



# Standard Test Method for Electrochemical Critical Pitting Temperature Testing of Stainless Steels<sup>1</sup>

This standard is issued under the fixed designation G150; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers a procedure for the evaluation of the resistance of stainless steel and related alloys to pitting corrosion based on the concept of the determination of a potential independent critical pitting temperature (CPT).

1.2 This test methods applies to wrought and cast products including but not restricted to plate, sheet, tubing, bar, forgings, and welds, (see [Note 1](#)).

NOTE 1—Examples of CPT measurements on sheet, plate, tubing, and welded specimens for various stainless steels can be found in Ref (1).<sup>2</sup> See the research reports (Section 14).

1.3 The standard parameters recommended in this test method are suitable for characterizing the CPT of austenitic stainless steels and other related alloys with a corrosion resistance ranging from that corresponding to solution annealed UNS S31600 (Type 316 stainless steel) to solution annealed UNS S31254 (6 % Mo stainless steel).

1.4 This test method may be extended to stainless steels and other alloys related to stainless steel that have a CPT outside the measurement range given by the standard parameters described in this test method. Appropriate test potential and solution must then be determined.

1.5 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.6 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

<sup>1</sup> This test method is under the jurisdiction of G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.11 on Electrochemical Measurements in Corrosion Testing.

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<sup>2</sup> The boldface numbers in parenthesis refer to the list of references at the end of this standard.

## 2. Referenced Documents

2.1 *ASTM Standards*:<sup>3</sup>

D1193 Specification for Reagent Water

D1293 Test Methods for pH of Water

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

G3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing

G5 Reference Test Method for Making Potentiodynamic Anodic Polarization Measurements

G46 Guide for Examination and Evaluation of Pitting Corrosion

G107 Guide for Formats for Collection and Compilation of Corrosion Data for Metals for Computerized Database Input

G193 Terminology and Acronyms Relating to Corrosion

## 3. Terminology

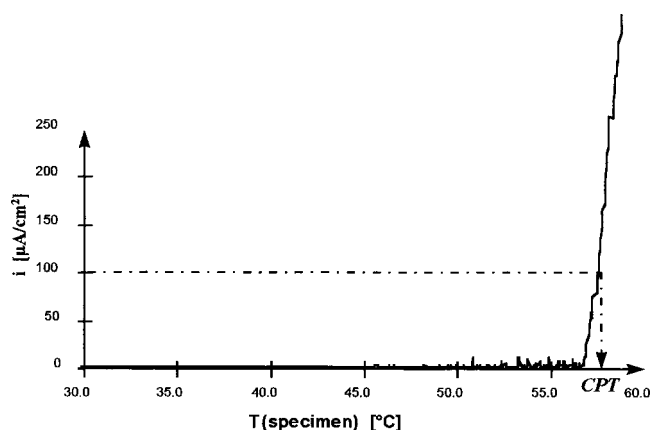
3.1 *Definitions*:

3.1.1 *critical pitting temperature (CPT)*—the lowest temperature on the test surface at which stable propagating pitting occurs under specified test conditions indicated by a rapid increase beyond a set limit of the measured anodic current density of the specimen.

3.1.2 *pitting potential range*—the range of measured potentials where pitting is initiated. This potential range only exists above the minimum critical pitting temperature; see also [Appendix X1](#).

3.1.3 *potential dependent CPT*—the CPT determined at a potential within the pitting potential range of the tested material; see also [Appendix X1](#).

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.



**FIG. 1 Determination of CPT**

3.1.4 *potential independent CPT*—the CPT determined at a potential above the pitting potential range, but below the transpassive potential; see also [Appendix X1](#).

3.1.5 *temperature ramp*—the rate ( $^\circ\text{C}/\text{min}$ ) at which the test temperature is increased during the test.

3.2 *sign conventions*—the sign conventions used in this procedure are in agreement with Practice [G3](#).

3.3 Unless otherwise stated, this test method uses the general terminology relating to corrosion and corrosion testing as defined in Terminology [G193](#).

#### 4. Summary of Test Method

4.1 The test method determines the potential independent critical pitting temperature (CPT) by way of a potentiostatic technique using a temperature scan and a specimen holder that is designed to eliminate the occurrence of crevice corrosion (see [Fig. 1](#)). The specimen is exposed, either entirely or in part, depending on test cell configuration to a 1M NaCl solution, initially at  $0^\circ\text{C}$ . After an initial temperature stabilization period, the solution is heated at a rate of  $1^\circ\text{C}/\text{min}$ . About 60 s before the temperature scan is commenced, the specimen is anodically polarized to a potential above the pitting potential range. This potential is held constant during the whole temperature scan. A potential of 700 mV versus SCE ( $25^\circ\text{C}$ ) has been found suitable for most stainless steels. The current is monitored during the temperature scan, and the CPT is defined as the temperature at which the current increases rapidly, which for practical reasons is defined as the temperature at which the current density exceeds  $100 \mu\text{A}/\text{cm}^2$  for 60 s. Pitting on the specimen is confirmed visually after the test.

#### 5. Significance and Use

5.1 This test method provides a prediction of the resistance to stable propagating pitting corrosion of stainless steels and related alloys in a standard medium (see [Note 1](#)). The CPT test can be used for product acceptance, alloy development studies, and manufacturing control. In the case of product acceptance, the supplier and user must agree upon the preconditioning of the specimen with regard to surface finish. The test is not

intended for design purposes since the test conditions accelerate corrosion in a manner that does not simulate any actual service environment.

5.2 Another method to determine the potential independent CPT with an electrochemical technique has been discussed in the literature ([1-4](#)). This test method involves a potentiodynamic (potential sweep) procedure performed on specimens at different temperatures. A comparison ([2](#)) of the test method described in this test method and the potentiodynamic technique has indicated no difference in the test result obtained.

#### 6. Apparatus

6.1 The apparatus necessary for determining the CPT consists of instruments for measuring electronic signals, a temperature controlling apparatus, a specimen holder, and a test cell. The instruments for measuring electronic signals may be integrated into one instrument package or may be individual components. Either form of instrumentation can provide acceptable data. Typical test equipment consists of the following: (1) potentiostat (2) potential measuring instrument (3) current measuring instrument (4) temperature controller (5) temperature measuring instrument (6) test cell (7) specimen holder, and (8) electrodes.

6.2 *Potentiostat*—The potentiostat shall be able to apply the constant potential to within 1 mV at a current density of  $10 \text{ mA}/\text{cm}^2$ . The applied potential is changed either automatically or manually by shifting the potential from the open circuit potential to another more noble potential.

6.3 *Potential Measuring Instrument*—Requirements shall be in accordance with the section on Potential Measuring Instruments in Test Method [G5](#).

6.4 *Current Measuring Instruments*—An instrument that is capable of measuring a current accurately to within 5 % of the actual value. The typical current densities encountered during the CPT test are in the range of  $1 \mu\text{A}/\text{cm}^2$  to  $10 \text{ mA}/\text{cm}^2$ .

##### 6.5 Temperature Controller:

6.5.1 Thermostat equipment is required that can provide cooling and heating of the test solution in the temperature range from  $0^\circ\text{C}$  to approximately  $100^\circ\text{C}$ . Further, the temperature controller is used to provide controlled heating, which gives the test solution temperature a temperature increase rate of  $1^\circ\text{C}/\text{min}$  in the range from  $0^\circ\text{C}$  to approximately  $100^\circ\text{C}$ .

6.5.2 Above  $10^\circ\text{C}$ , the average rate of temperature change of the test solution shall be  $1.0 \pm 0.3^\circ\text{C}/\text{min}$ , where the average is calculated over a temperature range of  $10^\circ\text{C}$ .

6.6 *Temperature Measurement Instrumentation*, shall be capable of measuring the temperature of the test solution with an accuracy of  $\pm 0.4^\circ\text{C}$ .

##### 6.7 Test Cell:

6.7.1 *Option 1, G5 Type*—The test cell should be similar to the one described in Test Method [G5](#). Other similar polarization cells may be equally suitable. The gas purger should distribute the gas in numerous small bubbles.

6.7.2 *Option 2, Flushed-port Cell*—This cell design is based on that published by R. Qvarfort ([3](#)) and includes the specimen holder in the design. The advantages of this cell design are that

the specimen edges and back do not need to be machined, the specimen does not have to be mounted inside the cell, and crevice corrosion at the contact area of the cell port is completely eliminated, even at elevated test temperatures. See [Appendix X2](#) for a description of this cell. The gas purger should distribute the gas in numerous small bubbles.

6.7.3 The test cell shall be able to contain a test solution volume of minimum 100 mL per square centimetre test area. A maximum dilution of 15 % of the test solution during the test period is allowed in case a flushed port cell or similar arrangement is used.

#### 6.8 Specimen Holder:

6.8.1 Any part of the specimen holder coming in contact with the test solution during testing shall be made of an inert material, and any seal shall not allow leakage of electrolyte.

6.8.2 The specimen holder shall have a design that ensures no occurrence of crevice corrosion at the contact area between specimen holder and specimen.

6.8.3 Two examples of specimen holder designs in accordance with this standard are shown in [Appendix X2](#) and [Appendix X3](#). The major difference between the specimen holder designs lies in the allowable specimen geometry and the number of surfaces on the specimen that are being tested simultaneously.

#### 6.9 Electrodes:

6.9.1 *Auxiliary (Counter) Electrode*—Requirements shall be in accordance with the section Auxiliary Electrodes in Test Method [G5](#) with the exception that only one counter electrode is necessary for CPT testing. The electrode material shall be of a type which can be considered inert under the test conditions.

6.9.2 *Reference Electrode*—The reference electrode shall be kept at room temperature outside the actual test cell. The reference electrode shall be capable of ensuring a constant reference potential within  $\pm 5$  mV during the entire test procedure (see [Note 2](#)). Electrical contact to the test solution shall be provided by the use of a luggin capillary placed in the test solution. Requirements shall otherwise be in accordance with the section on Reference Electrode in Test Method [G5](#).

**NOTE 2**—It may be difficult to ensure a fully constant reference potential due to the large variations in temperature of the test solution; therefore, the allowable is  $\pm 5$  mV. This does, however, not affect the measured potential independent CPT ([1](#)).

## 7. Test Specimens

7.1 *Finish*—Any geometry and surface finish (see [Note 3](#)) compatible with the chosen specimen holder as specified in [6.8](#) may be used.

**NOTE 3**—The state of the surface may be dependent on the time and location of storage between the final mechanical or chemical surface treatment and testing. The time and location of storage may, therefore, in some situations be considered an integral part of the surface finish.

7.2 *Sampling*—When using this test method to meet product acceptance criteria, the means of sampling of a test specimen shall be decided by agreement between the parties involved.

7.3 *Test Area*—A minimum test area of 1 cm<sup>2</sup> shall be used.

7.4 Specimens removed from a work piece or component by shearing, cutting, burning, and so forth shall have the affected

edges removed by grinding or machining, unless it is explicitly intended to study the effects of these edge factors.

## 8. Reagents and Materials

8.1 *Purity of Reagents*—Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society where such specifications are available.<sup>4</sup> Other grades may be used, provided it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

8.2 *Purity of Water*—Unless otherwise indicated, references to purified water shall be understood to mean reagent water as defined by Type IV of Specification [D1193](#).

8.3 *Standard Test Solution*—To prepare 1 L of 1 M sodium chloride (NaCl) solution, dissolve 58.45 g sodium chloride (NaCl) in purified water to a total solution volume of 1 L. The solution can be made up in bulk and stored for one month at room temperature.

8.4 *Purging Gas*—Nitrogen gas of minimum 99.99 % purity should be used.

## 9. Applied Potential

9.1 *Standard Potential*—An anodic potential of 700 mV versus SCE (25°C) is used. This has been found appropriate for most stainless steels ([1](#)).

#### 9.2 Alternative Potential:

9.2.1 If uncertainty exists concerning whether the standard potential is sufficiently high to obtain the potential independent CPT, a test at 800 mV versus SCE (25°C) may be performed. A significant deviation between the CPT obtained at 700 mV and 800 mV will indicate a need for a reevaluation and new choice of potential.

**NOTE 4**—Using a lower potential than the standard potential of 700 mV versus SCE (25°C) is fully acceptable, provided the determined CPT still is potential independent. To change the measurement range provided by the standard test conditions, a new test solution composition will have to be chosen. Following the choice of test solution, a test potential that ensures the determination of a potential independent CPT will have to be determined.

9.2.2 Evaluation of differences in obtained CPT at the two potentials should take into account the repeatability of the test method. The homogeneity of the material used for the two different potentials shall also be considered before an alternative potential is used.

## 10. Procedure

#### 10.1 Sample Mounting, Cleaning and Placement:

10.1.1 The recommendations given in Practice [G1](#) are to be followed, where applicable, unless otherwise stated in this procedure.

<sup>4</sup> *Reagent Chemicals, American Chemical Society Specifications*, American Chemical Society, Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see *Analar Standards for Laboratory Chemicals*, BDH Ltd., Poole, Dorset, U.K., and the *United States Pharmacopeia and National Formulary*, U.S. Pharmacopeial Convention, Inc. (USPC), Rockville, MD.

10.1.2 Clean the specimen just before immersion in the electrolyte by degreasing with a suitable detergent, rinsing in purified water, followed by ethanol or similar solvent, and air drying. After degreasing, handle the specimen with clean gloves, soft clean tongs, or equivalent preventive measures, to avoid surface contamination.

10.2 *Test Solution Preparation:*

10.2.1 Prepare the test solution according to Section 8.

10.2.2 Bring the solution to an initial temperature at or below 3°C.

10.3 Mount the specimen in the specimen holder.

10.4 Place the specimen, counter electrode, salt bridge probe, and other components in the empty test cell.

10.5 Fill the cell with cold ( $\leq 3^\circ\text{C}$ ) solution.

10.6 Ensure that the salt bridge is filled with the test solution and is free of air bubbles, particularly in the restricted space at the tip. A lugging probe should contain a wick, or equivalent device, to ensure electric contact even when small gas bubbles are formed during the test.

10.7 Commence bubbling nitrogen gas through the solution.

NOTE 5—The purpose of the purging gas is to enhance the stirring of the test solution. No reduction in the oxygen level of the test solution is intended. Presence or absence of oxygen has been shown not to affect the test result (1).

10.8 Connect the electrodes to the potentiostat and data recording device and the connections for temperature measurement and control. Let the system cool and stabilize at  $0 \pm 1^\circ\text{C}$  for a minimum of 10 min.

10.9 Record the open circuit potential (OCP) of the test specimen shortly before the test is begun.

10.10 Set the data acquisition for electrode current and solution temperature. The sampling rate shall correspond to a minimum of two measurements every minute to follow solution temperature and the variation of the current on the working electrode.

10.11 Apply the constant anodic potential to the working electrode.

10.12 The potential shall be applied for  $60 \pm 5$  s before the temperature increase.

10.13 The temperature is then ramped at  $1^\circ\text{C}/\text{min}$ .

10.14 Continue measuring the temperature until the CPT has been determined or the maximum required temperature is reached. The CPT is determined when the current density reaches  $100 \mu\text{A}/\text{cm}^2$  and remains above this level for a minimum of 60 s. Terminate the test and data acquisition after either of these limits has been reached.

10.15 *Completion of Test*—Dismount the specimen as soon as possible after test completion. Inspect the specimen to locate pits (see Note 6). Rinse the specimen in water, clean with ethanol (95 % is suggested) or detergent, rinse again with water, and then air dry.

NOTE 6—Pits may be difficult to locate if the test is stopped shortly after pitting initiation. Pits may be located based on leaking rust or by using a needle to uncover pits hidden below a thin metal or oxide film. The lack

of visible pitting may indicate that general corrosion has occurred, for example, transpassive corrosion. However, only a more thorough examination of the tested specimen can give a possible explanation.

## 11. Visual Examination of Test Electrode

11.1 Confirm the existence of pits and the absence of crevice corrosion using a microscope at  $20\times$  magnification. Note the location of pits relative to the test geometry (in the center, on edges, at the bottom center, at the bottom edge, and so forth).

11.2 Any crevice corrosion observed on the specimen after testing means that the test results are invalid and must be discarded.

11.3 If required, a more thorough examination of the electrode can involve measurement of pit density and pit depths on specimen electrodes, according to Guide G46, using a microscope at  $20\times$  magnification.

## 12. Data Analysis

12.1 Measured current as a function of time shall be converted to current density values. The data may be presented as in Fig. 1, which shows an example of a current density versus temperature plot.

### 12.2 *Evaluation of the CPT:*

12.2.1 *Standard Evaluation*—The critical pitting temperature is taken as the temperature at which the current increases above  $100 \mu\text{A}/\text{cm}^2$  (see Note 7) and stays above this critical current density for a minimum of 60 s; see Fig. 1.

NOTE 7—The CPT is defined as the lowest temperature at which stable propagating pitting occurs. For practical reasons, this is being translated to the temperature at which the current density increases above a certain level ( $100 \mu\text{A}/\text{cm}^2$  has been chosen as a standard in this test method). A 60 s delay is introduced in order to ensure that the observed current increase originates from stable propagating pitting and not short lived current peaks originating from metastable pitting.

### 12.2.2 *Alternative Evaluation:*

12.2.2.1 For materials that generally exhibit a very high passive current density (for example some, but not all, stainless steel welds) or low pitting propagation rate (some, but not all, nickel-base alloys) a different critical current density may be chosen, but generally this should be avoided. Any change in the evaluation criteria shall be noted specifically in the report.

12.2.2.2 Comparison of CPTs obtained with different critical current densities is very difficult and should generally not be attempted.

12.2.3 The registered temperature in the solution will not be exactly the same as the temperature of the specimen, because the solution temperature is continuously changed during most of the test. A conversion of the increasing solution temperature to specimen temperature should be performed and the CPT should be defined relative to the temperature of the specimen.

12.2.4 The conversion between solution and specimen temperature may be done either by direct measurement of the specimen surface temperature during the test or by using a suitable calibration formula based on an earlier parallel measurement of specimen temperature and solution temperature. A detailed guideline of how to obtain a suitable calibration formula is given in Annex A1.



### 13. Report

13.1 Report the following *mandatory* information:

13.1.1 Test identification number and date of test.

13.1.2 Critical pitting temperature (CPT). CPTs below 10°C shall only be reported as below 10°C or <10°.

13.1.3 Formula for conversion of test solution temperature to specimen temperature shall be reported. If no conversion of the solution temperature to specimen temperature has been done, this shall be stated specifically in the test report.

13.1.4 Location of pits on the tested surface.

13.1.5 Test area.

13.1.6 Material identification data.

13.1.7 Type of test cell and test solution volume.

13.1.8 Surface finish and approximate geometry of the tested specimen including the approximate storage time between final surface finish preparation and testing.

13.1.9 If no pits were observed despite an observed rapid current increase, this lack of visual pitting identification shall be noted explicitly. The evaluation of such deviations should lead to a more thorough examination of the specimen.

13.1.10 If parameters deviating from the standard values in this test method have been used, then all deviations shall be reported.

13.2 *Optional Reporting*—If required, a more elaborate report can, additional to the mandatory report, contain one or more of the following information:

13.2.1 Test identification number; specimen number; material; heat number; product form; solution temperature at CPT; open circuit potential; solution pH before start and after completion of test.

13.2.2 Together with the basic test results, it is recommended that the data from the CPT test should be presented graphically, as shown in [Fig. 1](#).

13.2.3 In addition the following data are useful to report, (a) the scatter or deviation in the CPT values based on multiple runs if available, (b) pit geometry, number of pits formed and their depth in accordance with [Guide G46](#).

13.3 The example data record sheet in [Appendix X4](#), or equivalent, may be used for reporting.

**TABLE 1 Precision**

| Material,<br>UNS No. | Average<br>CPT, °C | Repeatability<br>Standard<br>Deviation,<br>$s_r$ | Reproducibility<br>Standard<br>Deviation, $s_R$ | 95 %<br>Repeatability<br>Limit, r | 95 %<br>Reproducibility<br>Limit, R |
|----------------------|--------------------|--|---|-----------------------------------|-------------------------------------|
| S31600               | 19.5               | 1.9  | 2.8   | 5.4                               | 7.9                                 |
| S31803               | 51.9               | 1.7  | 2.4   | 4.9                               | 6.7                                 |
| N08904               | 54.1               | 3.7  | 3.7   | 11.3                              | 11.3                                |
| S31254               | 82.7               | 3.4  | 6.6   | 9.4                               | 18.5 <sup>A</sup>                   |

<sup>A</sup> See [Note 8](#).

### 14. Precision and Bias<sup>5</sup>

14.1 *Interlaboratory Test Program*—An interlaboratory study was run in which the critical pitting temperatures were determined for four grades of stainless steels with laboratory ground surface. Ten laboratories participated in the study. Each laboratory tested three to five test specimens of each of the four materials. Practice [E691](#) was followed for the design and analysis of the data.

14.2 *Precision*—See [Table 1](#). The terms, repeatability limit and reproducibility limit, are used as specified in Practice [E177](#). The repeatability and reproducibility limits were obtained by multiplying the respective standard deviations by 2.8.

NOTE 8—The high reproducibility limit for material UNS S31254 is believed to be caused by problems with temperature calibration, which is most critical for materials with high CPTs. The variations and reported procedures in the round robin results were, however, judged to be insufficient to exclude the values from two laboratories (out of ten laboratories), which otherwise would have resulted in that the repeatability limit would have been  $\pm 7.4^\circ\text{C}$  and the reproducibility limit would have been  $\pm 12.5^\circ\text{C}$ .

14.3 *Bias*—This test method has no bias, because the electrochemically (potentiostatic) determined potential independent CPT is defined by this test method and no accepted reference standard exists.

### 15. Keywords

15.1 critical pitting temperature; electrochemical test; pitting corrosion; stainless steel

<sup>5</sup> Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Reports RR:G01-1017 and RR:G01-1020.

ANNEX

(Mandatory Information)

A1. GUIDELINES FOR CALIBRATING THE SPECIMEN TEMPERATURE VERSUS THE TEST SOLUTION TEMPERATURE

A1.1 The registered temperature in the solution will not be exactly the same as the temperature of the specimen, because the solution temperature is continuously changed during most of the testing time.

A1.2 The temperature lag is further enhanced when using the flushed port cell or similar test cells and specimen holders, where the specimen is placed partly outside the test solution. In these cases there is an added cooling or heating of the specimen from the outside.

A1.3 The temperature lag between solution and specimen can be minimized by providing adequate stirring of the solution. A combination of mechanical stirring and dispersed gas bubbling has been found beneficial (see Ref (1)).

A1.4 When calibrating the specimen temperature versus the test solution temperature, the following guidelines for the calibration are recommended;

A1.4.1 The calibration should be performed by comparing the specimen temperature and the test solution temperature at 10°C intervals or less in the temperature range in question.

A1.4.2 The specimen temperature calibration formula should be calculated based on a linear order regression analysis.

A1.4.3 The calibration shall be performed under identical conditions to a real CPT test except that no control of the electrochemical potential of the specimen is required. It is recommended to standardize the specimen geometry and size in order to avoid large variations in the specimens heat capacity, which may influence the accuracy of the calibration.

A1.4.4 The specimen temperature shall be measured by installing a thermistor or similar device inside the specimen. The thermistor shall be located as close to the surface in contact with the solution as possible and at the same time centrally located relative to the specimen geometry, that is, the thermistor should be located on the shortest line between the center of the specimen and the exposed surface, but still as close to the surface as possible.

A1.4.5 The final accuracy of the temperature measurement of the specimen during the calibration should be  $\pm 0.4^{\circ}\text{C}$ .

APPENDIXES

(Nonmandatory Information)

X1. RELATIONSHIP BETWEEN PITTING POTENTIAL AND CPT

X1.1 *Pitting Potential Range*—The measured pitting potential at a given temperature varies because of the random nature of the pitting initiation process, see Ref (5, 6). Therefore the characteristic pitting potential is best described as a range. Generally the pitting potential will decrease with increasing temperature. The occurrence of pitting on stainless steels as a function of temperature and potential is shown in Fig. X1.1.

X1.2 *Potential Independent CPT*—Below a certain temperature, only passive or transpassive corrosion occurs on a stainless steel, see Ref (1, 3, 4, 7). This temperature limit signifies the potential independent CPT, see also Fig. X1.1.

X1.3 *Potential Dependent CPT*—At temperatures above the potential independent CPT, pitting may occur depending on the potential, see also Fig. X1.1. Fig. X1.1 depicts the potential dependent CPT range for a specific low potential. Principally the low temperature limit of the potential dependent CPT is the potential independent CPT.

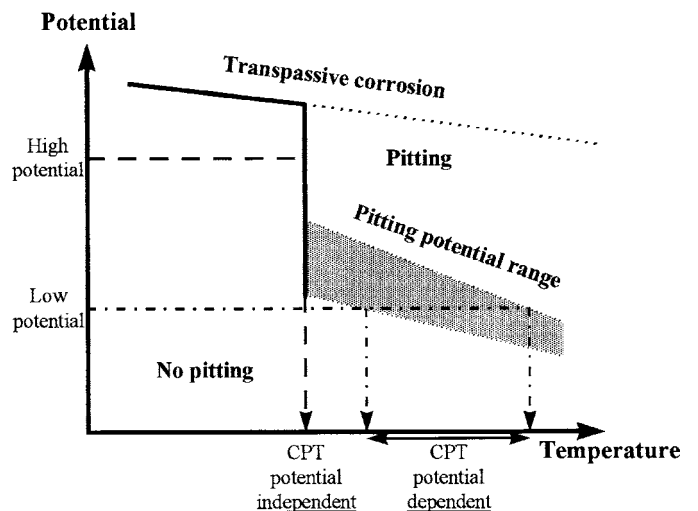


FIG. X1.1 Principles of the Potential and Temperature Effects on the Pitting Corrosion of Stainless Steels

X1.3.1 At potentials *within* the pitting potential range, pitting will occur if the temperature is sufficiently high. In this case, the critical pitting temperature will depend on the specific potential and variation in the pitting potential.

X1.3.2 At a potential *above* the pitting potential range and below the transpassive potential, pitting will occur virtually instantaneously.

X1.3.3 At potentials *below* the pitting potential range, no pitting will occur.

X1.4 The present standard defines a fast potentiostatic method to determine the potential independent CPT by using a

high potential of 700 mV versus SCE, this generally will correspond to a potential above the pitting potential range (2).

X1.5 If uncertainties exist in the correct choice of potential to determine the potential independent CPT, a simple CPT determination at a potential 100 mV above will indicate whether the CPT determined is truly potential independent. Any conclusions based on such a test should take into account the expected repeatability of the method, the homogeneity of the test material (2) and the level of the transpassive potential range.

## X2. FLUSHED PORT CELL

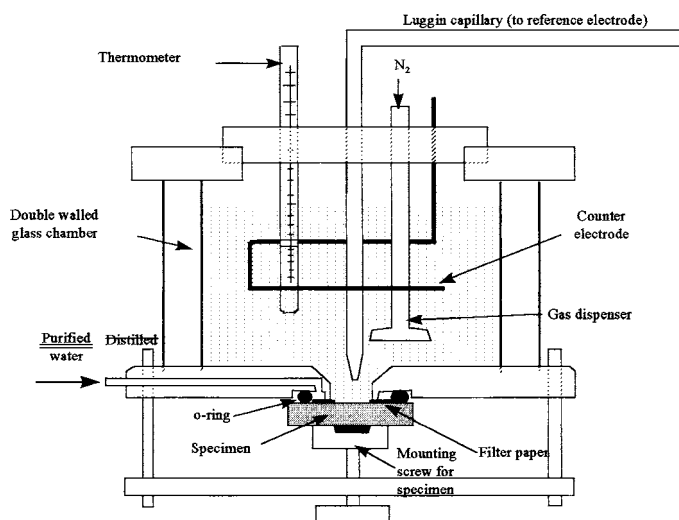


FIG. X2.1 Sketch of the Design Principles of the Flushed Port Cell

X2.1 The flushed port cell consists of a circular double walled glass chamber to facilitate heating by an external recirculating heating bath and various inlets, connections for temperature measurement, counter- and reference-electrodes and gas purging. The general principles of the flushed port cell are shown in Fig. X2.1.

X2.2 The bottom of the cell incorporates the specimen holder. The specimen is mounted outside the cell to enable easy isolation of a single test surface. Elimination of crevice corrosion at the contact point of the specimen and the cell port is achieved by continuously pumping a small volume of

purified water into the contact area of the cell port.

X2.3 The specimen is separated from the cell port by one or more filter paper rings, creating a diffusion barrier between the purified water, the specimen and the test solution. The purified water pumped into this region displaces any electrolyte that would otherwise be in this crevice-like region. The water flow is typically in the range of 4 to 5 mL/h for a 1 cm<sup>2</sup> port opening. The cell must be large enough to ensure sufficient test solution volume to minimize the dilution effect from the purified water within the time frame of the test.

X2.4 The test area exposed to the electrolyte is not isolated from the test solution by the purified water because the difference in density between purified water and test solution makes the purified water flow upwards just on the port sides. Furthermore, the stirring caused by gas purging or, more effectively, by using a mechanical stirrer, mixes the purified water with the test solution as soon as it enters the cell chamber.

X2.5 Because the specimen is mounted outside the cell, there will be a difference in temperature between the electrolyte and the specimen. Gas purging, but preferably a combination of gas purging and mechanical stirring, will minimize this problem. A fairly large test solution volume may be necessary to use mechanical stirring.

X2.6 To obtain the full precision inherent in the CPT method, calibration of the specimen temperature, relative to the solution temperature, should be performed using a thermocouple inserted in the center of a specimen as close to the test surface as possible.

X3. MODIFIED G5-TYPE SPECIMEN HOLDER

X3.1 For cylindrical specimens, the specimen holder design described in Test Method G5 is often practical. However, the original design is extremely prone to create crevice corrosion between the PTFE mount and stainless steel specimens. Fig. X3.1 is a sketch of one example of a modified G5-type specimen holder incorporating the flushed port cell principle as described in Appendix X1.

X3.2 Purified water is fed through a glass tube sealed with o-rings to the PTFE mount at the bottom. The water is distributed through the filter paper on top of the specimen. The stainless connecting rod, on which the specimen is mounted, is painted to avoid electrical contact with the purified water. A typical flow rate of the purified water is about 1.5 mL/h for a 10 mm diameter cylindrical specimen.

X3.3 The test area exposed to the electrolyte is not isolated from the test solution by the purified water, because there is a difference in density between purified water and test solution. The purified water will rise upwards when it enters the cell. The stirring obtained from the gas purge or, more effectively by mechanical stirring, mixes the purified water with the test solution immediately on entry into the cell chamber. The size

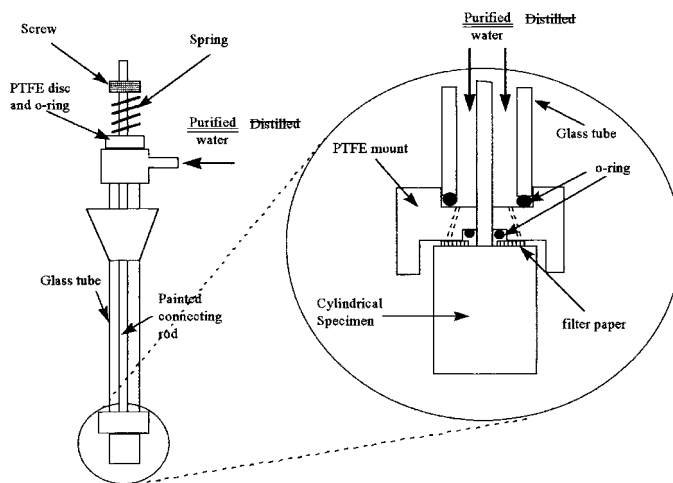


FIG. X3.1 Modified G5-type Specimen Holder using the Flushed Port Cell Principle

of the cell must ensure that there is sufficient test solution volume to minimize the dilution effect from the purified water within the time frame of the test.



#### X4. EXAMPLE OF TESTING REPORTING

X4.1 Fig. X4.1 is an example of test reporting.

### Electrochemical Critical Pitting Temperature Data Record Sheet

**Test Identification No.:**

**Date:**

#### Material Identification

Alloy:

Additional information regarding sampling and sample location in the product:

Product Form:

Heat No.:

Further ID:

#### Results

Pitting occurred: yes / no

CPT:

Crevice corrosion occurred: yes / no  
(if yes, the test result shall be discarded)

Solution Temperature at CPT:

Location of pits (use simple sketch of specimen):

Open Circuit Potential shortly before temperature ramp initiation: mV vs. SCE

#### Specimen preparation and description:

Final surface finish: as received: / other:

Storage Time between final surface finish and testing (circle):

<2 hours / 2-16 hours / >16 hours / specific:

Test Area: cm<sup>2</sup>

Specimen Geometry:

#### Test Method Information:

Test Solution: 1 M NaCl / other:

Test Solution Volume:

Applied Potential: 700 mV vs. SCE / other:

Type of test cell:

Type of specimen holder: Flushed Port Cell: / Modified G5: / Other:

Stirring: Yes / No

Calibration of Specimen Temperature vs. Solution Temperature Performed: Yes / No

Calibration Formula:

#### Other comments and observations:

FIG. X4.1 Example of Test Reporting

## **X5. STANDARD DATA ENTRY FORMAT**

X5.1 Fig. X5.1 defines the data categories and specific data element (fields) considered necessary for searching and comparing data using computerized databases. Pertinent items from Guide G107 have been included along with additional items specific to evaluation of the potential independent CPT using this test method.

X5.2 The Guide G107 Reference Number is shown in Fig. X5.1. Reference numbers not pertinent for this test method have been omitted from the table.

X5.3 Items in Fig. X5.1 which are not pertinent for a specific test may simply be omitted from the report.

| Reference Number        | Field Name             | Required | Description  | Field Type | Category Set/<br>Suggested Units   |
|-------------------------|------------------------|----------|--|------------|--|
| G107.5.1.1              | TestNo                 | Y        | individual test number to identify grouping of specimens tested concurrently. See subsequent entries for test method | STRING     |  |
| TYPE OF TEST            |                        |          |  |            |  |
| G107.5.1.2.1            | Standard               | Y        | standard test specification  | STRING     |  |
| G107.5.1.2.3            | Date                   | Y        | date test started  | DATE       |  |
| TEST CONDITIONS         |                        |          |  |            |  |
| G150.X5.1               | StandardTestCondition  | Y        | was the test performed using standard test condition   | SET        | (1) Y—yes<br>(2) N—no  |
| G150.X5.2               | StandardEvaluation     | Y        | was the test performed using standard evaluation conditions  | SET        | (1) Y—yes<br>(2) N—no  |
| G150.X5.3               | Potential              | N        | non standard electrochemical potential used relative to reference electrode  | QUANT      | mV   |
| G107.5.1.4.1            | Environment            | N        | generic description of environment   | STRING     |  |
| G107.5.1.4.2            | Component              | N        | Component—common name  | STRING     |  |
| G107.5.1.4.3            | Component.Registry     | N        | chemical abstracts registry number   | STRING     |  |
| G107.5.1.4.4            | Component.Conc         | N        | concentration (liquids)  | QUANT      | g/L  |
| G107.5.1.8.5            | ReferenceElectrode     | N        | reference electrode used   | STRING     |  |
| G150.X5.4               | TestCell               | Y        | type of test cell  | SET        | (1) G5 type<br>(2) Flushed port cell<br>(3) other—describe in G150.X5.5  |
| G150.X5.5               | TestCellDescription    | N        | description of (3) in G150.X5.4  | STRING     |  |
| G150.X5.6               | SpecimenHolder         | Y        | type of specimen holder  | SET        | (1) Flushed port cell<br>(2) Modified G5 type<br>(3) Gas collar type<br>(4) other—describe in G150.X5.7                    |
| G150.X5.7               | SpHolderDescription    | N        | description of (4) in G150.X5.6  | STRING     |  |
| G107.5.1.5.19           | Agitation              | N        | agitation  | SET        | (1) none<br>(2) stirred<br>(3) shaken<br>(4) shaken but not bruised  |
| G150.X5.8               | StirringDescription    | N        | description of stirring, type of stirrer, quantification of stirring effect  | STRING     |  |
| G107.5.1.5.24           | AV Ratio               | Y        | ratio of specimen surface area to corrodent volume   | QUANT      | cm <sup>2</sup> /L   |
| MATERIAL IDENTIFICATION |                        |          |  |            |  |
| G107.5.1.6.1            | Matl.Class             | Y        | material class   | STRING     |  |
| G107.5.1.6.2            | Matl.SubClass          | N        | sub-division of class  | STRING     |  |
| G107.5.1.6.3            | Mat.SubSubClass        | N        | finer sub-division of class  | STRING     |  |
| G107.5.1.6.4            | Matl.TradeName         | Y        | common name/trade name   | STRING     |  |
| G107.5.1.6.5            | Matl.UNSNo             | N        | material designation - UNS number  | STRING     |  |
| G150.X5.9               | Matl.ENNo              | N        | European designation - EN number   | STRING     |  |
| G107.5.1.6.6            | Matl.Spec              | N        | specification/standard   | STRING     |  |
| G107.5.1.6.7            | Shape                  | N        | product shape  | SET        | (1) pipe/tube<br>(2) plate<br>(3) sheet/strip<br>(4) wire/rod/bar<br>(5) other—describe in G107.5.1.6.8                    |
| G107.5.1.6.8            | Shape.Description      | N        | description for (5) in G107.5.1.6.7  | STRING     |  |
| G107.5.1.6.9            | ProdMethod             | N        | product production method  | SET        | (1) extrusion<br>(2) forging<br>(3) casting<br>(4) rolling<br>(5) powder compaction<br>(6) other—describe in G107.5.1.6.10 |
| G107.5.1.6.10           | ProdMethod.Description | N        | description of (6) in G107.5.1.6.9   | STRING     |  |
| G107.5.1.6.11           | Lot.ID                 | N        | heat/lot identification  | STRING     |  |

**FIG. X5.1 Standard Data Entry Fields for CPT Database Development**

| Reference Number        | Field Name                       | Required | Description   | Field Type | Category Set/<br>Suggested Units  |
|-------------------------|----------------------------------|----------|---|------------|---|
| G150.X5.10              | Producer                         | N        | producer of product   | STRING     |   |
| SPECIMEN IDENTIFICATION |                                  |          |   |            |   |
| G150.X5.11              | SamplProc                        | N        | description of the sampling of the test specimen from the product   | STRING     |   |
| G107.5.1.7.1            | Specimen.Thickness               | N        | specimen thickness  | QUANT      | mm  |
| G107.5.1.7.2            | Specimen.Width                   | N        | specimen width/diameter   | QUANT      | mm  |
| G107.5.1.7.3            | Specimen.Length                  | N        | specimen length   | QUANT      | mm  |
| G150.X5.12              | Specimen.TestArea                | Y        | area of tested surface  | QUANT      | cm <sup>2</sup>   |
| G107.5.1.7.6            | Weld                             | N        | welded specimen   | SET        | (1) Y—yes<br>(2) N—no   |
| G150.X5.13              | Weld.ID                          | N        | weld identification no  | STRING     |   |
| G107.5.1.7.10           | Thermomechanical                 | N        | thermomechanical condition  | SET        | (1) standard temper—<br>describe in<br>G107.5.1.7.11<br>(2) annealed<br>(3) normalized<br>(4) sensitized<br>(5) as cold worked<br>(6) as hot worked<br>(7) aged<br>(8) other H.T./<br>processing—describe in<br>G107.5.1.7.11 |
| G107.5.1.7.11           | Thermomechanical-<br>Description | N        | description for (1) or (7) in G107.5.1.7.10   |            |   |
| G150.X5.14              | Specimen.Geometry                | Y        | description of specimen geometry  | STRING     |   |
| G150.X5.15              | Specimen.Storage-time            | Y        | time between final surfacefinish treatment and commencement of test   | QUANT      | hours   |
| G150.X5.16              | Surfacefinish                    | Y        | description of surface finish on tested surface   | STRING     |   |
| EVALUATION AND RESULT   |                                  |          |   |            |   |
| G150.X5.17              | CriticalCurrentDensity           | N        | non standard critical current density defining a non standard CPT   | QUANT      | μA/cm <sup>2</sup>  |
| G150.X5.18              | CPT100Testsolution               | N        | temperature of test solution when the critical current density, 100μA/cm <sup>2</sup> , was reached and stayed above this for a minimum of 60 seconds - this corresponds to the standard CPT evaluation | QUANT      | °C  |
| G150.X5.19              | CPT100                           | Y        | standard CPT; temperature of test specimen when the current density reached 100μA/cm <sup>2</sup> at stayed above this for a minimum of 60 seconds  | QUANT      | °C  |
| G150.X5.20              | CPTNonStdTstSol                  | N        | temperature of test solution when the critical current density reached the value stated in "CriticalCurrentDensity" and stayed above this for a minimum of 60 seconds                                   | QUANT      | °C  |
| G150.X5.21              | CPTNonStd                        | N        | temperature of test specimen when the current density reached the value stated in "CriticalCurrentDensity" was reached and stayed above this for a minimum of 60 seconds                                | QUANT      | °C  |
| G150.X5.22              | PittingOccurence                 | Y        | was pitting confirmed visually after testing  | SET        | (1) Y—yes<br>(2) N—no   |
| G150.X5.23              | PitLocation                      | Y        | description of the location of observed pitting   | STRING     |   |
| G150.X5.24              | Crevicecorrosion                 | N        | was crevice corrosion detected after testing  | SET        | (1) Y—yes<br>(2) N—no   |
| G150.X5.25              | OpenCircuitPotential             | N        | open circuit potential at OCPTtime  | QUANT      | mV  |
| G150.X5.26              | OCPTtime                         | N        | time of measurement of "OpenCircuitPotential"   | QUANT      | minutes   |
| G150.X5.27              | TempCalibPerf                    | Y        | was calibration of specimen temperature vs. solution temperature performed  | SET        | (1) Y—yes<br>(2) N—no   |
| G150.X5.28              | TempCalibFormula                 | Y        | calibration formula used  | STRING     |   |
| SUPPLEMENTARY NOTES     |                                  |          |   |            |   |
| G107.5.2.0.1            | Notes                            | N        | supplementary notes   | STRING     |   |

**FIG. X5.1 Standard Data Entry Fields for CPT Database Development (continued)**

## REFERENCES

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