



Designation: G 157 – 98

# Standard Guide for Evaluating the Corrosion Properties of Wrought Iron- and Nickel-Based Corrosion Resistant Alloys for the Chemical Process Industries<sup>1</sup>

This standard is issued under the fixed designation G 157; 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 guide covers an evaluation approach that is designed to provide information on the corrosion properties of wrought iron- and nickel-based alloys for the chemical process industries. This guide incorporates test conditions for general corrosion measurements in a variety of environments, crevice corrosion resistance in chloride environments, and stress corrosion cracking resistance in chloride environments.

1.2 *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 to determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

- D 1193 Specification for Reagent Water<sup>2</sup>
- G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens<sup>3</sup>
- G 15 Terminology Relating to Corrosion and Corrosion Testing<sup>3</sup>
- G 30 Practice for Making and Using U-Bend Stress-Corrosion Test Specimens<sup>3</sup>
- G 36 Practice for Evaluating Stress-Corrosion-Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution<sup>3</sup>
- G 46 Guide for Examination and Evaluation of Pitting Corrosion<sup>3</sup>
- G 48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution<sup>3</sup>

G 123 Test Method of Evaluating Stress-Corrosion Cracking of Stainless Alloys with Different Nickel Content in Boiling Acidified Sodium Chloride Solution<sup>3</sup>

## 3. Terminology

3.1 Terms such as *crevice corrosion*, *stress corrosion cracking*, and *corrosion rate* are defined in Terminology G 15.

## 4. Significance and Use

4.1 This guide is intended to provide a series of evaluations that will assist engineers dealing with chemical environments in selecting appropriate alloys (1-3). In chemical environments, an important issue for determining general corrosion resistance is the temperature at which an alloy transitions from corrosion at a low rate to corrosion at a much higher rate. Other important concerns include the tendency towards crevice corrosion and stress corrosion cracking resistance, especially in hot chloride-containing aqueous environments.

4.2 This guide is also intended for alloy developers to assist them in choosing environments and test methods that are of particular interest to the chemical process industries.

4.3 The use of this approach will allow direct comparisons to be made among alloys from various suppliers and, thereby, to assist engineers in selecting the most appropriate materials for further testing to determine suitability in their application.

## 5. General Corrosion Resistance

5.1 The general corrosion resistance of nickel- and iron-based alloys is determined in 14 test solutions at various temperatures to determine the lowest temperature at which the corrosion rate exceeds 0.13 mm/y (5 mpy). The test solutions are listed in Table 1. A suggested procedure is provided in Appendix X1. The test is run on three coupons of metal for each environment. The tests are run for two 48-h exposures with one specimen exposed for the total 96 h. Welded specimens may be used if results are required on weldments.

5.2 The corrosion rates are based on mass loss measurements with appropriate conversion to thickness loss as shown in Appendix X1.

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee G-1 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.05 on Laboratory Corrosion Tests.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 11.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 03.02.

**TABLE 1 Fourteen Environments for Evaluating General Corrosion Resistance**

Corrodent	Formula	Concentration, % <sup>A</sup>
Hydrochloric Acid	HCl	0.2, 1.0, 5.0
Sulfuric Acid	H <sub>2</sub> SO <sub>4</sub>	10, 60, 96 <sup>B</sup>
Nitric Acid	HNO <sub>3</sub>	10, 70 <sup>B</sup>
Phosphoric Acid	H <sub>3</sub> PO <sub>4</sub>	85 <sup>B</sup>
Formic Acid	HCOOH	50
Acetic Acid	CH <sub>3</sub> COOH	80
Sodium Hydroxide	NaOH	50
Hydrochloric Acid + Ferric Chloride	HCl + FeCl <sub>3</sub>	1.0 HCl + 0.3 FeCl <sub>3</sub> <sup>C</sup>
Acetic Acid + Acetic Anhydride	CH <sub>3</sub> COOH + (CH <sub>3</sub> CO) <sub>2</sub> O	50/50

<sup>A</sup>All chemicals are ACS reagent grade mixed with Specification D 1193 Type 4 reagent water.

<sup>B</sup>Undiluted reagent grade acid may be used.

<sup>C</sup>Ferric chloride concentration calculated on anhydrous basis.

5.3 The results of the tests in each solution should be reported on a summary results sheet. A typical format is shown in Fig. 1 and Fig. 2.

**6. Six Percent Ferric Chloride Solution Critical Crevice Corrosion Temperature**

6.1 The crevice corrosion resistance of each alloy is to be evaluated as described in Test Methods G 48, Method D. The standard exposure period of 72 h is to be used. Mass loss results are also to be obtained and reported in this environment.

6.2 The results of this test are to be reported as discussed in Test Methods G 48. The results should also be entered on the summary results sheet shown in Fig. 3.

**7. Chloride Stress Corrosion Resistance**

7.1 The resistance to chloride stress corrosion cracking is an important characteristic of alloys used in the chemical process industries. Two environments are provided to evaluate and report chloride stress corrosion cracking behavior—acidified sodium chloride and magnesium chloride. The magnesium chloride environment is highly acidic and, as a consequence, tends to cause many suitably resistant alloys to fail. The acidified sodium chloride environment gives results closer to experience in cooling water and process water environments.

7.2 *Acidified Sodium Chloride Test*—Test Method G 123 should be used to evaluate all alloys for resistance to chloride stress corrosion cracking. The specimen design suggested in

<u>Commercial Designation</u> <u>UNS Number</u>	
Heat Treatment Designation	
Manufacturer:	XXX
Common Trade Designations:	XXX
Nominal Composition - Mass %	Cr   Ni   Mo   etc.
Mechanical Properties:	
Yield Strength	MPa (ksi)
Tensile Strength	MPa (ksi)
Elongation	%
Reduction in Area	%
Hardness	
Analysis of Specimen	
Test Condition - (Heat Treatment)	

**FIG. 1 Summary Results Form - Alloy Description**

Corrodent	Material: %(mass/ mass)	Temp. <sup>A</sup> °C	Corrosion Rates, mm/y (mpy)			Remarks
			0 - 48 h	48 - 96 h	0 - 96 h	
HCl	0.2					
	1.0					
	5.0					
HCl + FeCl <sub>3</sub>	1.0					
	0.3					
H <sub>2</sub> SO <sub>4</sub>	10					
	60					
	96					
HNO <sub>3</sub>	10					
	70					
H <sub>3</sub> PO <sub>4</sub>	85					
	50					
HCOOH	50					
	80					
CH <sub>3</sub> COOH	50					
	+					
(CH <sub>3</sub> CO) <sub>2</sub> O	50					
	50					

<sup>A</sup> An entry to be made for each environment where the corrosion rate is below 0.13 mm/y and at the next higher temperature where the corrosion rate exceeds 0.13 mm/y.

**FIG. 2 Summary Results Form - General Corrosion Resistance**

**Material:**

G48 Method D    Critical Crevice Corrosion Temperature - Acidified 6% FeCl<sub>3</sub>

Test No.	CCT Determined. °C	No. of Attacked Areas	Maximum Depth of Attack, mm	Mass Loss Area <sup>A</sup> mg/cm <sup>2</sup>
X				
Y				
Z				

G123    Acidified 25% NaCl Stress Corrosion Cracking

Replicate ID	Before Crack <sup>B</sup>	To Crack <sup>C</sup>	Days		Crack Location	Crack Morphology <sup>D</sup>
			Final pH			
1						
2						
3						

Magnesium Chloride Stress Corrosion Cracking

Replicate ID	Before Crack <sup>B</sup>	To Crack <sup>C</sup>	Days		Crack Location	Crack Morphology <sup>D</sup>
			Final pH			
1						
2						
3						

<sup>A</sup> This measurement is an addition to the requirements of G48 Method D.

<sup>B</sup> No. of days in test when specimen was observed with no cracks visible.

<sup>C</sup> No. of days in test when specimen was first observed with cracks.

<sup>D</sup> Crack Morphology observed after metallographic sectioning.

IG = Intergranular    TG = Transgranular    M = Mixed

**FIG. 3 Summary Results Form - Localized Corrosion Performance**

Test Method G 123 should be used, if possible. This design is based on the Practice G 30 U-bend and the tests should be carried out with at least triplicate specimens for a period of 1000 h. The results are to be reported as described in Test Method G 123 and entered on the summary results sheet. See Fig. 3.

7.3 *Magnesium Chloride Test, Optional*—Alloys that do not crack in the acidified sodium chloride environment may be tested in a magnesium chloride test. The test environment is described in Practice G 36. U-bend specimens similar to those suggested in Test Method G 123 should be used with triplicate replication. The test should be run for 30 days or until cracking is observed. The specimens should be removed at convenient

intervals not to exceed three days during exposure and examined for cracking. The time to first crack is reported. Metallographic sectioning is to be carried out on at least one of each set of replicates at the end of the exposure to document the crack morphology or, in the case of surviving specimens, that no microcracks are present. The result of this test is to be reported on the summary results sheet (Fig. 3).

## 8. Report

8.1 The results of these tests are to be reported as specified in the test method referenced. The summary results sheets

shown in Figs. 1-3 provide a convenient form to present the results in a consistent format.

## 9. Keywords

9.1 chemical process industry; crevice corrosion; general corrosion; iron-base corrosion resistant alloys; nickel-base corrosion resistant alloys; stress corrosion cracking

## APPENDIX

### (Nonmandatory Information)

## X1. SUGGESTED LABORATORY TESTING OF IRON- AND NICKEL-BASED ALLOYS FOR CORROSION RESISTANCE IN SELECTED MEDIA FOR GENERAL CORROSION PERFORMANCE

### X1.1 Scope

X1.1.1 This test method describes a suggested procedure for corrosion tests to determine the relative resistance of wrought iron- and nickel-based alloys to corrosion in selected media. These tests are intended to provide corrosion data suitable for preliminary evaluation prior to testing for specific chemical applications.

X1.1.2 Each alloy is tested in the as-manufactured condition; as-welded specimens may be included. (See X1.3.10.2 for when only the as-welded condition need be tested.)

X1.1.3 Specimen evaluation procedures provide for mass loss measurements for evaluation of general corrosion and low power surface microscopic examination for presence of localized corrosion, such as pitting, stress corrosion, intergranular attack, end-grain corrosion, and preferential weld attack.

### X1.2 Apparatus

X1.2.1 A 1000 mL Erlenmeyer flask equipped with a reflux condenser, a sparger with a fitted glass disc for deaerating certain solutions, a specimen support system, and a means for controlling the temperature of the contents of the flask are recommended for all tests.

X1.2.2 All components of the apparatus described in X1.2.1 which are in contact with the test environment (liquid and gas phases) are to be made of glass or polytetrafluoroethylene (PTFE) or other inert nonconductive material.

X1.2.3 The temperature-regulating device used for tests at temperatures other than the boiling temperature should be capable of controlling the temperature of the contents of the flask to within  $\pm 1^\circ\text{C}$  of the selected test temperature.

X1.2.4 The specimen support system should be designed so that the specimen is separated from the flask and its internal components. The specimen is to be maintained in a vertical position, totally immersed in the test solution. One desirable support system is to use an individual glass cradle for each specimen.

X1.2.5 A nitrogen sparging system, which is used for initial deaeration in tests at temperatures below boiling and in

non-oxidizing solutions, should be capable of sparging nitrogen at the rate of 100 mL/min. A device to prevent backflow of test solution into the gas supply system should be included.

### X1.3 Test Specimens

X1.3.1 The specimens should be made from sheet, plate, or strip produced by commercial methods.

X1.3.2 Material from which the specimens are made should be in the annealed condition, the final heat treatment being done after any cold rolling. Temperature of the final heat treatment and method of cooling should be reported.

X1.3.3 Thickness of the sheet materials used for specimens should be between 1.5 and 4.8 mm (0.06 and 0.188 in.). Width of the specimens should be 20 mm (0.8 in.) and the length 50 mm (2.0 in.).

X1.3.4 Specimens are to be cut to size by a machining operation. If sheared specimens are used, the sheared edges are to be removed by grinding or machining; the amount of metal removed by machining should equal the thickness of the specimen.

X1.3.5 All specimens should be abraded to provide a uniform surface finish free of scale and dirt, and to remove any sharp edges or burrs due to machining or drilling operations. The final step in this abrading operation should be done with wet No. 80 or dry No. 120 grit abrasive paper. Exercise care to avoid overheating the surface. This step should be omitted when the intent of the test is to evaluate mill finish or other surface conditions.

X1.3.6 Specimens should be stamped with identifying letters and numbers, using clean, hardened steel stamps.

X1.3.7 Specimens should be measured prior to test and the total exposed area, including edges, calculated and reported to the closest  $65\text{ mm}^2$  (0.1 in.<sup>2</sup>).

X1.3.8 Following the abrasive treatment, the specimens should be cleaned with a magnesium oxide paste or detergent solution to remove any residual dirt or grease, rinsed in water, and dipped in acetone and air dried.