



Standard Test Method for Detecting Detrimental Phases in Lean Duplex Austenitic/Ferritic Stainless Steels¹

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1. Scope*

1.1 The purpose of this test method is to allow detection of the presence of detrimental chromium-containing phases in selected lean duplex stainless steels to the extent that toughness or corrosion resistance is affected significantly. Such phases can form during manufacture and fabrication of lean duplex products. This test method does not necessarily detect losses of toughness nor corrosion resistance attributable to other causes, nor will it identify the exact type of detrimental phases that caused any loss of toughness or corrosion resistance. The test result is a simple pass/fail statement.

1.2 Lean duplex (austenitic-ferritic) stainless steels are typically duplex stainless steels composed of 30 to 70 % ferrite content with a typical alloy composition having Cr > 17 % and Mo < 1 % and with additions of Nickel, Manganese, Nitrogen and controlled low carbon content as well as other alloying elements. This standard test method applies only to those alloys listed in [Table 1](#). Similar test methods for some higher alloyed duplex stainless steels are described in Test Methods [A923](#), but the procedures described in this standard differ significantly for all three methods from the ones described in Test Methods [A923](#).

1.3 Lean duplex stainless steels are susceptible to the formation of detrimental chromium-containing compounds such as nitrides and carbides and other undesirable phases. Typically this occurs during exposures in the temperature range from approximately 300 to 955°C (570 to 1750°F) with a maximum susceptibility in the temperature range around 650 to 750°C (1200 to 1385°F). The speed of these precipitation reactions is a function of composition and the thermal or thermo-mechanical history of each individual piece. The presence of an amount of these phases can be detrimental to toughness and corrosion resistance.

1.4 Because of the low molybdenum content, lean duplex stainless steels only exhibit a minor susceptibility to sigma or

other types of molybdenum containing intermetallic phases. Heat treatment, that could lead to formation of small amounts of molybdenum containing intermetallics, would result in a large amount of precipitation of detrimental nitrides or carbides, long before any signs of sigma and similar phases would be observed.

1.5 Correct heat treatment of lean duplex stainless steels can eliminate or reduce the amount and alter the characteristics of these detrimental phases as well as minimizing Cr-depletion in the matrix phase in the immediate vicinity of these phases. Adequately rapid cooling of the product from a suitable annealing temperature provides the maximum resistance to formation of detrimental phases by subsequent thermal exposures. For details of the proper annealing temperature recommendations for the alloy and product in question, the user is referred to the relevant applicable ASTM product specification.

1.6 Compliance with the chemical and mechanical requirements for the applicable product specification does not necessarily indicate the absence of detrimental phases in the product.

1.7 These test methods include the following:

1.7.1 *Test Method A*—Etch Method for detecting the presence of potentially detrimental phases in Lean Duplex Stainless Steels

1.7.2 *Test Method B*—Charpy V-notch Impact Test for determining the presence of detrimental phases in Lean Duplex Stainless Steels.

1.7.3 *Test Method C*—Inhibited Ferric Chloride Corrosion Test for determining the presence of detrimental phases in Lean Duplex Stainless Steels.

1.7.4 Examples of the correlation of thermal exposures, the occurrence of detrimental phases, and the degradation of toughness and corrosion resistance are given in [Appendix X2](#), [Appendix X3](#), and the References.

1.8 Guidelines for the required data needed for subcommittee [A01.14](#) to consider listing a lean duplex stainless steel in this standard test method are given in [Annex A1](#).

1.9 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to other units that are provided for information only and are not considered standard.

¹ This test method is under the jurisdiction of ASTM Committee [A01](#) on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee [A01.14](#) on Methods of Corrosion Testing.

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TABLE 1 List of Lean Duplex Grades Covered by This Standard

Grades
UNS S32101
UNS S32304
UNS S32202
UNS S82011

1.10 *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.*

2. Referenced Documents

2.1 ASTM Standards:²

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels

A1084 Test Method for Detecting Detrimental Phases in Lean Duplex Austenitic/Ferritic Stainless Steels

E6 Terminology Relating to Methods of Mechanical Testing

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)³

G48 Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution

3. Terminology

3.1 Definitions:

3.1.1 The terminology used herein, if not specifically defined otherwise, shall be in accordance with Terminology **E6** and **G15**. Definitions provided herein and not given in Terminology **E6** or in **G15** are limited only to this standard.

4. Significance and Use

4.1 Test Method A shall only be used to supplement the results of Test Methods B and C. It shall not be used as a rejection criterion, nor shall it be used as an acceptance criterion. Test Methods B and C are intended to be the procedures giving the acceptance criteria for this standard.

4.2 Test Method A can reveal potentially detrimental phases in the metallographic structure. As the precipitated detrimental phases can be very small, this test demands high proficiency from the metallographer, especially for thinner material.

4.3 The presence of detrimental phases is readily detected by Test Methods B and C provided that a sample of appropriate location and orientation is selected.

4.4 The tests do not determine the precise nature of the detrimental phase but rather the presence or absence to the extent that the normally expected toughness and corrosion resistance of the material are significantly affected.

4.5 This standard covers testing of samples taken from coil, coil- and plate mill plate, sheet, tubing, piping, bar and deformed bar, though some of these products might not be suitable for testing according to Method B (see Test Method B for further details). Other product forms have thus far not been sufficiently tested and documented to be an integral part of this standard, though the standard does not prohibit testing of these product forms according to the three test methods. For these other product forms, this standard gives only limited and non-exhaustive guidance as to interpretation of result and associated acceptance criteria.

4.6 Testing on product forms outside the present scope of this standard shall be agreed between purchaser and supplier.

5. Sampling, Test Specimens, and Test Units

5.1 Sampling:

5.1.1 Because the occurrence of detrimental phases is a function of temperature and cooling rate, it is essential that the tests be applied to the region of the material experiencing the conditions most likely to promote the formation of detrimental phases. In the case of common heat treatment, this region can be that which cooled most slowly or undergoes extremely rapid cooling.

5.1.2 For practical purposes, it is considered sufficient that the sampling location for flat mill products be from a location that is at least twice the material thickness from the as-heated edges.

5.1.3 Purchaser and supplier may agree on more detailed rules regarding the sampling location.

5.1.4 The number of samples as well as frequency of sampling shall be agreed between purchaser and supplier of the material.

5.2 Test Specimens and Test Units:

5.2.1 Details of test specimen and test unit requirements are listed together with each of the Test Methods A, B and C.

TEST METHOD A—ETCH METHOD FOR EVALUATION OF THE PRESENCE OF POTENTIALLY DETRIMENTAL PHASES IN LEAN DUPLEX STAINLESS STEELS

6. Introduction

6.1 The etch test in this standard shall only be used for exploratory purposes. The reason for this is the small size of the detrimental phases typically occurring in lean duplex stainless steels and the difficulty in achieving a fully reproducible etch structure, which depends on factors such as specimen size and geometry, etching current and potential, composition of the lean duplex as well as the amount and type of detrimental phases present. The test method contained in this standard is, however, the best known metallographic procedure to show the appearance and approximate amount of detrimental phases in a lean duplex stainless steel.

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.

³ The last approved version of this historical standard is referenced on www.astm.org.

6.2 As there is no formal test result from the metallographic etch method, the actual test method is attached to this standard as **Appendix X1**.

TEST METHOD B—CHARPY V-NOTCH IMPACT TEST FOR DETERMINATION OF THE PRESENCE OF DETRIMENTAL PHASES IN LEAN DUPLEX STAINLESS STEELS

7. Scope

7.1 This test method describes the procedure for conducting the Charpy V-notch impact test as a method of detecting the precipitation of detrimental phases in lean duplex stainless steels. The presence or absence of an indication of a detrimental phase in this test is not necessarily a measure of performance of the material in service with regard to any property other than that measured directly. The Charpy V-notch procedure as applied here is different from that commonly applied for the determination of toughness and shall not be used when characterization of material toughness is the purpose of the testing.

8. Significance and Use (Test Method B)

8.1 The Charpy V-notch impact test may be used to evaluate mill products, provided that it is possible to obtain a specimen of the proper size from a relevant location.

8.2 Charpy V-notch impact toughness of a material is affected by factors other than the presence and absence of detrimental phases. These factors are known to include different compositions, even when the material is in fully annealed condition; small and otherwise acceptable variations in austenite/ferrite balance; and the lamellar distance between phases. Testing transverse and longitudinal test specimens from mill products can also give different absolute levels of impact toughness.

8.3 **Table 2** indicates the applicability and acceptance criteria for Test Method B. These acceptance criteria have been shown to allow for the natural variation of impact toughness in sound material tested in the transverse direction on plate and in the longitudinal direction on bar and deformed bar, while still being able to identify whether detrimental amounts of undesirable phases are present.

TABLE 2 Applicability and Acceptance Criteria for Test Method B

Grade	Sampling Location	Test Temperature	Minimum Impact Energy ^A
S32101	base metal	Room temperature ^B	70 J (50 ft-lb)
S32304	base metal	Room temperature ^B	100 J (75 ft-lb)
S32202	base metal	Room temperature ^B	70 J (50 ft-lb)
S82011	base metal	Room temperature ^B	70 J (50 ft-lb)

^A Energy for a full-size specimen tested in transverse direction for flat rolled products and tested in the longitudinal direction for bar products. Required energy for a sub-size specimen is discussed further in subsection **10.1.3** and **Note 2**.

^B In this standard, room temperature is defined as the temperature range 23 ± 5°C (73 ± 9°F).

8.4 Acceptance criteria for Test Method B for other products including mill welded pipe, weldments and weld metal are not presently covered by this standard, though purchaser and supplier may agree upon an acceptance criteria (see **Note 1**). Note that the results of weldment testing will depend on the filler metal or weld deposit chemistry.

8.5 Acceptance criteria of sub-size specimens are not covered by this standard, though purchaser and supplier may agree upon a proper conversion factor of the given acceptance criteria in **Table 2**. Conversion factors generally vary by product type and dimensions of product for which the sub-size specimen sampling is needed (see **Note 2**).

NOTE 1—As no data has been presented to subcommittee **A01.14** for welded mill products or other products, no recommendation can be given as to the acceptance criteria for these products. Any acceptance criteria and other details of the test should be supported with data from a pre-qualification test in line with the minimum requirements of **Annex A1** in this standard.

NOTE 2—As stated in Test Methods and Definitions **A370**, Appendix **A5.3.3** and Test Methods **E23**, Appendix **X1.3**, there is no general correlation between impact values obtained with specimens of different size or shape. However, limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. It is commonly seen that the conversion factor is set directly proportional to the ratio between standard and sub-size specimen fracture surface area or a percentage thereof, though whether this is an acceptable way forward to still be able to identify the presence or absence of detrimental phases needs to be documented.

9. Apparatus

9.1 The test apparatus shall be as described in Test Methods and Definitions **A370**.

10. Test Specimens

10.1 General Requirements (All Products):

10.1.1 The test specimen shall be as described in Test Methods and Definitions **A370**.

10.1.2 An impact test for the purpose of detecting detrimental phases shall consist of a single specimen taken from the product piece or lot to be represented.

10.1.3 Provided purchaser and supplier have agreed upon a proper acceptance criterion, sub-size specimens may be used for products with thickness less than that of full-size Charpy V-notch specimen. Required energy for sub-size specimens shall be established and agreed upon based on the specific product type and geometry in question.

10.2 Flat Products (Sheet, Coil, Plate):

10.2.1 The specimen shall be prepared in the transverse direction. The notch shall be perpendicular to the major rolled surface.

10.3 Non-deformed bar products:

10.3.1 The specimen shall be prepared in the longitudinal direction.

10.4 Deformed Bar Products:

10.4.1 The specimen shall be prepared in the longitudinal direction.

10.5 Other Products Including Mill Pipe:

10.5.1 When this test is applied to a welded structure or to any product having a less than uniform structure, particular attention shall be paid to the location of the V-notch. For