosing of chemicals for microbiological control should be undertaken in accordance with the manufacturer's instructions or appropriate standards for microbiological growth inhibition.

6.2.3.4 Sodium hypochlorite, liquid chlorine, chlorine ingot, chlorine dioxide and monochloramine should be used as oxidizing bactericides for circulating cooling water. The dosing mode and dosage should meet the following principles:

a) Sodium hypochlorite, solid chlorine tablet, monochloramine or liquid chlorine should be added continuously or by impactor via sequential treatment. For continuous dosing, the residual chlorine in cooling water blow down should be controlled between 0,1 mg/l and 0,5 mg/l; for impact dosing, it should be added one to three times a day, and the residual chlorine in water should be controlled between 0,5 mg/l and 1,0 mg/l and maintained for two to three hours; for solid chlorine tablet, the chemicals can be put into a solid woven bag and hoisted around the cooling pool. The dosage is controlled once every week of every two weeks, and the dosage concentration is 10 mg/l;

b) Chlorine dioxide should be added continuously. When the bacterial concentration is 10^5 CFU/ml to 10^6 CFU/ ml, the amount of chlorine dioxide in circulating cooling water blow down should be controlled at 0,5 mg/l;

c) Monochloramine can be used in sequential treatment in order to reduce the quantities of bactericide used and the chemical discharges while maintaining treatment efficiency.