INTERNATIONAL STANDARD

ISO 22449-1

First edition
2020-01

Use of reclaimed water in industrial cooling systems —

Part 1: Technical guidelines

Utilisation de l'eau recyclée dans les systèmes de refroidissement industriels —

Partie 1: Lignes directrices techniques

Reference number
ISO 22449-1:2020(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 282, *Water reuse*, Subcommittee SC 4, *Industrial water reuse*.

A list of all parts in the ISO 22449 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Industries can use large quantities of water in their production processes. Among various industrial water uses, cooling water is a significant proportion of the total used. Industrial wastewater reuse is one of the promising ways to solve water shortage and to provide a non-conventional water source for cooling systems. In addition, for cooling systems, the most common water conservation method to optimize water use is increasing the cycles of concentration inherently. Information about different types and characteristics of industrial cooling systems is included in Annex A. In many countries such as the United States, Japan, Israel and Indonesia, industrial wastewater reuse in industrial cooling systems has been developed rapidly.

Reclaimed water originates not only from industrial wastewater but also from domestic wastewater. In consideration of diverse water quality of industrial wastewater and water from other sources, it is necessary to describe different types of industrial cooling systems which can use industrial wastewater or most of industrial wastewater mixed with domestic wastewater, as make-up water and to give their characteristics. However, there are no relevant ISO standards to guide the use of industrial wastewater or mainly of industrial wastewater mixed with domestic wastewater, as make-up water and solve the common problems such as corrosion and scaling in water reuse. This document is designed to promote the use of reclaimed water by providing technical guidelines for the use of industrial wastewater in industrial cooling systems. This should drive the design and operation of industrial cooling systems. The document should lead worldwide water reuse in industrial cooling systems and is of great significance to promote the reuse of water resources, to improve the water use efficiency, and to practice the concept of industrial circular economy.

The design of a cooling system is a complex matter balancing the cooling requirements of the process, the site-specific factors and the environmental requirements using technologies which allows implementation under economically and technically viable conditions. The process of designing industrial cooling systems is completed by the assessment of the best choice considering the other environmental issues and the constraints linked to the industrial process. However, as a non-conventional water source, reclaimed water can reduce the replenishment of freshwater when it is used as make-up water. If technically and economically possible, the use of reclaimed water improves environmental performances of the system.

This document renders technical guidelines for the use of reclaimed water in industrial cooling systems. It provides a basic framework for industrial cooling systems using reclaimed water.

Use of reclaimed water in industrial cooling systems —

Part 1: Technical guidelines

1 Scope

This document defines terms related to industrial cooling water systems and specifies technical guidelines for the use of reclaimed water for make-up water purposes water in industrial cooling systems. It provides a basic framework for consideration in the design and operation of industrial cooling systems using reclaimed water. The aim of the document is to promote and to help the implementation of the use of reclaimed water in industrial cooling systems.

It provides:

— Terms and definitions;

— Technical guidelines for the use of reclaimed water in industrial cooling systems.

This document is applicable to cooling systems that are considered to work as auxiliary systems for the normal operation of an industrial process. However, the operation of a cooling system in relation to process safety is not covered in this document. In addition, some environmental concerns also need to be taken into consideration, for example the drift control or the use of some persistent biocides. This document can be used to encourage consistency within any organization engaged in the use of reclaimed water.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20670, *Water reuse — Terminology*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20670 and the following apply.

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

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

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

3.1.1
blowdown (purge) water
water discharged from the system to control the concentration of salts or other impurities in the circulating water, which requires treatment either in a municipal treatment system or onsite

[SOURCE: ISO 16345:2014, 2.11]

3.1.2
coolant
heat-absorbing medium or process

[SOURCE: ISO 8573-1:2010, 3.3]

3.1.3
cooling water
water which is used to absorb and remove heat

[SOURCE: ISO 6107-1:2004, 15]

3.1.4
cooling tower
tower used for evaporative cooling of circulating *cooling water* (3.1.3), normally constructed of wood, plastic, galvanized metal or ceramic materials

[SOURCE: ISO 16784-2:2006, 3.4]

3.1.5
corrosion
gradual destruction or slow degradation of a substance or surface by a chemical effect

[SOURCE: ISO 16797:2004, 2.7]

3.1.6
cycles of concentration
ratio of the concentration of specific ions in the circulating *cooling water* (3.1.3) to the concentration of the same ions in the *make-up water* (3.1.8)

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

3.1.7
heat transfer medium
medium (water, air, etc.) used for the transfer of the heat without change of state

Note 1 to entry: The fluid cooled by the evaporator, the fluid heated by the condenser, and the fluid circulating in the heat recovery heat exchanger.

[SOURCE: ISO 13612-2:2014, 3.22]

3.1.8
make-up water
water which is added to the system to compensate for the loss of water due to evaporation, blow-down, leakage and drift loss

[SOURCE: ISO 16784-2:2006, 3.9]

3.1.9
non-conventional water source
sources of water not originating from natural fresh surface water or groundwater, including seawater desalination, use of brackish water (directly or via desalination), and reuse of urban or industrial wastewaters with varying levels of treatment

3.1.10
Ryznar Stability Index
RSI
index to help monitor the scaling and *corrosion* (3.1.5) potential of water

Note 1 to entry: Ryznar values are always positive, which attempts to correlate an empirical database of scale thickness observed in municipal water systems and to quantify the relationship between calcium carbonate saturation state and scale formation. The Ryznar index takes the form: RSI = 2 pH_s--pH (pH_s is the pH at saturation in calcite or calcium carbonate; pH is the measured water pH). The application of RSI in water treatment plant demonstrated that RSI was fit in estimating the treated water chemical stability and appeared to be promising in the field of treated water quality management.

3.1.11
scaling
surface film and *corrosion* (3.1.5) products produced on the surface by high temperature corrosion

[SOURCE: ISO 13573:2012, 3.1]

3.2 Abbreviated terms

BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
HPC	Heterotrophic Plate Count
TDS	Total Dissolved Solid
TN	Total Nitrogen
TOC	Total Organic Carbon
TP	Total Phosphorus
TSS	Total Suspended Solid

4 Technical guidelines for the use of reclaimed water in industrial cooling systems

4.1 General

Considerations for using industrial wastewater as a source of makeup water for cooling water purposes will likely require either an upgrade to the existing wastewater treatment system, or an additional treatment process to improve effluent water quality and remove constituents of concern for reuse as make-up water for cooling water systems. Industry and facility may have specific requirements that include the space, design and choice of materials for the selection of a cooling system. A new installation also should have an upgrading in water treatment process and take economic factors into consideration to optimize the cost on operation and maintenance and balance the environmental efficiency. For the purpose of water reuse in industrial cooling systems, the following factors should be taken into consideration: water quality, water quantity and temperature, wastewater treatment technologies for reuse, treatment for inhibition of corrosion, scaling and biological fouling, based on the industrial water reuse experience among different regions.

4.2 Water quality specifications

The quality of reclaimed water is of great importance for the design, operation and maintenance of industrial cooling systems. The water quality of reclaimed water can be influenced by the type of industry and type of process; specific requirements for pipes, heat exchangers and cooling towers with the influence of construction material and risk of direct human contact requiring disinfection and chlorine residual, etc. Reclaimed water quality and treatment requirements may become a significant part of the local regulations and guidelines for water reuse. Water quality parameters of interest and their specifications of make-up water in most commonly used cooling system are listed in Table 1. Besides, make-up water quality specifications for a closed-circuit hybrid cooling system are listed in annex Table C.1. The recommended range of make-up water quality can be changed by controlling the reclaimed water volume and quality, which is important for the operation of recirculating cooling water system.

Table 1 — Typical water quality specifications in most commonly used cooling systems[9][10][11][12][13]

Parameter	Unit	Typical values and recommended range	Impact on Cooling Water Systems
pH	/	6,5-9	— Metal corrosion and scaling increases when pH is below and above recommended ranges, respectively.
Total hardness	($CaCO_3$mg/l)	≤250	— Calcium is more troublesome than magnesium in contributing to scaling. Magnesium is not as much of problem unless the silica levels are also high.
Alkalinity	($CaCO_3$mg/l)	100-500	— Scaling
BOD_5	mg/l	≤10	— Reflect the organic content and associated demand for oxidizing biocide.
COD_{cr}	mg/l	≤30	— Bio-fouling, biomass growth, disinfection by-products
TSS	mg/l	≤10	— Corrosion, fouling, scaling
TDS	mg/l	≤5 000	— Scaling, fouling
Conductivity	µs/cm	≤3 000[a]	— Scaling, fouling
Residual chlorine	mg/l	End 0,1~0,2[b]	— Disinfection by products, corrosion
Chloride	mg/l	≤300 (stainless steel) ≤1 000 (other metals)	— Corrosive to most metals, especially mild steel
Fecal Coliform	CFU/100ml	≤200	— Nutrient element, biomass growth, disinfection by-products.

[a] The range will depend upon the particular cooling water system's design and characteristics, the type of chemical program and the industrial process.

[b] Total chlorine residual should be met after a minimum contact time of 30 minutes.

[c] Iron may be a concern if it combines with phosphate to form undesirable foulants. It may also deactivate specialized polymers used to inhibit calcium phosphate scaling. Reclaimed water may have a high concentration at 0,12 to 0,32 of iron[14]. Specialized treatment of iron is required for this concentration to avoid fouling the heat exchangers.

[d] The concentration of phosphate is limited to be less than 3 mg/l according to Chinese standard GB/T 31329-2014[15]; In a water pollution control plant owned by San Jose and Santa Clara (US), it indicates that phosphate is a common anionic inhibitor and may also provide a mild steel corrosion protection at the levels equal to or less than 4 mg/l[14].

NOTE

— Parameters such as chemical stability (e.g., Mn, silica) and biological stability (e.g., HPC) could be considered on a case-by-case basis if specific risks are identified or required by local regulations.

— Specific metals and anions are considered for selection depending on reclaimed water source characteristics and use facilities. For example, copper and nickel can plate out on steel, causing localized galvanic corrosion that can rapidly penetrate thin steel heat exchanger tubes.

— Monitoring sites of biological stability could be considered at distribution and storage system outlets and point-of-use with long hydraulic retention time.

Table 1 *(continued)*

Parameter	Unit	Typical values and recommended range	Impact on Cooling Water Systems
NH_3-N	mg/l	≤5 ≤1 (if copper presents)	— Combine with chloride to form chloramines which can negate the disinfecting effect of chlorine and some non-oxidizing biocides. — Corrosive to copper alloys at concentrations as low as 2,0 ppm.
Sulfate (SO_4^{2-})	mg/l	≤800	— Scaling
Fe[c]	mg/l	≤0,3	— Form undesirable foulants if combines with phosphate.
PO_4^{3-}[d]	mg/l	≤3	— At higher concentrations (calcium greater than 1 000 mg/l and phosphate greater than 20 mg/l), there is a potential for calcium phosphate scaling in the heat exchanger.

[a] The range will depend upon the particular cooling water system's design and characteristics, the type of chemical program and the industrial process.

[b] Total chlorine residual should be met after a minimum contact time of 30 minutes.

[c] Iron may be a concern if it combines with phosphate to form undesirable foulants. It may also deactivate specialized polymers used to inhibit calcium phosphate scaling. Reclaimed water may have a high concentration at 0,12 to 0,32 of iron[14]. Specialized treatment of iron is required for this concentration to avoid fouling the heat exchangers.

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— Monitoring sites of biological stability could be considered at distribution and storage system outlets and point-of-use with long hydraulic retention time.

4.3 Water quantity and temperature requirements

Compared with fresh water, reclaimed water is more likely to contain higher concentrations of constituents during evaporation. Evaporation rate is influenced by water temperature and flow rate, which will further affect the blowdown volume and evaporation volume, therefore it is necessary to emphasize the water temperature and quantity requirements for using reclaimed water as make-up water. The minimal flow and quantity vary among the various cooling water systems as performance depends on the concentration factor applied, evaporation and to a lesser extent to the ambient temperature. Higher ambient temperatures can cause the cooling water temperature to increase. Increasing temperature may increase the scaling and corrosion tendency. The organisms that make up microbial tend to flourish between 40 °F and 150 °F, and increasing microbial will reduce the efficiency of heat transfer.

Table 2 shows the impact factors and formula of makeup volume, which creates opportunities for appropriate conservation methods to achieve water savings. An example of water quantity requirements for different industrial cooling systems under assumed conditions is shown in Table B.1 in Annex B. Additionally, scaling and corrosion in heat exchanger tubes are very velocity dependent.

At lower cooling water velocities, or in stagnant regions, biofilms increase and deposits occur from suspended solids or inorganic scale. The survey results show that it will lead to scaling and corrosion when the flow rate is lower than 0,3 m/s. In addition, the fouling thermal resistance value of water has a big difference between the flow rate above 1 m/s and below 1 m/s[10].

The temperature of make-up water is also an important factor because many chemical and industrial processes are temperature-critical applications and also correlated with the efficiency of the removal of waste heat. Some compounds have an inverse solubility at high temperatures (above 140 °F) which can cause increased scale formation. Because equipment designers usually incorporate one or more factors to accommodate less-than-ideal heat transfer conditions, heat exchangers are frequently over-designed so that the operation at the anticipated cooling water flow rates would lower the process fluid temperature below acceptable values. As a result, operators reduce the cooling tower water flow rates to certain heat exchangers as a means of controlling process temperatures.

Table 2 — The impact factors and formula for the makeup volume

Impact factors	Calculation formula
Evaporation rate (ER)	ER = Recirculated flow rate × (Warm water temperature-Desired cool temperature) × 0,01/10 °F[a]
Cycles of concentrations (COC)	COC = Cooling water concentration/Makeup water concentration
Blowdown Volume (BL)	BL = Evaporation Volume/(COC-1)
Makeup Volume = Blowdown Volume + Evaporation Volume	

[a] As a rule of thumb, for each 10 °F that the circulated water needs to be cooled, one percent of the cooling water is evaporated in the cooling tower.

4.4 Wastewater treatment technologies for reuse

To meet the requirements of reused water quality in industrial cooling systems, applicable treatment technologies are needed. According to the origins (industrial wastewater or blowdown), conventional wastewater, wastewater with high salinity and wastewater with toxic and non-biodegradable compounds should be treated at different treatment levels. Usually, many industrial wastewaters contain high concentrations of total dissolved solids, which may be a result of neutralization or other chemical treatment processes. TDS cause toxicity through increases in salinity, changes in the ionic composition of water and toxicity of individual ions. Wastewater with a high TDS level can have adverse impacts on the efficiency of biological treatment and exacerbate corrosion in water networks. In general, it is better to ensure water and makeup water chemistry are treated properly to avoid this issue, as once scale is formed, it is difficult and costly to remove. Lower dissolved solids will provide the right quality of makeup water and correct circulation chemistry, allowing the cooling system to run efficiently. This helps increase cycles for water and maintain a manageable amount of blowdown, which in turn, helps conserve the amount of any makeup water or chemicals needed.

4.5 Treatment for inhibition of corrosion, scaling and biological fouling

Corrosion and scaling are common problems in cooling water systems. The characteristic of industrial wastewater with complex constituents and a large amount of toxic and non-biodegradable substances calls for more specific requirements when using the reclaimed water originated from industrial wastewater as make-up water in cooling systems. For example, many schemes for reuse of treated industrial wastewater, particularly in the electronics industry, provide a soft water for use as cooling tower makeup. Besides, alkalinity of the treated effluent has a close connection with pH, which will indirectly impact the water stability when reusing in cooling systems. Therefore, it is required to identify water corrosion and scaling tendency in industrial cooling systems so as to cost-effectively reuse the industrial wastewater. A general method determining the tendency of scale or corrosion inhibitors is based on water stability index, which is listed in Table 3.

Treatments towards scaling and corrosion mainly include chemical and physical methods. Chemical agents are commonly used as scale and corrosion inhibitors. Scale and corrosion inhibitors should have low toxicity and be chemically stable, and the product should be confirmed based on the dynamic simulation testing. An economic analysis would also be needed for different products. It is also feasible to choose the chemical agents according to experience on water quality and site conditions. Dynamic simulated tests should follow an evaluation of make-up water qualities, stability and environmental influence of chemical agents, fouling resistance, corrosion rate, adhesion rate, concentration multiple of cooling water, materials of heat transfer equipment, water flow velocity in heat transfer equipment and temperature of circulating cooling water. Most successful treatment programs use several corrosion inhibitors blended together such as molybdate-silicate-azolepolydiol and phosphonate-phosphate-azole to take advantage of a synergistic effect, where the net reduction in corrosion from the use of a mixture is greater than the sum obtained from individual components.

In addition, some chemical programs designed to prevent scale can work only when the hardness level stays within the specified range. Some corrosion control programs require a certain hardness level to function correctly. For example, the most commonly used corrosion inhibitors, polyphosphates and phosphonates, do not work if less than 50 mg/l calcium hardness is present in the cycled cooling water. Physical technologies such as ultrasonic and electronic descaling are also effective methods to mitigate the fouling. The adoption of an appropriate physical technology depends on the operation efficiency, costs and water quality requirements of industrial cooling systems. Recommended treatments for scale and corrosion based on water stability index are listed in Table 3.

Table 3 — Treatment towards scale and corrosion based on water stability index[9][14][16][17][18]

Water stability index (RSI*)	Water corrosion and scaling tendency	Chemical treatment		Physical treatment
<6	Scaling	Scale inhibitors	Organic matter metal salt series (molybdenum, tungsten), Organic phosphates, Polyphosphates and water-soluble polymeric compounds	Electronic descaling
		pH Adjustment	Acids (for example, sulfuric)	
6	Basically stable	/	/	/
>6	Corrosion	Corrosion inhibitors	Organic inhibitors (acting by protective barrier formation): amines and polyamines (film-amine type), aromatic amines Inorganic inhibitors (acting on electrochemical corrosion processes): — Anodic inhibitors[a] (nitrites, silicates, phosphates, tannates, molybdates). — Cathodic inhibitors: zinc salts (chloride or zinc sulphate) — Mixtures — (zinc salts + chromates, zinc salts + phosphonates, phosphates, polyacrylates, molybdates, polyphosphates[b])	Electronic descaling

[a] It is presupposed that there is an awareness of applicable legal requirements depending on the process involved and the environmental constraints during discharges.

[b] Polyphosphates: under the condition of pH <7,5, T <60 °C (thermal degradation), scaling problems to handle, biocides treatments are recommended.

In addition, microbiological growth within a cooling system, if not controlled, can result in formation of biological fouling layers (biofilm) on the surfaces in contact with the cooling water. The biofilm acts as a thermal insulator decreasing heat transfer efficiency in the production equipment and usually results in a substantial increase of corrosion rate and pitting. Biocidal treatments aim at eradicating sulforeductive bacteria, pathogenic bacteria such as L. *pneumophila* and to maintain an acceptable level of banal bacteria to avoid the formation of the biofilm responsible for corrosion. The most commonly used biocides can be classified into two major categories, oxidizing biocides and non-oxidizing biocides, respectively. Sodium hypochlorite and monochloramine are mainly used as oxidizing biocides, while non-oxidizing biocides mainly include isothas zolones, 2,2-Dibromo-3-Nitrilopropionamide (DBNPA), glutaraldehyde and quaternary ammonium compounds, etc. Among them, sodium hypochlorite in solution is unstable and easily decomposes. Its corrosive properties could affect human body in terms of respiratory system from coughing and chest pains, to fluid accumulation in the lungs. Therefore, safety measures must be ensured during the construction process, to protect the workers and the environment.

Particular attention shall be paid pathogenic microorganisms due to ensure human health and safety. *Legionella* as a representative of pathogenic microorganisms is a group of bacteria present in cooling water systems. *Legionella* can live and multiply as a parasite in protozoa. As they multiply, *Legionella* will burst the protozoa and be released into the water. The water contains *Legionella* has a risk of resulting in Legionnaire's disease. The detection and quantification of *Legionella* is described in ISO/TS 12869:2019. Therefore, *Legionella* bacteria are generally controlled by maintaining a biologically clean system. No biocide is specific for *Legionella.* However, traditional oxidizing biocides such as chlorine, bromine and monochloramine have been proven effective in controlling *Legionella* in cooling systems. A program that includes non-oxidizing biocides together with oxidizers is also effective. In addition, water temperature could affect the removal rate of *Legionella* bacteria[19].

Occupational Safety and Health Administration (OSHA) has further set recommended action levels for *Legionella* bacteria in cooling water of below 100 CFU/ml, no action; from 100 CFU/ml to 1 000 CFU/ml, prompt cleaning and/or biocide treatment of system; and above 100 CFU/ml, immediate cleaning and/or biocide treatment, take prompt steps to prevent employee exposure[19]. Two tests per year are recommended to confirm that the *Legionella* level in any cooling system is below the OSHA recommended action levels.

Annex A
(informative)

Types and characteristics of industrial cooling systems

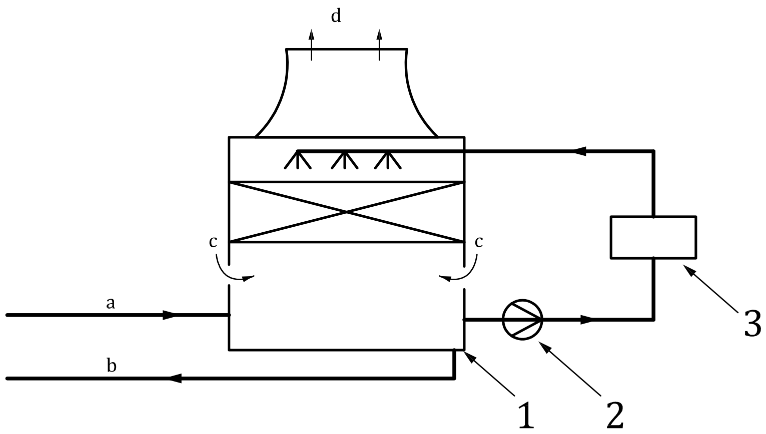
A.1 General

Industrial cooling systems can be categorized by their design and by the main cooling principle: using liquids or gasses, or a combination of liquids and gasses as coolants. Water has good thermal capacity and does not expand or compress significantly within normally encountered temperature ranges. Compared to gasses, water has a higher heat transfer in cooling systems, which makes water a better choice as a coolant. The exchange of heat between the heat transfer medium and coolant is enhanced by heat exchangers. From the heat exchangers, the coolant transports the heat into the environment. Generally, types of industrial cooling systems include: direct/indirect once-through cooling systems, direct/indirect open recirculating cooling water systems, closed circuit wet/dry air cooling systems, and open recirculating/closed circuiting hybrid cooling systems. The types of industrial cooling systems that can use reclaimed water can be classified to the following categories, as specified in A.2 to A.6.

A.2 Direct open recirculating cooling water systems

In this system, the heat obtained from heat exchange equipment in cooling water will be emitted to the atmosphere directly through cooling equipment. After the cooling process by water contacting directly with air, recirculating water will be pumped back to heat exchange equipment and repeat the process of transferring heat. In the operation of this system, make-up water must be supplemented continuously due to the water loss of evaporation, drift, and blowdown. Generally, the make-up water flow used by a direct open recirculating cooling water system is about 1 % to 5 % of the circulating water flow.

Example of process flow diagram is shown in Figure A.1.



Key

1 open cooling tower
2 pump
3 users
a Reclaimed water as make-up water.
b Blowdown.
c Air in.
d Air out.

NOTE Figure A.1 illustrates a direct open recirculating cooling water system.

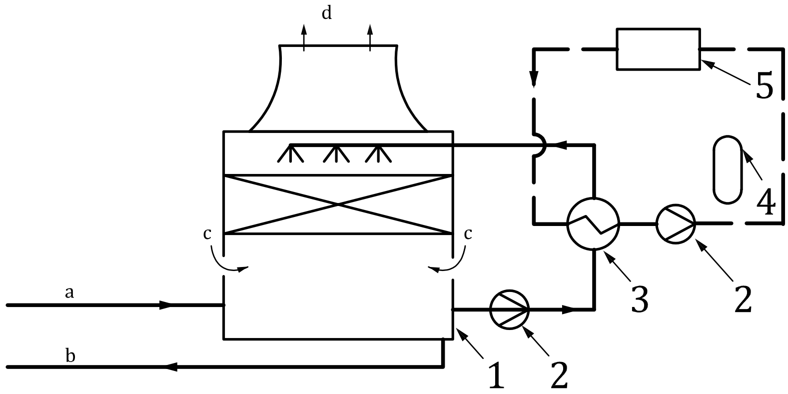
Figure A.1 — A kind of process flow diagram for a direct open recirculating cooling water system

In this system, recirculating water contacts directly with materials, process medium or facilities to be cooled. There is always a large number of impurities in recirculating water. For this system, owing to the high concentration of suspended solids and even the oil, it is necessary for recirculating to control salt concentration balance and water quality stability, remove turbidity and oil, and cool down the temperature.

A.3 Indirect open recirculating cooling water systems

In this system, recirculating water contacts indirectly with materials, process medium or facilities to be cooled. Due to the indirect cooling method, recirculating water is not contaminated just with temperature rising. However, during the recycle process of cooling, the salt concentration will increase continuously as water keeps evaporating. Hence, the system needs blowdown and replenishing make-up water to control the cycles of concentration and salt concentration balance. Generally, the make-up water flow used by an indirect open recirculating cooling water system is about 1-5 % of the circulating water flow.

Example of process flow diagram is shown in Figure A.2.



Key

1	open cooling tower
2	pump
3	heat exchanger
4	expansion tank
5	users
a	Reclaimed water as make-up water.
b	Blowdown.
c	Air in.
d	Air out.

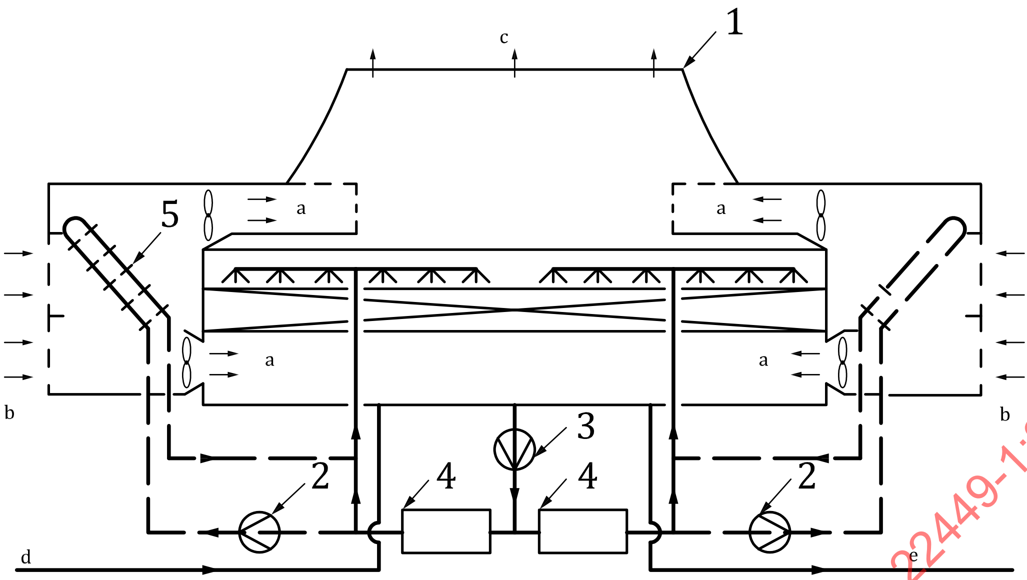
NOTE Figure A.2 illustrates an indirect open recirculating cooling water system.

Figure A.2 — A kind of process flow diagram for an indirect open recirculating cooling water system

A.4 Open recirculating hybrid cooling systems

The open recirculating hybrid cooling system or wet/dry cooling tower is a special design that has been developed as a solution to the problem of plume formation. The major difference between a hybrid cooling tower and a conventional cooling tower is its lower water use (which is make-up water) amounting to 20 % less than that of a wet cooling tower. It is a combination of a 'wet' and 'dry' cooling tower or, in other words, of an evaporative and a non-evaporative process. The hybrid cooling system can be operated either as a pure wet cooling tower or as a combined wet/dry cooling tower, depending on the ambient temperature. The heated cooling water first passes through a dry section of the cooling tower, where part of the heat load is removed by an air current, which is often induced by a fan. After passing the dry section, water is further cooled in the wet section of the tower, which functions similarly to an open recirculating tower. The heated air from the dry section is mixed with the vapour from the wet section in the upper part of the tower, thus lowering the relative humidity before the air current leaves the cooling tower, which (almost) completely reduces plume formation above the tower.

Example of process flow diagram is shown in Figure A.3.



Key

1 open hybrid cooling tower
2 booster pump
3 pump
4 users
5 fin-tube
a Air.
b Air in.
c Air out.
d Reclaimed water as make-up water.
e Blowdown.

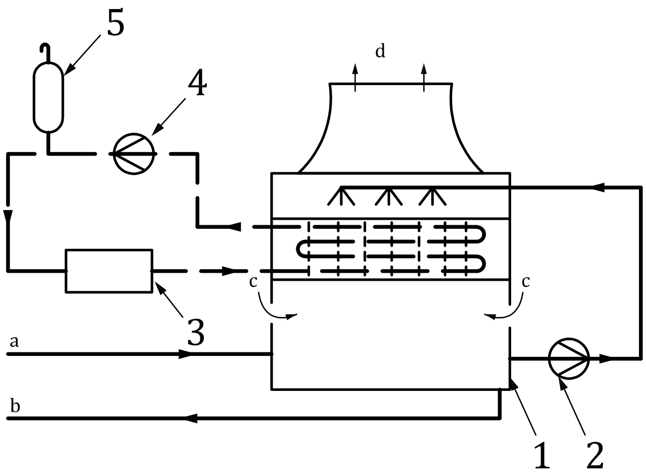
NOTE Figure A.3 illustrates an open recirculating hybrid cooling system.

Figure A.3 — A kind of process flow diagram for an open recirculating hybrid cooling system

A.5 Closed circuit cooling water systems

In closed circuit cooling systems, the medium to be cooled is circulated in a closed circuit without contacting with the environment. The medium is led through a coil (primary circuit). The coils are wetted from the outside (secondary or spray circuit). The heat is conducted from the medium to the spray water (sensible heat transfer). The evaporation of a small part of the water leads to evaporative cooling and the heat is transferred from the water to the air. There is an additional sensible heat transfer from the coil to the air. The wetting water is treated to avoid damage to the equipment. Evaporative losses drift and windage cause concentration, so some blowdown is needed and some make-up water has to be added. Generally, alkalised demineralised water or potable water is used as a secondary cooling medium in closed circuit cooling water systems. Make-up water is needed only when leakage and evaporation occur at pump packings or when water is drained to allow system repair. Depending on the technical concept, the mode of operation and the climatic conditions, plume formation may occur. Water can be saved since the tower can be operated as a dry tower when the ambient temperature is low.

Example of process flow diagram is shown in Figure A.4.



Key

1	closed wet cooling system
2	spray pump
3	users
4	pump
5	expansion tank
a	Reclaimed water as make-up water.
b	Blowdown.
c	Air in.
d	Air out.

NOTE Figure A.4 illustrates a closed-circuit cooling water system.

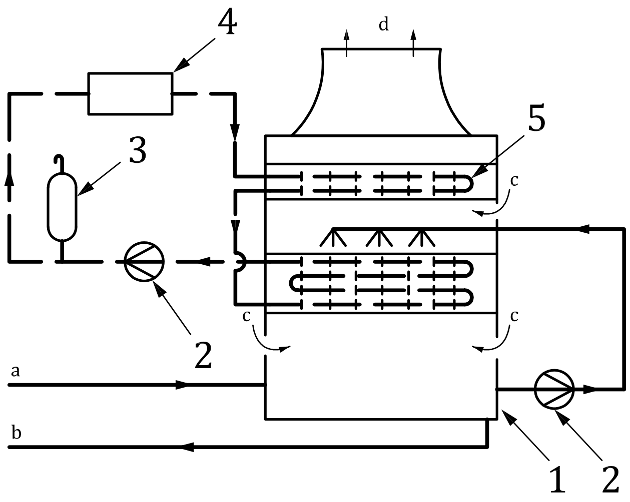
Figure A.4 — A kind of process flow diagram for a closed-circuit cooling water system

A.6 Closed-circuit hybrid cooling systems

For closed circuit hybrid cooling system, characteristics can be described in a similar way as for closed circuit cooling water system concerning fans (axial and radial), airflow direction (cross or counterflow) and noise abatement system. Generally, these units have a small space requirement. Three technical modes can be applied to closed circuit hybrid cooling towers: sprayed finned coils, adiabatic cooling or combined systems.

The closed-circuit hybrid cooling system combines the advantages of closed loop cooling with significant savings of water when compared to conventional closed-circuit cooling water system. Compared to closed circuit dry cooling towers, they offer the advantage of lower cooling temperatures. In terms of size, energy consumption and noise emission they compare with conventional closed-circuit cooling water system. Depending on their design (sprayed finned coils), special attention may need to be paid to the quality of the water treatment. Additional costs can be more than offset by the significant saving of water, as such products require the use of water only during a very short period of the year. The major difference between a closed-circuit hybrid cooling tower and a conventional cooling tower is its lower water use (which is make-up water) amounting to 20 % less than that of a wet cooling tower.

Example of process flow diagram is shown in Figure A.5.



Key

1 closed cooling system
2 pump
3 expansion tank
4 users
5 fin-tube
a Reclaimed water as make-up water.
b Blowdown.
c Air in.
d Air out.

NOTE Figure A.5 illustrates a closed circuit hybrid cooling system.

Figure A.5 — A kind of process flow diagram for a closed-circuit hybrid cooling system

Water is an important medium for cooling systems. Water use and water consumption are terms both used for the requirements of cooling water systems. The volume of water used is largely connected with the type of industry. The volume of reclaimed water used in industrial cooling system depends on various factors, among which the key parameters include water quality, temperature, and the number of recycling (for cooling towers[20]). Table B.1 shows examples of the volumes of reclaimed water for different industrial cooling systems.

