SECTION II
MATERIALS

2025 ASME Boiler and Pressure Vessel Code
An International Code

Part A
Ferrous Material Specifications
(SA-451 to End)

ASME
SETTING THE STANDARD

AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition July 1, 2025

II

MATERIALS

Part A

Ferrous Material Specifications (SA-451 to End)

ASME Boiler and Pressure Vessel Committee
on Materials

The American Society of Mechanical Engineers
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FOREWORD*

In 1911, The American Society of Mechanical Engineers established the Boiler and Pressure Vessel Committee to formulate standard rules for the construction of steam boilers and other pressure vessels. In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees:

(a) Committee on Power Boilers (I)
(b) Committee on Materials (II)
(c) Committee on Construction of Nuclear Facility Components (III)
(d) Committee on Heating Boilers (IV)
(e) Committee on Nondestructive Examination (V)
(f) Committee on Pressure Vessels (VIII)
(g) Committee on Welding, Brazing, and Fusing (IX)
(h) Committee on Fiber-Reinforced Plastic Pressure Vessels (X)
(i) Committee on Nuclear Inservice Inspection (XI)
(j) Committee on Transport Tanks (XII)
(k) Committee on Overpressure Protection (XIII)
(l) Technical Oversight Management Committee (TOMC)

Where reference is made to "the Committee" in this Foreword, each of these committees is included individually and collectively.

The Committee's function is to establish rules of safety relating to pressure integrity. The rules govern the construction** of boilers, pressure vessels, transport tanks, and nuclear components, and the inservice inspection of nuclear components and transport tanks. For nuclear items other than pressure-retaining components, the Committee also establishes rules of safety related to structural integrity. The Committee also interprets these rules when questions arise regarding their intent. The technical consistency of the Sections of the Code and coordination of standards development activities of the Committees is supported and guided by the Technical Oversight Management Committee. The Code does not address other safety issues relating to the construction of boilers, pressure vessels, transport tanks, or nuclear components, or the inservice inspection of nuclear components or transport tanks. Users of the Code should refer to the pertinent codes, standards, laws, regulations, or other relevant documents for safety issues other than those relating to pressure integrity and, for nuclear items other than pressure-retaining components, structural integrity. Except for Sections XI and XII, and with a few other exceptions, the rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service related to specific service fluids or external operating environments. In formulating the rules, the Committee considers the needs of users, manufacturers, and inspectors of components addressed by the Code. The objective of the rules is to afford reasonably certain protection of life and property, and to provide a margin for deterioration in service to give a reasonably long, safe period of usefulness. Advancements in design and materials and evidence of experience have been recognized.

The Code contains mandatory requirements, specific prohibitions, and nonmandatory guidance for construction activities and inservice inspection and testing activities. The Code does not address all aspects of these activities and those aspects that are not specifically addressed should not be considered prohibited. The Code is not a handbook and cannot replace education, experience, and the use of engineering judgment. The phrase *engineering judgment* refers to technical judgments made by knowledgeable engineers experienced in the application of the Code. Engineering judgments must be consistent with Code philosophy, and such judgments must never be used to overrule mandatory requirements or specific prohibitions of the Code.

The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools. The designer is responsible for complying with Code rules and demonstrating compliance with Code equations when such equations are mandatory. The Code

* The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. Therefore, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Code.

** *Construction*, as used in this Foreword, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and overpressure protection.

neither requires nor prohibits the use of computers for the design or analysis of components constructed to the requirements of the Code. However, designers and engineers using computer programs for design or analysis are cautioned that they are responsible for all technical assumptions inherent in the programs they use and the application of these programs to their design.

The rules established by the Committee are not to be interpreted as approving, recommending, or endorsing any proprietary or specific design, or as limiting in any way the manufacturer's freedom to choose any method of design or any form of construction that conforms to the Code rules.

The Committee meets regularly to consider revisions of the rules, new rules as dictated by technological development, Code cases, and requests for interpretations. Only the Committee has the authority to provide official interpretations of the Code. Requests for revisions, new rules, Code cases, or interpretations shall be addressed to the staff secretary in writing and shall give full particulars in order to receive consideration and action (see the Correspondence With the Committee page). Proposed revisions to the Code resulting from inquiries will be presented to the Committee for appropriate action. The action of the Committee becomes effective only after confirmation by ballot of the Committee and approval by ASME. Proposed revisions to the Code approved by the Committee are submitted to the American National Standards Institute (ANSI) and published at http://go.asme.org/BPVCPublicReview to invite comments from all interested persons. After public review and final approval by ASME, revisions are published at regular intervals in Editions of the Code.

The Committee does not rule on whether a component shall or shall not be constructed to the provisions of the Code. The scope of each Section has been established to identify the components and parameters considered by the Committee in formulating the Code rules.

Questions or issues regarding compliance of a specific component with the Code rules are to be directed to the ASME Certificate Holder (Manufacturer). Inquiries concerning the interpretation of the Code are to be directed to the Committee. ASME is to be notified should questions arise concerning improper use of the ASME Single Certification Mark.

When required by context in the Code, the singular shall be interpreted as the plural, and vice versa.

The words "shall," "should," and "may" are used in the Code as follows:

- *Shall* is used to denote a requirement.
- *Should* is used to denote a recommendation.
- *May* is used to denote permission, neither a requirement nor a recommendation.

STATEMENT OF POLICY ON THE USE OF THE ASME SINGLE CERTIFICATION MARK AND CODE AUTHORIZATION IN ADVERTISING

ASME has established procedures to authorize qualified organizations to perform various activities in accordance with the requirements of the ASME Boiler and Pressure Vessel Code. It is the aim of the Society to provide recognition of organizations so authorized. An organization holding authorization to perform various activities in accordance with the requirements of the Code may state this capability in its advertising literature.

Organizations that are authorized to use the ASME Single Certification Mark for marking items or constructions that have been constructed and inspected in compliance with the ASME Boiler and Pressure Vessel Code are issued Certificates of Authorization. It is the aim of the Society to maintain the standing of the ASME Single Certification Mark for the benefit of the users, the enforcement jurisdictions, and the holders of the ASME Single Certification Mark who comply with all requirements.

Based on these objectives, the following policy has been established on the usage in advertising of facsimiles of the ASME Single Certification Mark, Certificates of Authorization, and reference to Code construction. The American Society of Mechanical Engineers does not "approve," "certify," "rate," or "endorse" any item, construction, or activity and there shall be no statements or implications that might so indicate. An organization holding the ASME Single Certification Mark and/or a Certificate of Authorization may state in advertising literature that items, constructions, or activities "are built (produced or performed) or activities conducted in accordance with the requirements of the ASME Boiler and Pressure Vessel Code," or "meet the requirements of the ASME Boiler and Pressure Vessel Code." An ASME corporate logo shall not be used by any organization other than ASME.

The ASME Single Certification Mark shall be used only for stamping and nameplates as specifically provided in the Code. However, facsimiles may be used for the purpose of fostering the use of such construction. Such usage may be by an association or a society, or by a holder of the ASME Single Certification Mark who may also use the facsimile in advertising to show that clearly specified items will carry the ASME Single Certification Mark.

STATEMENT OF POLICY ON THE USE OF ASME MARKING TO IDENTIFY MANUFACTURED ITEMS

The ASME Boiler and Pressure Vessel Code provides rules for the construction of boilers, pressure vessels, and nuclear components. This includes requirements for materials, design, fabrication, examination, inspection, and stamping. Items constructed in accordance with all of the applicable rules of the Code are identified with the ASME Single Certification Mark described in the governing Section of the Code.

Markings such as "ASME," "ASME Standard," or any other marking including "ASME" or the ASME Single Certification Mark shall not be used on any item that is not constructed in accordance with all of the applicable requirements of the Code.

Items shall not be described on ASME Data Report Forms nor on similar forms referring to ASME that tend to imply that all Code requirements have been met when, in fact, they have not been. Data Report Forms covering items not fully complying with ASME requirements should not refer to ASME or they should clearly identify all exceptions to the ASME requirements.

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ASME codes and standards are developed and maintained by committees with the intent to represent the consensus of concerned interests. Users of ASME codes and standards may correspond with the committees to propose revisions or cases, report errata, or request interpretations. Correspondence for this Section of the ASME Boiler and Pressure Vessel Code (BPVC) should be sent to the staff secretary noted on the Section's committee web page, accessible at https://go.asme.org/CSCommittees.

NOTE: See ASME BPVC Section II, Part D for guidelines on requesting approval of new materials. See Section II, Part C for guidelines on requesting approval of new welding and brazing materials ("consumables").

Revisions and Errata

The committee processes revisions to this Code on a continuous basis to incorporate changes that appear necessary or desirable as demonstrated by the experience gained from the application of the Code. Approved revisions will be published in the next edition of the Code.

In addition, the committee may post errata and Special Notices at http://go.asme.org/BPVCerrata. Errata and Special Notices become effective on the date posted. Users can register on the committee web page to receive email notifications of posted errata and Special Notices.

This Code is always open for comment, and the committee welcomes proposals for revisions. Such proposals should be as specific as possible, citing the paragraph number, the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent background information and supporting documentation.

Cases

(a) The most common applications for cases are

(1) to permit early implementation of a revision based on an urgent need

(2) to provide alternative requirements

(3) to allow users to gain experience with alternative or potential additional requirements prior to incorporation directly into the Code

(4) to permit use of a new material or process

(b) Users are cautioned that not all jurisdictions or owners automatically accept cases. Cases are not to be considered as approving, recommending, certifying, or endorsing any proprietary or specific design, or as limiting in any way the freedom of manufacturers, constructors, or owners to choose any method of design or any form of construction that conforms to the Code.

(c) The committee will consider proposed cases concerning the following topics only:

(1) equipment to be marked with the ASME Single Certification Mark, or

(2) equipment to be constructed as a repair/replacement activity under the requirements of Section XI

(d) A proposed case shall be written as a question and reply in the same format as existing cases. The proposal shall also include the following information:

(1) a statement of need and background information

(2) the urgency of the case (e.g., the case concerns a project that is underway or imminent)

(3) the Code Section and the paragraph, figure, or table number to which the proposed case applies

(4) the editions of the Code to which the proposed case applies

(e) A case is effective for use when the public review process has been completed and it is approved by the cognizant supervisory board. Cases that have been approved will appear in the next edition or supplement of the Code Cases books, "Boilers and Pressure Vessels" or "Nuclear Components." Each Code Cases book is updated with seven Supplements. Supplements will be sent or made available automatically to the purchasers of the Code Cases books until the next edition of the Code. Annulments of Code Cases become effective six months after the first announcement of the annulment in a Code Case Supplement or Edition of the appropriate Code Case book. The status of any case is available at http://go.asme.org/BPVCCDatabase. An index of the complete list of Boiler and Pressure Vessel Code Cases and Nuclear Code Cases is available at http://go.asme.org/BPVCC.

Interpretations

(a) Interpretations clarify existing Code requirements and are written as a question and reply. Interpretations do not introduce new requirements. If a revision to resolve conflicting or incorrect wording is required to support the interpretation, the committee will issue an intent interpretation in parallel with a revision to the Code.

(b) Upon request, the committee will render an interpretation of any requirement of the Code. An interpretation can be rendered only in response to a request submitted through the online Inquiry Submittal Form at http://go.asme.org/InterpretationRequest. Upon submitting the form, the inquirer will receive an automatic email confirming receipt.

(c) ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Code requirements. If, based on the information submitted, it is the opinion of the committee that the inquirer should seek assistance, the request will be returned with the recommendation that such assistance be obtained. Inquirers may track the status of their requests at http://go.asme.org/Interpretations.

(d) ASME procedures provide for reconsideration of any interpretation when or if additional information that might affect an interpretation is available. Further, persons aggrieved by an interpretation may appeal to the cognizant ASME committee or subcommittee. ASME does not "approve," "certify," "rate," or "endorse" any item, construction, proprietary device, or activity.

(e) Interpretations are published in the ASME Interpretations Database at http://go.asme.org/Interpretations as they are issued.

Committee Meetings

The ASME BPVC committees regularly hold meetings that are open to the public. Persons wishing to attend any meeting should contact the secretary of the applicable committee. Information on future committee meetings can be found at http://go.asme.org/BCW.

(25)

PREFACE

The American Society of Mechanical Engineers (ASME) and the American Society for Testing and Materials (ASTM) have cooperated for more than fifty years in the preparation of material specifications adequate for safety in the field of pressure equipment for ferrous and nonferrous materials, contained in Section II (Part A — Ferrous and Part B — Nonferrous) of the ASME Boiler and Pressure Vessel Code.

The evolution of this cooperative effort is contained in Professor A. M. Greene's "History of the ASME Boiler Code," which was published as a series of articles in *Mechanical Engineering* from July 1952 through August 1953 and is now available from ASME in a special bound edition. The following quotations from this history, which was based upon the minutes of the ASME Boiler and Pressure Vessel Committee, will help focus on the cooperative nature of the specifications found in Section II, Material Specifications.

"General discussion of material specifications comprising Paragraphs 1 to 112 of Part 2 and the advisability of having them agree with ASTM specifications," (1914).

"ASME Subcommittee appointed to confer with ASTM," (1916).

"Because of this cooperation the specifications of the 1918 Edition of the ASME Boiler Code were more nearly in agreement with ASTM specifications. In the 1924 Edition of the Code, 10 specifications were in complete agreement with ASTM specifications, 4 in substantial agreement and 2 covered materials for which ASTM had no corresponding specifications."

"In Section II, Material Specifications, the paragraphs were given new numbers beginning with S-1 and extending to S-213," (1925).

"Section II was brought into agreement with changes made in the latest ASTM specifications since 1921," (1932).

"The Subcommittee on Material Specifications arranged for the introduction of the revisions of many of the specifications so that they would agree with the latest form of the earlier ASTM specifications...," (1935).

From the preceding, it is evident that many of the material specifications were prepared by the Boiler and Pressure Vessel Code Committees, then subsequently, by cooperative action, modified and identified as ASTM specifications. Section II, Parts A and B, currently contain many material specifications that are identical with the corresponding ASTM specifications and some that have been modified for Code usage. Many of these specifications are published in dual format. That is, they contain both U.S. Customary units and SI units. The metrication protocols followed in the specifications are those adopted by ASTM, and are usually to the rules of IEEE/ASTM SI 10-1997, Standard for the Use of the International System of Units (SI): The Modern Metric System.

In 1969, the American Welding Society began publication of specifications for welding rods, electrodes, and filler metals, hitherto issued by ASTM. The Boiler and Pressure Vessel Committee has recognized this new arrangement, and is now working with AWS on these specifications. Section II, Part C, contains the welding material specifications approved for Code use.

In 1992, the ASME Board of Pressure Technology Codes and Standards endorsed the use of non-ASTM material for Boiler and Pressure Vessel Code applications. It is the intent to follow the procedures and practices currently in use to implement the adoption of non-ASTM materials.

The specifications prepared and copyrighted by ASTM, AWS, and other originating organizations are reproduced in the Code with the permission of the respective Society. The ASME Boiler and Pressure Vessel Committee has given careful consideration to each new and revised specification, and has made such changes as they deemed necessary to make the specification adaptable for Code usage. In addition, ASME has furnished ASTM with the basic requirements that should govern many proposed new specifications. Joint action will continue an effort to make the ASTM, AWS, and ASME specifications identical.

To assure that there will be a clear understanding on the part of the users of Section II, ASME publishes both the identical specifications and those amended for Code usage every 2 years.

The ASME Boiler and Pressure Vessel Code has been adopted into law by 50 states and many municipalities in the United States and by all of the Canadian provinces.

SPECIFICATIONS LISTED BY MATERIALS

(25)

Corrosion-Resisting and Heat-Resisting Steels

Steel Bolting Materials

Steel Castings

Steel Flanges, Fittings, Valves, and Parts

Steel Pipe

Steel Plate, Sheet, and Strip

Steel Plates, Sheets, and Strip for Pressure Vessels

Steel Tubes

Structural Steel

Wrought Iron, Cast Iron, and Malleable Iron

SPECIFICATION REMOVAL

(25)

From time to time, it becomes necessary to remove specifications from this Part of Section II. This occurs because the sponsoring society (e.g., ASTM, AWS, CEN) has notified ASME that the specification has either been replaced with another specification, or that there is no known use and production of a material. Removal of a specification from this Section also results in concurrent removal of the same specification from Section IX and from all of the ASME Boiler and Pressure Vessel Construction Codes that reference the material. This action effectively prohibits further use of the material in ASME Boiler and Pressure Vessel construction.

The following specifications will be dropped from this Section in the next Edition, unless information concerning current production and use of the material is received before December 1 of this year:

SF-568M

If you are currently using and purchasing new material to this specification for ASME Boiler and Pressure Vessel Code construction, and if discontinuance of this specification would present a hardship, please notify the Secretary of the ASME Boiler and Pressure Vessel Committee, at the address shown below:

Secretary
ASME Boiler and Pressure Vessel Committee
Two Park Avenue
New York, NY 10016-5990

SUMMARY OF CHANGES

In this 2025 edition, the "ASTM Personnel" page has been deleted from the front matter. In addition, specifications originating with ASTM that are new or revised in this 2025 edition are formatted differently than those retained from the 2023 and earlier editions. The document following the cover sheet of each new or revised specification is the unedited ASTM specification. The ASME title for the specification and any ASME-approved exceptions to the ASTM specification are shown only on the cover sheet. Specifications affected by the new format are listed in the Summary of Changes.

Changes listed below are identified on the pages by a margin note, **(25)**, placed next to the affected area.

Page	*Location*	*Change*
xi	List of Sections	Title of Section XI, Division 1 revised
xii	Foreword	Updated
xv	Personnel	Updated
xl	Preface	Twelfth paragraph revised
xli	Specifications Listed by Materials	Updated
xlix	Specification Removal	Updated
1	Statement of Policy on the Use of ASME Material Specifications	Revised
185	SA-135/SA-135M	Revised in its entirety
195	SA-178/SA-178M	Revised in its entirety
211	SA-182/SA-182M	Revised in its entirety
265	SA-204/SA-204M	On cover sheet, Specification date changed from '18' to '17' by errata
273	SA-210/SA-210M	Revised in its entirety
277	SA-213/SA-213M	Revised in its entirety
299	SA-216/SA-216M	Revised in its entirety
305	SA-217/SA-217M	Revised in its entirety
327	SA-234/SA-234M	Revised in its entirety
423	SA-283/SA-283M	Revised in its entirety
451	SA-312/SA-312M	Revised in its entirety
505	SA-335/SA-335M	Revised in its entirety
517	SA-336/SA-336M	Revised in its entirety
527	SA-350/SA-350M	Revised in its entirety
575	SA-369/SA-369M	Revised in its entirety
785	SA-480/SA-480M	Revised in its entirety
845	SA-513/SA-513M	Revised in its entirety
943	SA-556/SA-556M	Revised in its entirety
977	SA-568/SA-568M	Revised in its entirety

Page	*Location*	*Change*
1047	SA-612/SA-612M	Revised in its entirety
1061	SA-649/SA-649M	Revised in its entirety
1097	SA-671/SA-671M	Revised in its entirety
1137	SA-693	Revised in its entirety
1285	SA-789/SA-789M	Revised in its entirety
1293	SA-790/SA-790M	Revised in its entirety
1365	SA-859/SA-859M	Added
1375	SA-905	Revised in its entirety
1497	SA-1008/SA-1008M	Revised in its entirety
1515	SA-1011/SA-1011M	Revised in its entirety
1553	SA-1091/SA-1091M	Added
1561	SF-568M	Deleted
1589	SA/EN 10216-2	Revised in its entirety
1593	SA/EN 10222-2	Revised in its entirety
1599	SA/ISO 898-1	Added
1610	Mandatory Appendix II	Revised in its entirety
1612	Table II-200-1	Updated
1620	Table II-200-2	Updated
1625	Mandatory Appendix IV	Revised in its entirety

CROSS-REFERENCING IN THE ASME BPVC

Paragraphs within the ASME BPVC may include subparagraph breakdowns, i.e., nested lists. The following is a guide to the designation and cross-referencing of subparagraph breakdowns:

(a) Hierarchy of Subparagraph Breakdowns

(1) First-level breakdowns are designated as (a), (b), (c), etc.

(2) Second-level breakdowns are designated as (1), (2), (3), etc.

(3) Third-level breakdowns are designated as (-a), (-b), (-c), etc.

(4) Fourth-level breakdowns are designated as (-1), (-2), (-3), etc.

(5) Fifth-level breakdowns are designated as (+a), (+b), (+c), etc.

(6) Sixth-level breakdowns are designated as (+1), (+2), etc.

(b) Cross-References to Subparagraph Breakdowns. Cross-references within an alphanumerically designated paragraph (e.g., PG-1, UIG-56.1, NCD-3223) do not include the alphanumerical designator of that paragraph. The cross-references to subparagraph breakdowns follow the hierarchy of the designators under which the breakdown appears. The following examples show the format:

(1) If X.1(c)(1)(-a) is referenced in X.1(c)(1), it will be referenced as (-a).

(2) If X.1(c)(1)(-a) is referenced in X.1(c)(2), it will be referenced as (1)(-a).

(3) If X.1(c)(1)(-a) is referenced in X.1(e)(1), it will be referenced as (c)(1)(-a).

(4) If X.1(c)(1)(-a) is referenced in X.2(c)(2), it will be referenced as X.1(c)(1)(-a).

SPECIFICATION FOR CENTRIFUGALLY CAST AUSTENITIC STEEL PIPE FOR HIGH-TEMPERATURE SERVICE

SA-451/SA-451M

(Identical with ASTM Specification A451/A451M-06(2010) except for editorial differences in 15.1.)

Standard Specification for Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service

1. Scope

1.1 This specification covers austenitic alloy steel pipe for use in high-temperature, corrosive, or nuclear pressure service.

1.2 Several grades of austenitic stainless steel are covered as indicated in Table 1.

1.3 Optional supplementary requirements are provided when additional testing may be required.

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 exactly equivalents; therefore, each system must be used independently of each other. Combining values from the two systems may result in nonconformance with the specification.

NOTE 1—This specification is not intended to cover centrifugal pipe made from alloys containing more than 0.20 % carbon, such as are covered by Specification A297/A297M.

2. Referenced Documents

2.1 *ASTM Standards:*

A297/A297M Specification for Steel Castings, Iron-Chromium and Iron-Chromium-Nickel, Heat Resistant, for General Application

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A999/A999M Specification for General Requirements for Alloy and Stainless Steel Pipe

E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E94 Guide for Radiographic Examination

E165 Practice for Liquid Penetrant Examination for General Industry

E186 Reference Radiographs for Heavy-Walled (2 to 4½-in. (50.8 to 114-mm)) Steel Castings

E280 Reference Radiographs for Heavy-Walled (4½ to 12-in. (114 to 305-mm)) Steel Castings

E446 Reference Radiographs for Steel Castings Up to 2 in. (50.8 mm) in Thickness

2.2 *ANSI Standard:*

B46.1 Surface Texture

3. Ordering Information

3.1 Orders for material to this specification shall include the following, as required, to describe the desired material adequately:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (centrifugally cast pipe),

3.1.3 Grade (Table 1),

3.1.4 Size (outside or inside diameter and minimum wall thickness in inches or millimetres),

3.1.5 Length (specific or random, Specification A999/A999M),

3.1.6 End Finish of Specification A999/A999M,

3.1.7 Optional Requirements (9.4 and Supplementary Requirements S1 through S7),

3.1.8 Test Report Required (Section 14), and

3.1.9 Special Requirements or Additions to Specification.

4. Materials and Manufacture

4.1 *Heat-Treatment*—The pipe shall receive a heat-treatment at the temperature and time specified in Table 2, followed by a quench in water or rapid cool by other means.

4.2 *Machining*—The pipe shall be machined on the inner and outer surfaces to a roughness value no greater than 250-µin. [6.35-µm] arithmetical average deviation (AA) from the mean line, as defined in American National Standard B46.1.

TABLE 1 Chemical Requirements

Grade	Composition, %										
	Carbon, max	Manganese, max	Phosphorus, max	Sulfur, max	Silicon, max	Nickel	Chromium	Molybdenum	Columbium	Tantalum, max	Nitrogen
CPF3	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF3A	0.03	1.50	0.040	0.040	2.00	8.0–12.0	17.0–21.0	...	...	...	...
CPF8	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF8A	0.08	1.50	0.040	0.040	2.00	8.0–11.0	18.0–21.0	...	...	...	...
CPF3M	0.03	1.50	0.040	0.040	1.50	9.0–13.0	17.0–21.0	2.0–3.0	...	...	...
CPF8M	0.08	1.50	0.040	0.040	1.50	9.0–12.0	18.0–21.0	2.0–3.0	...	...	...
CPF10MC[A]	0.10	1.50	0.040	0.040	1.50	13.0–16.0	15.0–18.0	1.75–2.25	1.2 max, 10 × C min	...	...
CPF8C[A]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	...	...
CPF8C(Ta max)[B]	0.08	1.50	0.040	0.040	2.00	9.0–12.0	18.0–21.0	...	1 max, 8 × C min	0.10	...
CPH8	0.08	1.50	0.040	0.040	1.50	12.0–15.0	22.0–26.0	...	...	...	...
CPH20 or CPH10	0.20[C]	1.50	0.040	0.040	2.00	12.0–15.0	22.0–26.0	...	...	...	...
CPK20	0.20	1.50	0.040	0.040	1.75	19.0–22.0	23.0–27.0	...	...	...	...
CPE20N	0.20	1.50	0.040	0.040	1.50	8.0–11.0	23.0–26.0	...	...	...	0.08–0.20

[A] Grades CPF10MC and CPF8C may have a columbium plus tantalum content maximum of 1.35 %.
[B] No designation as yet assigned by ASTM International or Steel Founders' Society of America.
[C] By agreement between the manufacturer and the purchaser, the carbon content of Grade CPH20 may be restricted to 0.10 % max. When so agreed, the grade designation shall be CPH10.

TABLE 2 Heat-Treatment Requirements

Grade	Temperature, min		Hold Time, h/in. of Thickness
	°F	°C	
CPF3, CPF3A, CPF8, CPF8A, CPF3M, CPF8M	1900	1040	1
CPF10MC, CPF8C, CPF8C (Ta max)	1950	1065	2
CPH8, CPH10, CPH20, CPK20	2100	1150	1
CPE20N	2225	1220	1

TABLE 3 Tensile Requirements

Grade	Tensile Strength, min, ksi [MPa]	Yield Strength, min, ksi [MPa]	Elongation in 2 in. or 50 mm, min
CPF3	70 [485]	30 [205]	35
CPF3A[A]	77 [535]	35 [240]	35
CPF3M	70 [485]	30 [205]	30
CPF8	70 [485]	30 [205]	35
CPF8A[A]	77 [535]	35 [240]	35
CPF8M	70 [485]	30 [205]	30
CPF10MC	70 [485]	30 [205]	20
CPH10	70 [485]	30 [205]	30
CPF8C (Ta max), CPF8C	70 [485]	30 [205]	30
CPH8	65 [448]	28 [195]	30
CPK20	65 [448]	28 [195]	30
CPH20	70 [485]	30 [205]	30
CPE20N	80 [550]	40 [275]	30

[A] The properties shown are obtained by adjusting the composition within the limits shown in Table 1 to obtain a ferrite-austenite ratio that will result in the higher ultimate and yield strengths indicated. A lowering of impact values may develop in these materials when exposed to service temperature above 800°F [425°C].

5. Chemical Analysis

5.1 *Heat Analysis*—An analysis of each heat shall be made by the manufacturer to determine the percentages of elements specified in Table 1. The analysis shall be made on a test sample taken preferably during the pouring of the heat. The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.2 *Product Analysis*—A product analysis may be made by the purchaser. The sample for analysis shall be selected so as to be thoroughly representative of the pipe being analyzed. The chemical composition thus determined shall conform to the requirements specified in Table 1.

5.3 To determine conformance with the chemical analysis requirements, an observed value or calculated value shall be rounded in accordance with Practice E29 to the nearest unit in the last right-hand place of values listed in Table 1.

6. Tensile Requirements

6.1 *Test Specimens:*

6.1.1 Test specimens shall be prepared in accordance with Test Methods and Definitions A370. Test bars shall be poured in special blocks from the same heat as the castings represented. Test bars shall be supplied in sufficient number to furnish all specimens required in 6.2 and 6.3 (see Table 3).

6.1.2 Test specimens may be cut from heat-treated castings instead of from test bars when agreed upon between the manufacturer and the purchaser.

6.1.3 Tension test specimens shall be machined to the form and dimensions of the standard round 2-in. [50-mm] gage length specimens shown in Fig. 6 of Test Methods and Definitions A370.

6.2 *Number of Tests:*

6.2.1 One tension test shall be made from each heat. The bar from which the test specimen is taken shall be heat-treated in the same manner as the castings represented.

6.2.2 If a specimen is machined improperly or flaws are revealed by machining or during testing, the specimen may be discarded and another substituted from the same heat.

6.3 *Retests*—If the results of the mechanical tests for any heat do not conform to the requirements specified, the castings may be reheat-treated and retested, but may not be solution-treated more than twice.

7. Hydrostatic Test

7.1 Each length of pipe shall be hydrostatically tested in accordance with Specification A999/A999M.

7.2 It is realized that the foundry may be unable to perform the hydrostatic test prior to shipment, or that the purchaser may wish to defer testing until additional work has been performed on the casting. In such cases, the foundry is responsible for the satisfactory performance of the casting when it is tested.

8. Quality

8.1 The surface of the casting shall be examined visually and shall be free from cracks and hot tears. Other surface defects shall be judged in accordance with visual acceptance criteria which may be specified in the order.

9. Rework and Retreatment

9.1 Defects as defined in Section 8 shall be removed and their removal verified by visual inspection of the resultant cavities. Defects which are located by inspecting with Supplementary Requirement S6 or S7, or both, shall be removed or reduced to an acceptable size.

9.2 If removal of the defect does not infringe upon the minimum wall thickness, the depression may be blended uniformly into the surrounding surface.

9.3 If the cavity resulting from defect removal infringes upon the minimum wall thickness, weld repair is permitted subject to the purchasers' approval. The composition of the weld rod used shall be suitable for the composition of the metal being welded.

9.3.1 Only operators and procedures qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, shall be used. All repair welds will be inspected to the same quality standards used to inspect the casting.

9.4 Postweld heat-treatment of the repaired casting is neither required nor prohibited.

10. Permissible Variations in Dimensions

10.1 *Thickness*—The wall thickness shall not vary over that specified by more than ⅛ in. (3 mm). There shall be no variation under the specified wall thickness.

11. General Requirements

11.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A999/A999M, unless otherwise provided herein.

12. Rejection

12.1 Each length of pipe received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the pipe may be rejected and the manufacturer shall be notified. Disposition of rejected pipe shall be a matter of agreement between the manufacturer and the purchaser.

13. Rehearing

13.1 Samples that represent rejected material shall be preserved for 2 weeks from the date of transmission of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

14. Certification

14.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

15. Product Marking

15.1 Each length of pipe shall be legibly marked with the manufacturer's name or brand, the letters ASTM, the specification number, and grade. In addition, heat numbers, or serial numbers that are traceable to heat numbers, shall be marked on each length of pipe.

16. Keywords

16.1 austenitic; centrifugally cast; height; high-temperature service; stainless steel; steel castings

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. Additional Tension Tests

S1.1 Additional tension tests shall be made at a temperature to be specified by the customer, and the properties to be met are a matter of agreement between purchaser and manufacturer.

S2. Flattening Test

S2.1 The flattening test shall be made on specimens from one or both ends of each length of pipe. If the specimen from any end of any length fails to conform to the requirements of Specification A999/A999M, that length shall be rejected.

S3. Photomicrographs

S3.1 The manufacturer shall furnish one photomicrograph at 100 diameters from one specimen of as-finished pipe from each heat in each heat-treatment lot. Such photomicrographs shall be suitably identified as to pipe size, wall thickness, and heat. Such photomicrographs are for information only, to show the actual metal structure of the pipe as furnished. No photomicrographs for the individual pieces purchased shall be required except as specified in Supplementary Requirement S4.

S4. Photomicrographs for Individual Pieces

S4.1 The manufacturer shall furnish photomicrographs from one or both ends of each pipe. All photomicrographs required shall be properly identified as to heat number, size, and wall thickness of pipe from which the section was taken. Photomicrographs shall be further identified to permit association of each photomicrograph with the individual length of pipe it represents.

S5. Metal Structure and Etching Tests

S5.1 Etching tests (Note S1) shall be made on transverse sections from the pipe and shall reveal the macrostructure of the material. Such tests are for information only.

NOTE S1—Pending development of etching methods applicable to the product covered by this specification, it is recommended that the Recommended Practice for a Standard Macroetch Test for Routine Inspection of Iron and Steel be followed.

S6. Radiographic Examination

S6.1 The castings shall be examined for internal defects by means of X rays or gamma rays. The inspection procedure shall be in accordance with Guide E94 and the types and degrees of discontinuities considered shall be judged by Reference Radiographs E446, E186, or E280. The extent of examination and the basis for acceptance shall be subject to agreement between the manufacturer and the purchaser.

S7. Liquid Penetrant Examination

S7.1 The castings shall be examined for surface discontinuities by means of liquid penetrant inspection. The method of performing the liquid penetrant test shall be in accordance with Test Method E165. The areas to be inspected, the methods and types of liquid penetrants to be used, the developing procedure, and the basis for acceptance shall be as specified on the inquiry or invitation to bid and on the purchase order or contract or both, or as agreed upon between the manufacturer and the purchaser.

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SPECIFICATION FOR HIGH-TEMPERATURE BOLTING, WITH EXPANSION COEFFICIENTS COMPARABLE TO AUSTENITIC STAINLESS STEELS

SA-453/SA-453M

(Identical with ASTM Specification A453/A453M-17.)

Specification for High-Temperature Bolting, with Expansion Coefficients Comparable to Austenitic Stainless Steels

1. Scope

1.1 This specification covers five grades of bolting materials with twelve classes of yield strength ranging from 50 to 120 ksi [345 to 827 MPa] for use in high-temperature service for bolting components, such as bolts, screws, nuts, or studs, for pressure vessel and valve flanges. See Specification A962/A962M for the definition of bolting. The material requires special processing and is not intended for general purpose applications.

1.2 The following referenced general requirements are indispensable for application of this specification: Specification A962/A962M.

1.3 Supplementary Requirements are provided for use at the option of the purchaser. The Supplementary Requirements shall only apply when specified individually by the purchaser in the purchase order or contract.

1.4 This specification is expressed in both inch-pound units and in SI units; however, unless the purchase order or contract specifies the applicable "M" specification designation (SI units), the inch-pound units shall apply.

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

1.6 *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:*

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A962/A962M Specification for Common Requirements for Bolting Intended for Use at Any Temperature from Cryogenic to the Creep Range

E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

E292 Test Methods for Conducting Time-for-Rupture Notch Tension Tests of Materials

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *heat-treatment charge*—one heat of material heat treated in one batch. If a continuous operation is used, the weight processed as a heat-treatment charge shall not exceed the weights in Table 1.

3.1.2 *lot*—a lot shall consist of the quantities shown in Table 2.

4. Ordering Information

4.1 The inquiry and order shall indicate the following:

4.1.1 Quantity (weight or number of pieces),

4.1.2 Description of item (bars, bolts, nuts, etc.),

4.1.3 Grade and class (see Table 3),

4.1.4 Method of finishing (see 6.1),

4.1.5 Type of thread desired (see 6.1.1),

4.1.6 Alternative test method option (see 8.2.4.3),

4.1.7 Bolt shape option, if any,

4.1.8 Thread option, if any,

4.1.9 Test method for surface quality, if any,

TABLE 1 Continuous Heat-Treatment Charge Sizes

Diameter, in. [mm]	Weight, lb [kg]
To 1¾ [44]	3000 [1400]
Over 1¾ [44] to 2½ [63]	6000 [2700]
Over 2½ [63]	12000 [5400]

TABLE 2 Lot Sizes

Diameter, in. [mm]	Maximum Lot Size, lb [kg]
1½ [38] and under	200 [90]
Over 1½ [38] to 1¾ [44], incl	300 [140]
Over 1¾ [44] to 2½ [63], incl	600 [270]
Over 2½ [63]	20 pieces

4.1.10 Test location option, if any,

4.1.11 Rejection option, if any, and

4.1.12 If stress-rupture testing is not required, except for Grade 660 Class D and Grade 668 (see 8.2.1).

5. Common Requirements

5.1 Bolting materials and bolting components supplied to this specification shall conform to the requirements of Specification A962/A962M. These requirements include test methods, finish, thread dimensions, marking, certification, optional supplementary requirements, and others. Failure to comply with the requirements of Specification A962/A962M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A962/A962M, this specification shall prevail.

6. Materials and Manufacture

6.1 *Finishing Process:*

6.1.1 Threads may be formed by machining or rolling. Threads may be formed after precipitation heat treatment or after solution anneal but prior to precipitation heat treatment. Type designations are as follows:

Type M1—threads formed by machining after precipitation heat treatment.

Type M2—threads formed by machining after solution anneal but prior to precipitation heat treatment.

Type R1—threads formed by rolling after precipitation heat treatment.

Type R2—threads formed by rolling after solution anneal but prior to precipitation heat treatment.

When not specified by the purchaser, the type supplied shall be the option of the manufacturer.

6.2 *Heat Treatment*—Each grade and class shall be heat treated as prescribed in Table 4.

7. Chemical Composition

7.1 Each alloy shall conform to the chemical composition requirements prescribed in Table 3.

8. Mechanical Properties

8.1 *Tension Test:*

8.1.1 *Requirements*—Bolting material in each heat-treatment charge shall conform to the room-temperature tensile requirements in Table 5.

8.1.2 *Number of Specimens:*

8.1.2.1 *Heat-Treated Bars*—When not more than two sizes of bars are heat treated in the same load, one tension test shall be made from each size in each heat of material in the heat-treatment charge (see 3.1.1). When more than two sizes of bars are treated in the same charge, one tension test shall be made from one bar of each of the two largest diameters from each heat of material in the heat-treating charge.

8.1.2.2 *Finished Bolting Components*—One tension test shall be made if the lot consists of parts of the same nominal diameter. If the lot consists of components of more than one nominal diameter, one tension test shall be made from each nominal diameter of each heat involved in the lot (see Section 3).

8.2 *Stress-Rupture Test:*

8.2.1 *Requirements*—Bolting material shall conform to the stress-rupture requirements prescribed in Table 6 for design temperatures above 800 °F [427 °C]. Bolting material not stress-rupture tested shall be permanently stamped NR. Grade 660 Class D and Grade 668 do not require stress-rupture and shall be stamped NR.

8.2.2 The number of specimens shall be the same as the required number of tension test specimens.

8.2.3 The test location and orientation shall be the same as that required for the tension test specimens.

8.2.4 *Test Method:*

8.2.4.1 The rupture test shall be performed in accordance with Practice E139.

NOTE 1—Fig. 1 is taken from Test Method E292. This is to facilitate detection of notch sensitivity. The specimen found in Practice E139 does not include a notch. The specimen in Fig. 1 is to be used only to determine if the material is notch sensitive. Actual testing is to Practice E139, not Test Method E292, so the additional test data required by Test Method E292 is not to be determined or reported.

8.2.4.2 A combination smooth and notched test specimen, machined to the dimensions prescribed in Fig. 1 and Table 7, shall be tested in accordance with the stress-rupture requirements prescribed in Table 6. The test shall be continued to rupture. The rupture shall occur in the smooth section of the bar.

8.2.4.3 As an alternative procedure and, when specifically approved by the purchaser, separate smooth and notched test specimens, machined from adjacent sections of the same piece, with gage sections conforming to the respective dimensions of Table 7, may be tested under the above conditions. The notched specimen need not be tested to rupture but shall not rupture in less time than the companion smooth specimen.

8.2.4.4 When the minimum specified time to rupture in Table 6 has been achieved, incremental loading may be used to accelerate the time to rupture. At intervals of 8 to 16 h, preferably 8 to 10 h, the stress shall be increased in increments of 5000 psi [34.5 MPa]. Rupture location, and elongation requirements shall be as prescribed in Table 6, 8.2.4.2, and 8.2.4.3.

8.3 *Hardness Test:*

8.3.1 *Requirements*—Bolting material shall conform to the room temperature hardness requirements prescribed in Table 5.

8.3.2 *Number of Tests:*

TABLE 3 Chemical Requirements

	Grade 660		Grade 651	
UNS Number	S66286		S63198	
	Content, %	Product Analysis Variation, Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.28–0.35	0.02
Manganese	2.00 max	0.04	0.75–1.50	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	1.00 max	0.05	0.30–0.80	0.05
Nickel	24.0–27.0	0.20	8.0–11.0	0.15
Chromium	13.5–16.0	0.20	18.0–21.0	0.25
Molybdenum	1.00–1.50	0.05	1.00–1.75	0.05
Tungsten	...	...	1.00–1.75	0.05
Titanium	1.90–2.35	0.05	0.10–0.35	0.05 over
Columbium[A]	...	...	0.25–0.60	0.05
Aluminum	0.35 max	0.05 over	...	...
Vanadium	0.10–0.50	0.03	...	...
Boron	0.001–0.010	0.0004 under to 0.001 over	...	...
Copper	...	...	0.50 max	0.03 over

	Grade 662		Grade 665	
UNS Number	S66220		S66545	
	Content, %	Product Analysis, Variation Over or Under, %	Content, %	Product Analysis Variation, Over or Under, %
Carbon	0.08 max	0.01 over	0.08 max	0.01 over
Manganese	0.40–1.00	0.03	1.25–2.00	0.04
Phosphorus	0.040 max	0.005 over	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over	0.030 max	0.005 over
Silicon	0.40–1.00	0.05	0.10–0.80	0.05
Nickel	24.0–28.0	0.20	24.0–28.0	0.20
Chromium	12.0–15.0	0.15	12.0–15.0	0.15
Molybdenum	2.0–3.5	0.10	1.25–2.25	0.10
Titanium	1.80–2.10	0.05	2.70–3.3	0.05
Aluminum	0.35 max	0.05 over	0.25 max	0.05 over
Copper	0.50 max	0.03 over	0.25 max	0.03 over
Boron	0.001–0.010	0.0004 under to 0.001 over	0.01–0.07	0.005

	Grade 668	
UNS Number	S66285	
	Content, %	Product Analysis, Variation Over or Under, %
Carbon	0.08 max	0.01 over
Manganese	2.00 max	0.04
Phosphorus	0.040 max	0.005 over
Sulfur	0.030 max	0.005 over
Silicon	1.00 max	0.05
Nickel	17.5 – 21.5	0.20
Chromium	13.5–16.0	0.20
Molybdenum	1.50 max	0.05
Tungsten	...	...
Titanium	2.2–2.8	0.05
Columbium[A]	...	...
Aluminum	0.50 max	0.05 over
Vanadium	0.50 max	0.03
Boron	0.001–0.010	0.0004 under to 0.001 over
Copper	...	...

[A] Or columbium plus tantalum.

8.3.2.1 *Bars 2 in. [50 mm] and Over*—One test on each mill-treated length.

8.3.2.2 *Bars under 2 in. [50 mm]*—One test on at least 10 % of the mill treated lengths.

8.3.2.3 *Bolting Components*—See Specification A962/A962M for the required number of tests.

8.3.3 *Test Locations*—The hardness test shall be made at the center of the cross section for bars up to 1 in. [25 mm] in diameter, and at the midradius on bars 1 in. [25 mm] and larger in diameter.

TABLE 4 Heat Treatment Requirements[A]

Grade Symbol	Class	Solution Treatment	Hardening Treatment
660	A	1650 ± 25 °F [900 ± 14 °C], hold 2 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	B	1800 ± 25 °F [980 ± 14 °C], hold 1 h, min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	C	1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and oil quench	1425 ± 25 °F [775 ± 14 °C] hold 16 h, air cool, followed by 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
	D	1650 ± 25 °F [900 ± 14 °C], hold 2 h min, and liquid quench or 1800 ± 25 °F [980 ± 14 °C], hold 1 h min, and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool If necessary to achieve properties, second age: 1200 ± 25 °F [650 ± 14 °C] hold 16 h, air cool
651	A		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction in cross-sectional area, stress relieve at 1200 °F [650 °C] min or 4 h, min
	B		hot-cold worked at 1200 °F [650 °C] min with 15 % min reduction of cross-sectional area, stress relieve at 1350 °F [730 °C] min for 4 h, min
662	A	1800 ± 25 °F [980 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	1950 ± 25 °F [1065 ± 14 °C], hold 2 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
665	A	1800 ± 25 °F [980 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
	B	2000 ± 25 °F [1095 ± 14 °C], hold 3 h, liquid quench	1350 to 1400 °F [730 to 760 °C], hold 20 h, furnace cool to 1200 ± 25 °F [650 ± 14 °C], hold 20 h, air cool
668	A	1650 ± 25 °F [900 ± 14 °C], hold 2 h, min and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool
	B	1800 ± 25 °F [980 ± 14 °C], hold 1 h, min and liquid quench	1325 ± 25 °F [720 ± 14 °C], hold 16 h, air cool

[A] Times refer to the minimum time material is required to be at temperature.

TABLE 5 Mechanical Property Requirements

Grade	Class	Tensile Strength, min		Yield Strength (0.2 % Offset), min		Elongation in 4× Diam, min, %	Reduction of Area, min, %	Brinell Hardness Number	Approximate Rockwell Hardness, B and C	
		ksi	MPa	ksi	MPa				min	max
660	A, B, and C	130	895	85	585	15	18	248–341	24 HRC	37 HRC
	D (≤2½ in. [63.5 mm])	130	895	105	725	15	18	248–321	24 HRC	35 HRC
	D (>2½ in. [63.5 mm])	120	825	95	655	15	18	248–321	24 HRC	35 HRC
651	A	100	690	70[A] 60[B]	485 415	18	35	217–277	95 HRB	29 HRC
	B	95	655	60[A] 50[B]	415 345	18	35	212–269	93 HRB	28 HRC[C]
662	A	130	895	85	585	15	18	248–321	24 HRC	35 HRC[C]
	B	125	860	80	550	15	18	248–321	24 HRC	35 HRC
665	A	170	1170	120	830	12	15	311–388	32 HRC	41 HRC
	B	155	1070	120	830	12	15	311–388	32 HRC	41 HRC
668	A and B	130	895	85	585	15	18	248–341	24 HRC	37 HRC

[A] Bolting material sizes 3 in. [76 mm] and under in diameter.
[B] Bolting material sizes over 3 in. [76 mm] in diameter.
[C] Conversion numbers taken from Specification A193/A193M, Table number 2 (austenitic steels); others by interpolation.

TABLE 6 Stress Rupture Requirements

Grade	Class	Test Temperature, °F [°C]	Stress, min		Time to Rupture, min, h[A]	Elongation, min, %
			ksi	MPa		
660	A, B, and C	1200 [650]	56	385	100	5
651	A and B	1200 [650]	40	275	100	5
662	A and B	1200 [650]	55	380	100	5
665	A	1200 [650]	75	515	100	3
	B	1200 [650]	70	485	100	5

[A] The combination bar specimen shown in Fig. 1 shall be tested continuously at the temperature and at the minimum stress specified or at a greater stress and shall rupture in a time not less than that specified.

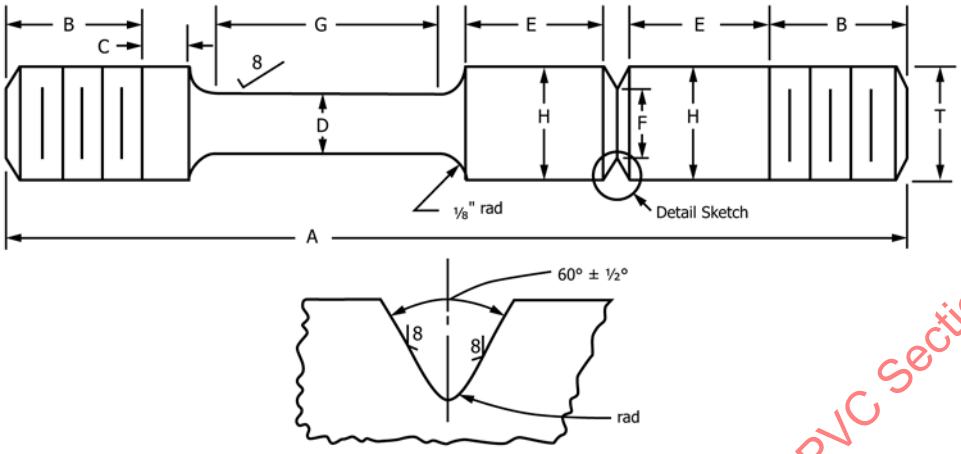

FIG. 1 Combination Smooth-Notch Stress-Rupture Test Specimen
(See Table 6)

9. Product Marking

9.1 *Bolts, Nuts, Screws, and Studs*—In addition to the requirements of Specification A962/A962M, the grade symbol and class shown in Table 4 and the type designation (see 6.1.1) shall also appear on all bolting components so processed. Grade 660 Class D and Grade 668 shall be stamped NR in addition to other required markings.

10. Certification

10.1 Certification is required. See Specification A962/A962M.

11. Keywords

11.1 bolts–steel; bolting components–steel; marking; nuts–steel; precipitation hardening steels; pressure vessel service; revision letter; steel bars–alloy; steel bolting; steel flanges; steel values; temperature service applications–high

TABLE 7 Test Specimen Dimensions

NOTE 1— Surfaces marked [8], finish to 8 µin. [0.2 µm] rms or better.

NOTE 2—The difference between dimensions *F* and *D* shall not exceed 0.0005 in. [0.01 mm] for specimens 1 or 2. The difference shall not exceed 0.001 in. [0.02 mm] for specimens 3, 4, 5, or 6.

NOTE 3—Taper the gage length *G* to the center so that the diameter *D* at the ends of the gage length exceeds the diameter at the center of the gage length by not less than 0.0005 in. [0.01 mm] nor more than 0.0015 in. [0.04 mm].

NOTE 4—All sections shall be concentric about the specimen axis within 0.001 in. [0.02 mm].

NOTE 5—Thread size *T* shall be equal to or greater than diameter *H*.

NOTE 6—Dimensions *A* and *B* are not specified.

NOTE 7—Length of shoulder *C*—⅛ + 1/32 –0 in. [3.2 + 0.8 mm].

NOTE 8—Length of shoulder *E*—⅜ + 1/32 –0 in. [10.0 + 0.8 mm].

Specimen Type	Mid-length Gage Dia *D* and Notch-Root Dia *F*	Gage Length, *G*	Shoulder Diameter, *H*	Notch-Root Radius
	Inches			
1	0.125	0.5	0.177	0.005
2	0.160	0.65	0.226	0.005
3	0.178	0.75	0.250	0.005
4	0.252	1.0	0.375	0.007
5	0.357	1.5	0.500	0.010
6	0.505	2.0	0.750	0.015
Tolerance	±0.001	±0.05	±0.003	±0.0005
	Millimetres			
7	3.17	12.0	4.5	0.13
8	4.06	17.0	5.5	0.13
9	4.52	20.0	6.5	0.13
10	6.40	25.0	9.5	0.18
11	9.07	40.0	12.0	0.25
12	12.8	50.0	19.0	0.38
Tolerance	±0.025	±1.3	±0.1	±0.01

TABLE 8 Permissible Variations in Size of Cold-Finished Bars

Specified Size, in. [mm]	Permissible Variations from Specified Size, in. [mm][A]	
	Over	Under
Over ½ to 1 [13 to 25], excl	0.002 [0.05]	0.002 [0.05]
1 to 1½ [25 to 38], excl	0.0025 [0.06]	0.0025 [0.06]
1½ to 4 [38 to 100], incl[B]	0.003 [0.08]	0.003 [0.08]

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, because of special hardness or mechanical property requirements, the permissible variations are generally double those shown in the table.

[B] For size tolerances of sizes over 4 in. [100 mm], the manufacturer should be consulted.

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SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, HIGH-STRENGTH MANGANESE

SA-455/SA-455M

(Identical with ASTM Specification A455/A455M-12a(2017).)

Standard Specification for Pressure Vessel Plates, Carbon Steel, High-Strength Manganese

1. Scope

1.1 This specification covers high-tensile strength carbon-manganese steel plates intended for welded pressure vessels.

1.2 This steel is usually made to a semi-killed or capped deoxidation practice; however, at the purchaser's or the steel producer's option, the steel may be made silicon-killed or aluminum-killed.

1.3 The maximum thickness of plates furnished under this specification shall be ¾ in. [20 mm].

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 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.

2. Referenced Documents

2.1 *ASTM Standards:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

3. General Requirements and Ordering Information

3.1 Material supplied to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plates from coil are described in Specification A20/A20M.

3.4 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Heat Treatment

4.1 Plates are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5. Chemical Composition

5.1 The steel shall conform to the chemical requirements given in Table 1.

6. Mechanical Properties

6.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

7. Keywords

7.1 carbon steel; high-strength steel plate for pressure purposes; welded pressure vessels

TABLE 1 Chemical Requirements

Elements	Composition, %
Carbon, max[A,B]	0.33
Manganese:[C]	
Heat analysis	0.85–1.20
Product analysis	0.79–1.30
Phosphorus, max[A]	0.025
Sulfur, max[A]	0.025
Silicon:[D]	
Heat analysis	0.10 max
Product analysis	0.13 max

[A] Applies to both heat and product analyses.
[B] When the silicon is higher than 0.10 %, the carbon maximum shall be 0.28 %.
[C] For each reduction of 0.01 percentage point below the specified maximum for carbon, and increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[D] At the purchaser's or the producer's option, silicon may be 0.40 % max on heat analysis, 0.45 % max on product analysis.

TABLE 2 Tensile Requirements

	Thickness		
	Up to 0.375 in. [9.5 mm]	Over 0.375 to 0.580 in. [15 mm]	Over 0.580 to 0.750 in. [20 mm]
Tensile strength, ksi [MPa]	75–95 [515–655]	73–93 [505–640]	70–90 [485–620]
Yield strength, min, ksi [MPa]	38 [260]	37 [255]	35 [240]
Elongation in 8 in. [200 mm], min, %[A]	15	15	15
Elongation in 2 in. [50 mm], min, %[A]	22	22	22

[A] See Specification A20/A20M for elongation adjustments.

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons.

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SPECIFICATION FOR DUCTILE IRON CASTINGS FOR PAPER MILL DRYER ROLLS

SA-476/SA-476M

(Identical with ASTM Specification A476/A476M-09(2018) except for editorial changes in 4.1.6 and 13.1 to make certification mandatory.)

SPECIFICATION FOR DUCTILE IRON CASTINGS FOR PAPER MILL DRYER ROLLS

SA-476/SA-476M

[Identical with ASTM Specification A 476/A 476M-00(2018) except for editorial changes in 4.1.6 and 13.1 to make certification mandatory.]

1. Scope

1.1 This specification covers ductile iron castings for use in pressure containing paper mill dryer rolls at temperatures up to 450°F [230°C].

1.2 No precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron (see Appendix X1).

1.3 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 shall be used independently of the other. Combining values from the two systems may result in nonconformance with the specification.

2. Referenced Documents

2.1 *ASTM Standards:*

A 644 Terminology Relating to Iron Castings
E 8 Test Methods for Tension Testing of Metallic Materials
E 10 Test Method for Brinell Hardness of Metallic Materials
E 94 Guide for Radiographic Testing
E 446 Reference Radiographs for Steel Castings Up to 2 in. (51 mm) in Thickness

3. Terminology

3.1 Definitions for many terms common to iron castings are found in Terminology A 644.

4. Ordering Information

4.1 Orders for material purchased to the requirements of this specification should include the following information:

4.1.1 Quantity,

4.1.2 Specification number and date of issue,

4.1.3 Description of casting by pattern number or drawing,

4.1.4 Heat treatment, if required (see 5.1),

4.1.5 Type of test coupon (see 9.2),

4.1.6 Certification, is required (see 13.1),

4.1.7 Marking location (see 14.1), and

4.1.8 Additional requirements.

5. Heat Treatment

5.1 The castings may be stress relieved at a temperature not to exceed 1200°F [650°C].

6. Chemical Requirements

6.1 The castings shall conform to the following chemical requirements:

Total carbon, min, %	3.0
Silicon, max, %	3.0
Phosphorus, max, %	0.08
Sulfur, max, %	0.05

6.2 The castings shall have a carbon equivalent of 3.8 to 4.5 inclusive.

NOTE 1 — The carbon content equivalent is calculated as follows:
Total carbon + 0.3 (silicon + phosphorus)

6.3 The chemical analysis for total carbon shall be made on either chilled cast pencil-type specimens or on thin wafers approximately $\frac{1}{32}$ in. [0.8 mm] thick, cut from test coupons. Drillings shall not be used due to attendant loss of graphite.

7. Mechanical Properties

7.1 The iron represented by test coupons shall conform to tensile requirements prescribed in Table 1.

7.2 The yield strength prescribed in Table 1 may be determined by any of the approved procedures described in 7.3 of Test Methods E 8.

7.3 The Brinell hardness of the material shall be a minimum of 201 HB. Hardness tests shall be conducted in accordance with Test Method E 10, using a 3000 kgf load. The test may be made on either the casting or on a test coupon representing the casting.

8. Workmanship, Finish, and Appearance

8.1 The castings shall conform to the dimensions on the drawings furnished by the purchaser, or if no drawing has been provided, to the dimensions predicated by the pattern supplied by the purchaser. Surfaces of the castings shall be free of adhering sand. Runners, risers, fins, and other extraneous metal shall be removed.

9. Sampling

9.1 Test coupons shall be poured from the same iron as the castings represented.

9.2 Test coupons shall be cast either to the "Y" block size and shape shown in Fig. 1 or to the dimensions of the 1 in. [25-mm] keel block shown in Fig. 2. The type of test coupon and, when selected, the size of the "Y" block shall be specified by the purchaser.

9.3 The test coupons shall be cast in open molds made of suitable core sand with a minimum 1½ in. [38 mm] of sand for the 1 in. [25 mm] size and 3 in. [75 mm] of sand for the 3 in. [75 mm] size. The coupons shall be left in the mold until black.

9.4 Table 2 shows the equivalent geometrical shapes with various dimensions and the equivalent "Y" block, based on cooling rates, and may be used as a guide for selection of the proper "Y" block to be specified to represent the casting.

9.5 When the castings are heat treated, the test coupons shall be heat treated with the castings they represent.

10. Tension Test

10.1 Tension test specimens shall be obtained from test coupons shown in either Fig. 1 or Fig. 2, and machined to the dimensions shown in Fig. 3. Test coupons cast as "Y" blocks (Fig. 1) shall be sectioned as shown in Fig. 4.

10.2 One tension test shall be performed for each casting.

10.3 If any specimen shows defective machining or flaws, it may be discarded and another substituted from the same casting represented.

10.4 If an apparently sound test specimen fails to conform to the tensile requirements, two retests may be made. If either retest fails to conform to the requirements specified, the castings shall be rejected.

11. Repairs

11.1 Castings made to this specification that leak on subsequent hydrostatic testing may be repaired by using threaded plugs provided the following requirements are met.

11.1.1 No welding or brazing shall be permitted.

11.1.2 The diameter of the plug shall not exceed the diameter of a standard 2 in. [ISO R2] iron pipe size pipe plug.

11.1.3 The plugs, where practical, shall conform in all dimensions to the standard iron pipe size pipe plugs. In addition, they shall have full thread engagement corresponding to the thickness of the repaired section. Where a tapered plug is impractical because of the excess wall thickness in terms of plug diameter and coincident thread engagement, other types of plugs may be used provided both full thread engagement and effective sealing against pressure are obtained. Where possible the ends of the plugs should be ground smooth after installation to conform to the inside and outside contours of the cylinder.

11.1.4 The material from which the plug is manufactured shall conform in all respects to this specification.

11.1.5 The area adjacent to the drilled hole should be examined radiographically in accordance with Guide E 94. The area examined shall meet the requirements of Severity Level 3 of Reference Radiographs E 446.

11.1.6 The thickness of any repaired section in relation to the size of plug used shall be not less than that given in Table 3.

11.1.7 The minimum radius of curvature of the repaired section of the cylinder in relation to the size of plug used shall be not less than that given in Table 4.

11.1.8 A repaired area may consist of a maximum of three plugs with a spacing such that the distance between adjacent plugs shall not be less than those listed in Table 5. Adjacent areas of repair, in which each contains more than one plug, shall be separated by at least twice the distance required in Table 5 for the two nearest plugs separating the two areas.

11.2 Surface imperfections not exceeding 20% of the thickness of the section and other minor defects may be repaired by plugging provided the diameter of the plug does not exceed its length.

12. Inspection

12.1 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 this specification. Foundry inspection by the purchaser shall not interfere unnecessarily with the manufacturer's operations. All tests and inspections shall be made at the place of manufacture unless otherwise agreed.

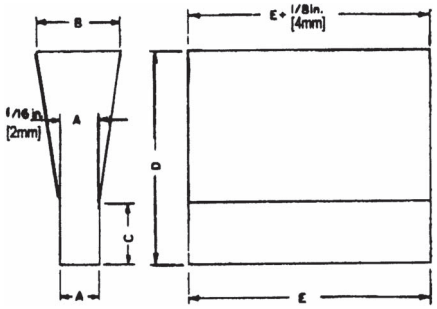
13. Certification

13.1 The manufacturer's certification shall be furnished stating that the material was manufactured, sampled, tested, and inspected in accordance with the requirements of this specification and was found to meet the requirements. In addition to the certification, a test report shall be furnished showing the results of all tests performed.

14. Product Marking

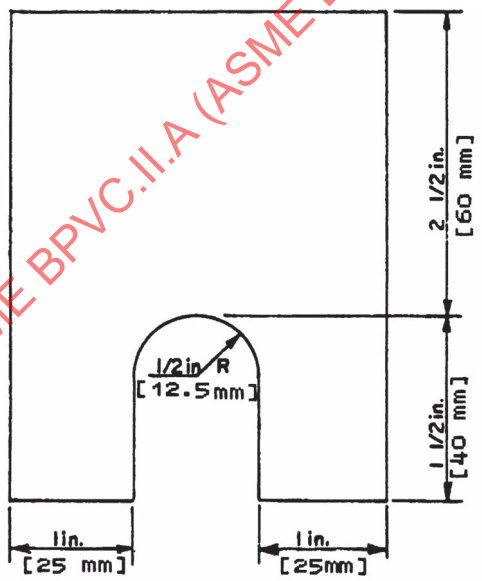
14.1 Castings made in accordance with this specification shall have the name of the manufacturer or his recognized trade mark and this specification number cast on or indelibly stamped on a surface designated by the purchaser.

FIG. 1 "Y" BLOCKS FOR TEST COUPONS



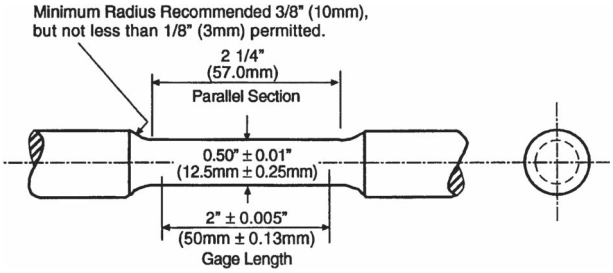
Dimensions	"Y" Block Size	
	For Casting of Thickness ½ in. to 1½ in. [12.5-40 mm]	For Castings of Thickness of 1½ in. [40 mm] and Over
	in. [mm]	in. [mm]
A	1 [25]	3 [75]
B	1⅛ [55]	5 [125]
C	3 [75]	4 [100]
D	6 [150]	8 [200]
E	7 [175] approx	7 [175] approx

FIG. 2 KEEL BLOCK FOR TEST COUPONS



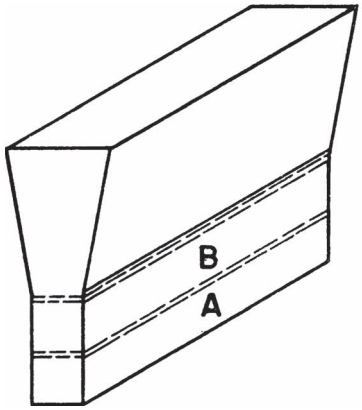
NOTE 1 — The length of keel block shall be 6 in. [150 mm].

FIG. 3 STANDARD ROUND TENSION TEST SPECIMEN WITH 2-IN. [50 MM] GAGE LENGTH

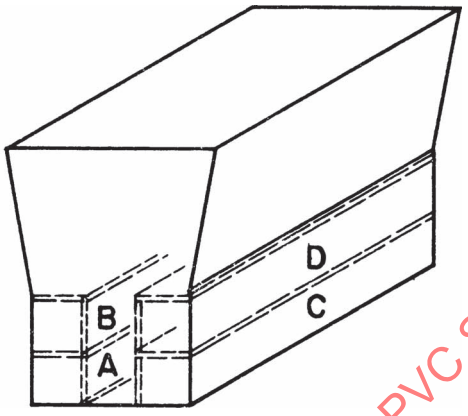


NOTE 1 — The gage length and fillets shall be as shown, but the ends may be of any shape to fit the holder of the testing machine in such a way that the load shall be axial. The reduced section shall have a gradual taper from the ends toward the center, with the ends 0.003 to 0.005 in. [0.08–0.13 mm] larger in diameter than the center.

FIG. 4 SECTIONING PROCEDURE FOR "Y" BLOCKS



(*a*) *1 in. [25 mm] "Y" Block* — Two blanks for 0.50 in. [12.5 mm] diameter tension test specimens.



(*b*) *3 in. [75 mm] "Y" Block* — Four blanks for 0.50 in. [12.5 mm] diameter tension test specimens.

TABLE 1
TENSILE REQUIREMENTS

Test Coupon Section Thickness	1 in. [25 mm]	3 in. [75 mm]
Tensile strength, min, ksi [MPa]	80 [555]	80 [555]
Yield strength, min, ksi [MPa]	60 [415]	60 [415]
Elongation in 2 in. [50mm], min, %	3.0 [3.0]	1.0 [1.0]

TABLE 2
EQUIVALENT GEOMETRIC SHAPES CORRESPONDING TO "Y" BLOCKS

"Y" Block Size, in. [mm]	Infinite Plate Thickness, in. [mm]	Round Diameter, in. [mm]	Cube Edge, in. [mm]
1 [25]	0.9 [22.5]	1.75 [44]	2.75 [44]
3 [75]	1.6 [40]	3.1 [78]	4.8 [120]

TABLE 3
MINIMUM THICKNESS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Section Thickness, in. [mm]
1/8 [R1/8]	11/32 [8]
1/4 [R1/4]	7/16 [10]
3/8 [R3/8]	1/2 [13]
1/2 [R1/2]	21/32 [17]
3/4 [R3/4]	3/4 [19]
1 [R1]	13/16 [21]
1 1/4 [R1 1/4]	7/8 [23]
1 1/2 [R1 1/2]	15/16 [24]
2 [R2]	1 [26]

TABLE 4
MINIMUM RADIUS OF REPAIRED SECTIONS

Iron Pipe Size Plug, in. [ISO Pipe Plug Size]	Minimum Radius of Curvature, in. [mm]
1/8 [R1/8]	9/16 [15]
1/4 [R1/4]	11/16 [18]
3/8 [R3/8]	1 1/16 [28]
1/2 [R1/2]	1 1/4 [32]
3/4 [R3/4]	2 [52]
1 [R1]	2 1/2 [64]
1 1/4 [R1 1/4]	4 [104]
1 1/2 [R1 1/2]	5 1/4 [136]
2 [R2]	8 1/8 [208]

TABLE 5
MINIMUM DISTANCE BETWEEN PLUG CENTERS
(Based on Ligament Efficiency of 80%)[A]

Adjacent Plug Diameters, in. [ISO Pipe Plug Size]	Minimum Distance Between Plug Centers, in. [mm]			
	1/8 [R1/8], 1/4 [R1/4], 3/8 [R3/8]	1/2 [R1/2], 3/4 [R3/4]	1 [R1], 1 1/4 [R1 1/4]	1 1/2 [R1 1/2], 2 [R2]
1/8 [R1/8], 1/4 [R1/4], 3/8 [R3/8]	2 5/8 [67]	4 1/8 [105]	6 5/8 [169]	9 1/2 [242]
1/2 [R1/2], 3/4 [R3/4]	4 1/8 [105]	4 1/8 [105]	6 5/8 [169]	9 1/2 [242]
1 [R1], 1 1/4 [R1 1/4]	6 5/8 [169]	6 5/8 [169]	6 5/8 [169]	9 1/2 [242]
1 1/2 [R1 1/2], 2 [R2]	9 1/2 [242]	9 1/2 [242]	9 1/2 [242]	9 1/2 [242]

[A] *Example* — Assume three plugs are required for repair, one 1/8 in. [R1/8], one 3/8 in. [R3/8], and one 1 1/2 in. The minimum distance permitted is as follows.

Ligament distance between 1/8 [R1/8] and 3/8 in. [R3/8] plugs = 2 5/8 in. [67 mm]
Ligament distance between 1/8 [R1/8] and 1 1/2 in. [R1 1/2] plugs = 9 1/2 in. [242 mm]
Ligament distance between 3/8 [R3/8] and 1 1/2 in. [R1 1/2] plugs = 9 1/2 in. [242 mm]

APPENDIX

(Nonmandatory Information)

X1. MECHANICAL PROPERTIES OF CASTINGS

X1.1 The mechanical properties of iron castings are influenced by the cooling rate during and after solidification, by chemical composition, by heat treatment, by the design of the casting, by the design and nature of the mold, by the location and effectiveness of gates and risers, and by certain other factors.

X1.2 The cooling rate in the mold and, therefore, the properties developed in any particular section are influenced by the presence of cores, chills and chaplets, changes in section thickness, and the existence of bosses, projections, and intersections, such as junctions of ribs and bosses. Because of the complexity of the interactions of these factors, no precise quantitative relationship can be stated between the properties of the iron in various locations of the same casting or between the properties of a casting and those of a test specimen cast from the same iron. When such a relationship is important and must be known for a specific application, it may be more closely ascertained by appropriate experimentation.

X1.3 When reliable information is unavailable on the relationship between properties in a casting and those in a separately cast test specimen, and where experimentation would be unfeasible, the size of the test casting should be so selected as to approximate the thickness of the main or controlling section of the casting.

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SPECIFICATION FOR STAINLESS STEEL BARS AND SHAPES FOR USE IN BOILERS AND OTHER PRESSURE VESSELS

SA-479/SA-479M

(Identical with ASTM Specification A479/A479M-21.)

Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

1. Scope

1.1 This specification covers hot- and cold-finished bars of stainless steel, including rounds, squares, and hexagons, and hot-rolled or extruded shapes such as angles, tees, and channels for use in boiler and pressure vessel construction.[2]

NOTE 1—There are standards covering high nickel, chromium, austenitic corrosion, and heat-resisting alloy materials. These standards are under the jurisdiction of ASTM Subcommittee B02.07 and may be found in *Annual Book of ASTM Standards*, Vol 02.04.

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

1.3 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

1.4 *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:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A484/A484M Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

A751 Test Methods and Practices for Chemical Analysis of Steel Products

E112 Test Methods for Determining Average Grain Size

E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 *SAE Document:*

SAE J 1086 Recommended Practice for Numbering Metals and Alloys

3. General Requirements

3.1 The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification A484/A484M.

3.1.1 Definitions,
3.1.2 General requirements for delivery,
3.1.3 Ordering information,
3.1.4 Process,
3.1.5 Special tests,
3.1.6 Heat treatment,
3.1.7 Dimensions and permissible variations,
3.1.8 Workmanship, finish, and appearance,
3.1.9 Number of tests/test methods,
3.1.10 Specimen preparation,
3.1.11 Retreatment,
3.1.12 Inspection,
3.1.13 Rejection and rehearing,
3.1.14 Material test report,
3.1.15 Certification, and
3.1.16 Packaging, marking, and loading.

4. Other Requirements

4.1 In addition to the requirements of this specification, all requirements of the current editions of Specification A484/

A484M shall apply. Failure to comply with the general requirements of Specification A484/A484M constitutes nonconformance with this specification.

5. Chemical Composition

5.1 Chemical composition shall be reported to the purchaser, or his representative, and shall conform to the requirements specified in Table 1.

5.2 When a product analysis is performed or requested by the purchaser, the tolerance limits as described in Specification A484/A484M apply unless Supplementary Requirement S3 is invoked.

5.3 Methods and practices relating to chemical analysis required by this specification shall be in accordance with Test Methods, Practices, and Terminology A751.

6. Grain Size for Austenitic Grades

6.1 All austenitic grades shall be tested for average grain size by Test Methods E112.

6.2 The H grades shall conform to an average grain size as follows:

6.2.1 ASTM No. 6 or coarser for Types 304H, 309H, 310H, and 316H, and

6.2.2 ASTM No. 7 or coarser for Types 321H, 347H, and 348H.

6.3 For S32615, the grain size as determined in accordance with Test Methods E112, comparison method, Plate 11, shall be No. 3 or finer.

6.4 For N08810 and N08811, the average grain size as determined in accordance with Test Methods E112 shall be No. 5 or coarser.

6.5 Supplementary Requirement S1 shall be invoked when non-H grade austenitic stainless steels are ordered for ASME Code applications for service above 1000 °F [540 °C].

7. Mechanical Properties Requirements

7.1 The material shall conform to the mechanical property requirements specified in Table 2 for the grade ordered. At least one room-temperature test shall be performed by the manufacturer on a sample from at least one bar or shape from each lot of material.

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

7.3 Martensitic material supplied in the annealed condition shall be capable of meeting the hardened and tempered mechanical properties when heat treated.

7.4 Hardness measurements, when required, shall be made at a location midway between the surface and the center of the cross section.

7.5 Martensitic grades shall be capable of meeting the hardness requirements after heat treating as specified in Table 3.

8. Testing for Intermetallic Compounds

8.1 When specified by the purchaser in the purchase order, the manufacturer shall test the austenitic or austenitic-ferritic (duplex) stainless steel material in its final condition in accordance with supplementary test requirements S6.

NOTE 2—Many, if not all, duplex stainless steels and some austenitic stainless steels will form intermetallic phases or compounds such as sigma, chi, and laves phases when exposed to temperatures below the specified annealing temperature or cooled slowly from a higher temperature during casting, welding, or annealing. These phases can have a negative effect on mechanical properties and corrosion resistance. These phases can typically be removed by correct annealing and cooling practices. The presence of these phases can be demonstrated by tests, typically involving metallography, impact toughness, or corrosion resistance, although the testing requirements may be different for different alloy grades. Such testing may or may not be routinely performed by the manufacturer.

9. Certification

9.1 The material manufacturer's certificate of compliance certifying that the material was manufactured and tested in accordance with this specification, together with a report of the results required by this specification and the purchase order, shall be furnished at the time of shipment. The certification shall be positively relatable to the lot of material represented.

10. Product Marking

10.1 In addition to the marking requirements of Specification A484/A484M, materials that have been heat treated or have been strain hardened shall be identified by placement of the following symbols after the grade designation:

10.1.1 *Austenitic Grades:*

10.1.1.1 All grades in the annealed condition—A,

10.1.1.2 Strain hardened Type 316, Level 1—S1,

10.1.1.3 Strain hardened Type 316, Level 2—S2,

10.1.1.4 Hot-rolled Type XM-19—H,

10.1.1.5 Strain hardened Type XM-19—S, and

10.1.1.6 Material meeting Supplementary Requirement S1—ELT (unnecessary for H grades).

10.1.1.7 In addition to all other marking requirements of this specification, when S1 is invoked, all grades in the direct quenched condition shall be marked "D."

10.1.2 *Austenitic-Ferritic Grades*—All grades in the annealed condition—A.

10.1.3 *Ferritic Grades*—All grades in the annealed condition—A.

10.1.4 *Martensitic Grades:*

10.1.4.1 All grades in the annealed condition—*A*.

10.1.4.2 Types 403 and 410—COND 1, COND 2, or COND 3 as appropriate for the tempering temperature employed.

10.1.4.3 Type 414, S41500, and Type XM-30 tempered materials—T.

11. Keywords

11.1 austenitic stainless steel; austenitic-ferritic duplex stainless steel; ferritic stainless steel; high temperature service applications; martensitic stainless steel; pressure vessel service; pressure-containing parts; stainless steel bars; stainless steel shapes

TABLE 1 Chemical Requirements

UNS Designation[A]	Type	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum	Other Elements[C]
						Austenitic Grades					
N08020	Alloy 20	0.07	2.00	0.045	0.035	1.00	19.0–21.0	32.0–38.0	. . .	2.00–3.00	Cu 3.0–4.0; Cb 8xC–1.00
N08367	. . .	0.030	2.00	0.040	0.030	1.00	20.0–22.0	23.5–25.5	0.18–0.25	6.0–7.0	Cu 0.75
N08800	800	0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60
N08810	800H	0.05–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al 0.15–0.60 Ti 0.15–0.60
N08811	. . .	0.06–0.10	1.50	0.045	0.015	1.00	19.0–23.0	30.0–35.0	. . .	. . .	Fe[K] 39.5 min. Cu 0.75 Al 0.25–0.60 Ti[L] 0.25–0.60
N08700	. . .	0.040	2.00	0.040	0.030	1.00	19.0–23.0	24.0–26.0	. . .	4.3–5.0	Cu 0.50; Cb 8xC–0.40
N08904	904L	0.020	2.00	0.045	0.035	1.00	19.0–23.0	23.0–28.0	0.10	4.0–5.0	Cu 1.0–2.0
N08925	. . .	0.020	1.00	0.045	0.030	0.50	19.0–21.0	24.0–26.0	0.10–0.20	6.0–7.0	Cu 0.80–1.50
N08926	. . .	0.020	2.00	0.030	0.010	0.50	19.0–21.0	24.0–26.0	0.15–0.25	6.0–7.0	Cu 0.50–1.50
S20161	. . .	0.15	4.0–6.0	0.045	0.030	3.0–4.0	15.0–18.0	4.0–6.0	0.08–0.20	. . .	. . .
S20910	XM-19	0.06	4.0–6.0	0.045	0.030	1.00	20.5–23.5	11.5–13.5	0.20–0.40	1.50–3.00	Cb 0.10–0.30; V 0.10–0.30
S21600	XM-17	0.08	7.5–9.0	0.045	0.030	1.00	17.5–20.5	5.0–7.0	0.25–0.50	2.00–3.00	. . .
S21603	XM-18	0.03	7.5–9.0	0.045	0.030	1.00	17.5–20.5	5.0–7.0	0.25–0.50	2.00–3.00	. . .
S21800	. . .	0.10	7.0–9.0	0.060	0.030	3.5–4.5	16.0–18.0	8.0–9.0	0.08–0.18	. . .	. . .
S21904	XM-11	0.04	8.0–10.0	0.045	0.030	1.00	19.0–21.5	5.5–7.5	0.15–0.40		
S24000	XM-29	0.08	11.5–14.5	0.060	0.030	1.00	17.0–19.0	2.3–3.7	0.20–0.40	. . .	. . .
S30200	302	0.15	2.00	0.045	0.030	1.00	17.0–19.0	8.0–10.0	0.10	. . .	. . .
S30400	304	0.08[D]	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.5	. . .	. . .	. . .
S30403	304L	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	. . .	. . .	. . .
S30409	304H	0.04–0.10	2.00	0.045	0.030	1.00	18.0–20.0	8.0–10.5	. . .	. . .	. . .
S30451	304N	0.08	2.00	0.045	0.030	1.00	18.0–20.0	8.0–12.0	0.10–0.16	. . .	. . .
S30453	304LN	0.030	2.00	0.045	0.030	1.00	18.0–20.0	8.0–11.0	0.10–0.16	. . .	. . .
S30600	. . .	0.018	2.00	0.020	0.020	3.7–4.3	17.0–18.5	14.0–15.5	. . .	0.20	Cu 0.50
S30815	. . .	0.05–0.10	0.80	0.040	0.030	1.40–2.00	20.0–22.0	10.0–12.0	0.14–0.20	. . .	Ce 0.03–0.08
S30908	309S	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30909	309H	0.04–0.10	2.00	0.045	0.030	1.00	22.0–24.0	12.0–15.0	. . .	. . .	. . .
S30940	309Cb	0.08	2.00	0.045	0.030	1.00	22.0–24.0	12.0–16.0	. . .	. . .	Cb 10×C- 1.10
S30880	ER308[E]	0.08	1.00–2.50	0.030	0.030	0.25–0.60	19.5–22.0	9.0–11.0	. . .	. . .	. . .
S31008	310S	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31009	310H	0.04–0.10	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	. . .
S31010[F]	. . .	0.030	5.50–6.50	0.030	0.0010	0.25–0.75	28.5–30.5	14.0–16.0	0.80–0.90	1.5–2.5	Al 0.05 B 0.005
S31040	310Cb	0.08	2.00	0.045	0.030	1.00	24.0–26.0	19.0–22.0	. . .	. . .	Cb 10×C-1.10
S31050	. . .	0.025	2.00	0.020	0.015	0.4	24.0–26.0	20.5–23.5	0.09–0.15	1.60–2.60	. . .
S31254	. . .	0.020	1.00	0.030	0.010	0.80	19.5–20.5	17.5–18.5	0.18–0.25	6.0–6.5	Cu 0.50–1.00
S31266	. . .	0.030	2.00–4.00	0.035	0.020	1.00	23.0–25.0	21.0–24.0	0.35–0.60	5.2–6.2	Cu 1.00–2.50 W 1.50–2.50
S31600	316	0.08[D]	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31603	316L	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31609	316H	0.04–0.10	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	. . .	2.00–3.00	. . .
S31635	316Ti	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10	2.00–3.00	Ti 5×(C+N)- 0.70
S31640	316Cb	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10	2.00–3.00	Cb 10×C- 1.10
S31651	316N	0.08	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10–0.16	2.00–3.00	. . .
S31653	316LN	0.030	2.00	0.045	0.030	1.00	16.0–18.0	10.0–14.0	0.10–0.16	2.00–3.00	. . .
S31700	317	0.08	2.00	0.045	0.030	1.00	18.0–20.0	11.0–15.0	. . .	3.0–4.0	. . .
S31725	. . .	0.030	2.00	0.045	0.030	1.00	18.0–20.0	13.5–17.5	0.20	4.0–5.0	. . .
S31726	. . .	0.030	2.00	0.045	0.030	1.00	17.0–20.0	14.5–17.5	0.10–0.20	4.0–5.0	. . .
S31727	. . .	0.030	1.00	0.030	0.030	1.00	17.5–19.0	14.5–16.5	0.15–0.21	3.8–4.5	Cu 2.8–4.0
S32050	. . .	0.030	1.50	0.035	0.020	1.00	22.0–24.0	20.0–23.0	0.21–0.32	6.0–6.8	Cu 0.40
S32053	. . .	0.030	1.00	0.030	0.010	1.00	22.0–24.0	24.0–26.0	0.17–0.22	5.0–6.0	. . .
S32100	321	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Ti 5×(C+N)- 0.70[G]
S32109	321H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Ti 4×(C+N)- 0.70[G]
S32615	. . .	0.07	2.00	0.045	0.030	4.8–6.0	16.5–19.5	19.0–22.0	. . .	0.30–1.50	Cu 1.50–2.50
S32654	. . .	0.020	2.0–4.0	0.030	0.005	0.50	24.0–25.0	21.0–23.0	0.45–0.55	7.0–8.0	Cu 0.30–0.60
S33228	. . .	0.04–0.08	1.00	0.020	0.015	0.30	26.0–28.0	31.0–33.0	. . .	. . .	Cb 0.60–1.00; Ce 0.05–0.10; Al 0.025
S34565	. . .	0.030	5.0–7.0	0.030	0.010	1.00	23.0–25.0	16.0–18.0	0.40–0.60	4.0–5.0	Cb 0.10
S34700	347	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 10×C–1.10
S34709	347H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	Cb 8×C–1.10

TABLE 1 *Continued*

UNS Designation[A]	Type	Composition, %[B]									
		Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Nickel	Nitrogen	Molybdenum	Other Elements[C]
S34752	. . .	0.005–0.02	2.00	0.035	0.010	0.60	17.0–18.0	10.0–13.0	0.06.-0.12	0.02–1.20	Cu 2.50–3.50 Nb 0.20–0.50 Nb/C ration, min 15 B00.001–0.005
S34800	348	0.08[D]	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	(Cb+Ta) 10×C–1.10; Ta 0.10; Co 0.20
S34809	348H	0.04–0.10	2.00	0.045	0.030	1.00	17.0–19.0	9.0–12.0	. . .	. . .	(Cb + Ta) 8×C–1.10; Co 0.20; Ta 0.10
S35315	. . .	0.04–0.08	2.00	0.040	0.030	1.20–2.00	24.0–26.0	34.0–36.0	0.12–0.18	. . .	Ce 0.03–0.08
S38815	. . .	0.030	2.00	0.040	0.020	5.50–6.50	13.0–15.0	15.0–17.0	. . .	0.75–1.50	Al 0.30; Cu 0.75–1.50
Austenitic-Ferritic Grades											
S31803	. . .	0.030	2.00	0.030	0.020	1.00	21.0–23.0	4.5–6.5	0.08–0.20	2.5–3.5	. . .
S32101	. . .	0.040	4.0–6.0	0.040	0.030	1.00	21.0–22.0	1.35–1.70	0.20–0.25	0.10–0.80	Cu 0.10–0.80
S32202	. . .	0.030	2.00	0.040	0.010	1.00	21.5–24.0	1.00–2.80	0.18–0.26	0.45	. . .
S32205	. . .	0.030	2.00	0.030	0.020	1.00	22.0–23.0	4.5–6.5	0.14–0.20	3.0–3.5	. . .
S32506	. . .	0.030	1.00	0.040	0.015	0.90	24.0–26.0	5.5–7.2	0.08–0.20	3.0–3.5	W 0.05–0.30
S32550	. . .	0.04	1.50	0.040	0.030	1.00	24.0–27.0	4.5–6.5	0.10–0.25	2.9–3.9	Cu 1.50–2.50
S32750[M]	. . .	0.030	1.20	0.035	0.020	0.80	24.0–26.0	6.0–8.0	0.24–0.32	3.0–5.0	Cu 0.50
S32760[H]	. . .	0.030	1.00	0.030	0.010	1.00	24.0–26.0	6.0–8.0	0.20–0.30	3.0–4.0	Cu 0.50–1.00; W 0.50–1.00
S32808	. . .	0.030	1.10	0.030	0.010	0.50	27.0–27.9	7.0–8.2	0.30–0.40	0.80–1.2	W 2.10–2.50
S32906	. . .	0.030	0.80–1.50	0.030	0.030	0.50	28.0–30.0	5.8–7.5	0.30–0.40	1.50–2.60	Cu 0.80
S32950	. . .	0.03	2.00	0.035	0.010	0.60	26.0–29.0	3.5–5.2	0.15–0.35	1.00–2.50	. . .
S39277	. . .	0.025	0.80	0.025	0.002	0.80	24.0–26.0	6.5–8.0	0.23–0.33	3.0–4.0	Cu 1.20–2.00 W 0.80–1.20
S82441	. . .	0.030	2.5–4.0	0.035	0.005	0.70	23.0–25.0	3.0–4.5	0.20–0.30	1.00–2.00	Cu 0.10–0.80
Ferritic Grades											
S40500	405	0.08	1.00	0.040	0.030	1.00	11.5–14.5	0.50	. . .	. . .	Al 0.10–0.30
S43000	430	0.12	1.00	0.040	0.030	1.00	16.0–18.0	. . .	. . .	. . .	. . .
S43035	439	0.07	1.00	0.040	0.030	1.00	17.0–19.0	0.50	0.04	. . .	Ti 0.20 + 4 × (C+N) –1.10; Al 0.15
S44400	444	0.025	1.00	0.040	0.030	1.00	17.5–19.5	1.00	0.035	1.75–2.50	(Ti+Cb) 0.20 + 4 × (C+N)-0.80
S44627	XM-27	0.010[I]	0.40	0.020	0.020	0.40	25.0–27.5	0.50	0.015[I]	0.75–1.50	Cu 0.20; Cb 0.05–0.20; (Ni+Cu) 0.50
S44700	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	0.15	0.020	3.5–4.2	(C+N) 0.025; Cu 0.15
S44800	. . .	0.010	0.30	0.025	0.020	0.20	28.0–30.0	2.00–2.50	0.020	3.5–4.2	(C+N) 0.025; Cu 0.15
Martensitic Grades											
S40300	403	0.15	1.00	0.040	0.030	0.50	11.5–13.0	. . .	. . .	. . .	. . .
S41000	410	0.15	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	. . .
S41040	XM-30	0.18	1.00	0.040	0.030	1.00	11.5–13.5	. . .	. . .	. . .	Cb 0.05–0.30
S41400	414	0.15	1.00	0.040	0.030	1.00	11.5–13.5	1.25–2.50	. . .	. . .	. . .
S41425	. . .	0.05	0.50–1.00	0.020	0.005	0.50	12.0–15.0	4.0–7.0	0.06–0.12	1.50–2.00	Cu 0.30
S41500	[J]	0.05	0.50–1.00	0.030	0.030	0.60	11.5–14.0	3.5–5.5	. . .	0.50–1.00	. . .
S43100	431	0.20	1.00	0.040	0.030	1.00	15.0–17.0	1.25–2.50	. . .	. . .	. . .

[A] New designations established in accordance with Practice E527 and SAE J 1086 published jointly by ASTM and SAE. See ASTM DS56C.[2]
[B] Maximum unless otherwise indicated.
[C] Except as required for specific alloy type, molybdenum, titanium, nickel, cobalt, tantalum, nitrogen, and copper need not be reported but shall not be present in other than residual amounts, the intent being to prohibit substitution of one alloy type for another due to absence of control of the above named elements in certain alloys.
[D] See Supplementary Requirement S1.
[E] American Welding Society designation.
[F] UNS S31010 is a highly alloyed austenitic stainless steel type 3b as defined in NACE MR0175/ISO 15156-3.
[G] Nitrogen content is to be reported for this grade.
[H] % Cr + 3.3 × % (Mo + ½ W) + 16 × % N ≥ 41.
[I] Product analysis tolerance over the maximum limit for carbon and nitrogen to be 0.002 %.
[J] Wrought version of CA6NM.
[K] Iron shall be determined arithmetically by difference of 100 minus the sum of specified elements.
[L] (Al+Ti) 0.85–1.20.
[M] % Cr + 3.3 × % Mo + 16 × % N ≥ 41.

TABLE 2 Mechanical Property Requirements

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %[B,C]	Brinell Hardness, max
		Austenitic Grades					
N08020	Alloy 20	stabilized-annealed	80 [550]	35 [240]	30[D]	50	
	Up to 2 in. [50.8 mm], incl	strain-hardened	90 [620]	60 [415]	15	40	
N08367	. . .	annealed	95 [655]	45 [310]	30	. . .	241
N08800	800	annealed	75 [515]	30 [205]	30	. . .	192
N08810	800H	annealed	65 [450]	25 [170]	30	. . .	192
N08811	. . .	annealed	65 [450]	25 [170]	30	. . .	192
N08700	. . .	annealed	80 [550]	35 [240]	30	50	. . .
N08904	904L	annealed	71 [490]	31 [220]	35	. . .	. . .
N08925	. . .	annealed	87 [600]	43 [295]	40	. . .	217
N08926	. . .	annealed	94 [650]	43 [295]	35	. . .	256
S20161	. . .	annealed	125 [860]	50 [345]	40	40	311
S20910	XM-19	annealed	100 [690]	55 [380]	35	55	293
	Up to 2 in. [50.8 mm], incl	hot-rolled	135 [930]	105 [725]	20	50	. . .
	Over 2 to 3 in. [50.8 to 76.2 mm], incl	hot-rolled	115 [795]	75 [515]	25	50	. . .
	Over 3 to 8 in. [76.2 to 203.2 mm], incl	hot-rolled	100 [690]	60 [415]	30	50	. . .
	Up to 1½ in. [38.1 mm], incl	strain-hardened	145 [1000]	125 [860]	12	40	. . .
	Over 1½ to 2¼ in. [38.1 to 57.2 mm], incl	strain-hardened	120 [825]	105 [725]	15	45	. . .
S21600, S21603	XM-17, XM-18	annealed	90 [620]	50 [345]	40	50	212
S21800	. . .	annealed	95 [655]	50 [345]	35	55	241
S21904	XM-11	annealed	90 [620]	50 [345]	45	60	. . .
S24000	XM-29	annealed	100 [690]	55 [380]	30	50	. . .
S30200, S30400, S30409, S30453, S30880, S30908, S30909, S30940, S31008, S31009, S31040, S31600, S31609, S31635, S31640, S31653, S31700, S32100, S32109, S34700, S34709, S34800, S34809	302, 304, 304H, 304LN, ER308,[E] 309S, 309H, 309Cb, 310S, 310H, 310Cb, 316, 316H, 316Ti, 316Cb, 316LN, 317, 321, 321H, 347, 347H, 348, 348H	annealed	75 [515][F]	30 [205]	30	40	. . .
S30403, S31603	304L, 316L	annealed	70 [485]	25 [170]	30	40	. . .
S31600, S31603, S30400, S30403	316, 316L, 304, 304L	strain-hardened level 1	85 [585]	65 [450][G]	30	40	. . .
	2 in. and under	strain-hardened level 2	95 [655]	75 [515]	25	40	. . .
	Over 2 to 2½ in. [50.8 to 63.5 mm], incl.	strain-hardened level 2	90 [620]	65 [450]	30	40	. . .
	Over 2½ to 3 in. [63.5 to 76.2 mm], incl	strain-hardened level 2	80 [550]	55 [380]	30	40	. . .
S30451, S31651	304N, 316N	annealed	80 [550]	35 [240]	30	40	. . .
S30600	. . .	annealed	78 [540]	35 [240]	40	. . .	. . .
S30815	. . .	annealed	87 [600]	45 [310]	40	50	. . .
S31010	. . .	annealed	110 [760]	75 [515]	40	50	330
S31050	0.25 in. [6 mm] and under	annealed	84 [580]	39 [270]	25	40	. . .
	Over 0.25 in. [6 mm]	annealed	78 [540]	37 [255]	25	40	
S31254	. . .	annealed	95 [655]	44 [305]	35	50	. . .
S31266	. . .	annealed	109 [750]	61 [420]	35	. . .	. . .
S31725	. . .	annealed	75 [515]	30 [205]	40	. . .	. . .
S31726	. . .	annealed	80 [550]	35 [240]	40	. . .	. . .
S31727	. . .	annealed	80 [550]	36 [245]	35	. . .	217
S32050	. . .	annealed	98 [675]	48 [330]	40	. . .	. . .
S32053	. . .	annealed	93 [640]	43 [295]	40	. . .	217
S32615	. . .	annealed	80 [550]	32 [220]	25	40	. . .
S32654	. . .	annealed	109 [750]	62 [430]	40	40	250
S33228	. . .	annealed	73 [500]	27 [185]	30	. . .	. . .
S34565	. . .	annealed	115 [795]	60 [415]	35	40	230
S34752	. . .	annealed	75 [515]	30 [205]	35	. . .	. . .
S35315	. . .	annealed	94 [650]	39 [270]	40	. . .	. . .
S38815	. . .	annealed	78 [540]	37 [255]	30	. . .	. . .
		Austenitic-Ferritic Grades					
S31803	. . .	annealed	90 [620]	65 [450]	25	. . .	290
S32101	. . .	annealed	94 [650]	65 [450]	30	. . .	290
S32202	. . .	annealed	94 [650]	65 [450]	30	. . .	290
S32205	. . .	annealed	95 [655]	65 [450]	25	. . .	290
S32506	. . .	annealed	90 [620]	65 [450]	18	. . .	302
S32550	. . .	annealed	110 [760]	80 [550]	15	. . .	297
S32750	2 in. and under	annealed	116 [800]	80 [550]	15	. . .	310
	over 2 in.	annealed	110 [760]	75 [515]	15	. . .	310

TABLE 2 *Continued*

UNS Designation	Type	Condition	Tensile Strength, min, ksi [MPa]	Yield Strength,[A] min, ksi [MPa]	Elongation in 2 in. [50 mm] or 4D, min, %	Reduction of Area, min, %[B,C]	Brinell Hardness, max
		Austenitic Grades					
S32760	. . .	annealed	109 [750]	80 [550]	25	. . .	310
S32808	. . .	annealed	101 [700]	72 [500]	15	. . .	310
S32906	. . .	annealed	109 [750]	80 [550]	25	. . .	310
S32950	. . .	annealed	100 [690]	70 [485]	15	. . .	297
S39277	. . .	annealed	118 [820]	85 [585]	25	50	293
S82441	Under 7/16 in. [11 mm]	annealed	107 [740]	78 [540]	25	. . .	290
S82441	7/16 in. and over [11 mm]	annealed	99 [680]	70 [480]	25	. . .	290
		Ferritic Grades					
S40500	405	annealed	60 [415]	25 [170]	20	45	207
S43000, S43035	430, 439	annealed	70 [485]	40 [275]	20[H]	45[H]	192
S44627	XM-27	annealed	65 [450]	40 [275]		45[H]	217
S44401	. . .	annealed	60 [415]	45 [310]	20[I]	45[I]	217
S44700	. . .	annealed	70 [485]	55 [380]	20	40	. . .
S44800	. . .	annealed	70 [485]	55 [380]	20	40	. . .
		Martensitic Grades					
S40300, S41000	403, 410	annealed	70 [485]	40 [275]	20[I]	45[I]	223
		1	70 [485]	40 [275]	20[I]	45[I]	223
		2	110 [760]	85 [585]	15	45	269
		3	130 [895]	100 [690]	12	35	331
S41400	414	tempered	115 [795]	90 [620]	15	45	321
S41425	. . .	tempered	120 [825]	95 [655]	15	45	321
S41500	. . .	normalized and tempered	115 [795]	90 [620]	15	45	293
S43100	431[J]	annealed	. . .	. . .	. . .	. . .	277
		tempered	115 [795]	90 [620]	15	45	321
S41040	XM-30	annealed	70 [485]	40 [275]	13[H]	45[H]	235
		quenched and tempered	125 [860]	100 [690]	13	45	302

[A] See Section 7.
[B] Reduction of area does not apply on flat bars 3/16 in. [4.80 mm] and under in thickness, as this determination is not generally made in this product size.
[C] The material shall be capable of meeting the required reduction of area where listed, but actual measurement and reporting of the reduction of area are not required unless specified in the purchase order.
[D] Cold-finished shapes require only 15 %, minimum, elongation.
[E] American Welding Society designation.
[F] Tensile strength 70 ksi [485 MPa] minimum permitted for extruded shapes.
[G] For bars greater than 2 in. [51 mm], a cross section, 60 ksi [415 MPa] minimum, shall be permitted.
[H] Elongation in 2 in. or 50 mm of 12 % minimum and reduction of area of 35 % minimum permitted for cold-finished bars.
[I] Elongation in 2 in. of 12 % minimum and reduction of area of 35 % minimum permitted for cold-drawn or cold-rolled bars.
[J] Annealed bars shall be capable of meeting the tempered condition requirements when heat treated.

TABLE 3 Response To Heat Treatment

Type[A]	Heat Treatment Temperature[B] °F (°C), min	Quenchant	Hardness HRC, min
403	1750 [955]	Air	35
410	1750 [955]	Air	35
414	1750 [955]	Oil	42

[A] Samples for testing shall be in the form of a section not exceeding 3/8 in. [9.50 mm] in thickness.
[B] Temperature tolerance is ±25 °F [15 °C].

SUPPLEMENTARY REQUIREMENTS

The following may be made requirements when the purchaser specifies them to be applicable.

S1. Materials for High-temperature Service

S1.1 Unless an H grade has been ordered, this supplementary requirement shall be specified for ASME Code applications for service above 1000 °F [540 °C].

S1.2 The user is permitted to use an austenitic stainless steel as the corresponding H grade when the material meets all requirements of the H grade including chemistry, annealing temperature, and grain size (see Section 6).

S1.3 The user is permitted to use an L grade austenitic stainless steel for service above 1000 °F [540 °C], subject to the applicable allowable stress table of the ASME Code, when the material meets all requirements of this specification and the grain size is ASTM No. 7 or coarser as determined in accordance with Test Methods E112. The grain size shall be reported on a Certified Test Report.

S2. Corrosion Tests

S2.1 Intergranular corrosion tests shall be performed by the manufacturer on sensitized specimens of Types 304L, 316L, 321, 347, and 348, and for the other austenitic grades, on specimens representative of the as-shipped condition. All austenitic stainless steels shall be capable of passing intergranular corrosion tests in the as-shipped condition. Tests shall be performed in accordance with Practice E of Practices A262.

S3. Product Analysis

S3.1 An analysis shall be made by the manufacturer on a sample from one bar in each lot as defined in Specification A484/A484M. The analysis shall meet the requirements of Table 1. In the event of failure, the lot represented shall be rejected except that, at the option of the manufacturer, each bar in the lot may be tested for acceptance. Product analysis tolerance provisions do not apply.

S4. Material for High Cycle Fatigue Service

S4.1 The mechanical properties of bars furnished in lengths under 20 ft [6 m] shall be determined by testing one end of each bar. Bars furnished in lengths of 20 ft [6 m] and over shall be tested at each end.

S5. Material for Optimum Resistance to Stress Corrosion Cracking

S5.1 This supplementary requirement is to be referenced when austenitic stainless steels are to be purchased with solution-annealing as the final operation and with no subsequent cold drawing permitted. Straightening is permitted as a final operation to meet the straightness requirements of Specification A484/A484M unless specifically prohibited by the purchaser.

S6. Demonstration of the Absence of Detrimental Intermetallic Phase in Austenitic and Austenitic-Ferritic (Duplex) Grades

S6.1 This supplementary requirement is to be referenced when the austenitic or duplex stainless steels are to be purchased with testing to demonstrate the absence of detrimental intermetallic phases that can have negative effects on mechanical properties or corrosion resistance of the material. The test method(s), reporting requirements, and acceptance criteria shall be agreed upon by the manufacturer and purchaser in the purchase agreement.

APPENDIX

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF SOLUTION ANNEALING

X1.1 It is generally recognized that austenitic stainless steels are solution annealed by heating to a temperature that dissolves (takes into solution) chromium carbides and quenching rapidly so that the chromium carbides will not precipitate in the grain boundaries, which could cause susceptibility to intergranular corrosion in a critically corrosive environment. Thus, solution annealing also can be accomplished for nonstabilized grades by taking advantage of hot rolling temperatures (which always exceed solution annealing temperature requirements), maintaining hot rolling finishing temperatures well above minimum solution annealing requirements, and immediately quenching integral with hot rolling. Stabilized grades (with columbium or titanium added) cannot be handled this way, since they would become destabilized due to columbium or titanium carbide solution, without subsequent reheating.

X1.2 For Boiler Code applications involving temperatures at which optimum resistance to creep is desired, the larger grain size of material solution annealed by reheating is generally desired. For that reason, a minimum grain size has been required of the H grades (created for optimum elevated temperature properties), and a mandatory grain size test and report has been added for the non-H grades so that the information is available for those desiring to reclassify a non-H grade to H grade.

X1.3 To satisfy the concerns of inadvertent assignment of fine grained material to elevated temperature applications, special marking has been added for material that meets the requirements of Supplementary Requirement S1.

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR FLAT-ROLLED STAINLESS AND HEAT-RESISTING STEEL PLATE, SHEET, AND STRIP

SA-480/SA-480M (25)

(Identical with ASTM Specification A480/A480M-23b.)

Designation: A480/A480M – 23b

Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip[1]

This standard is issued under the fixed designation A480/A480M; 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 U.S. Department of Defense.

1. Scope*

1.1 This specification[2] covers a group of general requirements that, unless otherwise specified in the purchase order or in an individual specification, shall apply to rolled steel plate, sheet, and strip, under each of the following specifications issued by ASTM: Specifications A240/A240M, A263, A264, A265, A666, A693, A793, and A895.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by waiving a test requirement or by making a test requirement less stringent.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The SI units are shown in brackets, except that when A480M is specified, Annex A3 shall apply for the dimensional tolerances and not the bracketed SI values in Annex A2. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.4 This specification and the applicable material specifications are expressed in both inch-pound and SI units. However, unless the order specifies the applicable "M" specification designation [SI units], the material shall be furnished in inch-pound units.

1.5 *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:*[3]

A240/A240M Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A263 Specification for Stainless Chromium Steel-Clad Plate

A264 Specification for Stainless Chromium-Nickel Steel-Clad Plate

A265 Specification for Nickel and Nickel-Base Alloy-Clad Steel Plate

A342/A342M Test Methods for Permeability of Weakly Magnetic Materials

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A666 Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar

A693 Specification for Precipitation-Hardening Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods and Practices for Chemical Analysis of Steel Products

A763 Practices for Detecting Susceptibility to Intergranular Attack in Ferritic Stainless Steels

A793 Specification for Rolled Floor Plate, Stainless Steel (Withdrawn 2023)[4]

[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 A01.17 on Flat-Rolled and Wrought Stainless Steel.

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[2] For ASME Boiler and Pressure Vessel Code applications see related Specification SA-480 in Section II of that Code.

[3] 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.

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

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

A895 Specification for Free-Machining Stainless Steel Plate, Sheet, and Strip
A923 Test Methods for Detecting Detrimental Intermetallic Phase in Duplex Austenitic/Ferritic Stainless Steels
A941 Terminology Relating to Steel, Stainless Steel, Related Alloys, and Ferroalloys
A1084 Test Method for Detecting Detrimental Phases in Lean Duplex Austenitic/Ferritic Stainless Steels
E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness
2.2 *AIAG Standard:*[5]
B-5 Primary Metals Identification Tag Application Standard
2.3 *ASME Document:*[6]
ASME BPVC.IX Boiler and Pressure Vessel Code, Section IX: Welding, Brazing, and Fusing Qualifications
2.4 *Federal Standard:*[7]
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms pertaining to this standard, not otherwise listed in 3.2, reference should be made to Terminology A941.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cold work, n*—the changing of mechanical properties by work hardening.

3.2.2 *plate, n*—material 3⁄16 in. [5.00 mm] and over in thickness and over 10 in. [250 mm] in width; finishes for *plate* are shown in Section 13.

3.2.3 *sheet, n*—material under 3⁄16 in. [5.00 mm] in thickness and 24 in. [600 mm] and over in width; finishes for *sheet* are shown in Section 11.

3.2.4 *strip, n*—cold-rolled material under 3⁄16 in. [5.00 mm] in thickness and under 24 in. [600 mm] in width; finishes are detailed in Section 12 for *strip*, and strip edges in Section 14 for cold-rolled strip.

4. Ordering Information

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

4.1.1 Quantity (weight and number of pieces),

4.1.2 Name of material (stainless steel),

4.1.3 Condition (hot-rolled, cold-rolled, annealed, heat-treated),

4.1.4 Finish (see Section 11 for sheet, Section 12 for strip, and Section 13 for plates); in the case of polished finishes, specify whether one or both sides are to be polished,

4.1.5 Temper (if the applicable material specification requires this detail),

4.1.6 Form (plate, sheet, or strip),

4.1.7 Dimensions (thickness, width, and length),

4.1.7.1 Thickness shall be ordered to decimal or fractional thickness. The use of the gauge number is discouraged as being an archaic term of limited usefulness not having general agreement on meaning. The gauge number shall not be a basis for rejection.

4.1.7.2 Thickness, width, and length, when applicable, should be ordered in the same units, for example, 0.060 in. by 48 in. by 120 in. [1.52 mm by 1219 mm by 3048 mm].

4.1.8 Edge, strip only (see Section 14 for cold-rolled strip),

4.1.9 Type or UNS designation, refer to the applicable material specification,

4.1.10 Specification designation and date of issue,

4.1.11 Additions to specification or special requirements,

4.1.12 Restrictions (if desired) on methods for determining yield strength (see appropriate footnote to mechanical properties table of the basic material specification),

4.1.13 Marking requirements (see Section 25),

4.1.14 Preparation for delivery (see Section 25), and

4.1.15 Magnetic permeability test (when required). Refer to Section 19.

5. Process

5.1 The steel shall be manufactured/produced by the following or as specified in the applicable material specification.

5.1.1 The steel shall be made by electric-arc, electric-induction, or other suitable processes.

5.1.2 If a specific type of melting is required by the purchaser, it shall be so specified on the purchase order.

6. Heat Analysis

6.1 Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology A751.

6.2 An analysis of each heat shall be made by the steel producer to determine the percentages of the elements specified in the applicable material specification. This analysis shall be made from a test sample taken during the pouring of the melt, or from the in-process product later in the manufacturing flow.

6.2.1 The heat analysis shall conform to the chemical requirements for each of the specified elements for the grade ordered, as listed in the applicable product specification.

6.2.2 All commercial metals contain small amounts of elements other than those which are specified. It is neither practical nor necessary to specify limits for unspecified elements that can be present. The producer is permitted to analyze for unspecified elements and is permitted to report such analyses. The presence of an unspecified element and the reporting of an analysis for that element shall not be a basis for rejection, unless the presence of that element causes the loss of a property typically expected for that metal, for the type and quality ordered.

6.2.3 The purchaser is permitted to require in the purchase order a maximum limit for an individual element not specified in the product specification. Such a requirement for an element

[5] Available from Automotive Industry Action Group (AIAG), 26200 Lahser Rd., Suite 200, Southfield, MI 48033-7156, http://www.aiag.org.

[6] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[7] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.

not listed in the product specification, when acknowledged in the order acceptance, shall be treated as a specified element, with determination of chemical analysis and reporting of that analysis.

6.2.4 The purchaser is permitted to make the requirements for any element more stringent; that is, require higher minimums for elements having minimum requirements or ranges with minimum requirements, or requiring lower maximums for elements having specified maximums, or ranges with maximums. The purchaser is not permitted to make chemical requirements less stringent.

6.2.5 Analysis limits shall be established for specific elements rather than groups of elements, including but not limited to *all others*, *rare earths*, and *balance*, unless all elements in such a group are similar in technical effect and are associated in typical methods of chemical analysis.

6.3 Except as permitted in 6.3.1, the steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade for which that element is a specified element having a required minimum content. For this requirement, a grade is defined as an alloy described individually and identified by its own UNS designation in a table of chemical requirements within this specification or any specification listed within the scope as being covered by the specification.

6.3.1 Unless otherwise specified to lower maximum limits on the purchase order, maximum allowances for unspecified elements will be established for Cu, Mo, Ti, and Nb for the specified grade if the amount of that element present in the material conforms with composition limits for that element in another grade. These allowances are Cu, 0.75 %; Mo, 0.75 %; Ti, 0.10 %; and Nb, 0.10 %.

6.3.2 If any allowance in 6.3.1 is used to demonstrate non-substitution, then the element involved shall be reported as if it were a specified element.

6.4 The producer is not permitted to certify that material is in compliance with an ASTM product specification when the purchase order has required that the material contain as a minimum or range an element that is neither a specified element nor an intentionally added unspecified element for the ordered grade in accordance with the definitions of Test Methods, Practices, and Terminology A751.

6.5 The names columbium (Cb) and niobium (Nb) both refer to element 41. The name Niobium is preferred, but either is acceptable for reporting composition.

7. Product Analysis

7.1 The purchaser is permitted to perform a product analysis (formerly check analysis) to verify the identity of the finished material representing each heat or lot. Such analysis shall be made by any of the commonly accepted methods that will positively identify the material.

7.2 The chemical composition determined in accordance with 7.1 shall conform to the limits of the material specification within the tolerances of Table A1.1, unless otherwise specified in the applicable material specification or the purchase order. The allowable variation of a particular element in a single sample for product analysis is permitted to be either above or below the specified range. However, percentages must exhibit the same tendencies in all samples; that is, the several determinations of any individual element in a heat shall not vary both above and below the specified range.

8. Material Test Report and Certification

8.1 A report of the results of all tests required by the product specification shall be supplied to the purchaser. This material test report shall reference the product specification designation and year date indicating that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the product specification and has been found to meet those requirements. The material test report shall report the melting process when the purchase order requires either a specific type of melting or requires that the melting process used is to be reported.

8.1.1 The report shall indicate the type of steel. If certifying that the material conforms to the requirements for more than one type of steel, the manufacturer may indicate each type of steel on the report, or may issue a separate report for each type of steel.

8.2 A signature is not required on the report. However, the document shall clearly identify the organization submitting the report. Notwithstanding the absence of a signature, the organization submitting the document is responsible for its content.

8.3 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 certifiers' facility. The content of the EDI transmitted document must meet the requirements of the invoked ASTM standard(s) and conform to any existing 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.

8.4 When finished material is supplied to a purchase order specifying the product specification, the organization supplying that material shall provide the purchaser with a copy of the original manufacturer's test report.

NOTE 1—Notwithstanding the absence of a signature, the organization submitting the report is responsible for the content of the report.

NOTE 2—The industry definition of EDI invoked herein is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

8.4.1 When the original manufacturer's test report was provided by EDI to the organization supplying the finished material to the purchaser, the organization supplying the finished material shall provide to the purchaser a printed form of the original test report or shall retransmit the test report by EDI to the purchaser. In either case, the test report shall be complete with the full identification of the original manufacturer and with all data provided on the test report of the original manufacturer.

9. Permitted Variations in Dimensions and Weight

9.1 Sheet, strip, and plate shall conform to the permitted variations in thickness, width, length and flatness, and other properties when specified, as listed in Annex A2 and Annex A3 for A480 and A480M respectively, for the ordered product form, or as agreed upon by seller and user and specified in the purchase order.

10. Workmanship

10.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. The steel shall have no imperfections of a nature or degree, for the type and quality ordered, that will adversely affect the stamping, forming, machining, or fabrication of finished parts.

10.2 *Sheet, Strip, and Plate*—For sheet and strip, restricted only to material ordered to have a No. 1 finish in accordance with 11.1.1 and 12.1.1 respectively, and for plate restricted to material ordered to hot-rolled and annealed or hot-rolled, annealed, and pickle finish in accordance with 13.1.1 and 13.1.2 respectively, it is permitted to grind to remove surface imperfections, provided such grinding does not reduce the thickness or width at any point beyond the permissible variations in dimensions. An iron free abrasive wheel shall be used for such grinding and shall be operated at a speed ample to ensure that defective areas are cleanly cut out.

11. Finish for Sheet

11.1 The types of finish available on sheet products are:

11.1.1 *No. 1 Finish*—Hot-rolled, annealed, and descaled.

11.1.2 *No. 2D Finish*—Cold-rolled, dull finish.

11.1.3 *No. 2B Finish*—Cold-rolled, bright finish.

11.1.3.1 *Bright Annealed Finish*—A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

11.1.4 *No. 3 Finish*—Intermediate polished finish, one or both sides.

11.1.5 *No. 4 Finish*—General purpose polished finish, one or both sides.

11.1.6 *No. 6 Finish*—Dull satin finish, Tampico brushed, one or both sides.

11.1.7 *No. 7 Finish*—High luster finish.

11.1.8 *No. 8 Finish*—Mirror finish.

11.1.9 *TR Finish*—Cold-worked to obtain specified properties.

NOTE 3—*Explanation of Sheet Finishes:*

No. 1—Commonly referred to as hot-rolled annealed and pickled or descaled. This is a dull, nonreflective finish.

No. 2D—A smooth, nonreflective cold-rolled annealed and pickled or descaled finish. This nondirectional finish is favorable for retention of lubricants in deep drawing applications.

No. 2B—A smooth, moderately reflective cold-rolled annealed and pickled or descaled finish typically produced by imparting a final light cold-rolled pass using polished rolls. This general-purpose finish is more readily polished than No. 1 or 2D finishes. Product with 2B finish is normally supplied in the annealed plus lightly cold-rolled condition unless a tensile-rolled product is specified.

Bright Annealed Finish—A smooth, bright, reflective finish typically produced by cold rolling followed by annealing in a protective atmosphere so as to prevent oxidation and scaling during annealing.

No. 3—A linearly textured finish that may be produced by either mechanical polishing or rolling. Average surface roughness (R_a) may generally be up to 40 µin. A skilled operator can generally blend this finish. Surface roughness measurements differ with different instruments, laboratories, and operators. There may also be overlap in measurements of surface roughness for both Nos. 3 and 4 finishes.

No. 4—A linearly textured finish that may be produced by either mechanical polishing or rolling. Average surface roughness (R_a) may generally be up to 25 µin. A skilled operator can generally blend this finish. Surface roughness measurements differ with different instruments, laboratories, and operators. There may also be overlap in measurements of surface roughness for both Nos. 3 and 4 finishes.

No. 6—This finish has a soft, satin appearance typically produced by tampico brushing a No. 4 finish.

No. 7—Has a high degree of reflectivity. It is produced by buffing a finely ground surface, but the grit lines are not removed. It is chiefly used for architectural or ornamental purposes.

No. 8—This is a highly reflective, smooth finish typically produced by polishing with successively finer grit abrasives, then buffing. Typically, very faint buff of polish lines may still be visible on the final product. Blending after part assembly may be done with buffing.

TR Finish—The finish resulting from the cold-rolling of an annealed and descaled or bright annealed product to obtain mechanical properties higher than that of the annealed condition. Appearance will vary depending upon the starting finish, amount of cold work, and the alloy.

Architectural Finishes—Sometimes described as a No. 5 finish, these are a separate category and may be negotiated between buyer and seller, as there are many techniques and finish variations available throughout the world.

11.1.10 Architectural finish, No. 5, or other proprietary names are special finishes.

11.1.11 Note 3 is not meant to be restrictive or to be used as a basis for rejection but is intended to give general guidelines. Various production methods may be used to obtain these finishes.

11.1.12 Sheets can be produced with one or two sides polished. When polished on one side only, it is permitted to rough grind the other side in order to obtain the necessary flatness.

12. Finish for Strip

12.1 The various types of finish procurable on cold-rolled strip products are:

12.1.1 *No. 1 Finish*—Cold-rolled to specified thickness, annealed, and descaled.

12.1.2 *No. 2 Finish*—Same as No. 1 finish, followed by a final light cold-roll pass, generally on highly polished rolls.

12.1.3 *Bright Annealed Finish*—A bright cold-rolled finish retained by final annealing in a controlled atmosphere furnace.

12.1.4 *TR Finish*—Cold-worked to obtain specified properties.

12.1.5 *Polished Finish*—Stainless steel strip is also available in polished finishes such as Nos. 3 and 4, which are explained in Note 3.

NOTE 4—*Explanation of Strip Finishes:*

No. 1—Appearance of this finish varies from dull gray matte finish to a fairly reflective surface, depending largely upon composition. This finish is used for severely drawn or formed parts, as well as for applications where the brighter No. 2 finish is not required, such as parts for heat resistance.

No. 2—This finish has a smoother and more reflective surface, the appearance of which varies with composition. This is a general purpose finish, widely used for household and automotive trim, tableware, utensils, trays, and so forth.

Bright Annealed Finish—See Note 3.

TR Finish—See Note 3.

13. Finish for Plates

13.1 The types of finish available on plates are:

13.1.1 *Hot-rolled or Cold-rolled, and Annealed or Heat Treated*—Scale not removed, an intermediate finish. Use of plates in this condition is generally confined to heat-resisting applications. Scale impairs corrosion resistance.

13.1.2 *Hot-rolled or Cold-rolled, and Annealed or Heat Treated, and Blast Cleaned or Pickled*—Condition and finish commonly preferred for corrosion-resisting and most heat-resisting applications, essentially a No. 1 finish.

13.1.3 *Hot-rolled or Cold-rolled, and Annealed or Heat Treated, and Surface Cleaned and Polished*—Polish finish is generally No. 4 finish.

13.1.4 *Hot-rolled or Cold-rolled, and Annealed or Heat Treated, and Descaled, and Temper Passed*—Smoother finish for specialized applications.

13.1.5 *Hot-rolled or Cold-rolled, and Annealed or Heat Treated, and Descaled; and Cold-rolled, and Annealed or Heat Treated, and Descaled, and Optionally Temper Passed*—Smooth finish with greater freedom from surface imperfections than in 13.1.4.

14. Edges for Cold-rolled Strip

14.1 The types of edges available on strip products are:

14.1.1 *No. 1 Edge*—A rolled edge, either round or square as specified.

14.1.2 *No. 3 Edge*—An edge produced by slitting.

14.1.3 *No. 5 Edge*—An approximately square edge produced by rolling or filing after slitting.

15. Heat Treatment

15.1 The heat treatments shown in this section are to be followed unless otherwise specified in the applicable material specification. Heat treatment thermal cycles shall be separate from other thermal processing cycles; for example, in-process thermal cycles are not permitted as a substitute for the separate annealing cycle.

15.2 *Austenitic Types:*

15.2.1 The austenitic types shall be annealed in accordance with Table A1.2.

15.2.2 The material shall be annealed to meet the mechanical property requirements of the applicable material specification unless otherwise stated in the material specification.

15.2.3 Except as indicated in Table A1.2, Series 300, XM-15, N08800, S30415, S30815, S31725, S31726, and S32615 austenitic chromium-nickel steels, when specified on the purchase order, shall be capable of meeting the test for resistance to intergranular corrosion specified in 18.2.

15.2.4 For grades stabilized with titanium or niobium, refer to Note 5.

Note 5—Solution-annealing temperatures above 1950 °F [1066 °C] can impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions in the stabilized grades, types 309Cb, 309HCb, 310Cb, 310HCb, 316Ti, 316Cb, 321, 321H, 347, 347H, 348, 348H, S21640, S31740, S33425, S35140, S35135, and S35125. When intergranular corrosion is of concern, the purchaser should specify the corrosion test of 18.2 (to be conducted on sensitized specimens). The manufacturer is permitted, if necessary, use a lower temperature resolution anneal or a stabilization anneal after a high temperature solution anneal in order to meet corrosion test requirements. Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800 °F [982 °C], as such treatment is not equally effective for all media.

15.2.5 For the stabilized H types, it is noted that the heat treatment requirements shown in Table A1.2 differ as a function of whether the material was cold worked or hot finished.

15.2.6 The chromium-manganese-nickel types (201, 202, S20103, S20400, S20153, S21800, S21640, XM-11, XM-17, XM-18, XM-19, XM-29, and XM-31) shall be solution annealed to meet the mechanical property requirements of the applicable material specification and to exhibit adequate resistance to intergranular corrosion (see 18.2). For S20161, the heat treatment is specified in Table A1.2. For S21640, see Note 5.

15.2.6.1 Note that some of these types contain high carbon content that can adversely affect resistance to intergranular corrosion.

15.3 *Duplex Types*—The duplex types shall be solution annealed in accordance with Table A1.2.

15.4 *Martensitic and Ferritic Types:*

15.4.1 The chromium steels (S32803, 400 Series, S40945, S41045, S41050, S41500, S43932, S44400, S44537, S44635, S44660, S44700, S44735, S44800, XM-27, and XM-33) shall be heat treated in such a manner as to satisfy all the requirements for mechanical and bending properties specified in the applicable material specification and (except for 400 Series, S41050, and S41500) to provide for adequate resistance to intergranular attack.

15.4.2 For S41500, heat to 1750 °F [955 °C] minimum, air cool to 200 °F [93 °C] or lower prior to any optional intermediate temper and prior to final temper. The final temper shall be between 1050 °F and 1150 °F [566 °C and 621 °C].

16. Number of Tests

16.1 Unless otherwise specified by the applicable material specification or by agreement between the seller and the purchaser to perform a greater number of tests, the following number of tests are to be performed.

16.1.1 In the case of plate, sheet, and strip produced in coil form, two or more hardness tests (one from each end of the coil); one bend test, when required; one permeability test, when required; and one or more tension tests shall be made on specimens taken from each coil. If the hardness difference between the two ends of the coil exceeds 5 HRB, or equivalent, or if the material is temper rolled, tensile properties must be determined on both coil ends.

16.1.2 In the case of plate, sheet, or strip produced in cut lengths, one tension test; two tension tests if the material is temper rolled (one tension test for single piece lots); one bend test when required, and one or more hardness tests shall be made on each 100 or less pieces of the same heat and nominal thickness rolled separately or continuously and heat treated within the same operating period, either as a lot or continuously.

Note 6—The term continuously, as applied to heat treatment, is meant to describe a heat-treating operation in which one cut length follows

another through the furnace. Interspersement of different melts is permissible if they are of approximately the same nominal thickness and are heat treated in the same operating period and under the same conditions (time and temperature).

16.1.3 One intergranular corrosion test, when required, shall be selected from each heat and thickness subjected to the same heat treatment practice. It is permitted to obtain such specimens from specimens selected for mechanical testing.

17. Test Specimens

17.1 *Tension Test:*

17.1.1 Tension test specimens shall be taken from finished material and shall be selected in either or both longitudinal and transverse direction. The tension test specimen shall conform to the appropriate sections of Test Methods and Definitions A370, unless otherwise specified in the applicable material specification or agreed upon by the seller and the purchaser.

17.1.2 The testing speed between the yield strength and the fracture of the specimen, shall be conducted at a constant strain rate between ⅛ in. and ½ in. [3.18 mm and 12.70 mm] inclusive, per in. [25.40 mm] of gauge length per minute, or at a crosshead speed that will give a strain rate within this range. For the purposes of this specification, the rate of strain shall be determined by a strain-rate pacer, indicator, or controller, or by dividing the unit elongation by the elapsed time from yield strength to fracture.

17.2 *Hardness Test*—It is permitted to perform hardness tests on the grip ends of the tension specimens before they are subjected to the tension test.

17.2.1 Unless otherwise specified in the purchase order, the manufacturer may use an alternate hardness test procedure when material size or form dictates. Hardness conversion shall be done using the applicable tables in Test Methods and Definitions A370. When the material is too thin to allow hardness testing using any of the Rockwell superficial hardness tests, the hardness requirement is waived.

17.3 *Bend Test:*

17.3.1 Bend test specimens (when required) shall be taken from finished material and shall be selected in the transverse direction or as indicated in the applicable material specification or as agreed upon by the seller and the purchaser. In the case of transverse bend test specimens, the axis of bend shall be parallel to the direction of rolling.

17.3.2 Bend test specimens from sheet and strip product shall be the full thickness of the material and approximately 1 in. [25.4 mm] in width. It is permitted to round the edges of the test specimen to a radius equal to one half the specimen thickness.

17.3.3 The width of strip for which bend tests can be made is subject to practical limitations on the length of the bend test specimen. For narrow strip, the following widths can be tested:

Strip Thickness, in. [mm]	Minimum Strip Width and Minimum Specimen Length for Bend Tests, in. [mm]
0.100 [2.5] and under	½ [12.7]
Over 0.100 to 0.140 [2.5 to 3.5], excl	1 [25.4]
0.140 [3.5] and over	1½ [38.1]

Bend test specimens shall be of any suitable length over the specified minimum length.

17.3.4 Bend test specimens taken from plates shall be in full thickness of the material up to and including ½ in. [12.7 mm] in thickness, of suitable length, and between 1 in. and 2 in. [25.4 mm and 50.8 mm] in width. It is permitted to remove the sheared edges to a depth of at least ⅛ in. [3.2 mm] and it is permitted to smooth the sides with a file. It is permitted to break the corners of the cross section of the specimen with a file, but no appreciable rounding of the corners is permitted.

17.3.5 In the case of plates over ½ in. [12.7 mm] in thickness, it is permitted to use bend test specimens, machined to 1 in. [25.4 mm] nominal width by ½ in. [12.7 mm] nominal thickness and at least 6 in. [152.4 mm] in length. One surface, to be the outside surface in bending, shall be the original surface of the plate; however, surface preparation by light grinding is permitted. It is permitted to round the edges to a 1/16 in. [1.6 mm] radius. When agreed by the seller and the purchaser, it is permitted to modify the cross section to ½ in. [12.7 mm] nominal square.

17.3.6 In the case of plates over 1 in. [25.4 mm] in thickness, bend tests must be agreed upon between the seller and the purchaser.

17.3.7 The bend test specimen shall withstand cold bending through the angle specified in the applicable material specification without cracking on the outside of the bent portion.

17.4 The bend shall be made over a diameter equal to the number of thicknesses of flat stock shown in the applicable material specification or over a single piece of flat stock equal to the number of thicknesses shown in the applicable material specification; or as follows:

17.4.1 Material up to and including ⅜ in. [9.5 mm] in thickness shall be bent over a piece (or pieces) of flat stock that has the same nominal thickness of the material being tested (1T), allowing the test material to form its natural curvature.

17.4.2 Material over ⅜ in. [9.5 mm] and up to and including 1 in. [25.4 mm] in thickness shall be bent over a piece (or pieces) of flat stock equalling two times the thickness of the material being tested (2T), allowing the test material to form its natural curvature.

18. Special Tests

18.1 If other tests are required, the methods and acceptance criteria shall be agreed upon between the seller and the purchaser and specified on the purchase order.

18.2 *Resistance to Intergranular Corrosion:*

18.2.1 The intergranular corrosion test, Practice E of Practices A262, is not required unless it is specified on the purchase order. All austenitic chromium-nickel types except the H types are expected to be capable of passing this test. However, it is not necessary to actually run the test unless it is specified on the purchase order. Note that Practices A262 requires the test to be performed on sensitized specimens in the low-carbon and stabilized types and on specimens representative of the as-shipped condition for other types. In the case of low-carbon types containing 3 % or more molybdenum in their specified composition, the applicability of the sensitizing treatment prior to testing shall be a matter for negotiation between the seller and the purchaser. When specified, all flat rolled products of the chromium-nickel series (300 series) in thickness up to and

including 2 in. [50.8 mm] nominal size shall be capable of passing the intergranular corrosion test in the as shipped condition. In the case of heavier plates of types other than 304L, 304LN, 309Cb, 310Cb, 316Cb, 316L, 316LN, 316Ti, 317L, 321, 347, 348, S31725, S31726, and S31740, the applicability of this test shall be a matter for negotiation between the seller and the purchaser.

18.2.2 The H types are not normally subject to intergranular corrosion tests. However, it is permitted to specify Practice E of Practices A262 for Type 321H when intergranular corrosion is of concern. In this case, the purchaser shall inform the seller and agree upon the requirements and these requirements shall be so stated on the purchase order.

18.2.3 Austenitic chromium-manganese-nickel types (201, 202, XM-17, XM-18, XM-19, XM-29, XM-31, S20400, S21640, and S21800) are to be heat treated for intergranular corrosion resistance. When intergranular corrosion tests are required, they shall be as agreed upon between the seller and the purchaser.

18.2.4 N08800 shall be heat treated for intergranular corrosion resistance. When intergranular corrosion tests are required, they shall be as agreed upon between the seller and purchaser.

18.2.5 Corrosion tests are not normally required for the 400 series types. Lower-carbon corrosion-resistant types (S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33) are heat treated for resistance to corrosion. For S44400, S44635, S44660, S44700, S44800, S44735, XM-27, and XM-33, intergranular corrosion testing of Practices A763, Practice X, Y, or Z shall be specified as agreed upon between the seller and the purchaser.

18.3 *Detrimental Intermetallic Phases in Duplex Stainless Steels*—The tests for detrimental intermetallic phases in wrought duplex stainless steels, Methods A, B, or C of Test Methods A923 or A1084, are not required unless it is specified on the purchase order. All duplex (austenitic-ferritic) types that are listed in Test Methods A923 or A1084 are expected to be capable of passing these tests. However, it is not necessary to actually run the tests unless specified on the purchase order. The applicability of these tests to duplex stainless steels not listed in Test Methods A923 or A1084 shall be a matter for negotiation between the seller and the purchaser.

19. Test Methods

19.1 The properties enumerated in applicable specifications shall be determined in accordance with the following ASTM standards.

19.1.1 *Tension Tests*—Test Methods and Definitions A370.

19.1.2 *Brinell Tests*—Test Methods and Definitions A370.

19.1.3 *Rockwell Hardness*—Test Methods and Definitions A370.

19.1.4 *Hardness Equivalents*—Tables E140.

19.1.5 *Intergranular Corrosion (When Specified)*—Practices A262, Practices A763.

19.1.6 *Permeability Test (When Required)*—Test Methods A342/A342M.

19.1.7 *Charpy Impact Testing (When Required)*—Test Methods and Definitions A370.

19.1.8 *Intermetallic Phases (When Specified)*—Test Methods A923 or A1084.

20. Retests and Retreatment

20.1 Retests are permitted in accordance with the provisions of Test Methods and Definitions A370.

20.2 If any test specimen shows defective machining or develops flaws, it is permitted to discard the flawed specimen and substitute another specimen.

20.2.1 If the percentage of elongation of any tension specimen is less than that specified and any part of the fracture is more than ¾ in. [19.1 mm] from the center of the gauge length of the 2 in. [50.8 mm] specimen or is outside the middle half of the gauge length of an 8 in. [203.2 mm] specimen, as indicated by scribe marks placed on the specimen before testing, a retest shall be allowed.

20.3 If a bend test specimen fails, due to conditions of bending more severe than required by the specification, a retest shall be permitted, either on a duplicate specimen or on a remaining portion of the failed specimen.

20.4 If the results of any test lot are not in conformance with the requirements of the applicable material specification, the producer is permitted the option of retreating such lots. The material shall be accepted if the results of retests on retreated material are within the specified requirements.

20.5 If any specimens selected to represent any heat fail to meet any of the test requirements as specified in the applicable material specification, it is permitted to reheat treat the material represented and resubmit it for testing.

20.6 If the product analysis fails to conform to the specified limits, analysis shall be made on a new sample. The results of this retest shall be within the specified requirements.

21. Repair of Plate by Welding

21.1 Repair of surface defects of plate, by welding, is permitted unless prohibited by other specifications or purchase order requirements.

21.2 Defect depth shall not exceed ⅓ of the nominal thickness, and the total area shall not exceed 1 % of the plate surface area, unless prior approval from the purchaser is obtained.

21.3 Unacceptable imperfections shall be suitably prepared for welding by grinding or machining. Open clean defects, such as pits or impressions, will not necessarily require preparation.

21.4 The welding procedure and the welders or welding operators shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

21.5 The welding consumables shall be suitable with the plate.

21.6 After repair welding, the welded area shall be ground smooth and blended uniformly to the surrounding surface.

22. Inspection

22.1 Inspection of the material by the purchaser's representative at the producing plant shall be made as agreed upon between the purchaser and the seller as part of the purchase order.

22.2 Unless otherwise specified in the contract or purchase order, (*1*) the seller is responsible for the performance of all the inspection and test requirements in this specification, (*2*) the seller is permitted to use own or other suitable facilities for the performance of the inspection and testing, and (*3*) the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

23. Rejection

23.1 Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the seller within 60 working days from the receipt of the material by the purchaser.

23.2 Material that shows injurious imperfections as described in Section 10 subsequent to its acceptance at the purchaser's works will be rejected and the seller shall be notified.

24. Rehearing

24.1 Samples tested in accordance with this specification that represent rejected material shall be retained for three weeks from the date of the notification to the seller of the rejection. In case of dissatisfaction with the results of the test, the seller is permitted to make claim for a rehearing within that time.

25. Packaging, Marking, and Loading

25.1 *For Commercial Procurement:*

25.1.1 *Marking*—Unless otherwise specified in the applicable material specification or the purchase order, marking shall be conducted as follows:

25.1.1.1 Sheet, strip, and plate shall be marked on one face, in the location indicated below with the specification designation number, type of steel (type or UNS designation), material identification number, and the name or mark of the manufacturer. For sheet, strip, and plate whose length and width dimensions are both less than 24 in., each piece shall be marked with the type of steel and material identification number. The specification and designation number, and name or mark of the manufacturer shall be marked on the piece(s) or attached to the item or bundle. The characters shall be of such size as to be clearly legible. The marking shall be sufficiently stable to withstand normal handling. Unless otherwise specified by the purchaser, the marking, at the producers option, is permitted to be done with (*1*) marking fluid (if a specific maximum impurity limit of designated elements in the marking fluid is required by the purchaser, it shall be so stated on the purchase order), (*2*) low-stress blunt-nosed continuous or low-stress blunt-nosed-interrupted-dot die stamp, (*3*) a vibratory tool with a minimum tip radius of 0.005 in. [0.1 mm], or (*4*) electrochemical etching.

25.1.1.2 Flat sheet, strip in cut lengths, and plate shall be marked in two places near the ends or shall be continuously line marked along one edge. For flat sheet, strip in cut lengths, and plate whose length and width dimensions are both less than 48 in., it is permitted to mark such pieces in only one place.

25.1.1.3 Sheet, strip, and plate in coil form shall be marked near the outside end of the coil. The inside of the coil shall also be marked or shall have a tag or label attached and marked with the information of 25.1.1.1.

25.1.1.4 Material less than ¼ in. [6.4 mm] in thickness shall not be marked with die stamps.

25.1.1.5 The manufacturer's test identification number shall be legibly stamped on each test specimen, if to be shipped to the customer.

25.1.1.6 Material that conforms completely with the requirements of two types of steel within the ordering specification is permitted to be marked as both types of steel provided that the manufacturer is certifying the material as meeting the requirements of each of the types of steel. Such marking, if used, shall be part of the same marking as used for a single type of steel, or shall be a separate but similar marking immediately adjacent to the marking used for a single type of steel.

25.1.1.7 The AIAG primary metals identification tag (AIAG B-5) is permitted to be used as an auxiliary method of identification in cases where a bar-coded identification tag is desired. Use of this method shall be by agreement between purchaser and supplier.

25.1.2 *Packaging and Loading*—Unless otherwise specified in the applicable material specification or the purchase order, packaging, and loading shall be in accordance with the procedures recommended by Practices A700.

25.2 *For U.S. Government Procurement:*

25.2.1 When specified in the contract or order, and for direct procurement by or direct shipment to the government, marking for shipment shall be in accordance with Fed. Std. No. 123.

26. Keywords

26.1 austenitic stainless steel; duplex stainless steel; ferritic stainless steel; martensitic stainless steel; stainless steel; stainless steel plate; stainless steel sheet; stainless steel strip

ANNEXES

(Mandatory Information)

A1. PRODUCT ANALYSIS TOLERANCES AND HEAT TREATMENT REQUIREMENTS

A1.1 Listed in Annex A1 are tables showing the permitted variations of composition for product analysis relative to specified chemical requirements (Table A1.1) and the heat treatment requirements for types of stainless steel covered by product specifications that reference Specification A480/A480M (Table A1.2). When the product requirement includes a ratio requirement that is the quotient of two, or more, elements, the minimum required ratio determined from product analysis shall be at least 0.90× the minimum in the product specification.

TABLE A1.1 Chemical Requirements (Product Analysis Tolerances)[A]

Elements	Limit or Maximum of Specified Range, %	Tolerance Over the Maximum Limit or Under the Minimum Limit
Carbon	to 0.010, incl	0.002
	over 0.010 to 0.030, incl	0.005
	over 0.030 to 0.20, incl	0.01
	over 0.20 to 0.60, incl	0.02
	over 0.60 to 1.20, incl	0.03
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00, incl	0.05
	over 6.00 to 10.00, incl	0.06
	over 10.00 to 15.00, incl	0.10
	over 15.00 to 20.00, incl	0.15
Phosphorus	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
Sulfur	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
	over 0.20 to 0.50, incl	0.020
Silicon	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 7.00, incl	0.15
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40.00	0.25
	over 40.00	0.30
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 8.00, incl	0.10
Titanium	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.07
Cobalt	over 0.05 to 0.50, incl	0.01[B]
	over 0.50 to 2.00, incl	0.02
	over 2.00 to 5.00, incl	0.05
Niobium[C]	to 1.50, incl	0.05
Tantalum	to 0.10, incl	0.02
Copper	to 0.50, incl	0.03
	over 0.50 to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 5.00, incl	0.15
	over 5.00 to 10.00, incl	0.20
Aluminum	to 0.15, incl	−0.005, +0.01
	over 0.15 to 0.50, incl	0.05
	over 0.50 to 2.00, incl	0.10
Nitrogen	to 0.02, incl	0.005
	over 0.02 to 0.19, incl	0.01
	over 0.19 to 0.25, incl	0.02
	over 0.25 to 0.35, incl	0.03
	over 0.35 to 0.45, incl	0.04
	over 0.45 to 0.55, incl	0.05
Tungsten	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
Vanadium	to 0.50, incl	0.03
	over 0.50 to 1.50, incl	0.05
Selenium	all	0.03

[A] This table does not apply to heat analysis.
[B] Product analysis limits for cobalt under 0.05 % have not been established, and the manufacturer should be consulted for those limits.
[C] Columbium (Cb) and niobium (Nb) are considered interchangeable names for element 41 in the periodic table and both names are acceptable for use.

TABLE A1.2 Heat Treatment Requirements

Designation/Type	Temperature[A]	Cooling/Testing Requirements
Austenitic (Chromium-Nickel) (Chromium-Nickel-Manganese)		
All Cr-Ni steels except as listed below	1900 °F [1040 °C]	[B]
302, 308, 309, 309Cb, 310, 310Cb, S21640, S30215, S30452, S30615, S31740, S32615, S33228, S33425, S35140, S38100, S38815	1900 °F [1040 °C]	[C]
304H, 309H, 310H, 316H 309HCb, 310HCb, 321H, 347H, 348H	1900 °F [1040 °C]	[C]
Cold Worked	2000 °F [1095 °C]	[C]
Hot Finished	1925 °F [1050 °C]	[C]
N08020	1700 to 1850 °F [925 to 1010 °C]	[C]
N08367	2025 °F [1105 °C]	[C]
N08700, N08904, S35115	2000 °F [1095 °C]	[C]
N08810, S31277	2050 °F [1120 °C]	[C]
N08811, N08925, S31025, S31254, S31266, S32050, S32654	2100 °F [1150 °C]	[C]
N08926, S35315	2010 °F [1100 °C]	[C]
S20161	1900 to 2000 °F [1040 to 1095 °C]	[C]
S20431, S20432, S20433, S30530	1900 to 2010 °F [1040 to 1100 °C]	[C]
S30600, S30601	2010 to 2140 °F [1100 to 1170 °C]	[C]
S30616	1920 to 2100 °F [1050 to 1150 °C]	[C]
S31060	1975 to 2160 °F [1080 to 1180 °C]	[C]
S31727, S32053	1975 to 2155 °F [1080 to 1180 °C]	[C]
S33228	2050 to 2160 °F [1120 to 1180 °C]	[C]
S33426	1925 to 2100 °F [1050 to 1150 °C]	[C]
S33550	2065 to 2155 °F [1130 to 1180 °C]	[C]
S34565	2050 to 2140 °F [1120 to 1170 °C]	[C]
S34752	1940 to 2140 °F [1060 to 1170 °C]	[C]
Duplex (Austenitic-Ferritic)		
S31200, S31803, S32001, S32550	1900 °F [1040 °C]	[C]
S31260	1870 to 2010 °F [1020 to 1100 °C]	[C]
S32003, S82011	1850 °F [1010 °C]	[C]
S32101	1870 °F [1020 °C]	[C]
S32202	1800 to 1975 °F [980 to 1080 °C]	[C]
S32205	1900 °F [1040 °C]	[D]
S32304	1800 °F [980 °C]	[C]
S32506	1870 to 2050 °F [1020 to 1120 °C]	[C]
S32520	1975 to 2050 °F [1080 to 1120 °C]	[C]
S32750[E]	1880 to 2060 °F [1025 to 1125 °C]	[C]
S32760	2010 °F [1100 °C]	[C]
S32808, S39274	1925 to 2100 °F [1050 to 1150 °C]	[C]
S32900	1750 ± 25 °F [955 ± 15 °C]	[C]
S32906	1900 to 2100 °F [1040 to 1150 °C]	[C]
S32950	1850 ± 25 °F [1010 ± 15 °C]	[C]
S44537	1922 °F [1050 °C]	[C]
S81921	1760 to 2010 °F [960 to 1100 °C]	[C]
S82012, S82031, S82441	1830 °F [1000 °C]	[C]
S82013, S82121	1830 to 2010 °F [1000 to 1100 °C]	[C]
S82122	1725 °F [940 °C]	[C]

[A] Minimum, unless otherwise indicated.
[B] Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing the test for resistance to intergranular corrosion specified in 18.2.
[C] Quenched in water or rapidly cooled by other means.
[D] Quenched in water, except that coiled product heat treated in a continuous annealing line shall be water quenched or rapidly cooled by other means.
[E] Temperatures above 2060 °F are permissible if the resulting microstructure provides the properties required by this specification or any additional requirements of the purchase order.

A2. PERMITTED VARIATIONS IN DIMENSIONS—INCH-POUND UNITS

A2.1 Listed in Annex A2 are tables showing the permissible variations in dimensions expressed in inch-pound units of measurement. These requirements, including the SI units shown in brackets within Annex A2, shall apply to A480, but shall not apply to A480M. Requirements for A480M are given in Annex A3.

A2.1.1 The dimensional tolerances are grouped by production method (hot rolling or cold rolling, with or without coiling), product width (narrow (<24 in. [610 mm]) or wide (≥24 in. [610 mm])), and by product dimension addressed.

A2.2 *Cold-rolled Narrow (<24 in. [610 mm] Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.1-A2.4.

A2.3 *Cold-rolled Wide (≥24 in. [610 mm] Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.5-A2.8.

A2.4 *Hot-rolled Narrow (<24 in. [610 mm] Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.9-A2.12.

A2.5 *Hot-rolled Wide (≥24 in. [610 mm] Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.13-A2.16.

A2.6 *Hot-rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Tables A2.17-A2.20.

A2.7 *Cold-rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Table A2.21.

A2.8 *Tolerances for Other Dimensional Characteristics*—For other tolerance tables, refer to Tables A2.22-A2.30.

TABLE A2.1 Permitted Variations in Thickness for Cold-rolled, Narrow, Coil-processed Product as Coils and Cut Lengths

NOTE 1—Thickness measurements are taken at least ⅜ in. [9.52 mm] in from the edge of the product, except on widths less than 1 in. [25.4 mm] the measurements should be taken at least ⅛ in. [3.18 mm] from the product edge.

NOTE 2—The tolerances in this table include crown tolerances.

Specified Thickness, in. [mm]	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, in. [mm]		
	Width (w), in. [mm]		
	3/16 to 6 [4.76 to 152], incl $w \le 6$ [152]	Over 6 to 12 [152 to 305], incl 6 [152] < $w \le 12$ [305]	Over 12 to 24 [305 to 610], excl 12 [305] < $w \le 24$ [610]
	Thickness Tolerances[A]		
0.002 to 0.005 [0.05 to 0.13], excl	10 %	10 %	10 %
0.005 to 0.010 [0.13 to 0.25] , incl.	0.0006 [0.015]	0.0008 [0.020]	0.001 [0.025]
Over 0.010 to 0.012 [0.25 to 0.30], incl	0.001 [0.025]	0.001 [0.025]	0.001 [0.025]
Over 0.012 to 0.015 [0.30 to [0.40], incl	0.001 [0.025]	0.0015 [0.04]	0.0015 [0.04]
Over 0.015 to 0.020 [0.40 to 0.50], incl	0.001 [0.025]	0.0015 [0.04]	0.0015 [0.04]
Over 0.020 to 0.029 [0.50 to 0.74], incl	0.0015 [0.04]	0.0015 [0.04]	0.002 [0.050]
Over 0.029 to 0.035 [0.74 to 0.89], incl	0.0015 [0.04]	0.002 [0.050]	0.002 [0.050]
Over 0.035 to 0.050 [0.89 to [1.27], incl	0.0025 [0.060]	0.003 [0.070]	0.003 [0.070]
Over 0.050 to 0.069 [1.27 to 1.75], incl	0.003 [0.070]	0.003 [0.070]	0.003 [0.070]
Over 0.069 to 0.100 [1.75 to 2.54], incl	0.003 [0.070]	0.003 [0.070]	0.004 [0.10]
Over 0.100 to 0.125 [2.54 to 2.98], incl	0.004 [0.10]	0.004 [0.10]	0.005 [0.12]
Over 0.125 to 0.161 [2.98 to 4.09], incl	0.005 [0.12]	0.005 [0.12]	0.005 [0.12]
Over 0.161 to under 3/16 [4.09 to under 4.76]	0.005 [0.12]	0.005 [0.12]	0.006 [0.15]

[A] Thickness tolerances given in inches [millimetres] unless otherwise indicated.

TABLE A2.2 Permitted Variations in Width for Cold-rolled, Narrow, Coil-processed Product as Coils and Cut Lengths for Edge No. 3[A]

Specified Thickness,[B] in. [mm]	Width Tolerance, Over and Under, for Thickness and Width Given, in. [mm]			
	$w \leq 1.60$ [40]	1.60 [40] < $w \leq 6$ [150]	6 [150] < $w \leq 12$ [305]	12 [300] < $w \leq 24$ [610]
0.010 [0.25]	0.003 [0.085]	0.004 [0.10]	0.005 [0.125]	0.020 [0.50]
0.020 [0.50]	0.005 [0.125]	0.005 [0.125]	0.010 [0.25]	0.020 [0.50]
0.040 [1.00]	0.005 [0.125]	0.005 [0.125]	0.010 [0.25]	0.020 [0.50]
0.060 [1.50]	0.005 [0.125]	0.006 [0.15]	0.010 [0.25]	0.020 [0.50]
0.100 [2.50]	. . .	0.010 [0.25]	0.016 [0.40]	0.020 [0.50]
0.120 [3.00]	. . .	0.010 [0.25]	0.016 [0.40]	0.024 [0.60]
0.160 [4.00]	. . .	0.016 [0.40]	0.016 [0.40]	0.024 [0.60]
0.200 [4.99]	. . .	0.030 [0.80]	0.030 [0.80]	0.030 [0.80]

[A] For tolerances applicable to narrow product with Edge No. 1 or No. 5, see Table A3.22.
[B] For specified thickness other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.3 Permitted Variations in Length for Cold-rolled, Narrow, Coil-processed Product as Cut Lengths

Specified Length, ft [mm]	Tolerances, in. [mm]
≤6 [1830]	+⅛ [3], −0
>6 to ≤12 [1830 to 3660]	+0.2 [5], −0
>12 to ≤20 [3660 to 6096]	+0.3 [8], −0

TABLE A2.4 Permitted Variations in Flatness of Cold-rolled, Narrow, Coil-processed Product as Cut Lengths

Tolerances for variations of flatness cold-rolled products, narrow, coil-processed product as cut lengths shall be identical to the tolerances for cold-rolled, wide, coil-processed product as listed in Table A2.8 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.5 Permitted Variations in Thickness of Cold-rolled, Wide, Coil-processed Product as Coil and Cut Lengths

Specified Thickness,[A,B] in. [mm]	Permitted Variation, Over and Under, in. [mm], for Specified Width (w), w, in.		
	$w \leq 40$ [1000]	40 [1000] < $w \leq$ 50 [1300]	50 [1300] < $w \leq$ 84 [2100]
0.012 [0.30]	0.001 [0.030]	. . .	. . .
0.016 [0.40]	0.0015 [0.04]	0.0015 [0.04]	. . .
0.020 [0.50]	0.0015 [0.04]	0.0015 [0.04]	. . .
0.024 [0.60]	0.002 [0.05]	0.002 [0.05]	. . .
0.032 [0.80]	0.002 [0.05]	0.002 [0.05]	. . .
0.040 [1.00]	0.0025 [0.06]	0.0025 [0.06]	0.003 [0.08]
0.047 [1.20]	0.003 [0.08]	0.003 [0.08]	0.003 [0.08]
0.059 [1.50]	0.003 [0.08]	0.003 [0.08]	0.004 [0.10]
0.079 [2.00]	0.004 [0.10]	0.004 [0.10]	0.0045 [0.11]
0.098 [2.50]	0.004 [0.10]	0.004 [0.10]	0.005 [0.13]
0.118 [3.00]	0.005 [0.13]	0.005 [0.13]	0.006 [0.15]
0.157 [4.00]	0.007 [0.17]	0.007 [0.17]	0.007 [0.17]
0.197 [5.00]	0.007 [0.17]	0.007 [0.17]	0.0075 [0.19]
0.236 [6.00]	0.007 [0.17]	0.008 [0.20]	0.009 [0.23]
0.3125 [8.00]	0.007 [0.17]	0.009 [0.23]	0.010 [0.25]

[A] Thickness measurements are taken at least ⅜ in. [9.52 mm] from the edge of the sheet.
[B] For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.6 Permissible Variations in Width for Cold-rolled Wide, Coil-processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness,[A] in. [mm]	Permitted Variation in Width (w), in. [mm], for Specified Width (w), in. [mm]				
	$w \le 6$ [150]	6 [125] < $w \le 12$ [300]	12 [300] < $w \le 24$ [600]	24 [600] < $w < 48$ [1200]	48 [1000] $\ge w$
0.040 [1.00]	+0.02 [0.5], –0	+0.02 [0.5], –0	+0.03 [0.7], –0	+1/16 [1.6], –0	+1/8 [3.2], –0
0.059 [1.50]	+0.03 [0.7], –0	+0.03 [0.7], –0	+0.04 [1.0], –0	+1/16 [1.6], –0	+1/8 [3.2], –0
0.098 [2.50]	+0.04 [1.0], –0	+0.04 [1.0], –0	+0.05 [1.2], –0	+1/16 [1.6], –0	+1/8 [3.2], –0
0.138 [3.50]	+0.05 [1.2], –0	+0.05 [1.2], –0	+0.06 [1.5], –0	+1/16 [1.6], –0	+1/8 [3.2], –0
0.3125 [8.00]	+0.08 [2.0], –0	+0.08 [2.0], –0	+0.08 [2.0], –0	+0.16 [4.0], –0	+0.16 [4.0], –0

[A] For specified thicknesses and other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A2.7 Permitted Variations in Length for Cold-rolled, Wide, Coil-processed Product as Cut Lengths Not Resquared

Specified Length (L), ft [mm]	Tolerances, in. [mm]	
	Over	Under
Up to 6 [1830], incl	3/16 [4.8]	0
Over 6 [1830]	0.03 × L [0.0025 × L]	0

TABLE A2.8 Permitted Variations in Flatness of Cold-rolled, Wide, Coil-processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness[A]		
Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance,[B] in. [mm]
<0.062 [1.57]	≤60 [1524]	0.40 [10]
	>60 [1524]	0.50 [12]
≥0.062 [1.57]	≤60 [1524]	0.40 [10]
	>60 [1524]	0.50 [12]

Stretcher-Leveled Standard of Flatness[C]			
Specified Thickness, in. [mm]	Width, in. [mm]	Length, in. [mm]	Flatness Tolerance,[B] in. [mm]
<3/16 [4.76]	<48 [1219]	<96 [2438]	1/8 [3.2]
	<48 [1219]	≥96 [2438]	1/4 [6.4]
<3/16 [4.76]	≥48 [1219]	<96 [2438]	1/4 [6.4]
	≥48 [1219]	≥96 [2438]	1/4 [6.4]

2xx and 3xx Series Specified to 1/4 and 1/2 Hard Tempers			
Specified Thickness, in. [mm]	Width, in. [mm]	Flatness Tolerance[B] in. [mm]	
		1/4 Hard	1/2 Hard
<0.016 [0.41]	24 to <36 [610 to 914]	1/2 [12.70]	3/4 [19.05]
0.016 to 0.030 [0.41 to 0.76]		5/8 [15.88]	7/8 [22.22]
>0.030 [0.76]		3/4 [19.05]	7/8 [22.22]
≤0.016 [0.41]	36 to <48 [914 to 1219]	5/8 [15.88]	1 [25.40]
>0.016 to 0.030 [0.41 to 0.76]		3/4 [19.05]	1 1/8 [28.58]
>0.030 [0.76]		1 [25.40]	1 1/8 [28.58]

[A] Not specified to stretcher-leveled standard of flatness, and not including hard tempers of 2xx and 3xx Series, dead-soft sheets, and deep-drawing sheets.
[B] Maximum deviation from a horizontal flat surface.
[C] Not including hard tempers of 2xx and 3xx Series, dead-soft sheets, and deep-drawing sheets.

TABLE A2.9 Permitted Variations in Thickness of Hot-rolled, Narrow, Flat-rolled, Coil-processed Product as Cut Lengths and Coil

Tolerances for variations of thickness of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.13, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.10 Permitted Variations in Width of Hot-rolled, Narrow, Flat-rolled, Coil-processed Product as Cut Lengths and Coil

Tolerances for variations of width of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.14 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.11 Permitted Variations in Length of Hot-rolled, Narrow, Coil-processed Product as Cut Lengths

Tolerances for variations of length of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.15 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.12 Permitted Variations in Flatness of Hot-rolled, Narrow, Coil-processed Product as Cut Lengths

Tolerances for variations of flatness of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A2.16 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.13 Permitted Variations in Thickness of Hot-rolled, Wide, Coil-processed Product as Coil and Cut Lengths

Specified Thickness,[A] in. [mm]	Permitted Variations, in. [mm], Over and Under, Except as Indicated Otherwise, for Specified Width (w) in. [mm]	
	$w \le 60$ [1525]	$w > 60$ [1525]
0.072 [1.83]	0.006 [0.15]	0.009 [0.22]
>0.072 to 0.083 [1.83 to 2.11]	0.007 [0.18]	0.010 [0.25]
>0.083 to 0.098 [2.11 to 2.49]	0.008 [0.20]	0.011 [0.27]
>0.098 to 0.114 [2.49 to 2.90]	0.009 [0.23]	0.012 [0.30]
>0.114 to 0.130 [2.90 to 3.30]	0.011 [0.27]	0.013 [0.33]
>0.130 to 0.145 [3.30 to 3.68]	0.012 [0.30]	0.013 [0.33]
>0.145 to 0.1875 [3.68 to 4.76]	0.013 [0.33]	0.014 [0.35]
>0.1875 to 0.250 [4.76 to 6.35]	–0.010 [0.25], +0.020 [0.50]	–0.010 [0.25], +0.020 [0.50]
>0.250 to 0.3125 [6.35 to 7.94]	–0.010 [0.25], +0.022 [0.55]	–0.010 [0.25], +0.022 [0.55]
>0.3125 [7.94]	–0.010 [0.25], +0.030 [0.75]	–0.010 [0.25], +0.030 [0.75]

[A] Thickness measurements are taken at least ⅜ in. [9.52 mm] from the edge of the sheet.

TABLE A2.14 Permitted Variations in Width of Hot-rolled, Wide, Coil-processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness, t, in. [mm]	Width (w), in. [mm]	Tolerances on Width, in. [mm], for Trimmed Edges
$t <$ 3⁄16 [4.76]	$w <$ 48 [1219]	+1⁄16 [1.59], –0
	$w \ge$ 48 [1219]	+¼ [6.35], –0
3⁄16 [4.76] $\le t <$ ⅜ [9.5]	$w <$ 48 [1219]	+5⁄32 [3.97], –0
	$w \ge$ 48 [1219]	+⅜ [9.5], –0
$t \ge$ ⅜ [9.5]	$w <$ 48 [1219]	+¼ [6.35], –0
	$w \ge$ 48 [1219]	+7⁄16 [11.1], –0

TABLE A2.15 Permitted Variations in Length of Hot-rolled, Wide, Coil-processed Product as Cut Lengths Not Resquared

Specified Thickness, t, in. [mm]	Length (L), ft [mm]	Tolerances, in. [mm], Over and Under
t < 3⁄16 [4.76]	$L \le$ 10 [3048]	+¼ [6.35], –0
	10 [3048] < $L \le$ 20 [6096]	½ [12.7] , –0
t ≥ 3⁄16 [4.76]	$L \le$ 10 [3048]	+½ [12.7], –0
	10 [3048] < $L \le$ 20 [6096]	+⅝ [15.9], –0

TABLE A2.16 Permitted Variations in Flatness of Hot-rolled, Wide, Coil-processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness		
Specified Thickness (t), in. [mm]	Width (w), in. [mm]	Flatness Tolerance,[A] in. [mm]
t < 3/16 [4.76]	$w \le$ 36 [914]	0.50 [12.7]
	36 [914] < $w \le$ 60 [1524]	
	w > 60 [1524]	
$t \ge$ 3/16 [4.76]	$w \le$ 60 [1524]	0.90 [23]
	60 [1524] < $w \le$ 72 [1829]	1.20 [30]
	w > 72 [1829]	1.50 [38]

Stretcher-Leveled Standard of Flatness			
Specified Thickness (t), in. [mm]	Specified Width (w), in. [mm]	Specified Length (L), in. [mm]	Flatness Tolerance,[A] in. [mm]
t < 3/16 [4.76]	$w \le$ 48 [1219]	$L \le$ 96 [2438]	1/8 [3.18]
	$w \le$ 48 [1219]	L > 96 [2438]	1/4 [6.35]
t < 3/16 [4.76]	w > 48 [1219]	$L \le$ 96 [2438]	1/4 [6.35]
	w > 48 [1219]	L > 96 [2438]	1/4 [6.35]

[A] Maximum deviation from a horizontal flat surface.

TABLE A2.17 Permitted Variations in Thickness of Hot-rolled Mill Plate (Quarto Plate)[A,B]

Specified Thickness (t), in. [mm]	Width (w), in. [mm]			
	$w \le$ 84 [2134]	84 [2134] < $w \le$ 120 [3048]	120 [3048] < $w \le$ 144 [3658]	w > 144 [3658]
	Tolerance Over Specified Thickness,[C,D] in. [mm]			
t < 3/16 [4.76]	0.055 [1.35]	0.070 [1.78]	. . .	. . .
3/16 [4.76] ≤ t < 3/8 [9.52]	0.045 [1.14]	0.050 [1.27]	0.085 [2.16]	. . .
3/8 [9.52] ≤ t < 3/4 [19.05]	0.055 [1.40]	0.060 [1.52]	0.085 [2.16]	0.090 [2.29]
3/4 [19.05] ≤ t < 1 [25.40]	0.060 [1.52]	0.065 [1.65]	0.085 [2.16]	0.100 [2.54]
1 [25.40] ≤ t < 2 [50.80]	0.070 [1.78]	0.075 [1.90]	0.095 [2.41]	0.115 [2.92]
2 [50.80] ≤ t < 3 [76.20]	0.125 [3.20]	0.150 [3.80]	0.175 [4.45]	0.200 [5.08]
3 [76.20] ≤ t < 4 [101.6]	0.150 [3.81]	0.160 [4.06]	0.200 [5.08]	0.225 [5.72]
4 [101.6] ≤ t < 6 [152.4]	0.180 [4.57]	0.200 [5.08]	0.335 [8.50]	0.355 [9.02]
6 [152.4] ≤ t < 8 [203.2]	0.235 [6.00]	0.255 [6.48]	0.355 [9.02]	0.435 [11.0]
8 [203.2] ≤ t < 10 [254.0]	0.315 [8.00]	0.335 [8.50]	0.435 [11.0]	0.550 [14.0]

[A] Thickness is measured along the original longitudinal edges of the as-produced plate at least 3/8 in. [9.52 mm], but not more than 3 in. [76.20 mm], from the edge.
[B] For plates up to 10 in. [254.0 mm], excl, in thickness, the tolerance under the specified thickness is 0.010 in. [0.25 mm].
[C] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown.
[D] The tolerance over specified thickness in the area more than 3 in. in from the longitudinal edges of the plate at the mill produced width shall not exceed twice the tabular tolerance.

TABLE A2.18 Permitted Variations in Width for Hot-rolled Rectangular Sheared Plate Mill Plates (Quarto Plates)

Specified Width (w), in. [mm]	Tolerances, Over Specified Width, in. [mm][A]
$w \le$ 84 [2135]	5/8 [15.9]
84 [2135] < $w \le$ 108 [2745]	3/4 [19.1]
w > 108 [2745]	1 [25.4]

[A] The tolerance under specified width is 1/4 in. [6.35 mm].

TABLE A2.19 Permitted Variations in Length for Hot-rolled Sheared Rectangular Plate Mill Plates (Quarto Plates)

Nominal Length (L), in. [mm]	Tolerances, Over and Under, in. [mm][A]
L < 160 [4064]	3/4 [19.1]
160 [4064] ≤ L < 240 [6096]	1 1/4 [31.8]
240 [6000] ≤ L < 315 [8000]	1 5/8 [41.3]
315 [8000] ≤ L < 394 [10 008]	2 [50.8]
394 [10 008] ≤ L < 590 [15 000]	2 1/4 [57.2]
590 [15 000] ≤ L < 790 [20 066]	2 1/4 [57.2]

[A] The tolerance under specified length is 1/4 in. [6.35 mm].

TABLE A2.20 Permitted Variations in Flatness of Plate Mill Plate (Quarto Plate)

NOTE 1—Tolerances in this table apply to any length, not necessarily the rolling direction, up to 36 in. [914 mm] and to any 36 in. [914 mm] of longer lengths in the plane of the plate measured while the plate rests on a flat surface with the concavity of the curvature upward.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than ¼ in. [6.4 mm].

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, the permitted variations are increased to 1½ times the amounts shown.

Specified Thickness (t), in. [mm]	Flatness Tolerance for Thicknesses Given, in. [mm]
t < ¼ [6.35]	7/16 [11]
¼ [6.35] ≤ t < ⅜ [9.52]	⅜ [9.5]
⅜ [9.52] ≤ t < ½ [12.70]	5/16 [7.9]
½ [12.70] ≤ t < ¾ [19.05]	5/16 [7.9]
¾ [19.05] ≤ t < 1 [25.40]	5/16 [7.9]
1 [25.40] ≤ t < 1½ [38.10]	¼ [6.4]
1½ [38.10] ≤ t < 4 [101.60]	¼ [6.4]
t ≥ 4 [101.60]	¼ [6.4]

TABLE A2.21 Cold-rolled Products, Processed Without Coiling

Tolerances for cold-rolled products processed without coiling shall be identical to the tolerances for hot-rolled products processed without coiling as listed in Table A2.17, Table A2.18, Table A2.19, and Table A2.20 unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A2.22 Permitted Variations in Width for Cold-rolled Narrow, Coil-processed Product in Coils and Cut Lengths for Edge No. 1 or 5

Specified Edge No.	Width, in. [mm]	Thickness, in. [mm]	Width Tolerance for Thickness and Width Given in. [mm]	
			Over	Under
1 and 5	9/32 [7.14] and under	1/16 [1.59] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over 9/32 to ¾ [7.14 to 19.05], incl	3/32 [2.38] and under	0.005 [0.13]	0.005 [0.13]
1 and 5	over ¾ to 5 [19.05 to 127.00], incl	⅛ [3.18] and under	0.005 [0.13]	0.005 [0.13]
5	over 5 to 9 [127.00 to 228.60], incl	0.008 to ⅛ [0.20 to 3.18], incl	0.010 [0.25]	0.010 [0.25]
5	over 9 to 20 [228.60 to 508.00], incl	0.015 to 0.105 [0.38 to 2.67]	0.010 [0.25]	0.010 [0.25]
5	over 20 to 24 [508.00 to 610], excl	0.023 to 0.080 [0.58 to 2.03]	0.015 [0.38]	0.015 [0.38]

TABLE A2.23 Permitted Variations in Width and Length for Hot-rolled and Cold-rolled Resquared Coil-processed Product (Stretcher Leveled Standard of Flatness)

Specified Dimensions, in. [mm]	Tolerances		
	Over		Under
	in.	mm	
For thicknesses under 0.131 [3.33]:			
Widths up to 48 [1219], excl	1/16	1.59	0
Widths 48 [1219] and over	⅛	3.18	0
Lengths up to 120 [3048], excl	1/16	1.59	0
Lengths 120 [3048] and over	⅛	3.18	0
For thicknesses 0.131 [3.33] up to 3/16, excl:			
All widths and lengths	¼	6.35	0

TABLE A2.24 Permitted Variations in Width and Length for Hot-rolled Product by Abrasive Cutting

Specified Thickness, in. [mm]	Tolerance over Specified Width and Length[A]	
	Width	Length
Up to 1 [25.40], incl	⅛ [3.18]	⅛ [3.18]
1 to 2 [25.40 to 50.80], incl	3/16 [4.76]	3/16 [4.76]
2 to 3 [50.80 to 76.20], incl	¼ [6.35]	¼ [6.35]
3 to 4 [76.20 to 101.6], incl[B]	5/16 [7.94]	5/16 [7.94]

[A] The tolerances under specified width and length are ⅛ in. [3.18 mm].
[B] Width and length tolerances for abrasive cut plates over 4 in. [101.6 mm] thick are not included in the table; consult producer.

TABLE A2.25 Permitted Variations in Diameter for Hot-rolled and Cold-rolled Coil-processed Product as Sheared Circles

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameters Under 30 in. [762 mm]	Diameters 30 to 48 in. [762 to 1219 mm]	Diameters Over 48 in. [1219 mm]
Up to 0.0567 [1.45], include	1/16 [1.59]	1/8 [3.18]	3/16 [4.76]
0.0568 to 0.0971 [1.45 to 2.46], incl	3/32 [2.38]	5/32 [3.97]	7/32 [5.56]
0.0972 up to 3/16 [2.46 up to 4.76], excl	1/8 [3.18]	3/16 [4.76]	1/4 [6.35]

TABLE A2.26 Permitted Variations in Diameter for Hot-rolled and Cold-rolled Coil-processed Product as Sheared Circles

Specified Thickness, in. [mm]	Tolerance Over Specified Diameter (No Tolerance Under), in. [mm]		
	Diameter and Thickness,[A] in. [mm]		
	To 3/8 in. [9.52 mm], excl, in Thickness	3/8 to 5/8 in. [9.52 to 15.88 mm], excl, in Thickness	5/8 in. [15.88 mm] and Over in Thickness[B]
To 60 [1524], excl	1/4 [6.35]	3/8 [9.52]	1/2 [12.70]
60 to 84 [1524 to 2134], excl	5/16 [7.94]	7/16 [11.11]	9/16 [14.29]
84 to 108 [2134 to 2743], excl	3/8 [9.52]	1/2 [12.70]	5/8 [15.88]
108 to 180 [2743 to 4572], excl	7/16 [11.11]	9/16 [14.29]	11/16 [17.46]

[A] No tolerance under.
[B] Circular and sketch plates over 5/8 in. [15.88 mm] in thickness are not commonly sheared but are machined or flame cut.

TABLE A2.27 Torch Cutting Tolerances[A] and Recommended Cleanup Allowance for Rectangular Plates, Circles, Rings, and Sketches

Specified Thickness, in.	Tolerance, in.		Cleanup Allowance[B] per Edge, in.
	Outside Dimension	Inside Dimension	
2 and under	+3/8 , –0	–3/8 , +0	±1/4
Over 2 to 3, incl	+1/2 , –0	–1/2 , +0	±3/8
Over 3 to 6, incl	+3/4 , –0	–3/4 , +0	±1/2

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.
[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A2.28 Permitted Variations in Weight for Hot-rolled or Cold-rolled Coil Processed Product With Thickness Less Than 3/16 in. [4.76 mm]

Any item of five sheets or less, or any item estimated to weigh 200 lb [90.72 kg] or less, may actually weigh as much as 10 % over the theoretical weight	weigh 200 lb [90.72 kg] or less
Any item of more than five sheets and estimated to weigh more than 200 lb [90.72 kg], may actually weigh as much as 7½ % over the theoretical weight	weigh more than 200 lb [90.72 kg]
Chromium-manganese-nickel	40.7 lb/ft^2·in. thickness [7.82 kg/m^2·mm thick]
Chromium-nickel	42.0 lb/ft^2·in. thickness [8.07 kg/m^2·mm thick]
Chromium	41.2 lb/ft^2·in. thickness [7.92 kg/m^2·mm thick]

TABLE A2.29 Permitted Variations in Camber for Cold-rolled Coil Processed Product in Coils and Cut Lengths[A]

Specified Width, in. [mm]	Tolerance per Unit Length of Any 8 ft [2438 mm], in. [mm]
To 1½ [38.10], incl	½ [12.70]
Over 1½ to 24 [38.10 to 609.60], excl	¼ [6.35]

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438 mm] straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A2.30 Permitted Variations in Camber for Sheared Mill and Universal Mill Plates[A]

maximum camber	=	⅛ inches in any 5 ft
	=	3.18 mm in any 1.524 m

[A] Camber is the deviation of a side edge from a straight line, and measurement is taken by placing a 5-ft straightedge on the concave side and measuring the greatest distance between the plate and the straightedge.

A3. PERMITTED VARIATIONS IN DIMENSIONS—SI UNITS

A3.1 Listed in Annex A3 are tables showing the permitted variations in dimensions expressed in SI units of measurement. These requirements shall apply to A480M but shall not apply to A480. Requirements for A480 are given in Annex A2.

A3.1.1 The dimensional tolerances are grouped by production method (hot rolling or cold rolling, with or without coiling), product width (narrow (<600 mm) or wide (≥600 mm)), and by product dimension addressed.

A3.2 *Cold-rolled Narrow (<600 mm Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.1-A3.4.

A3.3 *Cold-rolled Wide (≥600 mm Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.5-A3.8.

A3.4 *Hot-rolled Narrow (<600 mm Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.9-A3.12.

A3.5 *Hot-rolled Wide (≥600 mm Width) Coil-processed Product*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.13-A3.16.

A3.6 *Hot-rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Tables A3.17-A3.20.

A3.7 *Cold-rolled Product Processed Without Coiling*—For thickness, width, length, and flatness tolerance tables, refer to Table A3.21.

A3.8 *Tolerances for Other Dimensional Characteristics*—For other tolerance tables, refer to Tables A3.22-A3.30.

TABLE A3.1 Permitted Variations in Thickness of Cold-rolled, Narrow, Coil-processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 10 mm in from the edge of the product, except that on widths less than 26 mm, the tolerances are applicable for measurements at all locations.

NOTE 2—The tolerances in this table include crown tolerances.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Thickness Tolerances, for the Thickness and Widths Given, Over and Under, mm		
	Width (w), mm		
	50 to 150, incl $w \le 125$	Over 150 to 300, incl $125 < w \le 250$	Over 300 to 600, excl $250 < w < 600$
	Thickness Tolerances[A]		
0.15	0.010	0.015	0.020
0.25	0.015	0.020	0.025
0.50	0.025	0.030	0.035
0.75	0.030	0.040	0.050
1.00	0.030	0.040	0.050
1.25	0.035	0.045	0.050
1.50	0.040	0.050	0.060
1.75	0.050	0.060	0.070
2.00	0.050	0.060	0.070
2.50	0.050	0.070	0.080
3.00	0.060	0.070	0.090
4.00	0.070	0.070	0.090
4.99	0.070	0.070	0.090

[A] Thickness tolerances given in mm unless otherwise indicated.

TABLE A3.2 Permitted Variations in Width of Cold-rolled, Narrow, Coil-processed Product in Coils and Cut Lengths for Edge No. 3[A]

Specified Thickness, [B] mm	Width Tolerance, Over and Under, for Thickness and Width Given, mm			
	$w \le 40$	$40 < w \le 125$	$125 < w \le 250$	$250 < w \le 600$
0.25	0.085	0.10	0.125	0.50
0.50	0.10	0.125	0.15	0.50
1.00	0.125	0.125	0.20	0.50
1.50	0.125	0.15	0.25	0.50
2.50	. . .	0.20	0.30	0.50
3.00	. . .	0.25	0.30	0.60
4.00	. . .	0.25	0.40	0.60
4.99	. . .	0.40	0.50	0.60

[A] For tolerances applicable to narrow product with Edge No. 1 or No. 5, see Table A3.22.
[B] For specified thickness other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A3.3 Permitted Variations in Length of Cold-rolled, Narrow, Coil-processed Products as Cut Lengths

Specified Length, mm	Tolerances, mm
≤1500	+3, −0
>1500, ≤4000	+5, −0
>4000, ≤6000	+8, −0

TABLE A3.4 Permitted Variations in Flatness of Cold-rolled, Narrow, Coil-processed Product as Cut Lengths

Tolerances for variations of flatness cold-rolled products, narrow, coil-processed product as cut lengths shall be identical to the tolerances for cold-rolled, wide, coil-processed product as listed in Table A3.8, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.5 Permitted Variations in Thickness of Cold-rolled, Wide, Coil-processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 15 mm from the edge of the product in the case of slit edges and at least 25 mm from the edge of the product in the case of mill edges.

NOTE 2—Cold-rolled sheets in cut lengths and coils are produced in some type numbers and some widths and thickness to tolerances less than those shown in the table.

NOTE 3—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Permitted Variation, Over and Under, mm, for Specified Width (w), w in mm		
	$w \le 1000$	$1000 < w \le 1300$	$1300 < w \le 2100$
0.30	0.03	. . .	. . .
0.40	0.04	0.04	. . .
0.50	0.045	0.05	. . .
0.60	0.05	0.05	. . .
0.80	0.05	0.05	. . .
1.00	0.055	0.06	0.07
1.20	0.08	0.08	0.08
1.50	0.08	0.08	0.10
2.00	0.10	0.10	0.11
2.50	0.10	0.11	0.13
3.00	0.13	0.13	0.15
4.00	0.17	0.17	0.17
5.00	0.17	0.17	0.19
6.00	0.17	0.20	0.23
8.00	0.17	0.22	0.25

TABLE A3.6 Permitted Variations in Width of Cold-rolled, Wide, Coil-processed Product as Cut Lengths (Not Resquared) and Coil

Specified Thickness, mm[A]	Permitted Variation in Width, mm, for Specified Width (w), mm				
	$w \le 125$	$125 < w \le 250$	$250 < w \le 600$	$600 < w \le 1000$	$1000 < w \le 2100$
1.00	+0.5, –0	+0.5, –0	+0.7, –0	+1.5, –0	+2.0, +0
1.50	+0.7, –0	+0.7, –0	+1.0, –0	+1.5, –0	+2.0, +0
2.50	+1.0, –0	+1.0, –0	+1.2, –0	+2.0, –0	+2.5, –0
3.50	+1.2, –0	+1.2, –0	+1.5, –0	+3.0, –0	+3.0, –0
8.00	+2.0, –0	+2.0, –0	+2.0, –0	+4.0, –0	+4.0, –0

[A] For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

TABLE A3.7 Permitted Variations in Length of Cold-rolled, Wide, Coil-processed Product as Cut Lengths Not Resquared

Specified Length (L), mm	Tolerance, mm	
	Over	Under
≤2000	5	0
>2000	0.0025 × L	0

TABLE A3.8 Permitted Variations in Flatness of Cold-rolled, Wide, Coil-processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness[A]		
Specified Thickness, mm	Specified Width, mm	Flatness Tolerance[B], mm
<1.50	<1500	10
	≥1500	12
≥1.50	<1500	10
	≥1500	12

Stretcher-Leveled Standard of Flatness[C]			
Specified Thickness, mm	Specified Width, mm	Specified Length, mm	Flatness Tolerance,[B] mm
≤4.99	<1200	<2400	4
		≥2400	7
	≥1200	<2400	7
		≥2400	7

2xx and 3xx Series Specified to ¼ and ½ Hard Tempers			
Specified Thickness, mm	Specified Width, mm	Flatness Tolerance,[B] mm	
		¼ Hard	½ Hard
≤0.04	600 to 900, excl	19	23
>0.04 to ≤0.80		16	23
>0.80		13	19
≤0.04	900 to 1200, incl	26	29
>0.04 to ≤0.80		19	29
>0.80		16	26

[A] Not specified to stretcher-leveled standard of flatness, and not including hard tempers of 2xx and 3xx series, dead-soft sheets, and deep-drawing sheets.
[B] Maximum deviation from a horizontal flat surface.
[C] Not including hard tempers of 2xx and 3xx series, dead-soft sheets, and deep-drawing sheets.

TABLE A3.9 Permitted Variations in Thickness of Hot-rolled, Narrow, Flat-rolled, Coil-processed Product as Cut Lengths and Coil

Tolerances for variations of thickness of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.13, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.10 Permitted Variations in Width of Hot-rolled, Narrow, Flat-rolled, Coil-processed Product as Cut Lengths and Coil

Tolerances for variations of width of hot-rolled, narrow, coil-processed product as cut lengths and coil shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.14, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.11 Permitted Variations in Length of Hot-rolled, Narrow, Coil-processed Product as Cut Lengths

Tolerances for variations of length of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.15, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.12 Permitted Variations in Flatness of Hot-rolled, Narrow, Flat-rolled, Coil-processed Product as Cut Lengths

Tolerances for variations of flatness of hot-rolled, narrow, coil-processed product as cut lengths shall be identical to the tolerances for hot-rolled, wide, coil-processed product as listed in Table A3.16, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.13 Permitted Variations in Thickness of Hot-rolled, Wide, Coil-processed Product as Coil and Cut Lengths

NOTE 1—Thickness measurements are taken at least 10 mm from the edge of the product.

NOTE 2—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Permitted Variations of Thickness, mm, Over and Under, Except as Indicated Otherwise, for Specified Width (w)	
	$w \le 1500$	$w > 1500$
2.0	0.18	0.25
2.25	0.20	0.27
2.5	0.23	0.30
3.0	0.25	0.33
3.5	0.30	0.33
5.0	–0.25, +0.47	–0.25, +0.51
6.0	–0.25, +0.51	–0.25, +0.51
8.0	–0.25, +0.75	–0.25, +0.75
>8.0	–0.25, +0.75	–0.25, +0.75

TABLE A3.14 Permitted Variations in Width of Hot-rolled, Wide, Coil-processed Product as Cut Lengths (Not Resquared) and Coil

Specified Dimension, mm		Tolerance on Width, mm, for Trimmed Edges	
Thickness (t), mm	Width (w), mm	Over	Under
<5.00	$w < 1200$	2	0
	$w \ge 1200$	6	0
$5.00 < t \le 10.00$	$w < 1200$	4	0
	$w \ge 1200$	9	0
>10.00	$w < 1200$	6	0
	$w \ge 1200$	12	0

TABLE A3.15 Permitted Variations in Length of Hot-rolled, Wide, Coil-processed Product as Cut Lengths Not Resquared

Specified Length (L), mm	Tolerance, mm	
	Over	Under
$L < 3000$	$(0.005 \times L)$	0
$3000 \le L \le 6000$		0

TABLE A3.16 Permitted Variations in Flatness of Hot-rolled, Wide, Coil-processed Product as Cut Lengths

Not Specified to Stretcher-Leveled Standard of Flatness		
Specified Thickness (t), mm	Specified Width (w), mm	Flatness Tolerance,[A] mm
$t < 5$	$w < 900$	13
	$900 \le w < 1500$	19
	$w \ge 1500$	26
$t \ge 5$	$w < 1500$	23
	$1500 \le w < 1800$	30
	$w \ge 1800$	38

Stretcher-Leveled Standard of Flatness			
Specified Thickness (t), mm	Specified Width (w), mm	Specified Length (L), mm	Flatness Tolerance,[A] mm
$t \le 13$	$w < 1200$	$L < 2400$	4
		$L \ge 2400$	7
	$w \ge 1200$	$L < 2400$	7
		$L \ge 2400$	7

[A] Maximum deviation from a horizontal flat surface.

TABLE A3.17 Permitted Variations in Thickness of Hot-rolled Plate Mill Plate (Quarto Plate)[A,B]

NOTE 1—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness, mm	Width (w), mm			
	$w < 2100$	2100 $\le w <$ 3000	3000 $\le w <$ 3600	$w \ge 3600$
	Tolerance Over Specified Thickness,[C] mm			
5	1.35	1.75	. . .	. . .
8	1.15	1.30	2.15	. . .
10	1.15	1.30	2.15	. . .
20	1.40	1.55	2.15	2.30
25	1.55	1.65	2.15	2.55
50	1.80	1.90	2.40	2.95
75	3.20	3.80	4.45	5.10
100	3.75	4.00	5.00	5.70
150	4.50	5.00	8.50	9.00
200	6.00	6.50	9.00	11.0
250	8.00	8.50	11.0	14.0

[A] Thickness is measured along the original longitudinal edges of the as-produced plate at least 10 mm but not more than 75 mm from the edge.
[B] For circles, the over thickness tolerances in this table apply to the diameter of the circle corresponding to the width ranges shown. For plates of irregular shape, the over thickness tolerances apply to the greatest width corresponding to the width ranges shown. For plates up to 250 mm, incl, in thickness, the tolerance under the specified thickness is 0.30 mm.
[C] The tolerance over specified thickness in the area more than 75 mm in from the longitudinal edges of the plate at the mill produced width shall not exceed twice the tabular tolerance.

TABLE A3.18 Permitted Variations in Width for Hot-rolled Rectangular Sheared Plate Mill Plates (Quarto Plates)

Specified Width (w), mm	Tolerances, Over and Under, mm
$w < 2000$	+15, –0
$2000 \le w < 3000$	+20, –0
$w \ge 3000$	+25, –0

TABLE A3.19 Permitted Variations in Length for Hot-rolled Sheared Rectangular Plate Mill Plates (Quarto Plates)

Nominal Length (L), mm	Tolerances, Over and Under, mm
$L < 4000$	+20, –0
$4000 \le L < 6000$	+30, –0
$6000 \le L < 8000$	+40, –0
$8000 \le L < 10\,000$	+50, –0
$10\,000 \le L < 15\,000$	+75, –0
$15\,000 \le L < 20\,000$	+100, –0

TABLE A3.20 Permitted Variations in Flatness of Plate Mill Plate (Quarto Plate)

NOTE 1—Tolerances in this table apply to any length, not necessarily the rolling direction, up to 36 in. [914 mm] and to any 36 in. [914 mm] of longer lengths in the plane of the plate measured while the plate rests on a flat surface with the concavity of the curvature upward.

NOTE 2—If the longer dimension is under 36 in. [914 mm], the tolerance is not greater than ¼ in. [6.4 mm].

NOTE 3—For plates with specified minimum yield strengths of 35 ksi [240 MPa] or more, the permitted variations are increased to 1½ times the amounts shown.

NOTE 4—For specified thicknesses other than those shown, the tolerances for the next higher thickness shall apply.

Specified Thickness (t), in. [mm]	Flatness Tolerance for Thicknesses Given, in. [mm]
5	0.40 [10]
10	⅜ [9.5]
15	5⁄16 [7.9]
20	5⁄16 [7.9]
25	5⁄16 [7.9]
50	¼ [6.4]
150	¼ [6.4]
>150	¼ [6.4]

TABLE A3.21 Cold-rolled Products, Processed Without Coiling

Tolerances for cold-rolled products processed without coiling shall be identical to the tolerances for hot-rolled products processed without coiling as listed in Table A3.17, unless otherwise agreed upon by seller and purchaser and specified in the purchase order.

TABLE A3.22 Permitted Variations in Width for Cold-rolled Narrow, Coil-processed Product in Coils and Cut Lengths for Edge No. 1 or 5

Specified Edge No.	Width, mm	Thickness, mm	Width Tolerance for Thickness and Width Given, mm	
			Over	Under
1 and 5	under 10	1.50 and under	0.13	0.13
1 and 5	10 to 20, excl	2.50 and under	0.13	0.13
1 and 5	20 to 100, excl	3.00 and under	0.13	0.13
5	100 to 300, excl	0.20 to 3.00, incl	0.25	0.25
5	300 to 600, excl	0.40 to 2.60, incl	0.25	0.25
5	600 and over	0.60 to 2.00, incl	0.40	0.40

TABLE A3.23 Permitted Variations in Width and Length for Hot-rolled and Cold-rolled Resquared Coil-processed Product (Stretcher Leveled Standard of Flatness)

NOTE 1—Polished sheets with Finishes No. 4 and higher are produced to tolerances given in this table.

Specified Dimensions, mm			Width and Length Tolerance, mm	
Thickness	Width	Length	Over	Under
Under 3.30	Up to 1200	Up to 3000	2	0
	1200 and over	3000 and over	3	0
3.30 and over	All	All	7	0

TABLE A3.24 Permitted Variations in Abrasive Cutting Width and Length for Plates

Specified Thickness, [mm]	Tolerance over Specified Width and Length,[A] mm	
	Width	Length
Up to 25, incl	3.2	3.2
25 to 50, incl	4.8	4.8
50 to 75, incl	6.4	6.4
75 to 100, incl[B]	7.9	7.9

[A] The tolerances under specified width and length are 3.2 mm.
[B] Width and length tolerances for abrasive cut plates over 100 mm thick are not included in the table; consult producer.

TABLE A3.25 Permitted Variations in Diameter for Hot-rolled and Cold-rolled Coil-processed Product as Sheared Circles

Specified Thickness, mm	Tolerance Over Specified Diameter (No Tolerance Under), mm		
	Diameters Under 600	Diameters 600 to 1200 incl	Diameters Over 1200
Under 1.50	2	3	5
1.50 to 2.50 excl	3	4	6
2.50 and thicker	4	5	7

TABLE A3.26 Permitted Variations in Diameter for Circular Plates Taken From Hot-rolled Product Processed With or Without Coiling

NOTE 1—For specific diameters other than those shown, the tolerance for the next higher diameter shall apply.

Specified Diameter, mm	Tolerance Over Specified Diameter for Given Diameter and Thickness,[A] mm		
	Thickness of Plate		
	To 10, excl	10 to 15, excl	15 and over
1500 and under	7	10	13
2100	8	13	16
2700	10	11	15
4500	11	15	18

[A] No tolerance under.

TABLE A3.27 Torch Cutting Tolerances[A] and Recommended Cleanup Allowance for Rectangular Plates, Circles, Rings, and Sketches

Specified Thickness, mm	Tolerance, mm		Cleanup Allowance[B]
	Outside Diameter	Inside Diameter	Per Edge, mm
51 and under	+10, –0	–10, +0	±6
Over 51 to 76 incl	+13, –0	–13, +0	±10
Over 76 to 152 incl	+19, –0	–19, +0	±13

[A] Tolerances to apply unless otherwise agreed. Note that for some applications user may wish to specify minus rather than plus tolerance or vice versa.
[B] Recommended cleanup allowance which, unless otherwise specified, will be applied by supplier to purchasers ordered size.

TABLE A3.28 Permitted Variations in Weight for Hot-rolled and Cold-rolled Sheets

Any item of five sheets or less, and estimated to weigh 100 kg or less, may actually weigh 10 % over the theoretical weight	weigh 100 kg or less
Any item of more than five sheets and estimated to weigh more than 100 kg, may actually weigh 7½ % over the theoretical weight	weigh more than 100 kg
Chromium-manganese-nickel	7.82 kg/m^2/mm thick
Chromium-nickel	8.07 kg/m^2/mm thick
Chromium	7.92 kg/m^2/mm thick

TABLE A3.29 Permitted Variations in Camber for Cold-rolled Narrow Coil-processed Product in Coils and Cut Lengths[A]

Specified Width, mm	Tolerance Per Unit Length of Any 2400 mm
To 40, incl	13
Over 40 to 600, incl	7

[A] Camber is the deviation of a side edge from a straight line and measurement is taken by placing a 2400 mm straightedge on the concave side and measuring the greatest distance between the strip edge and the straightedge.

TABLE A3.30 Permitted Variations in Camber for Hot-rolled and Cold-rolled Wide Coil-processed Product as Cut Lengths Not Resquared and Cold-rolled Wide Coil-processed Product as Coils[A]

Specified Width, mm	Tolerance per Unit Length of Any 2400 mm, mm
600 to 900, excl	4
900 and over	3

[A] Camber is the greatest deviation of a side edge from a straight line and measurement is taken by placing an 8-ft [2438 mm] straightedge on the concave side and measuring the greatest distance between the sheet edge and the straightedge.

A4. REQUIREMENTS FOR INTRODUCTION OF NEW MATERIALS

A4.1 New materials may be proposed for inclusion in specifications referencing this specification subject to the following conditions:

A4.1.1 Application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A4.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A4.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A4.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A4.1.5 The application shall state whether the new grade is covered by patent.

A5. REQUIREMENTS FOR INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A5.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A5.1.1 Application for the addition of a grade that is already covered in another A01 or A01.17 specification shall be made to the chair of the subcommittee that has jurisdiction over that the specification to which the grade is to be added.

A5.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or A01.17 specification in which the grade is presently covered.

A5.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A5.1.4 The application shall state whether or not the grade is covered by patent.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue (A480/A480M – 23a) that may impact the use of this standard. (Approved Nov. 1, 2023.)

(1) Added UNS designation S31025 to Table A1.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A480/A480M – 23) that may impact the use of this standard. (Approved Sept. 1, 2023.)

(1) Removed reference to MIL-STD-129 and MIL-STD-163 in 25.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A480/A480M – 22a) that may impact the use of this standard. (Approved March 1, 2023.)

(1) Added UNS designation S31740 to Note 5, 18.2.1, and Table A1.2.

Committee A01 has identified the location of selected changes to this standard since the last issue (A480/A480M – 22) that may impact the use of this standard. (Approved Sept. 1, 2022.)

(1) Revised Terminology (Section 3) to comply with Form and Style Manual.

Committee A01 has identified the location of selected changes to this standard since the last issue (A480/A480M – 20a) that may impact the use of this standard. (Approved May 1, 2022.)

(1) Added reference to A1084 in 2.1, 18.3, and 19.1.8.

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SPECIFICATION FOR GENERAL REQUIREMENTS FOR STAINLESS STEEL BARS, BILLETS, AND FORGINGS

SA-484/SA-484M

(Identical with ASTM Specification A484/A484M-21.)

Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

1. Scope

1.1 This specification covers general requirements that shall apply to wrought stainless steel bars, shapes, forgings, and billets or other semi-finished material (except wire) for forging, under each of the following specifications issued by ASTM: Specifications A276/A276M, A314, A458, A477, A479/A479M, A564/A564M, A565/A565M, A582/A582M, A638/A638M, A705/A705M, and A831/A831M.

1.2 In the case of conflict between a requirement of a product specification and a requirement of this specification, the product specification shall prevail. In the case of conflict between a requirement of the product specification or a requirement of this specification and a more stringent requirement of the purchase order, the purchase order shall prevail. The purchase order requirements shall not take precedence if they, in any way, violate the requirements of the product specification or this specification; for example, by waiving a test requirement or by making a test requirement less stringent.

1.3 The requirements for introduction of new materials in specifications referencing this specification are given in Annex A1.

1.4 General requirements for flat-rolled stainless steel products other than bar are covered in Specification A480/A480M.

1.5 General requirements for wire products in coils are covered in Specification A555/A555M.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.7 Unless the order specifies an "M" designation, the material shall be furnished to inch-pound units.

1.8 *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:*

A262 Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels

A276/A276M Specification for Stainless Steel Bars and Shapes

A314 Specification for Stainless Steel Billets and Bars for Forging

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A458 Specification for Hot-Worked, Hot-Cold-Worked, and Cold-Worked Alloy Steel Bars for High Strength at Elevated Temperatures (Withdrawn 1988)

A477 Specification for Hot-Worked, Hot-Cold Worked and Cold-Worked Alloy Steel Forgings and Forging Billets for High Strength at Elevated Temperatures (Withdrawn 1988)[4]

A479/A479M Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

A480/A480M Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet, and Strip

A555/A555M Specification for General Requirements for Stainless Steel Wire and Wire Rods

A564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes

A565/A565M Specification for Martensitic Stainless Steel Bars for High-Temperature Service
A582/A582M Specification for Free-Machining Stainless Steel Bars
A638/A638M Specification for Precipitation Hardening Iron Base Superalloy Bars, Forgings, and Forging Stock for High-Temperature Service
A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
A705/A705M Specification for Age-Hardening Stainless Steel Forgings
A751 Test Methods and Practices for Chemical Analysis of Steel Products
A831/A831M Specification for Austenitic and Martensitic Stainless Steel Bars, Billets, and Forgings for Liquid Metal Cooled Reactor Core Components (Withdrawn 2005)
E112 Test Methods for Determining Average Grain Size
E139 Test Methods for Conducting Creep, Creep-Rupture, and Stress-Rupture Tests of Metallic Materials

2.2 *Federal Standards:*
Fed Std. No. 123 Marking for Shipment (Civil Agencies)
Fed Std. No. 183 Continuous Marking of Iron and Steel Products

2.3 *Military Standards:*
MIL-STD-129 Marking for Shipment and Storage
MIL-STD-163 Preservation of Steel Products for Shipment (Storage and Overseas Shipment)

2.4 *Other Standard:*
Primary Metals Bar Code Standard

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *bars, n*—straight lengths that are produced by processing that includes hot deformation, such as rolling, forging, or extrusion; the permitted cross-sections include round, rectangular, and complex shapes; shall include shapes with all dimensions under 5 in. [125 mm]; shall include hot-rolled flats with width of 10 in. [250 mm] or less, and with thickness 0.125 in. [3.00 mm] or greater; shall include flats with width of 10 in. [250 mm] or less, and with thickness 0.125 in. [3.00 mm] or greater, cut from strip or plate provided that the long direction of the cut bar is parallel to the final rolling direction of the strip or plate.

3.1.1.1 *Discussion*—All cold-reduced flat material with thickness less than 0.1875 in. [5.00 mm] and width 0.375 in. [9.50 mm] and over is classified as strip.

3.1.2 *billets, n*—semi-finished products, typically produced by rolling, forging, or continuous casting, that require subsequent hot working by rolling, forging, or extrusion; typically have a cross-section area of 36 in.^{2} [230 cm^2] or less and shape that is square or rectangular with width less than twice the thickness; rectangular cross sections with width equal to or greater than twice the thickness are classified as slabs or sheet bars.

3.1.3 *blooms, n*—semi-finished products, typically produced by rolling or continuous casting, that require subsequent hot working by rolling or forging; typically have a cross section area of greater than 36 in.^{2} [230 cm^2] and shape that is square or rectangular with width less than twice the thickness; rectangular cross sections with width equal to or greater than twice the thickness are classified as slabs or sheet bars.

3.1.4 *condition, n*—identification of the final step or steps thermomechanical processing as required to describe the metallurgical state of the material as delivered (examples include hot-worked; hot-worked and annealed; hot-worked, annealed, and cold-worked for increased mechanical properties; and hot-worked, quenched, and tempered).

3.1.5 *dead lengths or exact lengths, n*—bars, typically hot-sheared, hot-sawed, or machine-cut after machine-straightening, meeting the permitted variations in length as listed in the tolerance tables of this specification.

3.1.6 *finish, n*—description of the surface finish and applicable dimensional tolerances of the product as delivered, most typically by identification of the process applied to the product, and identification of the applicable category of product dimensional tolerances; examples of finishing operations include blasting, pickling, rough turning, machine straightening, centerless grinding, polishing, and light cold drawing for surface finish but not for increased mechanical properties; see also 8.1.1 for *hot-finished* bars and 8.1.3 for *cold-finished* bars.

3.1.7 *forgings, n*—parts, including bars, billets, semi-finished products, or complex shapes, produced by hot mechanical working using hammers, presses, or forging machines.

3.1.8 *multiple lengths, n*—lengths that are specified as containing a predetermined number of units of length associated with production of a particular part, commonly including an allowance of ¼ in. [6.5 mm] per unit for cutting to insure obtaining the required number of pieces.

3.1.9 *random lengths, n*—a length range not less than 24 in. [1 m]; for example, 10 to 12 ft [3 to 4 m], 14 to 17 ft [4 to 5 m], or 15 to 20 ft [5 to 6 m].

3.1.10 *shapes, n*—bar having a cross section other than circular, rectangular, or hexagonal.

3.1.11 *slabs or sheet bars, n*—products, typically produced by blooming, slabbing, or sheet bar mills or by continuous casting, that are shipped without further hot working to be further processed into plate, sheet, or strip; it is permitted to heat treat, cut to shape, or surface condition a slab or sheet bar.

4. Ordering Information

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

4.1.1 Quantity (weight or number of pieces),

4.1.2 Dimensions, including shape or form with diameter or width and thickness as applicable, length, and prints or sketches as applicable,

4.1.3 Type or UNS designation,

4.1.4 ASTM specification designation and edition year if other than the latest edition,

4.1.5 Condition,

4.1.6 Finish,

4.1.7 Supplementary Requirements when invoked,

4.1.8 Whether bars are to be rolled as bars or cut from strip or plate, when applicable,

4.1.9 Preparation for delivery,

4.1.10 Marking requirements,

4.1.11 Surface preparation, for shapes, and

4.1.12 Special requirements.

NOTE 1—A typical ordering description is as follows: 5000 lb [2000 kg]; 1.000 in. [25 mm] round bar by 10 to 12 ft [3 to 4 m]; Type 304 or S30400; Specification A479/A479M; annealed, centerless ground; plus optional requirements, such as special marking instructions.

5. Materials and Manufacture

5.1 The material shall be made by any process.

5.2 The material shall be furnished in one of the conditions detailed in the applicable product specification, for example, hot-worked; hot-worked and annealed; hot-worked, annealed, and cold-worked; or hot-worked, annealed, and heat-treated.

5.3 The material shall be furnished in one of the finishes as detailed in Section 8 or further described in the applicable product specification, for example, hot-finished or cold-finished.

6. Chemical Composition

6.1 *Heat or Cast Analysis*—The chemical analysis of each heat shall be determined in accordance with the applicable materials specification and Test Methods, Practices, and Terminology A751.

6.1.1 The analysis of each heat shall be made from a test sample taken during the pouring of the melt or from the in-process product later in the manufacturing flow.

6.1.2 The heat analysis shall conform to the chemical requirements for each of the specified elements for the grade ordered, as listed in the applicable product specification.

6.1.3 All commercial metals contain small amounts of elements other than those which are specified. It is neither practical nor necessary to specify limits for unspecified elements that can be present. The producer is permitted to analyze for unspecified elements and is permitted to report such analyses. The presence of an unspecified element and the reporting of an analysis for that element shall not be a basis for rejection unless the presence of that element cause the loss of a property typically expected for that metal, for the type and quality ordered.

6.1.4 The purchaser is permitted to require in the purchase order a maximum limit for an individual element not specified in the product specification. Such a requirement for an element not listed in the product specification, when acknowledged in the order acceptance, shall be treated as a specified element, with determination of chemical analysis and reporting of that analysis.

6.1.5 The purchaser is permitted to make the requirements for any element more stringent, that is, require higher minimums for elements having minimum requirements or ranges with minimum requirements, or requiring lower maximums for elements having specified maximums, or ranges with maximums. The purchaser is not permitted to make chemical requirements less stringent.

6.1.6 Analysis limits shall be established for specific elements rather than groups of elements, including but not limited to *all others*, *rare earths*, and *balance*, unless all elements in such a group are similar in technical effect and are associated in typical methods of chemical analysis.

6.2 *Product Analysis*—When required, a product analysis shall be determined in accordance with Test Methods, Practices, and Terminology A751. The chemical composition thus determined shall conform to the tolerances shown in Table 1.

6.2.1 When the product requirement includes a ratio requirement that is the quotient of two, or more, elements, the minimum required ratio determined from product analysis shall be at least 0.90× the minimum in the product specification.

6.3 The steel shall not contain an unspecified element for the ordered grade to the extent that the steel conforms to the requirements of another grade in the referencing product specification, and any of the product specifications within the scope of this general requirements specification, for which that element has a specified minimum.

7. Heat Treatment

7.1 The heat treatments shown in this section are to be followed unless otherwise specified in the applicable product specification.

7.2 *Austenitic Grades:*

7.2.1 Except for strain-hardened grades (see 7.2.4), hot-rolled grades (see 7.2.5), and UNS N08020 (see 7.2.6), all austenitic stainless steels shall be furnished in the solution annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.2.2 Except as indicated in Table 2, the austenitic grades shall be annealed, at the option of the manufacturer, by a separate annealing treatment or by process annealing.

7.2.2.1 The separate annealing treatment shall consist of heating the material to the minimum annealing temperature for the grade as listed in Table 2, holding for a sufficient time to permit grain boundary carbides to enter into solution, and cooling rapidly enough to prevent unacceptable grain boundary carbide precipitation. Except as indicated in Table 2, austenitic stainless steels solution annealed by a separate annealing treatment shall be capable of meeting the requirements of Practice E of Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.2.2 Process annealing shall consist of completing hot working above the minimum annealing temperature required

TABLE 1 Product Analysis Tolerances

NOTE 1—This table specifies tolerances over the maximum limits or under the minimum limits of the chemical requirements of the applicable material specification (see 1.1); it does not apply to heat analysis.

Element	Upper Limit of Maximum of Specified Range, %	Tolerances over the Maximum (Upper Limit) or Under the Minimum (Lower Limit)
Carbon	to 0.010, incl	0.002
	over 0.010 to 0.030, incl	0.005
	over 0.030 to 0.20, incl	0.01
	over 0.20 to 0.60, incl	0.02
	over 0.60 to 1.20, incl	0.03
Manganese	to 1.00, incl	0.03
	over 1.00 to 3.00, incl	0.04
	over 3.00 to 6.00, incl	0.05
	over 6.00 to 10.00, incl	0.06
	over 10.00 to 15.00, incl	0.10
	over 15.00 to 20.00, incl	0.15
Phosphorus	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
Sulfur	to 0.040, incl	0.005
	over 0.040 to 0.20, incl	0.010
	over 0.20 to 0.50, incl	0.020
Silicon	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 7.00 incl	0.15
Chromium	over 4.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 20.00, incl	0.20
	over 20.00 to 30.00, incl	0.25
Nickel	to 1.00, incl	0.03
	over 1.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
	over 20.00 to 30.00, incl	0.20
	over 30.00 to 40.00, incl	0.25
	over 40.00	0.30
Molybdenum	over 0.20 to 0.60, incl	0.03
	over 0.60 to 2.00, incl	0.05
	over 2.00 to 7.00, incl	0.10
	over 7.00 to 15.00, incl	0.15
	over 15.00 to 30.00, incl	0.20
Titanium	to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.07
	over 3.00	0.10
Cobalt	over 0.05 to 0.50, incl	0.01
	over 0.50 to 2.00, incl	0.02
	over 2.00 to 5.00, incl	0.05
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 15.00, incl	0.15
	over 15.00 to 22.00, incl	0.20
	over 22.00 to 30.00, incl	0.25
Columbium[A] + Tantalum	to 1.50, incl	0.05
	over 1.50 to 5.00, incl	0.10
	over 5.00	0.15
Tantalum	to 0.10, incl	0.02
Copper	to 0.50, incl	0.03
	over 0.50 to 1.00, incl	0.05
	over 1.00 to 3.00, incl	0.10
	over 3.00 to 5.00, incl	0.15
	over 5.00 to 10.00, incl	0.20
Aluminum	to 0.15, incl	−0.005, +0.01
	over 0.15 to 0.50, incl	0.05
	over 0.50 to 2.00, incl	0.10
	over 2.00 to 5.00, incl	0.20
	over 5.00 to 10.00, incl	0.35
Nitrogen	to 0.02, incl	0.005
	over 0.02 to 0.19, incl	0.01
	over 0.19 to 0.25, incl	0.02
	over 0.25 to 0.35, incl	0.03
	over 0.35 to 0.45, incl	0.04
	over 0.45	0.05
Tungsten	to 1.00, incl	0.03
	over 1.00 to 2.00, incl	0.05
	over 2.00 to 5.00, incl	0.07
	over 5.00 to 10.00, incl	0.10
	over 10.00 to 20.00, incl	0.15
Vanadium	to 0.50, incl	0.03
	over 0.50 to 1.50, incl	0.05
Selenium	all	0.03

[A] Columbium (Cb) and niobium (Nb) are considered interchangeable names for element 41 in the periodic table and both names are acceptable for use.

for each grade as indicated in Table 2, and cooling rapidly enough to prevent unacceptable grain boundary carbide precipitation. Except as indicated in Table 2, austenitic stainless steels solution annealed by process annealing shall be capable of meeting the requirements of Practice E of Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.3 For the stabilized grades, Types 321, 321H, 347, 347H, 348, and 348H, the manufacturer is permitted, if necessary, to use a lower temperature resolution anneal or a stabilization anneal after a high temperature anneal in order to maximize resistance to intergranular corrosion.

NOTE 2—Solution annealing temperatures above 1950 °F [1065 °C] may impair the resistance to intergranular corrosion after subsequent exposure to sensitizing conditions for the stabilized grades. When intergranular corrosion is of concern, the purchaser should specify Practice E of Practices A262 (to be conducted on specimens exposed to a sensitizing treatment). Consideration should be given to the corrosive media before using a stabilization anneal at less than 1800 °F [980 °C], as such a treatment may not be fully effective for all media.

7.2.4 *Strain-hardened Austenitic Grades*—When a particular austenitic grade is desired with increased mechanical properties, the purchaser is permitted to specify a strain hardened condition. This condition is produced by solution annealing the product in accordance with Table 2, followed by strain hardening sufficient to meet the required mechanical properties. Annealing in accordance with Table 2 is permitted between strain hardening steps. The solution annealed and strain hardened material shall be capable of meeting the intergranular corrosion test requirements of Practice E of

TABLE 2 Annealing Requirements

Designation/Type	Temperature[A]	Cooling/Testing Requirements	Permitted Annealing[B]	
			Separate	Process
	Austenitic (Chromium-Nickel) (Chromium-Nickel-Manganese)			
All austenitic grades except as listed below	1900 °F [1040 °C]	C	x	x[D]
All Cr-Ni-Mn grades, 302, S30215, S30452, S30600, S30615, 308, S30815, S30880, 309, 309S, 310, 310S, 314, 317, S31725, S31726, S32615, S38100	1900 °F [1040 °C]	E	x	x[D]
309Cb, 310Cb, 316Cb, 316Ti, 321, 347, 348	1900 °F [1040 °C]	E	x	
304H, 309H, 310H, 316H	1900 °F [1040 °C]	E	x	
321H, 347H, 348H				
Hot-worked	1925 °F [1050 °C]	E	x	
Cold-worked	2000 °F [1095 °C]	E	x	
S31254, S32050	2100 °F [1150 °C]	E	x	
S31727, S32053	1975 to 2155 °F [1080° to 1180 °C]	E	x	
S33228	2050 to 2140 °F [1120° to 1170 °C]	E	x	
S34565	2050 to 2140 °F [1120° to 1170 °C]	E	x	
S34752	1940 to 2140 °F [1060° to 1170 °C]	E	x	
S35315	2010 °F [1100 °C]	E	x	
N08367	2025 °F [1105 °C]	E	x	
N08700	2000 °F [1095 °C]	E	x	
N08020	1700 to 1850 °F [930 to 1010 °C]	E	x	
N08810	2050 °F [1120 °C]	E	x	
N08811	2100 °F [1150 °C]	E	x	
N08904	2000 °F [1095 °C]	E	x	
N08925, N08926	2010 to 2100 °F [1100 to 1150 °C]	E	x	
	Austenitic-Ferritic (Duplex)			
S32100	1900 °F [1040 °C]	E	x	x[F]
S31260	1870° to 2010 °F [1020° to 1100 °C]	E	x	x[F]
S31266	2100 °F [1150 °C]	E	x	
S31803	1900 °F [1040 °C]	E	x	x[F]
S32101	1870 °F [1020 °C]	E	x	x[F]
S32202	1800 to 1975 °F [980 to 1080 °C]	E	x	x[F]
S32205	1900 °F [1040 °C]	G	x	x[F]
S32304	1800 °F [980 °C]	E	x	x[F]
S32506	1870° to 2050 °F [1020° to 1120 °C]	E	x	x[F]
S32550	1900 °F [1040 °C]	E	x	x[F]
S32750	1880 °F [1025 °C]	E	x	x[F]
S32760	2010 °F [1100 °C]	E	x	x[F]
S32808	1925 to 2100 °F [1050 to 1150 °C]	E	x	x[F]
S32900	1750° ± 25 °F [955°± 15 °C]	E	x	x[F]
S32906	1830° to 2100 °F [1000° to 1150 °C]	E	x	x[F]
S32950	1850° ± 25 °F [1010°± 15 °C]	E	x	x[F]
S82441	1830 °F [1000 °C]	E	x	x[F]

[A] Minimum annealing temperature unless otherwise specified.
[B] Permitted annealing procedure, see 7.2.2.
[C] Quenched in water or rapidly cooled by other means at a rate sufficient to prevent reprecipitation of carbides, as demonstrable by the capability of passing Practice E of Practices A262. Performance of the test is not required unless specified in the purchase order.
[D] Minimum temperature at which hot rolling is completed shall be 1850 °F [1010 °C].
[E] Quenched in water or rapidly cooled by other means.
[F] Minimum temperature at which hot rolling is completed shall be the minimum temperature for separate annealing.
[G] Quenched in water.

Practices A262. Practice E of Practices A262 is not required unless specified on the purchase order.

7.2.4.1 Individual product specifications are permitted to define particular strain hardened conditions as functions of grade, size, and degree of strain hardening.

7.2.5 *Hot-rolled Austenitic Grades*—Individual product specifications are permitted to define requirements for particular hot-rolled austenitic grades without annealing.

7.2.6 Except when strain-hardened (see 7.2.4), UNS N08020 shall be furnished in the stabilized annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.3 *Austenitic-Ferritic (Duplex) Grades:*

7.3.1 The austenitic-ferritic (duplex) grades shall be furnished in the solution annealed condition in accordance with Table 2, with subsequent light cold drawing for cold finishing and straightening permitted.

7.3.2 Except as indicated in Table 2, the duplex grades shall be annealed, at the option of the manufacturer, by a separate annealing treatment or by process annealing.

7.3.2.1 The separate annealing treatment shall consist of heating the material to the minimum annealing temperature for the grade as listed in Table 2, holding for a sufficient time to permit dissolution of intermetallic phases, and cooling rapidly enough to prevent unacceptable precipitation of intermetallic phases.

7.3.2.2 Process annealing shall consist of completing hot working above the minimum annealing temperature required for each grade as indicated in Table 2, and cooling rapidly enough to prevent unacceptable precipitation of intermetallic phases.

7.4 *Ferritic Grades*—Ferritic grades shall be annealed to meet their respective mechanical testing requirements as shown in the applicable product specification.

7.5 *Martensitic Grades:*

7.5.1 All martensitic grades shall be supplied in either the annealed condition or in the tempered condition as specified by the purchaser. Tempered material shall be normalized, or shall be liquid quenched from 1700 °F [925 °C], minimum, followed by tempering in accordance with 7.5.2, 7.5.3, or 7.5.4.

7.5.2 Types 403 and 410 tempered material shall be held at the tempering temperature for at least 1 h/in. [25.4 mm] of cross section as follows:

7.5.2.1 *Condition 1*—1250 °F [675 °C] minimum, 1400 °F [760 °C] maximum.

7.5.2.2 *Condition 2*—1100 °F [595 °C] minimum, 1400 °F [760 °C] maximum.

7.5.2.3 *Condition 3*—1050 °F [565 °C] minimum, 1400 °F [760 °C] maximum.

7.5.3 Types XM-30, 414, and 431 tempered materials shall be held at 1100 °F [595 °C], minimum for at least 1 h/in. [25 mm] of cross section. Maximum tempering temperature shall be 1400 °F [760 °C].

7.5.4 S41500 shall be heated to 1750 °F [955 °C] minimum, air cooled to 200 °F [95 °C] or lower prior to any optional intermediate temper and prior to the final temper. The final temper shall be between 1050 and 1150 °F [565 and 620 °C].

7.5.5 When the purchaser elects to perform the hardening and tempering heat treatment, martensitic materials shall be supplied by the manufacturer in the annealed condition (see 7.5.1). In this case the purchaser shall be responsible to apply the proper heat treatment and to conduct the tests deemed necessary to assure that the required properties are obtained.

8. Finish

8.1 The following types of finishes are permitted, as applicable to the product ordered:

8.1.1 *Hot-finished Bars*—Hot-finished bars shall have the surface finish that results from hot processing, with or without certain additional surface modification. Hot-finished bars are commonly produced by hot rolling, forging, pressing, extruding, or similar hot working procedures applied to ingots, blooms, or billets. The resulting products are typically subject to various additional operations affecting the surface of the bars, including but not limited to one or more of the following: annealing or other heat treatment; cleaning by blasting, pickling, or other descaling methods; rough turning; and machine straightening. The producer is permitted to use centerless grinding, polishing, or other operations commonly associated with cold finishing in order to provide improved dimensional tolerances or surface condition for the hot-finished bar. The dimensional tolerances applicable to hot-finished bars are less stringent than those applicable to cold-finished bars.

8.1.2 *Bars Cut from Strip or Plate*—Bars cut from flat-rolled stainless steel products shall have two surfaces that are pickled or descaled, and two cut surfaces, except when the bar is heat treated subsequent to cutting, in which case all surfaces shall be descaled or pickled.

8.1.3 *Cold-finished Bar*—Cold-finished bars shall have the surface finish that results from hot-finished bars being further processed by additional mechanical operations on the surface of the bar, including but not limited to light cold drawing, burnishing, centerless grinding, and polishing to provide closer tolerances and improved surface finish. The dimensional tolerances applicable to cold-finished bars are more stringent than those applicable to hot-finished bars.

8.1.4 *Bars and Billets or Other Semi-finished Material for Reforging*—Material intended for reforging shall be delivered in the hot-finished condition or in the cold-drawn condition. The cold-drawn condition alternative is only permitted for austenitic and austenitic-ferritic stainless steel forgings. When delivered in the hot-finished condition, it is permitted to condition the surface by removing surface defects provided that the depth of the conditioning does not exceed that which affects the surface condition or dimensions of the article to be forged from the bar or billet. When delivered in the cold-drawn condition, it is permitted to hot forge forgings from cold-drawn bar provided this bar has been cold-drawn from material in the solution-annealed condition.

8.1.5 *Shapes*—Shapes shall be descaled by machining, grinding, blasting, or pickling.

8.1.5.1 Shapes shall be subject to either Class A or Class C surface preparation as specified on the purchase order. Class A consists of grinding for the removal of imperfections of a hazardous nature, such as fins, tears, and jagged edges, provided the underweight tolerance is not exceeded and the maximum depth of grinding at any one point does not exceed 10 % of the thickness of the section. Class C consists of grinding for the removal of all visible surface imperfections, provided that the underweight tolerance is not exceeded and the maximum depth of grinding at any point does not exceed 10 % of the thickness of the section.

8.1.6 *Forgings*—Forgings shall be descaled by machining, blasting, or pickling. The selection of the descaling methods shall be at the option of the producer unless a particular descaling method is specified in the purchase order.

9. Dimensions, Mass, and Permissible Variations

9.1 Unless otherwise specified on the purchase order, the material shall conform to the permitted variations in dimensions as specified in the following:

9.1.1 *Bars*—Tables 3-12.

9.1.2 *Shapes*—Tables 13-19 and Figs. 1 and 2.

9.1.3 *Forgings*—As specified in the purchase order, or in prints or sketches accompanying the purchase order.

9.1.4 *Billets or Other Semi-finished Material for Reforging*—Billets and other semi-finished material shall conform to the shape and dimensions specified by the purchaser within a permitted variation of ±5 %.

TABLE 3 Permitted Variations in Size of Hot-finished Round, Turned,[A] and Square Bars

Specified Size, in. [mm]	Permitted Variations from Specified Size, in. [mm]		Out-of-Round[B] or Out-of-Square,[C] in. [mm]
	Over	Under	
5/16 to 7/16 [8.00 to 11.00], incl[D]	0.006 [0.15]	0.006 [0.15]	0.009 [0.23]
Over 7/16 to 5/8 [11.00 to 15.50], incl[D]	0.007 [0.18]	0.007 [0.18]	0.010 [0.26]
Over 5/8 to 7/8 [15.50 to 22.00], incl	0.008 [0.20]	0.008 [0.20]	0.012 [0.30]
Over 7/8 to 1 [22.00 to 25.00], incl	0.009 [0.23]	0.009 [0.23]	0.013 [0.34]
Over 1 to 1 1/8 [25.00 to 28.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 1/8 to 1 1/4 [28.00 to 31.50], incl	0.011 [0.28]	0.011 [0.28]	0.016 [0.42]
Over 1 1/4 to 1 3/8 [31.50 to 34.50], incl	0.012 [0.30]	0.012 [0.30]	0.018 [0.46]
Over 1 3/8 to 1 1/2 [34.50 to 38.00], incl	0.014 [0.35]	0.014 [0.35]	0.021 [0.53]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/64 [0.40]	1/64 [0.40]	0.023 [0.60]
Over 2 to 2 1/2 [50.00 to 63.00], incl	1/32 [0.80]	0	0.023 [0.60]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	3/64 [1.20]	0	0.035 [0.90]
Over 3 1/2 to 4 1/2 [90.00 to 115.00], incl	1/16 [1.60]	0	0.046 [1.20]
Over 4 1/2 to 5 1/2 [115.00 to 140.00], incl	5/64 [2.00]	0	0.058 [1.50]
Over 5 1/2 to 6 1/2 [140.00 to 165.00], incl	1/8 [3.00]	0	0.070 [1.80]
Over 6 1/2 to 8 [165.00 to 200.00], incl	5/32 [4.00]	0	0.085 [2.20]
Over 8 to 12 [200.00 to 300.00], incl[A]	3/16 [4.80]	0	3/32 [2.40]
Over 12 to 15 [300.00 to 400.00], incl[A]	7/32 [5.50]	0	7/64 [2.80]
Over 15 to 25 [400.00 to 625.00], incl[A]	1/4 [6.50]	0	1/8 [3.20]

[A] Turned bars are generally available from 2 to 25 in. [50 to 625 mm] in diameter, over 8 in. [200 mm] only turned bars are available.
[B] Out-of-round is the difference between the maximum and minimum diameters of the bar measured at the same cross section.
[C] Out-of-square section is the difference in the two dimensions at the same cross section of a square bar, each dimension being the distance between opposite faces.
[D] Size tolerances have not been evolved for round sections in the size range of 5/16 in. [8.00 mm] to approximately 5/8 in. [15.5 mm] in diameter which are produced on rod mills in coils.

TABLE 4 Permitted Variations in Size of Hot-finished Hexagonal and Octagonal Bar

Specified Sizes Measured Between Opposite Sides, in. [mm]	Permitted Variations from Specified Size, in. [mm]		Maximum Difference in 3 Measurements for Hexagons Only, in. [mm]
	Over	Under	
1/4 to 1/2 [6.50 to 13.00], incl	0.007 [0.18]	0.007 [0.18]	0.011 [0.28]
Over 1/2 to 1 [13.00 to 25.00], incl	0.010 [0.25]	0.010 [0.25]	0.015 [0.38]
Over 1 to 1 1/2 [25.00 to 38.00], incl	0.021 [0.53]	0.021 [0.53]	0.025 [0.64]
Over 1 1/2 to 2 [38.00 to 50.00], incl	1/32 [0.80]	1/3 [0.80]	1/32 [0.80]
Over 2 to 2 1/2 [50.00 to 63.00], incl	3/64 [1.20]	3/64 [1.20]	3/64 [1.20]
Over 2 1/2 to 3 1/2 [63.00 to 90.00], incl	1/16 [1.60]	1/16 [1.60]	1/16 [1.60]

TABLE 5 Permitted Variations in Thickness and Width for Hot-finished Flat Bars Rolled as Bars

Specified Width, in. [mm]	Permitted Variations in Thickness for Thicknesses Given, in. [mm]												Permitted Variations in Width, in. [mm]	
	1/8 to 1/2 [3.2 to 13], incl		Over 1/2 to 1 [13 to 25], incl		Over 1 to 2 [25 to 50], incl		Over 2 to 4 [50 to 100], incl		Over 4 to 6 [100 to 150], incl		Over 6 to 8 [150 to 200], incl			
	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under	Over	Under
To 1 [25.00], incl	0.008 [0.20]	0.008 [0.20]	0.010 [0.25]	0.010 [0.25]	...	...	...	...	...	...	...	...	0.015 [0.40]	0.015 [0.40]
Over 1 to 2 [25.00 to 50.00], incl	0.012 [0.30]	0.012 [0.30]	0.015 [0.40]	0.015 [0.40]	0.031 [0.80]	0.031 [0.80]	...	...	...	...	...	...	0.031 [0.80]	0.031 [0.80]
Over 2 to 4 [50.00 to 100.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	...	...	...	...	0.062 [1.60]	0.031 [0.80]
Over 4 to 6 [100.00 to 150.00], incl	0.015 [0.40]	0.015 [0.40]	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	...	...	0.093 [2.40]	0.062 [1.60]
Over 6 to 8 [150.00 to 200.00], incl	0.016 [0.40]	0.016 [0.40]	0.025 [0.65]	0.025 [0.65]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.125 [3.20]	0.156 [4.00]
Over 8 to 10 [200.00 to 250.00], incl	0.020 [0.50]	0.020 [0.50]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.031 [0.80]	0.062 [1.60]	0.031 [0.80]	0.093 [2.40]	0.062 [1.60]	0.125 [3.20]	0.156 [4.00]	0.156 [4.00]	0.187 [4.80]

10. Workmanship, Finish, and Appearance

10.1 The material shall be of uniform quality consistent with good manufacturing and inspection practices. Imperfections shall be of such a nature or degree for the type and quality ordered, that they shall not adversely affect the forming, machining, or fabrication of finished parts.

TABLE 6 Permitted Variations in Dimensions for Flat Bars Cut from Strip or Plate

Order Thickness	Permitted Variation in Thickness, in. [mm]		Permitted Variation[A] in Width				Permitted Variation in Length[B]	
			Widths to 4 [100]		Widths Over 4 [100]			
	Over	Under	Over	Under	Over	Under	Over	Under
Over 0.114 to 0.130 [2.90 to 3.30], incl	0.010 [0.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.130 to 0.145 [3.30 to 3.70], incl	0.012 [0.30]	0.012 [0.30]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
Over 0.145 to less than 3/16, [3.70 to 4.80]	0.014 [0.35]	0.014 [0.35]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3/16 to 3/8 [4.80 to 9.00], excl	0.050 [1.25]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3/8 to 3/4 [9.00 to 19.00], excl	0.060 [1.50]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
3/4 to 1 [19.00 to 25.00], excl	0.065 [1.65]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
1 to 2 [25.00 to 50.00], excl	0.075 [1.90]	0.010 [0.25]	0.094 [2.40]	0.031 [0.80]	0.094 [2.40]	0.094 [2.40]	0.188 [4.80]	0
2 to 3 [50.00 to 75.00], excl	0.150 [3.80]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
3 to 4 [75.00 to 100.00], excl	0.210 [5.30]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
4 to 6 [100.00 to 150.00], excl	0.300 [7.60]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
6 to 8 [150.00 to 200.00], excl	0.420 [10.65]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0
8 to 10 [200.00 to 250.00], excl	0.540 [13.70]	0.010 [0.25]	0.125 [3.00]	0.062 [1.60]	0.125 [3.00]	0.125 [3.00]	0.250 [6.50]	0

[A] By agreement between purchaser and seller, tolerances can be shifted as desired to any combination of plus-minus tolerance between all minus and all plus.
[B] Not applicable when bars are ordered random length.

TABLE 7 Permitted Variations in Size of Cold-finished Round Bars

Specified Size, in. [mm]	Permitted Variations from Specified Size, in. [mm][A,B]	
	Over	Under
1/16 to 5/16 [1.50 to 8.00], excl	0.001 [0.03]	0.001 [0.03]
5/16 to 1/2 [8.00 to 13.00], excl	0.0015 [0.04]	0.0015 [0.04]
1/2 to 1 [13.00 to 25.00], excl	0.002 [0.05]	0.002 [0.05]
1 to 1 1/2 [25.00 to 38.00], excl	0.0025 [0.06]	0.0025 [0.06]
1 1/2 to 3 1/4 [38.00 to 83.00], incl[C]	0.003 [0.08]	0.003 [0.08]
3 1/4 to 4 [83.00 to 100], incl[C]	0.005 [0.13]	0.005 [0.13]

[A] Unless otherwise specified, size tolerances are over and under as shown in the above table. When required, however, they may be specified all over and nothing under, or all under and nothing over, or any combination of over and under, if the total spread in size tolerance for a specified size is not less than the total spread shown in the table.
[B] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.
[C] Cold-finished bars over 4 in. [100 mm] in diameter are produced; size tolerances for such bars are not included herein.

TABLE 8 Permitted Variations in Size of Cold Finished Hexagonal, Octagonal, and Square Bars

Specified Size,[A] in. [mm]	Permitted Variations from Specified Size, in. [mm][B]	
	Over	Under
1/8 to 5/16 [3.00 to 8.00], excl	0	0.002 [0.05]
5/16 to 1/2 [8.00 to 13.00], excl	0	0.003 [0.08]
1/2 to 1 [13.00 to 25.00], incl	0	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0	0.006 [0.15]
Over 2 to 3 [50.00 to 75.00], incl	0	0.008 [0.20]
Over 3 [75.00]	0	0.010 [0.25]

[A] Distance across flats.
[B] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.

11. Sampling

11.1 A lot for product analysis shall consist of all bars, shapes, or forgings made from the same heat.

11.2 For other tests required by the product specification, a lot shall consist of all bar products of the same size, or forgings weighing less than 1000 lb [500 kg] each, from the same heat, and produced under the same processing conditions. All austenitic, ferritic, austenitic-ferritic, and free-machining grades, martensitic grades annealed to Condition A, and precipitation or age-hardening grades when solution treated are permitted to be heat treated in the same furnace or in several furnaces utilizing controlled processing and equipment (see Appendix X1). When heat treating martensitic stainless steels to Condition T or H, and when age hardening the precipitation hardening grades, a lot shall consist of the same size, same heat, and the same heat treat charge in a batch-type furnace or under the same conditions in a continuous furnace.

11.2.1 For forgings weighing from 1000 lb [500 kg] to 5000 lb [2500 kg] each, a lot shall consist of one size classification from each heat and each heat-treating charge. Where continuous heat-treating furnaces are used, a lot shall consist of one size classification from each heat, heated in a period of 8 h or less.

11.2.2 For all classes of forgings weighing from 5000 to 7000 lb [2300 to 3200 kg], each unit shall be considered a lot.

11.2.3 For all classes of forgings weighing more than 7000 lb [3200 kg], each unit shall be considered a double lot, and two tension tests shall be required, one from each end of each forging. In the case of ring forgings, the tension test specimens shall be removed from each of two locations on the

TABLE 9 Permitted Variations in Width and Thickness of Cold-finished Flat Bars

Width, in. [mm]	Permitted Variations in Width, Over and Under, in. [mm][A]	
	For Thicknesses ¼ in. [6.5] and Under	For Thicknesses Over ¼ in. [6.5]
1/16 to 3/8 [1.50 to 9.50], incl	0.005 [0.12]	0.005 [0.12]
Over 3/8 to 1 [9.50 to 25.00], incl	0.004 [0.10]	0.004 [0.10]
Over 1 to 2 [25.00 to 50.00], incl	0.006 [0.15]	0.004 [0.10]
Over 2 to 3 [50.00 to 75.00], incl	0.008 [0.20]	0.004 [0.10]
Over 3 to 4½ [75.00 to 115.00], incl	0.010 [0.25]	0.005 [0.13]
Thickness, in. [mm]	Permitted Variations in Thickness, Over and Under, in. [mm][A]	
Up to .029 [0.70], incl	0.001 [0.03]	
Over .029 to .035 [0.70 to 1.00], incl	0.0015 [0.04]	
Over .035 to 1 [1.00 to 25.00], incl	0.002 [0.05]	
Over 1 to 2 [25.00 to 50.00], incl	0.003 [0.08]	
Over 2 to 3 [50.00 to 75.00], incl	0.004 [0.10]	
Over 3 to 4½ [75.00 to 115.00], incl[B]	0.005 [0.13]	

[A] When it is necessary to heat treat or heat treat and pickle after cold finishing, size tolerances are double those shown in the table.
[B] Cold-finished flat bars over 4½ in. [115 mm] wide or thick are produced; width and thickness tolerances for such bars are not included herein.

TABLE 10 Permitted Variations in Length of Hot-finished or Cold-finished Bars

Specified Size of Rounds, Squares, Hexagons, Octagons, and Widths of Flats,[A] in. [mm]	Permitted Variations in Length, in. [mm][B]			
	For Lengths up to 12 ft[C] [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
Up to 6 [150.00], incl	1 [25]	0	1¼ [31.50]	0
Over 6 to 9 [150.00 to 225.00], incl	1¼ [31.5]	0	1½ [38.00]	0
Over 9 to 12 [225.00 to 300.00], incl	1½ [38]	0	2 [50.00]	0

[A] The maximum width of bar flats is 10 in. [250 mm].
[B] Random Lengths—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.
[C] For lengths under 3 ft [1 m] and sizes up to ½ in. [13.00 mm] incl., the permissible variation in length is 1/32 in. [0.80 mm] over and nothing under.

TABLE 11 Permitted Variations in Length of Hot-finished or Cold-finished Bars Machine Cut After Machine Straightening[A]

NOTE 1—These tolerances are not applicable when bars are ordered random length.

Specified Size of Rounds, Squares, Hexagons, Octagons, and Width of Flats,[B] in. [mm]	Permitted Variations in Length, in. [mm]			
	For Lengths up to 12 ft [4 m], incl		For Lengths Over 12 to 25 ft [4 to 8 m], incl	
	Over	Under	Over	Under
To 3 [75], incl		0		0
Over 3 [75] to 12 [225 to 300], incl	½ [13.0]	0	½ [13.0]	0

[A] Table 11 does not apply to product produced on coil to bar equipment.
[B] The maximum width of bar flats is 10 in. [250 mm].

TABLE 12 Permitted Variations in Straightness of Machine Straightened Hot-finished or Cold-finished Bars[A]

NOTE 1—Measurement is taken on the concave side of the bar with a straightedge. Unless otherwise specified, hot-finished or cold-finished bars for machining purposes are furnished machine straightened to the following tolerances.

Hot-finished
1/8 in. [3.00 mm] in any 5 ft [1.50 m]; but may not exceed 1/8 in. [3.00 mm] × (length in ft/5) [m/1.50]
Cold-finished
1/16 in. [1.5 mm] in any 5 ft [1.5 m]; but may not exceed 1/16 in. [1.5 mm] × (length in ft/5) [m/1.50]

[A] Straightness tolerances have not been established for sizes less than ½ in. [13.00 mm].

TABLE 13 Permitted Variations for Hot-finished Angles

NOTE 1—For unequal leg angles, the longer leg determines the tolerance for the length of each leg.

Weight[A]
For angles of 6 lb/ft [9.0 kg/m] or less, the weight tolerances shall not exceed ±7½ %. For angles over 6 lb/ft [9 kg/m], the weight tolerance shall not exceed ±4½ %.
Length of Legs
For angles having legs or flanges up to 6 in. [150 mm], incl, the length tolerance shall not exceed ±1/8 in. [3.00 mm]. For angles having legs or flanges over 6 in., the length tolerance shall not exceed +3/16 in. [5.00 mm] and –1/8 in.
Squareness of Legs
The tolerance for the right angle between the legs is ±2°.

[A] For equal leg angles, the theoretical weight per foot is:

$$\text{weight/foot} = (24\ W \times t - 12t^2)\ (0.2871\ \text{lb/ft})$$

where:
W = specified length of the leg, in inches, and
t = specified thickness, in inches.

For unequal leg angles, the theoretical weight per foot is:

$$\text{weight/foot} = [12\ W1 \times t + 12\ W2 \times t - 12t^2]\ (0.2871\ \text{lb/ft})$$

where:
$W1$ and $W2$ = specified leg lengths, in inches, and
t = specified leg thickness, in inches.

periphery, approximately 180° apart, and insofar as practicable, from opposite ends of the forging.

12. Number of Tests and Retests

12.1 Unless otherwise specified in the product specification, one sample per heat shall be selected for chemical analysis and one mechanical test sample shall be selected from each lot of bars and shapes and from each lot of forgings. Except for bars cut from strip or plate, tension tests of bars and shapes shall be made in the longitudinal direction or, at the manufacturer's option unless otherwise specified in the purchase order, in the transverse (through thickness) direction. Material tensile tested in the transverse direction and meeting the specified tensile property requirements need not be tested in the longitudinal direction. Testing for bars cut from strip or plate shall conform to the requirements of the applicable product specification for the strip or plate and to Specification A480/A480M. Hardness tests on bars shall be conducted midway between the center and surface of the product. Tension tests on forgings shall be prepared from suitable prolongations, or at the option of the supplier, excess forgings may be provided for test. All tests shall conform to the chemical and mechanical requirements of the product specification.

12.2 One intergranular corrosion test, when required, and one grain size test, when required shall be made on each lot. Often, it is convenient to obtain test material from the specimen selected for mechanical testing.

TABLE 14 Permitted Variations in Size of Hot-finished Channels

Specified Size of Channel, in. [mm]	Size Tolerances, Over and Under, in. [mm]				
	Depth of Section[A]	Width of Flanges	Thickness of Web for Thickness Given		Out-of-Square[B] of Either Flange, in./in. [mm/ mm] of Flange Width
			To 3/16 incl [5.00 mm]	Over 3/16 [5.00 mm]	
To 1½ [38.00], incl	3/64 [1.20]	3/64 [1.20]	0.015 [0.41]	0.023 [0.60]	3/64 [1.20]
Over 1½ to 3 [38.00 to 75.00], excl	3/32 [2.40]	3/32 [2.40]	0.023 [0.60]	0.030 [0.80]	3/64 [1.20]

[A] Channel depth is measured at back of web.
[B] For channels 5/8 in. [15.50 mm] and under in depth, the out-of-square tolerance is 5/64 in./in. [2.00 mm/mm] of depth. Out-of-squareness is determined by placing a square against the bottom surface of the web and measuring the amount of toe-in or toe-out of either flange. Measurements for depth of section and width of flanges are over-all.

TABLE 15 Permitted Variations in Size of Hot-finished Tees

Specified Size of Tee, in. [mm][A]	Width or Depth, in.[B]		Thickness of Flange, in. [mm]		Thickness of Stem, in. [mm]		Stem Out-of-Square[C] in. [mm]
	Over	Under	Over	Under	Over	Under	
To 1½ [38.00], incl.	5/64 [2.00]	5/64 [2.00]	0.015 [0.38]	0.015 [0.38]	0.008 [0.20]	0.030 [0.75]	3/64 [1.20]
Over 1½ to 2 [38.00 to 50.00], incl	3/32 [2.40]	3/32 [2.40]	0.018 [0.46]	0.018 [0.46]	0.015 [0.38]	0.030 [0.75]	3/32 [2.40]
Over 2 to 3 [50.00 to 75.00], excl	9/64 [3.60]	9/64 [3.60]	0.023 [0.60]	0.023 [0.60]	0.023 [0.60]	0.030 [0.75]	9/64 [3.60]

[A] The longer member of an unequal tee determines the size for tolerances.
[B] Measurements for both width and depth are over-all.
[C] Stem out-of-square is the variation from its true position of the center line of stem measured at the point.

TABLE 16 Permitted Variations in Size of Hot-extruded Shapes

Specified Size, in [mm]	Section Tolerances, in. [mm]	
	Over	Under
Dimensions under 1 [25]	0.020 [0.50]	0.020 [0.50]
Dimensions 1 to 3 [25 to 75], excl	0.031 [0.80]	0.031 [0.80]
Dimensions 3 to 4 [75 to 100], incl	0.046 [1.20]	0.046 [1.20]
Over 4 [100]	0.062 [1.60]	0.062 [1.60]

TABLE 17 Angularity Tolerance for Extruded Shapes

Plus and minus	max 2°

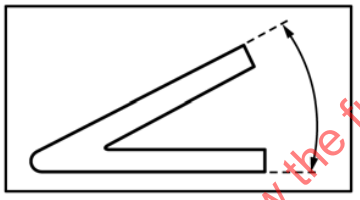


TABLE 18 Length Tolerances for Extruded Shape Length[A,B]

Specified Size	For Lengths up to 12 ft [4 m], incl.		For Lengths over 12 ft [4 m]	
	Over	Under	Over	Under
Up to 3 in. [75 mm], excl	3/16 in. [4.8 mm]	0	1/4 in. [6.5 mm]	0

[A] *Multiple Lengths*—Unless otherwise specified, 1/4 in. [6.5 mm] is added to the total length of each piece for each multiple contained.
[B] *Random Lengths*—When ordered as random lengths, permissible variation is 2 ft [0.6 m] over and under the specified length. When ordered as random lengths subject to a minimum length requirement, permissible variation is 2 ft [0.6 m] over and nothing under the specified length.

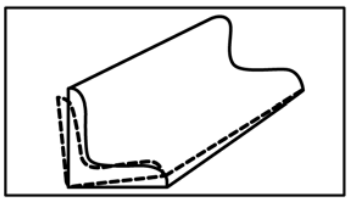
12.3 If any test specimen shows defective machining or flaws, it is permitted to discard the specimen and to substitute another specimen.

12.4 If the results of any test are not in conformance with the requirements of this specification or the requirements of the applicable product specification, it is permitted to retest a new sample of two specimens, to replace the original failed sample. If one of the retest specimens fails, the lot shall be rejected.

TABLE 19 Twist Tolerances

NOTE 1—The amount of spiraling in an extruded shape is called twist. It can be measured by the height of the high corner from a flat reference base (established rise).

NOTE 2—Using the following calculation the twist tolerance must not exceed what is shown in the table.



$$\text{rise in 5 ft} = \frac{\text{established rise} \times \text{number of ft in length}}{5}$$

Section Width	Rise in 5 ft
½ to 1½ in. [13 to 39 mm]	0.125 in. [3.00 mm]
Over 1½ to 4 in. [39 to 100 mm]	0.188 in. [4.80 mm]
Over 4 in. [100 mm]	0.250 in. [6.50 mm]

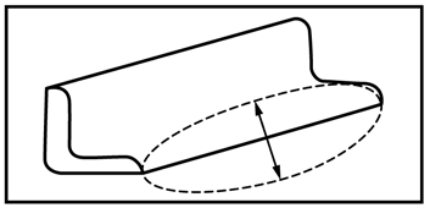
13. Retreatment

13.1 Where the failure of a lot is attributable to inadequate heat treatment, the producer may reheat treat the material and submit the retreated material for test.

14. Test Methods

14.1 The properties enumerated in the applicable product specification shall be tested in accordance with the following ASTM methods:

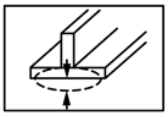
14.1.1 *Chemical Analysis*—Test Methods, Practices, and Terminology A751.



NOTE 1—Camber or bow tolerances shall not exceed 0.025 in. [0.60 mm] × length in ft [m/3].

Camber tolerances for hot finished or extruded shapes camber (or bow) is the greatest deviation of a side from a straight line. Measurement is taken on the concave side of the shapes with a straight edge.

FIG. 1 Camber or Bow Tolerances



NOTE 1—Allowable deviation from flat is max 0.010 in. [0.25 mm] per 1 in. [25 mm] of width. Maximum deviation on dimensions of less than 1 in. [25 mm] is 0.010 in. [0.250 mm].

The transverse flatness tolerance is the maximum deviation from a reference base across any cross-section flat surface.

FIG. 2 Transverse Flatness Tolerances

14.1.2 *Tension Tests*—Test Methods and Definitions A370.

14.1.3 *Stress Rupture*—Test Methods E139.

14.1.4 *Brinell Hardness*—Test Methods and Definitions A370.

14.1.5 *Rockwell Hardness*—Test Methods and Definitions A370.

14.1.6 *Intergranular Corrosion*—Practice E of Practices A262.

14.1.7 *Grain Size*—Test Methods E112.

14.1.8 *Charpy V-notch Impact Test*—Test Methods and Definitions A370.

15. Inspection

15.1 *Civilian Procurement*—Inspection of the material shall be as agreed upon between the purchaser and the supplier as part of the purchase contract.

15.2 *Government Procurement*—Unless otherwise specified in the contract or purchase order, the seller is responsible for the performance of all inspection and test requirements in this specification, the seller is permitted to use their own facilities or other suitable facilities for the performance of the inspection and testing, and the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy purchaser that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

16. Rejection and Rehearing

16.1 The purchaser is permitted to reject material that fails to conform to the requirements of this specification. Rejection shall be reported to the producer or supplier promptly, preferably in writing. In case of dissatisfaction with the results of a test, the producer or supplier is permitted to make claim for a rehearing.

17. Certification

17.1 A report of the results of all tests required by the product specification shall be supplied to the purchaser. This material test report shall reference the product specification designation and year date indicating that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the product specification and has been found to meet those requirements. The material test report shall report the melting process when the purchase order requires either a specific type of melting or requires that the melting process used is to be reported.

17.1.1 The report shall indicate the type of steel. If certifying that the material conforms to the requirements for more than one type of steel, the manufacturer may indicate each type of steel on the report, or may issue a separate report for each type of steel.

17.2 A signature is not required on the report. However, the document shall clearly identify the organization submitting the report. Not withstanding the absence of a signature, the organization submitting the document is responsible for its content.

17.3 A 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 shall meet the requirements of the invoked ASTM standard(s) and conform to any existing EDI agreement between the purchaser and the supplier. Not withstanding the absence of a signature, the organization submitting the EDI transmission is responsible for the content of the report.

NOTE 3—The industry definition of EDI invoked herein is the computer-to-computer exchange of business information in a standard format such as ANSI ASC X12.

17.4 When finished material is supplied to a purchase order specifying the product specification, the organization supplying that material shall provide the purchaser with a copy of the original manufacturer's test report.

17.4.1 When the original manufacturer's test report was provided by EDI to the organization supplying the finished material to the purchaser, the organization supplying the finished material shall provide to the purchaser a printed form of the original test report or shall retransmit the test report by EDI to the purchaser. In either case, the test report shall be complete with the full identification of the original manufacturer and with all data provided on the test report of the original manufacturer.

18. Product Marking

18.1 *Civilian Procurement:*

18.1.1 Bars and shapes shall be marked or tagged with the name of manufacturer, purchaser's name and order number, ASTM specification designation, heat number, grade or type, condition, finish, and where appropriate, the size, length, and weight. Unless otherwise specified, the method of marking is at

the option of the manufacturer. Marking shall be made by hot stamping, cold stamping, or painting of bars, or by marking tags attached to bundles, lifts, or boxes.

18.1.2 Forgings shall be legibly die stamped with the manufacturer's symbol or name, material specification designation, grade or type, and heat identification. When die stamping is not permitted by the purchaser, electric pencil or electro-etching shall be used.

18.2 *Government Procurement:*

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

18.2.2 For government procurement by the Defense Supply Agency, bars and shapes shall be marked continuously for identification in accordance with Fed. Std. No. 183.

19. Packaging and Package Marking

19.1 Unless otherwise specified, the bars and shapes shall be packaged and loaded in accordance with Practices A700.

19.2 When specified in the contract or order, and for direct procurement by or direct shipment to the government, when Level A is specified, preservation, packaging, and packing shall be in accordance with the Level A requirements of MIL-STD-163.

20. Keywords

20.1 general delivery requirements; stainless steel bars; stainless steel billets; stainless steel forgings; stainless steel shapes

ANNEXES

(Mandatory Information)

A1. REQUIREMENTS FOR INTRODUCTION OF NEW MATERIALS

A1.1 New materials may be proposed for inclusion in specifications referencing this specification, subject to the following conditions:

A1.1.1 The application for the addition of a new grade to a specification shall be made to the chair of the subcommittee that has jurisdiction over that specification.

A1.1.2 The application shall be accompanied by a statement from at least one user indicating that there is a need for the new grade to be included in the applicable specification.

A1.1.3 The application shall be accompanied by test data as required by the applicable specification. Test data from a minimum of three test lots, as defined by the specification, each from a different heat, shall be furnished.

A1.1.4 The application shall provide recommendations for all requirements appearing in the applicable specification.

A1.1.5 The application shall state whether the new grade is covered by patent.

A2. REQUIREMENTS FOR INTRODUCTION OF MATERIALS FROM OTHER A01 OR B02.07 SPECIFICATIONS

A2.1 Wrought materials that are already covered by another A01 or B02.07 specification may be proposed for inclusion in specifications referencing this specification of general requirements subject to the following conditions:

A2.1.1 Application for the addition of a grade that is already covered in another A01 or B02.07 specification shall be made to the chair of the subcommittee that has jurisdiction over that the specification to which the grade is to be added.

A2.1.2 The chemical requirements, the specified mechanical properties, and the heat treatment requirements of the grade being added shall be the same as those for the grade in the A01 or B02.07 specification in which the grade is presently covered.

A2.1.3 The application shall provide recommendations for all requirements appearing in the applicable specification.

A2.1.4 The application shall state whether or not the grade is covered by patent.

APPENDIXES

(Nonmandatory Information)

X1. RATIONALE REGARDING DEFINITION OF LOT FOR MECHANICAL PROPERTIES AND CORROSION TESTING

X1.1 It is generally recognized that material described as a lot must be "produced under the same processing conditions," which means the same manufacturing order number, same size, same heat, same heat-treating procedure, and same subsequent processing. Under those conditions, single samples can be selected to be representative of the total lot, with at least one sample for each 20 000 pounds of material.

X1.2 Following the principle described in X1.1 generally requires that the producer control each of several furnace loads constituting the same lot so that:

X1.2.1 Set point temperature and process tolerance match,

X1.2.2 Time at temperature for all thermal treatment shall match within 10 %,

X1.2.3 All furnaces used be similar in size and meet the uniformity requirements of a documented furnace quality assurance program, and

X1.2.4 The quench systems are the same with respect to volume, type of quenchant, and circulation rate.

X1.2.5 Further, it would be expected that grouped loads be handled within a relatively short time period, and that hardness testing be performed on at least one sample per charge.

X1.3 The old definition of a lot for mechanical testing based on simply the words "same size, heat, and heat treatment charge in a batch furnace" assumes that heat treating is the only process affecting properties. This kind of definition ignores the effects of other processing, prior to and subsequent to heat treating. Moreover, it assumes that each heat-treated batch will be uniform and unique rather than reproducible. In reality, heat treating is a process which can be controlled easily throughout a batch and from batch to batch, with the net result that multiple batches can be considered part of a single lot if equipment and processing parameters meet the mandates of X1.1 and X1.2.

X1.4 The sampling specified for mechanical properties is not a statistical sampling plan. Therefore, it provides only typical data. Assurance of uniformity within the lot can be obtained only by the producer adequately controlling the processing parameters.

X2. BAR CODING

X2.1 Bar coding to identify steel is not specifically addressed in Committee A01 specifications. Committee A01 endorses the AIAG bar code standard for primary metals for steel products and proposes that this bar coding standard be considered as a possible auxiliary method of identification.

SPECIFICATION FOR STEEL CASTINGS SUITABLE FOR PRESSURE SERVICE

SA-487/SA-487M

(Identical with ASTM Specification A487/A487M-21 except no welding for Grade 17 per Table 4.)

Specification for
Steel Castings Suitable for Pressure Service

1. Scope

1.1 This specification covers low-alloy steels and martensitic stainless steels in the normalized and tempered, or quenched and tempered, condition suitable for pressure-containing parts. The weldability of the classes in this specification varies from readily weldable to weldable only with adequate precautions, and the weldability of each class should be considered prior to assembly by fusion welding.

1.2 Selection will depend on design, mechanical, and service conditions. Users should note that hardenability of some of the grades mentioned may restrict the maximum size at which the required mechanical properties are obtained.

1.3 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be 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.

1.3.1 Within the text, the SI units are shown in brackets.

1.4 *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:*

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A488/A488M Practice for Steel Castings, Welding, Qualifications of Procedures and Personnel

A703/A703M Specification for Steel Castings, General Requirements, for Pressure-Containing Parts

A985/A985M Specification for Steel Investment Castings General Requirements, for Pressure-Containing Parts

E165/E165M Practice for Liquid Penetrant Testing for General Industry

E709 Guide for Magnetic Particle Testing

2.2 *American Society of Mechanical Engineers:*

ASME Boiler and Pressure Vessel Code, Section IX

2.3 *Manufacturers Standardization Society of the Valve and Fittings Industry Standards:*

SP-55 Quality Standard for Steel Castings—Visual Method

3. General Conditions for Delivery

3.1 Except for investment castings, castings furnished to this specification shall conform to the requirements of Specification A703/A703M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A703/A703M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A703/A703M, this specification shall prevail.

3.2 Investment castings furnished to this specification shall conform to the requirements of Specification A985/A985M, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the general requirements of Specification A985/A985M constitutes nonconformance with this specification. In case of conflict between the requirements of this specification and Specification A985/A985M, Specification A985/A985M shall prevail.

4. Ordering Information

4.1 The inquiry and order should include or indicate the following:

4.1.1 A description of the casting by pattern number or drawing (dimensional tolerances shall be included on the casting drawing),
4.1.2 ASTM designation and year of issue,
4.1.3 Grade and class of steel,
4.1.4 Options in the specification, and
4.1.5 The supplementary requirements desired, including the standard of acceptance.

5. Heat Treatment

5.1 All castings shall receive a heat treatment indicated in Table 1. Preliminary heat treatment prior to final heat treatment, as well as multiple tempering, is permitted.

5.2 Heat treatment shall be performed after the castings have been allowed to cool below the transformation range.

5.3 The furnace temperature for heat treating shall be effectively controlled by use of recording-type pyrometers.

6. Chemical Composition

6.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 2. Except for investment castings, product analysis tolerance shall conform to the product analysis tolerance shown in Specification A703/A703M. For investment castings, the product analysis tolerance shall conform to the product analysis tolerance shown in Specification A985/A985M.

7. Tensile Requirements

7.1 Tensile properties of steel used for the castings shall conform to the requirements prescribed in Table 3.

TABLE 1 Heat Treat Requirement

Grade	Class	Austenitizing Temperature, min, °F [°C]	Media[A]	Quenching Cool Below °F [°C]	Tempering Temperature,[B] °F [°C]
1	A	1600 [870]	A	450 [230]	1100 [595]
1	B	1600 [870]	L	500 [260]	1100 [595]
1	C	1600 [870]	A or L	500 [260]	1150 [620]
2	A	1600 [870]	A	450 [230]	1100 [595]
2	B	1600 [870]	L	500 [260]	1100 [595]
2	C	1600 [870]	A or L	500 [260]	1150 [620]
4	A	1600 [870]	A or L	500 [260]	1100 [595]
4	B	1600 [870]	L	500 [260]	1100 [595]
4	C	1600 [870]	A or L	500 [260]	1150 [620]
4	D	1600 [870]	L	500 [260]	1150 [620]
4	E	1600 [870]	L	500 [260]	1100 [595]
6	A	1550 [845]	A	500 [260]	1100 [595]
6	B	1550 [845]	L	500 [260]	1100 [595]
7	A	1650 [900]	L	600 [315]	1100 [595]
8	A	1750 [955]	A	500 [260]	1250 [675]
8	B	1750 [955]	L	500 [260]	1250 [675]
8	C	1750 [955]	L	500 [260]	1250 [675]
9	A	1600 [870]	A or L	500 [260]	1100 [595]
9	B	1600 [870]	L	500 [260]	1100 [595]
9	C	1600 [870]	A or L	500 [260]	1150 [620]
9	D	1600 [870]	L	500 [260]	1150 [620]
9	E	1600 [870]	L	500 [260]	1100 [595]
10	A	1550 [845]	A	500 [260]	1100 [595]
10	B	1550 [845]	L	500 [260]	1100 [595]
11	A	1650 [900]	A	600 [315]	1100 [595]
11	B	1650 [900]	L	600 [315]	1100 [595]
12	A	1750 [955]	A	600 [315]	1100 [595]
12	B	1750 [955]	L	400 [205]	1100 [595]
13	A	1550 [845]	A	500 [260]	1100 [595]
13	B	1550 [845]	L	500 [260]	1100 [595]
14	A	1550 [845]	L	500 [260]	1100 [595]
16	A	1600 [870][C]	A	600 [315]	1100 [595]
17	A	1590 [865][C]	L	500 [260]	1095 [590][F,G]
CA15	A	1750 [955]	A or L	400 [205]	900 [480]
CA15	B	1750 [955]	A or L	400 [205]	1100 [595]
CA15	C	1750 [955]	A or L	400 [205]	1150 [620][D,E]
CA15	D	1750 [955]	A or L	400 [205]	1150 [620][D,E]
CA15M	A	1750 [955]	A or L	400 [205]	1100 [595]
CA6NM	A	1850 [1010]	A or L	200 [95]	1050–1150 [565–620]
CA6NM	B	1850 [1010]	A or L	200 [95]	1225–1275 [665–690][E,F] 1050–1150 [565–620][G]

[A] A = air, L = liquid.
[B] Minimum temperature unless a range is specified.
[C] Double austenitize.
[D] Double temper with the final temper at a lower temperature than the intermediate temper.
[E] Air cool to below 200 °F [95 °C] after first temper.
[F] Intermediate.
[G] Final.

TABLE 2 Chemical Composition Requirements[A,B]

Grade Class Type (UNS Number)	Element, %											
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Vanadium	Boron	Tungsten
1 ABC V (J13002)	0.30	1.00	0.035	0.035	0.80	0.50[D]	0.35[D]	[C,D]	0.50[D]	0.04–0.12	. . .	[C,D]
2 ABC Mn-Mo (J13005)	0.30	1.00–1.40	0.035	0.035	0.80	0.50[D]	0.35[D]	0.10–0.30	0.50[D]	0.03[D]	. . .	0.10[D]
4 ABCDE Ni-Cr-Mo (J13047)	0.30	1.00	0.035	0.035	0.80	0.40–0.80	0.40–0.80	0.15–0.30	0.50[E]	0.03[E]	. . .	0.10[E]
6 AB Mn-Ni-Cr-Mo (J13855)	0.05–0.38	1.30–1.70	0.035	0.035	0.80	0.40–0.80	0.40–0.80	0.30–0.40	0.50[E]	0.03[E]	. . .	0.10[E]
7 A Ni-Cr-Mo-V[F] (J13084)	0.05–0.20	0.60–1.00	0.035	0.035	0.80	0.70–1.00	0.40–0.80	0.40–0.60	0.15–0.50	0.03–0.10	0.002–0.006	0.10
8 ABC Cr-Mo (J22091)	0.05–0.20	0.50–0.90	0.035	0.035	0.80	. . .	2.00–2.75	0.90–1.10	0.50[E]	0.03[E]	. . .	0.10[E]
9 ABCDE Cr-Mo (J13345)	0.05–0.33	0.60–1.00	0.035	0.035	0.80	0.50[D]	0.75–1.10	0.15–0.30	0.50[D]	0.03[D]	. . .	0.10[D]
10 AB Ni-Cr-Mo (J23015)	0.30	0.60–1.00	0.035	0.035	0.80	1.40–2.00	0.55–0.90	0.20–0.40	0.50[E]	0.03[E]	. . .	0.10[E]
11 AB Ni-Cr-Mo (J12082)	0.05–0.20	0.50–0.80	0.035	0.035	0.60	0.70–1.10	0.50–0.80	0.45–0.65	0.50[G]	0.03[G]	. . .	0.10[G]
12 AB Ni-Cr-Mo (J22000)	0.05–0.20	0.40–0.70	0.035	0.035	0.60	0.60–1.00	0.50–0.90	0.90–1.20	0.50[G]	0.03[G]	. . .	0.10[G]
13 AB Ni-Mo (J13080)	0.30	0.80–1.10	0.035	0.035	0.60	1.40–1.75	0.40[H]	0.20–0.30	0.50[H]	0.03[H]	. . .	0.10[H]

TABLE 2 *Continued*

Grade Class Type (UNS Number)	Element, %											
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Nickel	Chromium	Molybdenum	Copper	Vanadium	Boron	Tungsten
14 A Ni-Mo (J15580)	0.55	0.80–1.10	0.035	0.035	0.60	1.40–1.75	0.40[H]	0.20–0.30	0.50[H]	0.03[H]	. . .	0.10[H]
16 A Low C-Mn-Ni (J31200)	0.12[I]	2.10[I]	0.02	0.02	0.50	1.00–1.40	0.20[G]	0.10[G]	0.20[G]	0.02[G]	. . .	0.10[G]
17 A Ni-Cr-Mo	0.05–0.20	0.55–0.70	0.01	0.005	0.20–0.50	3.0–3.80	1.35–1.60	0.35–0.60	0.20	0.03	. . .	. . .
CA15 ABCD Martensitic Cr (J91150)	0.15	1.00	0.035	0.035	1.50	1.00	11.5–14.0	0.50	0.50[G]	0.05[G]	. . .	0.10[G]
CA15M A Martensitic Cr (J91151)	0.15	1.00	0.035	0.035	0.65	1.00	11.5–14.0	0.15–1.0	0.50[G]	0.05[G]	. . .	0.10[G]
CA6NM AB Martensitic Cr-Ni (J91540)	0.06	1.00	0.035	0.03	1.00	3.5–4.5	11.5–14.0	0.4–1.0	0.50[G]	0.05[G]	. . .	0.10[G]

[A] All values are maximums unless a range is provided.
[B] Where ellipses (…) appear in this table, there is no requirement and the element need not be analyzed for or reported.
[C] The Mo + W content shall not exceed 0.25 %.
[D] Specified Residual Elements—the total content of these elements is 1.00 % maximum.
[E] Specified Residual Elements—the total content of these elements is 0.60 % maximum.
[F] Proprietary steel composition.
[G] Specified Residual Elements—the total content of these elements is 0.50 % maximum.
[H] Specified Residual Elements—the total content of these elements is 0.75 % maximum.
[I] For each reduction of 0.01 % below the specified maximum carbon content, an increase of 0.04 % manganese above the specified maximum will be permitted up to a maximum of 2.30 %.

TABLE 3 Required Mechanical Properties

Previous Designation	Grade	Class	Tensile Strength,[A] ksi [MPa]	Yield Strength,[A] ksi [MPa], at 0.2 % Offset	Elongation,[A] 2 in. [50 mm] or 4*d*, %	Reduction of Area,[A] %	Maximum Hardness, HRC [HB]	Thickness, in. [mm]
1N	1	A	85–110 [585–760]	55 [380]	22	40		
1Q	1	B	90–115 [620–795]	65 [450]	22	45		
	1	C	90 [620]	65 [450]	22	45	22 [235]	
2N	2	A	85–110 [585–760]	53 [365]	22	35		
2Q	2	B	90–115 [620–795]	65 [450]	22	40		
	2	C	90 [620]	65 [450]	22	40	22 [235]	
4N	4	A	90–115 [620–795]	60 [415]	18	40		
4Q	4	B	105–130 [725–895]	85 [585]	17	35		
	4	C	90 [620]	60 [415]	18	35	22 [235]	
	4	D	100 [690]	75 [515]	17	35	22 [235]	
4QA	4	E	115 [795]	95 [655]	15	35		
6N	6	A	115 [795]	80 [550]	18	30		
6Q	6	B	120 [825]	95 [655]	12	25		
7Q	7	A	115 [795]	100 [690]	15	30		2.5 [63.5] max
8N	8	A	85–110 [585–760]	55 [380]	20	35		
8Q	8	B	105 [725]	85 [585]	17	30		
	8	C	100 [690]	75 [515]	17	35	22 [235]	
9N	9	A	90 [620]	60 [415]	18	35		
9Q	9	B	105 [725]	85 [585]	16	35		
	9	C	90 [620]	60 [415]	18	35	22 [235]	
	9	D	100 [690]	75 [515]	17	35	22 [235]	
	9	E	115 [795]	95 [655]	15	35		
10N	10	A	100 [690]	70 [485]	18	35		
10Q	10	B	125 [860]	100 [690]	15	35		
11N	11	A	70–95 [484–655]	40 [275]	20	35		
11Q	11	B	105–130 [725–895]	85 [585]	17	35		
12N	12	A	70–95 [485–655]	40 [275]	20	35		
12Q	12	B	105–130 [725–895]	85 [585]	17	35		
13N	13	A	90–115 [620–795]	60 [415]	18	35		
13Q	13	B	105–130 [725–895]	85 [585]	17	35		
14Q	14	A	120–145 [825–1000]	95 [655]	14	30		
16N	16	A	70–95 [485–655]	40 [275]	22	35		
	17	A	113 [780]	97 [670]	15	30		up to 6.0 [150], incl.
	17	A	110 [760]	94 [650]	15	30		over 6.0 [150] to 8.0 [200], incl.
	17	A	106 [730]	91 [625]	15	30		over 8.0 [200] to 12.0 [300], incl.
	17	A	102 [705]	88 [605]	15	30		over 12.0 [300] to 14.0 [360], incl.
CA15A	CA15	A	140–170 [965–1170]	110–130 [760–895]	10	25		
CA15	CA15	B	90–115 [620–795]	65 [450]	18	30		
	CA15	C	90 [620]	60 [415]	18	35	22 [235]	
	CA15	D	100 [690]	75 [515]	17	35	22 [235]	
CA15M	CA15M	A	90–115 [620–795]	65 [450]	18	30		
CA6NM	CA6NM	A	110–135 [760–930]	80 [550]	15	35		
CA6NM	CA6NM	B	100 [690]	75 [515]	17	35	23 [255][B]	

[A] Minimum value, unless a range is provided.
[B] Test Methods and Definitions A370, Table 2 does not apply to CA6NM. The conversion given is based on CA6NM test coupons. (For example, see ASTM STP 756.)

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. Visual Method SP-55 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. When methods involving high temperatures are used in the removal and repair of discontinuities, the casting shall be preheated to at least the minimum temperature in Table 4.

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

9. Repair By Welding

9.1 For castings other than those intended for use under ASME Boiler and Pressure Vessel Code, repairs shall be made using procedures and welders qualified under Practice A488/A488M.

9.2 On castings intended for use under the ASME Boiler and Pressure Vessel Code, repairs shall be made by procedures and welders qualified under Section IX of that code.

9.3 After repair welding, all castings shall be post-weld heat treated in accordance with Table 4 or reheat treated in accordance with Table 1.

9.4 Weld repairs shall be inspected using the same quality standards as are used to inspect the castings. Re-examination of

TABLE 4 Minimum Preheat and Post-Weld Heat Treat Requirements

Grade	Class	Minimum Preheat Temperature, °F [°C]	Post-Weld Heat Treat, °F [°C]
1	A, B	200 [95]	1100 [595][A] minimum
1	C	200 [95]	1150 [620][A] minimum
2	A, B	200 [95]	1100 [595][A] minimum
2	C	200 [95]	1150 [620][A] minimum
4	A, B, E	200 [95]	1100 [595][A] minimum
4	C, D	200 [95]	1150 [620][A] minimum
6	A, B	300 [150]	1100 [595][A] minimum
7	A	300 [150]	1100 [595][A] minimum
8	A, B, C	300 [150]	1250 [675][A] minimum
9	A, B, E	300 [150]	1100 [595][A] minimum
9	C, D	300 [150]	1150 [620][A] minimum
10	A, B	300 [150]	1100 [595][A] minimum
11	A, B	300 [150]	1100 [595][A] minimum
12	A, B	300 [150]	1100 [595][A] minimum
13	A, B	400 [205]	1100 [595][A] minimum
14	A	400 [205]	1100 [595][A] minimum
16	A	50 [10]	1100 [595][A] minimum
17	A	...	No welding
CA15	A	400 [205]	1750 [955] air cool or liquid quench below 400 [205] temper at 900 [480] minimum
CA15	B	400 [205]	1100 [595][A] minimum
CA15	C, D	400 [205]	1150 [620][A] minimum
CA15M	A	400 [205]	1100 [595][A] minimum
CA6NM	A	50 [10]	Final temper between 1050 [565] and 1150 [620]
CA6NM	B	50 [10]	Intermediate PWHT between 1225 [665] and 1275 [690] Final temper PWHT 1050 [565] and 1150 [620][B]

[A] Post-weld heat treat temperature must be at or below the final tempering temperature.
[B] The intermediate and final PWHT temperatures shall be the same as the intermediate and final tempering temperatures, respectively, as the original heat treatment of the castings. Cool to below 200 °F [95 °C] between the intermediate and final PWHT.

the weld repair by radiography when Supplementary Requirement S5 has been specified will not be necessary when an applicable surface inspection method was used to locate the discontinuity except for the following:

9.4.1 Weld repairs on castings which have leaked on hydrostatic test.

9.4.2 Weld repairs on castings in which the depth of any cavity prepared for repair welding is more than 20 % of the wall thickness or 1 in. [25 mm], whichever is smaller.

9.4.3 Weld repairs on castings in which any cavity prepared for welding is greater than approximately 10 in.^{2} [65 cm^2].

10. Product Marking

10.1 Castings shall be marked for material identification with the grade and class symbols (1-A, 4-C, CA15-A).

11. Keywords

11.1 alloy steel; martensitic stainless steel; pressure-containing parts; stainless steel; steel castings

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall not apply unless specified in the purchase order. A list of standardized supplementary requirements for use at the option of the purchaser is included in Specifications A703/A703M and A985/A985M. Those which are ordinarily considered suitable for use with this specification are given below. Others enumerated in Specifications A703/A703M and A985/A985M may be used with this specification upon agreement between the manufacturer and purchaser.

S1. Unspecified Elements

S4. Magnetic Particle Inspection

S5. Radiographic Inspection

S8. Charpy Impact Test

S8.1 In addition to the requirements listed in S8 of Specifications A703/A703M and A985/A985M, the following specific requirements apply to this specification:

S8.1.1 When S8 is specified for Grades 1B, 2B, 4B, 6B, 7A, 8B, 9B, or 10B, impact properties shall be determined by performing a Charpy V-notch impact test at −50 °F [−46 °C] with a specific minimum average value of 15 ft-lb [20 J] and a specified minimum single value of 10 ft-lb [14 J]. Other temperatures may be used upon agreement between the manufacturer and the purchaser, in which case S8.1.3 shall apply. Other higher specified minimum average and single values may be used upon agreement between the manufacturer and the purchaser.

S8.1.2 Impact requirements for grades other than 1B, 2B, 4B, 6B, 7A, 8B, 9B, and 10B shall be agreed upon between the manufacturer and the purchaser.

S8.1.3 When an impact test temperature other than −50 °F [−46 °C] is used for those grades listed in S8.1.1, the lowest test temperature at which the material meets the impact requirements shall be stamped with low-stress stamps immediately ahead of the material symbol on the raised pad (for example, 25 10B for +25 °F [−4 °C] and 025 10B for −25 °F [−32 °C]).

S10. Examination of Weld Preparation

S10.1 The method of performing the magnetic particle or liquid penetrant test shall be in accordance with Guide E709 or Practice E165/E165M.

S26. Alternate Tension Test Coupons and Specimen Locations for Castings

S27. Hot Isostatic Pressing (HIPing)

SPECIFICATION FOR QUENCHED AND TEMPERED VACUUM-TREATED CARBON AND ALLOY STEEL FORGINGS FOR PRESSURE VESSELS

SA-508/SA-508M

(Identical with ASTM Specification A508/A508M-18.)

Specification for Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels

1. Scope

1.1 This specification covers quenched and tempered vacuum-treated carbon and alloy steel forgings for pressure vessels such as those used in reactor systems. Specifically, it covers forgings for vessel closures, shells, flanges, tube sheets, rings, heads, and similar parts.

1.2 All grades are considered weldable under proper conditions. Welding technique is of fundamental importance, and it is presupposed that welding procedure and inspection will be in accordance with approved methods for the grade of material used.

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

1.4 Unless the order specifies the applicable "M" specification designation, the material shall be furnished to the inch-pound units.

NOTE 1—Grades 1 and 1A are composed of different chemistries but have the same mechanical requirements.

NOTE 2—Designations have been changed as follows:

Current	Formerly
Grade 1	Class 1
Grade 1A	Class 1A
Grade 2 Class 1	Class 2
Grade 2 Class 2	Class 2A
Grade 3 Class 1	Class 3
Grade 3 Class 2	Class 3A
Grade 4N Class 1	Class 4
Grade 4N Class 2	Class 4A
Grade 4N Class 3	Class 4B
Grade 5 Class 1	Class 5
Grade 5 Class 2	Class 5A
Grade 22 Class 3	Class 22B
Grade 22 Classes 4, 5, 6, and 7	
Grade 3V	Class 3V

1.5 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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:*

A275/A275M Practice for Magnetic Particle Examination of Steel Forgings

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A388/A388M Practice for Ultrasonic Examination of Steel Forgings

A788/A788M Specification for Steel Forgings, General Requirements

A966/A966M Practice for Magnetic Particle Examination of Steel Forgings Using Alternating Current

E208 Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels

E428 Practice for Fabrication and Control of Metal, Other than Aluminum, Reference Blocks Used in Ultrasonic Testing

2.2 *American Society of Mechanical Engineers Standard:*
Boiler and Pressure Vessel Code—Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, NG 2300

3. Terminology

3.1 *Definitions:*

3.1.1 *controlling cross section thickness (T_C)*—the diameter of the largest theoretical sphere which can be inscribed within the volume of the forging.

4. Ordering Information

4.1 *Purchase Order*—In addition to the ordering information required by Specification A788/A788M, the purchaser shall include with the inquiry and order a detailed drawing that locates the areas of significant loading in the forging (when required), the method of selecting test locations (see 7.1.5 and 7.1.6), and purchase options (see 5.2.2, 7.2, and 11.1) and any supplementary requirements desired.

4.2 *Forging Drawing*—Each forging shall be manufactured in accordance with a purchaser-approved drawing showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to significant loading, and the locations of mechanical test specimens.

4.3 Material supplied to this specification shall conform to the requirements of Specification A788/A788M, which outlines additional ordering information, manufacturing requirements, testing and retesting methods and procedures, marking, certification, product analysis variations, and additional supplementary requirements.

4.3.1 When specified by the purchaser, it is permissible to perform Magnetic particle examination using the AC yoke in accordance with Practice A966/A966M instead of using Practice A275/A275M (see 9.2.1).

4.4 The optional minimum silicon content as expressed in Footnote B to Table 1, if required.

4.5 If the requirements of this specification are in conflict with the requirements of Specification A788/A788M, the requirements of this specification shall prevail.

5. Materials and Manufacture

5.1 *Melting Process:*

5.1.1 The steel shall be made by the basic electric-furnace process except when secondary ladle refining or the remelting process is employed, in which case the melting processes of Specification A788/A788M are permitted.

5.1.2 The molten steel shall be vacuum treated in accordance with the methods described in Specification A788/A788M, prior to or during the pouring of the ingot, in order to remove objectionable gases, particularly hydrogen.

Grade 22 Classes 4, 5, 6, and 7 liquid steel shall be produced to a fine grain melting practice which has been shown to result in a prior austenitic grain size of five or finer.

5.1.3 *Discard*—Sufficient discard shall be made from each ingot to secure freedom from piping and excessive segregation.

5.2 *Heat Treatment:*

5.2.1 *Preliminary Heat Treatment*—After forging and before reheating, the forgings shall be cooled to provide substantially complete transformation of austenite. Preliminary heat treatment may be applied to improve machinability and to enhance subsequent heat treatments.

5.2.2 *Heat Treatment for Mechanical Properties*—The forgings shall be heated to a temperature which produces an austenitic structure and then quenched in a suitable liquid medium by spraying or immersion. For Grade 4N, Classes 1

TABLE 1 Chemical Requirements

	Composition, %									
	Grade 1	Grade 1A	Grade 2	Grade 3	Grade 4N	Grade 5	Grade 22[A]	Grade 3V	Grade 3VCb	Grade 6
Carbon	0.35 max	0.30 max	0.27 max	0.25 max	0.23 max	0.23 max	0.11–0.15	0.10–0.15	0.10–0.15	0.28–0.33
Manganese	0.40–1.05	0.70–1.35	0.50–1.00	1.20–1.50	0.20–0.40	0.20–0.40	0.30–0.60	0.30–0.60	0.30–0.60	0.75–1.15
Phosphorus	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.020 max	0.025 max
Sulfur	0.025 max	0.025 max	0.025 max	0.025 max	0.020 max	0.020 max	0.015 max	0.020 max	0.010 max	0.025 max
Silicon[B]	0.40 max	0.40 max	0.40 max	0.40 max	0.40 max	0.30 max	0.35 max	0.10 max	0.10 max	0.35 max
Nickel	0.40 max	0.40 max	0.50–1.00	0.40–1.00	2.8–3.9	2.8–3.9	0.25 max	. . .	0.25 max	0.75–0.95
Chromium	0.25 max	0.25 max	0.25–0.45	0.25 max	1.50–2.00	1.50–2.00	2.00–2.50	2.8–3.3	2.7–3.3	0.70–1.00
Molybdenum	0.10 max	0.10 max	0.55–0.70	0.45–0.60	0.40–0.60	0.40–0.60	0.90–1.10 max	0.90–1.10	0.90–1.10	0.30–0.45
Vanadium	0.05 max	0.05 max	0.05 max	0.05 max	0.03 max	0.08 max	0.02 max	0.20–0.30	0.20–0.30	0.05 max
Columbium[C]	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.01 max	0.015–0.070	0.01 max
Copper	0.20 max	0.20 max	0.20 max	0.20 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max	0.25 max
Calcium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.0005–0.0150	0.015 max
Boron	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.003 max	0.001–0.003	0.003 max	0.003 max
Titanium	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015 max	0.015–0.035	0.015 max	0.015 max
Aluminum[D]	0.030 max	0.030 max	0.030 max	0.030 max	0.025 max	0.025 max	0.025 max	0.015 max	0.015 max	0.025 max

[A] For Grade 22 Classes 5, 6, and 7 with section thickness at heat treat of 8 in. or greater, the carbon and manganese shall be held to 0.13 to 0.15 and 0.50 to 0.60, respectively.
[B] When required by the purchaser a minimum silicon content of 0.15 % shall apply for Grades 1, 1A, 2, 3, and 4N.
[C] Columbium (Cb) and Niobium (Nb) are alternate names for Element 41 in the Periodic Table of the Elements.
[D] Aluminum content reported shall be the combined total soluble and insoluble aluminum.

and 3, the austenitizing temperature shall be 1540 °F [840 °C] min to 1640 °F [895 °C] max. Quenching shall be followed by tempering at a subcritical temperature and holding at this temperature for a minimum time of one-half hour per inch of maximum section thickness. Except when Supplementary Requirement S 13 is specified for Grades 2 and 3, the minimum tempering temperatures shall be as follows:

Grades 1, 1A, 2 Class 2, and 3 Class 2	1150 °F [620 °C]
Grades 2 Class 1 and 3 Class 1	1200 °F [650 °C]
Grades 4N Classes 1 and 2, and 5 Classes 1 and 2	1100 °F [595 °C]
Grade 4N Class 3	1125 °F [605 °C]
Grades 3V and 3VCb	1250 °F [675 °C]
Grade 22, Class 3	1200 °F [650 °C]
Grade 22, Classes 4, 5, 6, and 7	1100 °F [593 °C]

Specific cooling rates from the tempering temperature shall be applied if Supplementary Requirement S14 is specified.

5.3 For Grades 1, 1A, 2, 2A, 3, or 3A, a multiple stage austenitizing procedure may be used whereby the forging is first fully austenitized and liquid quenched, followed by reheating within the intercritical temperature range to partially reaustenitize and again liquid quenched. On completion of the austenitizing/quenching cycles, the forgings shall be tempered at a subcritical temperature as described in 5.2.2.

6. Chemical Composition

6.1 *Heat Analysis*—The heat analysis obtained from sampling in accordance with Specification A788/A788M shall comply with Table 1 except that the additional features of Supplementary Requirements S7, S8, S9, and S11 shall also apply as individually specified in the ordering information.

6.2 *Product Analysis*—The manufacturer shall use the product analysis provision of Specification A788/A788M to obtain a product analysis from a forging representing each heat or multiple heat. The permissible variations provided in the table on Permissible Variations in Product Analysis for Killed Steel in Specification A788/A788M apply for manganese, nickel, chromium, molybdenum, and vanadium only. Boron is not subject to product analysis. The purchaser may also make this determination in accordance with Specification A788/A788M.

7. Mechanical Properties

7.1 *Tension Test:*

7.1.1 The steel shall conform to the requirements of Table 2.

7.1.2 The location and number of tension test specimens for each forging or multiple forging shall be as follows:

7.1.2.1 *Individual Forgings with Weights Not Exceeding 1000 lb [455 kg] or Multiple Forgings Separated into Identical Individual Forgings with Weights not Exceeding 1000 lb [455 kg] Prior to Quenching and Tempering Treatment*—At least one individual forging from each heat and each heat-treating lot shall be tested using the test specimen locations of 7.1.5 or 7.1.6 as specified on the purchase orders, except that test specimens located at midlength may be closer to the ends of the production forging than the specified distance to the second surfaces. All forgings shall be quenched and tempered in the same furnace charge. All forgings from the multiple shall be Brinell hardness tested after heat treatment and forgings not tested for mechanical properties shall have a Brinell Hardness within 20 points of the Brinell Hardness of the forging that has been tested for mechanical properties.

7.1.2.2 *Forgings or Multiple Forgings (Note 3) with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation (Note 4) shall be located at one end. One tension test specimen shall be taken from the test prolongation.

7.1.2.3 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Not Exceeding 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. One tension test specimen shall be taken from each test prolongation. An orientation of 180° shall be established between the two tension test specimens.

7.1.2.4 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongation) of 80 in. [2032 mm] or Less*—A test prolongation shall be located at one end. Two tension test specimens shall be taken from the test prolongation and shall be oriented 180° apart.

7.1.2.5 *Forgings or Multiple Forgings with Weight at Time of Heat Treatment Over 10 000 lb [4540 kg] and Having a Heat-Treated Length (Exclusive of Test Prolongations) Exceeding 80 in. [2032 mm]*—A test prolongation shall be located at each end. The tension test specimens oriented 180° apart from each other shall be taken from each test prolongation. The two tension specimens located in one test prolongation shall be oriented 90° in relation to the two tension specimens located in the other test prolongation.

NOTE 3—Multiple forgings in 7.1.2.2 through 7.1.2.5 are those which will be separated after the quench and temper treatment.

NOTE 4—A test prolongation is defined as that integral test metal located at an end of the forging or forging multiples.

7.1.3 Samples for mechanical test specimen shall be removed from forgings after the quenching and tempering heat treatment. The sample material shall be subjected to a simulated post weld heat treatment if Supplementary Requirement S1 is specified.

7.1.4 For upset disk forgings, the longitudinal axis of the test specimens shall be in the tangential direction. For all other parts, the longitudinal axis of the specimens shall be parallel to the direction of major working of the forging.

7.1.5 Each forging shall be manufactured in accordance with a purchaser-approved drawing, showing the prequenched dimensions, the finished dimensions, the surfaces that will be subjected to critical stresses, and the location of mechanical test specimens.

7.1.6 The tension test specimens shall be positioned so that the longitudinal axis and mid-length is in accordance with one of the following methods:

7.1.6.1 *Method 1—t* by 2*t*, where *t* is the distance from the area of significant loading (see 4.1) to the nearest quenched surface. Specimens shall be removed at least 2*t* from the nearest second surface. However, they shall not be nearer to one quenched surface than ¾ in. [20 mm] and to the second quenched surface than 1½ in. [40 mm].

TABLE 2 Tensile Requirements

	Grades 1 and 1a	Grades 2 Class 1 and 3 Class 1	Grades 2 Class 2 and 3 Class 2	Grades 4N Class 1 and 5 Class 1	Grades 4N Class 2 and 5 Class 2	Grade 4N Class 3	Grade 22 Class 3	Grades 3V and 3VCb	Grade 6 Class 1	Grade 6 Class 2	Grade 6 Class 3	Grade 6 Class 4	Grade 22 Class 4	Grade 22 Class 5	Grade 22 Class 6	Grade 22 Class 7
Tensile strength, ksi [MPa]	70–95 [485–655]	80–105 [550–725]	90–115 [620–795]	105–130 [725–895]	115–140 [795–965]	90–115 [620–795]	85–110 [585–760]	85–110 [585–760]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]	85–110 [585–760]	95–120 [655–825]	100–125 [690–860]	105–130 [725–895]
Yield strength, min [0.2 % offset], ksi [MPa]	36 [250]	50 [345]	65 [450]	85 [585]	100 [690]	70 [485]	55 [380]	60 [415]	60 [415]	75 [515]	80 [550]	85 [585]	60 [415]	75 [515]	80 [550]	85 [585]
Elongation in 2 in. or 50 mm, min, %	20	18	16	18	16	20	18	18	20	18	18	18	20	18	18	18
Reduction of area, min, %	38	38	35	45	45	48	45	45	35	35	35	35	35	35	35	35

7.1.6.2 *Method 2*—¼ T_C by T_C. Specimens shall be removed ¼ T_C from the nearest quenched surface and at least T_C from all other surfaces exclusive of the T_C dimension surfaces. Where this method of testing is employed, the following limitations for T_C shall generally apply:

Grades 1 and 1a	3 in. [75 mm], max
Grades 2 Class 2 and 3 Class 2	6 in. [150 mm], max
Grades 2 Class 1 and 3 Class 1	8 in. [205 mm], max
Grade 4N Class 2 and 5 Class 2	16 in. [405 mm], max
Grade 4N Class 1 and 5 Class 1	30 in. [760 mm], max
Grade 4N Class 3	40 in. [1015 mm], max
Grades 3V and 3VCb	20 in. [510 mm], max
Grade 22 Class 3	20 in. [510 mm], max
Grade 22 Classes 4, 5, 6, and 7	12 in. [305 mm], max

7.1.6.3 *Method 3*—Test specimens shall be taken from a representative separate test forging made from the same heat of steel and shall receive substantially the same reduction and type of hot working as the production forgings that it represents and shall have the same T_C as the as-quenched production forgings. The separate test forging shall be heat treated in the same furnace charge and under the same conditions as the production forgings. Test specimens shall be removed from the region midway between the mid-thickness and the surface, and not closer than T_C to a second heat treated surface with the same limitation on forging thickness as in 7.1.6.2. Alternatively, an extra production forging of the same configuration (right and left handed configurations being considered equivalent) as that ordered, may be tested as described in Method 2.

7.1.6.4 *Method 4*—A thermal buffer ring, at least T_C by T_C in cross section, or segments of such a ring at least 3 T_C in length, shall be welded to the test end of a forging prior to heat treatment for mechanical properties. The buffer material may be any weldable carbon or low-alloy steel and shall be joined to the forging with a partial-penetration type weld which completely seals the buffered surface. The test coupons shall be removed from the forging in the region buffered by the ring or ring segments. If ring segments are used, the test coupons shall be removed from the forging in the area under the buffer ring segment at a minimum distance of T_C from each end of that segment. In either case, the test specimens shall be located at a minimum distance of ½ in. [13 mm] from the buffered surface of the forging, and at least ¼ T_C from a quenched surface of the forging. Where this method of testing is employed, the limitations for T_C given in 7.1.6.2 shall generally apply.

NOTE 5—For forgings with a maximum T_C of 2 in. [50 mm], the specimens shall be taken at midthickness and at least 2 in. from a second surface. This provision is applicable to all four methods in 7.1.6.

7.1.7 Tension specimens shall be the standard 0.5 in. [12.5 mm] round by 2 in. [50 mm] gauge length, as shown in Test Methods and Definitions A370.

7.2 *Impact Test*—The steel shall conform to the requirements of Table 3, or Supplementary Requirement S10 may be specified instead of these requirements.

7.2.1 *Number, Location, and Orientation of Specimens:*

7.2.1.1 One set of three Charpy V-notch specimens shall be taken from each tensile specimen location required in 7.1.2. Orientation shall be the same as in 7.1.4. When S10 is specified, the required number of tests shall be governed by NB, NC, ND, NE, NF, or NG 2300, as applicable.

7.2.1.2 The requirements of 7.1.3 also apply to impact specimens.

7.2.1.3 The longitudinal axis and mid-length of the impact specimen shall be located similarly to the longitudinal axis of the tension test specimens as defined in 7.1.6. The axis of the notch shall be normal to the nearest heat-treated surface of the forging. When Supplementary Requirement S10 is specified the orientation shall be governed by NB, NC, ND, NE, NF, or NG 2300.

7.2.2 Impact specimens shall be Charpy V-notch as shown in Test Methods and Definitions A370.

8. Workmanship and Quality Level Requirements

8.1 See requirements in 9.1, 9.2.2, 9.3.1.1, and 9.3.2.2.

9. Nondestructive Inspection Requirements

9.1 *General Requirements*—Dimensional and visual inspections, and magnetic particle and ultrasonic inspection shall be conducted by the manufacturer. Forgings shall be free of cracks, thermal ruptures, or other injurious indications.

9.2 *Magnetic Particle Inspection:*

9.2.1 Following final machining by the manufacturer all accessible surfaces of each forging shall be examined by the continuous current magnetic particle method. This examination shall be in accordance with Practice A275/A275M unless the purchaser has required the use of the AC yoke in accordance with Practice A966/A966M instead (see 4.3.1).

9.2.2 The following conditions are subject to rejection or removal:

9.2.2.1 Indications with major dimension exceeding 3⁄16 in. [4.8 mm].

9.2.2.2 Four or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions that are aligned and separated by 1⁄16 in. [1.6 mm] or less end to end.

9.2.2.3 Ten or more indications exceeding 1⁄16 in. [1.6 mm] in major dimensions contained in any 6 in.^{2} [39 cm^2] of surface, with the major dimension of this area not to exceed 6 in. [150 mm]. The area shall be taken in the most unfavorable location relative to the indications being evaluated.

9.3 *Ultrasonic Inspection*—Forgings shall be ultrasonically inspected in accordance with the procedures of Practice A388/A388M.

9.3.1 *Longitudinal Wave Inspection:*

9.3.1.1 Unless otherwise specified by Supplementary Requirement S2, the back reflection method of tuning shall be used in accordance with 7.2.2.1 of Practice A388/A388M. In addition to the reportable conditions in Section 7 of Practice A388/A388M, indications exceeding the resultant back reflection shall be recorded. The following conditions are considered rejectable:

9.3.1.2 Complete loss of back reflection not associated with forging configuration or surface and accompanied by an indication of a discontinuity. For this purpose, a back reflection less than 5 % of full screen height shall be considered complete loss of back reflection.

TABLE 3 Charpy Impact Requirements

	Grades 1 and 1a at +40 °F [4.4 °C]	Grades 2 Class 1 and 3 Class 1 at +40 °F [4.4 °C]	Grades 2 Class 2 and 3 Class 2 at +70 °F [21 °C]	Grades 4N (all classes) and 5 (all classes) at −20 °F [−29 °C]	Grade 22, Class 3, and Grades 3V and 3VCb at 0 °F [−18 °C]	Grade 6 Classes 1, 2, 3, and 4 at −75 °F [−59 °C]	Grade 22 Classes 4, 5, 6, and 7 at −75 °F [−60 °C]
Minimum average value of set of three specimens, ft·lbf [J][A]	15 [20]	30 [41]	35 [48]	35 [48]	40 [54]	20 [27]	40 [55]
Minimum value of one specimen, ft lbf [J]	10 [14]	25 [34]	30 [41]	30 [41]	35 [50]	15 [20]	35 [50]

[A] Not more than one specimen from a set may be below this value.

9.3.1.3 Indications whose amplitude equals or exceeds that of the back reflection established in an indication-free area of the forging.

9.3.2 *Angle Beam Inspection:*

9.3.2.1 Calibration notches shall be cut into the inside- and outside-diameter surfaces with a depth equal to 3 % of the nominal section thickness (or ⅜ in. [9.5 mm], max), a length of approximately 1 in. [25 mm], and a width not greater than twice its depth. Adjust instrument controls to obtain an indication from the inside-diameter notch approximately 75 % of full screen height. Measure the amplitude of indication from the outside-diameter notch. Draw a straight line on the shield in front of the cathode ray tube from this peak to that of the inside-diameter notch and continue it as a horizontal line to the initial pulse. This line constitutes the angle beam reference line.

9.3.2.2 A forging containing a discontinuity which results in an indication exceeding the amplitude of the reference line is subject to rejection.

NOTE 6—Signals from discontinuities within approximately ¼ in. [6.4 mm] of inside and outside surfaces are reinforced by wave trapping during angle beam inspection; they are therefore amplified in respect to internal discontinuities.

9.3.3 The report of the ultrasonic inspection shall be in compliance with Section 8 of Practice A388/A388M.

9.3.4 Additional nondestructive inspection or trepanning may be employed to resolve questions of interpretation of ultrasonic indications. The manufacturer shall accept responsibility for injurious indications which will not be removed in final machining.

10. Repair Welding

10.1 Repair welding of forgings may be permitted, but only at the option of the purchaser.

10.2 If repair welding is performed, welders and weld procedures shall be qualified in accordance with Section IX of the ASME Boiler and Pressure Vessel Code.

11. Certification and Reports

11.1 In addition to items to be reported by Specification A788/A788M, the following items shall also be reported:

11.1.1 Product chemical analysis,

11.1.2 The method used for locating test specimens, and

11.1.3 Sketches showing the locations of all recordable indications in the report of all nondestructive examinations.

11.1.3.1 If Practice A966/A966M has been used, this also shall be recorded in the certification.

11.1.4 Details of the heat treatment cycle, as listed in Specification A788/A788M.

12. Product Marking

12.1 The purchaser may specify additional identification marking and the location of the stamping. The type of stamps to be used when impression stamping is performed shall be round-nosed or "interrupted-dot" die stamps having a minimum radius of 1/32 in. [0.8 mm].

13. Keywords

13.1 chromium-molybdenum steel; nickel-chromium-molybdenum alloy steels; pressure vessel service; quenched and tempered steels; steel forgings—alloy; steel forgings—carbon; vacuum-treated steels

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements shall apply only when specified by the purchaser in the inquiry or order. Details of these supplementary requirements shall be agreed upon between the manufacturer and the purchaser.

S1. Simulated Post-Weld Heat Treatment of Mechanical Test Samples

S1.1 All test coupons shall be subjected to single or multiple heat treatments at subcritical temperatures prior to testing. Such treatments are intended to simulate post-weld or other treatments to which the forgings will be subjected during subsequent fabrication. The purchaser shall furnish the manufacturer with details of the desired heat treatment for the test coupons, including temperatures, timers, and cooling rates.

S2. Ultrasonic Testing-Reference Block Calibration (for examining sections 24-in. [610 mm] thick or less)

S2.1 Reference blocks of acoustically similar metal shall be used for calibration. Blocks shall meet one of the following requirements:

S2.1.1 A comparison of the back reflections between equivalent thicknesses of the reference block material and the actual forging to be tested, without change in instrument setting shall not show a variation in excess of 25 %.

S2.1.2 The reference blocks shall be manufactured from steel that is similar in chemistry and processing history to the production forging being tested. The reference blocks shall be fabricated in accordance with the procedures of Practice E428.

S2.2 For test sections up to 12 in. [305 mm] thick, the reference blocks shall contain a ¼-in. [6.4-mm] diameter flat-bottom hole; for over 12 to 18 in. [305 to 457 mm], the hole diameter shall be ⅜ in. [9.5 mm]; and for over 18 to 24 in. [457 to 610 mm], it shall be ½ in. [13 mm].

S2.3 A distance-amplitude correction curve shall be established for the proper grade of steel and specified hole size.

S2.4 A forging containing one or more indications equal in amplitude to that of the applicable reference hole, when properly corrected for distance, is subject to rejection.

S3. Charpy V-Notch Impact Transition Curve

S3.1 Sufficient impact tests shall be made from the forging test material to establish a temperature-absorbed energy curve. The test-temperature range shall be wide enough to establish

the upper and lower shelf foot-pound energies, with sufficient testing at intermediate temperatures to permit plotting a reasonably smooth curve.

S4. Additional Charpy Data

S4.1 The percent shear fracture and mils of lateral expansion, defined in Test Methods and Definitions A370, shall be reported for each Charpy specimen tested.

S4.2 Acceptance values for percent shear fracture and/or lateral expansion values shall be as specified by the purchaser.

S5. Alternative Impact Test

S5.1 Charpy impact tests shall be made in accordance with the provisions of 7.2 of the specification except that the test temperature shall be lower than specified in Table 3. This test shall be instead of that specified in 7.2.

S6. Drop-Weight Test

S6.1 Drop-weight tests shall be conducted in accordance with the requirements of Test Method E208. The fracture plane of the specimens shall coincide with the location required for other mechanical test specimens as specified by the purchaser in accordance with 7.1.6. However, since the drop weight specimen can be taken in any orientation, the fracture plane of the specimen when tested to Method 1 (7.1.6.1) shall be a minimum distance of 7⁄16 in. [11 mm] from the nearest quenched surface, and 1½ in. [38 mm] from any second surface. The purchaser may specify either duplicate no-break performance when tested 10 °F [6 °C] warmer than a specified temperature or request a determination of the NDT temperature.

S7. Restrictive Chemistry for Grades 4N and 5

S7.1 Phosphorus and sulfur limits for Grades 4N and 5 shall be 0.015 % maximum heat and 0.018 % maximum product.

S8. Additional Vanadium

S8.1 The vanadium content for Grade 5 forgings shall be 0.05 to 0.15 %.

S9. Restrictive Chemistry for Grades 2, 3, or 4N

S9.1 Grades 2, 3, or 4N shall be specified with restricted phosphorus and copper limits, as follows:

S9.1.1 P 0.012 maximum heat and 0.015 maximum product; Cu 0.10 maximum heat and product, or

S9.1.2 P 0.015 maximum heat and 0.018 maximum product; Cu 0.15 maximum heat and product.

S9.2 Grades 2, 3, 4N shall be specified with restricted sulfur of 0.015 heat and 0.018 product.

S10. Alternative Fracture Toughness Requirements

S10.1 The fracture toughness requirements (drop weight and Charpy impact tests) for materials of the ASME Boiler and Pressure Vessel Code, Section III, Articles NB 2300, NC 2300, ND 2300, NE 2300, NF 2300, or NG 2300, as specified, shall be used instead of the Charpy impact test requirements of this specification.

S11. Vacuum Carbon-Deoxidized Steels

S11.1 Material made to Grades 1, 1a, 2, 3, 4N, or 5 shall be vacuum carbon-deoxidized, in which case the silicon content shall be 0.10 % max. The test report shall indicate that the steel was vacuum carbon-deoxidized.

S12. Vacuum-Treated Basic Oxygen Furnace Steels

S12.1 For Grades 1, 1a, 2, or 3 material, vacuum-treated basic oxygen furnace steel shall be used.

S13. Minimum Tempering Temperature

S13.1 For Grades 2 Class 1 and 3 Class 1 the minimum tempering temperature shall be 1175 °F [635 °C] and the simulated post weld heat treatment temperature shall not exceed 1150 °F [620 °C] when S1 is required.

S14. Cooling from the Tempering Temperature

S14.1 The purchaser shall provide specific cooling rates from the tempering temperature.

S15. Product Analysis

S15.1 More than one forging per heat shall be subject to product analysis by either the manufacturer or purchaser. The purchaser shall indicate in the ordering information the number of forgings to be tested, and whether the manufacturer, purchaser, or both shall perform the additional analyses.

S16. Silicon Content

S16.1 The silicon content shall be 0.05 to 0.15 % as a result of ladle refining with aluminum as the deoxidizer. Use of Vacuum Ladle Degassing is optional.

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SPECIFICATION FOR ELECTRIC-RESISTANCE-WELDED CARBON AND ALLOY STEEL MECHANICAL TUBING

SA-513/SA-513M (25)

(Identical with ASTM Specification A513/A513M-20 except that Supplementary Requirements S5, S6, and either S7 or S8 at the manufacturer's option and certification have been made mandatory, and for editorial corrections in 3.1.7 and S5.1.)

ASME SA-513/SA-513M replaces paras. 3.1.7, 6.1, 7.1, and S5.1 of ASTM A513/A513M with the following:

3.1.7 Report chemical analysis (see Section 6), product analysis (See Section 7), and results of tests performed to Supplementary Requirements S5, S6, and either S7 or S8.

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified, except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. A report of such analysis shall be furnished to the purchaser.

7.1 A product analysis shall be made by the supplier. The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material:

S5.1 Round tubing shall conform to the tensile requirements and not necessarily the hardness limits shown in Table S5.1. For grades of round tubing not shown in Table S5.1, and for all square and rectangular tubing, tensile or hardness limits shall be upon agreement between the manufacturer and the purchaser.

Designation: A513/A513M – 20a

Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing[1]

This standard is issued under the fixed designation A513/A513M; 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 electric-resistance-welded carbon and alloy steel tubing for use as mechanical tubing.

1.2 This specification covers mechanical tubing made from hot- or cold-rolled steel.

1.3 This specification covers round, square, rectangular, and special shape tubing.

Type	Size Range (Round Tubing)
Electric-Resistance-Welded Tubing from Hot-Rolled Steel	outside diameter from ½ to 15 in. [12.7 to 380 mm] wall from 0.065 to 0.650 in. [1.65 to 16.5 mm]
Electric-Resistance-Welded Tubing from Cold-Rolled Steel	outside diameter from ⅜ to 12 in. [9.5 to 300 mm] wall from 0.022 to 0.134 in. [0.56 to 3.40 mm]

1.3.1 Indeterminate wall thicknesses may be ordered. In those cases the more stringent tolerances of Tables 4, 6, 7, 8, 9, 10, 11, 12, 16, and 17 shall apply. When sizes within the allowable ranges are ordered all other requirements of the specification shall be met.

1.4 This specification covers mechanical tubing in various Grades (see Section 5), Types (see 12.1), and Thermal Conditions (12.1).

1.5 Optional supplementary requirements are provided and when desired, shall be so stated in the order.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text the SI units are shown in brackets. The values stated in each system may not be exact equivalents; therefore each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard. The inch-pound units shall apply unless the "M" designation of this specification is specified in the order. In this specification hard or rationalized conversions apply to diameters, lengths and tensile properties. Soft conversion applies to other SI measurements.

1.7 *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]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment

A751 Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products

A1008/A1008M Specification for Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable

A1011/A1011M Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength

A1039/A1039M Specification for Steel, Sheet, Hot Rolled, Carbon, Commercial, Structural, and High-Strength Low-Alloy, Produced by Twin-Roll Casting Process

A1040 Guide for Specifying Harmonized Standard Grade Compositions for Wrought Carbon, Low-Alloy, and Alloy Steels

E213 Practice for Ultrasonic Testing of Metal Pipe and Tubing

E273 Practice for Ultrasonic Testing of the Weld Zone of Welded Pipe and Tubing

E309 Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation

[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 A01.09 on Carbon Steel Tubular Products.

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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

E570 Practice for Flux Leakage Examination of Ferromagnetic Steel Tubular Products

2.2 *ASME Standard:*[3]

B46.1 Surface Texture

2.3 *Military Standards:*[4]

MIL-STD-129 Marking for Shipment and Storage

2.4 *Federal Standard:*[4]

Fed. Std. No. 123 Marking for Shipments (Civil Agencies)

3. Ordering Information

3.1 Orders for material under this specification should include the following as required to adequately describe the desired material:

3.1.1 Quantity (feet, metres, or number of lengths),

3.1.2 Name of material (electric resistance-welded carbon or alloy steel mechanical tubing),

3.1.3 Types, conditions and code letters, (See Sections 1 and 12),

3.1.4 Thermal condition, (See 12.2),

3.1.5 Flash condition, (See 12.3),

3.1.6 Grade designation, if required, (See Section 5),

3.1.7 Report chemical analysis and product analysis, if required (See Sections 6 and 7),

3.1.8 Individual supplementary requirements, if required (S1 to S10, inclusive),

3.1.9 Cross section (round, square, rectangular and special shapes),

3.1.10 Dimensions, round, outside and inside and wall thickness (See 8.1 and 8.2) or square and rectangular, outside dimension and wall thickness and corner radii, if required (See 9.1 and 9.2),

3.1.11 Length, round, mill lengths or definite cut length (See 8.3), square and rectangular, specified length (See 9.4),

3.1.12 Squareness of cut, round tubing, if required, (See 8.4),

3.1.13 Burrs removed, if required (See 11.2),

3.1.14 Protective coating (See 14.1),

3.1.15 Special packaging (See 17.1),

3.1.16 Specification designation,

3.1.17 End use,

3.1.18 Special requirements,

3.1.19 Special marking (See Section 16), and

3.1.20 Straightness Test Method (See 8.5 and 9.6).

4. Materials and Manufacture

4.1 The steel may be made by any process.

4.2 If a specific type of melting is required by the purchaser, it shall be as stated on the purchase order.

4.3 The primary melting may incorporate separate degassing or refining, and may be followed by secondary melting, such as electroslag or vacuum-arc remelting. If secondary melting is employed, the heat shall be defined as all of the ingots remelted from a single primary heat.

4.4 Steel may be cast in ingots or may be strand cast. When steel of different grades is sequentially strand cast, identification of the resultant transition material is required. The producer shall remove the transition material by an established procedure that positively separates the grades.

4.5 Tubes shall be made by the electric-resistance-welded process and shall be made from hot- or cold-rolled steel as specified.

4.5.1 The weld shall not be located within the radius of the corners of any shaped tube unless specified by the purchaser.

5. Chemical Composition

5.1 The steel shall conform to the requirements as to chemical composition prescribed in Table 1 or Table 2 (See Specification A1040). If no grade is specified, Grades MT 1010 to MT 1020 may be furnished. Analyses of steels other than those listed are available. To determine their availability, the purchaser should contact the producer.

5.2 When a carbon steel grade is ordered under this specification, supplying an alloy grade that specifically requires the addition of any element other than those listed for the ordered grade in Tables 1 and 2 is not permitted.

5.3 Mechanical tubing with improved ductility may be produced from Drawing Steel (Types A and B), Deep Drawing Steel, or Extra Deep Drawing Steels identified in Specifications A1008/A1008M, A1011/A1011M, or A1039/A1039M. Those Specifications offer guidance in the form of nonmandatory Typical Ranges of Mechanical Properties.

6. Heat Analysis

6.1 An analysis of each heat of steel shall be made by the steel manufacturer to determine the percentages of the elements specified; if secondary melting processes are employed, the heat analysis shall be obtained from one remelted ingot or the product of one remelted ingot of each primary melt. The heat analysis shall conform to the requirements specified,

TABLE 1 Chemical Requirements for Standard Low-Carbon Steels[A]

NOTE 1— Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %			
	Carbon	Manganese	Phosphorus, max	Sulfur, max
MT[B] 1010	0.02–0.15	0.30–0.60	0.035	0.035
MT 1015	0.10–0.20	0.30–0.60	0.035	0.035
MT X 1015	0.10–0.20	0.60–0.90	0.035	0.035
MT 1020	0.15–0.25	0.30–0.60	0.035	0.035
MT X 1020	0.15–0.25	0.70–1.00	0.035	0.035

[A] Rimmed or capped steels which may be used for the above grades are characterized by a lack of uniformity in their chemical composition, and for this reason product analysis is not technologically appropriate unless misapplication is clearly indicated.

[B] The letters MT under grade designation indicate Mechanical Tubing.

[3] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, http://www.asme.org.

[4] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

TABLE 2 Chemical Requirements for Other Carbon and Alloy Steels[A]

NOTE 1—Chemistry represents heat analysis. Product analysis, except for rimmed or capped steel, is to be in accordance with usual practice as shown in Table 3.

Grade Designation	Chemical Composition Limits, %							
	Carbon	Manganese	Phosphorus, max	Sulfur, max	Silicon	Nickel	Chromium	Molybdenum
1006	0.08 max	0.45 max	0.030	0.035	...	...	...	...
1008	0.10 max	0.50 max	0.035	0.035	...	...	...	...
1009	0.15 max	0.60 max	0.035	0.035	...	...	...	...
1010	0.08–0.13	0.30–0.60	0.035	0.035	...	...	...	...
1012	0.10–0.15	0.30–0.60	0.035	0.035	...	...	...	...
1015	0.13–0.18	0.30–0.60	0.035	0.035	...	...	...	...
1016	0.13–0.18	0.60–0.90	0.035	0.035	...	...	...	...
1017	0.15–0.20	0.30–0.60	0.035	0.035	...	...	...	...
1018	0.15–0.20	0.60–0.90	0.035	0.035	...	...	...	...
1019	0.15–0.20	0.70–1.00	0.035	0.035	...	...	...	...
1020	0.18–0.23	0.30–0.60	0.035	0.035	...	...	...	...
1021	0.18–0.23	0.60–0.90	0.035	0.035	...	...	...	...
1022	0.18–0.23	0.70–1.00	0.035	0.035	...	...	...	...
1023	0.20–0.25	0.30–0.60	0.035	0.035	...	...	...	...
1024	0.18–0.25	1.30–1.65	0.035	0.035	...	...	...	...
1025	0.22–0.28	0.30–0.60	0.035	0.035	...	...	...	...
1026	0.22–0.28	0.60–0.90	0.035	0.035	...	...	...	...
1027	0.22–0.29	1.20–1.55	0.035	0.035	...	...	...	...
1030	0.28–0.34	0.60–0.90	0.035	0.035	...	...	...	...
1033	0.30–0.36	0.70–1.00	0.035	0.035	...	...	...	...
1035	0.32–0.38	0.60–0.90	0.035	0.035	...	...	...	...
1040	0.37–0.44	0.60–0.90	0.040	0.050	...	...	...	...
1050	0.48–0.55	0.60–0.90	0.040	0.050	...	...	...	...
1060	0.55–0.65	0.60–0.90	0.040	0.050	...	...	...	...
1340	0.38–0.43	1.60–1.90	0.035	0.040	0.15–0.35	...	...	...
1524	0.19–0.25	1.35–1.65	0.040	0.050	...	...	...	...
4118	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	...	0.40–0.60	0.08–0.15
4130	0.28–0.33	0.40–0.60	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
4140	0.38–0.43	0.75–1.00	0.035	0.040	0.15–0.35	...	0.80–1.10	0.15–0.25
5130	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	...	0.80–1.10	...
8620	0.18–0.23	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25
8630	0.28–0.33	0.70–0.90	0.035	0.040	0.15–0.35	0.40–0.70	0.40–0.60	0.15–0.25

[A] Where the ellipsis (...) appears in this table, there is no requirement.

except that where the heat identity has not been maintained or where the analysis is not sufficiently complete to permit conformance to be determined, the chemical composition determined from a product analysis made by the tubular manufacturer shall conform to the requirements specified for heat analysis. When requested in the order or contract, a report of such analysis shall be furnished to the purchaser.

7. Product Analysis

7.1 When requested on the purchase order, a product analysis shall be made by the supplier. The number and source of samples for such product analysis shall be based on the individual heat or lot identity of one of the following forms of material:

7.1.1 *Heat Identity Maintained*—One product analysis per heat shall be made on either the flat-rolled stock or tube.

7.1.2 *Heat Identity Not Maintained*—A product from one tube per 2000 ft [600 m] or less for sizes over 3 in. [75 mm], and one tube per 5000 ft [1500 m] or less for sizes 3 in. [75 mm] and under.

7.2 Samples for product analysis shall be taken in accordance with Practice A751. The composition thus determined shall correspond to the requirements of Table 1 or Table 2.

7.3 If the original test for product analysis fails, retests of two additional lengths of flat-rolled stock or tubes shall be made. Both retests for the elements in question shall meet the requirements of the specification; otherwise, all remaining material in the heat or lot shall be rejected or, at the option of

TABLE 3 Tolerances for Product Analysis for Steels Shown in Tables 1 and 2[A,B]

Element	Limit, or Maximum of Specified Range, %	Variation, Over the Maximum Limit or Under the Minimum Limit	
		Under min, %	Over max, %
Carbon	to 0.15, incl	0.02	0.03
	over 0.15 to 0.40, incl	0.03	0.04
	over 0.40 to 0.55, incl	0.03	0.05
Manganese	to 0.60, incl	0.03	0.03
	over 0.60 to 1.15, incl	0.04	0.04
	over 1.15 to 1.65, incl	0.05	0.05
Phosphorus		...	0.01
Sulfur		...	0.01
Silicon	to 0.30, incl	0.02	0.03
	over 0.30 to 0.60	0.05	0.05
Nickel	to 1.00, incl	0.03	0.03
Chromium	to 0.90, incl	0.03	0.03
	over 0.90 to 2.10, incl	0.05	0.05
Molybdenum	to 0.20, incl	0.01	0.01
	over 0.20 to 0.40, incl	0.02	0.02

[A] Individual determinations may vary from the specified heat limits or ranges to the extent shown in this table, except that any element in a heat may not vary both above and below a specified range.

[B] Where the ellipsis (...) appears in this table, there is no requirement.

the producer, each length of flat-rolled stock or tube may be individually tested for acceptance. Lengths of flat-rolled stock or tubes which do not meet the requirements of the specification shall be rejected.

8. Permissible Variations in Dimensions for Round Tubing

8.1 *Diameter and Wall Thickness (Hot-Rolled Steel)*—Variations from specified outside diameter for "as-welded" and "as-welded and annealed" tubing made from hot-rolled steel shall not exceed the amounts prescribed in Table 4. Permissible variations in outside diameter for tubing that has been sink-drawn for closer tolerance on outside diameter are shown in Table 5. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameters are ±10 % of the nominal wall or ±0.010 in. [0.25 mm], whichever is greater. Permissible variations in wall thickness for tubing made from hot-rolled steel are shown in Tables 6 and 7. Permissible variation in outside and inside diameter for tubing made from hot-rolled steel that has been Drawn Over a Mandrel (DOM) for closer tolerances are shown in Table 5 with wall tolerances shown in Tables 8 and 9.

8.2 *Diameter and Wall Thickness (Cold-Rolled Steel)*—Variations in outside diameter and inside diameter of "as-welded" and "as-welded and annealed" tubing made from cold-rolled steel are shown in Table 10. Outside diameter tolerances for cold-rolled steel tubing, sink drawn and DOM, are shown in Table 5. Wall thickness tolerances for "as-welded" tubing made from cold-rolled steel are shown in Tables 11 and 12. Permissible variations in wall thickness for round tubing, DOM for closer tolerances, are shown in Tables 8 and 9. Permissible variations in wall thickness for tubing that has been sink-drawn for closer tolerances on outside diameter are ±10 % of the nominal wall or ±0.010 in. [0.25 mm], whichever is greater.

8.3 *Length (Hot- and Cold-Rolled Steel)*—Mechanical tubing is commonly furnished in mill lengths 5 ft [1.5 m] and over. Definite cut lengths are furnished when specified by the purchaser. Tolerances for definite cut lengths round tubing shall be as given in Tables 13 and 14.

8.4 *Squareness of Cut (Hot- and Cold-Rolled Steel)*—When specified, tolerance for squareness of cut of round tubing shall be as given in Table 15. Measurements are made with use of an "L" square and feeler gauge. The long leg (blade) of the square to be equal to tube diameter plus a minimum of 1 in. [25.4 mm]. Outside diameter burr to be removed for measurement.

8.5 *Straightness*—The straightness tolerance for round tubing is 0.030 in./3 ft [0.75 mm/1 m] lengths to 8.000 in. [200 mm] outside diameter. For 8.000 in. [200 mm] outside diameter and above, straightness tolerance is 0.060 in./3 ft [1.5 mm/1 m] lengths. For lengths under 1 ft [305 mm] the straightness tolerance shall be agreed upon between the purchaser and producer. The test method for straightness measurement is at the manufacturer's option, unless a specific test method is specified in the purchase order.

8.6 *Ovality (Hot- and Cold-Rolled Steel)*—Ovality is the difference between maximum and minimum outside diameters measured at any one cross section. The ovality shall be within the tolerances except when the wall thickness is less than 3 % of the outside diameter.

8.6.1 In such cases for Types 1 and 2 (A.W.H.R. and A.W.C.R.) the ovality may be 50 % greater than the outside tolerances but the mean outside diameter shall be within the specified tolerance.

8.6.2 For Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., DOM, and S.S.I.D.) the additional ovality shall be as follows but the mean outside diameter shall be within the specified tolerance:

Outside Diameter, in. [mm]	Additional Ovality Tolerance, in. [mm]
Up to 2 [50], incl	0.010 [0.25]
Over 2 to 3 [50 to 75], incl	0.015 [0.38]
Over 3 to 4 [75 to 100], incl	0.020 [0.51]
Over 4 to 5 [100 to 125], incl	0.025 [0.64]
Over 5 to 6 [125 to 150], incl	0.030 [0.76]
Over 6 to 7 [150 to 180], incl	0.035 [0.89]
Over 7 to 8 [180 to 205], incl	0.040 [1.02]
Over 8 to 9 [205 to 230], incl	0.045 [1.14]
Over 9 to 10 [230 to 255], incl	0.050 [1.27]
Over 10 to 11 [255 to 280], incl	0.055 [1.40]
Over 11 to 12 [280 to 305], incl	0.060 [1.52]
Over 12 to 12.500 [305 to 320], incl	0.065 [1.65]

9. Permissible Variations in Dimensions of Square and Rectangular Tubing

9.1 *Diameter and Wall Thickness*—Permissible variations in outside dimensions for square and rectangular tubing shall be as given in Table 16. The wall thickness tolerance is ±10 % of the nominal wall thickness.

9.2 *Corner Radii*—Unless otherwise specified, the corners of square and rectangular tubing shall be slightly rounded inside and outside, consistent with wall thickness. The outside corners may be slightly flattened. The radii of corners shall be as given in Table 17.

9.3 *Squareness*—Permissible variations for squareness shall be determined by the following equation:

$$\pm b = c \times 0.006 \ in. \ (0.15 \ mm)$$

where:

b = tolerance for out-of-square, and
c = largest external dimension across flats.

The squareness of sides is commonly determined by one of the following methods.

9.3.1 A square with two adjustable contact points on each arm, is placed on two sides. A fixed feeler gauge is then used to measure the maximum distance between the free contact point and the surface of the tubing.

9.3.2 A square equipped with a direct reading vernier, may be used to determine the angular deviation which, in turn, may be related to distance in in. [mm].

9.4 *Length*—Variations from the specified length shall not exceed the amount prescribed in Table 18.

9.5 *Twist*—Twist tolerances are shown in Table 19. The twist in square and rectangular tubing may be measured by holding one end of the tubing on a surface plate and noting the height of either corner of the opposite end of same side above the surface plate. Twist may also be measured by the use of a

TABLE 4 Diameter Tolerances for Type I (A.W.H.R.) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. [50 mm] from the ends of the tubes.

Outside Diameter Range in. [mm]	Wall Thickness		Flash-in-Tubing[A,B]	Flash Controlled to 0.010 in. [0.26 mm] max Tubing[B,C]	Flash Controlled to 0.005 in. [0.13 mm]. max Tubing[C,D]	
	Bwg[E]	in. [mm]	Outside Diameter, ±	Outside Diameter, ±	Outside Diameter, ±	Inside Diameter, ±
			Tolerances[F]			
			in. [mm]	in. [mm]	in. [mm]	in. [mm]
½ to 1⅛, incl [15 to 30]	16 to 10	0.065 to 0.134 [1.7 to 3.4]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.020 [0.51]
Over 1⅛ to 2, incl [30 to 50]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.021 [0.53]
Over 1⅛ to 2, incl [30 to 50]	13 to 7	0.095 to 0.180 [2.4 to 4.6]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.025 [0.64]
Over 1⅛ to 2, incl [30 to 50]	6 to 5	0.203 to 0.220 [5.2 to 5.6]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.029 [0.74]
Over 1⅛ to 2, incl [30 to 50]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.039 [0.99]
Over 2 to 2½, incl [50 to 65]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.022 [0.56]
Over 2 to 2½, incl [50 to 65]	13 to 5	0.095 to 0.220 [2.4 to 5.6]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.024 [0.61]
Over 2 to 2½, incl [50 to 65]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.040 [1.02]
Over 2½ to 3, incl [65 to 75]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.024 [0.61]
Over 2½ to 3, incl [65 to 75]	13 to 5	0.095 to 0.220 [2.4 to 5.6]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.026 [0.66]
Over 2½ to 3, incl [65 to 75]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.040 [1.02]
Over 2½ to 3, incl [65 to 75]	2 to 0.320 [8.1]	0.284 to 0.320 [7.2 to 8.1]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.048 [1.22]
Over 3 to 3½, incl [75 to 90]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.025 [0.64]
Over 3 to 3½, incl [75 to 90]	13 to 5	0.095 to 0.220 [2.4 to 5.6]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.027 [0.69]
Over 3 to 3½, incl [75 to 90]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.043 [1.09]
Over 3 to 3½, incl [75 to 90]	2 to 0.360 [9.1]	0.284 to 0.360 [7.2 to 9.1]	0.012 [0.30]	0.012 [0.30]	0.012 [0.30]	0.050 [1.27]
Over 3½ to 4, incl [90 to 100]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.026 [0.66]
Over 3½ to 4, incl [90 to 100]	13 to 5	0.095 to 0.220 [2.4 to 5.6]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.028 [0.72]
Over 3½ to 4, incl [90 to 100]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.044 [1.12]
Over 3½ to 4, incl [90 to 100]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]	0.053 [1.35]
Over 4 to 5, incl [100 to 130]	16 to 14	0.065 to 0.083 [1.7 to 2.1]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.036 [0.91]
Over 4 to 5, incl [100 to 130]	13 to 5	0.095 to 0.220 [2.4 to 5.6]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.045 [1.14]
Over 4 to 5, incl [100 to130]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.054 [1.37]
Over 4 to 5, incl [100 to 130]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.058 [1.47]
Over 5 to 6, incl [130 to 150]	16 to 10	0.065 to 0.134 [1.7 to 3.4]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.036 [0.91]
Over 5 to 6, incl [130 to 150]	9 to 5	0.148 to 0.220 [3.8 to 5.6]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.040 [10.02]
Over 5 to 6 incl [130 to 150]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.054 [1.37]
Over 5 to 6, incl [130 to 150]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.058 [1.47]
Over 6 to 8, incl [150 to 200]	11 to 10	0.120 to 0.134 [3.0 to 3.4]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.043 [1.09]
Over 6 to 8, incl [150 to 200]	9 to 5	0.148 to 0.220 [3.8 to 5.6]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.045 [1.14]
Over 6 to 8, incl [150 to 200]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.059 [1.50]
Over 6 to 8, incl [150 to 200]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.063 [1.60]
Over 8 to 10, incl [200 to 250]	14 to 12	0.083 to 0.109 [2.1 to 2.8]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.041 [1.04]
Over 8 to 10, incl [200 to 250]	11 to 10	0.120 to 0.134 [3.0 to 3.4]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.043 [1.09]
Over 8 to 10, incl [200 to 250]	9 to 5	0.148 to 0.220 [3.8 to 5.6]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.045 [1.14]
Over 8 to 10, incl [200 to 250]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.059 [1.50]
Over 8 to 10, incl [200 to 250]	2 to 0.500 [12.7]	0.248 to 0.500 [7.2 to 12.7]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.063 [1.60]
Over 10 to 12, incl [250 to 300]	14 to 12	0.083 to 0.109 [2.1 to 2.8]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.041 [1.04]
Over 10 to 12, incl [250 to 300]	11 to 10	0.120 to 0.134 [3.0 to 3.4]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.043 [1.09]
Over 10 to 12, incl [250 to 300]	9 to 5	0.148 to 0.220 [3.8 to 5.6]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.045 [1.14]
Over 10 to 12, incl [250 to 300]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.059 [1.50]
Over 10 to 12, incl [250 to 300]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.063 [1.60]
Over 12 to 15, incl [300 to 380]	14 to 12	0.083 to 0.109 [2.1 to 2.8]	0.040 [1.02]	0.040 [1.02]	0.040 [1.02]	0.058 [1.47]
Over 12 to 15, incl [300 to 380]	11 to 10	0.120 to 0.134 [3.0 to 3.4]	0.040 [1.02]	0.040 [1.02]	0.040 [1.02]	0.058 [1.47]
Over 12 to 15, incl [300 to 380]	9 to 5	0.148 to 0.220 [3.8 to 5.6]	0.040 [1.02]	0.040 [1.02]	0.040 [1.02]	0.060 [1.52]
Over 12 to 15, incl [300 to 380]	4 to 3	0.238 to 0.259 [6.0 to 6.6]	0.040 [1.02]	0.040 [1.02]	0.040 [1.02]	0.074 [1.88]
Over 12 to 15, incl [300 to 380]	2 to 0.500 [12.7]	0.284 to 0.500 [7.2 to 12.7]	0.040 [1.02]	0.040 [1.02]	0.040 [1.02]	0.086 [2.18]

[A] Flash-In-Tubing is produced only to outside diameter tolerances and wall thickness tolerances and the inside diameter welding flash does not exceed the wall thickness or 3/32 in. [2.4 mm], whichever is less.

[B] Flash Controlled to 0.010 in. [0.25 mm] maximum tubing consists of tubing which is commonly produced only to outside diameter tolerances and wall thickness tolerances, in which the height of the remaining welding flash is controlled not to exceed 0.010 in.

[C] Flash Controlled to 0.005 in. [0.13 mm] maximum tubing is produced to outside diameters and wall thickness tolerance, inside diameter and wall thickness tolerances, or outside diameters and inside diameter tolerances, in which the height of the remaining flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.

[D] No Flash tubing is further processed by DOM for closer tolerances, produced to outside diameter and wall, inside diameter and wall, or outside diameter and inside diameter, with no dimensional indication of inside diameter flash, and is available in Types 5 and 6.
[E] Birmingham Wire Gauge.
[F] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.

TABLE 5 Diameter Tolerances for Types 3, 4, 5, and 6 (S.D.H.R., S.D.C.R., DOM, and S.S.I.D) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. [50 mm] from the ends of the tubes.

OD Size Range[A] in. [mm]	Wall % of OD	Types 3, 4, (Sink Drawn)[A,B] and 5, 6, (DOM)[B,C] OD		Types 5 and 6 (DOM)[B,C] ID	
		Over in. [mm]	Under in. [mm]	Over in. [mm]	Under in. [mm]
Up to 0.499 [12.67]	all	0.004 [0.10]	0.000 [0.00]	. . .	. . .
0.500 to 1.699 [12.70 to 43.15]	all	0.005 [0.13]	0.000 [0.00]	0.000 [0.00]	0.005 [0.13]
1.700 to 2.099 [43.18 to 53.31]	all	0.006 [0.15]	0.000 [0.00]	0.000 [0.00]	0.006 [0.15]
2.100 to 2.499 [53.34 to 63.47]	all	0.007 [0.18]	0.000 [0.00]	0.000 [0.00]	0.007 [0.18]
2.500 to 2.899 [63.50 to 73.63]	all	0.008 [0.20]	0.000 [0.00]	0.000 [0.00]	0.008 [0.20]
2.900 to 3.299 [73.66 to 83.79]	all	0.009 [0.23]	0.000 [0.00]	0.000 [0.00]	0.009 [0.23]
3.300 to 3.699 [83.82 to 93.95]	all	0.010 [0.25]	0.000 [0.00]	0.000 [0.00]	0.010 [0.25]
3.700 to 4.099 [93.98 to 104.11]	all	0.011 [0.28]	0.000 [0.00]	0.000 [0.00]	0.011 [0.28]
4.100 to 4.499 [104.14 to 114.27]	all	0.012 [0.30]	0.000 [0.00]	0.000 [0.00]	0.012 [0.30]
4.500 to 4.899 [114.30 to 124.43]	all	0.013 [0.33]	0.000 [0.00]	0.000 [0.00]	0.013 [0.33]
4.900 to 5.299 [124.46 to 134.59]	all	0.014 [0.36]	0.000 [0.00]	0.000 [0.00]	0.014 [0.36]
5.300 to 5.549 [134.62 to 140.94]	all	0.015 [0.38]	0.000 [0.00]	0.000 [0.00]	0.015 [0.38]
5.550 to 5.999 [140.97 to 152.37]	under 6	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]
	6 and over	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]
6.000 to 6.499 [152.40 to 165.07]	under 6	0.013 [0.33]	0.013 [0.33]	0.013 [0.33]	0.013 [0.33]
	6 and over	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]
6.500 to 6.999 [165.10 to 177.77]	under 6	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]
	6 and over	0.012 [0.30]	0.012 [0.30]	0.012 [0.30]	0.012 [0.30]
7.000 to 7.499 [177.80 to 190.47]	under 6	0.018 [0.46]	0.018 [0.46]	0.018 [0.46]	0.018 [0.46]
	6 and over	0.013 [0.33]	0.013 [0.33]	0.013 [0.33]	0.013 [0.33]
7.500 to 7.999 [190.50 to 203.17]	under 6	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]
	6 and over	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]	0.015 [0.38]
8.000 to 8.499 [203.20 to 215.87]	under 6	0.023 [0.58]	0.023 [0.58]	0.023 [0.58]	0.023 [0.58]
	6 and over	0.016 [0.41]	0.016 [0.41]	0.016 [0.41]	0.016 [0.41]
8.500 to 8.999 [215.90 to 228.57}	under 6	0.025 [0.64]	0.025 [0.66]	0.025 [0.66]	0.025 [0.64]
	6 and over	0.017 [0.43]	0.017 [0.43]	0.017 [0.43]	0.017 [0.43]
9.000 to 9.499 [228.60 to 241.27]	under 6	0.028 [0.71]	0.028 [0.71]	0.028 [0.71]	0.028 [0.71]
	6 and over	0.019 [0.48]	0.019 [0.48]	0.019 [0.48]	0.019 [0.48]
9.500 to 9.999 [241.30 to 253.97]	under 6	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]
	6 and over	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]
10.000 to 10.999 [254.00 to 279.37]	all	0.034 [0.85]	0.034 [0.85]	0.034 [0.85]	0.034 [0.85]
11.000 to 11.999 [279.40 to 304.77]	all	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]
12.000 to 12.999 [304.80 to 330.17]	all	0.036 [0.91]	0.036 [0.91]	0.036 [0.94]	0.036 [0.91]
13.000 to 13.999 [330.20 to 355.57]	all	0.037 [0.94]	0.037 [0.94]	0.037 [0.94]	0.037 [0.94]
14.000 to 14.999 [355.60 to 380.97]	all	0.038 [0.97]	0.038 [0.97]	0.038 [0.97]	0.038 [0.97]

[A] Tubing, flash in or flash controlled which is further processed without mandrel to obtain tolerances closer than those shown in Tables 4 and 10.
[B] The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.2.
[C] Tubing produced to outside diameter and wall thickness, or inside diameter and wall thickness, or outside diameter and inside diameter, by DOM to obtain tolerances closer than those shown in Tables 4 and 10 and no dimensional indication of inside diameter flash.

beveled protractor equipped with a level, and noting the angular deviation on opposite ends, or at any point throughout the length.

9.6 *Straightness*—The straightness tolerance is 1/16 in./3 ft [1.7 mm/1 m]. The test method for straightness measurement is at the manufacturer's option, unless a specific test method is specified in the purchase order.

10. Tubing Sections Other Than Square and Rectangular

10.1 In addition to square and rectangular tubing, many producers supply a variety of special sections, such as oval, streamlined, hexagonal, octagonal, round inside and hexagonal or octagonal outside, ribbed inside or out, triangular, rounded rectangular and D shapes. Manufacturing practices limit the size range and section available from the various producers. These special sections may be made through turkshead rolls or through a die with or without use of a mandrel. Since the sections are special, dies and other tools are not held available. Therefore, when inquiring for shapes other than square and rectangular, it is essential to give full details as to dimensions and finish.

11. Workmanship, Finish, and Appearance

11.1 The tubing shall be free of injurious defects and shall have a workmanlike finish.

TABLE 6 Wall Thickness Tolerance for Type I (A.W.H.R.) Round Tubing (Inch Units)

Wall Thickness		Outside Diameter,[A]																	
		¾ to 1, incl		Over 1 to 1 15/16, incl		Over 1 15/16 to 3¾, incl		Over 3¾ to 4½, incl		Over 4½ to 6, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl		Over 12 to 15, incl	
in.[A]	Bwg[A]	Wall Thickness Tolerances, in., ±[B]																	
		+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.065	16	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	...	...	...	...	...	...
0.072	15	0.005	0.009	0.004	0.010	0.003	0.011	0.002	0.012	0.002	0.012	0.002	0.012	0.003	0.013	...	...	...	...
0.083	14	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.095	13	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.109	12	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.120	11	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.134	10	0.006	0.010	0.005	0.011	0.004	0.012	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013	0.003	0.013
0.148	9	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.165	8	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.180	7	...	...	0.006	0.012	0.005	0.013	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014	0.004	0.014
0.203	6	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.220	5	...	...	...	...	0.007	0.015	0.006	0.016	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017	0.005	0.017
0.238	4	...	...	...	...	0.012	0.020	0.011	0.021	0.010	0.022	0.010	0.022	0.010	0.022	0.010	0.022	0.010	0.022
0.259	3	...	...	...	...	0.013	0.021	0.012	0.022	0.011	0.023	0.011	0.023	0.011	0.023	0.011	0.023	0.011	0.023
0.284	2	...	...	...	...	0.014	0.022	0.013	0.023	0.012	0.024	0.012	0.024	0.012	0.024	0.012	0.024	0.012	0.024
0.300	1	...	...	...	...	0.015	0.023	0.014	0.024	0.013	0.025	0.013	0.025	0.013	0.025	0.013	0.025	0.013	0.025
0.320		...	...	...	...	0.016	0.024	0.015	0.025	0.014	0.026	0.014	0.026	0.014	0.026	0.014	0.026	0.014	0.026
0.344		...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.360		...	...	...	...	0.017	0.025	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.375		...	...	...	...	...	...	0.016	0.026	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027	0.015	0.027
0.406		...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.438		...	...	...	...	...	...	0.017	0.027	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.469		...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028
0.500		...	...	...	...	...	...	...	...	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028	0.016	0.028

[A] Birmingham Wire Gauge.
[B] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

TABLE 7 Wall Thickness Tolerance for Type I (A.W.H.R.) Round Tubing (SI Units)

Wall Thickness mm	Outside Diameter, mm																	
	20 to 25 mm, incl		Over 25 to 50 mm, incl		Over 50 to 95 mm, incl		Over 95 to 115 mm incl		Over 115 to 150 mm incl		Over 150 to 200 mm Incl		Over 200 to 250 mm incl		Over 250 to 305 mm Incl		Over 305 to 380 mm, incl	
	Wall Thickness Tolerances, mm, ±[A]																	
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
1.65	0.13	0.23	0.10	0.25	0.08	0.28	0.05	0.30	0.05	0.30	0.05	0.30	...	...	...	...	...	...
1.83	0.13	0.23	0.10	0.25	0.08	0.28	0.05	0.30	0.05	0.30	0.05	0.30	0.08	0.33	...	...	...	...
2.11	0.15	0.25	0.13	0.28	0.10	0.30	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33
2.41	0.15	0.25	0.13	0.28	0.10	0.30	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33
2.77	0.15	0.25	0.13	0.28	0.10	0.30	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33
3.05	0.15	0.25	0.13	0.28	0.10	0.30	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33
3.40	0.15	0.01	0.13	0.28	0.10	0.30	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33	0.08	0.33
3.76	...	...	0.15	0.30	0.13	0.33	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36
4.19	...	...	0.15	0.30	0.13	0.33	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36
4.57	...	...	0.16	0.30	0.13	0.33	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36	0.10	0.36
5.16	...	...	...	...	0.18	0.38	0.15	0.41	0.13	0.43	0.13	0.43	0.13	0.43	0.13	0.43	0.13	0.43
5.59	...	...	...	...	0.18	0.38	0.15	0.41	0.13	0.43	0.13	0.43	0.13	0.43	0.13	0.43	0.13	0.43
6.05	...	...	...	...	0.30	0.51	0.28	0.53	0.25	0.56	0.25	0.56	0.25	0.56	0.25	0.56	0.25	0.56
6.58	...	...	...	...	0.33	0.53	0.30	0.56	0.28	0.58	0.28	0.58	0.28	0.58	0.28	0.58	0.28	0.58
7.21	...	...	...	...	0.36	0.56	0.33	0.58	0.30	0.61	0.30	0.61	0.30	0.61	0.30	0.61	0.30	0.61
7.62	...	...	...	...	0.38	0.58	0.36	0.61	0.33	0.64	0.33	0.64	0.33	0.64	0.33	0.64	0.33	0.64
8.13	...	...	...	...	0.41	0.61	0.38	0.64	0.36	0.66	0.36	0.66	0.36	0.66	0.36	0.66	0.36	0.66
8.74	...	...	...	...	0.43	0.64	0.41	0.66	0.38	0.69	0.38	0.69	0.38	0.69	0.38	0.69	0.38	0.69
9.14	...	...	...	...	0.43	0.64	0.41	0.66	0.38	0.69	0.38	0.66	0.38	0.66	0.38	0.66	0.38	0.66
9.53	...	...	...	...	...	...	0.41	0.66	0.38	0.69	0.38	0.69	0.38	0.69	0.38	0.69	0.38	0.69
10.31	...	...	...	...	...	...	0.43	0.69	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71
11.13	...	...	...	...	...	...	0.43	0.69	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71
11.91	...	...	...	...	...	...	...	...	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71
12.70	...	...	...	...	...	...	...	...	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71	0.41	0.71

[A] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

TABLE 8 Wall Thickness Tolerances of Types 5 and 6 (DOM and S.S.I.D.) Round Tubing (Inch Units)

Wall Thickness		Outside Diameter, in.[A]							
		3/8 to 7/8, incl		Over 7/8 to 1 7/8, incl		Over 1 7/8 to 3 3/4, incl		Over 3 3/4 to 15, incl	
		Wall Thickness Tolerances, in.,[A,B] ±							
in.[A]	Bwg[A]	+	−	+	−	+	−	+	−
0.035	20	0.002	0.002	0.002	0.002	0.002	0.002	...	...
0.049	18	0.002	0.002	0.002	0.003	0.002	0.003	...	...
0.065	16	0.002	0.002	0.002	0.003	0.002	0.003	0.004	0.004
0.083	14	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.095	13	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.005
0.109	12	0.002	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.120	11	0.003	0.003	0.002	0.004	0.003	0.003	0.005	0.005
0.134	10	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.148	9	...	...	0.002	0.004	0.003	0.003	0.005	0.005
0.165	8	...	...	0.003	0.004	0.003	0.004	0.005	0.006
0.180	7	...	...	0.004	0.004	0.003	0.005	0.006	0.006
0.203	6	...	...	0.004	0.005	0.004	0.005	0.006	0.007
0.220	5	...	...	0.004	0.006	0.004	0.006	0.007	0.007
0.238	4	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.259	3	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.284	2	...	...	0.005	0.006	0.005	0.006	0.007	0.007
0.300	1	...	...	0.006	0.006	0.006	0.006	0.008	0.008
0.320		...	...	0.007	0.007	0.007	0.007	0.008	0.008
0.344		...	...	0.008	0.008	0.008	0.008	0.009	0.009
0.375		...	...	...	...	0.009	0.009	0.009	0.009
0.400		...	...	...	...	0.010	0.010	0.010	0.010
0.438		...	...	...	...	0.011	0.011	0.011	0.011
0.460		...	...	...	...	0.012	0.012	0.012	0.012
0.480		...	...	...	...	0.012	0.012	0.012	0.012
0.531		...	...	...	...	0.013	0.013	0.013	0.013
0.563		...	...	...	...	0.013	0.013	0.013	0.013
0.580		...	...	...	...	0.014	0.014	0.014	0.014
0.600		...	...	...	...	0.015	0.015	0.015	0.015
0.625		...	...	...	...	0.016	0.016	0.016	0.016
0.650		...	...	...	...	0.017	0.017	0.017	0.017

[A] Birmingham Wire Gauge.
[B] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

TABLE 9 Wall Thickness Tolerances of Types 5 and 6 (DOM and S.S.I.D.) Round Tubing (SI Units)

Wall Thickness mm	Outside Diameter, mm							
	10 to 20, incl		Over 20 to 50, incl		Over 50 to 100, incl		Over 100 to 380, incl	
	Wall Thickness Tolerances, mm[A]							
	+	−	+	−	+	−	+	−
0.89	0.05	0.05	0.05	0.05	0.05	0.05	...	...
1.24	0.05	0.05	0.05	0.08	0.05	0.08	...	...
1.65	0.05	0.05	0.05	0.08	0.05	0.08	0.10	0.10
2.11	0.05	0.05	0.05	0.08	0.08	0.08	0.10	0.13
2.41	0.05	0.05	0.05	0.08	0.08	0.08	0.10	0.13
2.77	0.05	0.08	0.05	0.10	0.08	0.08	0.13	0.13
3.05	0.08	0.08	0.05	0.10	0.08	0.08	0.13	0.13
3.40	...	...	0.05	0.10	0.08	0.08	0.13	0.13
3.76	...	...	0.05	0.10	0.08	0.08	0.13	0.13
4.19	...	...	0.08	0.10	0.08	0.10	0.13	0.15
4.57	...	...	0.10	0.10	0.08	0.13	0.15	0.15
5.16	...	...	0.10	0.13	0.10	0.13	0.15	0.18
5.59	...	...	0.10	0.15	0.10	0.15	0.18	0.18
6.05	...	...	0.13	0.15	0.13	0.15	0.18	0.18
6.58	...	...	0.13	0.15	0.13	0.13	0.18	0.18
7.21	...	...	0.13	0.15	0.13	0.15	0.18	0.18
7.62	...	...	0.15	0.15	0.15	0.15	0.20	0.20
8.13	...	...	0.18	0.18	0.18	0.18	0.20	0.20
8.74	...	...	0.20	0.20	0.20	0.20	0.23	0.23
9.53	...	...	...	...	0.23	0.23	0.23	0.23
10.16	...	...	...	...	0.25	0.25	0.25	0.25
11.13	...	...	...	...	0.28	0.28	0.28	0.28
11.68	...	...	...	...	0.30	0.30	0.30	0.30
12.19	...	...	...	...	0.30	0.30	0.30	0.30
13.49	...	...	...	...	0.33	0.33	0.33	0.33
14.3	...	...	...	...	0.33	0.33	0.33	0.33
14.73	...	...	...	...	0.36	0.36	0.36	0.36
15.24	...	...	...	...	0.38	0.38	0.38	0.38
15.88	...	...	...	...	0.41	0.41	0.41	0.016
16.51	...	...	...	...	0.43	0.43	0.43	0.43

[A] Where the ellipsis (...) appears in this table, the tolerance is not addressed.

11.2 When burrs must be removed from one or both ends, it shall be specified in the purchase order.

12. Types and Conditions

12.1 The types of tubing covered by this specification are:

Type Number	Code Letters	Description
1a	A.W.H.R.	"as-welded" from hot-rolled steel (with mill scale)
1b	A.W.P.O.	"as-welded" from hot-rolled pickled and oiled steel (mill scale removed)
2	A.W.C.R.	"as-welded" from cold-rolled steel
3	S.D.H.R.	"sink-drawn" hot-rolled steel
4	S.D.C.R.	"sink-drawn," cold-rolled steel
5	DOM	Drawn Over a Mandrel
6	S.S.I.D.	special smooth inside diameter

12.2 The thermal conditions under which tubing may be furnished are:

Code	Description
NA	Not Annealed; in the as-welded or as-drawn condition
SRA	Stress Relieved Annealed (at a temperature below the lower critical temperature)
N	Normalized or Annealed (at a temperature above the upper critical temperature)

12.2.1 When the thermal condition is not specified, the tube may be supplied in the NA condition.

12.2.2 When a final thermal treatment is specified, a tight oxide is normal. When an oxide-free surface is specified, the tube may be bright annealed or pickled at the manufacturer's option.

12.3 Flash conditions under which tubing may be furnished are as follows. The flash shall be removed from the outside diameter of tubing covered by this specification. Tubing furnished to this specification may have the following conditions of welding flash on the inside diameter.

12.3.1 *Flash-In*—Tubing in which the inside diameter welding flash does not exceed the wall thickness or 3/32 in. [2.38 mm], whichever is less. This condition is available in Types 1a, 1b, 2, 3, and 4.

12.3.2 *Flash Controlled to 0.010 in. [0.26 mm], maximum*—Tubing in which the height of the remaining welding flash is controlled so as not to exceed 0.010 in. This condition is available in Types 1a, 1b, and 2 over 1 1/8-in. [28.5-mm] outside diameter and Types 3 and 4.

12.3.3 *Flash Controlled to 0.005 in. [0.13 mm], maximum*—Tubing produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter tolerances which are so controlled that the height of the remaining inside diameter flash does not exceed 0.005 in. Any remaining inside diameter flash is part of the applicable inside diameter tolerance. This condition is available in Types 1a, 1b, 2, 3, and 4.

TABLE 10 Diameter Tolerances for Type 2 (A.W.C.R.) Round Tubing

NOTE 1—Measurements for diameter are to be taken at least 2 in. [50 mm] from the ends of the tubes.

Outside Diameter Range in. [mm]	Wall Thickness		Flash-in-Tubing[A]	Flash Controlled to 0.010 in. [0.26 mm] max Tubing[B]	Flash Controlled[C] to 0.005 in. [0.13 mm] max Tubing	
	Bwg[A]	in.[D] [mm]	Outside Diameter, ±	Outside Diameter, ±	Outside Diameter, ±	Inside Diameter, ±
			Tolerances[E,F]			
			in. [mm]	in. [mm]	in. [mm]	in. [mm]
⅜ to ⅝, incl [10 to 15]	24 to 16	0.022 to 0.065 [0.56 to 1.65]	0.003 [0.08]	...	...	...
Over ⅝ to 1⅛, incl [15 to 30]	24 to 19	0.022 to 0.042 [0.56 to 1.07]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.013 [0.33]
Over ⅝ to 1⅛, incl [15 to 30]	18	0.049 [1.24]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.015 [0.38]
Over ⅝ to 1⅛, incl [15 to 30]	16 to 14	0.065 to 0.083 [1.65 to 2.11]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.019 [0.48]
Over ¾ to 1⅛, incl [20 to 50]	13	0.095 [2.41]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.019 [0.48]
Over ⅞ to 1⅛, incl [20 to 30]	12 to 11	0.109 to 0.120 [2.77 to 3.05]	0.0035 [0.09]	0.0035 [0.09]	0.0035 [0.09]	0.021 [0.53]
Over 1⅛ to 2, incl [30 to 50]	22 to 18	0.028 to 0.049 [0.71 to 1.24]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.015 [0.38]
Over 1⅛ to 2, incl [30 to 50]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.019 [0.48]
Over 1⅛ to 2, incl [30 to 50]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.005 [0.13]	0.005 [0.13]	0.005 [0.13]	0.022 [0.56]
Over 2 to 2½, incl [50 to 65]	20 to 18	0.035 to 0.049 [0.89 to 1.24]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.016 [0.41]
Over 2 to 2½, incl [50 to 65]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.020 [0.51]
Over 2 to 2½, incl [50 to 65]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.006 [0.15]	0.006 [0.15]	0.006 [0.15]	0.023 [0.58]
Over 2½ to 3, incl [65 to 75]	20 to 18	0.035 to 0.049 [0.89 to 1.24]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.018 [0.46]
Over 2½ to 3, incl [65 to 75]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.022 [0.56]
Over 2½ to 3, incl [65 to 75]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.008 [0.20]	0.008 [0.20]	0.008 [0.20]	0.025 [0.64]
Over 3 to 3½, incl [75 to 90]	20 to 18	0.035 to 0.049 [0.89 to 1.24]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.019 [0.48]
Over 3 to 3½, incl [75 to 90]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.023 [0.58]
Over 3 to 3½, incl [75 to 90]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.009 [0.23]	0.009 [0.23]	0.009 [0.23]	0.026 [0.66]
Over 3½ to 4, incl [90 to 100]	20 to 18	0.035 to 0.049 [0.89 to 1.24]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.020 [0.51]
Over 3½ to 4, incl [90 to 100]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.024 [0.61]
Over 3½ to 4, incl [90 to 100]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.010 [0.25]	0.010 [0.25]	0.010 [0.25]	0.027 [0.69]
Over 4 to 6, incl [100 to 150]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.034 [0.85]
Over 4 to 6, incl [100 to 150]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.020 [0.51]	0.020 [0.51]	0.020 [0.51]	0.037 [0.94]
Over 6 to 8, incl [150 to 200]	14 to 13	0.083 to 0.095 [2.11 to 2.41]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.039 [0.99]
Over 6 to 8, incl [150 to 200]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.025 [0.64]	0.025 [0.64]	0.025 [0.64]	0.042 [1.07]
Over 8 to 10, incl [200 to 250]	16 to 13	0.065 to 0.095 [1.65 to 2.41]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.044 [1.12]
Over 8 to 10, incl [200 to 250]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.030 [0.76]	0.030 [0.76]	0.030 [0.76]	0.049 [1.24]
Over 10 to 12, incl [250 to 300]	14 to 13	0.083 to 0.095 [2.11 to 2.41]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.049 [1.24]
Over 10 to 12, incl [250 to 300]	12 to 10	0.109 to 0.134 [2.77 to 3.40]	0.035 [0.89]	0.035 [0.89]	0.035 [0.89]	0.054 [1.37]

[A]Flash-In-Tubing is produced to outside diameter tolerances and wall thickness tolerances only, and the height of the inside welding flash does not exceed the wall thickness or 3⁄32 in. [2.38 mm], whichever is less.
[B]Flash Controlled to 0.010 in. [0.26 mm] maximum tubing consists of tubing over ⅝ in. [15 mm] outside diameter which is commonly produced to outside diameter tolerances and wall thickness tolerances only, in which the height of the remaining inside welding flash is controlled not to exceed 0.010 in.
[C]Flash Controlled to 0.005 in. [0.13 mm] maximum tubing is produced to outside diameter tolerances and wall thickness tolerances, inside diameter tolerances and wall thickness tolerances, or outside diameter tolerances and inside diameter tolerances, in which the height of the remaining inside welding flash is controlled not to exceed 0.005 in. Any remaining flash is considered to be part of the applicable inside diameter tolerances.
[D]Birmingham Wire Gauge.
[E]The ovality shall be within the above tolerances except when the wall thickness is less than 3 % of the outside diameter, in such cases see 8.6.1.
[F]Where the ellipsis (...) appears in this table, the tolerance is not addressed.

12.3.4 *No Flash*—Tubing further processed by DOM for closer tolerances, produced to outside diameter and wall thickness, inside diameter and wall thickness, or outside diameter and inside diameter to tolerances, with no dimensional indication of inside diameter flash, is available in Types 5 and 6.

12.4 Tubes shall be furnished in the following shapes, as specified by the purchaser: round, square, rectangular, or special shapes (as negotiated).

13. Surface Finish

13.1 Tubes shall have a surface finish compatible with the conditions (See Section 12) to which they are ordered (See Appendix X1).

14. Coating

14.1 When specified, tubing shall be coated with a film of oil before shipping to retard rust. Should the order specify that tubing be shipped without rust retarding oil, the film of oils

TABLE 11 Wall Thickness Tolerances for Type 2 (A.W.C.R.) Round Tubing (Inch Units)

Wall Thickness		Outside Diameter, in.[A]															
		⅜ to ⅞, incl		Over ⅞ to 1⅞, incl		Over 1⅞ to 3¾, incl		Over 3¾ to 5, incl		Over 5 to 6, incl		Over 6 to 8, incl		Over 8 to 10, incl		Over 10 to 12, incl	
in.[A]	Bwg[A]	Wall Thickness Tolerances, in.,[A,B] ±															
		+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.022	24	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...				
0.028	22	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...	...	...
0.035	20	0.002	0.005	0.001	0.005	0.001	0.005	...	...	...	...	...	...	...	...	...	...
0.042	19	0.002	0.006	0.001	0.006	0.001	0.006	...	...	...	...	...	...	...	...	...	...
0.049	18	0.003	0.006	0.002	0.006	0.002	0.006	...	...	...	...	...	...	...	...	...	...
0.065	16	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.007	0.004	0.007	...	...	0.004	0.008	...	...
0.083	14	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.095	13	0.006	0.007	0.005	0.007	0.004	0.007	0.004	0.007	0.004	0.008	0.004	0.008	0.004	0.008	0.004	0.008
0.109	12	...	...	0.006	0.008	0.005	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.120	11	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009
0.134	10	...	...	0.007	0.008	0.006	0.008	0.005	0.008	0.005	0.009	0.005	0.009	0.005	0.009	0.005	0.009

[A] Birmingham Wire Gauge.
[B] Where the ellipsis appears in this table, the tolerance is not addressed.

TABLE 12 Wall Thickness Tolerances for Type 2 (A.W.C.R.) Round Tubing (SI Units)

Wall Thickness mm	Outside Diameter, mm															
	[10 to 20], incl		Over [20 to 50], incl		Over [50 to 100], incl		Over [100 to 130], incl		Over [130 to 150], incl		Over [150 to 205], incl		Over [205 to 250], incl		Over [250 to 305], incl	
	Wall Thickness Tolerances, mm[A] ±															
	+	−	+	−	+	−	+	−	+	−	+	−	+	−	+	−
0.56	0.03	0.13	0.03	0.13	...	...	...	...	...	...	...	...				
0.71	0.03	0.13	0.03	0.13	...	...	...	...	...	...	...	...	...	...	...	...
0.89	0.05	0.13	0.03	0.13	0.03	0.13	...	...	...	...	...	...	...	...	...	...
1.07	0.05	0.15	0.03	0.15	0.03	0.15	...	...	...	...	...	...	...	...	...	...
1.24	0.08	0.15	0.05	0.15	0.05	0.15	...	...	...	...	...	...	...	...	...	...
1.65	0.13	0.18	0.10	0.18	0.10	0.18	0.10	0.18	0.10	0.18	...	...	0.10	0.20	...	...
2.11	0.15	0.18	0.13	0.18	0.10	0.18	0.10	0.18	0.10	0.20	0.10	0.20	0.10	0.20	0.10	0.20
2.41	0.15	0.18	0.13	0.18	0.10	0.18	0.10	0.18	0.10	0.20	0.10	0.20	0.10	0.20	0.10	0.20
2.77	...	...	0.15	0.20	0.13	0.20	0.13	0.20	0.13	0.23	0.13	0.23	0.13	0.23	0.13	0.23
3.05	...	...	0.18	0.20	0.15	0.20	0.13	0.20	0.13	0.23	0.13	0.23	0.13	0.23	0.13	0.23
3.40	...	...	0.18	0.20	0.15	0.20	0.13	0.20	0.13	0.23	0.13	0.23	0.13	0.23	0.13	0.23

[A] Where the ellipsis appears in this table, the tolerance is not addressed.

TABLE 13 Cut-Length Tolerances for Lathe-Cut Round Tubing

Outside Diameter in. [mm]	6 in. [150 mm] and under 12 in. [305 mm] in. [mm]	12 in. [305 mm] and under 48 in. [1200 mm] in. [mm]	48 in. [1200 mm] and under 10 ft [3000 mm] in. [mm]	10 ft [3000 mm] to 24 ft [7300 mm] incl[A] in. [mm]
⅜ to 3 incl [10 to 75]	±1/64 in. [0.40]	±1/32 in [0.79]	±3/64 in. [1.19]	±⅛ in. [3.17]
Over 3 to 6, incl [75 to 150]	±1/32 in. [0.79]	±3/64 in. [1.19]	±1/16 in. [1.59]	±⅛ in. [3.17]
Over 6 to 9, incl [150 to 230]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in. [3.17]	±⅛ in. [3.17]
Over 9 to 12, incl [230 to 305]	±3/32 in. [2.38]	±3/32 in. [2.38]	±⅛ in. [3.17]	±⅛ in. [3.17]
Over 12 to 15, incl [305 to 380]	±3/32 in. [2.38]	±3/32 in. [2.38]	±⅛ in. [3.17]	±⅛ in. [3.17]

[A] For each additional 10 ft [3.0 m] or fraction thereof over 24 ft [7.3 m] an additional allowance should be made of plus or minus 1/16 in. [1.60 mm].

TABLE 14 Length Tolerances for Punch-, Saw-, or Disc-Cut Round Tubing

Outside Diameter in. [mm]	6 in. [150 mm] and under 12 in. [300 mm] in. [mm]	12 in. [300 mm] and under 48 in. [1200 mm] in. [mm]	48 in. [1200 mm] and under 10 ft [3.0 m] in. [mm]	10 ft [3.0 m] to 24 ft [7.3 m] incl.[A] in. [mm]
⅜ to 3, incl [10 to 75]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in. [3.17]	±¼ in. [6.35]
Over 3 to 6, incl [75 to 150]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in .[3.17]	±¼ in. [6.35]
Over 6 to 9, incl [150 to 230]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in. [3.17]	±¼ in. [6.35]
Over 9 to 12, incl [230 to 305]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in. [3.17]	±¼ in. [6.35]
Over 12 to 15, incl [305 to 380]	±1/16 in. [1.59]	±1/16 in. [1.59]	±⅛ in. [3.17]	±¼ in. [6.35]

[A] For each additional 10 ft [3.0 m] or fraction thereof over 24 ft [7.3 m] an additional allowance should be made of plus or minus 1/16 in. [1.60 mm].

TABLE 15 Tolerance (Inch) for Squareness of Cut (Either End) When Specified for Round Tubing[A,B]

Length of Tube ft [m]	Outside Diameter, in. [mm]						
	Under 1 [25] in. [mm]	1 to 2, [25 to 50] incl in. [mm]	Over 2 to 3, [25 to 75] incl in. [mm]	Over 3 to 4, [75 to 100] incl in. [mm]	Over 4 to 6, [100 to 150] incl in. [mm]	Over 6 to 10, [150 to 250] incl in. [mm]	Over 10 to 15, [250 to 380] incl in. [mm]
Under 1 [0.3]	0.006 [0.15]	0.008 [0.20]	0.010 [0.25]	0.015 [0.38]	0.020 [0.50]	0.060 [1.52]	0.080 [2.03]
1 to 3, incl [0.3 to 1]	0.008 [0.20]	0.010 [0.25]	0.015 [0.38]	0.020 [0.50]	0.030 [0.76]	0.060 [1.52]	0.080 [2.03]
Over 3 to 6, incl [1 to 2]	0.010 [0.25]	0.015 [0.38]	0.020 [0.50]	0.025 [0.63]	0.040 [1.01]	0.070 [1.77]	0.090 [2.28]
Over 6 to 9, incl [2 to 3]	0.015 [0.38]	0.020 [0.50]	0.025 [0.63]	0.030 [0.76]	0.040 [1.01]	0.070 [1.77]	0.090 [2.28]

[A] Actual squareness normal to length of tube, not parallelness of both ends.
[B] Values given are "go" value of feeler gauge. "No go" value is 0.001 in. [0.025 mm] greater in each case.

incidental to manufacture will remain on the surface. If the order specifies no oil, the purchaser assumes responsibility for rust in transit.

14.2 Special surface preparations as may be required for specific applications are not within the scope of this section. Such requirements shall be considered under the supplementary or basis of purchase provisions of this specification and details shall be provided in the purchase order.

15. Rejection

15.1 Tubes that fail to meet the requirements of this specification shall be set aside and the producer shall be notified.

16. Product and Package Marking

16.1 *Civilian Procurement*—Each box, bundle, lift, or piece shall be identified by a tag or stencil with manufacturers name or brand, specified size, type, purchaser's order number, and this specification number. Bar coding is acceptable as a supplementary identification method. Bar coding should be consistent with the Automotive Industry Action Group [AIAG] standard prepared by the Primary Metals Subcommittee of the AIAG Bar Code Project Team.

16.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the 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 in accordance with Fed. Std. No. 123 for civil agencies.

16.3 *Bar Coding*—In addition to the requirements in 16.1 and 16.2, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used.

17. Packaging

17.1 *Civilian Procurement*—On tubing 16 gauge, 0.065 in. [1.7 mm] and lighter, the producer will determine whether or not the tubing will be boxed, crated, cartoned, packaged in secured lifts, or bundled to ensure safe delivery unless otherwise instructed. Tubing heavier than 16 gauge will normally be shipped loose, bundled, or in secured lifts. Special packaging

TABLE 16 Tolerances, Outside Dimensions[A] Square and Rectangular Tubing

Largest Nominal Outside Dimension, in. [mm]	Wall Thickness, in. [mm]	Outside Tolerance at All Sides at Corners ± in. [mm]
3/16 to 5/8, incl [5 to 15]	0.020 to 0.083, incl [0.51 to 2.11]	0.004 [0.10]
Over 5/8 to 1 1/8, incl [15 to 30]	0.022 to 0.156, incl [0.56 to 3.96]	0.005 [0.13]
Over 1 1/8 to 1 1/2, incl [30 to 40]	0.025 to 0.192, incl [0.64 to 4.88]	0.006 [0.15]
Over 1 1/2 to 2, incl [40 to 50]	0.032 to 0.192, incl [0.81 to 4.88]	0.008 [0.20]
Over 2 to 3, incl [50 to 75]	0.035 to 0.259, incl [0.89 to 6.58]	0.010 [0.25]
Over 3 to 4, incl [75 to 100]	0.049 to 0.259, incl [1.24 to 6.58]	0.020 [0.51]
Over 4 to 6, incl [100 to 150]	0.065 to 0.259, incl [1.65 to 6.58]	0.020 [0.51]
Over 6 to 8, incl [150 to 200]	0.185 to 0.259, incl [4.70 to 6.58]	0.025 [0.64]

[A] Measured at corners at least 2 in. [50 mm] from the cut end of the tubing.

Convexity and concavity: Tubes having two parallel sides are also measured in the center of the flat sides for convexity and concavity. This tolerance applies to the specific size determined at the corners, and is measured on the following basis:

Largest Nominal Outside Dimension, in. [mm]	Tolerance ±, in. [mm]
2 1/2 [65] and under	0.010 [0.25]
Over 2 1/2 to 4 [65 to 100]	0.015 [0.38]
Over 4 to 8 [100 to 200]	0.025 [0.63]

TABLE 17 Radii of Corners of Electric-Resistance-Welded Square and Rectangular Tubing[A]

Squares and Rectangles Made from Tubes of the Following Diameter Ranges, in. [mm]	Wall Thickness Bwg (in.) [mm]	Radius Tolerances[B] in. [mm]
1/2 to 1 1/2, incl [15 to 40]	24 (0.022) [0.56]	1/64 to 3/64 [0.40 to 1.19]
1/2 to 1 1/2, incl [15 to 40]	22 (0.028) [0.71]	1/32 to 1/16 [0.79 to 1.59]
1/2 to 2 1/2, incl [15 to 65]	20 (0.035) [0.89]	1/32 to 1/16 [0.79 to 1.59]
1/2 to 2 1/2, incl [15 to 65]	19 (0.042) [1.07]	3/64 to 5/64 [1.19 to 1.98]
1/2 to 4, incl [15 to 100]	18 (0.049) [1.24]	3/64 to 5/64 [1.19 to 1.98]
1/2 to 4 1/8, incl [15 to 105]	16 (0.065) [1.65]	1/16 to 7/64 [1.59 to 2.78]
3/4 to 4 1/8, incl [20 to 105]	14 (0.083) [2.11]	5/64 to 1/8 [1.98 to 3.18]
Over 4 1/8 to 6, incl [105 to 150]	14 (0.083) [2.11]	3/16 to 5/16 [4.76 to 7.94]
1 to 4 1/8 , incl [25 to 105]	13 (0.095) [2.41]	3/32 to 5/32 [2.38 to 3.97]
Over 4 1/8 to 6, incl [105 to 150]	13 (0.095) [2.41]	3/16 to 5/16 [4.75 to 7.94]
1 1/4 to 4, incl [30 to 100]	12 (0.109) [2.77]	1/8 to 13/64 [3.18 to 5.16]
Over 4 to 6, incl [100 to 150]	12 (0.109) [2.77]	3/16 to 5/16 [4.76 to 7.94]
1 1/4 to 4, incl [30 to 100]	11 (0.120) [3.05]	1/8 to 7/32 [3.18 to 5.56]
Over 4 to 6, incl [100 to 150]	11 (0.120) [3.05]	7/32 to 7/16 [5.56 to 11.11]
2 to 4, incl [50 to 100]	10 (0.134) [3.40]	5/32 to 9/32 [3.97 to 7.14]
Over 4 to 6, incl [100 to 150]	10 (0.134) [3.40]	7/32 to 7/16 [5.56 to 11.11]
2 to 4, incl [50 to 100]	9 (0.148) [3.76]	3/16 to 5/16 [4.76 to 7.94]
Over 4 to 8, incl [100 to 200]	9 (0.148) [3.76]	7/32 to 7/16 [5.56 to 11.11]
2 to 8, incl [50 to 200]	8 (0.165) [4.19]	1/4 to 1/2 [6.35 to 12.70]
2 to 8, incl [50 to 200]	7 (0.180) [4.57]	1/4 to 1/2 [6.35 to 12.70]
2 1/2 to 4, incl [65 to 100]	6 (0.203) [5.16]	5/16 to 9/16 [7.93 to 14.29]
Over 4 to 8, incl [100 to 200]	6 (0.203) [5.16]	5/16 to 9/16 [7.93 to 14.29]
2 1/2 to 8, incl [65 to 200]	5 (0.220) [5.59]	3/8 to 5/8 [9.53 to 15,88]
2 1/2 to 8, incl [65 to 200]	4 (0.238) [6.05]	3/8 to 5/8 [9.53 to 15.88]
2 1/2 to 8, incl [65 to 200]	3 (0.259) [6.58]	3/8 to 5/8 [9.53 to 15.88]

[A] This table establishes a standard radius. The purchaser and producer may negotiate special radii. Slight radius flattening is more pronounced in heavier wall tubing.
[B] These radius tolerances apply to grades of steel covered in Table 1. The purchaser and producer may negotiate tolerances on other grades of steel.

TABLE 18 Length Tolerances—Square and Rectangular Tubing

Lengths, ft. [m]	Tolerances, in. [mm]
1 to 3, incl [0.3 to 1]	±1/16 [1.6]
Over 3 to 12, incl [1 to 4]	±3/32 [2.4]
Over 12 to 20, incl [4 to 6]	±1/8 [3.2]
Over 20 to 30, incl [6 to 9]	±3/16 [4.8]
Over 30 to 40, incl [9 to 12]	±3/8 [9.5]

TABLE 19 Twist Tolerances Electric-Resistance-Welded for Square and Rectangular-Mechanical Tubing

Largest Dimension, in. [mm]	Twist Tolerance in 3 ft [1 m] in. [mm]
1/2 and under [15]	0.032 [0.81]
Over 1/2 to 1 1/2, incl [15 to 40]	0.050 [1.27]
Over 1 1/2 to 2 1/2, incl [40 to 65]	0.062 [1.57]
Over 2 1/2 to 4, incl [65 to 100]	0.075 [1.91]
Over 4 to 6, incl [100 to 150]	0.087 [2.20]
Over 6 to 8, incl [150 to 200]	0.100 [2.54]

requiring extra operations other than those normally used by a producer must be specified on the order.

17.2 *Government Procurement*—When specified in the contract or order, and for direct procurement by or direct shipment to the Government when Section 10, Tubular Products is specified, preservation, packaging, and packing shall be in accordance with the Practices A700.

18. Keywords

18.1 alloy steel tube; carbon steel tube; mechanical tubing; resistance welded steel tube; steel tube; welded steel tube

SUPPLEMENTARY REQUIREMENTS

One or more of the following supplementary requirements may become a part of the specification when specified in the inquiry or invitation to bid, and purchase order or contract. These requirements shall not be considered, unless specified in the order and the necessary tests shall be made at the mill. Mechanical tests shall be performed in accordance with the applicable portions of Test Methods and Definitions A370.

S1. Tubes for Cylinders

S1.1 Round tubing, DOM for cylinder applications with inside diameter cleanup allowances is considered to be cylinder tubing. Table S1.1 shows the minimum inside diameter allowance for removal of inside surface imperfections by a honing operation.

S2. Cleanup by Centerless Grinding

S2.1 Round tubing, DOM for applications with outside diameter allowances is considered to be special smooth outside surface tubing. Table S2.1 shows the minimum outside diameter stock allowance for removal of outside surface imperfections by centerless grinding.

S3. Cleanup by Machining

S3.1 Cleanup is permitted on round tubing, DOM for applications where machining is required to remove surface imperfections. Table S3.1 shows the minimum stock allowance for removal of surface imperfections from either or both the outside and inside surfaces by machining.

S4. Special Smooth Inside Surface

S4.1 Round tubing, special smooth inside diameter for cylinder applications with microinch finish and inside diameter cleanup allowances is considered to be special smooth inside surface tubing. Table S4.1 shows the maximum average

TABLE S1.1 Minimum Inside Diameter Stock Allowance on Diameter[A] for Removal of Inside-Surface Imperfections by Honing Operation (DOM Tubing)

Outside Diameter, in. [mm]	Wall Thickness, in.,[B] [mm]							
	0.065 [1.65] and under	Over 0.065 [1.65] to 0.125 [31.2], incl	Over 0.125 [31.2] to 0.180 [4.57] incl	Over 0.180 [4.57] to 0.230 [5.84], incl	Over 0.230 [5.84] to 0.360 [9.14], incl	Over 0.360 [9.14] to 0.460 [11.7] incl	Over 0.460 [11.7] to 0.563 [14.3], incl	Over 0.563 [14.3]
Up to and incl 1½ [40]	0.010 [0.25]	0.011 [0.28]	0.013 [0.33]	0.015 [0.38]	0.018 [0.46]	...	...	...
Over 1½ to 3 incl [40 to 75]	0.010 [0.25]	0.012 [0.30]	0.014 [0.36]	0.016 [0.41]	0.018 [0.46]	0.021 [0.53]	0.023 [0.58]	...
Over 3 to 4 incl [75 to 100]	0.011 [0.28]	0.013 [0.33]	0.015 [0.38]	0.017 [0.43]	0.019 [0.48]	0.021 [0.53]	0.023 [0.58]	0.025 [0.64]
Over 4 to 4¾ incl [100 to 120]	...	0.014 [0.36]	0.016 [0.41]	0.018 [0.46]	0.020 [0.51]	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]
Over 4¾ to 6 incl [120 to 150]	...	0.015 [0.38]	0.017 [0.43]	0.019 [0.48]	0.021 [0.53]	0.023 [0.58]	0.025 [0.64]	0.027 [0.69]
Over 6 to 8 incl [150 to 200]	...	0.016 [0.41]	0.018 [0.46]	0.020 [0.51]	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]	0.028 [0.71]
Over 8 to 10½ incl [200 to 265]	...	...	...	0.021 [0.53]	0.023 [0.58]	0.025 [0.64]	0.027 [0.69]	0.029 [0.74]
Over 10½ to 12½ incl [265 to 320]	...	...	...	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]	0.028 [0.71]	0.030 [0.76]
Over 12½ to 14 incl [320 to 355]	...	...	...	0.024 [0.61]	0.025 [0.64]	0.027 [0.69]	0.029 [0.74]	0.031 [0.79]
Over 14 to 15 incl [355 to 380]	...	...	...	0.025 [0.64]	0.026 [0.66]	0.028 [0.71]	0.030 [0.76]	0.032 [0.81]

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] Where the ellipsis (...) appears in this table, no allowances have been established.

TABLE S2.1 Minimum Outside Diameter Stock Allowance on Diameter[A] for Removal of Outside-Surface Imperfections by Centerless Grinding (DOM Tubing)

Outside Diameter, in. [mm]	Tubing Wall Thickness, in. [mm][B]					
	Up to 0.125 [3.2] incl	Over 0.125 [3.2] to 0.180 [4.57] incl	Over 0.180 [4.57] to 0.230 [5.84] incl	Over 0.230 [5.84] to 0.360 [9.14] incl	Over 0.360 [9.14] to 0.460 [11.7], incl	Over 0.460 [11.7]
Up to 3, incl [75]	0.012 [0.30]	0.014 [0.36]	0.016 [0.41]	0.020 [0.51]	0.024 [0.61]	0.026 [0.66]
Over 3 to 4¾, inc [75 to 120]	0.016 [0.41]	0.018 [0.46]	0.020 [0.51]	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]
Over 4¾ to 6, incl [120 to 150]	0.018 [0.46]	0.020 [0.51]	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]	0.028 [0.71]
Over 6 to 7, incl [150 to 180]	0.020 [0.51]	0.022 [0.56]	0.024 [0.61]	0.026 [0.66]	0.028 [0.71]	0.030 [0.76]
Over 7 to 8, incl [180 to 200]	...	...	0.026 [0.66]	0.027 [0.69]	0.029 [0.74]	0.031 [0.79]
Over 8 to 10½, incl [200 to 265]	...	...	0.027 [0.69]	0.028 [0.71]	0.030 [0.76]	0.032 [0.81]
Over 10½ to 12½, incl [265 to 320]	...	...	0.028 [0.71]	0.030 [0.76]	0.032 [0.81]	0.034 [0.85]
Over 12½ to 14 incl [320 to 355]	...	...	0.030 [0.76]	0.032 [0.81]	0.034 [0.85]	0.036 [0.91]
Over 14 [355]	...	...	0.033 [0.84]	0.035 [0.89]	0.036 [0.91]	0.037 [0.94]

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] Where the ellipsis (...) appears in this table, no allowances have been established.

TABLE S3.1 Minimum Diameter Stock Allowance for Outside Diameter and Inside Diameter for Removal of Imperfections by Machining (DOM Tubing)[A]

NOTE 1—*Camber*—For every foot or fraction thereof over one foot of length, add 0.010 in. [0.25] for camber.

Outside Diameter, in. [mm][B]	Wall Thickness, in. [mm][B,C]				
	Up to 0.187 [4.75]	0.187 [4.75] to 0.230 [5.84] incl	Over 0.230 [5.84] to 0.360 [9.14] incl	Over 0.360 [9.14] to 0.460 [11.7] incl	Over 0.460 [11.7]
Up to 1½ incl [40]	0.015 [0.38]	0.020 [0.51]	0.025 [0.64]	...	...
Over 1½ to 3 incl [40 to 75]	0.020 [0.51]	0.025 [0.64]	0.030 [0.76]	0.030 [0.76]	0.035 [0.89]
Over 3 to 4¾ incl [75 to 120]	0.025 [0.64]	0.030 [0.76]	0.035 [0.89]	0.035 [0.89]	0.040 [1.02]
Over 4¾ to 6 incl [120 to 150]	0.030 [0.76]	0.035 [0.89]	0.040 [1.02]	0.040 [1.02]	0.045 [1.14]
Over 6 to 7 incl [150 to 180]	0.035 [0.89]	0.040 [1.02]	0.045 [1.14]	0.045 [1.14]	0.050 [1.27]
Over 7 to 8 incl [170 to 200]	...	0.045 [1.14]	0.048 [1.22]	0.048 [1.22]	0.053 [1.35]
Over 8 to 10½ incl [200 to 265]	...	0.048 [1.22]	0.050 [1.27]	0.050 [1.27]	0.055 [1.40]
Over 10½ to 15 incl [265 to 380]	...	0.050 [1.27]	0.055 [1.40]	0.055 [1.40]	0.060 [1.52]

[A] If a specific size is desired, those allowances plus normal size tolerances must be considered in calculating size to be ordered.
[B] Where the ellipsis (...) appears in this table, no allowances have been established.
[C] 1 in. = 25.4 mm.

TABLE S4.1 Maximum Average Microinch Readings on Inside Surface (Special Smooth Inside Diameter Tubing)

Outside Diameter, in. [mm]	Tubing Wall Thickness in. [mm][A]				
	0.065 [1.65] and Under	Over 0.065 [1.65] to 0.150 [3.80], incl	Over 0.150 [3.80] to 0.187 [4.75], incl	Over 0.187 [4.75] to 0.225 [5.72], incl	Over 0.225 [5.72] to 0.312 [7.92], incl
1 to 2½, incl [25 to 65]	40 [0.00101]	45 [0.00114]	50 [0.00127]	55 [0.001397]	70 [0.00178]
Over 2½ to 4½, incl [65 to 115]	40 [0.00101]	50 [0.00127]	60 [0.00152]	70 [0.00178]	80 [0.00203]
Over 4½ to 5½, incl [115 to 140]	...	55 [0.001397]	70 [0.00178]	80 [0.00203]	90 [0.00229]
Over 5½ to 7 incl [140 to 180]	...	55 [0.001397]	70 [0.00178]	80 [0.00203]	90 [0.00229]

[A] Where the ellipsis (...) appears in this table, there is no requirement.

microinch readings on the inside surface. Table S4.2 shows the minimum wall depth allowance for inside surface imperfections.

S5. Hardness and Tensile Requirements

S5.1 When hardness properties are specified on the order, round tubing shall conform to the hardness limits specified in Table S5.1 unless "Tensile Properties Required" is specified in the purchase order. When "Tensile Properties Required" is specified in the purchase order, round tubing shall conform to the tensile requirements and not necessarily the hardness limits shown in Table S5.1. For grades of round tubing not shown in Table S5.1, and for all square and rectangular tubing, tensile or hardness limits shall be upon agreement between the manufacturer and the purchaser.

S5.2 Number of tests and retests shall be as follows: one tension test per lot shall be made (See Note S1) and 1 % of all tubes per lot but in no case less than 5 tubes shall be tested for hardness. If the results of the mechanical tests do not conform to the requirements shown in the table, retests shall be made on additional tubes double the original number selected, each of which shall conform to the specified requirements.

NOTE S1—A lot shall consist of all tubes, before cutting to length, of the same size and wall thickness which are produced from the same heat of

TABLE S4.2 Allowance for Surface Imperfections on Inside Diameters of Special Smooth Finish Tubes[A]

Outside Diameter Size, in. [mm]	Wall Thickness, in. [mm]	Wall Depth Allowance for Inside Diameter Surface Imperfections, in. [mm]	
		Scores	Pits
Up to 2½ incl [65]	0.065 to 0.109 incl [1.65 to 2.77]	0.001 [0.03]	0.0015 [0.04]
	Over 0.109 to 0.250 incl [2.77 to 6.35]	0.001 [0.03]	0.002 [0.05]
	Over 0.250 to 0.312 incl [6.35 to 7.92]	0.001 [0.03]	0.0025 [0.06]
Over 2½ to 5½ incl [65 to 140]	0.083 to 0.125 incl [2.11 to 3.18]	0.0015 [0.04]	0.0025 [0.06]
	Over 0.125 to 0.187 incl [3.18 to 4.75]	0.0015 [0.04]	0.003 [0.08]
	Over 0.187 to 0.312 incl [4.75 to 7.92]	0.002 [0.05]	0.004 [0.10]
Over 5½ to 7 incl [140 to 180]	0.125 to 0.187 incl [3.18 to 4.75]	0.0025 [0.06]	0.005 [0.13]
	Over 0.187 to 0.312 incl [4.75 to 7.92]	0.003 [0.08]	0.006 [0.15]

[A] If a specific size is desired, these allowances plus normal size tolerances must be considered in calculating size to be ordered.

steel and, when heat treated, subjected to the same finishing treatment in a continuous furnace. When final heat treatment is done in a batch-type furnace, the lot shall include all those tubes which are heat treated in the same furnace charge.

S5.3 The yield strength corresponding to a permanent offset of 0.2 % of the gauge length of the specimen or to a total extension of 0.5 % of the gauge length under load shall be determined.

S6. Destructive Weld Tests

S6.1 Round tubing and tubing to be formed into other shapes when in the round form shall meet the following destructive weld tests.

S6.2 *Flattening Test*—A test 4 to 6 in. [100 to 150 mm] in length shall be flattened between parallel plates with the weld 90° from the direction of applied force (at the point of maximum bending) until opposite walls of the tubing meet. Except as allowed in S6.2.1, no opening in the weld shall take place until the distance between the plates is less than two thirds of the original outside diameter of the tubing. No cracks or breaks in the base metal shall occur until the distance between the plates is less than one third of the original outside diameter of the tubing, but in no case less than five times the thickness of the tubing wall. Evidence of lamination or burnt material shall not develop during the flattening process, and the weld shall not show injurious defects.

S6.2.1 When low D-to-t ratio tubing is tested, because the strain imposed due to geometry is unreasonably high on the inside surface at the six and twelve o'clock locations, cracks at these locations shall not be cause for rejection if the D-to-t ratio is less than 10.

S6.3 *Flaring Test*—A section of tube approximately 4 in. [100 mm] in length shall stand being flared with a tool having a 60° included angle until the tube at the mouth of the flare has been expanded 15 % of the inside diameter, without cracking or showing flaws.

S6.4 In order to properly evaluate weld quality, the producer at his option may normalize the test specimen prior to testing.

S6.5 Number of tests and retests:

S6.5.1 Two flattening and two flaring tests shall be made from each lot as specified. Each tested specimen shall conform to the respective requirement (See Note S1).

S6.5.2 If the results of the testing do not conform to the requirements, retests shall be made on four additional specimens, each of which shall conform to the respective requirement.

S7. Hydrostatic Test Round Tubing

S7.1 All tubing will be given a hydrostatic test calculated as follows:

$$P = \frac{2St}{D}$$

where:

P = minimum hydrostatic test pressure, psi or MPa,
S = allowable fiber stress of 14 000 psi or 96.5 MPa,
t = specified wall thickness, in. or mm, and
D = specified outside diameter, in. or mm.

S7.2 The minimum hydrostatic test pressue shall be maintained for not less than 5 s.

S8. Nondestructive Electric Test

S8.1 Each tube shall be tested with a nondestructive electric test in accordance with Practice E213, Practice E273, Practice E309, or Practice E570. It is the intent of this test to reject tubes containing injurious defects.

S8.2 For eddy-current testing, the calibration tube shall contain, at the option of the producer, any one of the following discontinuities to establish a minimum sensitivity level for rejection. For welded tubing, they shall be placed in the weld if visible.

S8.2.1 *Drilled Hole*—A hole not larger than 0.031 in. [0.78 mm] in diameter shall be drilled radially and completely through the tube wall, care being taken to avoid distortion of the tube while drilling.

S8.2.2 *Transverse Tangential Notch*—Using a round tool or file with a ¼-in. [6.4-mm] diameter, a notch shall be filed or milled tangential to the surface and transverse to the longitudinal axis of the tube. Said notch shall have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.101 mm], whichever is greater.

S8.2.3 *Longitudinal Notch*—A notch 0.031 in. [0.78 mm] or less in width shall be machined in a radial plane parallel to the tube axis on the outside surface of the tube, to have a depth not exceeding 12½ % of the specified wall thickness of the tube or 0.004 in. [0.101 mm], whichever is greater. The length of the notch shall be compatible with the testing method.

S8.3 For ultrasonic testing, the longitudinal calibration reference notches shall be at the option of the producer, any one of the three common notch shapes shown in Practice E213 or Practice E273. The depth of notch shall not exceed 12½ % of the specified wall thickness of the tube or 0.004 in. [0.101

TABLE S5.1 Mechanical Properties for Round Tubing

NOTE 1—These values are based on normal mill stress relieving temperatures. For particular applications, properties may be adjusted by negotiation between purchaser and producer.

NOTE 2—For longitudinal strip tests, the width of the gauge section shall be according to A370 Annex A2, Steel Tubular Products and a deduction of 0.5 percentage points from the basic minimum elongation for each 1/32 in. [0.8 mm] decrease in wall thickness under 5/16 in. [7.9 mm] in wall thickness shall be permitted.

	Yield Strength, ksi [MPa], min	Ultimate Strength, ksi [MPa], min	Elongation in 2 in. [50 mm], %, min	RB min	RB max
As-Welded Tubing					
1008	30 [205]	42 [290]	15	50	
1009	30 [205]	42 [290]	15	50	
1010	32 [220]	45 [310]	15	55	
1015	35 [240]	48 [330]	15	58	
1020	38 [260]	52 [360]	12	62	
1021	40 [275]	54 [370]	12	62	
1025	40 [275]	56 [385]	12	65	
1026	45 [310]	62 [425]	12	68	
1030	45 [310]	62 [425]	10	70	
1035	50 [345]	66 [455]	10	75	
1040	50 [345]	66 [645]	10	75	
1340	55 [380]	72 [495]	10	80	
1524	50 [345]	66 [455]	10	75	
4130	55 [380]	72 [495]	10	80	
4140	70 [480]	90 [620]	10	85	
Normalized Tubing					
1008	23 [160]	38 [260]	30		65
1009	23 [160]	38 [260]	30		65
1010	25 [170]	40 [275]	30		65
1015	30 [205]	45 [310]	30		70
1020	35 [240]	50 [345]	25		75
1021	35 [240]	50 [345]	25		78
1025	37 [255]	55 [380]	25		80
1026	40 [275]	60 [415]	25		85
1030	40 [275]	60 [415]	25		85
1035	45 [310]	65 [450]	20		88
1040	45 [310]	65 [450]	20		90
1340	50 [345]	70 [480]	20		100
1524	45 [310]	65 [450]	20		88
4130	50 [345]	70 [480]	20		100
4140	65 [450]	90 [620]	20		105
Sink-Drawn Tubing					
1008	38 [260]	48 [330]	8	65	
1009	38 [260]	48 [330]	8	65	
1010	40 [275]	50 [345]	8	65	
1015	45 [310]	55 [380]	8	67	
1020	50 [345]	60 [415]	8	70	
1021	52 [360]	62 [425]	7	70	
1025	55 [380]	65 [450]	7	72	
1026	55 [380]	70 [480]	7	77	
1030	62 [425]	70 [480]	7	78	
1035	70 [480]	80 [550]	7	82	
DOM Tubing					
1008	50 [345]	60 [415]	5	73	
1009	50 [345]	60 [415]	5	73	
1010	50 [345]	60 [415]	5	73	
1015	55 [380]	65 [450]	5	77	
1020	60 [415]	70 [480]	5	80	
1021	62 [425]	72 [495]	5	80	
1025	65 [450]	75 [515]	5	82	
1026	70 [480]	80 [550]	5	85	
1030	75 [515]	85 [585]	5	87	
1035	80 [550]	90 [620]	5	90	
1040	80 [550]	90 [620]	5	90	
1340	85 [585]	95 [655]	5	90	
1524	80 [550]	90 [620]	5	90	
4130	85 [585]	95 [655]	5	90	
4140	100 [690]	110 [760]	5	90	
DOM Stress-Relieved Tubing					
1008	45 [310]	55 [380]	12	68	
1009	45 [310]	55 [380]	12	68	
1010	45 [310]	55 [380]	12	68	
1015	50 [345]	60 [415]	12	72	

TABLE *Continued*

	Yield Strength, ksi [MPa], min	Ultimate Strength, ksi [MPa], min	Elongation in 2 in. [50 mm], %, min	RB min	RB max
1020	55 [380]	65 [450]	10	75	
1021	58 [400]	68 [470]	10	75	
1025	60 [415]	70 [480]	10	77	
1026	65 [450]	75 [515]	10	80	
1030	70 [480]	80 [550]	10	81	
1035	75 [515]	85 [585]	10	85	
1040	75 [515]	85 [585]	10	85	
1340	80 [550]	90 [620]	10	87	
1524	75 [515]	85 [585]	10	85	
4130	80 [550]	90 [620]	10	87	
4140	95 [655]	105 [725]	10	90	

mm], whichever is greater. For welded tubing the notch shall be placed in the weld, if visible.

S8.4 For flux leakage testing, each of the longitudinal calibration notches shall be a straight sided notch not over 12½ % of the wall thickness in depth and not over 1.0 in. [25 mm] in length. Both outside diameter and inside diameter notches shall be placed in the tube located sufficiently apart to enable separation and identification of the signals.

S8.5 Tubing producing a signal equal to or greater than the calibration defect shall be subject to rejection. The area producing the signal may be examined.

S8.5.1 Test signals produced by imperfections which cannot be identified, or produced by cracks or crack-like defects shall result in rejection of the tube subject to rework and retest.

S8.5.2 Test signals produced by imperfections such as those listed below may be judged as injurious or noninjurious depending on visual observation of their severity or the type of signal they produce on the testing equipment used, or both:

S8.5.2.1 Dings,

S8.5.2.2 Straightener marks,

S8.5.2.3 Loose inside diameter bead and cutting chips,

S8.5.2.4 Scratches,

S8.5.2.5 Steel die stamps,

S8.5.2.6 Chattered flash trim,

S8.5.2.7 Stop marks, or

S8.5.2.8 Tube reducer ripple.

S8.5.3 Any imperfection of the above type exceeding 0.004 in. [0.101 mm] or 12½ % of the specified wall thickness (whichever is greater) in depth shall be considered injurious.

S8.5.3.1 If the imperfection is judged as injurious, the tubes shall be rejected but may be reconditioned and retested providing the dimensional requirements are met.

S8.5.3.2 If the imperfection is explored to the extent that it can be identified as noninjurious, the tubes may be accepted without further test providing the imperfection does not encroach on the minimum wall thickness, after due allowance for cleanup in mandrel drawn tubes.

S9. Certification for Government Orders

S9.1 A producer's or supplier's certification shall be furnished to the Government that the material was manufactured, sampled, tested, and inspected in accordance with this specification and has been found to meet the requirements. This certificate shall include a report of heat analysis (product analysis when requested in the purchase order), and when specified in the purchase order or contract, a report of test results shall be furnished.

S10. Rejection Provisions for Government Orders

S10.1 Each length of tubing received from the manufacturer may be inspected by the purchaser and, if it does not meet the requirements of the specification based on the inspection and test method as outlined in the specification, the tube may be rejected and the manufacturer shall be notified. Disposition of rejected tubing shall be a matter of agreement between the manufacturer and the purchaser.

S10.2 Material that fails in any of the forming operations or in the process of installation and is found to be defective shall be set aside and the manufacturer shall be notified for mutual evaluation of the material's suitability. Disposition of such material shall be a matter for agreement.

APPENDIX

(Nonmandatory Information)

X1. MEASURING MICROINCH FINISH

X1.1 The procedure for making microinch readings on interior surfaces of cold worked tubing (not polished or ground) ½-in. [12.7-mm] inside diameter and larger is as follows:

X1.1.1 Measurements on tubing with longitudinal or no predominant lay should be circumferential on the inside surface of the straight tube, prior to any fabrication, on a plane approximately perpendicular to the tube axis. Measurements on tubing with circumferential lay should be longitudinal.

X1.1.2 Measurements should be made not less than 1 in. [25.4 mm] from the end.

X1.1.3 Measurements should be made at four positions approximately 90° apart or over a complete circumference if the trace should otherwise overlap.

X1.1.4 The length of trace should be in accordance with the latest revision of Section 4.5 of ASME B46.1 (not less than 0.600 in. [15.24 mm] long).

X1.1.5 A minimum of three such measurements should be made spaced not less than ¼ in. [6.4 mm] apart along the longitudinal axis.

X1.1.6 The numerical rating shall be the arithmetical average microinch of all readings taken. Each reading to be averaged should be the mean position of the indicator during the trace; any momentary meter excursions occupying less than 10 % of the total trace should be ignored.

X1.1.7 A deviation in numerical rating in various parts of a tube may be expected. Experience to date indicates that a variation of about ±35 % is normal.

X1.2 Instruments should meet the specifications given in the latest revision of ASME B46.1.

X1.3 Mechanical tracing is preferred. If hand tracing is used, the speed of trace should not vary by more than ±20 % from the required to give the appropriate cutoff. The 0.030-in. [0.76 mm] roughness width cutoff should be used.

X1.4 Microinch [0.0000254 mm] determinations only refer to roughness of areas that do not contain a defect, injurious or otherwise. Such defects as seams, slivers, pits, laps, etc., are subject to ordinary visual inspection in accordance with applicable specifications or trade customs, and have no relationship to roughness.

SUMMARY OF CHANGES

Committee A01 has identified the location of selected changes to this standard since the last issue, A513/A513M – 20, that may impact the use of this standard. (Approved July 1, 2020.)

(1) Changed 1.3.1 to allow indeterminate wall thicknesses.

Committee A01 has identified the location of selected changes to this specification since the last issue, A513/A513M – 19, that may impact the use of this specification. (Approved May 1, 2020.)

(1) Added 1.4 to the Scope to incorporate various grades types and thermal conditions.

(2) Corrected conversion errors in Table S5.1.

Committee A01 has identified the location of selected changes to this specification since the last issue, A513/A513M – 18, that may impact the use of this specification. (Approved March 1, 2019.)

(1) Corrected seven conversion errors in Table 10. 0.109 in. was incorrectly identified as 1.77 mm.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR INTERMEDIATE- AND HIGHER-TEMPERATURE SERVICE

SA-515/SA-515M

(Identical with ASTM Specification A515/A515M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service

1. Scope

1.1 This specification covers carbon-silicon steel plates primarily for intermediate- and higher-temperature service in welded boilers and other pressure vessels.

1.2 Plates under this specification are available in three grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results, of Specification A20/A20M apply.

1.5 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.

1.6 *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:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates supplied to this product specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

3.4 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

TABLE 1 Chemical Requirements

Elements	Composition, %		
	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max:[A, B]			
1 in. [25 mm] and under	0.24	0.28	0.31
Over 1 to 2 in. [25 to 50 mm], incl	0.27	0.31	0.33
Over 2 to 4 in. [50 to 100 mm], incl	0.29	0.33	0.35
Over 4 to 8 in. [100 to 200 mm], incl	0.31	0.33	0.35
Over 8 in. [200 mm]	0.31	0.33	0.35
Manganese,[B] max:			
Heat analysis	0.90	0.90	1.20
Product analysis	0.98	0.98	1.30
Phosphorus, max[A]	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025
Silicon:			
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.

TABLE 2 Tensile Requirements

	Grade		
	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min, ksi [MPa]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[A]	21	19	17
Elongation in 2 in. [50 mm], min, %[A]	25	23	21

[A] See Specification A20/A20M for elongation adjustment.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A20/A20M.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and made to a coarse austenitic grain size practice.

5. Heat Treatment

5.1 Plates 2 in. [50 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 2 in. [50 mm] in thickness shall be normalized.

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S4.1 Additional Tension Test,

S5. Charpy V-Notch Impact Test,

S6. Drop-Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

Also listed below is an additional optional supplementary requirement suitable for this specification:

S61. Austenitic Grain Size

S61.1 The material shall have a carburized austenitic grain size of 1 to 5.

SPECIFICATION FOR PRESSURE VESSEL PLATES, CARBON STEEL, FOR MODERATE- AND LOWER-TEMPERATURE SERVICE

SA-516/SA-516M

(Identical with ASTM Specification A516/A516M-17.)

Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

1. Scope

1.1 This specification covers carbon steel plates intended primarily for service in welded pressure vessels where improved notch toughness is important.

1.2 Plates under this specification are available in four grades having different strength levels as follows:

Grade U.S. [SI]	Tensile Strength, ksi [MPa]
55 [380]	55–75 [380–515]
60 [415]	60–80 [415–550]
65 [450]	65–85 [450–585]
70 [485]	70–90 [485–620]

1.3 The maximum thickness of plates is limited only by the capacity of the composition to meet the specified mechanical property requirements.

1.4 For plates produced from coil and furnished without heat treatment or with stress relieving only, the additional requirements, including additional testing requirements and the reporting of additional test results of Specification A20/A20M apply.

1.5 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.

1.6 *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:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Material supplied to this product specification shall conform to Specification A20/A20M, which outlines the testing and retesting methods and procedures, permissible variations in dimensions and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available where additional control, testing, or examination is required to meet end use requirements. The purchaser is referred to the listed supplementary requirements in this specification and to the detailed requirements in Specification A20/A20M.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

3.4 Coils are excluded from qualification to this specification until they are processed into finished plates. Plates produced from coil means plates that have been cut to individual lengths from coil. The processor directly controls, or is responsible for, the operations involved in the processing of coils into finished plates. Such operations include decoiling, leveling, cutting to length, testing, inspection, conditioning, heat treatment (if applicable), packaging, marking, loading for shipment, and certification.

TABLE 1 Chemical Requirements

Elements	Composition, %			
	Grade 55 [Grade 380]	Grade 60 [Grade 415]	Grade 65 [Grade 450]	Grade 70 [Grade 485]
Carbon, max:[A,B]				
½ in. [12.5 mm] and under	0.18	0.21	0.24	0.27
Over ½ in. to 2 in. [12.5 to 50 mm], incl	0.20	0.23	0.26	0.28
Over 2 in. to 4 in. [50 to 100 mm], incl	0.22	0.25	0.28	0.30
Over 4 to 8 in. [100 to 200 mm], incl	0.24	0.27	0.29	0.31
Over 8 in. [200 mm]	0.26	0.27	0.29	0.31
Manganese:[B]				
½ in. [12.5 mm] and under:				
Heat analysis	0.60–0.90	0.60–0.90[C]	0.85–1.20	0.85–1.20
Product analysis	0.55–0.98	0.55–0.98[C]	0.79–1.30	0.79–1.30
Over ½ in. [12.5 mm]:				
Heat analysis	0.60–1.20	0.85–1.20	0.85–1.20	0.85–1.20
Product analysis	0.55–1.30	0.79–1.30	0.79–1.30	0.79–1.30
Phosphorus, max[A]	0.025	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025	0.025
Silicon:				
Heat analysis	0.15–0.40	0.15–0.40	0.15–0.40	0.15–0.40
Product analysis	0.13–0.45	0.13–0.45	0.13–0.45	0.13–0.45

[A] Applies to both heat and product analyses.
[B] For each reduction of 0.01 percentage point below the specified maximum for carbon, an increase of 0.06 percentage point above the specified maximum for manganese is permitted, up to a maximum of 1.50 % by heat analysis and 1.60 % by product analysis.
[C] Grade 60 plates ½ in. [12.5 mm] and under in thickness may have 0.85–1.20 % manganese on heat analysis, and 0.79–1.30 % manganese on product analysis.

TABLE 2 Tensile Requirements

	Grade			
	55 [380]	60 [415]	65 [450]	70 [485]
Tensile strength, ksi [MPa]	55–75 [380–515]	60–80 [415–550]	65–85 [450–585]	70–90 [485–620]
Yield strength, min,[A] ksi [MPa]	30 [205]	32 [220]	35 [240]	38 [260]
Elongation in 8 in. [200 mm], min, %[B]	23	21	19	17
Elongation in 2 in. [50 mm], min, %[B]	27	25	23	21

[A] Determined by either the 0.2 % offset method or the 0.5 % extension-under-load method.
[B] See Specification A20/A20M for elongation adjustment.

NOTE 1—For plates produced from coil and furnished without heat treatment or with stress relieving only, three test results are reported for each qualifying coil. Additional requirements regarding plate produced from coil are described in Specification A20/A20M.

3.5 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Materials and Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Plates 1.50 in. [40 mm] and under in thickness are normally supplied in the as-rolled condition. The plates may be ordered normalized or stress relieved, or both.

5.2 Plates over 1.50 in. [40 mm] in thickness shall be normalized.

5.3 When notch-toughness tests are required on plates 1½ in. [40 mm] and under in thickness, the plates shall be normalized unless otherwise specified by the purchaser.

5.4 If approved by the purchaser, cooling rates faster than those obtained by cooling in air are permissible for improvement of the toughness, provided the plates are subsequently tempered in the temperature range 1100 to 1300°F [595 to 705°C].

6. Chemical Composition

6.1 The steel shall conform to the chemical requirements given in Table 1 unless otherwise modified in accordance with Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M.

7. Mechanical Properties

7.1 *Tension Test*—The plates, as represented by the tension test specimens, shall conform to the requirements given in Table 2.

8. Keywords

8.1 carbon steel; carbon steel plate; pressure containing parts; pressure vessel steels; steel plates for pressure vessels

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the purchase order.

A list of standardized supplementary requirements for use at the option of the purchaser is included in ASTM Specification A20/A20M. Those that are considered suitable for use with this specification are listed below by title.

S1. Vacuum Treatment,
S2. Product Analysis,
S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,
S4.1 Additional Tension Test,
S5. Charpy V-Notch Impact Test,
S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),
S7. High-Temperature Tension Test,
S8. Ultrasonic Examination in accordance with Specification A435/A435M,
S9. Magnetic Particle Examination,
S11. Ultrasonic Examination in accordance with Specification A577/A577M,
S12. Ultrasonic Examination in accordance with Specification A578/A578M, and
S17. Vacuum Carbon-Deoxidized Steel.

ADDITIONAL SUPPLEMENTARY REQUIREMENTS

In addition, the following supplementary requirement is suitable for this application.

S54. Requirements for Carbon Steel Plate for Hydrofluoric Acid Alkylation Service

S54.1 Plates shall be provided in the normalized heat-treated condition.

S54.2 The maximum carbon equivalent (CE) shall be as follows:

Plate thickness less than or equal to 1 in. [25 mm]:

$$\text{CE maximum} = 0.43$$

Plate thickness greater than 1 in. [25 mm]:

$$\text{CE maximum} = 0.45$$

S54.3 Determine the CE as follows:

$$CE = C + Mn/6 + (Cr + Mo + V)/5 + (Ni + Cu)/15$$

S54.4 Vanadium (V) and niobium (Nb) maximum content based on heat analysis shall be:

$$\text{Maximum vanadium} = 0.02\ \%$$

$$\text{Maximum niobium} = 0.02\ \%$$

$$\text{Maximum vanadium plus niobium} = 0.03\ \%$$

(Note: niobium = columbium.)

S54.5 The maximum composition based on heat analysis of nickel (Ni) plus copper (Cu) shall be 0.15 %.

S54.6 The minimum carbon (C) content based on heat analysis shall be 0.18 %. The maximum C content shall be as specified for the ordered grade.

S54.7 Welding consumables for repair welds shall be of the low-hydrogen type. E60XX electrodes shall not be used and the resulting weld chemistry shall meet the same chemistry requirements as the base metal.

S54.8 In addition to the requirements for product marking in the specification, an "HF-N" stamp or marking shall be provided on each plate to identify that the plate complies with this supplementary requirement.

SPECIFICATION FOR PRESSURE VESSEL PLATES, ALLOY STEEL, HIGH-STRENGTH, QUENCHED AND TEMPERED

SA-517/SA-517M

(Identical with ASTM Specification A517/A517M-17 except for the addition of Footnote A to Boron in Table 1.)

Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered

1. Scope

1.1 This specification covers high-strength quenched and tempered alloy steel plates intended for use in fusion welded boilers and other pressure vessels.

1.2 This specification includes a number of grades as manufactured by different producers, but all having the same mechanical properties and general characteristics.

1.3 The maximum thickness of plates furnished under this specification shall be as follows:

Grade	Thickness
A, B	1.25 in. [32 mm]
H, S	2 in. [50 mm]
P	4 in. [100 mm]
F	2.50 in. [65 mm]
E, Q	6 in. [150 mm]

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 is to be used independently of the other without combining values in any way.

1.5 *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:*

A20/A20M Specification for General Requirements for Steel Plates for Pressure Vessels

A435/A435M Specification for Straight-Beam Ultrasonic Examination of Steel Plates

A577/A577M Specification for Ultrasonic Angle-Beam Examination of Steel Plates

A578/A578M Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications

3. General Requirements and Ordering Information

3.1 Plates furnished to this material specification shall conform to Specification A20/A20M. These requirements outline the testing and retesting methods and procedures, permitted variations in dimensions, and mass, quality and repair of defects, marking, loading, and ordering information.

3.2 In addition to the basic requirements of this specification, certain supplementary requirements are available when additional control, testing, or examination is required to meet end use requirements.

3.3 If the requirements of this specification are in conflict with the requirements of Specification A20/A20M, the requirements of this specification shall prevail.

4. Manufacture

4.1 *Steelmaking Practice*—The steel shall be killed and shall conform to the fine austenitic grain size requirement of Specification A20/A20M.

5. Heat Treatment

5.1 Except as allowed by 5.2, the plates shall be heat treated by heating to not less than 1650°F [900°C], quenching in water or oil and tempering at not less than 1150°F [620°C].

5.2 Plates ordered without the heat treatment specified in 5.1 shall be stress relieved by the manufacturer, and subsequent heat treatment of the plates to conform to 5.1 shall be the responsibility of the purchaser.

6. Chemical Requirements

6.1 The steel shall conform to the chemical requirements shown in Table 1 unless otherwise modified in accordance with

TABLE 1 Chemical Requirements

NOTE 1—Where " … " appears there is no requirement.

Elements	Composition, %							
	Grade A	Grade B	Grade E	Grade F	Grade H	Grade P	Grade Q	Grade S
Carbon:								
Heat analysis	0.15–0.21	0.15–0.21	0.12–0.20	0.10–0.20	0.12–0.21	0.12–0.21	0.14–0.21	0.10–0.20
Product analysis	0.13–0.23	0.13–0.23	0.10–0.22	0.08–0.22	0.10–0.23	0.10–0.23	0.12–0.23	0.10–0.22
Manganese:								
Heat analysis	0.80–1.10	0.70–1.00	0.40–0.70	0.60–1.00	0.95–1.30	0.45–0.70	0.95–1.30	1.10–1.50
Product analysis	0.74–1.20	0.64–1.10	0.35–0.78	0.55–1.10	0.87–1.41	0.40–0.78	0.87–1.41	1.02–1.62
Phosphorus, max[A]	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Sulfur, max[A]	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.025
Silicon:								
Heat analysis	0.40–0.80	0.15–0.35	0.10–0.40	0.15–0.35	0.15–0.35	0.20–0.35	0.15–0.35	0.15–0.40
Product analysis	0.34–0.86	0.13–0.37	0.08–0.45	0.13–0.37	0.13–0.37	0.18–0.37	0.13–0.37	0.13–0.45
Nickel:								
Heat analysis	. . .	. . .	. . .	0.70–1.00	0.30–0.70	1.20–1.50	1.20–1.50	. . .
Product analysis	. . .	. . .	. . .	0.67–1.03	0.27–0.73	1.15–1.55	1.15–1.55	. . .
Chromium:								
Heat analysis	0.50–0.80	0.40–0.65	1.40–2.00	0.40–0.65	0.40–0.65	0.85–1.20	1.00–1.50	. . .
Product analysis	0.46–0.84	0.36–0.69	1.34–2.06	0.36–0.69	0.36–0.69	0.79–1.26	0.94–1.56	. . .
Molybdenum:								
Heat analysis	0.18–0.28	0.15–0.25	0.40–0.60	0.40–0.60	0.20–0.30	0.45–0.60	0.40–0.60	0.10–0.35
Product analysis	0.15–0.31	0.12–0.28	0.36–0.64	0.36–0.64	0.17–0.33	0.41–0.64	0.36–0.64	0.10–0.38
Boron [A]	0.0025 max	0.0005–0.005	0.001–0.005	0.0005–0.006	0.0005 min	0.001–0.005	. . .	. . .
Vanadium:								
Heat analysis	. . .	0.03–0.08	[B]	0.03–0.08	0.03–0.08	. . .	0.03–0.08	. . .
Product analysis	. . .	0.02–0.09	. . .	0.02–0.09	0.02–0.09	. . .	0.02–0.09	. . .
Titanium:								
Heat analysis	. . .	0.01–0.04	0.01–0.10	0.10 max	0.10 max	0.10 max	. . .	0.06 max
Product analysis	. . .	0.01–0.05	0.005–0.11	0.11 max	0.11 max	0.11 max	. . .	0.07 max
Zirconium:								
Heat analysis	0.05–0.15[C]	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Product analysis	0.04–0.16	. . .	. . .	. . .	. . .	. . .	. . .	. . .
Copper:								
Heat analysis	. . .	. . .	. . .	0.15–0.50	. . .	. . .	. . .	. . .
Product analysis	. . .	. . .	. . .	0.12–0.53	. . .	. . .	. . .	. . .
Columbium (Niobium),[D] max								
Heat analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.06
Product analysis	. . .	. . .	. . .	. . .	. . .	. . .	. . .	0.07

[A] Applied to both heat and product analyses.
[B] May be substituted for part or all of titanium content on a one for one basis.
[C] Zirconium may be replaced by cerium. When cerium is added, the cerium/sulfur ratio should be approximately 1.5 to 1, based on heat analysis.
[D] Columbium and niobium are interchangeable names for the same element and both names are acceptable for use in A01 specifications.

TABLE 2 Tensile Requirements

	2.50 in. [65 mm] and Under	Over 2.50 to 6 in. [65 to 150 mm]
Tensile strength, ksi [MPa]	115–135 [795–930]	105–135 [725–930]
Yield strength, min, ksi [MPa]	100 [690]	90 [620]
Elongation in 2 in. [50 mm], min, %[A]	16	14
Reduction of area, min, %:		
Rectangular specimens	35	. . .
Round specimens	45	45

[A] See Specification A20/A20M for elongation adjustment.

Supplementary Requirement S17, Vacuum Carbon-Deoxidized Steel, in Specification A20/A20M for grades other than Grade A.

7. Mechanical Requirements

7.1 *Tension Tests:*

7.1.1 *Requirements*—The plates as represented by the tension-test specimens shall conform to the requirements given in Table 2.

7.1.2 *Test Methods:*

7.1.2.1 The yield strength may be determined by the 0.2 % offset method or by the total extension under load of 0.5 % method.

7.1.2.2 For plates ¾ in. [20 mm] and under in thickness, the test specimen shall be the 1½ in. [40 mm] wide rectangular-test specimen.

7.1.2.3 For plates over ¾ in. [20 mm], either the full thickness rectangular-test specimen or the ½ in. [12.5 mm] round-test specimen may be used.

7.1.2.4 When the 1½ in. [40 mm] wide rectangular-test specimen is used, the elongation is measured in a 2 in. or [50 mm] gage length which includes the fracture.

7.2 *Impact Properties Requirements:*

7.2.1 Transverse Charpy V-notch impact test specimens shall have a lateral expansion opposite the notch of not less than 0.015 in. [0.38 mm].

7.2.2 The test temperature shall be agreed upon between the manufacturer and the purchaser, but shall not be higher than 32°F [0°C].

8. Keywords

8.1 alloy steel; boilers; high-strength; impact tested; plates; pressure vessels; quenched; tempered

SUPPLEMENTARY REQUIREMENTS

Supplementary requirements shall not apply unless specified in the order.

A list of standardized supplementary requirements for use at the option of the purchaser are included in Specification A20/A20M. Several of those considered suitable for use with this specification are listed by title. Other tests may be performed by agreement between the supplier and the purchaser.

S1. Vacuum Treatment,

S2. Product Analysis,

S3. Simulated Post-Weld Heat Treatment of Mechanical Test Coupons,

S5. Charpy V-Notch Impact Test,

S6. Drop Weight Test (for Material 0.625 in. [16 mm] and over in Thickness),

S7. High-Temperature Tension Test,

S8. Ultrasonic Examination in accordance with Specification A435/A435M,

S9. Magnetic Particle Examination,

S11. Ultrasonic Examination in accordance with Specification A577/A577M,

S12. Ultrasonic Examination in accordance with Specification A578/A578M, and

S17. Vacuum Carbon-Deoxidized Steel.

SPECIFICATION FOR FORGED OR ROLLED 8 AND 9% NICKEL ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR LOW-TEMPERATURE SERVICE

SA-522/SA-522M

(Identical with ASTM Specification A522/A522M-07.)

SPECIFICATION FOR FORGED OR ROLLED 8 AND 9% NICKEL ALLOY STEEL FLANGES, FITTINGS, VALVES, AND PARTS FOR LOW-TEMPERATURE SERVICE

SA-522/SA-522M

(Identical with ASTM Specification A 522/A 522M-07.)

1. Scope

1.1 This specification covers 8 and 9% nickel-alloy steel forged or rolled flanges, fittings, valves, and parts intended for use in welded pressure vessels for low-temperature service. The specification is applicable to forgings with maximum section thickness of 3 in. [75 mm] in the double normalized and tempered condition and 5 in. [125 mm] in the quenched and tempered condition. Forgings under this specification are intended for service at operating temperatures not lower than −320°F [−196°C] for Type I or −275°F [−170°C] for Type II or higher than 250°F [121°C].

1.2 Material under this specification is available in two types having different chemical compositions as follows:

Type	Nominal Nickel Content, %
I	9
II	8

1.3 This specification is expressed in both inch-pound units and SI units. However, unless the order specifies the applicable "M" specification designation (SI units), the material shall be furnished to inch-pound units.

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.

2. Referenced Documents

2.1 *ASTM Standards:*

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

A 788/A 788M Specification for Steel Forgings, General Requirements

A 961/A 961M Specification for Common Requirements for Steel Flanges, Forged Fittings, Valves, and Parts for Piping Applications

3. General Requirements and Ordering Information

3.1 Product furnished to this specification shall conform to the requirements of Specification A 961, including any supplementary requirements that are indicated in the purchase order. Failure to comply with the requirements of Specification A 961 constitutes nonconformance with this specification.

3.2 It is the purchaser's responsibility to specify in the purchase order all ordering information necessary to furnish the needed material. Examples of such information include but are not limited to the ordering information in Specification A 961 and following:

3.2.1 Any supplementary requirements, and

3.2.2 Additional requirements, (See 4.5, 5.2, 6.1, 7.2, and 10.3).

4. Materials and Manufacture

4.1 The steel shall be produced in accordance with the melting process section of Specification A 788.

4.2 Material for forgings shall consist of ingots, or either forged or rolled blooms, billets, or bars.

4.3 The finished product shall be a forging as defined in the Terminology Section of Specification A 788.

4.4 Except for flanges of all types, hollow cylindrically shaped parts may be made from hot-rolled or forged bar,

provided that the axial length of the part is approximately parallel to the metal flow lines of the stock. Except for all types of flanges, elbows, return bends, tees, and header tees, other parts up to and including NPS 4 may be machined from hot-rolled or forged bar.

4.5 When specified in the order, the manufacturer shall submit for purchaser's approval a sketch showing the shape of the rough forging before machining.

5. Chemical Composition

5.1 The steel shall conform to the requirements of Table 1.

5.2 If required by the purchaser, product analysis may be performed in accordance with the requirements of A 961.

6. Heat Treatment

6.1 The forgings shall be heat treated by the manufacturer by either of the following methods as mutually agreed upon between the purchaser and the manufacturer.

6.1.1 *Quenched and Tempered* — Heat to a uniform temperature of 1475 ± 25°F [800 ± 15°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; quench by immersion in circulating water. Reheat until the forging attains a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

6.1.2 *Double Normalized and Tempered* — Heat to a uniform temperature of 1650°F [900°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air. Reheat until the forging attains a uniform temperature of 1450°F [790°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air. Reheat to a uniform temperature within the range from 1050 to 1125°F [565 to 605°C]; hold at this temperature for a minimum time of 1 h/in. [2.5 min/mm] of thickness but in no case less than 30 min; cool in air or water quench, at a rate not less than 300°F [165°C]/h.

6.2 When stress relieving is to be performed after fabrication, the recommended stress-relieving treatment is as follows: gradually and uniformly heat the steel to a temperature between 1025 and 1085°F [550 and 585°C]; hold for a minimum of 2 h for thicknesses up to 1 in. [25 mm]. For thicknesses over 1 in. [25 mm], a minimum additional holding time in the ratio of 1 h/in. [2.5 min/mm] of thickness in excess of 1 in. [25 mm] shall be added. Cool at a minimum rate of 300°F [165°C]/h to a temperature not exceeding 600°F [315°C].

7. Mechanical Properties

7.1 *Tension Test* — Forgings to Types 1 and 2 shall conform to the tensile requirements of Table 2.

7.2 *Impact Test* — The Charpy impact test requirements in Table 3 shall be met unless Supplementary Requirement S2 of this specification has been specified.

7.2.1 The values for energy absorption and the fracture appearance in percentage of shear fracture for each specimen shall be recorded and reported for information.

8. Workmanship, Finish, and Appearance

8.1 The forgings shall have a workman-like finish and shall be free of injurious defects.

9. Number of Tests and Retests

9.1 At least one tension test and one set of Charpy V-notch impact tests shall be made from each heat in each heat-treatment charge.

9.2 If the results of the mechanical tests do not conform to the specified requirements, the manufacturer may retreat the forgings, but not more than three additional times. Retreatment involves re-austenitizing the forgings. Retests shall be made in accordance with this section.

9.3 If the lateral expansion result from one Charpy impact specimen falls below 0.015 in. [0.38 mm], but not less than 0.010 in. [0.25 mm], and the average test result equals or exceeds 0.015 mm [0.38 mm], then one retest of three additional specimens may be made. The lateral expansion obtained from each of the three retest specimens shall equal or exceed 0.015 in. [0.38 mm].

10. Test Specimens

10.1 The test specimens shall be located at any point midway between the center and surface of solid forgings, and at any point mid-thickness of the heaviest section of hollow or bored forgings. For solid forgings where test metal is provided on the periphery, test specimens shall be taken at mid-thickness of the test prolongation.

10.2 Tests shall be oriented so that the longitudinal axis of the specimen is parallel to the major direction of grain flow.

10.3 When fabrication requires stress relieving, the purchaser shall specify stress relieving of the test pieces prior to machining of the test specimens. Stress relieving shall be carried out as prescribed in 6.2.

11. Method of Impact Testing

11.1 The impact test shall be made in accordance with the simple beam, Charpy type of test described in the latest issue of Test Methods and Definitions A 370.

11.2 Precaution shall be taken so that when broken, the test specimens shall be within ± 3°F [1.7°C] of the specified test temperature.

12. Inspection

12.1 The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works that concern the manufacture of the material ordered. The manufacturer shall afford the inspector all reasonable facilities to satisfy the inspector that the material is being furnished in accordance with this specification. All tests (except product analysis) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be conducted so as not to interfere unnecessarily with the operation of the works.

12.2 The manufacturer shall report to the purchaser or the purchaser's representative the heat treatments applied to the material and to the test blocks and the results of the chemical analysis and mechanical tests made in accordance with this specification and the heat number or his heat identification.

13. Rejection

13.1 Unless otherwise specified, any rejection based on tests made in accordance with Section 5 and 7 shall be reported to the manufacturer within 60 days from the receipt of samples or test reports by the purchaser.

13.2 Each forging in which injurious metal defects are exposed during subsequent machining shall be rejected and the manufacturer notified.

14. Certification

14.1 Test reports, when required, shall include certification that all requirements of this specification have been met. The manufacturer shall provide the following where applicable:

14.1.1 Whether Type 1 or Type 11 material has been supplied and the chemical analysis results in accordance with Section 5,

14.1.2 Type of heat treatment used,

14.1.3 Results of tension and Charpy impact tests (together with absorbed energy and % shear fracture) including the impact test temperature, and test coupon stress relief details if applicable,

14.1.4 Results of any additional or supplementary requirements specified by the purchaser, and

14.1.5 The year date and revision letter, if any, of the specification. Note, this information is not required to be marked on the forgings.

15. Product Marking

15.1 Each forging shall be legibly stamped by the manufacturer with the heat number or his heat identification, the manufacturer's name (see Note 1) or trademark, and this specification number, A 522 or A 522M as applicable, 8NI, or 9NI, and QT or NNT as applicable.

NOTE 1 — For purposes of identification marking, the manufacturer is considered the organization that certifies the piping component was manufactured, sampled, and tested in accordance with this specification and the results have been determined to meet the requirements of this specification.

15.2 Forgings impact tested at a temperature other than that specified in Table 3, by the use of Supplementary Requirement S2, shall be marked with the letters LTV following the specification number, as well as the temperature scale used. For forgings to A 522, these letters shall be followed by the impact test temperature in degrees Fahrenheit. A prefix 0 to the test temperature indicates a temperature below 0°F, for example A 522 Type 1 LTV0300F indicates −300°F. For forgings to A 522M, the letters LTV shall be followed by the impact test temperature in degrees Celsius. A prefix 0 to the test temperature indicates a temperature below 0°C, for example A 522M Type 1 LTV0150C indicates −150°C.

15.3 The purchaser may specify additional identification marking and the location of all stamping. The type of stamps shall be round or "interrupted-dot" die stamps having a radius of $\frac{1}{32}$ in. [0.8 mm].

15.4 *Bar Coding* — In addition to the requirements in 15.1, 15.2, and 15.3, bar coding is acceptable as a supplemental identification method. The purchaser may specify in the order a specific bar coding system to be used. The bar coding system, if applied at the discretion of the supplier, should be consistent with one of the published industry standards for bar coding. If used on small parts, the bar code may be applied to the box or a substantially applied tag.

16. Keywords

16.1 low temperature applications; nickel alloy steel; pipe fittings; steel; piping applications; pressure containing parts; steel flanges; steel forgings; alloy; steel valves