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Corrosion of metals and alloys — Corrosion and fouling in industrial cooling water systems —

Part 2:
Evaluation of the performance of cooling water treatment programmes using a pilot-scale test rig

Corrosion des métaux et alliages — Corrosion et encrassement des circuits de refroidissement à eau industriels —
Partie 2: Évaluation des performances des programmes de traitement de l'eau de refroidissement sur banc d'essai pilote

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 document 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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This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 262, *Metallic and other inorganic coatings, including for corrosion protection and corrosion testing of metals and alloys*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 16784-2:2006), which has been technically revised.

The main changes are as follows:

— the Introduction has been modified;

— the Scope has been modified;

— Normative references have been added;

— the Terms and definitions have been updated;

— Clause 4 has been modified to include principles on the simulation process of cooling water treatments;

— the title of Clause 5 has been changed from “Reagents and materials” to “Water for test”;

— the apparatus has been modified: the components and their descriptions have been added;

— the assessment of results has been modified to be divided into three aspects: corrosion phenomena and type of corrosion, pitting corrosion and corrosion rate;

— the bibliography has been modified.

A list of all parts in the ISO 16784 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

There is an industrial need to improve the safety, reliability and cost-effectiveness of open recirculating cooling water systems. This is due to the rise in stringent environmental requirements as well as the rise in the costs of water. It is therefore important to establish a standard framework for evaluating the performance of cooling water treatment programmes. The aim is to provide users of cooling systems and vendors of treatment materials for those systems with a procedure to make consistent evaluations of cooling water treatment programmes on a pilot scale.

With the continuous development of circulating water treatment technology, some new circulating water treatment technologies, such as reverse osmosis treatment and electrochemical treatment, have become an important part of cooling water treatment schemes.

This document has been revised and updated to add a new test device along with more detailed descriptions of the components. The simulation device uses steam to heat the heat exchange tube, which solves the problem of uneven heating caused by electric heating and is closer to the actual operating conditions on site.

Corrosion of metals and alloys — Corrosion and fouling in industrial cooling water systems —

Part 2:
Evaluation of the performance of cooling water treatment programmes using a pilot-scale test rig

1 Scope

This document specifies the principles, reagents and materials, test apparatus, test methods, evaluation of results and requirements for test reports using pilot tests for industrial cooling water systems.

This document specifies a method to evaluate the performance of treatment programmes for open recirculating cooling water systems. It is based primarily on laboratory testing, but the heat exchanger testing facility can also be used for on-site evaluation. This document does not include heat exchangers with cooling water on the shell-side (i.e. external to the tubes).

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 3696, *Water for analytical laboratory use — Specification and test methods*

ISO 8044, *Corrosion of Metals and Alloys — Basic Terms and Definitions*

ISO 8407, *Corrosion of metals and alloys — Removal of corrosion products from corrosion test specimens*

ISO 16784-1, *Industrial cooling water systems — Testing and performance — Part 1: Guidelines for conducting pilot-scale evaluation of corrosion and fouling control additives for open recirculating cooling water systems*

ISO 11463, *Corrosion of metals and alloys — Guidelines for the evaluation of pitting corrosion*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 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 https://www.electropedia.org/

3.1
adenosine tri-phosphate
ATP
active chemical present in living bacteria

Note 1 to entry: ATP concentrations can be indirectly measured and are used as an indicator for the presence of biology in cooling water.

3.2
blow-down
discharge of water from the cooling water circuit expressed as a discharge rate

3.3
cooling tower
tower used for evaporative cooling of circulating cooling water, normally constructed of wood, plastic, galvanized metal or ceramic material

3.4
cooling water treatment
adjustment of cooling water chemistry by which corrosion and fouling can be controlled

3.5
cycle 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

3.6
heat rejection capacity
amount of heat that can be rejected by a cooling-tower system

3.7
half-life
time needed to reduce the initial concentration of a non-degradable and/or non-precipitable compound to 50 % of its concentration in the cooling water

3.8
make-up water
total water mass per time unit, which is added to the system to compensate for the loss of water due to evaporation, blow-down, leakage and drift loss

3.9
Reynolds number
dimensionless form, $\frac{LV\rho}{\eta}$, which is proportional to the ratio of inertial force to viscous force in a flow system

where:

L is the characteristic dimension of the flow system, expressed in m;

V is the linear velocity, expressed in m/s;

ρ is the fluid density, expressed in kg/m^3;

η is the fluid viscosity, expressed in kg/m/s.

3.10
surface temperature
temperature of the interface between the cooling water film and the heat-transfer surface, whether the surface is the tube wall or the outside of a fouling deposit

3.11
film fill
portion of a cooling tower, which constitutes its primary heat-transfer surface and over which water flows as evaporation occurs

3.12
wall temperature
temperature sensed by a thermocouple placed between the heater element and the inside of the heat-transfer tube wall, preferably as close to the tube wall as possible

4 Principle

Model the circulating cooling water treatment process under specified experimental conditions. The metal pipe samples are placed in circulating cooling water for heat exchange. Evaluate the performance of the cooling water treatment scheme based on factors such as cooling water flow rate, water quality, material flow intensity, heat transfer, the temperature of the cooling water inlet and outlet, concentration ratio, pH, conductivity, concentration of water treatment additives and other critical technological parameters.

A test assembly of metallic test tubes is submitted under heat-transfer conditions to the circulation of cooling water for a specified period. This can be connected directly to the cooling water system on-site, to be representative of service conditions. For laboratory testing, the cooling water composition is designed to reflect the chemistry for the service application but modified with the appropriate treatment programme under investigation. The adoption of synthetic chemistry in laboratory tests can be effective for comparative purposes, for example screening, but will not be representative of service conditions. The effect of the cooling water circulation and the treatment programme on the corrosion and fouling of the test tubes is assessed using a number of measurement parameters.

5 Water for test

5.1 General

The cooling water composition of the test should reflect the likely service application. For laboratory testing using synthetic water, only reagents of recognized analytical grade and only water complying with the minimum requirements of grade 3 of ISO 3696 shall be used.

There are two main operating environments. The first is to use the make-up water used in the specific cooling system on-site (or to use synthetic make-up water) and concentrate it to the required number of cycles in the test system. Annex A includes recommended forms for recording test conditions (see Table A.1, Table A.2, Table A.3), compositions of make-up and recirculating water (see Table A.4) and test results (see Table A.5, Table A.6, Table A.7). Annex B includes measurement and test methods.

The second approach involves using a synthetic water simulating on-site circulating water for the required number of cycles. The use of synthetic circulating water obviates the need to concentrate the synthetic water to obtain the desired cycles of concentration. This approach simplifies the test by avoiding the use of the pilot cooling tower.

Synthetic circulating water usually contains a higher level of dissolved ionic solids than corresponding natural water, thus making the synthetic water more corrosive.

5.2 Water characteristics

The natural or synthetic water(s) used should be characterized as specified in Table 1. Table 1 should be used to record compositions of both the circulating water and the make-up water, if used. Turbidity, total silica, bacteria and adenosine tri-phosphate (ATP) shall only be measured for on-site waters.

Table 1 — Composition of make-up and circulating cooling water

No.	Component	Value	Units
1	pH, 25 °C		pH units
2	Conductivity		µS/cm
3	Total hardness		[a]
4	Alkalinity – p		[a]
5	Alkalinity – m		[a]
6	Ca^{2+}		mg/l
7	Mg^{2+}		mg/l

[a] Depending on the test method, the unit of measurement is either mmol/L or mg/L.

Table 1 *(continued)*

No.	Component	Value	Units
8	Na^+		mg/l
9	K^+		mg/l
10	NH_4^+		mg/l
11	Fe^{2+}		mg/l
12	Cu^{2+}		mg/l
13	Al^{3+}		mg/l
14	CO_3^{2-}		mg/l
15	HCO_3^-		mg/l
16	Cl^-		mg/l
17	SO_4^{2-}		mg/l
18	NO_3^-		mg/l
19	PO_4^{3-}		mg/l
20	SiO_2		mg/l
21	Cl_2		mg/l
22	Turbidity		FTU or NTU
23	Suspended solids		mg/l
24	Bacteria		Cfu/ml or Cfu/l
25	ATP		RLU

[a] Depending on the test method, the unit of measurement is either mmol/L or mg/L.

5.3 Preparation of synthetic test waters using mother solutions

Synthetic test waters are normally prepared in the laboratory at the time of use by mixing mother or stock solutions. One mother solution contains the alkalinity. The other stock solution contains the hardness and other salts required in the test water. The composition of these two solutions is calculated so that, when the solutions are mixed in the proper proportion, they prepare either the circulating test water or an appropriate make-up water. Typical mother solutions are shown in Table B.1. Alternatively, mother solutions can be prepared as concentrates and subsequently diluted with demineralised water.

6 Apparatus

6.1 Heat exchanger section

The core of the test assembly is the heat exchanger section, which is specified further in 6.2 to 6.7. The inner wall of the heat exchange tube should have no pitting, crack, rust or other obvious defects. The length should be determined according to the need. The test assembly comprises two or more metal heat-transfer tubes, made of the relevant alloy used in the on-site heat exchanger. The heating mode can be steam heat exchange (see Figure B.1) or electric, mounted either in series (see Figure B.2) or in parallel (see Figure B.3). Conduction and convection of heat occurs through the heat-transfer tube wall into the circulating cooling water. The materials of construction of the test assembly shall be chosen so as to not influence the composition of the test water. Glass or plastic (e.g. polyvinyl chloride, chlorinated polyvinyl chloride or polyvinylidene fluoride) is commonly used.

From the cooling water reservoir, the cooling water is pumped through the heat exchanger section at a controlled flow rate. If the heat transfer tubes are mounted in series, only one flow rate controller is required. If they are mounted in parallel, one flow rate controller is required for each heat exchange tube. Through partial evaporation of water in a cooling tower (see 6.4), the heat absorbed is subsequently released to the environment. Alternatively, if a cooling tower is not required to concentrate make-up water, a closed cooling loop to extract heat is used. In order to determine corrosion rates on non-heat-transfer surfaces, corrosion coupons (flush mounted probes) of the relevant metals in the system should be used.