Designation: A955/A955M – 17

Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement[1]

This standard is issued under the fixed designation A955/A955M; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This specification covers deformed and plain stainless-steel bars for concrete reinforcement in cut lengths and coils used in applications requiring resistance to corrosion or controlled magnetic permeability. The standard sizes and dimensions of deformed bars and their numerical designation shall be those listed in Table 1. The text of this specification references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the specification.

1.1.1 Supplementary requirement (S1) of an optional nature is provided. It shall apply only when specified by the purchaser. In order to obtain a controlled magnetic permeability product, steel conforming to Supplementary Requirement S1 should be ordered.

1.2 The chemical composition of the stainless steel alloy shall be selected for suitability to the application involved by agreement between the manufacturer and the purchaser. This is an important consideration in achieving the desired corrosion resistance or controlled magnetic permeability, or both, because these properties are not provided by all stainless steels.

NOTE 1—The alloys shown in Table 2 have found the most use in North America. Other alloys may also provide desired properties; consult with the manufacturer for stainless steel alloy properties and availability.

1.3 Requirements for the relative deformation area of three-sided deformed bars are contained in Annex A4.

1.4 Bars are of two minimum yield strength levels, namely, 60 000 [420 MPa] and 75 000 psi [520 MPa], designated as Grade 60 [420] and Grade 75 [520], respectively.

1.5 Plain bars in sizes up to and including 2 in. [50.8 mm] in diameter in coils or cut lengths, when ordered, shall be furnished under this specification in Grade 60 [420] and Grade 75 [520], respectively. Bending properties, when required, shall be by agreement between the manufacturer and purchaser. Requirements providing for deformations and marking shall not be applicable to plain bars.

1.6 Weldability of most stainless steel compositions is generally good, however, pre-weld or post-weld procedures, or both, are necessary. Where material is to be welded, a welding procedure suitable for the chemical composition and intended use or service shall be used. Retesting of physical properties should be considered following welding procedures depending upon the steel composition and welding operation involved.

NOTE 2—It is recommended that the user consult the manufacturer for information available from the Nickel Development Institute (NIDI) (Toronto, Canada).

1.7 This specification is applicable for orders in either inch-pound units (as Specification A955) or in SI units (as Specification A955M).

1.8 The values stated in either inch-pound or SI units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard.

1.9 *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.*

1.10 *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]

A6/A6M Specification for General Requirements for Rolled

[1] This specification is under the jurisdiction of ASTM Committee A01 on Steel, Stainless Steel and Related Alloys and is the direct responsibility of Subcommittee A01.05 on Steel Reinforcement.

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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.

*A Summary of Changes section appears at the end of this standard

TABLE 1 Deformed Bar Designation Numbers, Nominal Weights [Masses], Nominal Dimensions, and Deformation Requirements

Bar Designation No.	Nominal Weight, lb/ft [Nominal Mass, kg/m][A]		Nominal Dimensions[B]			Deformation Requirements, in. [mm]			
								Maximum Gap per Side[C]	
	400 Series; Duplex Alloys	300 Series	Diameter, in. [mm]	Cross-Sectional Area, in.^{2} [mm^2]	Perimeter, in. [mm]	Maximum Average Spacing	Minimum Average Height	Two-Sided Bar	Three-Sided Bar
3 [10]	0.374 [0.556]	0.378 [0.562]	0.375 [9.5]	0.11 [71]	1.178 [29.9]	0.262 [6.7]	0.015 [0.38]	0.143 [3.6]	0.097 [2.5]
4 [13]	0.679 [1.011]	0.686 [1.021]	0.500 [12.7]	0.20 [129]	1.571 [39.9]	0.350 [8.9]	0.020 [0.51]	0.191 [4.9]	0.129 [3.3]
5 [16]	1.048 [1.559]	1.058 [1.575]	0.625 [15.9]	0.31 [199]	1.963 [49.9]	0.437 [11.1]	0.028 [0.71]	0.239 [6.1]	0.162 [4.1]
6 [19]	1.495 [2.225]	1.511 [2.248]	0.750 [19.1]	0.44 [284]	2.356 [59.8]	0.525 [13.3]	0.038 [0.97]	0.286 [7.3]	0.194 [4.9]
7 [22]	2.038 [3.032]	2.059 [3.064]	0.875 [22.2]	0.60 [367]	2.749 [69.8]	0.612 [15.5]	0.044 [1.12]	0.334 [8.5]	0.226 [5.8]
8 [25]	2.685 [3.995]	2.713 [4.037]	1.000 [25.4]	0.79 [510]	3.142 [79.8]	0.700 [17.8]	0.050 [1.27]	0.383 [9.7]	0.259 [6.6]
9 [29]	3.396 [5.053]	3.441 [5.106]	1.128 [28.7]	1.00 [645]	3.544 [90.0]	0.790 [20.1]	0.056 [1.42]	0.431 [10.9]	0.292 [7.4]
10 [32]	4.312 [6.416]	4.358 [6.484]	1.270 [32.3]	1.27 [819]	3.990 [101.3]	0.889 [22.6]	0.064 [1.63]	0.487 [12.4]	0.329 [8.3]
11 [36]	5.296 [7.880]	5.352 [7.964]	1.410 [35.8]	1.56 [1006]	4.430 [112.5]	0.987 [25.1]	0.071 [1.80]	0.540 [13.7]	0.365 [9.3]
14 [43]	7.64 [11.37]	7.72 [11.49]	1.693 [43.0]	2.25 [1452]	5.32 [135.1]	1.185 [30.1]	0.085 [2.16]	0.648 [16.5]	0.438 [11.1]
18 [57]	13.59 [20.22]	13.72 [20.43]	2.257 [57.3]	4.00 [2581]	7.09 [180.1]	1.58 [40.1]	0.102 [2.59]	0.864 [21.9]	0.584 [14.8]

[A] The 400 and Duplex-Alloy Series is based on a density of 489.59 lb/ft^3 [7833.4 kg/m^3]. The 300 Series is based on a density of 494.78 lb/ft^3 [7916.5 kg/m^3]. Density varies with alloy content which may result in a variation of several percent.

[B] The nominal dimensions of a deformed bar are equivalent to those of a round bar having the same weight [mass] per foot [metre] as the deformed bar.

[C] The maximum gap (measured as a chord) between the ends of the deformations shall not exceed 25 %/*n* of the nominal perimeter of the bar, where n is the number of longitudinal gaps or longitudinal ribs around the perimeter of the bar.

TABLE 2 Chemical Requirements of Typical Alloys[A]

UNS Designation	Type	Composition %								
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Molybdenum	Nitrogen
S24000	XM-29	0.08	11.50-14.50	0.060	0.030	1.00	17.00-19.00	2.25-3.75	....	0.20-0.40
S24100	XM-28	0.15	11.00-14.00	0.060	0.030	1.00	16.50-19.00	0.50-2.50	....	0.20-0.45
S30400	304	0.08	2.00	0.045	0.030	1.00	18.00-20.00	8.00-10.50	....	0.10
S31603	316L	0.03	2.00	0.045	0.030	1.00	16.00-18.00	10.00-14.00	2.00-3.00	0.10
S31653	316LN	0.03 max	2.00	0.045	0.030	1.00	16.00-18.00	10.00-14.00	2.00-3.00	0.10-0.16
S31803	....	0.03	2.00	0.030	0.020	1.00	21.00-23.00	4.50-6.50	2.50-3.50	0.08-0.20

[A] Maximum, unless otherwise indicated.

Structural Steel Bars, Plates, Shapes, and Sheet Piling
A276 Specification for Stainless Steel Bars and Shapes
A342/A342M Test Methods for Permeability of Weakly Magnetic Materials
A370 Test Methods and Definitions for Mechanical Testing of Steel Products
A510 Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel
A510M Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel (Metric) (Withdrawn 2011)[3]
A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
C192/C192M Practice for Making and Curing Concrete Test Specimens in the Laboratory
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
E290 Test Methods for Bend Testing of Material for Ductility
G15 Terminology Relating to Corrosion and Corrosion Testing (Withdrawn 2010)[3]

2.2 *U.S. Military Standard:*[4]
MIL-STD-129 Marking for Shipment and Storage

2.3 *U.S. Federal Standard:*[4]
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

3. Terminology

3.1 *Definitions of Terms Specific to This Specification:*

3.1.1 *deformations, n*—transverse protrusions on a deformed bar.

3.1.2 *deformed bar, n*—steel bar with protrusions; a bar that is intended for use as reinforcement in reinforced concrete construction.

3.1.2.1 *Discussion*—The surface of the bar is provided with protrusions that inhibit longitudinal movement of the bar relative to the concrete surrounding the bar in such construction. The protrusions conform to the provisions of this specification.

3.1.3 *plain bar, n*—steel bar without protrusions.

3.1.4 *relative deformation area, n*—the ratio of the deformation bearing area (projected deformation area normal to the bar axis) to the shearing area (nominal bar perimeter times the average spacing of the deformations.

3.1.5 *rib, n*—longitudinal protrusion on a deformed bar.

3.1.6 *stainless steel, n*—a steel that contains 11 % or more chromium.

3.1.7 *three-sided bar, n*—deformed steel bar with three rows of transverse deformations.

3.1.8 *two-sided bar, n*—deformed steel bar with two rows of transverse deformations.

4. Ordering Information

4.1 It shall be the responsibility of the purchaser to specify all requirements that are necessary for material ordered to this specification. Such requirements shall include but are not limited to the following:

4.1.1 Quantity (weight) [mass],
4.1.2 Name of material (deformed and plain stainless steel bars for concrete reinforcement),
4.1.3 Chemical composition (stainless steel alloy),
4.1.4 Heat treatment condition,
4.1.5 Size,
4.1.6 Cut lengths or coils,
4.1.7 Deformed or plain,
4.1.8 Grade (strength level),
4.1.9 Descaling method and finish,
4.1.10 Requirements for inspection (20.1),
4.1.11 Packaging (see Section 24),
4.1.12 Supplementary requirement (if desired), and
4.1.13 ASTM designation and year of issue.

5. Materials and Manufacture

5.1 The bars shall be rolled from properly identified heats of mold or strand cast steel.

5.2 Bars shall be furnished in one of the following heat treatment conditions, as shown in Specification A276, and as needed to meet the requirements of this specification.

5.2.1 Annealed (A).
5.2.2 Hot rolled (HR).
5.2.3 Strain hardened (B).

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

[4] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, http://www.dodssp.daps.mil.

NOTE 3—The mechanical properties of the material result from the heat treat condition of the material. Any further heat treatment of the material may alter those properties and affect their ability to meet the specified strength level. No re-treatment should be imposed without retesting to the requirements of this specification.

6. Chemical Composition

6.1 The chemical analysis of each heat of steel shall be determined in accordance with Test Methods, Practices, and Terminology A751. The manufacturer shall make the analysis on test samples taken preferably during the pouring of the heat.

6.2 The chemical composition agreed to between manufacturer and purchaser shall conform to the requirements in Table 1 of Specification A276.

7. Requirements for Deformations

7.1 Deformations shall be spaced along the bar at substantially uniform distances. The deformations on all sides of the bar shall be similar in size, shape, and pattern.

7.2 The deformations shall be placed with respect to the axis of the bar so that the included angle is not less than 45°. Where the line of deformations forms an included angle with the axis of the bar of from 45 to 70° inclusive, the deformations on a two-sided bar shall alternately reverse in direction on each side or those on one side shall be reversed in direction from those on the opposite side. The deformations on three-sided bars shall reverse on one of the three sides (see Fig. 1). Where the line of deformation is over 70°, a reversal in direction is not required.

7.3 The average spacing or distance between deformations on each side of the bar shall not exceed seven tenths of the nominal diameter of the bar.

7.4 The overall length of deformations shall be such that the gap (measured as a chord) between the ends of the deformations shall not exceed 25 %/*n*, where *n* is the number of longitudinal gaps or longitudinal ribs, of the nominal perimeter of the bar. Where the ends of the deformations terminate in a longitudinal rib, the width of the longitudinal rib shall be considered as the gap between these ends. The summation of the gaps shall not exceed 25 % of the nominal perimeter of the bar. The nominal perimeter of the bar shall be 3.1416 times the nominal diameter.

7.5 The spacing, height, and gap of deformations shall conform to the requirements prescribed in Table 1.

8. Measurement of Deformations

8.1 The average spacing of deformations shall be determined by measuring the length of a minimum of ten spaces and dividing that length by the number of spaces included in the measurement. The measurement shall begin from a point on a deformation at the beginning of the first space to a corresponding point on a deformation after the last included space. Spacing measurements shall not be made over a bar area containing bar marking symbols.

8.2 The average height of deformations shall be determined from measurements made on not less than two typical deformations. Determinations shall be based on three measurements per deformation, one at the center of the overall length and the other two at the quarter points of the overall length.

8.3 For three-sided bars, the relative deformation area, R_d, shall meet the requirements of Annex A4.

8.4 Insufficient height, insufficient circumferential coverage, or excessive spacing of deformations shall not constitute cause for rejection unless it has been clearly established by determinations on each lot (Note 4) tested that typical deformation height, gap, or spacing does not conform to the minimum requirements prescribed in Section 7. No rejection shall be made on the basis of measurements if fewer than ten adjacent deformations on each side of the bar are measured.

NOTE 4—A lot, *for this purpose*, is defined as all the bars of one bar number and pattern of deformation contained in an individual shipping release or shipping order.

9. Tensile Requirements

9.1 The material, as represented by the test specimens, shall conform to the requirements for tensile properties prescribed in Table 3.

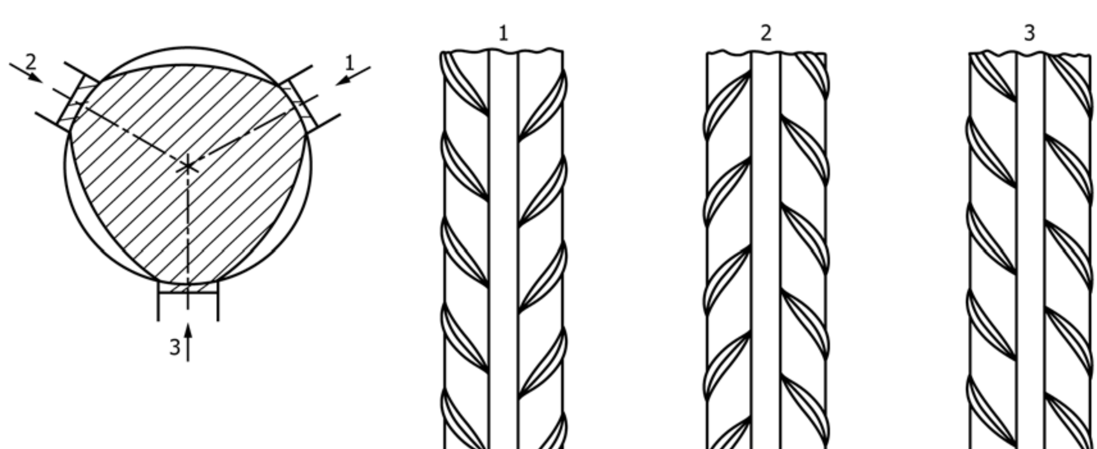

FIG. 1 Typical Three-Sided Deformed Bar

TABLE 3 Tensile Requirements

NOTE 1—Check with producer for availability of grades and sizes.

	Grade 60 [420]	Grade 75 [520]
Tensile strength, min, psi [MPa]	90 000 [620]	100 000 [690]
Yield strength, min, psi [MPa]	60 000 [420]	75 000 [520]
Elongation in 8 in. [200 mm], min, %		
Bar designation no.		
3, 4, 5 [10, 13, 16]	20	20
6 [19]	20	20
7, 8, 9, 10, 11, 14, 18 [22, 25, 29, 32, 36, 43, 57]	20	20

9.2 The yield strength shall be determined by the offset method (0.2 % offset), as described in Test Methods and Definitions A370.

9.3 When material is furnished in coils, the test specimen shall be taken from the coil and straightened prior to placing it in the jaws of the tensile test machine. Straightening of the test specimens shall be done carefully to avoid formation of local sharp bends and to minimize cold work. (See Note 5.)

9.3.1 Test specimens taken from post-fabricated material shall not be used to determine conformance to this specification.

NOTE 5—Insufficient straightening prior to attaching the extensometer can result in lower-than-actual yield strength readings. Multiple bending distortion from mechanical straightening and fabricating machines can lead to excessive cold work, resulting in higher magnetic permeability, higher yield strengths, lower elongation values, and a loss in deformation height.

9.4 The percentage of elongation shall be as prescribed in Table 3. When the actual percentage of elongation meets or exceeds 25 %, the bending requirements in Section 10 shall be waived.

10. Bending Requirements

10.1 The bend test specimen shall withstand being bent around a pin without cracking on the outside radius of the bent portion. The requirements for degree of bending and sizes of pins are prescribed in Table 4.

10.2 The bend test shall be made on specimens of sufficient length to ensure free bending and with apparatus that provides the following:

10.2.1 Continuous and uniform application of force throughout the duration of the bending operation.

10.2.2 Unrestricted movement of the specimen at points of contact with the apparatus and bending around a pin free to rotate.

10.2.3 Close wrapping of the specimen around the pin during the bending operation.

10.3 It shall be permissible to use other methods of bend testing as described in Test Methods E290, such as placing a specimen across two round bearings free to rotate and applying the bending force with a fixed round-tip mandrel conforming to the specified bend radius, allowing the bar to pass through with sufficient clearance. When failures occur under other methods of bend testing, retests shall be permitted under the bend-test method prescribed in 10.2.

TABLE 4 Bend Test Requirements

Bar Designation No.	Pin Diameter for Bend Test[A]	
	Grade 60 [420]	Grade 75 [520]
3, 4, 5 [10, 13, 16]	3½ d[B]	3½ d
6 [19]	5d	5d
7, 8 [22, 25]	5d	5d
9, 10, 11 [29, 32, 36]	7d	7d
14, 18 [43, 57] (90°)	9d	9d

[A] Test bends 180° unless noted otherwise.
[B] d = nominal diameter of specimen.

11. Hardness Requirements

11.1 Martensitic grades shall meet the minimum hardness requirements shown in Specification A276, or other referenced specifications.

12. Corrosion Resistance Requirements

12.1 Corrosion resistance testing shall be performed one time in accordance with Annex A1 for each stainless steel alloy processed as reinforcement by each manufacturer. Corrosion performance for the alloy shall be redemonstrated if the processing method is significantly altered.

13. Magnetic Properties

13.1 Controlled magnetic permeability shall be specified by invoking Supplementary Requirement S1.

14. Permissible Variation in Weight [Mass]

14.1 Deformed reinforcing bars shall be evaluated on the basis of nominal weight [mass]. The weight [mass] determined using the measured weight [mass] of the test specimen and rounding in accordance with Practice E29, shall be at least 94 % of the applicable weight [mass] per unit prescribed in Table 1. In no case shall overweight [excess mass] of any deformed bar be the cause for rejection. Weight [mass] variation for plain rounds shall be computed on the basis of permissible variation in diameter. For plain rounds smaller than ⅜ in. [9.5 mm], use Specification A510 [Specification A510M]. For larger bars up to and including 2 in. [50.8 mm], use Specification A6/A6M.

14.2 The specified limit of variation shall be evaluated in accordance with Practice E29 (rounding method).

15. Finish

15.1 The bars shall be free of detrimental surface imperfections.

15.2 Seams, surface irregularities, or mill oxidation shall not be cause for rejection, provided the mass, dimensions, cross-sectional area, and tensile properties of a test specimen are not less than the requirements of this specification.

15.3 Surface imperfections other than those specified in 15.1 shall be considered detrimental when specimens containing such imperfections fail to conform to either tensile or bending requirements.

15.4 Unless otherwise specified by the purchaser, after rolling, the bars shall be pickled to remove mill scale and surface oxidation.

NOTE 6—Pickling has been shown to be needed for the corrosion resistance of most stainless steel reinforcement.

16. Number of Tests

16.1 For all bar sizes, one tension test, one bend test, if required (see 9.4), and one set of dimensional property tests including bar weight [mass] and spacing, height, and gap of deformations shall be made of each bar size rolled from each heat and of the same heat treatment condition.

16.2 For martensitic material, two hardness tests shall be taken per lot of material. A manufacturing lot is defined as material from one heat of material heat treated in one furnace at one time. For continuous furnaces used for tempering or aging, a manufacturing lot is defined as material from one heat of material heat treated in one continuous run but not to exceed 10 000 lbs [4500 kg].

17. Retests

17.1 If the results of an original tension specimen fail to meet the specified minimum requirements and are within 2000 psi [14 MPa] of the required tensile strength, within 1000 psi [7 MPa] of the required yield strength, or within two percentage units of the required elongation, a retest shall be permitted on two random specimens for each original tension specimen failure from the lot. All retest specimens shall meet the requirements of this specification.

17.2 If a bend test fails for reasons other than mechanical reasons or flaws in the specimen as described in 17.5.2 and 17.5.3, a retest shall be permitted on two random specimens from the same lot. Both retest specimens shall meet the requirements of this specification. The retest shall be performed on test specimens that are at air temperature but not less than 60°F [16°C].

17.3 If a weight [mass] test fails for reasons other than flaws in the specimen as described in 17.5.3, a retest shall be permitted on two random specimens from the same lot. Both retest specimens shall meet the requirements of this specification.

17.4 If a corrosion resistance test fails for reasons other than flaws as described in 17.5.3, a retest shall be permitted on two random specimens from the same lot. Both retest specimens shall meet the requirements of this specification.

17.5 If the original test or any of the random retests fails because of any reasons listed in 17.5.1, 17.5.2, or 17.5.3, the test shall be considered an invalid test:

17.5.1 The elongation property of any tension test specimen is less than that specified, and any part of the fracture is outside the middle half of the gage length, as indicated by scribe marks on the specimen before testing,

NOTE 7—Marking specimens with multiple scribe or punch marks can reduce the occurrence of fracture outside or near these marks and the need for declaring the test invalid.

17.5.2 Mechanical reasons such as failure of testing equipment or improper specimen preparation,

17.5.3 Flaws are detected in a test specimen, either before or during the performance of the test.

17.6 The original results from 17.5.1, 17.5.2, or 17.5.3 shall be discarded and the test shall be repeated on a new specimen from the same lot.

18. Test Specimens

18.1 Tension test specimens shall be the full section of the bar as rolled. The unit stress shall be based on the nominal bar area.

18.2 The bend test specimens shall be the full section of the bar rolled.

19. Report

19.1 The following information shall be reported on a per heat or per lot basis as is appropriate.

19.1.1 Stainless steel type and name,

19.1.2 Chemical composition and product check (if appropriate),

19.1.3 Heat treat condition,

19.1.4 Descaling method and finish,

19.1.5 Bar size and number of sides,

19.1.6 Tensile properties,

19.1.7 Bend test (if required),

19.1.8 Hardness (if appropriate),

19.1.9 Corrosion test (if appropriate), and

19.1.10 Magnetic permeability (if appropriate).

19.2 A Material Test Report, Certificate of Inspection, or similar document printed from or used in electronic form from an electronic data interchange (EDI) transmission shall be regarded as having the same validity as a counterpart printed in the certifier's facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any EDI agreement between the purchaser and the supplier. Notwithstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 8—The industry definition invoked here is: EDI is the computer to computer exchange of business information in a standard format such as ANSI ASC X12.

20. Inspection

20.1 Inspection of the stainless steel reinforcing bars shall be agreed upon between the purchaser and the manufacturer as part of the purchase order or contract.

21. Rejection

21.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 6 shall be reported to the manufacturer within five days from the receipt of samples by the purchaser.

21.2 Material that shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

22. Rehearing

22.1 Samples tested in accordance with Section 6 that represent rejected material shall be preserved for two weeks from the date rejection is reported to the manufacturer. In case of dissatisfaction with the results of the tests, the manufacturer shall have the right to make claim for a rehearing within that time.

23. Marking

23.1 When loaded for mill shipment, bars shall be properly separated and tagged with the manufacturer's heat or test identification number.

23.2 Each manufacturer shall identify the symbols of his or her marking system.

23.3 All bars produced to this specification shall be identified by distinguishing marks legibly rolled onto the surface of one side of the bar to denote:

23.3.1 *Point of Origin*—Letter or symbol established as the manufacturer's mill designation.

23.3.2 *Size Designation*—Arabic number corresponding to bar designation number of Table 1.

23.3.3 *Type of Steel*—Either the letters SS or CR indicating that the bar was produced to this specification.

23.3.4 *Minimum Yield Strength Designation*—For Grade 60 [420] bars, one dot. For Grade 75 [520] bars, two dots.

NOTE 9—Prior to the revision of this specification to require bar markings for Type of Steel and the Minimum Yield Strength Designation, several manufacturers had already voluntarily adopted marking systems. The specific markings used and the order in which they appeared were not consistent. Hence, the phrase "in the following order" was deleted in Section 23.3 of A955/A955M – 11$^{\varepsilon1}$. As rolls are replaced and redressed, the manufacturers will arrange the markings in the order listed (Point of Origin, Size Designation, Type of Steel and Minimum Yield Strength Designation). At that time, the phrase "in the following order" will be reinstated in Section 23.3 and the two designations for Type of Steel, *CR* and *SS*, will be replaced with *SS*.

23.4 In addition to the bar marks, the following information shall be tagged on each bundle:

23.4.1 Stainless-steel alloy, and

23.4.2 Heat treat condition, and

23.4.3 Grade (corresponding to minimum yield strength level), and

23.4.4 Meets Supplementary Requirement S1, if appropriate.

23.5 For plain rounds, no rolled on symbols are required and all of the above information shall be tagged.

24. Packaging and Package Marking

24.1 Packing, marking, and loading for shipment shall be agreed upon between the purchaser and manufacturer.

24.2 When specified in the contract or order, and for direct procurement by or direct shipment to the U.S. Government, marking for shipment, in addition to requirements specified in the contract or order, shall be in accordance with MIL-STD-129 for military agencies and with Fed. Std. No. 123 for civil agencies.

25. Keywords

25.1 concrete reinforcement; corrosion resistance; deformations (protrusions); magnetic properties; stainless steel bars

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirement shall apply only when specified in the purchase order or contract.

S1. Magnetic Permeability Testing

S1.1 (See 13.1.) When material of a low permeability is desired, the purchaser shall specify that the material be tested to Test Methods A342/A342M. The specific limits of magnetic permeability shall be a matter of agreement between the manufacturer and the purchaser.

ANNEXES

(Mandatory Information)

A1. EVALUATION OF CORROSION RESISTANCE

A1.1 The corrosion resistance of the reinforcing steel, including the method of removing the mill scale, shall be evaluated based on either A1.2 or A1.3.

A1.2 Using a macrocell test of bare bars in a simulated concrete pore 15 % sodium chloride solution over a 15-week period, as specified in Annex A2, the average corrosion rate for a minimum of five specimens shall at no time during the test exceed 0.25 µm/year, with no single specimen exceeding a corrosion rate of 0.50 µm/year.

A1.3 Using a cracked beam test, the 24-week test cycle shall be repeated three or four times for a total duration of either 72 or 96 weeks as agreed with the entity requesting the test, as specified in Annex A3, the average corrosion rate for a minimum of five specimens shall at no time during the test exceed 0.20 µm/year, with no single specimen exceeding a corrosion rate of 0.50 µm/year.

A2. RAPID MACROCELL TEST

A2.1 Scope

A2.1.1 This test method describes procedures to measure the corrosion rate and corrosion potential of concrete reinforcing steel using the rapid macrocell test.

A2.2 Test Equipment and Materials

A2.2.1 *Plastic Containers*—Two 4.5-quart [4.5-L] plastic containers per test, approximately 7 in. [180 mm] in diameter by 7.5 in. [190 mm] in depth for each test setup.

A2.2.2 *Voltmeter*—High impedance voltmeter (at least one Mohm) capable of measuring 0.001 mV.

A2.2.3 *Reference Electrode*—A saturated calomel electrode, as defined in Practices G15.

A2.2.4 *Resistor*—10-ohm (± 0.3 ohm) electrical resistor.

A2.2.5 *Terminal Box*—Terminal boxes are used to make the electrical connections between the test specimens. Each terminal box consists of a project box with a minimum of 6 pairs of binding posts (identified here as red and black). A 10-ohm resistor connects each pair of binding posts in the terminal boxes.

A2.2.6 *Wire*—16-gauge [1.5 mm^2] insulated copper wire is used to make the electrical connections to the bars.

A2.2.7 *Epoxy Coating*—A two-part epoxy coating (such as used to as patching material for epoxy-coated bars) shall be used to cover the electrical connections. It shall be applied in accordance with manufacturer's recommendations.

A2.2.8 *Concrete Pore Solution*—Simulated concrete pore solution is prepared as follows: One litre of pore solution contains 974.8 g of distilled water, 18.81 g of potassium hydroxide (KOH), 17.87 g of sodium hydroxide (NaOH).

A2.2.9 *Sodium Chloride Solution*—The sodium chloride solution is prepared by adding 172.1 g of sodium chloride (NaCl) to one liter of simulated concrete pore solution to obtain a 15 % (6.04 molal ion) concentration solution.

A2.2.10 *Salt Bridges*—Salt bridges provide an ionic path between the solutions surrounding the cathode and the anode. The salt bridges shall be prepared as follows: A salt bridge consists of a flexible latex tube with an inner diameter of ⅜ in. (9.5 mm), filled with a gel. The gel is made using 4.5 g of agar, 30 g of potassium chloride (KCl), and 100 g of distilled water, enough to produce 4 salt bridges, each with a length of 2 ft [0.6 m]. Salt bridges are prepared by mixing the constituents and heating them over a burner or hotplate for about 1 min or until the solution starts to thicken. The gel is poured into the latex tubes using a funnel. The salt bridges are then placed in boiling water for one hour, keeping the ends of the tubes out of the water. After boiling, the salt bridges are allowed to cool until firm. To provide an adequate ionic path, the gel in the salt bridge must be continuous, without any air bubbles.

A2.2.11 *Air Scrubber*—Air is bubbled into the simulated concrete pore solution surrounding the cathode in the macrocells to provide enough oxygen for the cathodic reaction. An air scrubber is used to minimize carbonation of the pore solution by eliminating the carbon dioxide from the air. To prepare the air scrubber, a 5-gal [20-L] container is partially filled with a 1-*M* sodium hydroxide solution. Compressed air is channeled into the scrubber and out to the specimens through latex tubing. The procedure for preparing the air scrubber is as follows:

(1) Two barbed fittings are inserted on the top of the container.

(2) A5 ft [1.5 m] piece of plastic tubing is cut. On one end of the tubing, 4 ft [1.2 m] is perforated with a knife, making (typically, hundreds of) holes to allow the air to produce small bubbles. The end of the tubing closest to the holes is sealed with a clamp.

(3) The tubing end with the holes is coiled at the bottom of the container and trap rock is used to hold down the tubing. The other end of the tubing is connected to the inside part of one of the barbed fittings.

(4) The other side of the barbed fitting is connected to a plastic tube, which is connected to the compressed air outlet.

(5) Another piece of plastic tubing is connected to the outside of the other barbed fitting. The air is distributed to the solution surrounding the cathodes using 1 ft [0.3 m] lengths of latex tubing and polypropylene T-shaped connectors.

(6) Screw clamps are placed to regulate the amount of air bubbled into each container.

(7) Distilled water is periodically added to the container to replace water that is lost due to evaporation. NaOH is added, if necessary, to maintain the pH of the solution above 12.5.

A2.3 Test Specimen Preparation

A2.3.1 Reinforcing bars used in this test should be prepared in the same manner, including surface treatment, as it will be offered to the purchaser.

A2.3.2 An individual specimen (bare bar) shall consist of a 5 in. [125 mm] long, No. 5 [No. 16] reinforcing bar. Sharp edges on the bar ends shall be removed with a grinder, and the bar shall be drilled and tapped at one end to receive a ⅜-in. [10-mm] long 10-24 threaded stainless steel bolt, which is used to connect the copper wire to the bar. The bar shall be then cleaned with acetone to remove oil or dust from the bar surface. A 16-gauge [1.5 mm^2] insulated copper wire shall be attached to the top of the bar. The connection shall be covered with two layers of epoxy to prevent crevice corrosion. Each layer should be cured for a minimum of four hours.

A2.4 Test Method

A2.4.1 The macrocell test, shown in Fig. A2.1, consists of an anode and a cathode. The cathode shall consist of two bare bars in simulated concrete pore solution. The anode shall consist of one bare bar in simulated concrete pore solution with 15 % NaCl (6.04 molal ion concentration). The solutions shall be changed every five weeks. The test shall be run for 15 weeks at room temperature, 68 to 76°F [20 to 24°C].

A2.4.2 At the anode, simulated concrete pore solution with NaCl shall be placed in a container to a depth of 3 in. [75 mm]. One bar shall be placed in the center of the container, resting on the bottom of the container. The top of the bar shall be supported with the container lid, which shall be placed just above the water level. The free end of a copper wire shall be attached to the specimen and to a black binding post in a terminal box. Another container shall be filled with simulated concrete pore solution without NaCl to a depth of 3 in. [75 mm]. Two bars shall be placed in the container to act as the cathode. The bars shall be fixed in place with the lid. The free ends of copper wires shall be attached to the specimens and to a third wire that has its other end attached to a red binding post in a terminal box. Air, scrubbed to remove carbon dioxide (CO_2), shall be bubbled into the solution surrounding the

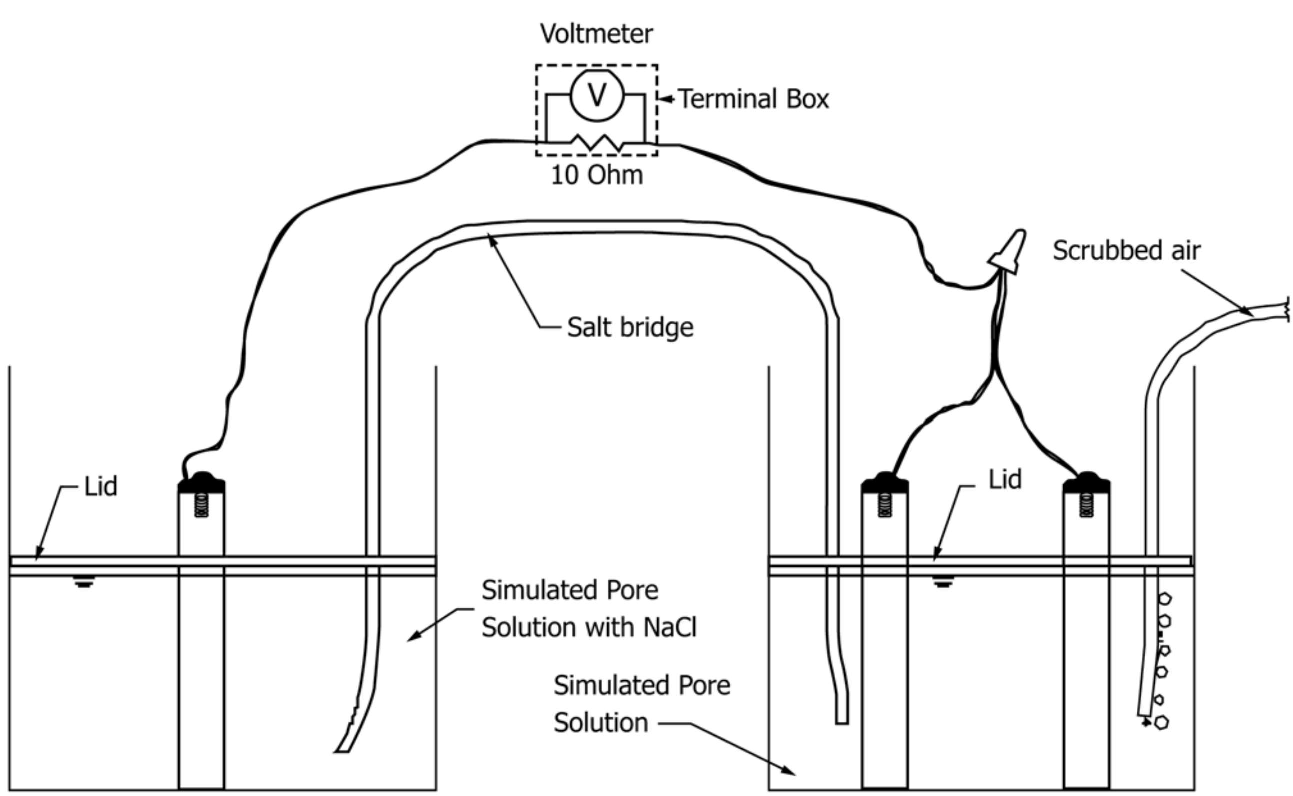

FIG. A2.1 Schematic of Macrocell Test with Bare Bars

cathode specimens to provide enough oxygen for the cathodic reaction. A salt bridge shall connect the solutions surrounding the cathode and the anode.

A2.4.3 The voltage drop shall be measured across the 10-ohm resistor that completes the macrocell circuit by connecting the black binding post to the red binding post in the terminal box. The negative terminal of the voltmeter shall be connected to the black binding post and the positive terminal of the voltmeter shall be connected to the red binding post. After the voltage drop has been measured, the anodes shall be disconnected from the terminal box. Two hours after being disconnected, the corrosion potentials of the anode and the cathode shall be measured by placing the saturated calomel electrode in the solution surrounding the bar and connecting it to the positive terminal on the voltmeter and the bar (cathode or anode) to the negative terminal of the voltmeter. Readings shall be taken once a day for the first seven days of the test and weekly, thereafter.

A2.4.4 The voltage drop obtained from the macrocell readings shall be converted to a corrosion rate (in µm/year) using the following equation:

$$\text{Rate} = 11.6 \cdot i_c = \frac{11600 \cdot V}{A \cdot R} \quad (A2.1)$$

where:

i_c = corrosion current density (µA/cm^2),
V = voltage drop across resistor (mV),
R = resistance of the resistor (ohm), and
A = area of exposed metal at the anode bar (cm^2).

A2.5 Report

A2.5.1 The following information shall be reported for each test setup:

A2.5.2 Type and source of the reinforcing bars, and description of the surface preparation.

A2.5.3 Individual readings of voltage drop and the calculated value of corrosion rate.

A2.5.4 Individual readings of corrosion potential for anode and cathode with respect to the saturated calomel electrode.

A3. CRACKED BEAM TEST

A3.1 Scope

A3.1.1 This test method describes procedures to measure the corrosion rate and corrosion potential of reinforcing bars in concrete using the cracked beam test.

A3.2 Test Equipment and Materials

A3.2.1 *Voltmeter*—High impedance voltmeter (at least one Mohm) capable of measuring 0.001 mV.

A3.2.2 *Reference Electrodes*—Saturated calomel electrode and copper-copper sulfate electrode, as defined in Practices G15.

A3.2.3 *Resistor*—10-ohm (± 0.3 ohm) electrical resistor.

A3.2.4 *Terminal Box*—Terminal boxes are used to make the electrical connections between the test specimens. Each terminal box consists of a project box with a minimum of 6 pairs of binding posts (identified here as red and black). A 10-ohm resistor connects each pair of binding posts in the terminal boxes.

A3.2.5 *Wire*—16-gauge [1.5 mm^2] insulated copper wire is used to make the electrical connections to the bars.

A3.2.6 *Epoxy Sealer*—A two-part epoxy sealer shall be used to cover the sides of the specimens and the electrical connections. It shall be applied in accordance with manufacturer's recommendations.[5]

A3.2.7 *Sodium Chloride Solution*—The 15 % sodium chloride solution is prepared by adding 150 g of NaCl to 850 g of distilled or deionized water.

A3.3 Test Specimen Preparation

A3.3.1 The procedures for preparing cracked beam specimens (see A3.4.1 and Fig. A3.1) shall be as follows:

A3.3.2 No. 5 [No. 16] bars shall be cut to a length of 12 in. [300 mm].

A3.3.3 Sharp edges on the ends of the bars shall be removed with a grinder.

A3.3.4 The ends of the bars shall be drilled and tapped to receive a ⅜-in. [10-mm] long 10-24 threaded stainless steel

[5] Ceilgard 615 made by Ceilcote and Sewer Guard HBS 100 Epoxy Liner made by BASF Construction Chemicals, Inc., have been found to be suitable for this purpose. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

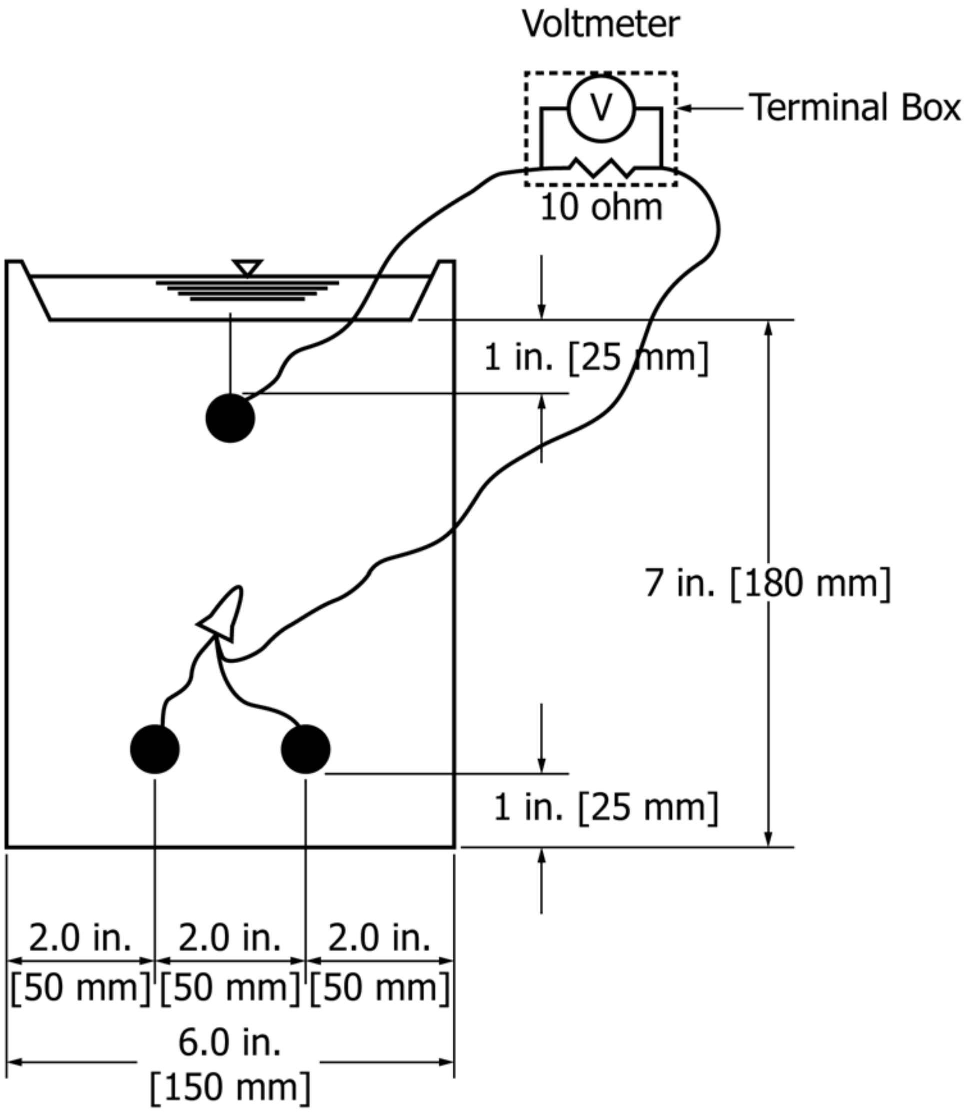

FIG. A3.1 Side View of Cracked Beam Specimen

bolt. The bolt is used to hold the bars in place during casting and to make an electrical connection during the testing period.

A3.3.5 The bars shall be cleaned with acetone to remove dust and oil.

A3.3.6 Mineral oil shall be applied to the forms prior to placing the bars in the forms.

A3.3.7 A 12-mil [0.30-mm] thick, 6-in. [150-mm] long stainless steel shim shall be fixed on to the bottom part of the form so that the shim is located underneath and parallel to the top bar.

A3.3.8 The bars shall be bolted into the forms. The specimens are cast upside down to allow for the integral concrete dam to be cast at the same time.

A3.3.9 The concrete in the test specimens shall be proportioned on a cubic yard [cubic metres] basis with the following constituents: 598 lb [355 kg] of Type I portland cement, 270 lb [160 kg] of water, normalweight fine aggregate constituting 32.5 % of the total concrete volume, normalweight ¾ in. [19 mm] nominal maximum size coarse aggregate constituting 34 % of the total concrete volume, and 6 ± 1 % air content by volume. The concrete shall be cast and cured using the following procedure:

(1) The concrete shall be mixed according to Practice C192/C192M.

(2) The specimens shall be cast in an inverted position in two layers. Each layer shall be vibrated for 30 s on a vibrating table with an amplitude of 0.0006 in. [0.15 mm] and a frequency of 60 hz.

(3) After the second layer is vibrated, the surface of the specimen shall be finished using a wooden float.

(4) The specimens shall be cured in the forms for 8 to 24 h.

(5) After the initial curing period, the specimens shall be removed from the molds, and the stainless steel shims shall be removed. The specimens shall be placed in a plastic bag with distilled water until 72 h after casting and then removed from the bags and cured in air for 25 days.

A3.3.10 Several days before the testing period starts, 16-gauge [1.5 mm^2] insulated copper wire shall be attached to the bars in the specimens using ⅜-in. [10-mm] long 10-24 threaded stainless steel bolts. The vertical sides of the specimens shall then be covered with two layers of the epoxy sealer. The electrical connections on the sides shall also be thoroughly coated to prevent crevice corrosion or galvanic corrosion from occurring.

A3.3.11 The top of the specimens shall be lightly sanded with 150-grit sand paper.

A3.3.12 The specimens shall be supported on two pieces of wood, at least 2 in. [50 mm] thick, to allow air to flow under the specimens.

A3.3.13 The top layer of steel shall then be connected to a red binding post on the terminal box, while the bottom layer of steel is connected to a black binding post.

A3.4 Test Method

A3.4.1 The cracked beam specimen (see Fig. A3.1) shall be 6 in. [150 mm] wide, 7 in. [175 mm] high, and 12 in. [300 mm] long ± 0.25 in. [6 mm] for any dimension. It shall contain one No. 5 [No. 16] bar in the top mat electrically connected across a 10-ohm (±0.3 ohm) resistor to two No. 5 [No. 16] bars in the bottom mat. A crack shall be simulated in the concrete parallel to and above the top bar using a 0.012 ± 0.001 in. [0.30 ± 0.02 mm] thick, 6 ± 0.25 in. [150 ± 6 mm] long stainless steel shim, cast into the concrete and removed 20 to 28 h after casting. The concrete cover to the top and bottom steel shall be 1 ± 0.04 in. [25 ± 1 mm]

A3.4.2 The test procedure for the cracked beam specimens shall proceed as follows beginning 28 days after casting.

(1) On the first day of a cycle, the specimens shall be ponded with a 15 % sodium chloride solution at room temperature, 68 to 76°F [20 to 24°C]. This solution shall be left on the specimen for 4 days ±3 h. Evaporation will be limited if the specimens are covered with plastic.

(2) On the fourth day of a cycle, the voltage drop across the 10-ohm resistor connecting the two mats of steel shall be recorded for each specimen. The 10-ohm resistor completes the macrocell circuit by connecting the black binding post to the red binding post in the terminal box. The negative terminal of the voltmeter shall be connected to the black binding post and the positive terminal of the voltmeter shall be connected to the red binding post.

(3) The voltage drop obtained from the macrocell readings shall be converted to a corrosion rate (in µm/year) using Eq A2.1.

(4) After the voltage drop has been measured, the circuit shall then be disconnected. Two hours after disconnecting the specimens, the solution on top of the specimens shall be removed with a vacuum cleaner, and the corrosion potentials with respect to a copper-copper sulfate electrode (CSE) of the top and bottom mats of steel recorded.

(5) After the readings have been taken, a heat tent shall be placed over the specimens to maintain a temperature of 100 ± 3°F [38 ± 2°C]. The specimens shall remain under the heat tent for 3 days ±3 h.

(6) After 3 days, the tent shall be removed and the specimens shall again be ponded with a 15 % sodium chloride solution and the cycle started again.

(7) The wet-dry cycle shall be repeated for 12 weeks. The specimens shall then be subjected to 12 weeks of continuous ponding. During this period the solution shall not removed and the specimens shall not placed under the heat tents. The solution depth shall be maintained by adding additional sodium chloride solution. The voltage drop across the 10-ohm resistor shall be taken once a week as described in A3.4.2(*2*).

(8) After 12 weeks of continuous ponding, the drying and ponding cycle shall be repeated for 12 weeks, followed by 12 weeks of continuous ponding. The 24-week cycle shall be repeated as agreed with the entity requesting the test.

NOTE A3.1—Because the specimens are ponded, the corrosion potential during this period should be taken with respect to a saturated calomel reference electrode (SCE) instead of a CSE, since the SCE is more convenient when the electrode has to be immersed in solution. Readings taken with the SCE are about 0.075 V more positive than those taken with the CSE.

A3.5 Report

A3.5.1 Type and source of reinforcing bars, and description of surface preparation.

A3.5.2 Individual readings of voltage drop and calculated value of corrosion rate.

A3.5.3 Individual readings of corrosion potential for anode and cathode with respect to the saturated calomel electrode.

A4. RELATIVE DEFORMATION AREA REQUIREMENTS FOR THREE-SIDED DEFORMED BARS

A4.1 Annex A4 prescribes the requirements for the relative deformation area of three-sided deformed reinforcing bars.

A4.2 The relative deformation area, R_d, shall be determined once for each bar size and shall meet or exceed a relative deformation area of 0.06.

A4.3 Measurements of deformations shall be made on as-rolled deformed bars.

A4.4 The relative deformation area, R_d, shall be calculated by the following equation:

$$R_d = \left(\frac{h_d}{s_d}\right)\left(1 - \frac{\sum gaps}{p}\right) \quad \text{(A4.1)}$$

where:

h_d = average height of deformations, in. or mm,
s_d = average spacing of deformations, in. or mm,
$\sum gaps$ = summation of the gaps or chord between ends of deformations, in. or mm, and
p = nominal perimeter of the bar, in. or mm.

NOTE A4.1—The term "relative deformation area," which has been adopted in this specification, is defined in Section 3.1.4 and is calculated by Eq A4.1. Some national standards for deformed (ribbed) reinforcing bars and technical documents use the analogous term "relative rib area." Further information on "relative rib area" is presented in a technical report by ACI Committee 408.[6]

A4.5 *Measurement of Deformation Height*—The average height of deformations, h_d, shall be based on measurements made on not less than two typical deformations on each side of the bar. Determinations shall be based on five measurements per deformation, one at the center of the overall length, two at the ends of the overall length, and two located halfway between the center and the ends. The measurements at the ends of the overall length shall be averaged to obtain a single value, and that value shall be combined with the other three measurements to obtain the average deformation height h_d. Deformation measurements shall be made using a depth gage with a knife-edge support that spans not more than two adjacent deformations. A knife edge is required to allow measurements to be made at the ends of the overall length of deformations, usually adjacent to a longitudinal rib. The calculation of h_d is based on a knife edge that spans only two deformations because measurements made with a longer knife edge result in higher average deformation heights and, thus, an overestimate of the relative deformation area of some three-sided deformed bars.

[6] "Bond and Development of Straight Reinforcing Bars in Tension (ACI 408R-03)." The report is available from the American Concrete Institute, 38000 International Way, P.O. Box 9094, Farmington Hills, Michigan 48333-9094, www.concrete.org.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A955/A955M – 16a) that may impact the use of this standard. (Approved March 15, 2017.)

(1) Revised A1.3 and A3.4.2 (*8*).

(2) Deleted Note A3.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A955/A955M – 16) that may impact the use of this standard. (Approved Sept. 15, 2016.)

(1) Revised Section 2 and 24.1.

(2) Revised 12.1 and deleted 12.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A955/A955M – 15) that may impact the use of this standard. (Approved Jan. 15, 2016.)

(1) Revised Sections 4 and 20.