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Corrosion of metals and alloys — Guidelines for corrosion testing in simulated environment of deep-sea water

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Foreword

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

Introduction

Corrosion is a crucial problem for subsea equipment and systems for oil/gas production, environmental observation, and scientific exploration due to exposure in deep-sea water. Guidelines for corrosion testing of metals and alloys exposed in deep-sea water have been given in ISO 23226.

This document gives guidance on the corrosion testing of metals and alloys in the simulated environment of deep-sea water, including testing apparatus, specimen preparation, testing procedure, evaluation after test and test report. Thereby, the testing can be conducted based on the specified conditions and procedures, and the meaningful comparisons may be made for different tests.

This document applies to the immersion testing of specimens related to general corrosion and localized corrosion, stress corrosion cracking (SCC) testing and electrochemical testing in the simulated environment of deep-sea water in the laboratory.

Corrosion of metals and alloys — Guidelines for corrosion testing in simulated environment of deep-sea water

1 Scope

This document gives guidelines on the corrosion testing of metals and alloys in a simulated environment of deep-sea water, including principle, testing equipment, specimen preparation, testing procedure and evaluation after test. This document applies to the immersion testing, corrosion testing under stress condition, and electrochemical testing in the simulated environment of deep-sea water in the laboratory.

Testing of other materials such as composites and elastomers can also be carried out in the simulated environment of deep-sea water with reference to these guidelines, but the evaluation of these materials after the testing is different from that of metals and alloys.

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 — Vocabulary*

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
deep-sea
sea water zone with depth generally ranging from 200 m to thousands of meters

Note 1 to entry: Deep-sea has a corrosive environment with parameters such as temperature, salinity, dissolved oxygen content and hydrostatic pressure of sea water quite different from those in surface sea water.

3.2
simulated environment
environment for which the main corrosion factors are simulated

4 Principle

This document provides guidelines on corrosion tests in a simulated environment of deep-sea water using a suitable apparatus. The apparatus should be able to form a corrosive environment similar to the practical deep-sea water. The main environmental factors should include at least hydrostatic pressure, temperature, dissolved oxygen content, and compositions of deep-sea water.

The immersion testing of metals and alloys in a simulated environment of deep-sea water for specimens with or without applied stress can be conducted using the apparatus. Electrochemical testing, galvanic corrosion measurement and slow strain rate testing for stress corrosion cracking under tensile condition can also be carried out when the apparatus is modified with these functions.

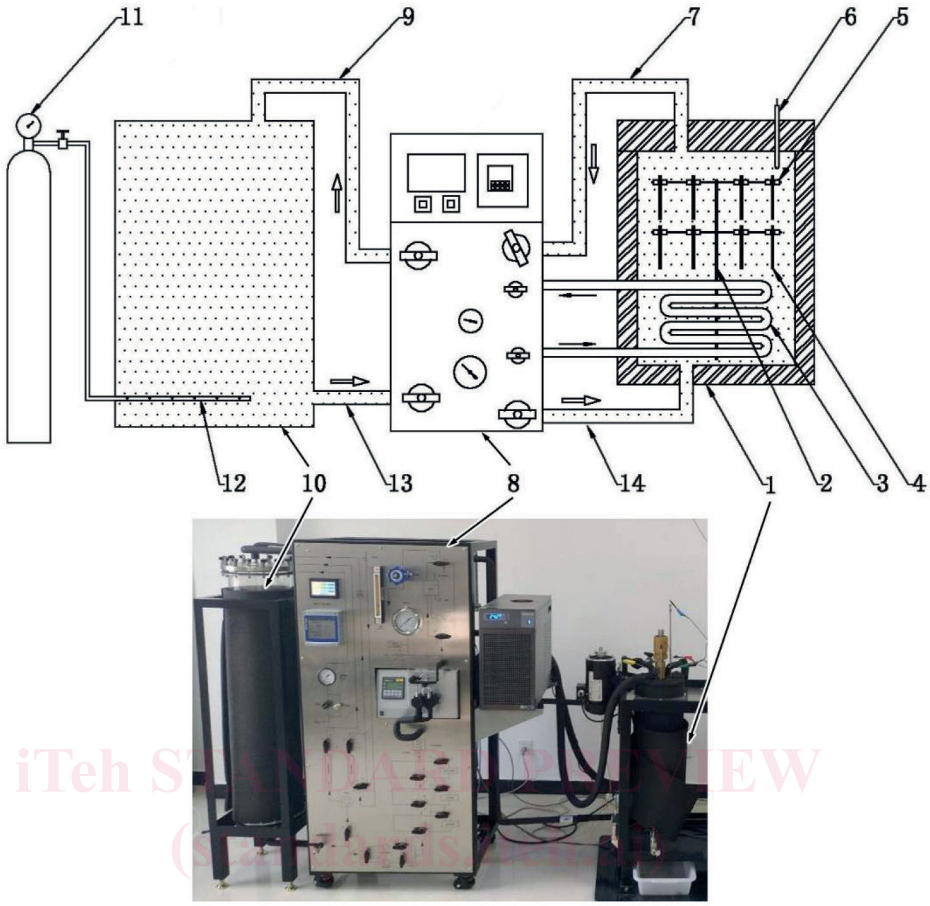
5 Testing equipment

5.1 General

5.1.1 The corrosion tests are carried out in a special testing apparatus which should be capable of simulating deep-sea corrosive environment.

5.1.2 The significant environmental factors affecting corrosion behaviours of metals and alloys should be included in the simulated deep-sea environment.

5.1.3 At least a test chamber, an environment controlling system, and an experimental system should be included in the corrosion test apparatus of simulating deep-sea environment. The schematic diagram of a typical test apparatus and an actual test setup are shown in Figure 1.



Key

1 test chamber
2 specimen support
3 cooling coil
4 specimen for immersion test
5 insulating sleeve
6 environmental factor monitoring components
7 chamber outlet pipe
8 environment controlling system
9 reservoir inlet pipe
10 reservoir
11 nitrogen or oxygen gas
12 aeration pipe
13 reservoir outlet pipe
14 chamber inlet pipe

Figure 1 — Schematic diagram of apparatus and actual setup for simulated deep-sea environment corrosion test

NOTE The placement of specimens shown in the test chamber is just for the demonstration of different corrosion test functions. Different tests that may have interference with each other should not be conducted in the test chamber at the same time.

5.1.4 All parts of the apparatus exposed to the test solution should be made of inert material which is corrosion resistant in the test environment to avoid contaminating the test solution and consumption or absorption of solute by the material of the apparatus. The recommended materials include non-metallic materials, such as UPVC, PTFE and metallic materials, such as titanium alloy, Hastelloy alloy, and stainless steel with high corrosion resistance.

5.2 Test chamber

5.2.1 The volume of test chamber should be appropriate to hold test specimens and solution, and to guarantee a uniform environmental condition.

5.2.2 The structure and components of the test chamber should have sufficient pressure rating to withstand the test pressure. The safety instructions with the test chamber as pressure container are given in section 5.5.

5.2.3 The inlet and outlet pipes connecting to the test chamber are used to establish a test solution recycling and environment controlling system.

5.2.4 For in situ electrochemical corrosion testing, connecting interface for electrochemical workstation should also be included, and the cables and connectors inside and through the test chamber should have adequate pressure bearing capability and water tightness.

5.3 Environment controlling system

5.3.1 The test solution conditions including hydrostatic pressure, temperature, dissolved oxygen content, etc. are monitored and controlled by the environment controlling system. It is reasonable to apply additional reservoir to store the test solution and to facilitate the adjustment of test solution conditions (excluding pressure) before injecting solution into the test chamber. The volume of the reservoir should be not less than twice that of the test chamber.

5.3.2 The high-pressure pump should be used to control the solution pressure in the test chamber and realize the solution circulation. The circulation rate of the solution can be determined according to the chamber volume and the test pressure. The pressure in the test chamber should be monitored throughout the test by installing pressure gauges or sensors.

5.3.3 The temperature of the test solution is adjusted by the installation of the condensing cooling coil in the test chamber to simulate the deep-sea low temperature conditions. The installation of condensing cooling coil in the reservoir is also applicable. Thermal preservation measures should be taken for the whole solution circulation system, for example, wrapping the outer walls of the test chamber, the reservoir, and the pipes with thermal insulation materials. The solution temperature in the test chamber should be monitored and controlled within ±1 °C of the set value.

5.3.4 The dissolved oxygen content of the test solution should be adjusted by injecting nitrogen or oxygen gas into the reservoir before solution circulation. During the test, the dissolved oxygen content should be monitored and adjusted accordingly.

5.3.5 If other conditions of the solution need to be controlled, such as salinity, pH value, etc., it is also advisable to adjust them in the reservoir before solution circulation according to the practical deep-sea environment to be simulated.

5.4 Experimental system

5.4.1 Specimen support in the chamber

The specimen support should be made of corrosion-resistant metal or non-metallic material, and the shape and size of specimen support should be specified according to the volume of the test chamber and the test requirement.

For general immersion test, the specimens should be placed in the test chamber with support.

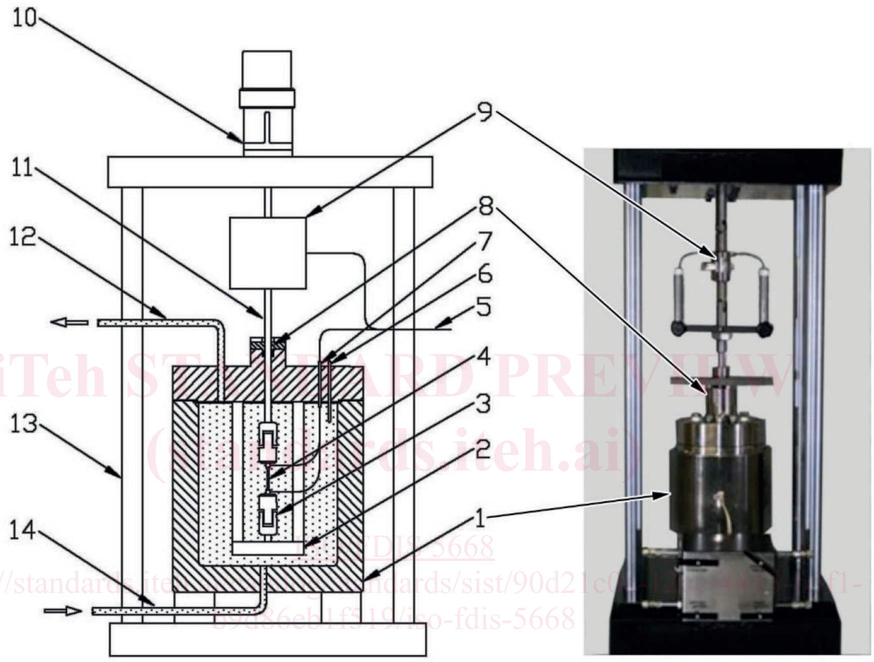
For crevice corrosion test, the crevice formers specified in ISO 18070 and ASTM G78 can be used.

For stress corrosion cracking test of constant load/displacement, the preloaded specimen in the loading jig should be used.

The above-mentioned specimen and assembly can be installed on the support by hanging or bolt fixing, and the insulation between the support and the specimen should be made to eliminate galvanic effect. In the multi-specimen test, sufficient spacing should be reserved to avoid the interference between specimens.

5.4.2 Loading device of slow strain rate tensile test

For stress corrosion cracking test under tension at a slow strain rate, a loading device can be added in the test chamber as shown in Figure 2.



Key

1 test chamber
2 loading frame
3 loading jig
4 specimen
5 connection cable for load and displacement measuring devices
6 series of environmental monitoring components
7 penetration gland
8 sealing mechanism
9 load and displacement testing device
10 loading motor
11 tension rod
12 test chamber outlet pipe
13 support bench
14 test chamber inlet pipe

Figure 2 — Schematic diagram and actual setup of simulated deep-sea environment test chamber with dynamic loading device

The loading frame, loading jig and tension rod of the loading device should be able to withstand the applied stress. For the sealing design of the bulkhead of the test chamber, the maximum rated pressure of the apparatus should be considered.

The connection part between the end cap of test chamber and the tension rod must be sealed to ensure no leakage under test pressure, but the sealing treatment should not affect the normal movement of tension rod.

Load and displacement measuring devices shall be provided on the loading device for real-time testing of the stress and strain of the specimen. When calculating the actual load of the specimen, the effect of