International Standard

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

Part 1: Guidelines and requirements for conducting pilot-scale evaluation of corrosion and fouling control additives for open recirculating cooling water systems

Second edition
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Corrosion des métaux et alliages — Corrosion et encrassement des circuits de refroidissement à eau industriels —

Partie 1: Lignes directrices et exigences pour l'évaluation pilote des additifs anti-corrosion et anti-encrassement pour circuits de refroidissement à eau à recirculation ouverts

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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 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 16784-1:2006), which has been technically revised.

The main changes are as follows:

— the Introduction has been modified;

— normative references have been added;

— Clause 3 has been modified;

— Clause 4 has been modified: the title was changed from "Types of testing" to "General requirements and recommendations" and the latest requirements on environmental protection have been added;

— Clauses 7 and 8 have been combined and content related to new water treatment methods has been added.

— 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

A lot of changes have taken place in the development environment of global industrial enterprises, including advances in related technologies. As the industry grows and competition intensifies, while at the same time more stringent pollution requirements are introduced and water becomes more scarce, businesses have to operate in a safer, greener and more economical way. In many cases, cooling water quality is declining, which leads to higher concentration rates, more corrosion and more susceptibility to scaling.

Cooling water treatment technologies have developed and their use is expanding. Water pollution caused by additives used in cooling system has attracted public attention, and green environmental protection additives have become a new trend in development. Factories need to achieve zero waste water discharge. Cooling water treatments are effective measures for maintaining the best operating efficiency, protect the economic life of equipment, suppress corrosion and prevent scaling, microbial pollution and deposition on various heat transfer surfaces.

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

Part 1: Guidelines and requirements for conducting pilot-scale evaluation of corrosion and fouling control additives for open recirculating cooling water systems

1 Scope

This document specifies general requirements and parameters for the pilot test evaluation of corrosion and scaling control additives in open recirculating cooling water systems. This document covers parameters including test unit design, operation, water quality and contamination. It also covers the design and operation of pilot test devices as well as parameters to be evaluated in pilot test units.

This document covers the criteria that are used in pilot scale testing programmes for selecting water treatment programmes for specific recirculating cooling water systems.

This document is only applicable to open recirculating cooling water systems. It does not apply to closed cooling systems and once-through cooling water systems.

This document applies only to systems that incorporate shell and tube heat exchangers with standard uncoated smooth tubes and cooling water on the tube side. This document does not apply to heat exchangers with shell-side water, plate and frame and/or spiral heat exchangers and other heat exchange devices. However, when the test conditions are properly set up to model the surface temperature and shear stress in more complex heat transfer devices, the test results can predict the results of operating heat exchangers of that design.

The test criteria established in this document are not intended to govern the type of bench and pilot scale testing normally carried out by water treatment companies as part of their proprietary product development programmes. However, water treatment companies can choose to use the criteria in this document as guidelines in the development of their own product development test procedures.

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 8044, *Corrosion of metals and alloys — Basic terms and definitions*

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 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
fouling
deposition of any material on a heat transfer surface

3.2
surface-to-volume ratio
S/V ratio
ratio of the total surface area of metal exposed to water in the cooling system to the total volume of water in the system

4 General requirements and recommendations

4.1 Selection of test methods

4.1.1 Laboratory and off-site testing

Laboratory testing, or testing at alternative off-site locations, can in some cases be necessary for selecting cooling water chemical treatment programmes. This type of testing can be used for new construction start-up programmes, when operating systems are not available, or for evaluating alternative treatment programmes. In such cases, the evaluation should include site-specific design criteria and environmental regulations that affect the cooling water system. Site-specific water supplies should be used whenever possible. All criteria in this document relating to water compositions, water treatment methods (as described in Annex A), test unit configuration, heat exchanger design and operating conditions should be followed insofar as possible.

No laboratory or off-site testing programme can completely duplicate plant conditions. Site-specific factors (e.g. process leaks, microbiological growth, corrosion products, airborne contamination) can affect the operation of cooling water systems and the performance of chemical treatment programmes in ways that override the results of laboratory or off-site testing programmes.

4.1.2 On-site testing

Whenever possible, water treatment programmes should be evaluated on site, using plant water supplies and actual design and operating conditions, particularly those that cannot be duplicated in the laboratory.

4.1.3 Online testing

Whenever possible, all off-site, laboratory and on-site pilot scale testing should be validated by monitoring actual performance results online. Pilot units can be adapted for online work by using a side stream from the plant circulating cooling water as feedwater, bypassing the pilot unit cooling tower. Such online testing validates offline or laboratory tests. Cooling systems can be evaluated online; however, the data collected will be the result of the combination of any existing treatment and all additional chemicals that were added for the evaluation period. Online testing in this way can optimize the treatment programme to meet specific plant requirements. For example, small quantities of a treatment chemical can be added just ahead of the test heat exchanger to measure the effects of increasing additive dosage, or the possible synergistic effects of a new chemical added to the existing treatment programme.

4.2 Cost analysis

Cost analysis of the selected additives should be evaluated according to ISO 22449-2.

5 Test unit design parameters

5.1 General

When designing a pilot-scale evaluation programme for water treatment products, the mechanical design and operation of each cooling water system shall be evaluated. It can be impractical to simulate a specific critical plant heat load or water flow pattern exactly. Contamination cannot develop in the same way in a pilot cooling tower as in the plant systems. Compromises can therefore be necessary. Plant design and operations shall be followed in all such circumstances. Deviations shall be noted in the test reports.

In addition to adding corrosion and scaling control additives to circulating cooling water, some water treatment methods are also commonly used for circulating cooling water treatment, including:

— the lime softening method;

— the ion exchange method;

— the reverse osmosis desalting method;

— the electrochemical treatment method;

— the electromagnetic method;

— bypass filtration methods.

These methods are discussed in 5.4. Specific attention shall be given to the impact of using these methods on additive selection in the design of the pilot unit.

For efficiency, pilot test research can be done on two or more identical test units at the same time.

5.2 Construction materials

5.2.1 Cooling towers

Small cooling tower basins can be made of uncoated, plastic-coated, galvanized low-carbon or stainless steel. Large tower basins are usually concrete. Splash fill can be wood, ceramic or plastic. It is not important that the pilot cooling tower duplicates the design of the plant towers. However, if the plant system contains galvanized steel, galvanized steel should be included as a non-heat-transfer test material in the pilot system.

5.2.2 Film fill

If the plant cooling towers contain film fill, a section of this fill (if available) should be used in the pilot tower. Film fill consists of closely packed layers of lightweight plastic material, normally PVC, arranged in a honeycomb-like structure. This maximizes the surface area over which water flows, and thereby improves evaporation efficiency. However, the increased surface area also encourages deposit formation in the fill.

Deposits can consist of mineral scales formed by the evaporation of water, microbiological deposits and corrosion products and silt carried into the tower. Biofilms tend to act as a glue that encourages other deposits to adhere to the fill. Because the space between adjacent layers of fill is often quite small, deposited material can bridge the fill and block water flow. This is a serious problem, because film fill cannot be cleaned chemically unless water can flow through all parts of the fill.

Mechanical cleaning, including water lancing, often damages the lightweight fill material. In addition, the weight of a significant deposit in the film fill can mechanically damage it. Hence, one performance requirement of any cooling water chemical treatment programme intended for use in a film-fill cooling tower shall be to prevent bridging of the fill.

The condition of the film fill in an operating cooling tower can be monitored using a fill test box. This is a section of fill, a cube with sides of 0,6 m, enclosed in a supporting box that is open at the top and bottom. The box is exposed to droplets of condensation that fall below the fill in the cooling tower, in an accessible location. If the fill surfaces feel slippery, or if there is a visible deposit layer, this indicates fouling conditions in the fill.

A fill test box is a very useful qualitative monitoring tool in an operating cooling tower. However, it can be impractical in a pilot cooling tower due to space and size limitations. It is best to design the pilot cooling tower so that the actual tower fill can be accessed conveniently for visual and physical inspection.

5.2.3 Non-heat-transfer metal surfaces

Circulating water lines can be lined with carbon steel, copper, brass, fiberglass, polyethylene or cement. Unless process-side conditions dictate otherwise, heat exchanger shells are usually made of carbon steel. Bimetallic corrosion shall be avoided.

All corrosion-prone metals that are present in the operating system should be included as non-heat-transfer test coupons in the pilot study. This is important for two reasons. First, localized corrosion of piping systems can lead to unexpected failures. Second, corrosion product deposits can accumulate on heat-transfer surfaces, which can lead to under-deposit corrosion and losses in efficiency. Water treatment chemicals can only provide corrosion protection when the chemicals can reach the metal surfaces. Unprotected metal areas beneath deposits thus become potential sites for under-deposit corrosion.

5.2.4 Heat exchangers

Heat exchanger design is generally focused on process-side requirements and on the actual process involved (liquid cooling, gas cooling or condensing). Process heat exchangers are designed to control the temperature of a process fluid under the most severe expected conditions. That is, the warmest cooling water and the maximum production rate.

Heat exchangers are designed with a built-in fouling factor that allows the unit to produce the desired process temperature control with some loss of efficiency due to either water- or process-side fouling of the tubes. For these reasons, process heat exchangers are often oversized. To achieve the desired process-side outlet temperature control, operators throttle the water flow in response to ambient conditions, production demands and the degree of fouling in the heat exchanger. Reducing the water flow rate through the tubes increases the surface temperature and allows suspended solids to settle on the tube surfaces and mineral scale deposits to form. This leads to losses in heat-transfer efficiency and increased opportunities for corrosion of the tubes. See also 9.3.1.

NOTE The terms "fouling factor" and "fouling thermal resistance" refer to the measured resistance to heat transfer caused by a deposit on a heat-transfer surface. The fouling factor is also used in heat-exchanger design to increase the heat-exchanger surface area to compensate for thermal inefficiency caused by a deposit on the heat-transfer surface. The term "fouling factor" is commonly used for both. However, "fouling thermal efficiency" can be substituted for the measured fouling factor.

One very important function of the chemical water treatment programme is to minimize corrosion and deposit formation of all kinds on heat exchanger surfaces. In designing a pilot-scale testing programme, one critical set of parameters involves the configuration of the heat-transfer section. Heat-transfer tubes can be made of carbon steel, copper, copper alloys or stainless steels. If required in petrochemical plants or other locations with severe process-side conditions, heat-transfer tubes can include a wide variety of other alloys and a few non-metallic materials.

Care should be taken when selecting the heat exchanger to be modelled. The most appropriate heat exchanger has a combination of the highest surface temperature and the lowest velocity, within reason. Some judgment is required in the selection process.

Petrochemical plants sometimes include vertically oriented shell-and-tube heat exchangers. Because of process requirements, water is often on the shell side in such exchangers. Shell-side water creates particularly severe corrosion and fouling problems that cannot be satisfactorily simulated in the type of pilot-scale equipment covered by this document. This is especially true of vertical shell-side water heat exchangers.

Many plant heat exchangers include multi-tube and multi-pass designs. Such designs are difficult to simulate in a pilot-scale unit. This document refers to single-tube, single-pass designs with parameters selected to simulate the conditions under study in the plant exchanger.

5.3 Measuring instrument

Online testing instruments shall be used to test the changes of parameters during the experiment, including but not limited to: temperature, pressure, flow rate, conductivity, pH, online corrosion rate test instrument.