Designation: A 494/A 494M – 07

Standard Specification for Castings, Nickel and Nickel Alloy[1]

This standard is issued under the fixed designation A 494/A 494M; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This specification covers nickel, nickel-copper, nickel-copper-silicon, nickel-molybdenum, nickel-chromium, and nickel-molybdenum-chromium alloy castings for corrosion-resistant service.

1.2 The values stated in either inch-pound units 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 must be used independently of the other. Combining values from the two systems may result in nonconformance with the specification. Inch-pound units are applicable for material ordered to Specification A 494 and SI units for material ordered to Specification A 494M.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 370 Test Methods and Definitions for Mechanical Testing of Steel Products

A 488/A 488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A 732/A 732M Specification for Castings, Investment, Carbon and Low Alloy Steel for General Application, and Cobalt Alloy for High Strength at Elevated Temperatures

A 781/A 781M Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use

E 8 Test Methods for Tension Testing of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 30 Test Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron, and Wrought Iron[3]

E 38 Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys[3]

E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys[3]

E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys

3. Terminology

3.1 *Definitions:*

3.1.1 *master heat*—a single furnace charge of refined alloy, which may either be poured directly into castings or into remelt alloy for individual melts.

3.1.2 *melts*—a single furnace charge poured into castings. When master heats are used to prepare melts, a melt analysis shall be reported.

4. General Conditions for Delivery

4.1 Material furnished to this specification shall conform to the requirements of Specification A 781/A 781M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A 781/A 781M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A 781/A 781M, this specification shall prevail.

5. Ordering Information

5.1 Orders for castings to this specification should include the following information:

5.1.1 Quantity, in pieces, and

5.1.2 Grade designation (Table 1) and class (Table 2).

5.2 The purchaser shall specify any of the following information required to describe adequately the desired material:

5.2.1 Heat-treat condition (see 6.1 and 6.2),

5.2.2 Repair welding (see Section 11)

[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 A01.18 on Castings.

Current edition approved May 1, 2007. Published May 2007. Originally approved in 1963. Last previous edition approved in 2005 as A 494/A 494M – 05.

[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] Withdrawn.

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

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TABLE 1 Chemical Requirements

NOTE—Values are maximum unless otherwise indicated.

Grade	CZ100	M35-1[A]	M35-2	M30H	M25S	M30C[A]	N12MV	N7M	N3M	CY40	CW12MW	CW6M	CW2M	CW6MC	CY5SnBiM	CX2MW	CU5MCuC	CX2M
UNS Numbers	N02100	N24135	N04020	N24030	N24025	N24130	N30012	N30007	J30003	N06040	N30002	N30107	N26455	N26625	N26055	N26022	N08826	N26059
	Composition, %																	
C, max	1.00	0.35	0.35	0.30	0.25	0.30	0.12	0.07	0.03	0.40	0.12	0.07	0.02	0.06	0.05	0.02	0.050 max	0.02
Mn, max	1.50	1.50	1.50	1.50	1.50	1.50	1.00	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.5	1.00	1.0 max	1.00
Si, max	2.00	1.25	2.00	2.7-3.7	3.5-4.5	1.0-2.0	1.00	1.00	0.50	3.00	1.00	1.00	0.80	1.00	0.5	0.80	1.0 max	0.50
P, max	0.03	0.03	0.03	0.03	0.03	0.03	0.040	0.040	0.040	0.03	0.040	0.040	0.03	0.015	0.03	0.025	0.030 max	0.020
S, max	0.03	0.03	0.03	0.03	0.03	0.03	0.030	0.030	0.030	0.03	0.030	0.030	0.03	0.015	0.03	0.025	0.030 max	0.020
Cu	1.25 max	26.0-33.0	26.0-33.0	27.0-33.0	27.0-33.0	26.0-33.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	1.50-3.50	. . .
Mo	. . .	. . .	. . .	. . .	. . .	. . .	26.0-30.0	30.0-33.0	30.0-33.0	. . .	16.0-18.0	17.0-20.0	15.0-17.5	8.0-10.0	2.0-3.5	12.5-14.5	2.5-3.5	15.0-16.5
Fe	3.00 max	3.50 max	3.50 max	3.50 max	3.50 max	3.50 max	4.0-6.0	3.00 max	3.00 max	11.0 max	4.5-7.5	3.0 max	2.0 max	5.0 max	2.0 max	2.0-6.0	balance	1.50 max
Ni	95.00 min	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	balance	38.0-44.0	balance
Cr	. . .	. . .	. . .	. . .	. . .	. . .	1.00	1.0	1.0	14.0-17.0	15.5-17.5	17.0-20.0	15.0-17.5	20.0-23.0	11.0-14.0	20.0-22.5	19.5-23.5	22.0-24.0
Cb (Nb)	. . .	0.5 max	0.5 max	. . .	. . .	1.0-3.0	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.15-4.50	. . .	. . .	0.60-1.20	. . .
W	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.75-5.25	. . .	1.0 max	. . .	. . .	2.5-3.5	. . .	. . .
V	. . .	. . .	. . .	. . .	. . .	. . .	0.20-0.60	. . .	. . .	. . .	0.20-0.40	. . .	. . .	. . .	. . .	0.35 max	. . .	. . .
Bi	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.0-5.0	. . .	. . .	. . .
Sn	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	3.0-5.0	. . .	. . .	. . .

[A] Order M35-1 or M30C when weldability is required.

TABLE 2 Heat Treat Requirements

Grade	Heat Treatment
CZ100, M35-1, M35-2, CY40 Class 1, M30H, M30C, M25S Class 1, CY5SnBiM	As cast
M25S, Class 2[A]	Load into furnace at 600°F [315°C] maximum. Heat to 1600°F [870°C] and hold for 1 h plus an additional 30 min for each ½ in. [13 mm] of cross section over 1 in.[B] Cool to 1300°F [705°C][C] and hold at temperature for 30 min then quench in oil to room temperature.
M25S, Class 3	Load into furnace at 600°F [315°C] maximum. Heat slowly to 1100°F [605°C] and hold to develop maximum hardness. Furnace or air cool to room temperature.
N12MV, N7M, N3M	Heat to 2000°F [1095°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CW12MW, CW6M, CW6MC, CW2M	Heat to 2150°F [1175°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CY40, Class 2	Heat to 1900°F [1040°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2MW	Heat to 2200°F [1205°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.
CU5MCuC	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water. Stabilize at 1725-1815°F [940-990°C], hold for sufficient time to heat castings to temperature, quench in water or rapid cool by other means.
CX2M	Heat to 2100°F [1150°C] minimum, hold for sufficient time to heat castings to temperature, quench in water or rapid air cool by other means.

[A] M25S, while machinable in the "as-cast" condition, is capable of being solution treated for improved machinability. It may be subsequently age hardened to the hardness specified in Table 3 and finished machined or ground.
[B] For cross sections over 6 in. [125 mm], it may be necessary to increase the hold time if maximum softness is desired.
[C] For maximum softness and the least variation in hardness levels, castings should be transferred from an oven at 1600°F [870°C] to a second oven at 1300°F [705°C].

5.2.3 Source inspection requirements, if any (see Specification A 781/A 781M),

5.2.4 Marking-for-identification requirements, if any (see 13.1), and

5.2.5 Supplementary requirements desired, including the standards of acceptance.

6. Heat Treatment

6.1 Castings shall be heat treated in accordance with the requirements in Table 2.

NOTE 1—Proper heat treatment of these alloys is usually necessary to enhance corrosion resistance and, in some cases, to meet mechanical properties. Minimum heat-treat temperatures are specified; however, it is sometimes necessary to heat treat at higher temperatures, hold for some minimum time at temperature, and then rapidly cool the castings in order to enhance the corrosion resistance and meet mechanical properties.

6.2 When Class 1 is specified, grades CY40 and M25S shall be supplied in the as-cast condition. When Class 2 is specified, grades CY40 and M25S shall be supplied in the solution-treated condition. When Class 3 is specified, grade M25S shall be supplied in the age-hardened condition.

7. Chemical Composition

7.1 These alloys shall conform to the chemical composition requirements prescribed in Table 1.

7.2 An analysis of each master heat shall be made by the manufacturer to determine the percentages of the elements specified in Table 1. The analysis shall be made from a representative sample taken during the pouring of the master heat. Chemical composition shall be reported to the purchaser or his representative.

7.3 Test Methods E 76 or Test Methods E 354 shall be used for referee purposes. Test Methods E 30 or Methods E 38 shall be used if Test Methods E 76 or Test Methods E 354 do not include a method for some element present in the material.

8. Tensile Properties

8.1 One tension test shall be made from each master heat except for grades M25S and CY5SnBiM when the master heat is used to pour the castings. One tension test shall be made from each melt except for grades M25S and CY5SnBiM. Test results shall conform to the tensile requirements specified in Table 3. Test bars shall be poured in special blocks from the same heat as the castings represented.

8.2 The bar from which the test specimen is taken shall be heat treated in production furnaces to the same procedure as the castings it represents. If the castings are not heat treated, the bar used for the test specimen must not be heat treated.

TABLE 3 Mechanical Properties

	CZ100	M35-1	M35-2	M30H	M25S	M30C	N12MV	N7M	N3M	CY40	CW-12MW	CW6M	CW2M	CW6MC	CY5S-nBiM	CX2MW	CU5-MCuC	CX2M
Tensile strength, min, ksi [MPa]	50 [345]	65 [450]	65 [450]	100 [690]	...	65 [450]	76 [525]	76 [525]	76 [525]	70 [485]	72 [495]	72 [495]	72 [495]	70 [485]	...	80 [550]	75 [520]	72 [495]
Yield strength, min, ksi [MPa]	18 [125]	25 [170]	30 [205]	60 [415]	...	32.5 [225]	40 [275]	40 [275]	40 [275]	28 [195]	40 [275]	40 [275]	40 [275]	40 [275]	...	45 [310]	35 [240]	39 [270]
Elongation in 2 in. [50 mm],[A] min, %	10	25	25	10	...	25	6	20	20.0	30	4	25	20	25	...	30	20	40
Hardness HB	...	...	...	...	[B]	...	...	...	...	...	...	...	...	...	...	...	...	...

[A] When ICI test bars are used in tensile testing as provided for in Specification A 732/A 732M, the gage length to reduced section diameter ratio shall be 4 to 1.
[B] 300 HB minimum for the age hardened condition.

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8.3 Test specimens may be cut from castings, at the producer's option, instead of from test bars.

8.4 When castings are produced by methods other than investment process, tension test coupons shall be machined to the form and dimension shown in Fig. 8 of, and tested in accordance with, Test Methods E 8.

8.4.1 When castings are produced by the investment process, test specimens in accordance with Specification A 732/A 732M shall be used for measurement of tensile properties.

8.5 If any specimen shows defective machining or develops flaws, it may be discarded and another substituted from the same heats.

8.6 To determine conformance with the tension test requirements, an observed value or calculated value shall be rounded in accordance with Practice E 29 to the nearest 500 psi [3.5 MPa] for yield and tensile strength and to the nearest 1 % for elongation and reduction of area.

9. Workmanship, Finish, and Appearance

9.1 Critical surfaces of all castings intended for corrosion-resistant service shall be cleaned. Cleaning may be accomplished by blasting with clean sand or metallic corrosion-resistant shot or by other approved methods.

10. Quality

10.1 The castings shall not be peened, plugged, or impregnated to stop leaks.

10.2 Internal chills and chaplets may be used in the manufacture of castings. However, the chills, chaplets and affected cast material must be completely removed.

11. Repair by Welding

11.1 Repairs shall be made by using a welding procedure and operators capable of producing sound welds. The composition of deposited weld metal shall be similar to that of the castings.

11.2 Weld repairs shall be considered major in the case of a casting that has leaked on hydrostatic test or when the depth of the cavity after preparation for repair exceeds 20 % of the actual wall thickness, or 1 in. [25 mm], whichever is smaller, or when the extent of the cavity exceeds approximately 10 $in.^2$[65 cm^2]. All other weld repairs shall be considered minor. Major and minor weld repairs shall be subject to the same quality standards as are used to inspect the castings.

11.3 Castings of M30H, M25S, and CY5SnBiM may not be weld repaired.

11.4 Grades N12MV, N7M, N3M, CW12MW, CW6M, CW2M, CX2MW, CX2M, CW6MC, and CU5MCuC may require post-weld heat treatment after major weld repairs. If post-weld heat treatment is required, it must be specified along with the grade. If required, it shall be performed in accordance with Section 6.

11.5 For grade CU5MCuC, the composition of the deposited weld metal shall be similar to that of AWS A5.14 ER NiCrMo3 or AWS A5.11 E NiCrMo3.

12. Rejection and Rehearing

12.1 Samples that represent rejected material shall be preserved for two weeks from the date of transmission of the rejection report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

13. Product Marking

13.1 Castings shall be marked for the material identification with the ASTM specification designation (A 494/A 494M) and grade symbol, that is, CY40. The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings except those of such small size as to make such marking impractical. To minimize small defects caused by dislodged particles of molding sand, the number of cast identification marks shall be minimized. The marking of heat numbers on individual castings shall be agreed upon by the manufacturer and the purchaser. Markings shall be in such position as not to injure the usefulness of the casting.

13.1.1 When the castings are too small to mark individually, a symbol traceable to the heat shall be placed on the castings and the required identification then placed on a tag affixed to the container in which these castings are shipped.

14. Keywords

14.1 corrosion-resistant applications; nickel; nickel alloy castings; nickel alloys; nickel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standard supplementary requirements for use at the option of the purchaser is included in Specification A 781/A 781M. Those which are ordinarily considered for use with this specification are given below; others enumerated in Specification A 781/A 781M may be used with this specification upon agreement between the manufacturer and the purchaser.

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S2. Radiographic Examination

S3. Liquid Penetrant Examination

S6. Certification

S10. Hardness Tests

S10.1 When composition M25S material is ordered with a hardness maximum or range in the as-cast or solution-treated condition, hardness tests shall be made in accordance with Test Methods and Definitions A 370. The test location, number of tests, and hardness values shall be agreed upon between the manufacturer and purchaser.

S10.1.1 If castings are ordered in the as-cast condition, hardness determinations shall be made on two different representative areas of each casting or coupon selected for test.

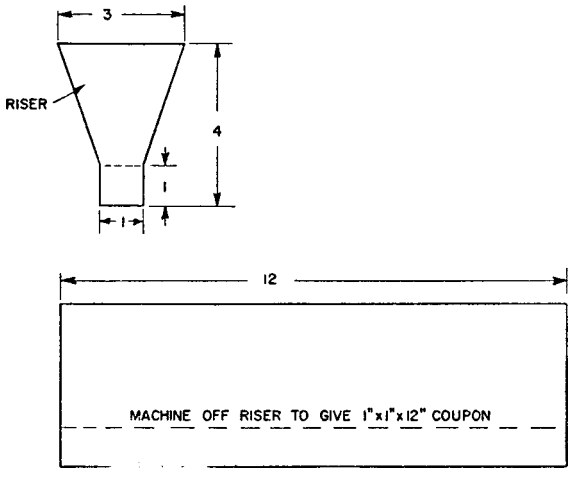
S10.1.1.1 By agreement between purchaser and producer, those as-cast castings that fail to meet the required hardness may be accepted in the solution annealed and hardened condition if the hardness thus developed meets the hardness requirement of the specification.

S10.1.2 If castings ordered are in the solution-treated condition, two sample castings or two coupons representing the lot shall be heat treated for tests (see S10.1.1). Hardness determinations shall be made on two different representative areas of each casting or coupon.

S10.1.3 When hardness tests are made, the specimens shall be at least ¼ in. [6 mm] in thickness and the area to be tested shall be ground clean before the hardness tests are made.

S22. Weldability Test

S22.1 If weldability tests are specified for M30C or M35-1, prepare a coupon obtained from a test bar shown in Fig. 1 or Fig. 2 for each lot of composition M30C or M35-1 castings.



Metric Equivalents

in.	1	3	4	12
[mm]	[25]	[75]	[100]	[305]

NOTE—Riser shall be machined off and 1 in. [25 mm] square by 12 in. [305 mm] coupon shall be used for x-weld test. See Fig. 3.

FIG. 1 Weld Test Bar (As Cast)

The weld test to be used shall be agreed upon between the purchaser and manufacturer.

S22.1.1 Prepare and weld the test bar cast in accordance with Fig. 1 and in accordance with Fig. 3.

S22.1.1.1 Machine the cast skin and unsound metal from two adjacent faces of the as-cast specimen, exclude the riser face, and cut the specimen into approximately 6-in. [150-mm] lengths.

S22.1.1.2 Clamp the two 6-in. [150 mm] lengths together to form a double V-joint and weld two passes at a time on alternate sides of the specimen using ⅛-in. [3-mm] diameter electrodes that will deposit metal of similar composition of the test pieces.

S22.1.1.3 Allow the specimen to cool to room temperature between passes, remove all flux, and examine visually for cracks.

S22.1.1.4 The clamps may be removed from the specimen after the first two weld passes have been completed.

S22.1.1.5 Deposit alternate series of passes until the double V-groove has been completely filled. After the second series (number 4 pass) a 5⁄32-in. [4-mm] diameter electrode may be used if desired.

S22.1.1.6 During welding allow each pass to cool, clean, and examine visually for cracks. The presence of cracks shall be cause for rejection.

S22.1.1.7 Upon completion of the welding, cut one section approximately ¾ in. [19 mm] long transverse to the weld from each end and discard.

S22.1.1.8 Polish each end of the remaining center section on a 100/200-grit wheel and etch with concentrated HNO_3 or with Lepito's etchant. Prepare Lepito's etchant as follows: (*1*) 15 g of $(NH_4)_2SO_4$ dissolved in 75 cm^3 of water; (*2*) 250 g of $FeCl_3$(powdered) dissolved in 100 cm^3 of HCl; (*3*) mix solutions (*1*) and (*2*) and add 30 $cm^3$of HNO_3.

S22.1.1.9 Examine the etched section under low magnification (5 to 10×). The lot represented by the test specimen shall be accepted if it complies with the following crack requirements: (*1*) Three cracks maximum in linear inch of base metal and (*2*) the length of any crack in the base metal does not exceed 0.20 in. [5 mm].

S22.1.1.10 Cracks observed in the weld metal during the low-magnification examination shall not be cause for rejection.

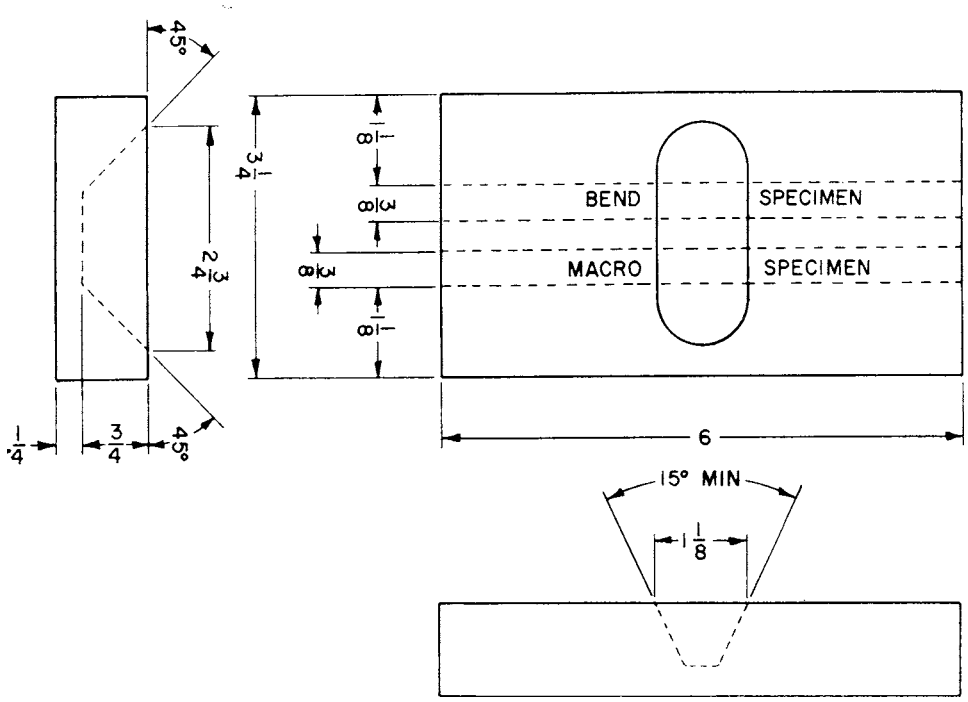
S22.1.1.11 Failure of welded test bars to comply with any of the requirements S22.1 through S22.1.1.10 shall result in rejection of the lot represented.

S22.1.2 Prepare and weld the test bar cast in accordance with Fig. 2 as follows:

S22.1.2.1 Fill the groove in the block completely with weld deposit using manual metallic arc process with ⅛-in. [3.2–mm] or 5⁄32-in. [4-mm] diameter electrodes that will deposit metal of similar composition of the test piece.

S22.1.2.2 Remove one ⅜-in. [10-mm] thick bend coupon longitudinally from the welded block by machining, sawing, abrasive cutting, or other suitable means. Make a transverse side bend test of the welded joint in accordance with Practice A 488/A 488M.

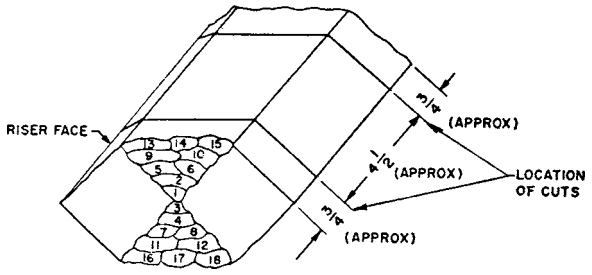
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Metric Equivalents

in.	¼	⅜	¾	1⅛	2¾	3¼	6
[mm]	[5]	[10]	[20]	[30]	[70]	[85]	[155]

FIG. 2 Weld Test Bar (As Cast)



Metric Equivalents

in.	¾	4½
[mm]	[20]	[115]

FIG. 3 X-Weld Test

S22.1.2.3 Remove a transverse weld macro-specimen from the welded plate and visually examine for cracks. This specimen may be the same one to be used for the bend specimen.

S22.1.3 *Acceptance:*

S22.1.3.1 Cracks as tears in the casting in the fusion zone or heat-affected zone of the macro-specimen shall be cause for rejection. Cracks originating at the weld bead undercuts, at weld slag inclusions, or at casting defects shall not be cause for rejection.

S22.1.3.2 Cracks or other open defects exceeding ⅛-in. [3.2 mm] measured in any direction on the convex surface of the bent specimens shall be cause for rejection, except that cracks occurring on the corners while testing and cracks originating at weld bead undercuts shall not be considered.

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SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 494/A 494M - 05, that may impact the use of this standard (Approved May 1, 2007).

(*1*) Changed the significant figures of Table 3 to agree with section 8.6.

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