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

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ISO 22449-1:2020
https://standards.iteh.ai/catalog/standards/sist/31f5c545-2649-4d8a-9e2a-662857da875f/iso-22449-1-2020

Reference number
ISO 22449-1:2020(E)

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Published in Switzerland

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

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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.

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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.

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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.

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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]

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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)

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

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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

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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

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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

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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.

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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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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.

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