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

*Corrosion des métaux et alliages — Lignes directrices et recommandations relatives aux essais de corrosion dans l'environnement simulé des eaux profondes*



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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*.

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

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 provides guidelines and requirements for the corrosion testing of metals and alloys under the conditions of simulating the environment of deep-sea water. Thereby, the testing can be conducted based on the specified conditions and procedures, and the meaningful comparisons can 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 and requirements for corrosion testing in simulated environment of deep-sea water

## 1 Scope

This document provides guidelines and requirements for the corrosion testing of metals and alloys in the 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 this document, 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 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**
**deep-sea water**
sea water zone with a depth generally ranging from 200 m to thousands of meters

Note 1 to entry: Deep-sea water has a corrosive environment with parameters such as temperature, salinity, dissolved oxygen content, microorganism and biofouling that are 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 and requirements on corrosion tests in the 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 the 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.

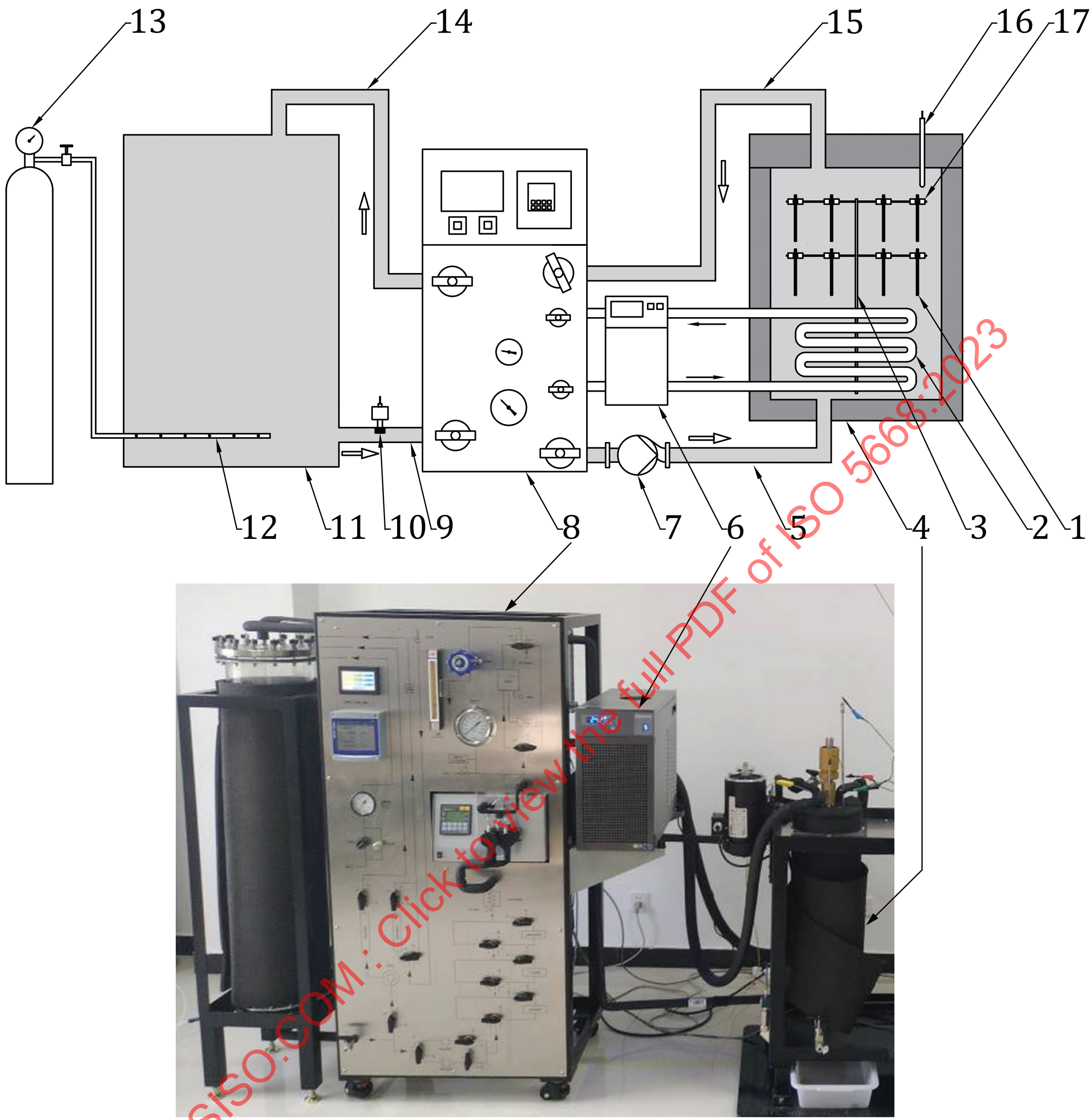
# 5 Testing equipment

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






**Key**

| | | | |
|---|---|---|---|
| 1 | specimen for immersion test | 10 | probe for dissolved oxygen and/or other electrolyte factors |
| 2 | cooling coil | 11 | reservoir |
| 3 | specimen support | 12 | aeration/deaeration pipe |
| 4 | test chamber | 13 | oxygen or nitrogen gas |
| 5 | chamber inlet pipe | 14 | reservoir inlet pipe |
| 6 | chiller | 15 | chamber outlet pipe |
| 7 | high-pressure pump | 16 | pressure sensor and temperature sensor (thermoprobe) |
| 8 | environment controlling system | 17 | insulating sleeve |
| 9 | reservoir outlet pipe | | |

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

**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 the 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 a pressure container are given in 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, a connecting interface for electrochemical workstation should 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 the 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 a pressure gauge or sensor as shown in Figure 1.

**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 by a thermoprobe 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. The dissolved oxygen content in the testing solution can be measured using an electrochemical probe method as specified in ISO 5814.

**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 the specimen support should be specified according to the volume of the test chamber and the test requirements.

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

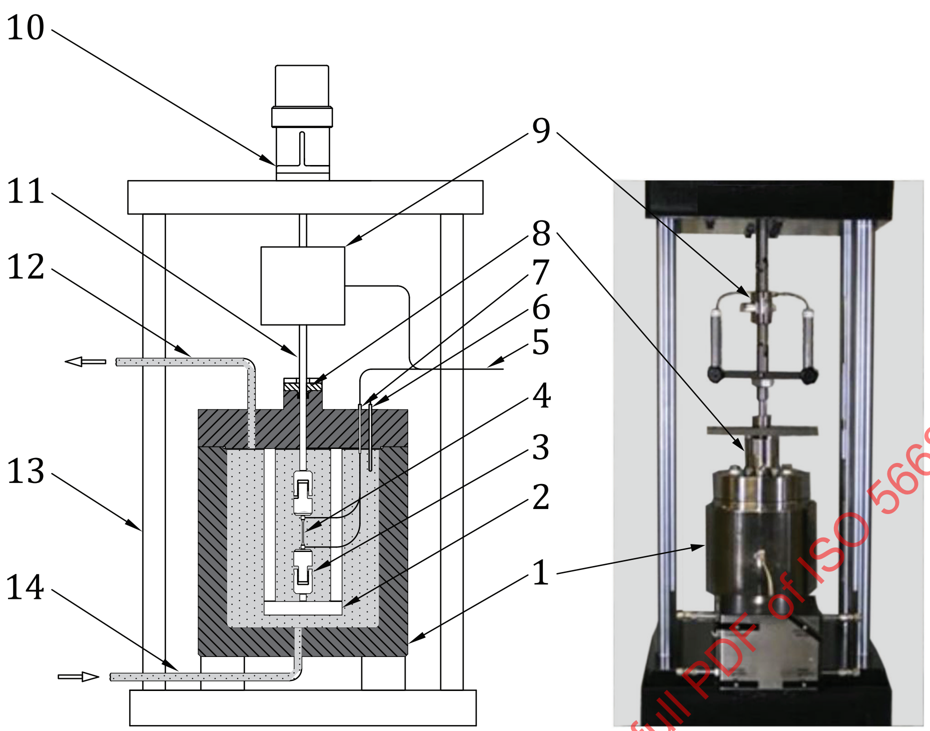
For crevice corrosion test, the crevice formers specified in ISO 18070 and ASTM G78 can be used.

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

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



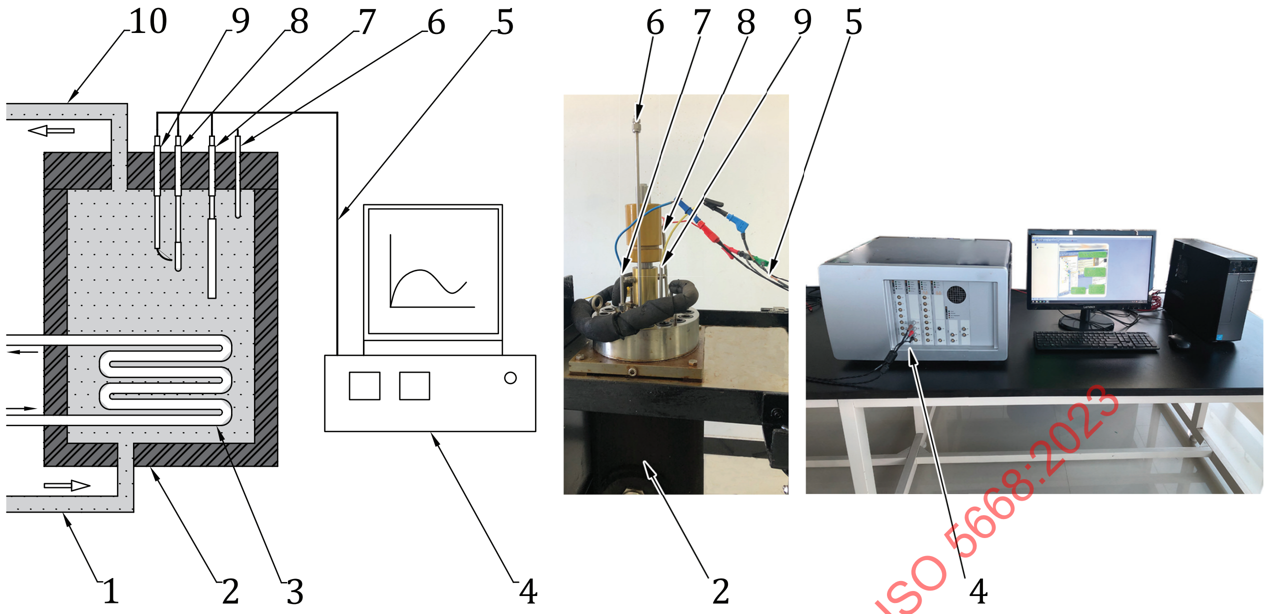
The loading frame, loading jig and tension rod of the loading device should be able to withstand the applied stress. For the sealing design of the bulkhead of the test chamber, the maximum rated pressure of the apparatus should be considered.

The connection part between the end cap of the 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 the 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 hydrostatic pressure and the friction force of the sealing structure on the tension rod should be fully considered. In practical, the actual load is obtained after reducing the load measured without specimen under the same conditions of strain rate and hydrostatic pressure as the case of applying specimen.

### 5.4.3 Electrochemical test system

The electrochemical test system in the simulated deep-sea water consists of a typical three-electrode cell, an external electrochemical workstation, cables and connectors. The schematic diagram of the test chamber for electrochemical test and an actual test setup are shown in Figure 3.




**Key**

1 chamber inlet pipe
2 test chamber
3 cooling coil
4 electrochemical measurement instrument
5 cables
6 series of environmental monitoring components
7 auxiliary electrode
8 work electrode
9 reference electrode
10 chamber outlet pipe

**Figure 3 — Schematic diagram and actual setup of simulated deep-sea environment test chamber for electrochemical test**

The specimen is used as a work electrode. The preparation of the work electrode is described in 6.5. The auxiliary (counter) electrode is commonly made of platinum or other suitable inert material in the form of a sheet or rod. The area of the auxiliary electrode should be at least the area of the working electrode. A solid-state reference electrode such as Ag/AgCl solid electrode should be applicable in the simulated deep-sea water. The information of Ag/AgCl electrode used in sea water can refer to ISO 12473. The performance of the reference electrode should be examined and calibrated at ambient pressure in the same solution as the simulated deep-sea water prior to the tests. The temperature coefficient of the reference electrode should be considered in the simulated deep-sea environment. The measured potentials should be converted to the values vs. a standard reference electrode (for example, Ag/AgCl with saturated KCl) in report.

The working electrode, auxiliary electrode and reference electrode should be able to withstand the hydrostatic pressure. The connecting point of the electrode to the cable or connector when exposed in the test chamber should be insulated reliably, and the interfaces of the electrodes through the test chamber should be sealed thoroughly in order to meet the requirement of high-pressure conditions.

For galvanic corrosion test, the couple can be connected to the electrochemical instrument to measure the galvanic current and the coupled potential.

Commercially available electrochemical workstations can be used for electrochemical testing. The instrument should meet the requirement specified in ISO 17475.

## 5.5 Safety instructions

**5.5.1** As the test involves high pressure, the test equipment should be equipped with necessary safety devices, e.g. blasting-proof disc/valve, emergency cut-off button, pressure monitoring instrument.

**5.5.2** The test equipment should be calibrated or checked regularly, especially pressure instrument and sealing system to ensure safety. Regular removal of corrosion products should also be exercised manually or by applying filtration device to prevent corrosion products from blocking pumps and valves.

**5.5.3** It is recommended to maintain the pressure in the test chamber by pumping using the test solution as the working fluid. The test gas should not be injected directly into the test chamber to maintain the pressure as far as possible, but the gas content in the test solution should be pre-adjusted in the reservoir. Tests that can produce a large amount of gas should not be allowed using this test equipment.

**5.5.4** The operator should use the equipment in strict accordance with the operating rules. It is strictly forbidden to open the test chamber when the pressure is not relieved.

**5.5.5** This document does not address all the safety concerns associated with its use. The user of this document has the responsibility to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.



# 6 Specimens

## 6.1 General

**6.1.1** In the simulated deep-sea environment, commonly used corrosion test specimen includes immersion test specimen (see 6.2), crevice corrosion specimen (see 6.3), stress corrosion cracking specimen (see 6.4), electrochemical specimen (see 6.5), and other type of specimen (see 6.6). Coated specimens or small-scale structural specimens may also be used.

**6.1.2** In principle, only specimens of the same type of material should be tested in the test chamber at the same time to avoid interference from dissolved ions and products unless it is required to test the interaction of different materials. Except for galvanic corrosion tests, no metallically conducting connection should exist between the specimens themselves. Insulation should also be kept for the specimens from the test chamber and the metal support.

**6.1.3** Specimens should be marked for identification. Drilled holes, edge notches, stamped codes or other appropriate methods can be used for this purpose. The marking methods and positions should not influence the corrosion testing of the specimens. The marks should be clear to be distinguished during the whole testing process without being faded by corrosion or other factors.

**6.1.4** The number of specimens should be determined according to the type of corrosion test, the nature of test material or the specific requirements. Typically, three or more replicated specimens are suggested in each test.

## 6.2 Immersion test specimen

**6.2.1** Specimens used for immersion test should be prepared according to the purpose and requirement of the corrosion test, which can refer to ASTM G1 and ASTM G31.

**6.2.2** The shape of the specimen depends on the objective of the corrosion test and the type of corrosion expected. Generally, specimen in the form of plate should be used. Specimens of other shapes, such as bar or tube, can also be used if required.

**6.2.3** The dimensions of the specimen vary with the purpose of the test, the nature of the material, and the volume of the test chamber. Typically, the flat specimen with a dimension of 50 mm × 20 mm × (2~4) mm is recommended. A small hole of 5 mm or less in diameter can be machined at one end of the specimen for fixing. If localized corrosion is likely to occur, specimens of sufficient thickness for determination of the depth of attack should be used.

**6.2.4** When evaluating the effect of welding on corrosion, welded specimens should be used. Usually, the specimen should contain weld seam, heat affected zone (HAZ) and parent metal, the area of the parent metal at either side of the weld should each be at least twice the weld area. The specimens taking from weld seam, HAZ and parent metal should also be tested, respectively.

**6.2.5** The test specimen should be prepared preferably by machining. The surface condition of the specimen should meet the test requirements. The original surface can be maintained for the specimen if the effect of original surface should be tested. When specimens are cut by shearing or other cutting method, the deformed or metallurgically affected metal should be removed by machining or grinding prior to testing unless the corrosion resistance of the sheared edges is going to be tested. It is a good practice to remove affected edges to a distance equal to the thickness of the specimens. A uniform layer of metal should be removed from the specimens to eliminate variations in condition of the original metallic surface, which can be conducted by chemical treatment (pickling), electrolytic removal, or by grinding with abrasive paper, taking care not to work harden the surface.

**6.2.6** The dimensions of the specimen should be measured to determine the total exposed area for testing. The measurement of geometric area accurate to ±1 % is usually adequate. Each specimen should be weighed to the accuracy of 0,001 g or better after complete cleaning and drying, and then stored in a desiccator until ready for use.

## 6.3 Crevice corrosion specimen

**6.3.1** Crevice corrosion specimens can be prepared according to ISO 18070 and ASTM G78. Both flat specimens and tubes can be used. Generally, the exposed area of the specimen should be at least 100 $cm^2$ or as required.

**6.3.2** Square flat specimen with a centre hole of 7 mm in diameter is preferred. For tubular specimen, the length of the tube should be at least 30 mm and a through hole of 7 mm in diameter in the middle of the tube should be drilled. For hanging specimen during the test, a small hole can be drilled at one end of the specimen.

**6.3.3** Crevice corrosion specimens should be installed on a crevice former which is used to form crevice structure with specified size on the specimen surface. The typical crevice former and its assembly can be found in ISO 18070 and ASTM G78.

## 6.4 Stress corrosion cracking specimen

**6.4.1** The type and loading mode of stress corrosion cracking specimen should be determined on the test purpose and the nature of the testing material. The preparation of the commonly used stress corrosion cracking specimens can be referred to the related parts of ISO 7539 and ISO 16540.

**6.4.2** Self-loading test specimens are recommended as a priority, such as three-point bending and four-point bending specimens with reference to ISO 7539-2, U-type bending specimens referred to ISO 7539-3, C-ring specimens with reference to ISO 7539-5, constant displacement pre-crack specimens including modified wedge opening loaded (WOL) specimens and double cantilever beam (DCB) specimens as referred to in ISO 7539-6.

**6.4.3** When uniaxial tensile specimens given in ISO 7539-4, constant load pre-crack specimens described in ISO 7539-6, dynamic loading pre-crack specimens referred to in ISO 7539-9 and slow strain rate tensile specimens shown in ISO 7539-7 are used, it is necessary to consider the loading conditions of the specimens, as well as the insulation method between specimen, loading jig and test chamber.

**6.4.4** The anisotropy of the material should be considered when sampling from the bulk material. Normally, the grain orientation, machining direction of the material will have a significant influence on the test results. The loading state of the specimen should be consistent with that in the practical use.

**6.4.5** Specimens with possibly large size are preferred to make the test representative, and to reduce the edge effect and measurement error of the test at the same time.

**6.4.6** The corrosion and the crack initiation are most influenced by the surface condition of the specimen. Unless otherwise specified, the surface of the specimen should be clean and smooth, and the surface state should be identical in duplication test.

**6.4.7** The original mechanical properties should preferably be tested on specimens used for evaluating the effect of corrosion on mechanical properties.

**6.4.8** For the test of stress corrosion of weldments, the welded specimens should be prepared with reference to ISO 7539-8.

**6.4.9** For the evaluation of hydrogen embrittlement or hydrogen induced cracking, the sampling method and specimen preparation should follow ISO 7539-11.

## 6.5 Electrochemical test specimen

**6.5.1** In order to carry out a conventional electrochemical measurement of a specimen electrode in the simulated deep-sea water, an experimental set-up should be composed of a working electrode, an auxiliary electrode and a reference electrode (see 5.4.3).

**6.5.2** The working electrode (specimen) is usually in the form of a rod or sheet, which should be mounted in such a way that the holder and mounting material have no influence on the measurement. A special precaution should be taken to prevent crevice attack for certain applications. The specimen should be sealed with epoxy resin or other method, leaving only an exposed work area and reliably enough to withstand the high hydrostatic pressure. The exposed surface area of the specimen should be measured accurately.

**6.5.3** The specimen should be prepared with a well-defined surface finish according to the application. In most cases, the surface roughness *R*a with a value of less than 1 µm should be desirable. Prior to test, the specimen should be cleaned, degreased, rinsed and dried.

**6.5.4** The electrical connection or soldered point between the specimen and the connector or cable should be sealed completely, with no damage even under the testing water pressure.

## 6.6 Other type of specimen

**6.6.1** For galvanic corrosion test in simulated deep-sea water, the selection and preparation of specimen can follow ASTM G71.

**6.6.2** On evaluating the performance of coatings, coated specimen should be made according to standard or specified process. Usually, the substrate material is flat sheet with the surface area large enough to reduce the edge effect. The edge of the coating specimen should be sealed.

**6.6.3** When non-standard specimen or structural specimen is used, the state, test parameters and evaluation methods of the specimens should be described in detail.

# 7 Testing procedure

## 7.1 Arrangement of specimens

**7.1.1** The specimens should be placed in such a manner that the surface of the solution is perpendicular to the long direction of the specimen, and the entire test surface is fully immersed in the solution.

**7.1.2** The method of supporting test specimens should be designed to hold the specimens securely enough to avoid rubbing against other specimens, to insulate the test specimens from each other electrically, and to insulate the test specimens from any metallic container or supporting device used within the test chamber.

**7.1.3** In order to avoid the impact of non-test required crevice corrosion, the specimen should be arranged with a minimum area in contact with the support. For flat or tubular specimens, the use of a small-diameter cylindrical hook through a large-diameter hole in the specimen is often effective.

**7.1.4** For stress corrosion cracking test, the arrangement of specimens should conform to the specimen type and loading mode as described in 6.4.

**7.1.5** For electrochemical measurement, the locations of the electrodes should be adjusted to ensure that they are located close to the centre of the test chamber without contact to the inner wall.

**7.1.6** The relative location of test specimens in the test chamber should be recorded prior to testing to identify the test specimens if necessary.

## 7.2 Preparation of test solutions

**7.2.1** The artificial seawater can be prepared based on ASTM D1141. The deep-sea water compositions of interest should be determined before preparation of the simulated test solution. Test solutions should be prepared accurately from chemicals that meet laboratory-grade standards and reagent water, except in those cases of using natural seawater.

**7.2.2** The composition of the simulated solution of deep-sea water should be controlled accurately, and the minor constituents should be included because they often affect corrosion rates.

**7.2.3** The volume of the test solution should be large enough to avoid any appreciable change in the corrosiveness of the test solution through either exhaustion of corrosive constituents or the buildup of corrosion products in the solution. The preferred minimum ratio of test solution volume to test specimen surface area is 20 ml/cm$^2$. The solution should be replaced during test intervals if required.

## 7.3 Test conditions

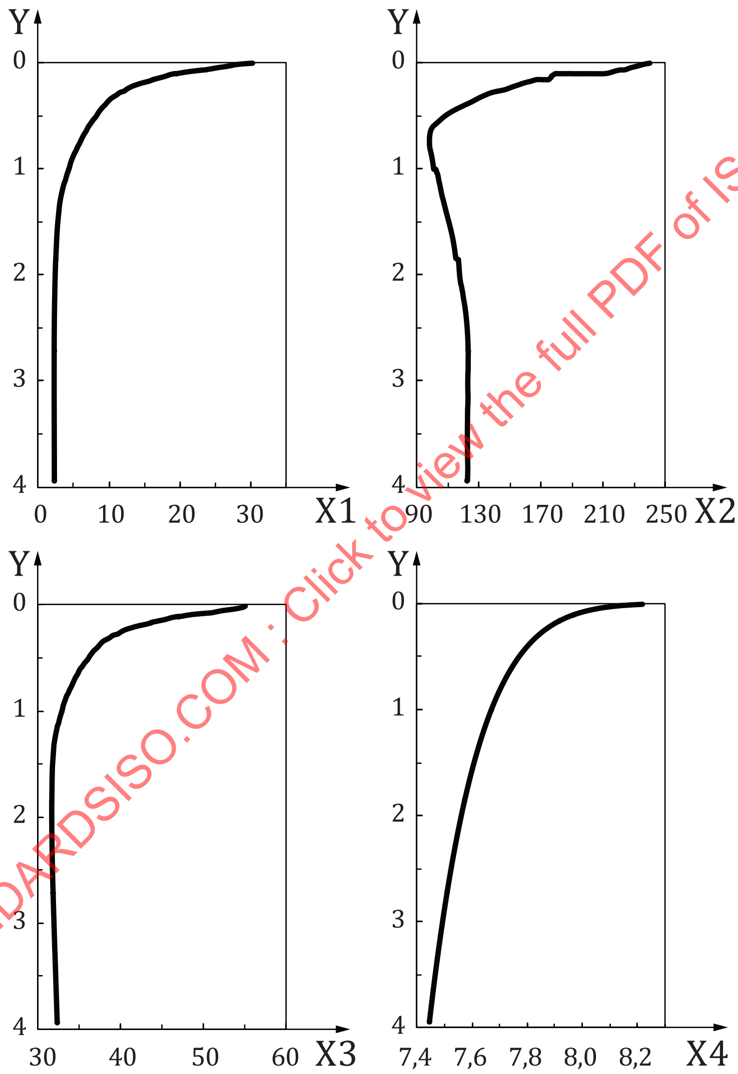
**7.3.1** The laboratory corrosion test conditions should be determined by the practical environmental factors in the deep sea. It should be noted that the environmental parameters are different in different sea areas. A typical example of the depth profiles of significant environmental factors in the deep-sea water is shown in Figure 4.

**7.3.2** Effort should be made to duplicate the practical service conditions in the corrosion test under simulated deep-sea water environment.

**7.3.3** If the test is to be a guide for the selection of a material for a particular purpose, the control range of environmental factors should be determined. These factors include temperature, dissolved oxygen content, hydrostatic pressure, pH, conductivity, composition and other important characteristics of the solution.

**7.3.4** Usually, the monitoring of hydrostatic pressure and temperature of the solution should be conducted in the test chamber, while the measurement of other environmental factors can be carried out in the reservoir or its attached pipe (see Figure 1). The conditions of the test solution except for those that need to be controlled in the test chamber should be adjusted and maintained constant prior to injection of the solution from the reservoir to the test chamber.

**7.3.5** The conditions should be monitored and controlled throughout the test in order to ensure reproducible results, especially when the test duration is for periods of several days or longer. The conditions can be adjusted automatically by the test apparatus or by manual intervention.






**Key**

X1 temperature, °C

X2 dissolved oxygen content, μM

X3 conductivity, mS·cm$^{-1}$

X4 pH

Y depth, km

**Figure 4 — Typical example of the depth profiles of significant environmental factors in the deep-sea water**

### 7.4 Immersion test

**7.4.1** The duration of test depends on the nature of specimen material and the purpose of test. The test duration can be determined with reference to ASTM G31, where the recommended test duration is based on the anticipated corrosion rate. Generally, metals and alloys that experience severe corrosion do not need lengthy tests, while for metals and alloys that form passive film, short-time tests can give misleading results. However, corrosion during the test period should not proceed to the point where the original specimen size or the exposed area is drastically reduced or where the metal is perforated.

**7.4.2** The results of corrosion rate often exhibit considerable discreteness. Therefore, each test result should take the mean value of at least three testing specimens. Each specimen should be used only once.

**7.4.3** It is advisable to include reference materials whose corrosion rates under practical conditions of service are known.

**7.4.4** After the tests, the specimens should be removed, rinsed with distilled or deionized water, and cleaned to remove corrosion products according to the recommendations from ISO 8407. Ultrasonic cleaning may be used as a substitute method in cases where it is difficult to remove corrosion products from deep pits. The specimens should be ready for mass loss measurement and the evaluation of localized corrosion, such as pitting, intergranular corrosion or exfoliation.

### 7.5 Crevice corrosion test

**7.5.1** For the assembled specimen with crevice former described in ISO 18070 and ASTM G78, to ensure that the torque on the specimens is constant during the exposure, the distance between the washers mounted towards the springs should be measured before and after exposure.

**7.5.2** The crevice formers should be wet ground up to at least P1200 grit paper specified in ISO 6344-3 before use. All grooves from machining should be completely removed. It should be ensured that there are no visible corrosion products on the crevice formers.

**7.5.3** The assembled specimen with crevice former should be placed in a glass cradle and immersed in the test solution after the assembly is ready.

**7.5.4** The test duration should be sufficient to allow for initiation and propagation of crevice corrosion.

**7.5.5** After the tests, the specimen surfaces should be cleaned with reference to ISO 8407 and ready for crevice corrosion examination.



### 7.6 Galvanic corrosion test

**7.6.1** Specimens should be electrically jointed before exposure. Laboratory testing generally applies external electrical connection through conducting wires to allow galvanic current and potential measurement.

**7.6.2** Control specimens should also be tested to provide corrosion rates of the individual metals and alloys without coupling for comparisons. These specimens should be of the same alloys, shapes, sizes, and metallurgical conditions as the materials in the couple.

**7.6.3** The electrical connection of conducting wire to the specimen should be sealed with insulating material, such as epoxy resin, which should not be damaged under the high pressure of seawater.

**7.6.4** The specimens should be positioned with nonconductive holders, if these do not result in other corrosion phenomena.

**7.6.5** Data recorded during the tests should include galvanic current and potentials of the coupled and control specimens. The corrosion data like galvanic current and potential can be taken as a function of time. These data can be recorded automatically using a data logger.

**7.6.6** The test duration should be sufficient to demonstrate the behaviour and results of galvanic attack between the coupled materials.

**7.6.7** After the tests, the specimens should be cleaned and weighed to determine corrosion mass loss which can be converted to corrosion rate. In the cases that mass loss measurements are not possible or meaningful, the depth of attack by localized corrosion or the changes in physical properties can be measured. Metallographic examination of specimen cross sections can be necessary to determine localized corrosion depth.

## 7.7 Stress corrosion cracking test

**7.7.1** Specimens specified in ISO 7539-2, ISO 7539-3, ISO 7539-5, ISO 7539-6, ISO 7539-7 and ISO 16540 should be prepared and assembled accordingly.

**7.7.2** After degreasing and cleaning, the test region of the specimens should not be touched prior to testing. If hydrogen pre-charging is necessary, pre-charging is best done in situ in the test conditions where the specimen will be exposed, in order to minimize the loss of hydrogen caused by any post-treatment process. In general, hydrogen charging involves cathodic polarization of the specimens.

**7.7.3** For plain or notched specimens, testing should be conducted under conditions of rising displacement (or rising load in some cases) using ISO 7539-7 as the reference standard. In selecting the strain rate, a value of $10^{-6}$ $s^{-1}$ is often used in the first instance to assess relative susceptibility of materials or to compare relative severity of environments. Where there is an anticipated risk, it is prudent to test at lower strain rates. For corrosion-resistant alloys under cathodic protection, testing at a strain rate of $10^{-8}$ $s^{-1}$ should be considered. To accelerate testing, a higher strain rate of $10^{-6}$ $s^{-1}$ should be adopted in the elastic region and then switched to the slower strain rate as close to yield.

**7.7.4** Testing of pre-cracked specimens should be undertaken where a significant defect is expected in service and should be conducted over a range of crack mouth displacement rates to obtain a minimum $K_{ISCC}$ ($K_{IH}$). The step-wise rising load test can be a useful preliminary test to give an approximate value of the threshold. This gives guidance on the initial $K$ value at which to start the slow rising displacement or rising load test.

**7.7.5** In cases where the applied stresses are high in relation to the yielding strength of the material and plastic deformation exceeds the assumptions of linear elastic fracture mechanics, as an approximate approach, $K_{QSCC}$ may be used (see ISO 7539-6 and ISO 7539-9).

**7.7.6** Testing with one surface of specimens is commonly based on bending, C-rings or flat tensile specimens. The material of construction of the loading jig or the force-bearing support (span or washer) should be resistant to stress corrosion cracking in the test condition and be sufficiently rigid in order to avoid any yielding or creep during the test. It should be ensured that the specimen is electrically isolated from the force-bearing support. This is best achieved by using non-conducting support or by application of an insulating coating to the electrical connection parts. At the same time, the working region of the specimen should be effectively exposed.

**7.7.7** For elastically loaded alloys, the deflection should be adjusted to attain the required strain and check after 1 h to ensure no significant relaxation has occurred. If relaxation has occurred, adjust the deflection and check again after 1 h.

