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# Standard Guide for Corrosion Tests in High Temperature or High Pressure Environment, or Both[1]

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## 1. Scope

1.1 This guide covers procedures, specimens, and equipment for conducting laboratory corrosion tests on metallic materials under conditions of high pressure (HP) or the combination of high temperature and high pressure (HTHP). See 3.2 for definitions of high pressure and temperature.

1.2 The procedures and methods in this guide are applicable for conducting mass loss corrosion, localized corrosion, and electrochemical tests as well as for use in environmentally induced cracking tests that need to be conducted under HP or HTHP conditions.

1.3 The primary purpose for this guide is to promote consistency of corrosion test results. Furthermore, this guide will aid in the comparison of corrosion data between laboratories or testing organizations that utilize different equipment.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

E8/E8M Test Methods for Tension Testing of Metallic Materials
G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
G4 Guide for Conducting Corrosion Tests in Field Applications
G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements
G30 Practice for Making and Using U-Bend Stress-Corrosion Test Specimens
G31 Guide for Laboratory Immersion Corrosion Testing of Metals
G34 Test Method for Exfoliation Corrosion Susceptibility in 2XXX and 7XXX Series Aluminum Alloys (EXCO Test)
G38 Practice for Making and Using C-Ring Stress-Corrosion Test Specimens
G39 Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens
G46 Guide for Examination and Evaluation of Pitting Corrosion
G49 Practice for Preparation and Use of Direct Tension Stress-Corrosion Test Specimens
G59 Test Method for Conducting Potentiodynamic Polarization Resistance Measurements
G78 Guide for Crevice Corrosion Testing of Iron-Base and Nickel-Base Stainless Alloys in Seawater and Other Chloride-Containing Aqueous Environments
G106 Practice for Verification of Algorithm and Equipment for Electrochemical Impedance Measurements
G129 Practice for Slow Strain Rate Testing to Evaluate the Susceptibility of Metallic Materials to Environmentally Assisted Cracking
G170 Guide for Evaluating and Qualifying Oilfield and Refinery Corrosion Inhibitors in the Laboratory

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

G184 Practice for Evaluating and Qualifying Oil Field and Refinery Corrosion Inhibitors Using Rotating Cage
G185 Practice for Evaluating and Qualifying Oil Field and Refinery Corrosion Inhibitors Using the Rotating Cylinder Electrode
G193 Terminology and Acronyms Relating to Corrosion
G208 Practice for Evaluating and Qualifying Oilfield and Refinery Corrosion Inhibitors Using Jet Impingement Apparatus

## 3. Terminology

3.1 *Definitions*—The definitions of terms given in Terminology G193 shall be considered as applying to this guide.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *high temperature and high pressure, HTHP, n*—for the purpose of this guide, any combination of pressure and temperature that requires the use of an autoclave.

3.2.2 *effectively non-reactive, adj*—free of significant mass loss or localized corrosion, stress corrosion cracking (SCC), or other embrittlement phenomena in the test environment; not contaminate the test environment with corrosion or other reaction products; and not significantly consume, absorb, or adsorb reactive chemical species from the test environment.

3.3 *Abbreviations and Acronyms:*

3.3.1 *AI*—artificial intelligence

3.3.2 *ALARP*—as low as reasonably practicable

3.3.3 *CUE*—corrosion under excursions

3.3.4 *HV*—high velocity

3.3.5 *ML*—machine learning

3.3.6 *PVT*—pressure volume temperature

3.3.7 *RT*—radiography testing (X-ray)

3.3.8 *SCC*—stressed-corrosion cracking

3.3.9 *SME*—subject matter expert

3.3.10 *UT*—ultrasonic testing

## 4. Summary of Guide

4.1 This guide describes the use of corrosion coupons, stress corrosion cracking specimens, and electrochemical electrodes in HP and HTHP environments. It also includes guidelines for the use of high-pressure test cells with these specimens to obtain reproducible, accurate corrosion test data.

4.2 Typically, HP and HTHP tests involve exposure of test specimens to a liquid (aqueous or non-aqueous), gaseous or multiphase environment, or both, in an appropriate test cell. The test cell shall be able to resist corrosion and cracking (mechanical and environmental) in the test environment while containing the pressurized, heated environment. Furthermore, the test specimens in the HP or HTHP test, or both, can be exposed in either stressed or unstressed condition in either the free corroding state or under electrochemical polarization.

## 5. Significance and Use

5.1 Autoclave tests are commonly used to evaluate the corrosion performance of metallic and non-metallic materials under simulated HP and HTHP service conditions. Examples of service environments in which HP and HTHP corrosion tests have been used include chemical processing, petroleum production and refining, food processing, pressurized cooling water, electric power systems, and aerospace propulsion.

5.2 For the applications of corrosion testing listed in 5.1, the service environment involves handling corrosive and potentially hazardous media under conditions of high pressure or high temperature, or both. The temperature and pressure, among other parameters, usually drive the composition and properties of the aqueous phase and, hence, the severity of the corrosion process. Consequently, the laboratory evaluation of corrosion severity cannot be performed in conventional low pressure glassware without making potentially invalid assumptions as to the potential effects of high temperature and pressure on corrosion severity.

5.3 Therefore, there is a substantial need to provide standardized methods by which corrosion testing can be performed under HP and HTHP. In many cases, however, the standards used for exposure of specimens in conventional low-pressure glassware experiments cannot be followed due to the limitations of access, volume, and visibility arising from the construction of high-pressure test cells. This guide refers to existing corrosion standards and practices, as applicable, and then goes further in areas in which specific guidelines for performing HP and HTHP corrosion testing are needed.

## 6. Apparatus

6.1 *Test Cell:*

6.1.1 Shall be constructed to applicable standards and codes so that it will have an adequate pressure rating to handle the test pressure safely.

6.1.2 Shall be made of materials that are corrosion resistant and effectively non-reactive with the test environment.

6.1.3 Shall have a seal mechanism that can withstand both the pressures, temperatures, and corrosive environment to be used in the test. Periodic hydrostatic testing of the test cell is recommended to ensure pressure retaining capabilities.

6.1.4 Shall be designed to have the necessary inlet and outlet ports to allow the test environment to be established in a controllable manner, monitored and sampled during the exposure period, released in a controlled manner at the completion of the test, and, if over temperature or pressure conditions may occur, adequate over pressure release and over temperature control equipment should be used.

6.2 *Test Cell Feedthroughs:*

6.2.1 Should be designed to minimize frictional forces when external loading fixtures are used for stressing specimens.

6.2.2 May be designed to balance the internal pressure in the test vessel with the external stressing assembly.

6.2.3 Shall be designed so that the electrodes or stressing rods and specimens cannot be ejected from the test cell under pressure.

6.2.4 Shall provide the electrical isolation of the specimen from the test cell unless galvanic coupling is specifically desired.

6.3 *Specimen Under Applied Load:*

6.3.1 Any frictional or pressure forces (or thermal expansion) acting on the specimen through the stressing fixtures should be taken into account when determining the actual load on the specimen.

6.3.2 Gripping devices should be designed such that they are in compliance with Test Methods E8/E8M where application of load to the specimen is required.

6.4 *Agitation:*

6.4.1 Agitation can be achieved by using a magnetic stir bar/plate, mechanically agitating the autoclave, for example, rollers within an oven recirculating the fluid through a pump, or using magnetic/mechanical feedthrough stirrers designed for this purpose. Care should be taken to ensure that components of the pump or stirrer are inert to the test environment.

NOTE 1—The potential for oxygen contamination and pressure loss increase with the use of pumps and additional autoclave ports.

6.4.2 Descriptions of test methods and equipment designs for testing under turbulent flow conditions, defined as a function of wall shear stress or mass transfer coefficient, can be found collectively in Guide G170, Practice G184 (rotating cage autoclaves), Practice G185 (rotating cylinder electrodes), and Practice G208 (jet impingement).

## 7. Reagents

7.1 In corrosion testing, providing a reproducible chemical environment in which to expose the corrosion test specimens is necessary.

7.2 In cases where the test environment is established by the mixing of chemicals in the laboratory, chemicals of reagent-grade purity with known contaminant levels are recommended.

7.3 In HP/HTHP corrosion testing, a common practice is to conduct tests in environments that have been sampled and retrieved from field or plant locations. Detailed information as to the chemical composition of the environment should be obtained. Particular attention should be given to the levels of impurities and contaminants that may be in the environment. Furthermore, under some conditions, these environments may be prone to changes after sampling or during testing, which can affect the corrosion test results.

7.4 In all cases, it is recommended that the test environment be fully documented with respect to its chemical composition.

## 8. Sampling and Test Specimens

8.1 *Sampling Selection Process*—Refer to G4, Standard Guide for Conducting Corrosion Tests in Field Applications.

8.2 *Preparation of Specimens:*

8.2.1 Frequently, the primary objective is to prepare a reproducible metallic surface with an absolute minimum of cold working followed by cleaning and degreasing. However, there are cases where the as-received surface is the desired test surface, or where the effect of cold working is to be studied.

8.2.2 Since test cells for HP and HTHP tests are usually of metallic construction, care must be taken to electrically isolate the specimens from the test cell unless galvanic coupling is specifically desired in the test. In cases where the test cell is used as a member of a galvanic couple, care must be taken to ensure that the galvanic action (anodic or cathodic) does not degrade the integrity of the test cell.

8.3 *Corrosion Specimens:*

8.3.1 Prepare specimens used in HP or HTHP corrosion tests in accordance with Practice G1 and Guide G31. Commonly, test cells used for HP and HTHP exposure tests are restricted in volume. The available volume in the test cell often decreases with increasing pressure rating. Therefore, it is frequently necessary to restrict the size and surface area of corrosion coupons used in HP and HTHP corrosion tests to attain a given volume to area ratio.

8.3.2 A minimum ratio, *R*, is often set for the volume of corrosive liquid to the surface area of the metal that can be corroded, for example, 200 $L/m^2$ to 400 $L/m^2$ or 20 $mL/cm^2$ to 40 $mL/cm^2$ (Guide G31, Test Method G34, and Practice G185). The origin of this concept is to minimize the buildup of corrosion products, which could subsequently impact solution pH, scaling tendencies, general corrosion rate, pit initiation, and pitting rates. Additionally, *R* can impact the rate at which reactants are depleted and potentially undesirable changes to the test environment occur. Consequently, an acceptable value for *R* will depend on the highest expected corrosion rate and the test duration. Another factor, not accounted for by *R*, arises from the possibility that certain chemicals, for example, components in a corrosion inhibitor, may adsorb (competitively) on metal surfaces other than the test specimen. Hence, in designing a test, one might also consider how the ratio of total immersed metal surface area to liquid volume compares with that in the field.

8.4 *Stressed Corrosion Specimens:*

8.4.1 Methods for the fabrication and use of appropriate stressed specimens are given in Section 2. These include tension, bent beam, C-ring, and U-bend specimens in accordance with Practices G129, G49, G39, G38, and G30, respectively. Fracture mechanics specimens can also be accommodated.

8.4.2 For similar reasons given in 8.3, when testing multiple specimens, it is recommended that the size of the specimens be restricted to the smallest applicable specimen provided for under the appropriate standards.

8.4.3 Because of the limited access of the specimens in HP and HTHP tests, self-stressed specimens are usually more convenient than specimens that require external stressing fixtures.

8.4.4 In cases such as direct tension and fracture mechanics tests, use of external loading frames and fixtures in conjunction with HP and HTHP corrosion tests may be desirable. In these cases, take both the frictional (sealing) forces and pressure forces acting on the specimens into account when determining the effect of applied stress.