Designation: A 781/A 781M – 06

# Standard Specification for Castings, Steel and Alloy, Common Requirements, for General Industrial Use[1]

This standard is issued under the fixed designation A 781/A 781M; 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 a group of requirements that are mandatory requirements of the following steel casting specifications issued by ASTM. If the product specification specifies different requirements, the product specification shall prevail.

| ASTM Designation | Title of Specification |
|---|---|
| A 27/A 27M | Steel Castings, Carbon, for General Application |
| A 128/A 128M | Steel Castings, Austenitic Manganese |
| A 148/A 148M | Steel Castings, High Strength, for Structural Purposes |
| A 297/A 297M | Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant for General Application |
| A 447/A 447M | Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service |
| A 494/A 494M | Castings, Nickel and Nickel Alloy |
| A 560/A 560M | Castings, Chromium-Nickel Alloy |
| A 743/A 743M | Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application |
| A 744/A 744M | Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe |
| A 747/A 747M | Steel Castings, Stainless, Precipitation Hardening |
| A 890/A 890M | Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application |
| A 915/A 915M | Steel Castings, Carbon and Alloy, Chemical Requirements Similar to Standard Wrought Grades |
| A 958 | Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similiar to Standard Wrought Grades |
| A 1002 | Castings, Nickel-Aluminum Ordered Alloy |

1.2 This specification also covers a group of supplementary requirements that may be applied to the above specifications as indicated therein. These are provided for use when additional testing or inspection is desired and apply only when specified individually by the purchaser in the order.

1.3 The requirements of the individual material specification, and this general specification shall prevail in the sequence named.

1.4 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 781 and SI units for material ordered to Specification A 781M.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 27/A 27M Specification for Steel Castings, Carbon, for General Application

A 128/A 128M Specification for Steel Castings, Austenitic Manganese

A 148/A 148M Specification for Steel Castings, High Strength, for Structural Purposes

A 297/A 297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

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

A 380 Practice for Cleaning, Descaling, and Passivation of Stainless Steel Parts, Equipment, and Systems

A 447/A 447M Specification for Steel Castings, Chromium-Nickel-Iron Alloy (25-12 Class), for High-Temperature Service

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

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy

A 560/A 560M Specification for Castings, Chromium-Nickel Alloy

A 609/A 609M Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

[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.

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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.**

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A 744/A 744M Specification for Castings, Iron-Chromium-Nickel, Corrosion Resistant, for Severe Service
A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
A 751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
A 800/A 800M Practice for Steel Casting, Austenitic Alloy, Estimating Ferrite Content Thereof
A 802/A 802M Practice for Steel Castings, Surface Acceptance Standards, Visual Examination
A 890/A 890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application
A 915/A 915M Specification for Steel Castings, Carbon, and Alloy, Chemical Requirements Similar to Standard Wrought Grades
A 941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A 958 Specification for Steel Castings, Carbon and Alloy, with Tensile Requirements, Chemical Requirements Similar to Standard Wrought Grades
A 967 Specification for Chemical Passivation Treatments for Stainless Steel Parts
A 991/A 991M Test Method for Conducting Temperature Uniformity Surveys of Furnaces Used to Heat Treat Steel Products
A 1002 Specification for Castings, Nickel-Aluminum Ordered Alloy
E 94 Guide for Radiographic Examination
E 125 Reference Photographs for Magnetic Particle Indications on Ferrous Castings
E 165 Test Method for Liquid Penetrant Examination
E 186 Reference Radiographs for Heavy-Walled (2 to 412-in. [51 to 114-mm]) Steel Castings
E 280 Reference Radiographs for Heavy-Walled (412 to 12-in. [114 to 305-mm]) Steel Castings
E 340 Test Method for Macroetching Metals and Alloys
E 353 Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys
E 354 Test Methods for Chemical Analysis of High-Temperature, Electrical, Magnetic, and Other Similar Iron, Nickel, and Cobalt Alloys
E 446 Reference Radiographs for Steel Castings Up to 2 in. [51 mm] in Thickness
E 709 Guide for Magnetic Particle Examination

## 3. Terminology

3.1 *Definitions:*

3.1.1 The definitions in Test Methods and Definitions A 370, Test Methods, Practices, and Terminology A 751, and Terminology A 941 are applicable to this specification and those listed in 1.1.

3.1.2 *test coupon*, *n*—the part from which the test specimen will be extracted.

3.1.3 *test specimen*, *n*—the part that will be acted upon in a test.

## 4. Materials and Manufacture

4.1 *Melting Process*—The steel shall be made by open-hearth or electric furnace process with or without separate refining, such as argon-oxygen-decarburization (AOD), unless otherwise specified in the individual specification.

4.2 *Heat Treatment*:

4.2.1 Castings shall be heat treated in the working zone of a furnace that has been surveyed in accordance with Test Method A 991/A 991M.

4.2.2 When castings are heat treated at temperatures above 2000°F [1100°C], then the working zone shall have been established by a survey performed at not more than 25°F [15°C] below nor more than 200°F [110°C] above the minimum heat treatment temperature specified for the grade. If a minimum heat treatment temperature is not specified for the grade, then the survey temperature shall be not more than 50°F [30°C] below nor more than 175°F [100°C] above the furnace set point used.

4.2.3 The maximum variation in measured temperature as determined by the difference between the highest temperature and the lowest temperature shall be as agreed between the purchaser and producer except that during production heat treatment, no portion of the furnace shall be below the minimum specified temperature nor above the maximum specified temperature for the grade being processed.

## 5. Chemical Composition

5.1 *Chemical Analysis*—Chemical analysis of materials covered by this specification shall be in accordance with Test Methods, Practices, and Terminology A 751.

5.2 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of the elements specified in the individual specification for the grade being poured. The analysis shall be made from a test sample preferably taken during the pouring of the heat. When drillings are used, they shall be taken not less than ¼ in. [6.4 mm] beneath the surface. The chemical composition thus determined shall conform to the requirements in the individual specification for the grade being poured.

5.3 *Product Analysis*—A product analysis may be made by the purchaser from material representing each heat, lot, or casting. The analysis shall be made on representative material. Samples for carbon analysis of carbon and alloy steel shall be taken no closer than ¼ in. [6 mm] to a cast surface, except that castings too thin for this shall be analyzed on representative material. The chemical composition thus determined shall meet the requirements specified in the applicable specification for the grade involved, or shall be subject to rejection by the purchaser, except that the chemical composition determined for carbon and low alloy steel castings may vary from the specified limits by the amounts shown in Table 1. The product analysis tolerances of Table 1 are not applicable as acceptance criteria for heat analysis by the casting manufacturer. When comparing product and heat analysis for other than carbon and low alloy steels, the reproducibility Data $R_2$, in Test Methods E 353 or E 354, as applicable, shall be taken into consideration.



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**TABLE 1 Product Analysis Tolerances**

| Element | Range, %[A] | Tolerances[B,C] Over Maximum or Under Minimum Limit, % |
|---|---|---|
| C | up to 0.65 | 0.03 × % $C_L$ + 0.02 |
| | above 0.65 | 0.04 |
| Mn | up to 1 | 0.08 × % $Mn_L$ + 0.01 |
| | above 1 | 0.09 |
| Si | up to 0.60 | 0.22 × % $Si_L$ – 0.01 |
| | above 0.60 | 0.15 |
| P | all | 0.13 × % $P_L$ + 0.005 |
| S | all | 0.36 × % $S_L$ + 0.001 |
| Ni | up to 2 | 0.10 × % $Ni_L$ + 0.03 |
| | above 2 | 0.25 |
| Cr | up to 2 | 0.07 × % $Cr_L$ + 0.04 |
| | above 2 | 0.18 |
| Mo | up to 0.6 | 0.04 × % $Mo_L$ + 0.03 |
| | above 0.6 | 0.06 |
| V | up to 0.25 | 0.23 × % $V_L$ + 0.004 |
| | above 0.25 | 0.06 |
| W | up to 0.10 | 0.08 × % $W_L$ + 0.02 |
| | above 0.10 | 0.02 |
| Cu | up to 0.15 | 0.18 × % $Cu_L$ + 0.02 |
| | above 0.15 | 0.05 |
| Al | up to 0.10 | 0.08 × % $Al_L$ + 0.02 |
| | above 0.10 | 0.03 |

[A] The range denotes the composition limits up to which tolerances are computed by the equation, and above which the tolerances are given by a constant.

[B] The subscript $_L$ for the elements in each equation indicates that the limits of the element specified by the applicable specification are to be inserted into the equation to calculate the tolerance for the upper limit and the lower limit (if applicable), respectively. Examples of computing tolerances are presented in footnote C.

[C] To illustrate the computation of the tolerance, consider the manganese maximum of 0.70 for a 0.30 carbon grade 65-35 in Specification A 27/A 27M. The maximum permissible deviation is (0.08 × 0.70 + 0.01) = 0.066. Therefore, the highest acceptable product analysis is 0.766. Similarly, for a 0.20 carbon grade 70-40 in Specification A 27/A 27M, the maximum manganese content is 1.40; thus, the highest acceptable product analysis is (1.40 + 0.09) = 1.49.

5.4 *Unspecified Elements*—When chemical analysis for elements not specified for the grade ordered is desired, Supplementary Requirement S13 may be specified.

5.4.1 Grade substitution, for stainless steel or nickel base alloy castings, is not permitted. Grade substitution occurs when the material supplied:

*(1)* contains an element, other than nitrogen, that is not specified in the ordered grade; and,

*(2)* the amount of that element equals or exceeds the minimum requirement for the element in another grade for which it is specified.

For this requirement, a grade is defined as an alloy described individually in a table of chemical requirements within any specification listed within the scope of A 781/A 781M.

## 6. Mechanical Test Requirements

6.1 The individual product specifications vary as to whether mechanical tests are required; for this reason, and to determine specific test requirements, the individual product specification should be reviewed.

6.2 Unless otherwise specified by the purchaser, when mechanical properties are required by the product specification, test coupons may be cast integrally with the castings, or as separate blocks, in accordance with Fig. 1, Fig. 2, or Fig. 3, except when Supplementary Requirement S15 is specified. The test coupon in Fig. 3 shall be employed only for austenitic alloy castings with cross sections less than 2½ in. [65 mm].[3]

## 7. Workmanship, Finish, and Appearance

7.1 All castings shall be made in a workmanlike manner and shall conform to the dimensions on drawings furnished by the purchaser before manufacture is started. If the pattern is supplied by the purchaser, the dimensions of the casting shall be as predicated by the pattern.

## 8. Quality

8.1 The surface of the casting shall be free of adhering sand, scale, cracks, and hot tears as determined by visual examination. Other surface discontinuities shall meet the visual acceptance standards specified in the order. Practice A 802/A 802M or other visual standards may be used to define acceptable surface discontinuities and finish. Unacceptable visual surface discontinuities shall be removed and their removal verified by visual examination of the resultant cavities.

8.2 When additional inspection is desired, Supplementary Requirements S1, S2, S3, S4, or S5 may be specified.

8.3 Rejectable indications shall not be peened, plugged, or impregnated.

## 9. Repair

9.1 Repair by welding shall be in accordance with the requirements of the individual specification using procedures and welders qualified in accordance with Practice A 488/A 488M.

## 10. Inspection

10.1 The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy that the material is being produced and furnished in accordance with the applicable specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections, with the exception of product analysis (5.3), shall be made at the place of manufacture unless otherwise agreed.

## 11. Rejection

11.1 Subsequent to acceptance at the manufacturer's works, material that is found to be unacceptable as determined by requirements specified in the order may be rejected by the purchaser. The manufacturer should be notified of such rejection. If the manufacturer is dissatisfied with the results of any tests performed by the purchaser, he may make claim for a rehearing.

## 12. Keywords

12.1 castings; common requirements; steel and alloy

[3] Information on the relationship of mechanical properties determined on test coupons obtained as specified in 6.2 with those obtained from the casting may be found in *The Steel Casting Handbook*, Fifth Edition, Steel Founders' Society of America, pp. 15-35 through 15-43, 1980.



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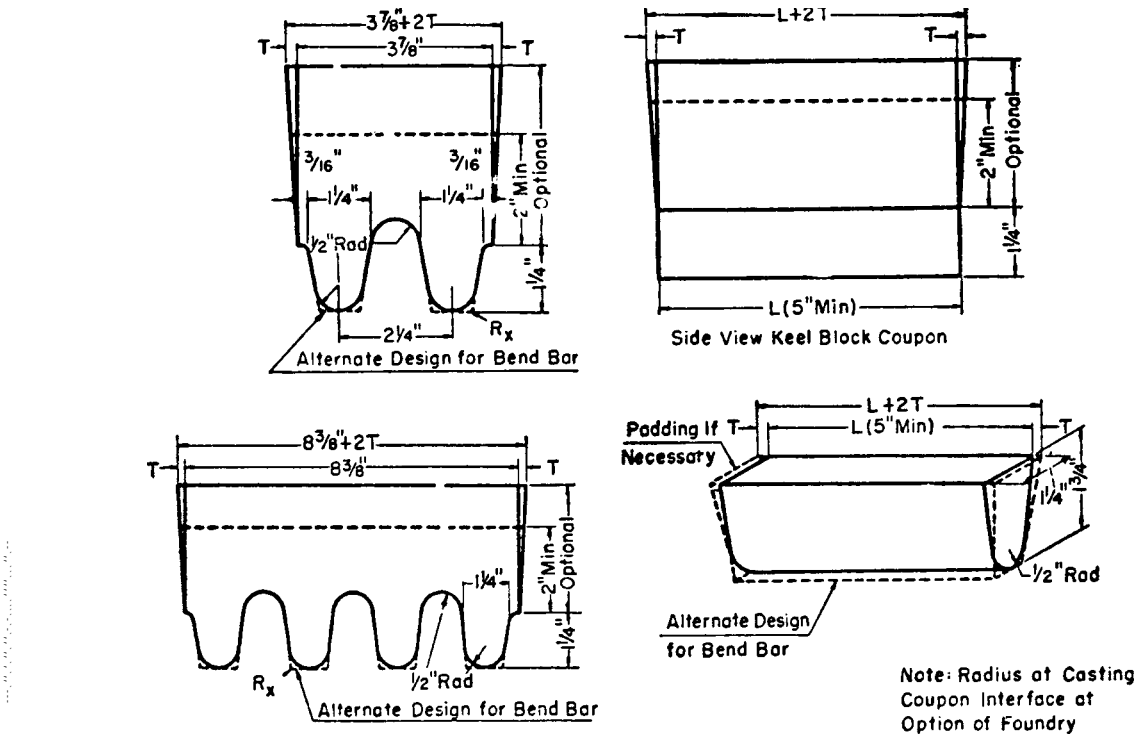


Metric Equivalents

| in. | 3/16 | ½ | 1¼ | 1¾ | 2 | 2¼ | 3⅞ | 5 | 8⅜ |
|---|---|---|---|---|---|---|---|---|---|
| [mm] | [4.8] | [13] | [32] | [45] | [51] | [57] | [98] | [127] | [213] |

| | | Leg Design [125 mm] | | Riser Design |
|---|---|---|---|---|
| 1. | *L* (length) | A 5 in. [125 mm] minimum length will be used. This length may be increased at the option of the foundry to accommodate additional test specimens (see Note 1). | 1. *L* (length) | The length of the riser at the base will be the same as the top length of the leg. The length of the riser at the top therefore depends on the amount of taper added to the riser. |
| 2. | End Taper | Use of and size of end taper is at the option of the foundry. | 2. Width | The width of the riser at the base of a multiple-leg coupon shall be *n* (2¼) [57 mm] - ⅝ [16 mm] where *n* equals the number of legs attached to the coupon. |
| 3. | Height | 1¼ in. [32 mm] | | |
| 4. | Width (at top) | 1¼ [32 mm] (see Note 1). | | The width of the riser at the top is therefore dependent on the amount of taper added to the riser. |
| 5. | Radius (at bottom) | ½ in. [13 mm], max | | |
| 6. | Spacing between legs | A ½-in. [13-mm] radius will be used between the legs. | 3. *T* (riser taper) Height | Use of and size is at the option of the foundry. The minimum height of the riser shall be 2 in. [51 mm]. The maximum height is at the option of the foundry for the following reasons: (*a*) many risers are cast open, (*b*) different compositions may require variation in risering for soundness, and (*c*) different pouring temperatures may require variation in risering for soundness. |
| 7. | Location of test specimens | The tensile, bend, and impact specimens will be taken from the lower portion of the leg (see Note 2). | | |
| 8. | Number of legs | The number of legs is at the option of the foundry providing they are equi-spaced according to Item 6. | | |
| 9. | $R_s$ | Radius from 0 to approximately 1/16 in. [2 mm]. | | |

NOTE 1—*Test Coupons for Large and Heavy Steel Castings:* The test coupons in Fig. 1 are to be used for large and heavy steel castings. However, at the option of the foundry the cross-sectional area and length of the standard coupon may be increased as desired.

NOTE 2—*Bend Specimen:* If a bend specimen is required, an alternate design (as shown by dotted lines in Fig. 1) is indicated.

**FIG. 1 Test Coupons for Castings with Details of Design**



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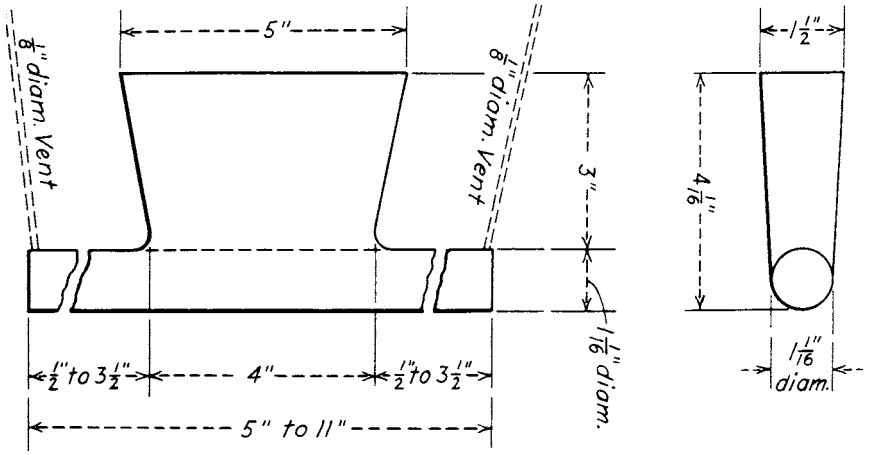
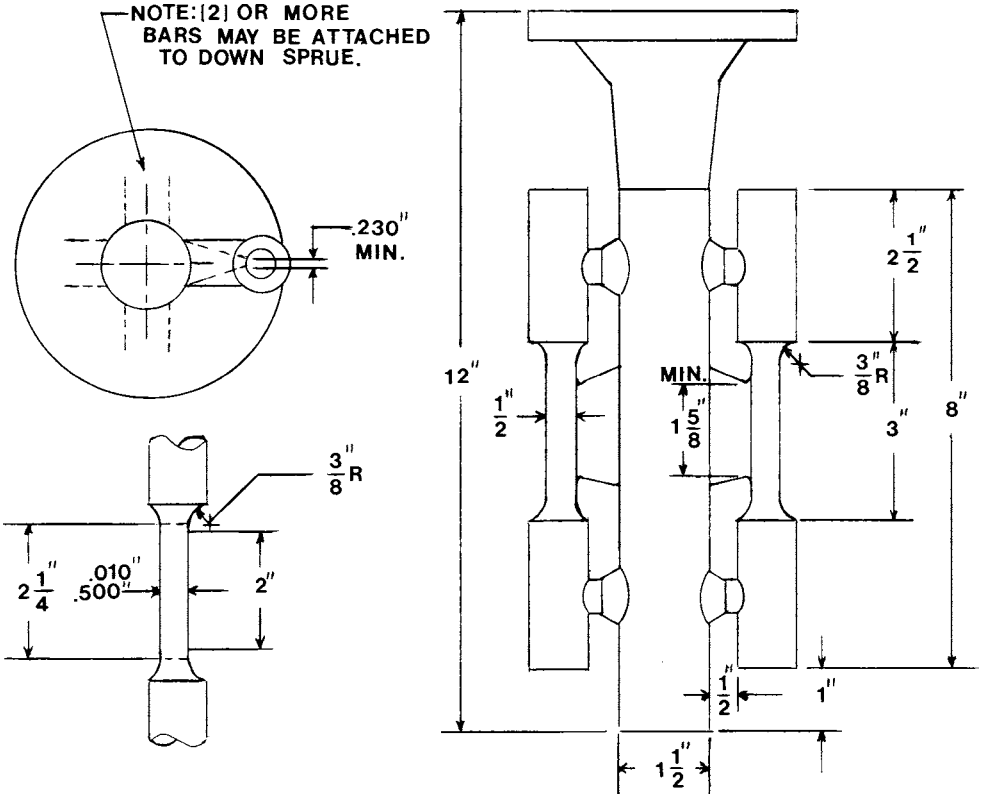



**Metric Equivalents**

| in. | [mm] | in. | [mm] |
|---|---|---|---|
| ⅛ | [3.2] | 3½ | [88.9] |
| ½ | [12.7] | 4 | [101.6] |
| 1 1⁄16 | [27.0] | 4 1⁄16 | [103.2] |
| 1½ | [38.1] | 5 | [127.0] |
| 3 | [76.2] | 11 | [279.4] |

NOTE—Pour through head; cover molten head with powdered charcoal, coke dust, and so forth, immediately after pouring, in order to keep head fluid as long as possible.

**FIG. 2 Test Coupon for Tension Test**




NOTE—Coupons produced in this manner are suitable for austenitic alloys only. The mold may be preheated for pouring to produce a sound coupon.

**FIG. 3 Cast-To-Shape Test Coupon for Tension Specimen**



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## SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall be applied only when specified by the purchaser. Details of the supplementary requirements shall be agreed upon by the manufacturer and purchaser. The specified tests shall be performed by the manufacturer prior to shipment of the castings.

### S1. Magnetic Particle Examination

S1.1 Castings shall be examined for surface and near surface discontinuities by magnetic particle examination. The examination shall be in accordance with Guide E 709. Extent of examination and the basis for acceptance shall be agreed upon between the manufacturer and purchaser.

### S2. Radiographic Examination

S2.1 Castings shall be examined for internal defects by means of X rays or gamma rays. The procedure shall be in accordance with Guide E 94, and types and degrees of discontinuities considered shall be judged by Reference Radiographs E 446, E 186, or E 280. Extent of examination and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

### S3. Liquid Penetrant Examination

S3.1 Castings shall be examined for surface discontinuities by means of liquid penetrant examination. The examination shall be in accordance with Test Method E 165. Areas to be inspected, methods and types of liquid penetrants to be used, developing procedure, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

### S4. Ultrasonic Examination

S4.1 Castings shall be examined for internal defects by means of ultrasonic examination. The examination procedure shall be in accordance with Practice A 609/A 609M. Extent of examination, methods of testing, and basis for acceptance shall be agreed upon between the manufacturer and purchaser.

### S5. Examination of Weld Preparation

S5.1 Magnetic particle or liquid penetrant examination of cavities prepared for welding shall be performed to verify removal of those discontinuities found unacceptable by the examination method specified for the casting. Unless other degrees of shrinkage or types of discontinuities found in the cavities are specified, Type II, Internal Shrinkage, of Reference Photographs E 125, of Degree 2 in sections up to 2 in. [50.8 mm] thick and of Degree 3 in sections over 2 in. thick shall be acceptable.

### S6. Certification

S6.1 The manufacturer's certification shall be furnished to the purchaser stating that the material was manufactured, sampled, tested, and inspected in accordance with the material specification (including year date) and was found to meet the requirements.

S6.2 A manufacturer's certification 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 provided it conforms to any existing EDI agreement between the purchaser and the supplier.

### S7. Prior Approval of Major Weld Repairs

S7.1 Major weld repairs as defined and agreed upon between the manufacturer and purchaser shall be subject to the prior approval of the purchaser.

### S8. Marking

S8.1 The manufacturer's name or identification mark and the pattern number shall be cast or stamped on all castings. When further specified, the heat numbers or serial numbers shall be marked on individual castings.

### S9. Charpy Impact Test

S9.1 Charpy impact test properties shall be determined by testing a set of three Charpy V-notch specimens made from each heat at a test temperature agreed upon by the manufacturer and purchaser. The material from which the test specimens are prepared shall be cast in accordance with 6.2. The acceptance requirements shall be either energy absorbed, lateral expansion, or percent shear area, or all three, and shall be that agreed upon between the manufacturer and purchaser. Test specimens shall be prepared as Type A and tested in accordance with Test Methods and Definitions A 370.

S9.2 *Absorbed Energy*—Average energy value of three specimens shall be not less than specified, with not more than one value permitted to fall below the minimum specified and no value permitted below the minimum specified for a single specimen.

S9.3 *Lateral Expansion*—Lateral expansion value shall be agreed upon between the manufacturer and purchaser.

S9.4 *Percent Shear Area*—Percent shear area shall be agreed upon between the manufacturer and purchaser.

### S10. Hardness Test

S10.1 Hardness measurements at specified locations on the castings shall be made in accordance with Test Methods and Definitions A 370 and reported.

### S11. Specified Ferrite Content Range

S11.1 The chemical composition of the heat shall be controlled such that the ferrite content, as determined by the chemical composition procedure of Practice A 800/A 800M, shall be in conformance with the specified ferrite content range.

S11.2 The specified ferrite content range shall be as agreed upon between the manufacturer and the purchaser. The minimum specified ferrite content range shall be 10 % with the minimum ferrite content being no lower than the percent



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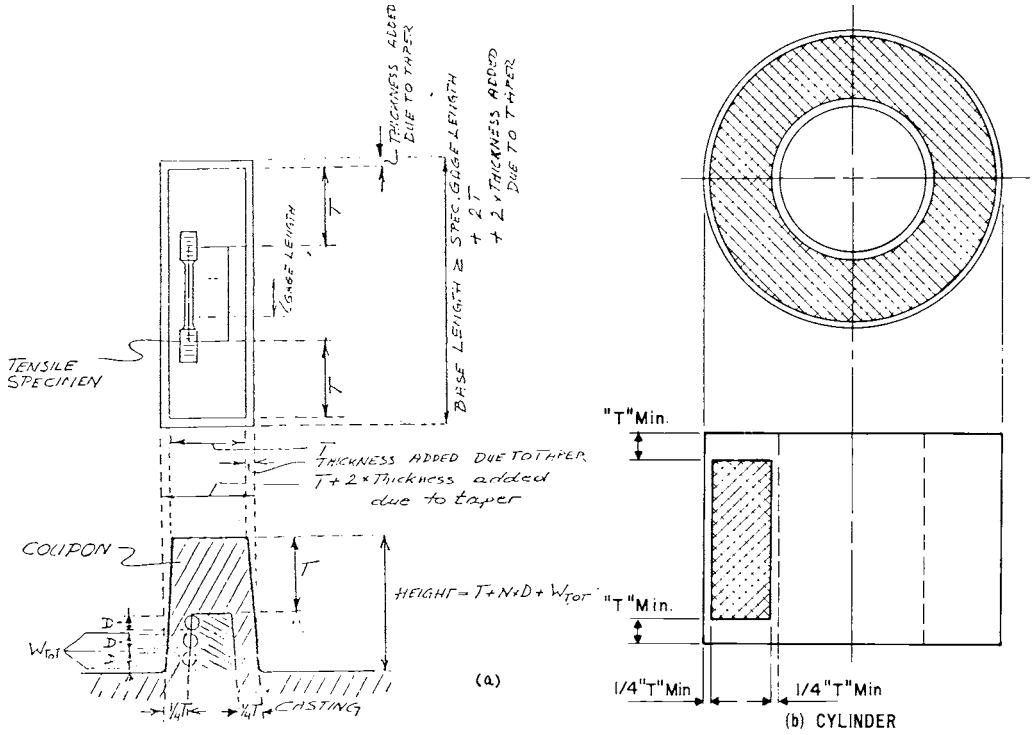


Minimum length of the base—Specimen gage length + 2x*T* + 2x *the thickness due to the tapes.*

Minimum width of the base—*T* + 2x *the thickness added due to the taper.*

Minimum height — $T + NxD + W_{tor}$.

The taper is to be selected by the producer for ease of drawing the pattern from the mold.

where:

$N$ = number of specimens to be cut from one side of the coupon,

$D$ = diameter of the specimens, and

$W_{tot}$ = the total width of metal required to remove the coupon from the casting, and to machine specimens from the coupon.

NOTE—Longitudinal axis and gage length of test specimen must be within shaded zone.

**FIG. S15.1 Specimen from Casting**

necessary to achieve the minimum mechanical properties required for the alloy.

S11.3 Should the purchaser wish to have the ferrite content determined by either magnetic response or metallographic methods, the purchaser should impose Supplementary Requirement S1 or S2 of Practice A 800/A 800M.

## S12. Test Report

S12.1 The manufacturer shall supply a test report to the purchaser giving the results of all tests performed including chemical analysis.

## S13. Unspecified Elements

S13.1 Chemical analysis and limits for elements not specified for the grade ordered shall be as agreed upon between the manufacturer and purchaser.

## S14. Tension Test from Castings

S14.1 In addition to the tension test required by the material specification, test material shall be cut from the casting. The mechanical properties and location for the test material shall be agreed upon by the manufacturer and purchaser.

## S15. Alternate Mechanical Test Coupons and Specimen Locations for Castings

S15.1 Test coupons may be cast integrally with the castings or separately. Separately cast coupons shall be heat-treated together with the castings they represent.

S15.2 In the following, the casting thickness, *T*, is the maximum thickness of the casting exclusive of padding added for directional solidification, flanges, appendages, and sections designated by the designer as noncritical. The order, inquiry, and drawing shall designate what the test dimension, *T*, is for the casting.

S15.3 One of the following shall apply:

S15.3.1 The longitudinal centerline of the test specimen shall be taken at least ¼ *T* from the *T* dimension surface and all of the gage length must be at least 1*T* from any other heat treated surface, exclusive of the surface opposite the *T* dimension surface. (See Fig. S15.1 (a).) For cylindrical castings, the longitudinal centerline of the specimens shall be taken at least ¼*T* from the outside or inside and all of the gage length must be at least *T* from the as-heat-treated end. (See Fig. S15.1 (b).) For ferritic and martensitic castings, partial severing of test coupons prior to final heat treatment is permitted.



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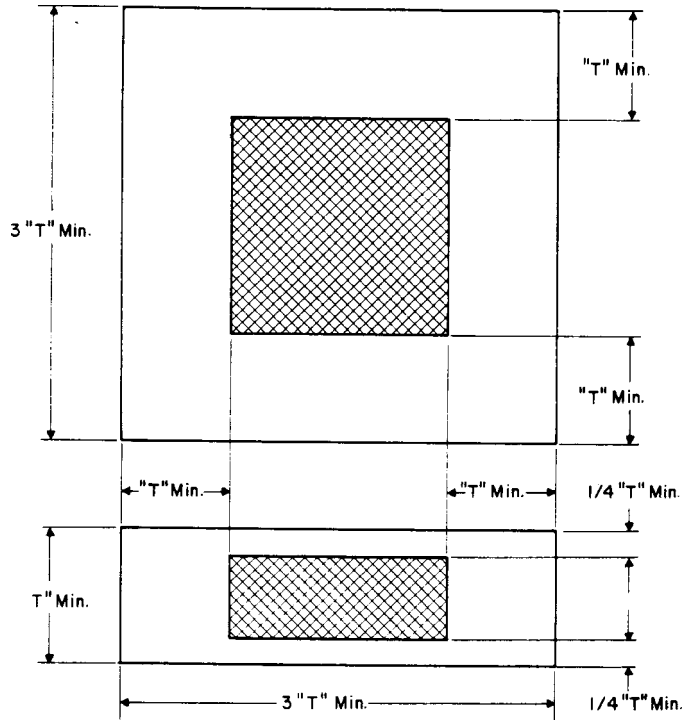


NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

**FIG. S15.2 Separately Cast Block**

S15.3.2 Where separately cast test coupons are used, the dimension shall not be less than 3*T* by 3*T* by *T* and each specimen shall meet the requirements of S15.3.1, except that when *T* exceeds 5 in. [125 mm], the dimension may be 15 by 15 by 5 in. [375 by 375 by 125 mm], by agreement between the manufacturer and the purchaser. The test coupon shall be of the same heat of steel and shall receive substantially the same casting practices as the production casting it represents. Centrifugal castings may be represented by statically cast coupons. (See Fig. S15.2.)

S15.3.3 When agreed upon by the manufacturer and the purchaser, castings that are cast or machined to essentially the finished configuration prior to heat-treatment shall have test specimens removed from a prolongation or other stock on the casting at a location below the nearest heat-treated surface indicated on the order. The specimen location shall be at a distance below the nearest heat-treated surface equivalent to at least the greatest distance that the indicated high-tensile-stress surface will be from the nearest heat-treated surface and a minimum of twice this distance from a second heat-treated surface, except that the test specimens shall be no nearer than ¾ in. [19 mm] to a heat-treated surface and 1½ in. [38 mm] from a second heat-treated surface. (See Fig. S15.3.)

S15.3.4 Where specimens are to be removed from the body of quenched and tempered castings, either the requirements of S15.3.1 shall be met or a steel thermal buffer pad or thermal insulation or other thermal barriers shall be used during heat-treatment. Steel thermal buffer pads shall be a minimum of *T* by *T* by 3*T* in length and shall be joined to the casting surface by a partial penetration weld completely sealing the buffered surface. Test specimens shall be removed from the casting in a location adjacent to the center third of the buffer pad. They shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface and ¼*T* from other heat-treated surfaces (see Fig. S15.4). When thermal insulation is used, it shall be applied adjacent to the casting surface where the test specimens are to be removed. The producer shall demonstrate that the cooling rate of the test specimen location is no faster than that of specimens taken by the method described in S15.3.1.

## S16. Weld Repair Charts

S16.1 Major weld repairs shall be documented by means of sketches or photographs, or both, showing the location and major dimensions of cavities prepared for welding. Documentation shall be submitted to the purchaser at the completion of the order.

S16.2 A weld repair shall be considered major when it is made to correct leakage on hydrostatic testing, or when the depth of the cavity prepared for welding 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$^2$].

## S17. Macroetch Test

S17.1 Apply Supplementary Requirement S13 for the spectrographic determination and reporting of the total residual aluminum content of all heats of ferritic and martensitic steels subjected to this macroetch test.

S17.2 When the heat analysis indicates a total residual aluminum content in excess of 0.08 %, the manufacturer shall etch a cross section of the casting with the heaviest section for



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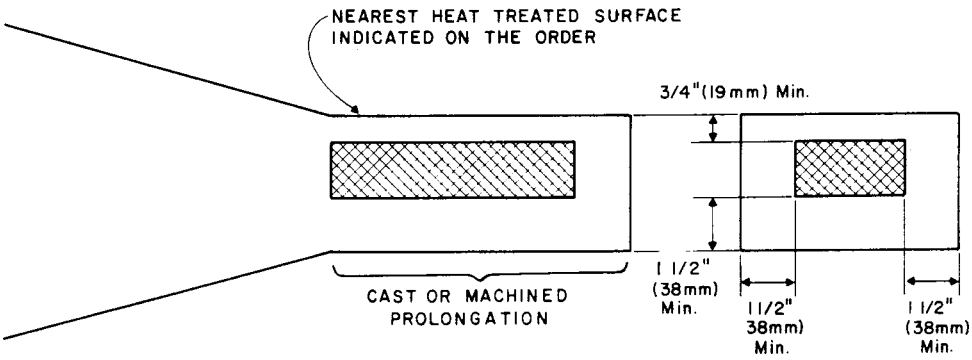
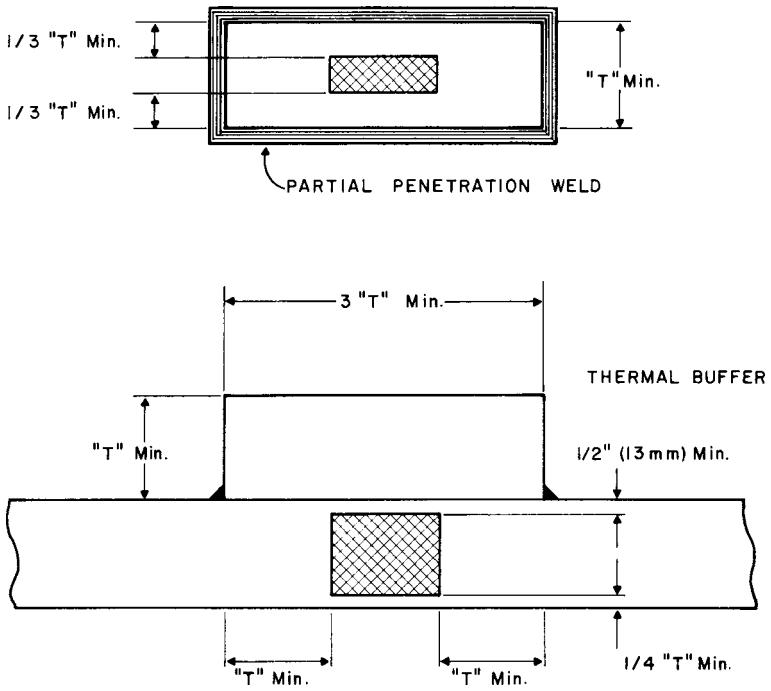



NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

**FIG. S15.3 Prolongation Test Specimen**




NOTE—Longitudinal axis and gage length of test specimen must be within cross-hatched zone.

**FIG. S15.4 Thermal Buffer Pad**

which this supplementary requirement is invoked, or a coupon attached to that heaviest section or an area directly under a riser (see Note S17.1). Cross sections from a separately cast test block from the same heat and of a thickness representative of the heaviest section of castings purchased under this supplementary requirement may also be used for macroetch testing. The etching shall be performed on the selected section after its heat treatment, that is, after annealing, normalizing, or quenching and tempering following the initial cooling of the steel below the transformation range.

Note S17.1—High strength martensitic castings, in particular, may be damaged beyond use if the etch is applied directly to the casting.

S17.3 The preparation of the surface and the macroetching procedure with Solution No. 1 (1:1 HCl) of Table 5 in Test Method E 340 shall be followed. The resulting etched surface shall be compared and rated with the reference photographs in Fig. S17.1 depicting ten levels of severity of intergranular network structures indicative of the presence of aluminum nitride or other constituents prone toward precipitating at grain boundaries during solidification and subsequent cooling. Fig. S17.1 relates the severity levels shown in these photographs with specific delineation widths and percent of boundary outlining in the etched structures.

S17.4 Castings represented by etched structures exhibiting a network rating in excess of Severity Level 4 shall be considered unacceptable until further evaluations are completed. The acceptability of individual castings may be determined by etching sections of each casting to ascertain the network severity level. Disposition of unacceptable castings shall be a matter of agreement between the manufacturer and purchaser. Those castings exhibiting etched severity levels greater than four may be evaluated further by any of the following agreed-upon methods:



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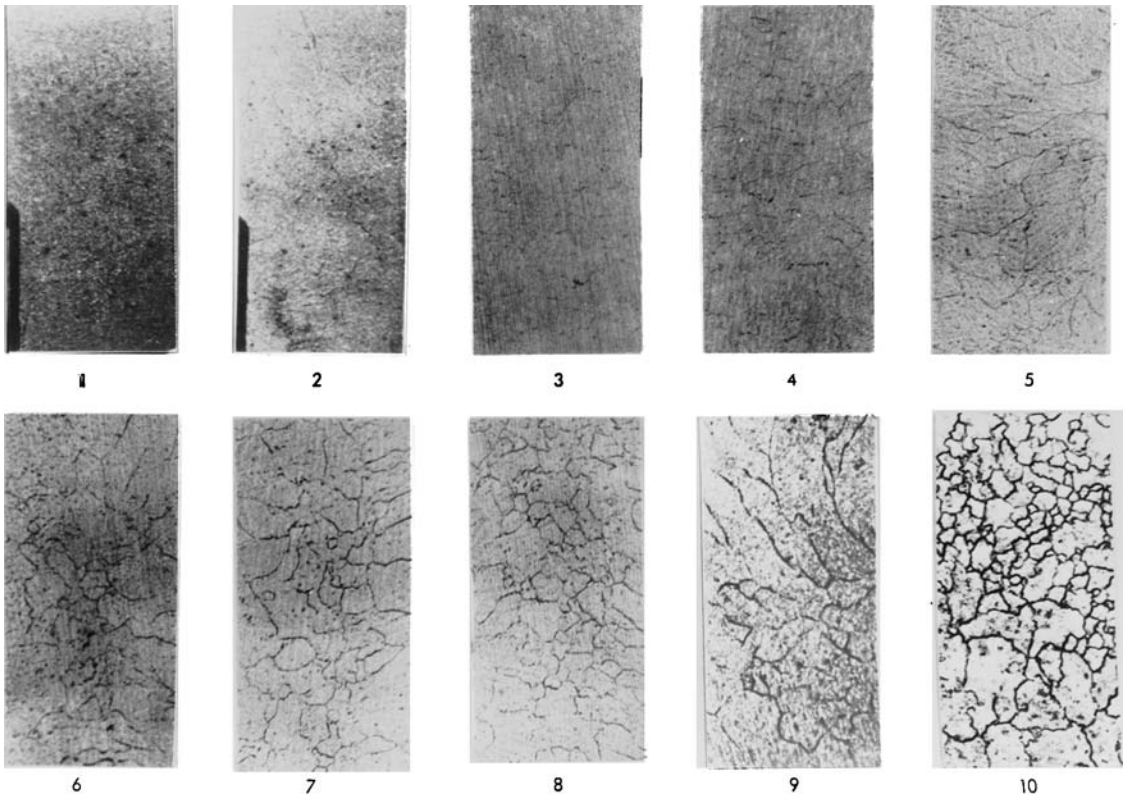


NOTE—The ten levels of severity of intergranular network structures shown are indicative of the presence of aluminum nitride precipitation in the primary austenitic grain boundaries.

**FIG. S17.1 Reference Photographs of Macroetched Cast Steel**

S17.4.1 Fracture testing to determine the amount of "rock candy" structure.

S17.4.2 Mechanical testing (for example, bend, tensile) to determine the ductility characteristics.

S17.4.3 Weld testing to determine crack susceptibility in the heat-affected zone of a circular groove welded with cellulose-coated electrodes.

S17.5 Alternatively, by agreement, it is permissible to subject castings from an unacceptable heat to a high temperature solution treatment prior to the normal production heat-treatment and subsequently macroetch test each casting.

S17.6 Heavy section castings (see Note S17.2) whose configurations are amenable to the attachment of test coupons representative of the section thickness involved and from which standard 0.505 in. [12.827 mm] diameter tension specimens may be machined are exempt from this macroetch test if the results of the tension test on the coupon after heat-treatment of the casting meet the minimum requirements specified for the grade of steel involved.

Note S17.2—For purposes of this supplementary requirement, a heavy section casting is defined as one having a wall thickness of 1½ in. [37 mm] or greater, in combination with a casting weight of at least 1000 lb [455 kg].

## S18. Hot Isostatic Pressing (HIPing)

S18.1 Castings shall be processed by Hot Isostatic Pressing (HIPing). The processing parameters for the HIPing process may be subject to an agreement between the manufacturer and purchaser.

## S19. Cleaning of Stainless Steels

S19.1 Final cleaning of the casting surfaces shall be performed in accordance with one of the cleaning methods in Practice A 380 or Specification A 967 as agreed upon between the purchaser and the supplier. Acceptance testing shall be subject to agreement between the purchaser and supplier.



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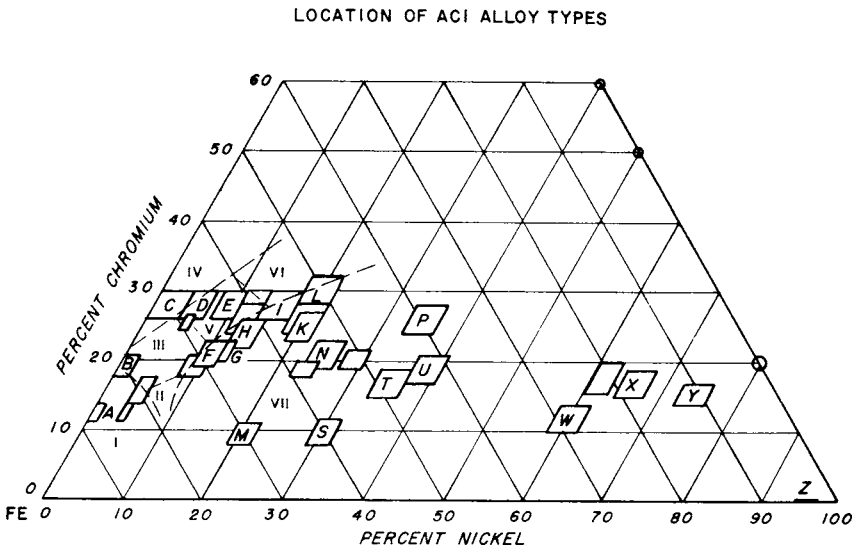



NOTE 1—The approximate areas of microstructures to be expected at room temperature are indicated as follows:
I—Martensite
II—Martensite and untransformed austenite
III—Ferrite plus martensite and untransformed austenite
IV—Ferrite
V—Ferrite plus austenite
VI—Ferrite plus austenite plus sigma
VII—Austenite
NOTE 2—Carbides also may be present depending on carbon content and thermal history.

**FIG. X1.1 Letters Assigned to Chromium and Nickel Ranges in ACI Designation System**

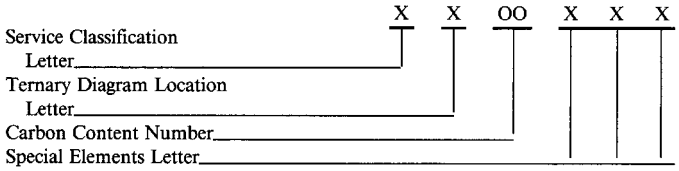
## APPENDIXES

**(Nonmandatory Information)**

### X1. ALLOY DESIGNATIONS FOR CAST STAINLESS STEELS

X1.1 Cast stainless steels are usually specified on the basis of composition using the alloy designation system established by the Alloy Casting Institute (ACI). The ACI designations, for example, CF8M, have been adopted by ASTM and are preferred for cast alloys over the designations used by the American Iron and Steel Institute for similar wrought steels.

X1.2 This nomenclature system has served successfully to accommodate changes in old alloys and to designate new ones.




X1.2.1 *Service Classification Letter*—The first letter of the cast stainless steel designation system identifies the intended service application of the alloy. The letter C indicates corrosion-resistant service, and the letter H indicates the heat-resistant service at and above 1200°F [649°C].

X1.2.2 *Ternary Diagram Location Letter*—The second letter indicates the approximate location of the nickel and chromium contents of the alloy grade on the FeCrNi ternary diagram shown in Fig. X1.1.

X1.2.3 *Carbon Content Number*—For C service classifications, this single or dual digit numeral represents the maximum carbon content in units of 0.01 %. For H service classifications, this number represents the midpoint of the range of carbon content in terms of 0.01 % with a ±0.05 % limit.

X1.2.4 *Special Elements Letter*—Additional letters following the numeral represent special chemical elements in the alloy grade, such as M for molybdenum, C for columbium, Cu for copper, W for tungsten. There are two exceptions; the letter A indicates Controlled Ferrite, and the letter F indicates Free Machining.

X1.3 In Fig. X1.1, unlettered Ni-Cr ranges are associated with the nearest lettered location. They may be the result of differences between corrosion and heat-resistant types, or because of the influence of additional elements, for example, the precipitation hardening grade CB-7Cu-1 and CB-7Cu-2.



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## X2. WROUGHT ALLOYS SIMILAR TO CASTING ALLOYS IN SPECIFICATIONS A 494/A 494M, A 743/A 743M, A 744/A 744M, A 747/A 747M, AND A 890/A 890M

X2.1 Table X2.1 is provided for the user of the above listed specifications as an aid in selecting cast alloys that are similar in chemical composition to wrought alloys. It is not intended to imply that the cast alloy would have the same mechanical, physical or corrosion properties as the indicated wrought alloy.

**TABLE X2.1 Similar Alloys**

| Nominal Composition | ASTM Casting Specification | Casting Grade Designation | UNS Number | Similar Wrought Alloy | UNS Number |
|---|---|---|---|---|---|
| 11Cr-7Ni | A 743/A 743M | CA6N | J91650 | . . . | . . . |
| 13Cr-4Ni | A 743/A 743M | CA6NM | J91540 | F-6NM[A] | S41500 |
| 13Cr | A 743/A 743M | CA15 | J91150 | 410[B] | S41000 |
| 13Cr | A 743/A 743M | CA40 | J91151 | . . . | . . . |
| 12Cr-Mo-V-W | A 743/A 743M | CA28MWV | J91422 | 422[B] | S42200 |
| 13Cr-Mo | A 743/A 743M | CA15M | J91153 | 420[B] | S42000 |
| 13Cr-S | A 743/A 743M | CA40F | J91154 | 420F[B] | S42020 |
| 19Cr-1Ni | A 743/A 743M | CB30 | J91803 | 442[B] | S44200 |
| 16Cr-4Ni-4Cu | A 747/A 747M | CB7Cu-1 | J92180 | 17-4[C] | S17400 |
| 15Cr-5Ni-3Cu | A 747/A 747M | CB7Cu-2 | J92110 | 15-5[C] | S15500 |
| 27Cr | A 743/A 743M | CC50 | J92615 | 446[B] | S44600 |
| 25Cr-5Ni-3Cu-2Mo | A 890/A 890M | 1A & CD4MCu | J93370 | 255[C] | S32550 |
| 25Cr-5Ni-3Cu-2Mo-N | A 890/A 890M | 1B & CD4MCuN | J93372 | 255[C] | S32550 |
| 25Cr-6Ni-2Cu-3Mo-N | A 890/A 890M | 1C & CD3MCuN | J93373 | 255[C] | S32550 |
| 24Cr-10Ni-3Mo-N | A 890/A 890M | 2A & CE8MN | J93345 | . . . | . . . |
| 25Cr-5Ni-2Mo-N | A 890/A 890M | 3A & CD6MN | J93371 | . . . | . . . |
| 22Cr-5Ni-3Mo-N | A 890/A 890M | 4A & CD3MN | J92205 | 2205[C] | S39205 |
| 25Cr-7Ni-4Mo-N | A 890/A 890M | 5A & CE3MN | J93404 | . . . | . . . |
| 25Cr-7Ni-Mo-N | A 890/A 890M | 6A & CD3MCuWN | J93380 | Zeron 100[D] | S32760 |
| 28Cr-9Ni | A 743/A 743M | CE30 | J93423 | . . . | . . . |
| 18Cr-8Ni | A 743/A 743M, A 744/A 744M | CF3 | J92500 | 304L[B] | S30403 |
| 16Cr-12Ni-2Mo | A 743/A 743M, A 744/A 744M | CF3M | J92800 | 316L[B] | S31603 |
| 16Cr-12Ni-2Mo-N | A 743/A 743M | CF3MN | J92804 | 316LN[B] | S31653 |
| 18Cr-8Ni | A 743/A 743M, A 744/A 744M | CF8 | J92600 | 304[B] | S30400 |
| 18Cr-10Ni-Cb | A 743/A 743M, A 744/A 744M | CF8C | J92710 | 347[B] | S34700 |
| 16Cr-12Ni-2Mo | A 743/A 743M, A 744/A 744M | CF8M | J92900 | 316[B] | S31600 |
| 18Cr-8Ni-4Si-N | A 743/A 743M | CF10SMnN | J92972 | Nitronic[E] 60 | S21800 |
| 18Cr-8Ni-S | A 743/A 743M | CF16F | J92701 | 303Se[B] | S30300 |
| 18Cr-8Ni | A 743/A 743M | CF20 | J92602 | 302[B] | S30200 |
| 22Cr-13Ni-5Mn | A 743/A 743M | CG6MMN | J93790 | Nitronic[E] 50 | S20910 |
| 18Cr-13Ni-3Mo | A 743/A 743M, A 744/A 744M | CG8M | J93000 | 317[B] | S31700 |
| 21Cr-11Ni | A 743/A 743M | CG12 | J93001 | 308[B] | S30800 |
| 23Cr-12Ni | A 743/A 743M | CH20 | J93402 | 309[B] | S30900 |
| 20Cr-18Ni-6Mo-Cu-N | A 743/A 743M, A 744/A 744M | CK3MCuN | J93254 | 254 SMO[F] | S31254 |
| 25Cr-20Ni | A 743/A 743M | CK20 | J94202 | 310[B] | S31000 |
| 24Ni-21Cr-6Mo-N | A 743/A 743M, A 744/A 744M | CN3MN | J94651 | AL-6XN[G] | N08367 |
| 29Ni-20Cr-3Cu-2Mo | A 743/A 743M, A 744/A 744M | CN7M | N08007 | Alloy 20[C] | N08020 |
| 24Ni-19Cr-3Mo-2Cu | A 743/A 743M, A 744/A 744M | CN7MS | J94650 | . . . | . . . |
| 41Ni-22Cr-3mO-fE | A 494/A 494M | CU5MCuC | N08826 | 825 | N28820 |
| 61Ni-16Mo-16Cr | A 494/A 494M | CW2M | N26455 | C4[C] | N06455 |
| 59Ni-18Mo-18Cr | A 494/A 494M | CW6M | N30107 | . . . | . . . |
| 60Ni-22Cr-9Mo-3.5Cb | A 494/A 494M | CW6MC | N26625 | 625[C] | N06625 |
| 55Ni-17Mo-16Cr-4W | A 494/A 494M | CW12MW | N30002 | C[C] | N10002 |
| 57Ni-13Mo-21Cr | A 494/A 494M | CX2MW | N26022 | C22[H] | N06022 |
| 74Ni-12Cr-4Bi-4Sn | A 494/A 494M | CY5SnBiM | N26055 | . . . | . . . |
| 72Ni-15Cr-8Fe | A 494/A 494M | CY40 | N06040 | 600[C] | N06600 |
| 95Ni | A 494/A 494M | CZ100 | N02100 | 200[C] | N02200 |
| 63Ni-29Cu-4Si | A 494/A 494M | M25S | N24025 | . . . | . . . |
| 63Ni-29Cu-2Cb | A 494/A 494M | M30C | N24130 | . . . | . . . |
| 63Ni-29Cu-Si | A 494/A 494M | M30H | N24030 | . . . | . . . |
| 67Ni-30Cu | A 494/A 494M | M-35-1 | N24135 | 400[C] | N04400 |
| 67Ni-30Cu | A 494/A 494M | M-35-2 | N04020 | 400[C] | N04400 |
| 65Ni-28Mo-2Fe | A 494/A 494M | N7M | N30007 | B2[C] | N10665 |
| 62Ni-28Mo-5Fe | A 494/A 494M | N12MV | N30012 | B[C] | N10001 |

[A] ASTM designation.
[B] Common description, formerly used by AISI.
[C] Common name used by two or more producers; not a trademark.
[D] Proprietary trademark: WEIR Materials.
[E] Proprietary trademark: AK Steel Corporation.
[F] Proprietary trademark: Avesta Sheffield AB.
[G] Proprietary trademark: Allegheny Ludlum Corporation.
[H] Proprietary trademark: Haynes International.

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## X3. ADDITION OF NEW GRADES TO PRODUCT SPECIFICATIONS COVERED BY A 781/A 781M

X3.1 Information required for the inclusion of new material grades in product specifications covered by A 781/A 781M:

*1.* At least one user should support the request.

*2.* A set of data from ten production heats, this data should include:

X3.1.1 Chemical composition.

X3.1.2 Mechanical properties as applicable to the product specification being cited. These may include but are not limited to the following:

X3.1.2.1 Ultimate tensile strength,

X3.1.2.2 Yield strength,

X3.1.2.3 Reduction in area,

X3.1.2.4 Elongation, and

X3.1.2.5 Impact properties (Charpy V).

X3.2 The test coupon size from which the test pieces are removed should be stated for each test.

X3.2.1 Heat treatment requirements.

X3.2.2 Weld procedure (welding should be carried out using commercially available consumables).

## SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A 781/A 781M – 05a, that may impact the use of this standard. (Approved June 15, 2006.)

(*1*) 8.3 modified restriction

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 05) that may impact the use of this standard (Approved July 1, 2005).

*(1)* Added 3.1.2 and 3.1.3.
*(2)* Revised Fig. 1 and S15.
*(3)* Changed numbering of Figs. 4-8 to Fig. S15.1, Fig. S15.2, Fig. S15.3, Fig. S15.4, and Fig. S17.1, respectively.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 04a) that may impact the use of this standard. (May 1, 2005.)

*(1)* Added metric equivalents to 5.3 and 6.2.
*(2)* Corrected S10.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 04) that may impact the use of this standard. (Approved May 1, 2004.)

*(1)* Deleted hyphens from ACI Grade designations.
*(2)* Added A 890 1B and 1C.
*(3)* Repositioned A 890 6A in Table X2.1 and added or corrected UNS numbers.
*(4)* Revised Footnote E and added Footnotes D and H to Table X2.1.

Committee A01 has identified the location of selected changes to this standard since the last issue (A 781/A 781M – 03a) that may impact the use of this standard. (Approved March 1, 2004.)

*(1)* Removed Supplementary Requirement S20.

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