
**Accelerated life test method of mixed
metal oxide anodes for cathodic
protection —**

**Part 1:
Application in concrete**

*Méthode d'essai accéléré de durabilité des anodes à oxydes
métalliques mixtes pour la protection cathodique —*

Partie 1: Application dans le béton

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Contents

	Page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Test method	2
4.1 Principle	2
4.2 Test solutions	2
4.2.1 General	2
4.2.2 Sodium chloride (NaCl) solution	2
4.2.3 Sodium hydroxide (NaOH) solution	3
4.2.4 Simulated pore water in sand	3
4.2.5 Other testing solutions	3
4.3 Test apparatus	4
4.4 Test specimens	4
4.5 Test conditions	5
4.6 Continuity of tests	7
4.7 Treatment of specimens after test	7
5 Reporting test results	8
6 Application of results	8
Annex A (informative) Typical apparatus for accelerated life test	9
Annex B (informative) The typical testing results of mixed metal oxide anode	11
Bibliography	14

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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 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

A list of all the parts in the ISO 19097 series can be found on the ISO website.

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Introduction

Impressed current cathodic protection (ICCP) is an effective method to control corrosion of metallic structures immersed in seawater, brackish water and fresh water or buried in soil. ICCP is also widely applied to prevent steel reinforcement in concrete from corrosion in marine or other chloride contaminated environment.

Mixed metal oxide (MMO) anodes have been widely taken as impressed current anodes in the ICCP system due to their good electrocatalytic activity, low consumption rate, long service life, light weight, malleability, high ratio of performance to cost, and wide suitability for different electrolytes.

Durability is one of the most important properties of MMO anodes. ISO 19097 (all parts) examines the accelerated life test method of MMO anodes for cathodic protection to evaluate the anode's ability to achieve an expected lifetime. The accelerated lifetime can also be used to compare the stability of different MMO anodes. This document is applicable to MMO anodes intended for use in concrete. This method is not intended to give the exact service life of the anodes in the practical applications, but to provide users and manufacturers of MMO anodes a way to evaluate whether the designed life expectancy can be achieved.

Large portions of this document were derived from NACE International Standard TM0294-2016^[1].

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Accelerated life test method of mixed metal oxide anodes for cathodic protection —

Part 1: Application in concrete

1 Scope

This document specifies accelerated life test method of mixed metal oxide anodes for impressed current cathodic protection used in concrete. The accelerated life test results can be used to compare the durability of the anodes and to evaluate whether the anodes can comply with required specifications of design life expectancy at rated current output.

This document is also applicable to other anode systems that are used as impressed current anodes embedded in concrete with suitably modified apparatus to hold anodes of different geometry.

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 679, *Cement — Test methods — Determination of strength*

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

ISO 19097-1:2018

<https://standards.iso/aaa2faa9-2a42-4119-9f63-7ada95426eb2/iso-19097-1-2018>

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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

mixed metal oxide anode

impressed current anode for cathodic protection consisting of conductive coating of mixed metal oxides formed on titanium substrate

Note 1 to entry: The most common mixture used for cathodic protection is iridium oxide and tantalum oxide. Exact compositions may vary.

3.2

accelerated life

lifetime of *mixed metal oxide anode* (3.1) under accelerated testing conditions, usually in the specific electrolyte applied with large current density

Note 1 to entry: The total period of testing until the deactivation of the mixed metal oxide anode is taken as the accelerated life.

3.3

cell voltage

voltage between anode and cathode in a single cell

3.4

charge density

product of applied current density multiplied by operating time

3.5

ripple

alternating current (AC) component in the output of a direct current (DC) power supply, arising within the power supply from incomplete filtering or from commutator action in a DC generator

4 Test method

4.1 Principle

The accelerated life testing of mixed metal oxide anode is conducted in specific simulated environments at a much higher current density than experienced in usual working conditions. This can shorten the period of time to deactivation of the anode significantly.

This document includes two parts of a test method for evaluating the anode material.

Test Method Part A is designed to evaluate whether the mixed metal oxide anode material can meet an expected lifetime criterion. It is possible that an anode may suffer from current reversal caused by erroneously connecting as a cathode or other reasons during the initial stage in practice. Therefore, current reversal testing should be conducted for a period of time before the later testing to ensure the ability of the anode to survive a brief current reversal.

Test Method Part B is a quicker test to ensure that a sample from a particular batch of anode material is suitable. It shall only be conducted on samples of a product that has passed Test Method Part A for the required design life.

ISO 19097-1:2018

4.2 Test solutions

4.2.1 General

Accelerated life testing cannot be conducted in concrete because testing at high-current levels results in premature failure of the concrete as the test electrolyte. Accelerated life testing shall therefore be conducted in an aqueous solution. The following clauses give instructions for the preparation and use of the simulated concrete electrolyte in Test Method Part A, and test solutions in Test Method Part B. All the chemicals used are reagent grade and water is distilled or deionized. All the solutions shall be freshly prepared for each test.

4.2.2 Sodium chloride (NaCl) solution

A mass of $30,0 \text{ g} \pm 0,1 \text{ g}$ sodium chloride shall be added to a 1,0 l volumetric flask, then about 500 ml of distilled or deionized water added to the above. The solution shall be swirled in the flask until the NaCl crystals are totally dissolved. More distilled or deionized water shall be added to the level of the 1,0 l mark in the flask to produce a concentration of 30 g/l NaCl solution. The solution shall be thoroughly mixed.

In the cathodic protection for reinforced concrete structures like bridge piers and pilings in marine or chloride contaminated environment, the mixed metal oxide anode is exposed to the solution containing chloride ions. So sodium chloride solution is used to simulate these environments and test the ability of the mixed metal oxide anodes to tolerate chlorine evolution reaction.

4.2.3 Sodium hydroxide (NaOH) solution

An amount of $40,0 \text{ g} \pm 0,1 \text{ g}$ sodium hydroxide shall be slowly added to a 1,0 l volumetric flask containing approximately 500 ml of distilled water or deionized water. The solution shall be swirled until the NaOH is totally dissolved. This reaction is exothermic and generates heat. More distilled water or deionized water shall be filled in the flask just under the 1,0 l level and the solution shall be left to cool to room temperature. Finally, the flask shall be filled to the 1,0 l mark with distilled water or deionized water to form the solution of 40 g/l NaOH. The solution shall be thoroughly mixed.

In new reinforced concrete, the pH of electrolyte solution is high with little contamination of chloride in the environment. This solution is used to simulate actual environment in new concrete and to measure the ability of the anode to tolerate oxygen evolution reaction, which is more favoured at low level of chloride contamination experienced with fresh overlays.

4.2.4 Simulated pore water in sand

A mass of $26,3 \text{ g} \pm 0,1 \text{ g}$ sodium hydroxide, $10,74 \text{ g} \pm 0,1 \text{ g}$ potassium hydroxide, $34,35 \text{ g} \pm 0,1 \text{ g}$ potassium chloride and $2,15 \text{ g} \pm 0,01 \text{ g}$ calcium hydroxide shall be dissolved in 1,0 l of distilled water or deionized water one by one in a flask, stirred until no solid left to form the simulated concrete pore solution. The composition by mass of the simulated pore water used shall be as follows:

- a) 0,20 % $\text{Ca}(\text{OH})_2$;
- b) 3,20 % KCl;
- c) 1,00 % KOH;
- d) 2,45 % NaOH;
- e) 93,15 % distilled or deionized water.

Fine natural silica sand ($270 \text{ } \mu\text{m}$ to $380 \text{ } \mu\text{m}$) shall be obtained in accordance with ISO 679. The test cell shall first be filled with enough sand to cover the anode completely after the electrodes and Luggin probe are in place. The simulated pore water shall then be added to displace any air and fill the remainder of the cell.

The electrolyte available to the embedded mixed metal oxide anode in a cured concrete structure is pore water. This solution tests the ability of the anode to tolerate the actual concentrations of the pore water components and any possible synergistic effects imposed by these components. The use of fine sand to encompass the electrode, eliminating convective mixing, tests the ability of the anode to tolerate the situation most closely simulating its operation in cured concrete.

4.2.5 Other testing solutions

The composition of the electrolyte used for Test Method Part B shall be suitable to force the reaction of oxygen evolution at the anode. The ionic concentrations shall be suitable to provide sufficient conductivity in the solution to avoid excessive voltage requirements for the power supply.

Some suitable solutions are as follows:

- 1 M sulfuric acid (H_2SO_4);
- 1 M sodium sulfate (Na_2SO_4);
- 180 g/l sodium sulfate with 0,1 N sulfuric acid to maintain pH at 1.

4.3 Test apparatus

NOTE A schematic diagram of test apparatus is shown in [Annex A](#).

4.3.1 The test cell shall be a tall-form glass 1,0 l beaker fitted with a rubber stopper at the top to hold the electrodes and reduce air contact. Glass beakers of other sizes may be used as long as electrodes remain immersed for the duration of the test. The gap between the anode and cathode shall be approximately 50 mm. The rubber stopper shall have a hole located midway between the electrodes that is fitted with an extension tube to vent gases away from the electrical connections. This hole may be used to locate the current reverse supplemental anode and Luggin probe. There shall be an additional hole large enough to measure pH of the test solution. A typical setup for a test cell taking a reference electrode with Luggin probe for anode potential measurement is shown in [Annex A](#).

4.3.2 A sample of the anode having 2 000 mm² of anode surface area shall be used. The anode surface area shall be calculated by including all the active surfaces that will be in contact with concrete when embedded. The anode sample shall be welded to a 1,6 mm diameter x 203 mm long Ti rod in two spots as shown in [Figure A.1](#). The Ti rod acts as the current carrier. For other types of anodes, an appropriate anode connection shall be made in accordance with the anode manufacturer's recommendations. The anode shall be connected to the positive lead (the negative lead during the current reversal test) of the power supply external to the cell using an insulated 1 mm diameter copper wire with a copper spring-loaded clip with jaws.

4.3.3 The cathode shall be a 12,7 mm diameter x 200 mm long Ti rod. Other shape of cathode like Ti plate with enough surface area may also be applicable. Alternatively, relatively inert cathodes such as platinum or niobium or zirconium may also be used. The cathode shall be fitted through the rubber stopper and extended to approximately 10 mm from the bottom of the cell. The cathode shall be connected to the negative lead of the power supply (not connected during the current reversal test) external to the cell using an insulated 1 mm diameter copper wire with a copper spring-loaded clip with jaws.

4.3.4 A supplemental anode is required for the current reversal portion of the testing. This anode shall be identical to the one being life tested and shall be referred to as the current reversal (CR) anode. The CR anode should be installed midway between the cathode rod and the anode to be life tested. During the current reversal test, the CR anode shall be connected to the positive lead of the power supply external to the cell using an insulated 1 mm diameter copper wire with a copper spring-loaded clip with jaws or similar type fastener. The CR anode shall be removed from the cell during normal testing.

4.3.5 The DC power supply shall be a constant current control type filtered with a maximum ripple of 5 %. One power supply can also energize several electrolytic cells connected in series at the same time. The required voltage depends on the testing current and the number of test stations in series that may be used. Typically, 8 volts per cell times the number of cells in series is sufficient.

4.3.6 [Figure A.2](#) illustrates a typical setup for a series electrical hookup for duplicate evaluations.

4.3.7 A voltmeter shall be used to measure the anode potential and the voltage of each cell at the specified intervals. The voltmeter shall have a high input impedance of 10 MΩ or greater and shall be capable of measuring cell voltage with an accuracy of ±1 %. A data logging voltmeter may also be used.

4.4 Test specimens

4.4.1 The number and type of test specimens shall be selected according to the specifications for the anode material or product being tested. To ensure the accuracy of the data, at least two duplicate specimens of each anode shall be tested in the separate cells under identical operating conditions.