

SECTION II
MATERIALS

2025

ASME Boiler and
Pressure Vessel Code
An International Code

Part B
Nonferrous Material
Specifications

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AN INTERNATIONAL CODE

2025 ASME Boiler & Pressure Vessel Code

2025 Edition

July 1, 2025

II MATERIALS

Part B

Nonferrous Material Specifications

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 In 2009, the Boiler and Pressure Vessel Committee was superseded by the following committees: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)
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- (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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January 1, 2025

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A. A. Campbell	S. Sekar
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T. Le	B. J. Mollitor, <i>Contributing Member</i>
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J. Rust	

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R. Duan	G. Xu
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J. Hu	Y. Yuan
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K. Li	S. Zhao
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D. A. Bowers	J. P. Swezy, Jr.
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G. Grant	X. J. Zhai
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CORRESPONDENCE WITH THE COMMITTEE

General

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/CSCcommittees>.

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>.

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.

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(25)

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SB-752/SB-752M	Specification for Castings, Zirconium-Base, Corrosion Resistant, for General Application ..	1079

SPECIFICATION REMOVAL

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:

None

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.

<i>Page</i>	<i>Location</i>	<i>Change</i>
ix	List of Sections	Title of Section XI, Division 1 revised
x	Foreword	Third, fourth, seventh, tenth, and eleventh paragraphs editorially revised
xiii	Personnel	Updated
xxxix	Specifications Listed by Materials	Updated
1	Statement of Policy on the Use of ASME Material Specifications	Revised
33	SB-61	Revised in its entirety
37	SB-62	Revised in its entirety
223	SB-167	Title on cover sheet corrected by errata
233	SB-168	Title on cover sheet corrected by errata
271	SB-209/SB-209M	Revised in its entirety
341	SB-221	Revised in its entirety
359	SB-221M	Added
387	SB-241/SB-241M	Revised in its entirety
479	SB-271/SB-271M	Revised in its entirety
487	SB-283/SB-283M	Revised in its entirety
553	SB-359/SB-359M	Revised in its entirety
605	SB-395/SB-395M	Revised in its entirety
709	SB-467	Revised in its entirety
745	SB-505/SB-505M	Revised in its entirety
843	SB-564	Revised in its entirety
887	SB-584	Revised in its entirety
935	SB-625	Added section 6 and renumbered subsequent paragraphs
955	SB-649	(1) Note 1 revised (2) Para. 5.3 added

<i>Page</i>	<i>Location</i>	<i>Change</i>
1011	SB-677	Para. 6.1 revised
1246	Mandatory Appendix II	Revised in its entirety
1257	Mandatory Appendix IV	Revised

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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 alphanumeric 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).

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STATEMENT OF POLICY ON THE USE OF ASME MATERIAL SPECIFICATIONS

(25)

The ASME material specifications in Section II, Part A or Section II, Part B shall be used when ordering, producing, and certifying materials for ASME BPV Code construction. The use of a specification not in Section II, Part A or Section II, Part B is acceptable only when it is referenced in an approved Code Case.

A complete list of ASME material specifications can be found in Mandatory Appendix II, Tables II-200-1 and II-200-2. Since the body of ASME material specifications does not originate with the Section II committee, at times wording may be found that differs from ASME BPV Code requirements. This Statement of Policy outlines the Section II committee's position on the following:

(a) *Scope.* Some specifications contain statements in the Scope about the service temperatures for listed alloys. Others contain statements that restrict alloy application to a particular component (e.g., heat exchangers, condensers). Such statements are to be viewed as guidance in the corresponding ASME material specification. Alloys approved for ASME BPV Code construction are restricted by maximum design temperatures stipulated in Section II, Part D, and any stipulations of the individual construction Codes.

(b) *Units.* Specifications often designate one system of units as the standard for the specification with conversions of the other being cited as for information only. Compliance and acceptance for the purposes of Code usage is not governed by this. Section II, Part D has a U.S. Customary volume and an SI volume for mechanical and physical properties of all materials approved for Code construction.

(c) *References.* References to other material specifications within the text often carry the original title given to it by the parent organization. The following are two examples:

(1) From 2021 Edition of Section II, Part A, SA-203

4.1 *Steelmaking Practice* — The steel shall be killed and shall conform to the fine grain size requirement of Specification A20/A20M.

(2) From 2021 Edition of Section II, Part B, SB-98/SB-98M

9.1 Refer to the appropriate paragraphs in Specification B249/B249M with particular reference to the following tables.

Such references shall be interpreted as referring to the corresponding ASME material specification. If no corresponding ASME specification exists, then the user is bound to the latest edition of the cited specification.

(d) *Ordering Information.* The Ordering Information section of some specifications state that furnishing test reports and certification is optional. This is not valid for ASME BPVC. When alloys are purchased for use in ASME construction, test reports and certifications shall be furnished to the purchaser.

(e) *Listed Alloys.* To be used for Code construction, any alloy listed in a specification shall also have allowable stress values or mechanical property values, as appropriate, in the ASME BPV Code. Though exceptions exist, these values are typically found in Section II, Part D or a Code Case for most Code-approved materials.

(f) *Table Notes.* Table notes are mandatory.

(g) *Main Body Notes.* Notes within the main body of the text are for information only.

(h) *Terminology.* If a specification contains a term that has not been defined in the ASME BPV Code, then it is acceptable to refer to the term's definition set forth by the corresponding standard's organization (see Mandatory Appendix II, II-200 for information on how to identify the organization).

Material produced to an acceptable material specification is not limited to country of origin. Before the material is ordered, it is the responsibility of the user to ensure that the intended construction Code permits materials certified to the desired specification.

With the exception of ASTM International, ASME has not entered into copyright agreements with publishers of material specifications. Limits on usage appear on the specification's cover sheets. For sources from which an official English-language version of a specification can be purchased, see Nonmandatory Appendix A.

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SPECIFICATION FOR ALUMINUM-ALLOY SAND CASTINGS



SB-26/SB-26M

(Identical with ASTM Specification B26/B26M-11 except that certification and test reports have been made mandatory, and ASME welding requirements are invoked.)

Standard Specification for Aluminum-Alloy Sand Castings

1. Scope

1.1 This specification covers aluminum-alloy sand castings designated as shown in Table 1.

1.2 This specification is not intended for aluminum-alloy sand castings used in aerospace applications.

1.3 Alloy and temper designations are in accordance with ANSI H35.1/H35.1M. Unified Numbering System alloy designations are in accordance with Practice E527.

1.4 Unless the order specifies the “M” specification designation, the material shall be furnished to the inch-pound units.

1.5 For acceptance criteria for inclusion of new aluminum and aluminum alloys and their properties in this specification, see Annex A1 and Annex A2.

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 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.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 ASTM Standards:

B179 Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes

B275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought

B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products

B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)

B660 Practices for Packaging/Packing of Aluminum and Magnesium Products

B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products

B917/B917M Practice for Heat Treatment of Aluminum-Alloy Castings from All Processes

D3951 Practice for Commercial Packaging

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

E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys

E94 Guide for Radiographic Examination

E155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings

E165 Practice for Liquid Penetrant Examination for General Industry

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

E607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere

E716 Practices for Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spectrochemical Analysis

E1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Spark Atomic Emission Spectrometry

E2422 Digital Reference Images for Inspection of Aluminum Castings

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.3 AMS Standard:

AMS 2771 Heat Treatment of Aluminum Alloy Castings

TABLE 1 Chemical Composition Limits

NOTE 1—When single units are shown, these indicate the maximum amounts permitted.

NOTE 2—Analysis shall be made for the elements for which limits are shown in this table.

NOTE 3—The following applies to all specified limits in this table: For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit in accordance with the rounding method of Practice E29.

Alloy		Composition, (Values in Weight Percent)											Others	
ANSI	UNS	Aluminum	Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Tin	Titanium	Each	Total
201.0	A02010	remainder	0.10	0.15	4.0–5.2	0.20–0.50	0.15–0.55	...	...	...	...	0.15–0.35	0.05 ^A	0.10
204.0	A02040	remainder	0.20	0.35	4.2–5.0	0.10	0.15–0.35	...	0.05	0.10	0.05	0.15–0.30	0.05	0.15
242.0	A02420	remainder	0.7	1.0	3.7–4.5	0.35	1.2–1.8	0.25	1.7–2.3	0.35	...	0.25	0.05	0.15
A242.0	A12420	remainder	0.6	0.8	3.7–4.5	0.10	1.2–1.7	0.15–0.25	1.8–2.3	0.10	...	0.07–0.20	0.05	0.15
295.0	A02950	remainder	0.7–1.5	1.0	4.0–5.0	0.35	0.03	...	...	0.35	...	0.25	0.05	0.15
319.0	A03190	remainder	5.5–6.5	1.0	3.0–4.0	0.50	0.10	...	0.35	1.0	...	0.25	...	0.50
328.0	A03280	remainder	7.5–8.5	1.0	1.0–2.0	0.20–0.6	0.20–0.6	0.35	0.25	1.5	...	0.25	...	0.50
355.0	A03550	remainder	4.5–5.5	0.6 ^B	1.0–1.5	0.50 ^B	0.40–0.6	0.25	...	0.35	...	0.25	0.05	0.15
C355.0	A33550	remainder	4.5–5.5	0.20	1.0–1.5	0.10	0.40–0.6	...	...	0.10	...	0.20	0.05	0.15
356.0	A03560	remainder	6.5–7.5	0.6 ^B	0.25	0.35 ^B	0.20–0.45	...	...	0.35	...	0.25	0.05	0.15
A356.0	A13560	remainder	6.5–7.5	0.20	0.20	0.10	0.25–0.45	...	...	0.10	...	0.20	0.05	0.15
443.0	A04430	remainder	4.5–6.0	0.8	0.6	0.50	0.05	0.25	...	0.50	...	0.25	...	0.35
B443.0	A24430	remainder	4.5–6.0	0.8	0.15	0.35	0.05	...	...	0.35	...	0.25	0.05	0.15
512.0	A05120	remainder	1.4–2.2	0.6	0.35	0.8	3.5–4.5	0.25	...	0.35	...	0.25	0.05	0.15
514.0	A05140	remainder	0.35	0.50	0.15	0.35	3.5–4.5	...	...	0.15	...	0.25	0.05	0.15
520.0	A05200	remainder	0.25	0.30	0.25	0.15	9.5–10.6	...	...	0.15	...	0.25	0.05	0.15
535.0	A05350	remainder	0.15	0.15	0.05	0.10–0.25	6.2–7.5	...	...	...	...	0.10–0.25	0.05 ^C	0.15
705.0	A07050	remainder	0.20	0.8	0.20	0.40–0.6	1.4–1.8	0.20–0.40	...	2.7–3.3	...	0.25	0.05	0.15
707.0	A07070	remainder	0.20	0.8	0.20	0.40–0.6	1.8–2.4	0.20–0.40	...	4.0–4.5	...	0.25	0.05	0.15
710.0 ^D	A07100	remainder	0.15	0.50	0.35–0.65	0.05	0.6–0.8	...	...	6.0–7.0	...	0.25	0.05	0.15
712.0 ^D	A07120	remainder	0.30	0.50	0.25	0.10	0.50–0.65	0.40–0.6	...	5.0–6.5	...	0.15–0.25	0.05	0.20
713.0	A07130	remainder	0.25	1.1	0.40–1.0	0.6	0.20–0.50	0.35	0.15	7.0–8.0	...	0.25	0.10	0.25
771.0	A07710	remainder	0.15	0.15	0.10	0.10	0.8–1.0	0.06–0.20	...	6.5–7.5	...	0.10–0.20	0.05	0.15
850.0	A08500	remainder	0.7	0.7	0.7–1.3	0.10	0.10	...	0.7–1.3	...	5.5–7.0	0.20	...	0.30
851.0 ^D	A08510	remainder	2.0–3.0	0.7	0.7–1.3	0.10	0.10	...	0.30–0.7	...	5.5–7.0	0.20	...	0.30
852.0 ^D	A08520	remainder	0.40	0.7	1.7–2.3	0.10	0.6–0.9	...	0.9–1.5	...	5.5–7.0	0.20	...	0.30

^A Contains silver 0.40–1.0 %.

^B If iron exceeds 0.45 %, manganese content shall not be less than one half of the iron content.

^C Contains beryllium 0.003–0.007 %, boron 0.005 % max.

^D 710.0 formerly A712.0, 712.0 formerly D712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

2.4 American National Standards:

H35.1/H35.1(M) Alloy and Temper Designation System for Aluminum

2.5 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-276 Impregnation of Porous Nonferrous Metal Castings

NAVSEA Technical Publication S9074-AR-GIB-010/278

2.6 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

2.7 Other Standards:

EN 14242 Aluminum and Aluminum Alloys — Chemical Analysis — Inductively Coupled Plasma Optical Emission Spectral Analysis

3. Terminology

3.1 *Definitions*—Refer to Terminology B881 for definitions of product terms used in this specification.

3.2 *sand casting*—a metal object produced by pouring molten metal into a sand mold and allowing it to solidify.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information (1.4 and 1.5):

4.1.1 This specification designation (which includes the number, year, and revision letter, if applicable),

NOTE 1—For inch-pound application, specify Specification B26 and for metric application specify Specification B26M. Do not mix units.

4.1.2 The quantity in either pieces or pounds [kilograms],

4.1.3 Alloy (Section 7 and Table 1),

4.1.4 Temper (Section 10 and Table 2), and

4.1.5 Applicable drawing or part number,

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser:

4.2.1 Whether chemical analysis and tensile property reports are required (Table 1 and Table 2),

4.2.2 Whether castings or test bars, or both, may be artificially aged for Alloys 705.0-T5, 707.0-T5, 712.0-T5, and 713.0-T5 (10.2) and whether yield strength tests are required for these alloys;

TABLE 2 Tensile Requirements^A (Inch-Pound Units)

NOTE 1—For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 0.1 ksi and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

Alloy		Temper ^B	Tensile Strength, min, ksi	Yield Strength (0.2 % offset), min, ksi	Elongation in 2 in. or 4 x diameter, min, %	Typical Brinell Hard- ness, ^C 500 kgf, 10 mm
ANSI ^D	UNS					
201.0	A02010	T7	60.0	50.0	3.0	...
204.0	A02040	T4	45.0	28.0	6.0	...
242.0	A02420	O ^E	23.0	F	F	70
		T61	32.0	20.0	F	105
A242.0	A12420	T75	29.0	F	1.0	75
295.0	A02950	T4	29.0	13.0	6.0	60
		T6	32.0	20.0	3.0	75
		T62	36.0	28.0	F	95
		T7	29.0	16.0	3.0	70
319.0	A03190	F	23.0	13.0	1.5	70
		T5	25.0	F	F	80
		T6	31.0	20.0	1.5	80
328.0	A03280	F	25.0	14.0	1.0	60
		T6	34.0	21.0	1.0	80
355.0	A03550	T6	32.0	20.0	2.0	80
		T51	25.0	18.0	F	65
		T71	30.0	22.0	F	75
C355.0	A33550	T6	36.0	25.0	2.5	...
356.0	A03560	F	19.0	9.5	2.0	55
		T6	30.0	20.0	3.0	70
		T7	31.0	F	F	75
		T51	23.0	16.0	F	60
		T71	25.0	18.0	3.0	60
A356.0	A13560	T6	34.0	24.0	3.5	80
		T61	35.0	26.0	1.0	...
443.0	A04430	F	17.0	7.0	3.0	40
B443.0	A24430	F	17.0	6.0	3.0	40
512.0	A05120	F	17.0	10.0	...	50
514.0	A05140	F	22.0	9.0	6.0	50
520.0	A05200	T4	42.0	22.0	12.0	75
535.0	A05350	F	35.0	18.0	9.0	70
705.0	A07050	T5	30.0	17.0 ^G	5.0	65
707.0	A07070	T7	37.0	30.0 ^G	1.0	80
710.0 ^H	A07100	T5	32.0	20.0	2.0	75
712.0 ^H	A07120	T5	34.0	25.0 ^G	4.0	75
713.0	A07130	T5	32.0	22.0	3.0	75
771.0	A07710	T5	42.0	38.0	1.5	100
		T51	32.0	27.0	3.0	85
		T52	36.0	30.0	1.5	85
		T6	42.0	35.0	5.0	90
		T71	48.0	45.0	2.0	120
850.0	A08500	T5	16.0	F	5.0	45
851.0 ^H	A08510	T5	17.0	F	3.0	45
852.0 ^H	A08520	T5	24.0	18.0	F	60

^A If agreed upon between the manufacturer and the purchaser, other mechanical properties may be obtained by other heat treatments such as annealing, aging, or stress relieving.

^B Refer to ANSI H35.1/H35.1M, or both, for description of tempers.

^C For information only, not required for acceptance.

^D ASTM alloy designations are recorded in Practice B275.

^E Formerly designated as 222.0-T2 and 242.0-T21.

^F Not required.

^G Yield strength to be determined only when specified in the contract or purchase order.

^H 710.0 formerly A712.0, 712.0 formerly D712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

4.2.3 Whether test specimens cut from castings are required in addition to, or instead of, separately cast specimens (Sections 10 and 13);

4.2.4 Whether repairs are permissible (16.1),

4.2.5 Whether inspection is required at the producer's works (Section 18);

4.2.6 DELETED

4.2.7 Whether surface requirements shall be checked against observational standards where such standards are established (19.1);

4.2.8 Whether liquid penetrant inspection is required (19.2);

4.2.9 Whether radiographic inspection is required and, if so, the radiographic grade of casting required (19.3, Table 3);

4.2.10 Whether foundry control is required (Section 9); and

4.2.11 Whether Practice B660 applies and, if so, the levels of preservation, packaging, and packing required (23.4).

5. Quality Assurance

5.1 Unless otherwise specified in the contract or purchase order, the producer shall be responsible for the performance of all inspections and test requirements specified herein. Unless disapproved by the purchaser, the producer may use his own or

TABLE 3 Discontinuity-Level Requirements for Aluminum Castings in Accordance with Film Reference Radiographs E155 or Digital Reference Radiographs E2422

Discontinuity	Radiograph	Section Thickness in. [mm]							
		Grade A ^A		Grade B		Grade C		Grade D	
		¼ [6.4]	¾ [19.0]	¼ [6.4]	¾ [19.0]	¼ [6.4]	¾ [19.0]	¼ [6.4]	¾ [19.0]
Gas holes	1.1	none		1	1	2	2	5	5
Gas porosity (round)	1.21	none		1	1	3	3	7	7
Gas porosity (elongated)	1.22	none		1	1	3	4	5	5
Shrinkage cavity	2.1	none		1	^B	2	^B	3	3
Shrinkage porosity or sponge	2.2	none		1	1	2	2	4	3
Foreign material (less dense material)	3.11	none		1	1	2	2	4	4
Foreign material (more dense material)	3.12	none		1	1	2	1	4	3
Segregation	3.2	none							
Cracks	...	none		none		none		none	
Cold shuts	...	none		none		none		none	
Surface irregularity	...	...				not to exceed drawing tolerance			
Core shift	...	...				not to exceed drawing tolerance			

^A Caution should be exercised in requesting Grade A.^B Not available.

any other suitable facilities for the performance of the inspection and test requirements specified herein. The purchaser shall have the right to perform any of the inspections and tests set forth in this specification where such inspections are deemed necessary to confirm that the material conforms to prescribed requirements.

6. Manufacture

6.1 The responsibility of furnishing castings that can be laid out and machined to the finished dimensions within the permissible variations specified, as shown on the blueprints or drawings, shall rest with the producer, except where pattern equipment is furnished by the purchaser.

7. Chemical Composition

7.1 The Product shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by the producer by taking samples at the time castings are poured in accordance with Practice E716 and analyzed in accordance with Test Methods E607, E1251, or E34, or EN 14242. If the producer has determined the composition of the material during casting, they shall not be required to sample and analyze the finished product.

7.2 If it becomes necessary to analyze castings for conformance to chemical composition limits, the method used to sample castings for the determination of chemical composition shall be by agreement between the producer and the purchaser. Analysis shall be performed in accordance with Practice E716, Test Methods E607, E1251, or E34, or EN 14242 (ICP method).

7.3 Other methods of analysis or in the case of a dispute the method of analysis shall be agreed upon by the producer and the purchaser.

7.4 A sample for determining of chemical composition shall be taken to represent the following:

7.4.1 Not more than 4000 lb [2000 kg] of clean castings (gates and risers removed) or a single casting poured from one furnace.

7.4.2 The maximum elapsed time between determinations shall be established for each alloy, but in any case the maximum elapsed time shall not exceed 8 h.

8. Material Requirements—Castings Produced for Governmental and Military Agencies

8.1 Unless otherwise specified, only aluminum alloy conforming to the requirements of Specification B179 or producer's foundry scrap (identified as being made from alloy conforming to Specification B179) shall be used in the remelting furnace from which molten metal is taken for pouring directly into castings. Additions of small amounts of modifiers and grain refining elements or alloys are permitted.

8.1.1 Pure materials, recycled materials, and master alloys may be used to make alloys conforming to this specification, provided chemical analysis can be taken and adjusted to conform to Table 1 prior to pouring any castings.

9. Foundry Control—Castings Produced for Governmental or Military Agencies, or Both

9.1 When specified, castings shall be produced under foundry control approved by the purchaser. Foundry control shall consist of examination of castings by radiographic or other approved methods for determining internal discontinuities until the gating, pouring, and other foundry practices have been established to produce castings meeting the quality standards furnished by the purchaser or agreed upon between the purchaser and the producer. When foundry practices have been so established, the production method shall not be significantly changed without demonstrating to the satisfaction of the purchaser that the change does not adversely affect the quality of the castings. Minor changes in pouring temperature of $\pm 50^\circ\text{F}$ [$\pm 28^\circ\text{C}$] from the established nominal temperature are permissible.

10. Tensile Properties

10.1 The separately cast test specimens representing the castings shall meet the mechanical properties prescribed in Table 2.

10.2 Although Alloys 705.0, 707.0, 712.0, and 713.0 are most frequently used in the naturally aged condition, by agreement between the producer and the purchaser, the castings may be artificially aged to the T5 temper. The producer and the purchaser may also agree to base the acceptance of castings on artificially aged test bars. The conditions of

artificial aging shown in Practice B917/B917M shall be employed unless other conditions are accepted by mutual consent.

10.3 When specified, the tensile strength, yield strength, and elongation values of specimens cut from castings shall be not less than 75 % of the tensile and yield strength values and not less than 25 % of the elongation values specified in Table 2 [Table 4]. The measurement of the elongation is not required for test specimens cut from castings if 25 % of the specified minimum elongation value published in Table 2 [Table 4] is 0.5 % or less. If grade D quality castings as described in Table 3 are specified, no tensile tests shall be specified nor tensile requirements be met on specimens cut from castings.

11. Workmanship, Finish, and Appearance

11.1 The finished castings shall be uniform in composition and free of blowholes, cracks, shrinks, and other discontinuities except as designated and agreed upon as acceptable by the purchaser.

12. Number of Tests and Retests

12.1 Unless otherwise agreed upon between the purchaser and producer, a minimum of two tension test specimens shall be separately cast and tested to represent the following:

12.1.1 Not more than 4000 lb [2000 kg] of clean castings (gates and risers removed) or a single casting poured from one furnace.

12.1.2 The castings poured continuously from one furnace in not more than eight consecutive hours.

12.2 When tensile properties from castings are to be determined, one per melt-heat combination shall be tested unless otherwise shown on the drawing or specified in the purchase order.

12.3 If any test specimen shows defective machining or flaws, it may be discarded; in which case the purchaser and the producer shall agree upon the selection of another specimen in its stead.

12.4 If the results of the tension tests do not conform to the requirements prescribed in Table 2 [Table 4]; the test bars representative of the castings may be retested in accordance with the replacement tests and retest provisions of Test Methods B557 and B557M, and the results of retests shall conform to the requirements as to mechanical properties specified in Table 2 [Table 4].

13. Specimen Preparation

13.1 The tension test specimens shall be cast to size in sand without chills in accordance with the dimensions shown in Fig. 1 [Fig. 2]. They shall not be machined prior to test except to adapt the grip ends in such a manner as to ensure axial loading.

13.2 The recommended method for casting tension test specimens is shown in Fig. 1 [Fig. 2].

13.3 When properties of castings are to be determined, tension test specimens shall be cut from the locations designated on the drawing, unless otherwise negotiated. If no locations are designated, one or more specimens shall be taken to include locations having significant variation in casting thickness, except that specimens shall not be taken from areas directly under risers. The tension test specimens shall be the

standard 0.500-in. [12.5-mm] diameter specimens shown in Fig. 9 of Test Methods B557 and B557M or a round specimen of smaller size proportional to the standard specimen.

	in.	mm
Diameter of reduced section	0.250	6.00
Length of reduced section	1¼	36
Gage length	1.000	30.00
Radius of fillet	¾	6
Diameter of end section	¾	9
Overall length:		
With shouldered ends	2¾	60
With threaded ends	3	75
With plain cylindrical ends	4	100

When necessary, a rectangular specimen may be used proportional to that shown for the 0.500-in. [12.5-mm] wide specimen in Fig. 6 of Test Methods B557 and B557M, but in no case shall its dimensions be less than the following:

	in.	mm
Width of reduced section	¼	6.00
Length of reduced section	1¼	32
Radius of fillet	¼	6
Overall length	4	100
Thickness	0.100	2.50

The specific elongation values shall not apply to tests of rectangular specimens.

13.4 If the castings are to be heat treated and separately cast specimens are to be used, the specimens representing such castings shall be heat treated with the castings they represent. If castings are to be heat treated and tests are to be obtained on the castings, the test specimens shall be taken from the castings after heat treatment.

14. Test Methods

14.1 The determination of chemical composition shall be made in accordance with suitable chemical (Test Methods E34), or spectrochemical (Test Methods E607 and E1251), methods. Other methods may be used only when no published ASTM method is available. In case of dispute, the methods of analysis shall be agreed upon between the producer and purchaser.

14.2 The tensile properties shall be determined in accordance with Test Methods B557 and B557M.

15. Heat Treatment

15.1 Heat treatment of castings shall be performed in accordance with Practice B917/B917M or AMS 2771.

16. Repair of Castings

16.1 Castings may be repaired only by processes approved and agreed upon between the producer and purchaser, that is, welding, impregnation, peening, blending, soldering, and so forth. Limitations on the extent and frequency of such repairs, and methods of inspection of repaired areas should also be agreed upon.

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

TABLE 4 Tensile Requirements (SI Units)—[Metric]^A

NOTE 1—For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

Alloy		Temper ^B	Tensile Strength, min, MPa ^C	Yield Strength (0.2 % offset), min, MPa ^C	Elongation in 5× diameter, min %	Typical Brinell Hardness, ^D 500 kgf, 10 mm
ANSI ^E	UNS					
201.0	A02010	T7	415	345	3.0	...
204.0	A02040	T4	310	195	6.0	...
242.0	A02420	O ^F	160	^G	^G	70
		T61	220	140	^G	105
A242.0	A12420	T75	200	^G	1.0	75
295.0	A02950	T4	200	90	6.0	60
		T6	220	140	3.0	75
		T62	250	195	^G	95
		T7	200	110	3.0	70
319.0	A03190	F	160	90	1.5	70
		T5	170	^G	^G	80
		T6	215	140	1.5	80
328.0	A03280	F	170	95	1.0	60
		T6	235	145	1.0	80
355.0	A03550	T6	220	140	2.0	80
		T51	170	125	^G	65
		T71	205	150	^G	75
C355.0	A33550	T6	250	170	2.5	...
356.0	A03560	F	130	65	2.0	55
		T6	205	140	3.0	70
		T7	215	^G	^G	75
		T51	160	110	^G	60
		T71	170	125	3.0	60
A356.0	A13560	T6	235	165	3.5	80
		T61	245	180	1.0	...
443.0	A04430	F	115	50	3.0	40
B443.0	A24430	F	115	40	3.0	40
512.0	A05120	F	115	70	...	50
514.0	A05140	F	150	60	6.0	50
520.0	A05200	T4	290	150	12.0	75
535.0	A05350	F	240	125	9.0	70
705.0	A07050	T5	205	115 ^H	5.0	65
707.0	A07070	T7	255	205 ^H	1.0	80
710.0 ^I	A07100	T5	220	140	2.0	75
712.0 ^I	A07120	T5	235	170 ^H	4.0	75
713.0	A07130	T5	220	150	3.0	75
771.0	A07710	T5	290	260	1.5	100
		T51	220	185	3.0	85
		T52	250	205	1.5	85
		T6	290	240	5.0	90
		T71	330	310	2.0	120
850.0	A08500	T5	110	^G	5.0	45
851.0 ^I	A08510	T5	115	^G	3.0	45
852.0 ^I	A08520	T5	165	125	^G	60

^A If agreed upon between the manufacturer and the purchaser, other mechanical properties may be obtained by other heat treatments such as annealing, aging, or stress relieving.

^B Temper designations:

F As fabricated.

O Annealed.

T1 Cooled from an elevated temperature shaping process and naturally aged to a substantially stable condition.

T4 Solution heat-treated and naturally aged to a substantially stable condition.

T5 Cooled from an elevated temperature shaping process and then artificially aged.

T6 Solution heat-treated and then artificially aged.

T7 Solution heat-treated and stabilized.

Additional digits, the first of which shall not be zero, may be added to designation T1 through T10 to indicate a variation in treatment that significantly alters the characteristics of the product.

^C For explanation of the SI unit "MPa" see Appendix X2.

^D For information only, not required for acceptance.

^E ASTM alloy designations are recorded in Practice B275.

^F Formerly designated as 222.0-T2 and 242.0-T21.

^G Not required.

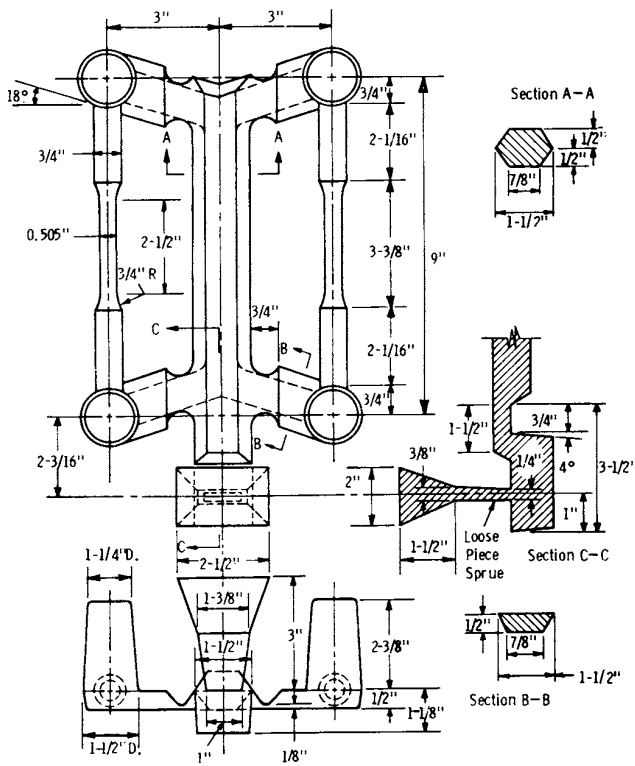
^H Yield strength to be determined only when specified in the contract or purchase order.

^I 710.0 formerly A712.0, 712.0 formerly D712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

17. Repairing of Castings—Produced for Governmental and Military Agencies

17.1 Welding:

17.1.1 When welding is permitted, it shall be done by methods suitable for the particular alloy. Welding methods



NOTE 1—1 in. = 25.4 mm.

FIG. 1 Tension Test Specimen Casting

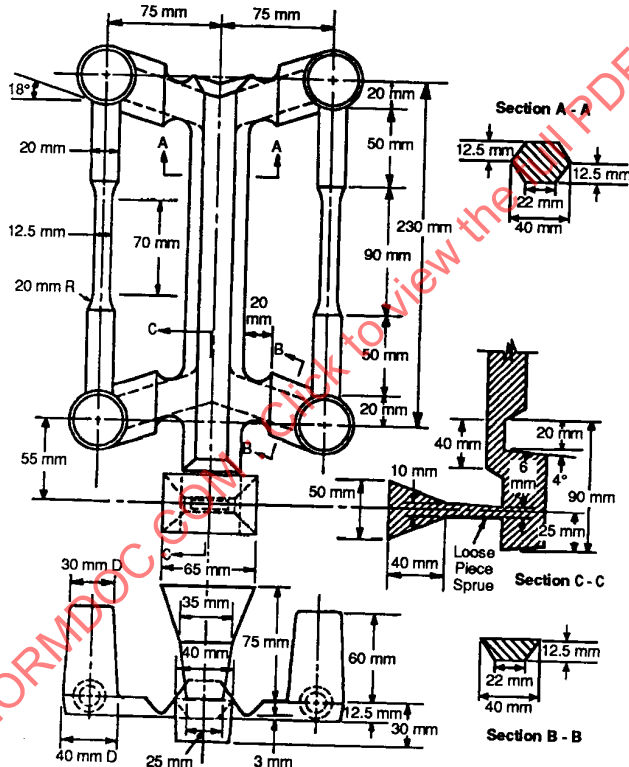


FIG. 2 Tension Test Specimen Casting [Metric]

shall be in accordance with such specifications as are referenced on the applicable drawings, or as are required by the contract or order.

17.1.2 All welding shall be done by qualified welders approved by the purchaser.

17.1.3 When castings are to be supplied in the heat-treated condition, they shall be heat treated to the required temper after welding, except that small arc welds may be performed without subsequent heat treatment upon approval of the purchaser. //

17.1.4 Unless otherwise specified, castings that have been repaired by welding shall have the welded areas examined radiographically after all reworking and heat treatment have been completed.

17.1.5 All welds shall be free of cracks, excess gas, porosity, lack of fusion and meet the same quality requirements as the parent material.

17.1.6 Welded castings shall be marked with a symbol of three concentric circles with a letter or number designating the welder adjacent to the symbol. The outer circle of the symbol shall be not larger than $\frac{1}{4}$ in. [6 mm] in outside diameter. All welded areas shall be encircled with a ring of white paint prior to submission for final inspection.

17.1.7 *Naval Shipboard Applications*—Repair welding of castings used in Naval shipboard pressure vessels, piping systems and machinery shall be performed in accordance with requirements for repair of castings specified in NAVSEA Technical Publication S9074-AR-GIB-010/278.

17.2 ***Impregnation***—When impregnation is permitted, it shall be to correct general seepage leaks only and shall not be used to correct poor foundry technique or significant porosity. It shall be accomplished in accordance with MIL-STD-276. Unless otherwise authorized by the purchaser, castings which have been impregnated shall be marked “IMP.”

17.3 *Peening*—When peening is permitted, it shall be to correct localized minor seepage leaks and small surface imperfections only, or to disclose subsurface voids for purpose of inspection. Peening will not be permitted to repair cracks, cold shuts, shrinks, misruns, defects due to careless handling, or other similar major defects. Peening may be accomplished either hot or cold and shall be performed by methods which are acceptable to the purchaser. Peened castings shall be marked with Maltese cross approximately ¼ in. [6 mm] high.

17.4 *Blending*—Blending with suitable grinders or other tools will be permitted for the removal of surface imperfections only, and shall not result in dimensions outside the tolerances shown on the applicable drawing.

18. Source Inspection

18.1 If the purchaser elects to make an inspection of the casting at the producer's works, it shall be so stated in the contract or order.

18.2 If the purchaser elects to have inspection made at the producer's works, the producer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. Foundry Inspection

19.1 Requirements such as surface finish, parting line projections, snagging projections where gates and risers were removed, and so forth, may be checked visually. It is advisable to have agreed-upon observational standards representing both acceptable and unacceptable material.

19.2 Liquid Penetrant Inspection:

19.2.1 When specified, liquid penetrant inspection shall be in accordance with Test Method E165, and the required sensitivity shall be specified.

19.2.2 Acceptance standards for discontinuities shall be agreed upon, including size and frequency per unit area and location.

19.3 Radiographic Inspection:

19.3.1 Radiographic inspection shall be in accordance with Guide E94 and Film Reference Radiographs E155.

19.3.2 When agreed upon between the manufacturer and purchaser digital radiographic inspection shall be in accordance with Guide E94 and Digital Reference Radiographs E2422.

19.3.3 Radiographic acceptance shall be in accordance with requirements selected from Table 3. Any modifications of this table and the frequency per unit area and location should also be agreed upon.

19.3.4 The number, film size, and orientation of radiographs and the number of castings radiographically inspected shall be agreed upon between the manufacturer and purchaser.

20. Rejection and Rehearing

20.1 Castings that show unacceptable defects revealed by operations subsequent to acceptance and within an agreed time may be rejected, and shall be replaced by the producer.

20.2 In the case of dissatisfaction regarding rejections based on chemical composition and mechanical properties specified in Section 7 and 10, respectively, the producer may make claim for rehearing as the basis of arbitration within a reasonable time after receipt by the producer of the rejection notification.

21. Certification

21.1 The producer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and inspected in accordance with this specification, and has met the requirements. In addition, all test reports required by this specification shall be supplied with the certification.

22. Identification and Repair Marking—Castings Produced for Government and Military Agencies

22.1 *Identification*—Unless otherwise specified, each casting shall be marked with the applicable drawing or part number. The marking shall consist of raised Arabic numerals,

and when applicable capital letters, cast integral. The location of the identification marking shall be as specified on the applicable drawing. When the location is not specified on the drawing, the drawing/part number shall be placed in a location mutually agreeable to the purchaser and producer.

22.1.1 *Lot Identification*—When practicable, each casting shall also be marked with the melt of inspection lot number.

22.2 *Lot*—A lot shall consist of all of the cleaned castings poured from the same heat or melt when subsequent heat treatment is not required.

22.2.1 When the castings consist of alloys which require heat treatment, the lot shall consist of all castings from the same melt or heat which have been heat treated in the same furnace charge, or if heat treated in a continuous furnace, all castings from the same melt or heat that are discharged from the furnace during a 4-h period.

22.3 *Repair Markings*—All identification markings indicating repairs as specified in 17.1.6, 17.2, and 17.3, shall be made with a waterproof marking fluid.

23. Packaging, Marking, and Shipping

23.1 The material shall be packaged in such a manner as to prevent damage in ordinary handling and transportation. The type of packaging and gross weight of individual containers shall be left to the discretion of the producer unless otherwise agreed upon. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or container shall contain only one size, alloy, and temper of material when packaged for shipment unless otherwise agreed upon.

23.2 Each package or container shall be marked with the purchase order number, drawing number, quantity, specification number, alloy and temper, gross and net weights, and the name of the producer.

23.3 Packages or containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

23.4 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirements of Practices B660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 or Practice D3951 for civil agencies and MIL-STD-129 for military agencies.

24. Keywords

24.1 aluminum; sand casting

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no

more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to “Statistical Aspects of Mechanical Property Assurance” in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1/H35.1(M). The Aluminum Association holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1/H35.1(M). A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgement of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in the specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain

refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5.)	
Over 0.55 %	0.X, X.X, and so forth
(except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc (Note A2.1); Titanium; Other Elements, Each; Other Elements, Total; Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between zinc and titanium, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as minimum for unalloyed aluminum and as a remainder for aluminum alloys.

APPENDIXES**(Nonmandatory Information)****X1. ALLOY PROPERTIES AND CHARACTERISTICS**

X1.1 The data in Table X1.1 are approximate and are supplied for general information only.

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TABLE X1.1 Properties and Characteristics

NOTE 1—1 indicates best of group, 5 indicates poorest of group.

Alloy		Pattern Shrinkage Allowance, ^A in./ft [mm/m]	Approximate Melting Range, ^B °F [°C]	Resistance to Hot Cracking ^C	Pressure Tightness	Fluidity ^D	Solidification Shrinkage Tendency ^E	Normally Heat Treated	Resistance to Corrosion ^F	Machining ^G	Polishing ^H	Electroplating ^I	Anodizing (Appearance) ^J	Chemical Oxide Coating (Protection) ^K	Strength at Elevated Temperature ^L	Suitability for Welding ^M	Suitability for Brazing ^N
ANSI ^O	UNS																
201.0	A02010	[13]	1060–1200 [571–649]	4	3	3	4	yes	4	1	1	1	2	2	1	4	no
204.0	A02040	⁵ / ₃₂ [13]	985–1200 [529–649]	4	3	3	4	yes	4	1	2	1	3	4	1	4	no
242.0	A02420	⁵ / ₃₂ [13]	990–1175 [532–635]	4	3	3	4	yes	4	2	2	1	3	4	1	4	no
295.0	A02950	⁵ / ₃₂ [13]	970–1190 [521–643]	4	4	3	3	yes	3	2	2	1	2	3	3	3	no
319.0	A03190	⁵ / ₃₂ [13]	950–1125 [510–607]	2	2	2	2	yes	3	3	4	2	4	3	3	2	no
328.0	A03280	⁵ / ₃₂ [13]	960–1135 [516–613]	1	1	1	1	yes	3	4	5	2	4	2	2	2	no
355.0	A03550	⁵ / ₃₂ [13]	1015–1150 [546–621]	1	1	1	1	yes	3	3	3	1	4	2	2	2	no
C355.0	A33550	⁵ / ₃₂ [13]	1015–1150 [546–621]	1	1	1	1	yes	3	3	3	1	4	2	2	2	no
356.0	A03560	⁵ / ₃₂ [13]	1035–1135 [557–613]	1	1	1	1	yes	2	4	5	2	4	2	3	2	no
A356.0	A13560	⁵ / ₃₂ [13]	1035–1135 [557–613]	1	1	1	1	yes	2	4	5	2	4	2	3	2	no
443.0	A04430	⁵ / ₃₂ [13]	1065–1170 [574–632]	1	1	1	1	no	3	5	5	2	5	2	4	1	ltd
B443.0	A24430	⁵ / ₃₂ [13]	1065–1170 [574–632]	1	1	1	1	no	2	5	5	2	5	2	4	1	ltd
514.0	A05140	⁵ / ₃₂ [13]	1110–1185 [599–640]	4	5	5	5	no	1	1	1	5	1	1	2	4	no
520.0	A05200	¹ / ₁₀ [8]	840–1120 [449–604]	2	5	4	5	yes	1	1	1	4	1	1	^P	5	no
535.0	A05350	⁵ / ₃₂ [13]	1020–1165 [549–629]	3	5	5	5	no	1	1	1	5	1	1	3	4	no
705.0	A07050	³ / ₁₆ [16]	1105–1180 [596–638]	5	3	4	4	aged only	2	1	1	3	2	2	5	4	yes
707.0	A07070	³ / ₁₆ [16]	1085–1165 [585–629]	5	3	4	4	yes	2	1	1	3	2	2	5	4	yes
710.0 ^O	A07100	³ / ₁₆ [16]	1105–1195 [596–646]	5	3	4	4	aged only	2	1	1	2	2	3	5	4	yes
712.0 ^O	A07120	³ / ₁₆ [16]	1110–1185 [599–641]	5	3	4	4	aged only	2	1	1	2	2	3	5	4	yes
713.0	A07130	³ / ₁₆ [16]	1100–1185 [593–641]	5	3	4	4	aged only	2	1	1	2	2	3	5	4	yes
771.0	A07710	³ / ₁₆ [16]	1120–1190 [604–643]	5	3	4	4	yes	2	1	1	3	2	2	5	4	yes
850.0	A08500	⁵ / ₃₂ [13]	435–1200 [224–649]	5	5	5	5	aged only	3	1	1	5	4	5	^P	5	no
851.0 ^O	A08510	⁵ / ₃₂ [13]	440–1165 [227–629]	4	4	5	4	aged only	3	1	1	5	4	5	^P	5	no
852.0 ^O	A08520	⁵ / ₃₂ [13]	400–1175 [204–635]	5	5	5	5	aged only	3	1	1	5	4	5	^P	5	no

^A Allowances for average castings. Shrinkage requirements will vary with intricacy of design and dimensions.^B Temperatures of solids and liquids are indicated; pouring temperatures will be higher.^C Ability of alloy to withstand contraction stresses while cooling through hot-short or brittle-temperature range.^D Ability of liquid alloy to flow readily in mold and fill thin sections.^E Decreased in volume accompanying freezing of alloy and measure of amount of compensating feed metal required in form of risers.^F Based on alloy resistance in standard-type salt-spray test.^G Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life. Ratings, in the case of heat-treatable alloys, based on a -T6 temper. Other tempers, particularly the annealed temper, may have lower rating.^H Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.^I Ability of casting to take and hold an electroplate applied by present standard methods.^J Rated on lightness of color, brightness, and uniformity of clear anodized coating applied in sulfuric acid electrolyte.^K Rated on combined resistance of coating and base alloy to corrosion.^L Rating based on tensile and yield strengths at temperatures up to 500°F [260°C], after prolonged heating at testing temperature.^M Based on ability of material to be fusion welded with filler rod of same alloy.^N Refers to suitability of alloy to withstand brazing temperatures without excessive distortion or melting.^O ASTM alloy designations are recorded in Practice B275.^P Not recommended for service at elevated temperatures.^Q 710.0 formerly A712.0, 712.0 formerly D712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

X2. SI UNITS

X2.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI) (IEEE/ASTM SI 10). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg}\cdot\text{m}/\text{s}^2$). The derived SI unit

for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

X3. INACTIVE ALLOYS

X3.1 Alloys listed as inactive by the Aluminum Association—208.0 and 222.0. Listing the composition limits, mechanical properties, and characteristics of the alloys is a

method of preserving this data should it be needed at some future date.

TABLE X3.1 Chemical Composition Limits—Inactive Alloys

NOTE 1—All applicable notes and footnotes can be found in Table 1

Alloy			Composition, (Values in Weight Percent)										Others	
ANSI	UNS	Aluminum	Silicon	Iron	Copper	Man-ganese	Magne-sium	Chromium	Nickel	Zinc	Tin	Titanium	Each	Total
208.0	A02080	remainder	2.5-3.5	1.2	3.5-4.5	0.50	0.10	...	0.35	1.0	...	0.25	...	0.50
222.0	A02220	remainder	2.0	1.5	9.2-10.7	0.50	0.15-0.35	...	0.50	0.8	...	0.25	...	0.35

TABLE X3.2 Tensile Requirements (Inch-Pound Units)—Inactive Alloys

NOTE 1—All applicable notes and footnotes can be found in Table 2.

Alloy		Temper	Tensile Strength, min, ksi	Yield Strength 0.2 % offset, min, ksi	Elongation in 2 in. or 4 x diameter, min, %	Typical Brinell Hard- ness, 500 kgf, 10 mm
ANSI	UNS					
208.0	A02080	F	19.0 (131)	120 (83)	1.5	55
222.0	A02220	O	23.0 (159)			80
		T6	30.0 (207)			115

TABLE X3.3 Properties and Characteristics—Inactive Alloys

NOTE 1—1 indicates best of group, 5 indicates poorest of group.

NOTE 2—All applicable notes and footnotes can be found in Table X1.1.

Alloy		Pattern Shrinkage Allowance, ^A in./ft [mm/m]	Approximate Melting Range, ^B °F [°C]	Resistance to Hot Cracking ^C	Pressure Tightness	Fluidity ^D	Solidification Shrinkage Tendency ^E	Normally Heat Treated	Resistance to Corrosion ^F	Machining ^G	Polishing ^H	Electroplating ^I	Anodizing (Appearance) ^J	Chemical Oxide Coating (Protection) ^K	Strength at Elevated Temperature ^L	Suitability for Welding ^M	Suitability for Brazing ^N
ANSI ^O	UNS																
208.0	A02080	5/32 [13]	970-1160 [521-627]	2	2	2	2	yes	4	3	3	2	3	3	3	2	no
222.0	A02220	5/32 [13]	965-1155 [518-624]	3	3	3	3	yes	4	1	2	1	3	4	1	4	no

SPECIFICATION FOR SEAMLESS COPPER PIPE, STANDARD SIZES



SB-42

(Identical with ASTM Specification B42-20 except that certification and mill test reports have been made mandatory, and nondestructive testing is required for all diameters.)

Specification for Seamless Copper Pipe, Standard Sizes

1. Scope

1.1 This specification establishes the requirements for seamless copper pipe in all nominal or standard pipe sizes, both regular and extra-strong, suitable for use in plumbing, boiler feed lines, and for similar purposes.

1.2 *Units*—The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and are not considered standard.

1.3 The following safety hazard caveat pertains only to the test methods described in this specification.

1.3.1 *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.*

1.4 *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:

B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing

B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes

B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper

B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast

B846 Terminology for Copper and Copper Alloys

B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube

E8/E8M Test Methods for Tension Testing of Metallic Materials

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

E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry

E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)

E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes

E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

E478 Test Methods for Chemical Analysis of Copper Alloys

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

2.2 ASME Code:

ASME Boiler and Pressure Vessel Code

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

4. Ordering Information

4.1 Include the following specified choices when placing orders for product under this specification as applicable:

4.1.1 ASTM designation and year of issue;

4.1.2 Copper UNS No. designation, if required, (see Chemical Composition section);

4.1.3 Temper (see Temper section and Table 2);

4.1.4 Pipe size, regular or extra-strong (see Dimensions section and Table 3);

4.1.5 Length (see 10.3) if different than standard; and

4.1.6 Quantity—total weight, or total length or number of pieces of each size.

4.2 The following options are available, but may not be included unless specified at the time of placing of the order when required:

4.2.1 DELETED

4.2.2 If product is required for bending (see 6.2) and the temper to be furnished;

4.2.3 DELETED

4.2.4 DELETED

4.2.5 Hydrostatic test, if required (see Nondestructive Testing section);

4.2.5.1 If hydrostatic test pressure above 1000 psi is required;

4.2.6 Pneumatic test, if required (see Nondestructive Testing section);

4.2.7 If product is purchased for agencies of the U.S. Government (see the Other Requirements section of this specification); and

4.2.8 If specification number is required to be shown on each shipping unit (see Packaging and Package Marking section).

5. Chemical Composition

5.1 The material shall conform to the following chemical requirements:

Copper (incl silver), min, %	99.9
Phosphorus, max, %	0.04

5.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance specified in Table 1.

5.2 The pipe shall be produced from one of the following coppers, and unless otherwise specified, any one of them is permitted to be furnished:

Copper UNS No.	Previously Used Designation	Type of Copper
C10200	OF	Oxygen-free without residual deoxidants
C10300		Oxygen-free, extra-low phosphorus
C10800		Oxygen-free, low phosphorus
C12000	DLP	Phosphorized, low residual phosphorus
C12200	DHP	Phosphorized, high residual phosphorus

TABLE 1 Chemical Requirements

Copper UNS No.	Copper (incl Silver), min, %	Phosphorus, %
C10200 ^A	99.95	...
C10300	99.95 ^B	0.001 to 0.005
C10800	99.95 ^B	0.005 to 0.012
C12000	99.90	0.004 to 0.012
C12200	99.9	0.015 to 0.040

^A Oxygen in C10200 shall be 10 ppm max.

^B Copper + silver + phosphorus.

5.3 When the copper UNS No. designation is specified, the material shall conform to the chemical requirements specified in Table 1.

5.4 These composition limits do not preclude the presence of other elements. By agreement between manufacturer or supplier and purchaser, limits may be established and analysis required for unnamed elements.

6. Temper

6.1 The standard tempers as prescribed in Classification B601, for products described in this specification are:

6.1.1 Annealed O61,

6.1.2 Light Drawn H55, and

6.1.3 Hard Drawn H80.

6.2 When pipe is required for bending, it shall be so specified in the purchase order, and the pipe shall be furnished in the temper agreed upon between the manufacturer or supplier and the purchaser.

7. Mechanical Property Requirements

7.1 *Tensile Strength Requirements:*

7.1.1 Product furnished under this specification shall conform to the tensile requirements prescribed in Table 2, when tested in accordance with Test Methods E8/E8M.

8. Performance Requirements

8.1 *Expansion Test:*

8.1.1 Pipe ordered in the annealed (O61) temper, selected for test, shall withstand an expansion of 25 % of the outside diameter when expanded in accordance with Test Method B153. The expanded pipe shall show no cracking or rupture visible to the unaided eye. Pipe ordered in the drawn tempers H55 or H80 are not subject to this test.

NOTE 1—The term “unaided eye,” as used herein, permits the use of corrective spectacles necessary to obtain normal vision.

8.2 *Flattening Test:*

8.2.1 As an alternative to the expansion test for pipe over 4 in. (102 mm) in diameter in the annealed temper, a flattening test in accordance with Test Method B968/B968M shall be performed.

8.3 *Microscopical Examination:*

8.3.1 The pipe shall be made from copper that is free of cuprous oxide as determined by microscopical examination in accordance with Method A of Test Methods B577 at a 75× magnification.

TABLE 2 Tensile Requirements

Temper Designation		Pipe Size Nominal or Standard, in.	Tensile Strength, min, ksi ^A (MPa) ^B	Yield Strength, ^C min, ksi ^A (MPa) ^B
Code	Name			
O61	annealed	all	30 (205)	9 (60) ^D
H80	hard drawn	½ –2, incl	45 (310)	40 (275)
H80	hard drawn	over 2	38 (260)	32 (220)
H55	light drawn	2–12, incl	36 (250)	30 (205)

^A ksi = 1000 psi.

^B See Appendix X1.

^C At 0.5 % extension under load.

^D Light-straightening operation is permitted.

8.3.2 When Copper UNS No. C12200 is supplied, microscopical examination for cuprous oxide is not required.

9. Other Requirements

9.1 Nondestructive Testing:

9.1.1 The material shall be tested in the final size but is permitted to be tested before the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

9.1.2 The eddy current test, the hydrostatic test, or the pneumatic test shall be conducted on each tube at the manufacturer's option. The requirements of Section 12 do not apply.

9.2 *Eddy-Current Test*—Testing shall follow the procedures of Practice E243, except for determination of “end effect.” The material shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the material for the intended application.

9.2.1 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 10 % of the nominal wall thickness. The notch depth tolerance shall be ± 0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed-insensitive equipment that allows the selection of a maximum imbalance signal, a maximum imbalance signal of 0.3 % is permitted to be used.

9.2.2 Material that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Material with discontinuities indicated by the testing unit is permitted to be re-examined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil, or moisture shall not be cause for rejection of the material provided the dimensions of the material are still within prescribed limits and the material is suitable for its intended application.

9.3 *Hydrostatic Test*—The material shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi (41 MPa), determined by the following equation for thin hollow cylinders under tension. The material need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified.

$$P = 2St/(D - 0.8t) \quad (1)$$

where:

P = hydrostatic pressure, psi (or MPa);

t = wall thickness of the material, in. (or mm);

D = outside diameter of the material in. (or mm); and

S = allowable stress of the material, psi (or MPa).

9.4 *Pneumatic Test*—The material shall be subjected to an internal air pressure of 60 psi (415 kPa) minimum for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the material under water or by the pressure-differential method. Any evidence of leakage shall be cause for rejection.

9.5 *Purchases for U.S. Government*—If the product is purchased for agencies of the U.S. Government, when specified in the contract or purchase order, the product furnished shall conform to the conditions specified in the Supplementary Requirements of this specification.

10. Dimensions and Permissible Variations

10.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the limiting values for any dimensions shall be sufficient cause for rejection.

10.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 3.

10.3 *Length and Length Tolerances*—The standard length of copper pipe is 12 ft (3.66 m) with a tolerance of $\pm \frac{1}{2}$ in. (13 mm).

10.4 Roundness:

10.4.1 For pipe of H (drawn) tempers in straight lengths, the roundness tolerances shall be as follows:

t/d (ratio of Wall Thickness to Outside Diameter)	Roundness Tolerances as Percent of Outside Diameter (Expressed to the Nearest 0.001 in. (0.025 mm))
0.01 to 0.03, incl	1.5
Over 0.03 to 0.05, incl	1.0
Over 0.05 to 0.10, incl	0.8
Over 0.10	0.7

10.4.2 Compliance with the roundness tolerance shall be determined by taking measurements on the outside diameter only, irrespective of the manner in which the pipe dimensions are specified.

10.4.3 The deviation from roundness is measured as the difference between major and minor diameters as determined at any one cross section of the tube.

10.5 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed the following:

Outside Diameter, in. (mm)	Tolerance
Up to $\frac{5}{8}$ (15.9), incl	0.010 in. (0.25 mm)
Over $\frac{5}{8}$ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

10.6 *Straightness Tolerance*—For pipe of H (drawn) tempers of nominal pipe sizes from $\frac{1}{4}$ to 12 in. inclusive, the maximum curvature (depth of arc) shall not exceed $\frac{1}{2}$ in. (13 mm) in any 10 ft portion of the total length. For H temper pipe of other sizes, and for the O61 (annealed) temper, no numerical values are established; however, the straightness of the pipe shall be suitable for the intended application.

11. Workmanship, Finish, and Appearance

11.1 The product shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable. It shall be well cleaned and free of dirt.

12. Sampling

12.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

TABLE 3 Standard Dimensions, Weights, and Tolerances

NOTE 1—All tolerances plus and minus except as otherwise indicated.

Nominal or Standard Pipe Size, in.	Outside Diameter, in. (mm)	Average Outside Diameter Tolerance, ^A in. (mm) All Minus	Wall Thickness, in. (mm)	Tolerance, ^B in. (mm)	Theoretical Weight, lb/ft (kg/m)
Regular					
1/8	0.405 (10.3)	0.004 (0.10)	0.062 (1.57)	0.004 (0.10)	0.259 (0.385)
1/4	0.540 (13.7)	0.004 (0.10)	0.082 (2.08)	0.005 (0.13)	0.457 (0.680)
3/8	0.675 (17.1)	0.005 (0.13)	0.090 (2.29)	0.005 (0.13)	0.641 (0.954)
1/2	0.840 (21.3)	0.005 (0.13)	0.107 (2.72)	0.006 (0.15)	0.955 (1.42)
3/4	1.050 (26.7)	0.006 (0.15)	0.114 (2.90)	0.006 (0.15)	1.30 (1.93)
1	1.315 (33.4)	0.006 (0.15)	0.126 (3.20)	0.007 (0.18)	1.82 (2.71)
1 1/4	1.660 (42.2)	0.006 (0.15)	0.146 (3.71)	0.008 (0.20)	2.69 (4.00)
1 1/2	1.900 (48.3)	0.006 (0.15)	0.150 (3.81)	0.008 (0.20)	3.20 (4.76)
2	2.375 (60.3)	0.008 (0.20)	0.156 (3.96)	0.009 (0.23)	4.22 (6.28)
2 1/2	2.875 (73.0)	0.008 (0.20)	0.187 (4.75)	0.010 (0.25)	6.12 (9.11)
3	3.500 (88.9)	0.010 (0.25)	0.219 (5.56)	0.012 (0.30)	8.76 (13.0)
3 1/2	4.000 (102)	0.010 (0.25)	0.250 (6.35)	0.013 (0.33)	11.4 (17.0)
4	4.500 (114)	0.012 (0.30)	0.250 (6.35)	0.014 (0.36)	12.9 (19.2)
5	5.562 (141)	0.014 (0.36)	0.250 (6.35)	0.014 (0.36)	16.2 (24.1)
6	6.625 (168)	0.016 (0.41)	0.250 (6.35)	0.014 (0.36)	19.4 (28.9)
8	8.625 (219)	0.020 (0.51)	0.312 (7.92)	0.022 (0.56)	31.6 (47.0)
10	10.750 (273)	0.022 (0.56)	0.365 (9.27)	0.030 (0.76)	46.2 (68.7)
12	12.750 (324)	0.024 (0.61)	0.375 (9.52)	0.030 (0.76)	56.5 (84.1)
Extra Strong					
1/8	0.405 (10.3)	0.004 (0.10)	0.100 (2.54)	0.006 (0.15)	0.371 (0.552)
1/4	0.540 (13.7)	0.004 (0.10)	0.123 (3.12)	0.007 (0.18)	0.625 (0.930)
3/8	0.675 (17.1)	0.005 (0.13)	0.127 (3.23)	0.007 (0.18)	0.847 (1.26)
1/2	0.840 (21.3)	0.005 (0.13)	0.149 (3.78)	0.008 (0.20)	1.25 (1.86)
3/4	1.050 (26.7)	0.006 (0.15)	0.157 (3.99)	0.009 (0.23)	1.71 (2.54)
1	1.315 (33.4)	0.006 (0.15)	0.182 (4.62)	0.010 (0.25)	2.51 (3.73)
1 1/4	1.660 (42.2)	0.006 (0.15)	0.194 (4.93)	0.010 (0.25)	3.46 (5.15)
1 1/2	1.900 (48.3)	0.006 (0.15)	0.203 (5.16)	0.011 (0.28)	4.19 (6.23)
2	2.375 (60.3)	0.008 (0.20)	0.221 (5.61)	0.012 (0.30)	5.80 (8.63)
2 1/2	2.875 (73.0)	0.008 (0.20)	0.230 (5.84)	0.015 (0.38)	8.85 (13.2)
3	3.500 (88.9)	0.010 (0.25)	0.304 (7.72)	0.016 (0.41)	11.8 (17.6)
3 1/2	4.000 (102)	0.010 (0.25)	0.321 (8.15)	0.017 (0.43)	14.4 (21.4)
4	4.500 (114)	0.012 (0.30)	0.341 (8.66)	0.018 (0.46)	17.3 (25.7)
5	5.562 (141)	0.014 (0.36)	0.375 (9.52)	0.019 (0.48)	23.7 (35.3)
6	6.625 (168)	0.016 (0.41)	0.437 (11.1)	0.027 (0.69)	32.9 (49.0)
8	8.625 (219)	0.020 (0.51)	0.500 (12.7)	0.035 (0.89)	49.5 (73.7)
10	10.750 (273)	0.022 (0.56)	0.500 (12.7)	0.040 (1.0)	62.4 (92.9)

^A The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the pipe.^B Maximum deviation at any one point.**12.1.1 Lot Size**—The lot size shall be as follows:

Pipe Size, in.	Lot Weight, lb (kg)
Up to 1 1/2, incl	5 000 (2270) or fraction thereof
Over 1 1/2 to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

12.1.2 Portion Size—Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken ^A
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot, but not to exceed ten sample pieces

^A Each sample piece shall be taken from a separate tube.**13. Number of Tests and Retests**

13.1 Chemical Analysis—Samples for chemical analysis shall be taken in accordance with Practice E255. Drillings, millings, and so forth shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 12.1.2 and combined into one composite sample. The

minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

13.1.1 Instead of sampling in accordance with Practice E255, the manufacturer shall have the option of determining conformance to chemical composition as follows: conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

13.1.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

13.1.1.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

13.1.1.3 Because of the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

13.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

13.2 Retests:

13.2.1 If any test specimen shows defective machining or develops flaws, it shall be discarded and another specimen substituted.

13.2.2 If a bend test specimen fails because of conditions of bending more severe than required by the specification, a retest shall be permitted on a new sample piece or on the remaining portion of the first sample piece.

13.2.3 If the results of the test on one of the specimens fail to meet the specified requirements, two additional specimens shall be taken from different sample pieces and tested. The results of the tests on both of these specimens shall meet the specified requirements. Failure of more than one specimen to meet the specified requirements for a particular property shall be cause for rejection of the entire lot.

13.2.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 12.1. The results of this retest shall comply with the specified requirements.

14. Test Methods

14.1 Chemical Analysis:

14.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement:

Test	ASTM Designation ^A
Chemical analysis	B170, ^B E58, E62, E478

^A See 2.1.

^B Reference to Specification B170 is to the suggested chemical methods in the annex thereof. When Committee E01 has tested and published methods for assaying the low-level impurities in copper, the Specification B170 annex will be eliminated.

14.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

14.2 The product furnished shall conform to the specified requirements when subjected to test in accordance with the following applicable test methods:

Test	ASTM Designation ^A
Tensile Strength	E8/E8M
Expansion (pin test)	B153
Eddy current	E243
Microscopical Examination	B577
Flattening Test	B968/B968M

^A See 2.1.

14.3 Tensile Strength Requirements:

14.3.1 Tensile test specimens shall be of the full section of the pipe and shall conform to the requirements of the Specimens for Pipe and Tube section of Test Methods E8/E8M unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E8/E8M is permitted to be used when a full-section specimen cannot be tested.

14.3.2 Whenever tensile test results are obtained from both full-size and machined test specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

14.3.3 Tensile test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, it is recommended that the rate of stressing to the yield strength not exceed 100 ksi (700 MPa)/min. Above the yield strength, it is recommended that the movement per minute of the testing machine head under load not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

15. Significance of Numerical Limits

15.1 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength	
Yield strength	nearest ksi (nearest 5 MPa)

16. Inspection

16.1 The manufacturer or supplier shall inspect and make tests necessary to verify the furnished product conforms to the specification requirements.

16.2 Source inspection of the product by the purchaser may be agreed upon between the manufacturer or supplier and the purchaser as part of the purchase order. In such case, the nature of the facilities needed to satisfy the inspector representing the purchaser that the product is being furnished in accordance with the specification shall be included in this agreement. All testing and inspection shall be conducted so as not to interface unnecessarily with the operation of the works.

16.3 When mutually agreed upon, the manufacturer or supplier and purchaser shall conduct the final inspection simultaneously.

17. Rejection and Rehearing

17.1 Rejection:

17.1.1 Product that fails to conform to the specification requirements when tested by the purchaser or purchaser's agent shall be subject to rejection.

17.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

17.1.3 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer or supplier shall have the option to make claim for a rehearing.

17.2 Rehearing:

17.2.1 As a result of product rejection, the manufacturer or supplier shall have the option to make claim for a retest to be conducted by the manufacturer or supplier and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification or, alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

18. Certification

18.1 The purchaser shall be furnished certification that samples representing each lot have been tested and inspected as directed in this specification and the requirements have been met.

18.2 DELETED

19. Test Report

19.1 A report of test results shall be furnished.

20. Packaging and Package Marking

20.1 Packaging:

20.1.1 The product shall be separated by size, composition, and temper, and prepared for shipment by common carrier in such a manner as to afford protection from the normal hazards of transportation.

20.2 Package Marking:

20.2.1 Each package shall be legibly marked with the metal or alloy designation, temper, size, gross and net weight, total length or piece count, or both, and name of supplier. Upon agreement between the purchaser and supplier, the purchase order number shall be indicated on each package or on the shipping documents.

20.2.2 When specified in the purchase order or contract, the product specification number shall be shown.

21. Keywords

21.1 copper pipe; extra strong; regular; standard sizes ; UNS No. C10200; UNS No. C10300; UNS No. C10800; UNS No. C12000; UNS No. C12200

SUPPLEMENTARY REQUIREMENTS

S1. Scope

S1.1 The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S2. Referenced Documents

S2.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S2.1.1 ASTM Standard:

B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

S2.1.2 Federal Standard:

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

S2.1.3 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-2073/1 Standard Practice for Military Packaging

S2.1.4 SAE Standard:

AMS-STD-185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S3. Quality Assurance

S3.1 *Responsibility for Inspection:*

S3.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S4. Identification Marking

S4.1 All material shall be properly marked for identification in accordance with AMS-STD-185 except that the ASTM specification number and the alloy number shall be used.

S5. Preparation for Delivery

S5.1 Preservation, Packaging, Packing:

S5.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, and packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of Practice B900.

S5.1.2 *Civil Agencies*—The requirements of MIL-STD-2073 shall be referenced for definitions of the various levels of packaging protection.

TABLE S6.1 Part or Identifying Numbers

B42	XXXXXX	XXX	-XX	X	X	XXX	X
Document Identifier	Alloy (See Table 1)	Temper (See 6.1)	Size (See Table 3)		Wall thickness (R = regular, S = extra strong)	Length	
			inches	eighths of an inch		inches	eighths of an inch

S5.2 Marking:

S5.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S5.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

S6. Part or Identifying Numbers (PINs)

S6.1 Part numbers are essential to maintain the integrity of the Department of Defense cataloging system as multiple National Stock Numbers (NSN) exist for this product. The

following information is provided for cross-reference purposes. The pipe previously described in WW-P-377 and MS14302 corresponds to ASTM B42 copper pipe of copper UNS No. C12000 with a regular wall thickness.

S6.2 Part identifying numbers, for government use, shall be formulated by selecting from the options in this specification as shown in Table S6.1.

S6.3 An example of a PIN follows: A part identifying number of B42C12000H80-030R1264 indicates an ASTM B42 pipe of copper UNS No. C12000 in the hard drawn (H80) temper, 3 in. standard pipe size, regular wall thickness, and it is 10 ft 6½ in. (3213 mm) in length.

APPENDIX**(Nonmandatory Information)****X1. METRIC EQUIVALENTS**

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg} \cdot \text{m}/\text{s}^2$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

SPECIFICATION FOR SEAMLESS RED BRASS PIPE, STANDARD SIZES



SB-43

(Identical with ASTM Specification B43-20 except that certification and mill test reports have been made mandatory, and nondestructive testing is required for all diameters.)

Specification for Seamless Red Brass Pipe, Standard Sizes

1. Scope

1.1 This specification establishes requirements for seamless red brass (Copper Alloy UNS No. C23000) pipe in nominal pipe sizes, both regular and extra-strong. In the annealed temper (O61), the pipe is suitable for use in plumbing, boiler feed lines, and for similar purposes. In the drawn general purpose temper (H58), the pipe is suitable for architectural applications, such as guard railings and stair hand railings.

1.2 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 The following hazard caveat pertains only to the test method portion, 9.1.1, of this specification. *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.*

1.4 **Warning**—Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location. (See 9.2.)

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:

- B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B154 Test Method for Mercurous Nitrate Test for Copper Alloys
- B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
- B846 Terminology for Copper and Copper Alloys
- B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
- B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies
- B950 Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys
- B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E112 Test Methods for Determining Average Grain Size
- E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
- E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
- E478 Test Methods for Chemical Analysis of Copper Alloys
- E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

2.2 ASME Code:

ASME Boiler and Pressure Vessel Code

3. Terminology

3.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

4. Ordering Information

4.1 Include the following specified choices when placing orders for product under this specification as applicable:

4.1.1 ASTM designation and year of issue;

4.1.2 Temper (see Temper section);

4.1.3 Pipe size, regular or extra-strong (see Table 1);

4.1.4 Length (see 11.3);

4.1.5 Quantity—total weight or total length of each size; and

4.1.6 Intended application.

4.2 The following options are available but may not be included unless specified at the time of placing the order when required:

4.2.1 DELETED

4.2.2 DELETED

4.2.3 DELETED

TABLE 1 Standard Dimensions, Weights, and Tolerances

NOTE 1—All tolerances are plus and minus except as otherwise indicated.

Nominal or Standard Pipe Size, in.	Outside Diameter, in. (mm)	Average Outside Diameter Tolerances, ^A in. (mm) All Minus	Wall Thickness, in. (mm)	Tolerance, ^B in. (mm)	Theoretical Weight, lb/ft (kg/m)
Regular					
1/8	0.405 (10.3)	0.004 (0.10)	0.062 (1.57)	0.004 (0.10)	0.253 (0.376)
1/4	0.540 (13.7)	0.004 (0.10)	0.082 (2.08)	0.005 (0.13)	0.447 (0.665)
3/8	0.675 (17.1)	0.005 (0.13)	0.090 (2.29)	0.005 (0.13)	0.627 (0.933)
1/2	0.840 (21.3)	0.005 (0.13)	0.107 (2.72)	0.006 (0.15)	0.934 (1.39)
3/4	1.050 (26.7)	0.006 (0.15)	0.114 (2.90)	0.006 (0.15)	1.27 (1.89)
1	1.315 (33.4)	0.006 (0.15)	0.126 (3.20)	0.007 (0.18)	1.78 (2.65)
1 1/4	1.660 (42.2)	0.006 (0.15)	0.146 (3.71)	0.008 (0.20)	2.63 (3.91)
1 1/2	1.900 (48.3)	0.006 (0.15)	0.150 (3.81)	0.008 (0.20)	3.13 (4.66)
2	2.375 (60.3)	0.008 (0.20)	0.156 (3.96)	0.009 (0.23)	4.12 (6.13)
2 1/2	2.875 (73.0)	0.008 (0.20)	0.187 (4.75)	0.010 (0.25)	5.99 (8.91)
3	3.500 (88.9)	0.010 (0.25)	0.219 (5.56)	0.012 (0.30)	8.56 (12.7)
3 1/2	4.000 (102)	0.010 (0.25)	0.250 (6.35)	0.013 (0.33)	11.2 (16.7)
4	4.500 (114)	0.012 (0.30)	0.250 (6.35)	0.014 (0.36)	12.7 (18.9)
5	5.562 (141)	0.014 (0.36)	0.250 (6.35)	0.014 (0.36)	15.8 (23.5)
6	6.625 (168)	0.016 (0.41)	0.250 (6.35)	0.014 (0.36)	19.0 (28.3)
8	8.625 (219)	0.020 (0.51)	0.312 (7.92)	0.022 (0.56)	30.9 (46.0)
10	10.750 (273)	0.022 (0.56)	0.365 (9.27)	0.030 (0.76)	45.2 (67.3)
12	12.750 (324)	0.024 (0.61)	0.375 (9.52)	0.030 (0.76)	55.3 (82.3)
Extra Strong					
1/8	0.405 (10.3)	0.004 (0.10)	0.100 (2.54)	0.006 (0.15)	0.363 (0.540)
1/4	0.540 (13.7)	0.004 (0.10)	0.123 (3.12)	0.007 (0.18)	0.611 (0.909)
3/8	0.675 (17.1)	0.005 (0.13)	0.127 (3.23)	0.007 (0.18)	0.829 (1.23)
1/2	0.840 (21.3)	0.005 (0.13)	0.149 (3.78)	0.008 (0.20)	1.23 (1.83)
3/4	1.050 (26.7)	0.006 (0.15)	0.157 (3.99)	0.009 (0.23)	1.67 (2.48)
1	1.315 (33.4)	0.006 (0.15)	0.182 (4.62)	0.010 (0.25)	2.46 (3.66)
1 1/4	1.660 (42.2)	0.006 (0.15)	0.194 (4.93)	0.010 (0.25)	3.39 (5.04)
1 1/2	1.900 (48.3)	0.006 (0.15)	0.203 (5.16)	0.011 (0.28)	4.10 (6.10)
2	2.375 (60.3)	0.008 (0.20)	0.221 (5.61)	0.012 (0.30)	5.67 (8.44)
2 1/2	2.875 (73.0)	0.008 (0.20)	0.280 (7.11)	0.015 (0.38)	8.66 (12.9)
3	3.500 (88.9)	0.010 (0.25)	0.304 (7.72)	0.016 (0.41)	11.6 (17.3)
3 1/2	4.000 (102)	0.010 (0.25)	0.321 (8.15)	0.017 (0.43)	14.1 (21.0)
4	4.500 (114)	0.012 (0.30)	0.341 (8.66)	0.018 (0.46)	16.9 (25.1)
5	5.562 (141)	0.014 (0.36)	0.375 (9.52)	0.019 (0.48)	23.2 (34.5)
6	6.625 (168)	0.016 (0.41)	0.437 (11.1)	0.027 (0.69)	32.2 (47.9)
8	8.625 (219)	0.020 (0.51)	0.500 (12.7)	0.035 (0.89)	48.4 (72.0)
10	10.750 (273)	0.022 (0.56)	0.500 (12.7)	0.040 (1.0)	61.1 (90.9)

^A The average outside diameter of a tube is the average of the maximum and minimum outside diameters as determined at any one cross section of the pipe.

^B Maximum deviation at any one point.

- 4.2.4 Hydrostatic test, if required (see 10.3);
 4.2.5 Pneumatic test, if required (see 10.4);
 4.2.6 Residual stress test, if required (Performance Requirements section);
 4.2.6.1 Ammonia Vapor Test or Mercurous Nitrate Test;
 4.2.6.2 For Ammonia Vapor Test, pH value other than 10;
 4.2.7 Inclusion of the specification number on the packaging unit (see 19.2); and
 4.2.8 If product is purchased for agencies of the U.S. Government (see the Supplementary Requirements section of this specification) for additional requirements, if specified.

5. Chemical Composition

5.1 The material shall conform to the following chemical composition requirements:

Copper, %	84.0 to 86.0
Lead, max, %	0.05
Iron, max, %	0.05
Zinc	remainder

5.1.1 Results of analysis on a product (check) sample shall conform to the composition requirements within the permitted analytical variance specified above.

5.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer or supplier and purchaser, limits may be established and analysis required for unnamed elements.

5.2.1 For copper alloys in which zinc is listed as “remainder,” either copper or zinc may be taken as the difference between the sum of results of all other elements determined and 100 %.

5.2.1.1 When all the elements in the table in 5.1 are determined, the sum of the results shall be 99.8 % minimum.

6. Temper

6.1 All pipe shall normally be furnished in the O61 (annealed) (see Classification B601) temper.

6.2 The pipe is permitted to be furnished in the H58 (drawn general purpose) temper, if agreed upon between the manufacturer and the purchaser. (See Table 2.)

7. Grain Size for Annealed Temper

7.1 Grain size shall be the standard requirement for all product in the annealed temper.

7.2 Acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions, and each specimen shall be within the limits prescribed in 7.3 when determined in accordance with Test Methods E112.

TABLE 2 Tensile Requirements

Temper Designation		Tensile Strength, min. ksi (MPa)	Yield Strength ^A min. ksi (MPa)	Elongation in 2-in. min. %
Code	Name			
O61	Annealed	40.0 (275)	12.0 (85)	35
H58	Drawn general purpose	44.0 (300)	18.0 (125)	...

^A At 0.5 % extension under load.

7.3 In the O61 (annealed) temper, the degree of annealing shall be sufficient to produce complete recrystallization with an average grain size not in excess of 0.050 mm.

8. Mechanical Property Requirements

8.1 Product furnished under this specification shall conform to the tensile, yield, and elongation requirements (where required) prescribed in Table 2, when tested in accordance with Test Methods E8/E8M¹

9. Performance Requirements

9.1 Expansion Test:

9.1.1 Specimens in the O61 (annealed) temper shall withstand an expansion of 25 % of the outside diameter when expanded in accordance with Test Method B153. The expanded pipe shall show no cracking or rupture visible to the unaided eye. Pipe ordered in the drawn (H) condition is not subject to this test.

NOTE 1—The term “unaided eye,” as used herein, permits the use of corrective spectacles necessary to obtain normal vision.

9.1.2 As an alternative to the expansion test for pipe over 4 in. (102 mm) in diameter in the O61 (annealed) condition, a flattening test in accordance with Test Method B968/B968M shall be performed.

9.2 Residual Stress Test:

9.2.1 When specified in the contract or purchase order, product of the O61 (annealed) shall be tested for residual stress according to the requirements of Test Method B154 or Test Method B858, and show no signs of cracking.

Warning—Mercury is a definite health hazard. With the Mercurous Nitrate Test, equipment for the detection and removal of mercury vapor produced in volatilization, and the use of protective gloves is recommended.

NOTE 2—A residual stress test provides information about the adequacy of the stress relief of the material. Tube straightening is a method of mechanical stress relief. Stress relief annealing is a method of thermal stress relief.

10. Other Requirements

10.1 *Nondestructive Testing*—The material shall be tested in the final size but is permitted to be tested prior to the final anneal or heat treatment, when these thermal treatments are required, unless otherwise agreed upon by the manufacturer or supplier and purchaser.

10.1.1 Either the eddy current, hydrostatic, or pneumatic test shall be conducted on each tube at the manufacturer’s option. The sampling requirements of Section 13 do not apply.

10.2 *Eddy-Current Test*—Testing shall follow the procedures of Practice E243 except for determination of “end effect.” The material shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the material for the intended application.

10.2.1 Notch-depth standards rounded to the nearest 0.001 in. (0.025 mm) shall be 10 % of the nominal wall thickness. The notch depth tolerances shall be ± 0.0005 in. (0.013 mm). Alternatively, when a manufacturer uses speed

insensitive equipment that allows the selection of a maximum imbalance signal, a maximum imbalance signal of 0.3 % is permitted to be used.

10.2.2 Material that does not actuate the signaling device of the eddy-current test shall be considered as conforming to the requirements of this test. Material with discontinuities indicated by the testing unit is permitted to be reexamined or retested, at the option of the manufacturer, to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil or moisture shall not be cause for rejection of the material provided the dimensions of the material are still within prescribed limits and the material is suitable for its intended application.

10.3 *Hydrostatic Test*—The material shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 6000 psi (41 MPa), determined by the following equation for thin hollow cylinders under tension. The material need not be tested at a hydrostatic pressure of over 1000 psi (6.9 MPa) unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

- P = hydrostatic pressure, psi (or MPa);
 t = wall thickness of the material, in. (or mm);
 D = outside diameter of the material in. (or mm); and
 S = allowable stress of the material, psi (or MPa).

10.3.1 For material less than ½ in. (12.7 mm) in outside diameter and less than 0.060 in. (1.5 mm) in wall thickness, the test is permitted to be made at the option of the manufacturer by pneumatically testing to the requirements of 10.4.

10.4 *Pneumatic Test*—The material shall be subjected to an internal air pressure of 60 psi (415 kPa) minimum for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the material under water or by the pressure-differential method. Any evidence of leakage shall be cause for rejection.

11. Dimensions and Permissible Variations

11.1 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the limiting values for any dimensions may be cause for rejection.

11.2 *Standard Dimensions, Wall Thickness, and Diameter Tolerances*—The standard dimensions, wall thickness, and diameter tolerances shall be in accordance with Table 1.

11.3 *Length and Length Tolerances*—The standard length of red brass pipe is 12 ft (3.66 m) with a tolerance of ±½ in. (13 mm).

11.4 *Squareness of Cut*—The departure from squareness of the end of any pipe shall not exceed the following:

Outside Diameter, in. (mm)	Tolerance
Up to ⅝ (15.9), incl	0.010 in. (0.25 mm)
Over ⅝ (15.9)	0.016 in./in. (0.016 mm/mm) of diameter

11.5 *Roundness*—The roundness tolerance for straight length tubes with a wall thickness to outside diameter ratio of 0.01 to 0.05 (inclusive) shall be 6 % of the nominal outside diameter. For tubes with a wall thickness to outside diameter ratio over 0.05, the roundness tolerance shall be 3 % of the nominal outside diameter.

11.5.1 The measurement for roundness shall be made from the outside diameter. The deviation from roundness is measured as the difference between the major and minor diameters as determined at any one cross section of the tube. The major and minor diameters are the diameters of two concentric circles just enclosing the outside surface of the tube at the cross section.

11.6 *Straightness Tolerance*—For pipe of H58 (drawn general purpose) temper of Nominal Pipe Sizes from ¼ to 12 in. inclusive, the maximum curvature (depth of arc) shall not exceed ½ in. (13 mm) in any 10 ft (3048 mm) portion of the total length. For H58 temper pipe of other sizes, and for the O61 (annealed) temper, no numerical values are established; however, the straightness of the pipe shall be suitable for the intended application.

12. Workmanship, Finish, and Appearance

12.1 The product shall be free of defects, but blemishes of a nature that do not interfere with normal commercial applications are acceptable. It shall be well cleaned and free of dirt.

13. Sampling

13.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

13.1.1 *Lot Size*—The lot size shall be as follows:

Pipe Size, in.	Lot Weight, lb (kg)
Up to 1½, incl	5 000 (2270) or fraction thereof
Over 1½ to 4, incl	10 000 (4550) or fraction thereof
Over 4	40 000 (18 100) or fraction thereof

13.1.2 *Portion Size*—Sample pieces shall be taken for test purposes from each lot according to the following schedule:

Number of Pieces in Lot	Number of Sample Pieces to be Taken ^A
1 to 50	1
51 to 200	2
201 to 1500	3
Over 1500	0.2 % of total number of pieces in the lot, but not to exceed 10 sample pieces

^A Each sample piece shall be taken from a separate tube.

13.1.3 *Sampling for Visual and Dimensional Examination*—Minimum sampling for visual and dimensional examination shall be as follows:

Lot size (Pieces/lot)	Sample size
2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 100 000	38
10 001 to 350 000	46

In all cases, the acceptance number is zero and the rejection number is one. Rejected lots are permitted to be screened and resubmitted for visual and dimensional examination. All defective items shall be replaced with acceptable items prior to lot acceptance.

14. Number of Tests and Retests

14.1 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E255. Drillings, millings, etc., shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 13.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

14.1.1 Instead of sampling in accordance with Practice E255, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semi-finished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

14.1.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

14.1.1.2 When samples are taken from the semi-finished product, a sample shall be taken to represent each 10 000 lb (4550 kg) or fraction thereof, except that not more than one sample shall be required per piece.

14.1.1.3 Due to the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

14.1.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired.

14.2 Retests

14.2.1 When requested by the manufacturer or supplier, a retest shall be permitted when results of tests obtained by the purchaser fail to conform to the requirements of the product specification.

14.2.2 The retest shall be as directed in the product specification for the initial test, except the number of test specimens shall be twice that normally required for the specified test.

14.2.3 All test specimens shall conform to the product specification requirement(s) in retest. Failure to conform shall be cause for rejection.

14.2.4 If the chemical analysis fails to conform to the specified limits, analysis shall be made on a new composite sample prepared from additional pieces selected in accordance with 13.1. The results of this retest shall comply with the specified requirements.

15. Test Methods

15.1 Chemical Analysis:

15.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser.

15.1.2 The test methods listed below and others not listed may be used, subject to agreement to determine the composition:

Element	Method
Copper	E478
Lead	E478
Iron	E478
Zinc	E478

15.1.3 Test methods to be followed for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

15.2 Residual Stress Tests:

15.2.1 Unless otherwise agreed upon between the manufacturer or supplier and the purchaser, the manufacturer shall have the option of using either the mercurous nitrate test or the ammonia vapor test.

15.2.2 *Mercurous Nitrate Test*—The material shall be subjected to test in accordance with Test Method B154.

15.2.3 *Ammonia Vapor Test*—The material shall be subjected to test in accordance with Test Method B858. If the pH value is not specified in the product specification, it shall be established in accordance with agreement between the supplier and purchaser.

15.3 Other Tests:

15.3.1 The product furnished shall conform to specified requirements when subjected to test in accordance with the following table:

Test	ASTM Designation (Section 2)
Grain Size	E112
Tension	E8/E8M
Expansion (pin test)	B153

15.4 *Tensile Test*—Tensile test specimens shall be of the full section of the pipe and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E8/E8M, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E8/E8M is permitted to be used when a full section specimen cannot be tested.

15.4.1 Whenever tensile test results are obtained from both full size and from machined test specimens and they differ, the results obtained from full size test specimens shall be used to determine conformance to the specification requirements.

15.4.2 Tensile test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, it is recommended that the rate of stressing to the yield strength not exceed 100 ksi (690 MPa)/min. Above the yield strength it is recommended that the movement per minute of the testing machine head under load not exceed 0.5 in./in. (0.5 mm/mm) of gage length (or distance between grips for full-section specimens).

16. Significance of Numerical Limits

16.1 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29.

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand place of figures of the specified limit
Tensile Strength Yield Strength	nearest ksi (nearest 5 MPa)
Elongation	nearest 1 %
Grain size under 0.060 mm	nearest multiple of 0.005 mm
0.060 mm and over	nearest 0.01 mm

17. Inspection

17.1 The manufacturer or supplier shall inspect and make tests necessary to verify that the furnished product conforms to specification requirements.

17.2 Source inspection of the product by the purchaser may be agreed upon between the manufacturer or supplier and the purchaser as part of the purchase order. In such case, the nature of the facilities needed to satisfy the inspector that the product is being furnished in accordance with the specification shall be included in the agreement.

17.3 When mutually agreed upon, the manufacturer or supplier and the purchaser shall conduct the final inspection simultaneously.

18. Rejection and Rehearing

18.1 Rejection:

18.1.1 Product that fails to conform to the specification requirements when tested by the purchaser or purchaser's agent shall be subject to rejection.

18.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

18.1.3 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer or supplier shall have the option to make claim for a rehearing.

18.2 Rehearing:

18.2.1 As a result of product rejection, the manufacturer or supplier shall have the option to make claim for a retest to be conducted by the manufacturer or supplier and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification, and subjected to test by both parties using the test method(s) specified by the product specification or, alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

19. Packaging and Package Marking

19.1 Packaging:

19.1.1 The product shall be separated by size and temper, and prepared for shipment by common carrier, in such a manner to afford protection from the normal hazards of transportation.

19.2 Package Marking:

19.2.1 Each package shall be legibly marked with the metal or alloy designation, temper, size, gross and net weights, total length or piece count, or both, and name of supplier. Upon agreement between the purchaser and supplier, the purchase order number shall be indicated on each package or on the shipping documents.

19.2.2 When specified in the contract or purchaser order, the specification number shall be shown.

20. Certification

20.1 The purchaser shall be furnished certification that samples representing each lot have been tested and inspected as directed in this specification and requirements have been met.

20.2 DELETED

21. Test Report

21.1 A report of test results shall be furnished.

22. Keywords

22.1 copper alloy UNS No. C23000; red brass pipe

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standard:*

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

S1.1.2 *Military Standards:*

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-2073/1 Standard Practice for Military Packaging

S1.1.3 *ASTM Standard:*

B900 Practice for Packaging of Copper and Copper-Base Alloy Mill Products for U.S. Government Agencies

S1.1.4 *SAE Standard:*

AMS-STD-185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements

unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with AMS-STD-185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, and packed, Level A, B, or C, as specified in the contract or purchase order, in accordance with the requirements of Practice B900.

S4.1.2 *Civil Agencies*—The requirements of MIL-STD-2073/1 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg} \cdot \text{m} \cdot \text{s}^{-2}$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$ the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

SPECIFICATION FOR STEAM OR VALVE BRONZE CASTINGS

**SB-61**

(25)

(Identical with ASTM Specification B61-15(2021) except certification and test reports have been made mandatory.)

ASME SB-61 replaces 5.1.7, 5.1.8, 5.1.10, 10, and 10.1 of ASTM B61 with the following:

5.1.7 Certification (Specification B824).

5.1.8 Foundry test report (Specification B824),

5.1.10 DELETED

10. Certification and Test Report

10.1 The certification and test report requirements of Specification B824 shall apply.



Designation: B61 – 15 (Reapproved 2021)

Standard Specification for Steam or Valve Bronze Castings¹

This standard is issued under the fixed designation B61; 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 specification² establishes requirements for a high-grade steam-metal or valve-bronze alloy (Copper Alloy UNS No. C92200³) used for component castings of valves, flanges, and fittings.

1.2 The castings covered are used in products that may be manufactured in advance and supplied from stock by the manufacturer or other dealer.

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

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:⁴

B208 Practice for Preparing Tension Test Specimens for Copper Alloy Sand, Permanent Mold, Centrifugal, and Continuous Castings

B824 Specification for General Requirements for Copper Alloy Castings

B846 Terminology for Copper and Copper Alloys

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

2.2 ASME Code:⁵

ASME Boiler and Pressure Vessel Code

2.3 MSS Standard:⁶

SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

3. General Requirements

3.1 The following sections of Specification B824 form a part of this specification. In the event of a conflict between this specification and Specification B824, the requirements of this specification shall take precedence.

3.1.1 Terminology (Section 3),

3.1.2 Other Requirements (Section 7),

3.1.3 Dimensions, Mass, and Permissible Variations (Section 8),

3.1.4 Workmanship, Finish, and Appearance (Section 9),

3.1.5 Sampling (Section 10),

3.1.6 Number of Tests and Retests (Section 11),

3.1.7 Specimen Preparation (Section 12),

3.1.8 Test Methods (Section 13),

3.1.9 Significance of Numerical Limits (Section 14),

3.1.10 Inspection (Section 15),

3.1.11 Rejection and Rehearing (Section 16),

3.1.12 Certification (Section 17),

3.1.13 Test Report (Section 18),

3.1.14 Product Marking (Section 19), and

3.1.15 Packaging and Package Marking (Section 20).

4. Terminology

4.1 For definitions of terms relating to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following information when placing orders for castings under this specification:

⁵ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

⁶ Available from Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, 127 Park St., NE, Vienna, VA 22180-4602, <http://www.msshq.org>.

¹ This practice is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.05 on Castings and Ingots for Remelting.

Current edition approved Oct. 1, 2021. Published October 2021. Originally approved in 1927. Last previous edition approved in 2015 as B61 – 15. DOI: 10.1520/B0061-15R21.

² For ASME Boiler and Pressure Vessel Code applications, see related Specification SB-61 of that Code.

³ The UNS system for copper and copper alloys (see Practice E527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix “C” and a suffix “00.” The suffix can be used to accommodate composition variations of the base alloy.

⁴ 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.

- 5.1.1 Quantity of castings required,
- 5.1.2 Copper Alloy UNS No. (Table 1),
- 5.1.3 Specification title, number, and year of issue,
- 5.1.4 Pattern or drawing number and condition (as-cast, machined),
- 5.1.5 Pressure test requirements, if specified in the purchase order (Specification B824),
- 5.1.6 Soundness requirements, if specified in the purchase order (Specification B824),
- 5.1.7 Certification, if specified in the purchase order (Specification B824),
- 5.1.8 Foundry test report, if specified in the purchase order (Specification B824),
- 5.1.9 Witness inspection, if specified in the purchase order (Specification B824),
- 5.1.10 ASME Boiler and Pressure Vessel Code application (Section 10), and
- 5.1.11 Product marking, if specified in the purchase order (Specification B824 and Section 11).

5.2 When material is purchased for agencies of the U.S. government, specify the Supplementary Requirements in Specification B824.

6. Chemical Composition

6.1 The alloy shall conform to the chemical requirements specified in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits may be established for unnamed elements by agreement between manufacturer or supplier and

TABLE 1 Chemical Requirements, Copper Alloy UNS No. C92200

Elements	Composition, % max (Except as indicated)
Copper	86.0–90.0
Tin	5.5–6.5
Lead	1.0–2.0
Zinc	3.0–5.0
Nickel including Cobalt	1.0 ^A
Iron	0.25
Antimony	0.25
Sulfur	0.05
Phosphorus ^B	0.05
Aluminum	0.005
Silicon	0.005

^A In determining copper minimum, copper may be calculated as copper plus nickel.

^B For continuous castings, phosphorus shall be 1.5 % max.

purchaser. Copper or zinc may be given as remainder and may be taken as the difference between the sum of all elements analyzed and 100 %. When all named elements in Table 1 are analyzed, their sum shall be as follows:

Copper plus named elements, 99.3 % minimum. (1)

7. Mechanical Property Requirements

7.1 Mechanical properties shall be determined from separately cast test bars and shall meet the requirements shown in Table 2.

8. Casting Repair

8.1 Castings shall not be plugged, welded, burned-in, or impregnated.

9. Sampling

9.1 Copper Alloy UNS No. C92200 test bar castings shall be cast to the form and dimensions shown in Figs. 2, 3, or 4 of Practice B208.

10. Certification

10.1 When material is specified to meet the requirements of ASME Boiler and Pressure Vessel Code, the certification requirements of Specification B824 are mandatory.

11. Product Marking

11.1 Valves, flanges, and fittings shall be marked in accordance with the latest revision of the Standard Marking System for Valves, Fittings, Flanges, and Unions (No. SP-25) of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position as not to injure the usefulness of the casting.

12. Keywords

12.1 Copper Alloy UNS No. C92200 valves; fittings; flanges; Navy M castings; steam bronze castings; valve castings; valve bronze

TABLE 2 Tensile Properties

Tensile strength, min, ksi ^A (MPa ^B)	34 (235)
Yield strength, ^C min, ksi ^A (MPa ^B)	16 (110)
Elongation in 2 in. (50.8 mm), min %	24

^A ksi = 1000 psi.

^B See Appendix.

^C Yield strength shall be determined as the stress producing an elongation under load of 0.5 % that is, 0.01 in. (0.25 mm) in a gage length of 2 in. (51 mm).

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg}\cdot\text{m}/\text{s}^2$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$ the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B61-08(2013)) that may impact the use of this standard. (Approved May 1, 2015.)

(1) Table 1 was revised.

(2) Sections 5.1.5 and 6.3 were deleted.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, at the address shown below.

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SPECIFICATION FOR COMPOSITION BRONZE OR OUNCE METAL CASTINGS

**SB-62****(25)**

(Identical with ASTM Specification B62-17 except that certification and foundry test reports have been made mandatory.)

ASME SB-62 replaces 5.1.7, 5.1.8, 5.1.10, 10, and 10.1 of ASTM B62 with the following:

5.1.7 Certification (Specification B824);

5.1.8 Foundry test report (Specification B824);

5.1.10 DELETED

10. Certification and Foundry Test Report

10.1 The certification and foundry test report requirements of Specification B824 are mandatory.



Designation: B62 – 17

Standard Specification for Composition Bronze or Ounce Metal Castings¹

This standard is issued under the fixed designation B62; 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 specification² establishes requirements for an alloy having a composition of copper, tin, lead, and zinc, used for component castings of valves, flanges, and fittings. The common trade name of this alloy is 85-5-5-5; the correct identification is Copper Alloy UNS No. C83600.³

1.2 The castings covered are used in products that may be manufactured in advance and supplied from stock from the manufacturer or other dealer.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units, which are provided for information only and are not considered standard.

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:⁴

B208 Practice for Preparing Tension Test Specimens for Copper Alloy Sand, Permanent Mold, Centrifugal, and Continuous Castings

B824 Specification for General Requirements for Copper Alloy Castings

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

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

2.2 MSS Standard:⁵

SP-25 Standard Marking System for Valves, Fittings, Flanges and Unions

3. General Requirements

3.1 The following sections of Specification B824 constitute a part of this specification. In the event of a conflict between this specification and Specification B824, the requirements of this specification shall take precedence.

3.1.1 Other Requirements (Section 7),

3.1.2 Dimensions, Mass, and Permissible Variations (Section 8),

3.1.3 Workmanship, Finish, and Appearance (Section 9),

3.1.4 Sampling (Section 10),

3.1.5 Number of Tests and Retests (Section 11),

3.1.6 Specimen Preparation (Section 12),

3.1.7 Test Methods (Section 13),

3.1.8 Significance of Numerical Limits (Section 14),

3.1.9 Inspection (Section 15),

3.1.10 Rejection and Rehearing (Section 16),

3.1.11 Certification (Section 17),

3.1.12 Test Report (Section 18),

3.1.13 Product Marking (Section 19), and

3.1.14 Packaging and Package Marking (Section 20).

4. Terminology

4.1 For definitions of terms relating to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following information when placing orders for castings under this specification:

5.1.1 Quantity of castings required;

5.1.2 Copper Alloy UNS No. (Table 1);

¹ This specification is under the jurisdiction of ASTM Committee B05 on Copper and Copper Alloys and is the direct responsibility of Subcommittee B05.05 on Castings and Ingots for Remelting.

Current edition approved April 1, 2017. Published May 2017. Originally approved in 1926. Last previous edition approved in 2015 as B62-15. DOI: 10.1520/B0062-17.

² For ASME Boiler and Pressure Vessel Code applications see related Specification SB-61 of that Code.

³ The UNS system for copper and copper alloys (see Practice E527) is a simple expansion of the former standard designation system accomplished by the addition of a prefix “C” and a suffix “00”. The suffix can be used to accommodate composition variations of the base alloy.

⁴ 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.

⁵ Available from Manufacturers Standardization Society (MSS) of the Valve and Fittings Industry, 127 Park St., NE, Vienna, VA 22180-4602, <http://www.msshq.org>.

TABLE 1 Chemical Requirements Copper Alloy UNS No. C83600

Elements	Composition, % max (Except as Indicated)
Copper	84.0–86.0
Tin	4.0–6.0
Lead	4.0–6.0
Zinc	4.0–6.0
Nickel including Cobalt	1.0 ^A
Iron	0.30
Antimony	0.25
Sulfur	0.08
Phosphorus ^B	0.05
Aluminum	0.005
Silicon	0.005

^A In determining copper minimum, copper may be calculated as copper plus nickel.

^B For continuous castings, Phosphorus shall be 1.5 % max.

- 5.1.3 Specification title, number, and year of issue;
 5.1.4 Pattern or drawing number and condition (as-cast, machined);
 5.1.5 Pressure test requirements, if specified in the purchase order (Specification B824);
 5.1.6 Soundness requirements, if specified in the purchase order (Specification B824);
 5.1.7 Certification, if specified in the purchase order (Specification B824);
 5.1.8 Foundry test report, if specified in the purchase order (Specification B824);
 5.1.9 Witness inspection, if specified in the purchase order (Specification B824);
 5.1.10 ASME Boiler and Pressure Vessel application (Section 10); and
 5.1.11 Product marking, if specified in the purchase order (Specification B824 and Section 11).

5.2 When material is purchased for agencies of the U.S. Government, specify the Supplementary Requirements in Specification B824.

6. Materials and Manufacture

6.1 Material(s):

6.1.1 The material of manufacture shall be a casting of Copper Alloy UNS No. C83600 of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.1.2 When specified in the contract or purchase order that heat identification or traceability is required, the purchaser shall specify the details desired.

6.2 Manufacture:

6.2.1 The product shall be manufactured by such casting methods as to produce a uniform finished product.

6.2.2 Castings shall not be repaired, plugged, welded, or burned-in.

TABLE 2 Tensile Properties

Tensile strength, min, ksi ^A (MPa ^B)	30 (205)
Yield strength, ^C min, ksi ^A (MPa ^B)	14 (95)
Elongation in 2 in. or 50 mm, min, %	20

^A ksi = 1000 psi.

^B See Appendix X1.

^C Yield strength shall be determined as the stress producing an elongation under load of 0.5 %; that is, 0.01 in. (0.25 mm) in a gage length of 2 in. (51 mm).

7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements specified in Table 1 for the Copper Alloy UNS No. C83600.

7.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

7.3 Copper or zinc may be given as remainder and may be taken as the difference between the sum of all elements analyzed and 100 %. When all named elements in Table 1 are analyzed, their sum shall be as follows:

Copper Plus Named Elements, 99.3 % Minimum (1)

8. Mechanical Property Requirements

8.1 Mechanical properties shall be determined from separately cast test bars and shall meet the requirements shown in Table 2, when tested in accordance with Test Methods E8/E8M.

9. Specimen Preparation

9.1 Copper Alloy UNS No. C83600 test bar castings for tensile testing shall be cast to the form and dimensions shown in Fig. 2, Fig. 3, or Fig. 4 of Practice B208.

10. Certification

10.1 When material is specified to meet the requirements of *ASME Boiler and Pressure Vessel Code*, the certification requirements of Specification B824 are mandatory.

11. Packaging and Package Marking

11.1 Valves, flanges, and fittings shall be marked in accordance with the latest revision of the Standard Marking System for Valves, Fittings, Flanges, and Unions (ANSI/MSS SP-25) of the Manufacturers Standardization Society of the Valve and Fittings Industry, and in such position as not to injure the usefulness of the casting.

12. Keywords

12.1 copper-alloy castings; Copper Alloy UNS No. C83600; fittings; flanges; ounce metal castings; red brass castings; valves

APPENDIX

(Nonmandatory Information)

X1. METRIC EQUIVALENTS

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg} \cdot \text{m}/\text{s}^2$). The derived SI unit for pressure or

stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$ the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

SUMMARY OF CHANGES

Committee B05 has identified the location of selected changes to this standard since the last issue (B62-15) that may impact the use of this standard. (Approved April 1, 2017.)

- | | |
|--|--|
| <p>(1) A comprehensive review was made, incorporating current proper form and style practices.</p> <p>(2) Added Section 6 and renumbered sections that follow.</p> | <p>(3) Relocated requirements of Section 8 into new Section 6.</p> <p>(4) Renamed and revised Section 9 to align with referenced requirements in Specification B824.</p> |
|--|--|

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SPECIFICATION FOR SEAMLESS COPPER TUBE



SB-75/SB-75M

(Identical with ASTM Specification B75/B75M-19 except for deletion of 11.1.3, footnote G in Table 2, footnote F in Table 3; certification and test report have been made mandatory.)

Specification for Seamless Copper Tube

1. Scope

1.1 This specification establishes the requirements for seamless round, rectangular, and square copper tube suitable for general engineering applications.

1.1.1 Tubes made from any of the following Copper UNS No. designations shall be supplied unless otherwise specified in the contract or purchase order:

Copper UNS No.	Type of Copper
C10100	Oxygen-free electronic
C10200	Oxygen-free without residual deoxidants
C10300	Oxygen-free, extra low phosphorus
C10800	Oxygen-free, low phosphorus
C12000	Phosphorus deoxidized, low residual phosphorus
C12200	Phosphorus deoxidized, high residual phosphorus

1.2 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, SI units are shown in brackets. 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.

1.3 The following safety hazard caveat pertains only to the test methods described in this specification: *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.*

1.4 *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:

- B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes
- B193 Test Method for Resistivity of Electrical Conductor Materials
- B251/B251M Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
- B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper
- B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
- B846 Terminology for Copper and Copper Alloys
- E8/E8M Test Methods for Tension Testing of Metallic Materials
- E18 Test Methods for Rockwell Hardness of Metallic Materials
- E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
- E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)
- E112 Test Methods for Determining Average Grain Size
- E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
- E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition

2.2 ASME Standard:

- ASME Boiler and Pressure Vessel Code

3. General Requirements

- 3.1 The following sections of Specification B251/B251M are a part of this specification.

- 3.1.1 Terminology, General;
- 3.1.2 Material and Manufacture;
- 3.1.3 Workmanship, Finish, and Appearance;
- 3.1.4 Significance of Numerical Limits;
- 3.1.5 Inspection;
- 3.1.6 Rejection and Rehearing;
- 3.1.7 Certification;
- 3.1.8 Mill Test Reports;
- 3.1.9 Packaging and Package Marking; and
- 3.1.10 Supplementary Requirements.

3.2 In addition, when a section with an identical title to those referenced in section 3.1 appears in this specification, and is in conflict with the section appearing in Specification B251/B251M, the section in this specification shall prevail.

4. Terminology

4.1 *Definitions*—For definitions of terms related to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following specific choices when placing orders for product under this specification, as applicable.

- 5.1.1 ASME designation
- 5.1.2 Copper UNS No. (for example, C10100);
- 5.1.3 Temper (Section 8);
- 5.1.4 Dimensions; diameter or distance between parallel surfaces, and wall thickness (Section 17);
- 5.1.5 How furnished; coils or straight lengths;
- 5.1.6 Number of pieces or footage; each size and type;
- 5.1.7 Total weight.

5.2 The following options are available but may not be included unless specified at the time of placing the order, when required:

- 5.2.1 Electrical mass resistivity test,
- 5.2.2 Hydrogen embrittlement test,
- 5.2.3 Hydrostatic test for pressures less than or equal to 1000 psi (21.2.8),
- 5.2.4 Hydrostatic test for pressures over 1000 psi (21.2.8.1),
- 5.2.5 Pneumatic test,
- 5.2.6 DELETED
- 5.2.7 DELETED
- 5.2.8 Expansion test,
- 5.2.9 DELETED
- 5.2.10 When product is purchased for agencies of the U.S. Government.

6. Material and Manufacture

6.1 *Material*—The material of manufacture shall be billets, bars, or tube of Copper UNS No. C10100, C10200, C10300, C10800, C12000, or C12200, and shall be of such soundness as to be suitable for processing into the tubular products described.

6.2 *Manufacture:*

6.2.1 The tube shall be manufactured by such hot- and cold-working processes as to produce a uniform wrought structure in the finished product. It shall be cold drawn to the finished size and wall thickness.

6.2.2 When cold-drawn temper is required, the final drawing operation shall be such as to meet the specified temper. When annealed temper is required, the tube shall be annealed subsequent to the final cold draw.

7. Chemical Composition

7.1 The material shall conform to the requirements in Table 1 for the specified Copper UNS No. designation.

7.1.1 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer or supplier and the purchaser, limits may be established and analysis required for unnamed elements.

8. Temper

8.1 The requirements and size availability of tube in the cold-drawn tempers H55, H58, and H80, as defined in Classification B601, are specified in Table 2 or Table 3.

8.1.1 Rectangular, including square, tube shall normally be supplied only in H58 temper. When requested by the manufacturer or supplier, and upon agreement with the purchaser, tube may be supplied in H55 temper.

8.1.1.1 For any combination of diameter and wall thickness not listed under H80 temper, the requirements specified for H58 temper shall apply.

8.2 The requirements and size availability of tube in the annealed tempers O50, O60, and O62 as defined in Classification B601, are specified in Table 2 or Table 3.

NOTE 1—The purchaser shall confer with the manufacturer or supplier for the availability of product in a specific temper.

NOTE 2—Refer to Appendix X1 for recommended applications based on temper.

9. Grain Size Requirements

9.1 Tube in the annealed temper shall conform to the grain size specified in Table 2 or Table 3.

TABLE 1 Chemical Requirements

Element	Composition, %					
	Copper UNS No.					
	C10100 ^A	C10200 ^B	C10300	C10800	C12000	C12200
Copper, min	99.99	99.95	...	...	99.90	99.9
Copper + phosphorus, min	...	...	99.95	99.95	...	...
Phosphorus	...	...	0.001–0.005	0.005–0.012	0.004–0.012	0.015–0.040

^A Refer to Table 1, Chemical Requirements, Grade 1, of Specification B170 for impurity limits for Copper UNS No. C10100.

^B Refer to Table 1, Chemical Requirements, Grade 2, of Specification B170 for impurity limits for Copper UNS No. C10200.

TABLE 2 Mechanical Property Requirements of Drawn-Temper and Annealed-Temper Tube (inch-pound values)

Temper Designation		Outside Diameter, or Major Distance Between Outside Parallel Surfaces, in.	Wall Thickness, in.	Rockwell Hardness ^A		Average Grain Size, mm	Tensile Strength, ksi ^B	Yield Strength, ^C min, ksi ^D
Code	Name			Scale	Hardness			
H55	light-drawn ^D	all	all	30T	30 to 60		36–47	30
H58	drawn (general purpose)	all	all	30T	30 min		36 min	30
H80	hard-drawn ^D	up to 4	0.020 to 0.250, incl	30T	55 min		45 min	40
O62	heavy anneal	all	0.015 to 0.035 0.035 and over	15T ^E F ^E	60 max 55 max	0.050 max 0.050 max	30 min 30 min	6.5 ^F ^E 6.5 ^F ^E
O60	soft anneal	all	0.015 to 0.035 0.035 and over	15T F	60 max 50 max	0.040 min 0.040 min	30 min 30 min	9 9
O50	light anneal	all	0.015 to 0.035 0.035 and over	15T F	65 max 55 max	0.040 max 0.040 max	30 min 30 min	9 9

^A Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and supplier.

^B ksi = 1000 psi.

^C Yield strength to be determined at 0.5 % extension under load.

^D Light-drawn and hard-drawn tempers are normally available in round tubes only.

^E Rockwell hardness values shall apply only to tubes having a wall thickness of 0.015 in. or over, to round tubes having an inside diameter of 5/16 in. or over, and to rectangular, including square, tubes having an inside major distance between parallel surfaces of 3/16 in. or over. For all other tube, no Rockwell values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and supplier.

^F Light-straightening operation is acceptable.

^G DELETED

TABLE 3 Mechanical Property Requirements of Drawn-Temper and Annealed-Temper Tube (SI Values)

Temper Designation		Outside Diameter, or Major Distance Between Outside Parallel Surfaces, mm	Wall Thickness, mm	Rockwell Hardness ^A		Average Grain Size, mm	Tensile Strength, ^B MPa	Yield Strength, ^B min, MPa
Standard	Former			Scale	Hardness			
H55	light-drawn ^C	all	all	30T	30 to 60		250–325	205
H58	drawn (general purpose)	all	all	30T	30 min		250 min	205
H80	hard-drawn ^C	up to 102	0.508 to 6.35, incl	30T	55 min		310 min	275
O62	heavy anneal	all	0.381 to 0.889 0.889 and over	15T ^D F ^D	60 max 55 max	0.050 max 0.050 max	205 min 205 min	45 ^E , ^F 45 ^E , ^F
O60	soft anneal	all	0.381 to 0.889 0.889 and over	15T F	60 max 50 max	0.040 min 0.040 min	205 min 205 min	62 62
O50	light anneal	all	0.381 to 0.889 0.889 and over	15T F	65 max 55 max	0.040 max 0.040 max	205 min 205 min	62 62

^A Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and supplier.

^B Yield strength to be determined at 0.5 % extension under load.

^C Light-drawn and hard-drawn tempers are normally available in round tubes only.

^D Rockwell hardness values shall apply only to tubes having a wall thickness of 0.040 mm or over, to round tubes having an inside diameter of 8.0 or over, and to rectangular, including square, tubes having an inside major distance between parallel surfaces of 5.0 mm or over. For all other tube, no Rockwell values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the purchaser and supplier.

^E Light-straightening operation shall be permitted.

^F DELETED

9.2 Acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions, and each specimen shall be within the limits prescribed in Table 2 or Table 3 when determined in accordance with Test Methods E112.

10. Physical Property Requirements

10.1 *Electrical Resistivity*—When specified in the contract or purchase order, tube ordered for electrical conductor application produced from Copper UNS No. C10100, C10200,

C10300, or C12000 shall have an electrical mass resistivity, $\Omega \cdot \text{g}/\text{m}^2$, not to exceed the following limit for the specified copper and temper when tested in accordance with Test Method B193:

Temper	Copper UNS No.			
	C10100	C10200	C10300	C12000
O60, O50	0.151 76	0.153 28	0.156 14	0.170 31
H55, H58, H80	0.156 14	0.157 37	0.159 40	0.174 18

NOTE 3—Refer to Appendix X2 for the International Annealed Copper Standard (IACS) electrical conductivity equivalents.

11. Mechanical Property Requirements

11.1 Tensile and Yield Strength Requirements:

11.1.1 The tube furnished under this specification shall conform to the requirements of Table 2 or Table 3 for the specified temper and wall thickness when tested in accordance with Test Methods E8/E8M.

11.1.2 For any combination of diameter and wall thickness not listed under H80, the requirements for H58 shall apply.

11.1.3 DELETED

11.2 Rockwell Hardness Requirements:

11.2.1 The tube shall conform to the Rockwell hardness requirements of Table 2 or Table 3 for the specified temper and wall thickness when tested in accordance with Test Methods E18.

11.2.1.1 The Rockwell Hardness values for tube in the H55, H58, and H80 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.020 in. [0.508 mm] and over,

(b) Round tubes having an inside diameter of $\frac{5}{16}$ in. [8.0 mm] and over,

(c) Rectangular and square tubes having major distances between parallel surfaces of $\frac{3}{16}$ in. [5 mm] and over.

11.2.1.2 The Rockwell Hardness values for tube in the O60 and O50 temper shall apply only to the following:

(a) Tubes having a wall thickness of 0.015 in. [0.38 mm] and over;

(b) Round tubes having an inside diameter of $\frac{5}{16}$ in. [8 mm] and over;

(c) Rectangular and square tubes having inside major distances between parallel surfaces of $\frac{3}{16}$ in. [5 mm] and over.

11.3 Straightening—It shall not be prohibited to use light straightening for tube in the O60 and O50 temper.

11.4 When a discrepancy between tensile and Rockwell hardness exists, tensile always takes precedence for acceptance or rejection criteria.

12. Performance Requirements

12.1 Expansion Test for Round Tube:

12.1.1 When specified in the contract or purchase order, annealed tubes shall be capable of withstanding an expansion of the outside diameter of 40 % for tube $\frac{3}{4}$ in. [19.0 mm] and under and 30 % for tube over $\frac{3}{4}$ in. [19.0 mm] when tested in accordance with Test Method B153.

12.1.2 The expanded tube shall show no cracking or rupture visible to the unaided eye.

13. Microscopical Examination

13.1 Tubes furnished in Copper UNS No. C10100, C10200, C10300, and C12000 shall be essentially free of cuprous oxide as determined by Procedure A of Test Methods B577.

14. Hydrogen Embrittlement

14.1 When specified in the contract or purchase order, tubes produced in all designated copper material shall be capable of conforming to the requirements of Procedure B of Test Methods B577.

15. Nondestructive Test

15.1 The tubes shall be tested in drawn tempers or as drawn before the final-annealed temper unless otherwise agreed upon between the manufacturer and the purchaser.

15.2 Electromagnetic (Eddy-Current) Test:

15.2.1 Each tube up to and including $3\frac{1}{8}$ in. [79 mm] in outside diameter shall be subjected to test.

15.2.2 When tested in accordance with Practice E243, tubes which do not actuate the signaling device of the testing unit shall be considered as conforming to the requirements of the test.

15.3 Hydrostatic Pressure Test—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal hydrostatic pressure sufficient to produce a fiber stress of 6000 psi [41 MPa] without leakage. The tube need not be subjected to a pressure gauge reading over 1000 psi [6.9 MPa] unless specifically stipulated in the contract or purchase order.

15.4 Pneumatic Pressure Test—When specified in the contract or purchase order, each tube shall be capable of withstanding an internal air pressure of 60 psi [400 kPa], minimum, for 5 s without leakage.

16. Purchases for U.S. Government Agencies

16.1 When the contract or purchase order stipulates that the purchase is for an agency of the U.S. Government, the tubes furnished shall conform to the conditions specified in the Supplementary Requirements of Specification B251/B251M.

17. Dimensions, Mass, and Permissible Variations

17.1 The dimensions and tolerances for product described by this specification shall be as specified in the following tables and related sections of the current edition of Specification B251/B251M:

17.1.1 Wall Thickness Tolerances—Refer to Tables 1 and 2.

17.1.2 Tolerances for Diameter or Distance Between Parallel Surfaces—Refer to Tables 3 and 4.

17.1.3 Length Tolerances—Refer to Tables 5 and 6.

17.1.4 Straightness Tolerance—Refer to Table 7.

17.1.5 Corner Radius for Rectangular, including Square, Tube—Refer to Table 8.

17.1.6 Roundness, Squareness of Cut and Twist Tolerances for Rectangular and Square Tubes—Refer to titled sections.

17.2 *Length Tolerances for Tube in Coils*—Refer to Table 4, Table 5, Table 6, Table 7, Table 8 and Table 9 of this specification.

18. Sampling

18.1 The lot size, portion size, and selection of sample portions shall be as follows:

18.1.1 *Lot Size*—An inspection lot shall be 10 000 lb [5000 kg] or fraction thereof,

18.1.2 *Portion Size*—Sample pieces shall be selected to be represented of the lot as follows:

Number of Pieces in Lot	Number of Portions to Be Taken ^A
1 to 50	1
51 to 200	2
201 to 1500	3

^A Each test portion shall be taken from a separate tube.

18.2 Chemical Composition:

18.2.1 The composite sample shall be taken in approximate equal weights from each portion piece selected in 18.1.2 and in accordance with Practice E255. The minimum weight of the composite shall be 150 g.

18.2.2 The manufacturer shall have the option of sampling at the time the castings are poured or taken from the semifinished product. The number of samples taken during the course of manufacture shall be as follows:

18.2.2.1 When sampled at the time castings are poured, at least two samples shall be taken, one after the start and one near the end of the pour, for each group of castings poured simultaneously from the same source of molten metal.

18.2.2.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb [5000 kg] or fraction thereof, except that not more than one sample per piece shall be required.

18.2.2.3 When composition is determined during the course of manufacture, sampling and analyses of the finished product is not required.

18.3 *Other Tests*—Specimens for all other tests shall be taken from two of the sample portions taken in 18.1.2. In the event only one sample portion is taken, all specimens shall be taken from the portion selected.

19. Number of Tests and Retests

19.1 Tests:

19.1.1 *Chemical Analysis*—Chemical composition shall be determined in accordance with the element mean of the results from at least two replicate analyses of the sample(s).

19.1.2 *Grain Size, Electrical Resistivity, Tensile and Yield Strength, and Rockwell Hardness*—Results shall be reported as

TABLE 4 Coil Length Tolerances (Specific Lengths) Inch-Pound Values

Outside Diameter or Major Distance Between Parallel Surfaces, in.	Tolerances, in., All Plus, for Nominal Lengths, ft	
	Up to 50, incl	Over 50 to 100, incl
Up to 2, incl	12	24

TABLE 5 Coil Length Tolerances (Specific Lengths) SI Values

Outside Diameter or Major Distance Between Parallel Surfaces, mm	Tolerances, mm, All Plus, for Nominal Lengths, m	
	Up to 15, incl	Over 15 to 30, incl
Up to 50.8, incl	300	610

the average obtained from two test specimens, each taken from a separate test piece, where possible.

19.1.3 *Other Tests*—At least two specimens shall be prepared for each of the other tests and each shall conform to test requirements.

19.2 Retests:

19.2.1 When requested by the manufacturer or supplier, a retest shall be permitted when results of tests obtained by the purchaser fail to conform to the requirements of the product specification.

19.2.2 The retest shall be as directed in the product specification for the initial test, except for the number of test specimens shall be twice that normally required for the specified test.

19.2.3 All test specimens shall conform to the product specification requirement(s) in retest. Failure to conform shall be cause for rejection.

20. Specimen Preparation

20.1 *Chemical Analysis*—Preparation of the analytical specimens shall be the responsibility of the reporting laboratory.

20.2 *Tensile and Yield Strength Test*—The test specimens shall be of the full section of the tube and shall conform with the requirements of the Test Specimen section of Test Methods E8/E8M, unless the limitation of the testing machine precludes the use of such specimens in which case test specimens conforming to Type No. 1 of Fig. 13 in Test Methods E8/E8M shall be used.

20.3 Rockwell Hardness:

20.3.1 The test specimen shall be of a size and shape to permit testing by the available test equipment.

20.3.2 The surface of the test specimen shall be sufficiently flat and smooth so as to permit the accurate determination of hardness.

20.3.3 The test specimen shall be free from scale and foreign matter and care shall be taken to avoid any change in condition (for example, heating or cold working).

20.4 *Grain Size*—Test specimens shall be prepared in accordance with the appropriate procedure in Test Methods E112

20.5 Electrical Resistivity:

20.5.1 The test specimen shall be full size and shall be the full cross section of the material it represents when possible.

20.5.2 When the test specimen is taken from material in bulk, care shall be taken that the properties are not appreciably altered in the preparation.

NOTE 4—Plastic deformation tends to work harden a material and raise its resistivity, while heating tends to anneal the material with a subsequent reduction in resistivity.

**TABLE 6 Coil Length Tolerances (Mill Lengths) Inch-Pound Values
(Applicable Only to Full-Length Pieces)**

Tube Outside Diameter or Major Distance Between Parallel Surfaces, in. [mm]	Tolerances, %, for Nominal Lengths, ft [mm]	
	Up to 100 [30 480], incl	Over 100 to 2000 [30 480 to 609 600], incl
Up to 1 [25], incl	5 ^A or 2 ft, whichever is greater	10 ^A
Over 1 to 2 [25 to 51], incl	5 ^A or 2 ft, whichever is greater	no tolerances established

^A Expressed to the nearest 1 ft.**TABLE 7 Coil Length Tolerances (Mill Lengths) SI Values
(Applicable Only to Full-Length Pieces)**

Tube Outside Diameter or Major Distance Between Parallel Surfaces, mm	Tolerances, %, for Nominal Lengths in mm	
	Up to 30 000, incl	Over 30 000 to 600 000, incl
Up to 25, incl	5 ^A or 600, whichever is greater	10 ^A
25 to 50, incl	5 ^A or 600, whichever is greater	no tolerances established

^A Expressed to the nearest 300 mm.**TABLE 8 Coil Schedule of Mill Lengths with Ends, Inch-Pound Values**

Tube Outside Diameter or Major Distance Between Parallel Surfaces, in.	Nominal Length, ft	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Weights of Ends, % of Lot Weight
Up to 1, incl	up to 100, incl	70 ^A	10
Over 1 to 2, incl	up to 100, incl	60 ^A	20
Up to 1, incl	over 100 to 2000, incl	50	50 ^B

^A Expressed to the nearest 1 ft.^B Short pieces of lengths between 50 ft and one-quarter of full length shall not exceed 10 % of lot weight. Short pieces of lengths between one-quarter of a full length and full length shall not exceed 40 % of lot weight.**TABLE 9 Coil Schedule of Mill Lengths with Ends, SI Values**

Tube Outside Diameter or Major Distance Between Parallel Surfaces, mm	Nominal Length, mm	Shortest Permissible Length, % of Nominal Length	Maximum Permissible Mass of Ends, % of Lot Weight
Up to 25, incl	up to 30 000, incl	70 ^A	10
Over 25 to 50, incl	up to 30 000, incl	60 ^A	20
Up to 25, incl	over 30 000 to 600 000, incl	50	50 ^B

^A Expressed to the nearest 300.^B Short pieces are permitted to be included as follows: up to 10 % of lot weight between 15 200 and one quarter of full length and up to 40 % between one quarter and full length.

20.6 Expansion (Pin) Test—Test specimens shall conform to the requirements of the Specimen Preparation section of Test Method B153.

20.7 Microscopical Examination—The test specimen shall be prepared in accordance with Procedure A of Test Methods B577 and the specimen surface shall approximate a radial longitudinal section of round tube or a longitudinal section of rectangular and square tube perpendicular to, and bisecting, the major dimensional surface.

20.8 Hydrogen Embrittlement—The test specimen shall conform to the appropriate requirements of Procedure B of Test Methods B577.

21. Test Methods

21.1 Chemical Analyses—In case of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published methods, some of which may no longer be viable, which, along with others not listed, may be used subject to agreement.

Element	Test Method
Copper	E53
Phosphorus	E62

21.1.1 The test methods for the determination of composition for Coppers C10100 and C10200 shall be as described in Annex of Specification B170.

21.1.2 Test method(s) for the determination of element(s) required by contractual or purchase order agreement shall be as agreed upon between the manufacturer and the purchaser.

21.2 The tubes furnished shall conform to the physical and mechanical properties and other requirements of this specification when tested or examined in accordance with the following appropriate test method or practice:

Test	Test Method
Tensile strength	E8/E8M
Yield strength	E8/E8M
Rockwell Hardness	E18
Grain size	E112
Electrical resistivity	B193
Expansion (pin test)	B153

Electromagnetic examination (eddy current)	E243
Microscopical examination, Procedure A	B577
Hydrogen embrittlement, Procedure B	B577
Hydrostatic pressure	B75/B75M, 21.2.8
Pneumatic pressure	B75/B75M, 21.2.9

21.2.1 Whenever test results are obtained from both full-size and machined specimens and they differ, the test results from the full-size specimens shall prevail.

21.2.2 Rockwell hardness shall be determined on the inside surface of the tube and a minimum of three readings shall be taken on each specimen, each at a different location.

21.2.2.1 When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified by agreement between the manufacturer and the purchaser.

21.2.3 Grain size shall be determined, in case of dispute, by the intercept method.

21.2.4 *Electrical Resistivity*—The limit of measurement uncertainty shall be $\pm 0.30\%$ as a process control method and $\pm 0.15\%$ as an umpire method.

21.2.5 *Microscopical Examination*—Cuprous oxide content shall be determined in accordance with Procedure A, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B577 shall be followed.

21.2.6 *Hydrogen Embrittlement*—Procedure B shall be followed, or, in case of dispute, Procedure C, Closed Bend Test, of Test Methods B577 shall be followed.

21.2.7 *Electromagnetic (Eddy-Current) Test*—Each tube up to and including $3\frac{1}{8}$ in. [79 mm] in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedures in Practice E243.

21.2.7.1 Either notch depth or drilled hole standards shall be used.

(a) Notch depth standards, rounded to the nearest 0.001 in. [0.025 mm] shall be 22 % maximum of the wall thickness. The notch depth tolerance shall be ± 0.0005 in. [± 0.013 mm].

(b) Drilled holes shall be drilled radially through the wall using a suitable drill jig that has a bushing to guide the drill, care being taken to avoid distortion of the tube while drilling. The diameter of the drilled hole shall be in accordance with the following and shall not vary by more than $+0.001$, -0.000 in. [$+0.025$ mm, -0.000 mm] of the hole diameter specified.

Tube Outside Diameter, in. [mm]	Diameter of Drilled Holes, in. [mm]	Drill Number
$\frac{1}{4}$ to $\frac{3}{4}$, incl [6.0 to 19, incl]	0.025 [0.635]	72
Over $\frac{3}{4}$ to 1, incl [Over 19.0 to 25, incl]	0.031 [0.787]	68
Over 1 to $1\frac{1}{4}$, incl [Over 25 to 32, incl]	0.036 [0.915]	64
Over $1\frac{1}{4}$ to $1\frac{1}{2}$, incl [Over 32 to 38, incl]	0.042 [1.07]	58
Over $1\frac{1}{2}$ to $1\frac{3}{4}$, incl [Over 38 to 45, incl]	0.046 [1.17]	56
Over $1\frac{3}{4}$ to 2, incl [Over 45 to 50, incl]	0.052 [1.32]	55

21.2.7.2 Alternatively, at the option of the manufacturer, using speed-insensitive eddy-current units that are equipped to select a fraction of the maximum imbalance signal, the following percent maximum imbalance signals shall be used:

Standard Tube Size, in. [mm]	Maximum Percent Imbalance Signal Magnitude
Up to $\frac{3}{8}$, incl [Up to 9, incl]	0.2
Over $\frac{3}{8}$ to 2, incl [Over 13 to 50, incl]	0.3
Over 2 to 3, incl [Over 50 to 76, incl]	0.4

21.2.7.3 Tubes that do not activate the signaling device of the eddy-current tester shall be considered as conforming to the requirements of this test. Tubes with discontinuities indicated by the testing unit are not prohibited, at the option of the manufacturer, from being reexamined or retested to determine whether the discontinuity is cause for rejection. Signals that are found to have been caused by minor mechanical damage, soil or moisture, shall not be cause for rejection of the tubes provided the tube dimensions are still within prescribed limits and the tube is suitable for its intended application.

21.2.8 *Hydrostatic Test*—The internal hydrostatic pressure necessary to produce the required fiber stress shall be determined by the following equation for thin hollow cylinders under tension.

$$P = 2St/(D - 0.8t) \quad (1)$$

where:

P = hydrostatic pressure, psi [or MPa];
 t = thickness of tube wall, in. [or mm];
 D = outside diameter of tube, in. [or mm]; and
 S = allowable fiber stress of the material, psi [MPa].

21.2.8.1 The tube need not be tested at a pressure gauge reading over 1000 psi [6.9 MPa] unless so specified.

21.2.9 *Pneumatic Test*—The test method shall permit easy visual detection of leakage, such as having the material under water or by the pressure differential method.

22. Rejection and Rehearing

22.1 Rejection:

22.1.1 Product that fails to conform to the specification requirements when tested by the purchaser or purchaser's agent shall be subject to rejection.

22.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

22.1.3 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer or supplier shall have the option to make claim for a rehearing.

22.2 Rehearing:

22.2.1 As a result of product rejection, the manufacturer or supplier shall have the option to make claim for a retest to be conducted by the manufacturer or supplier and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification, or alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

23. Certification

23.1 The purchaser shall be furnished certification that samples representing each lot have been tested and inspected as directed in this specification and requirements have been met.

23.2 DELETED

24. Test Report

24.1 A report of test results shall be furnished.

25. Keywords

25.1 seamless copper tube; seamless tube; tube; C10100; C10200; C10300; C10800; C12000; C12200

APPENDIXES

(Nonmandatory Information)

X1. RECOMMENDED APPLICATIONS

X1.1 Tube in the H55 temper is recommended when a tube of some stiffness is required yet capable of being bent when necessary.

X1.2 Tube in the H58 temper is recommended for general applications in which there is no specific need for high strength or bending qualities.

X1.3 Tube in the H80 temper is recommended for applications in which there is a need for a tube as strong as technically feasible for the size indicated.

X2. INTERNATIONAL ANNEALED COPPER STANDARD (ELECTRICAL CONDUCTIVITY EQUIVALENTS)

Electrical Resistivity, $\Omega \cdot \text{g}/\text{m}^2$

0.151 76
0.153 28
0.156 14
0.157 37
0.159 40
0.170 31
0.174 18

Conductivity, %

101.00
100.00
98.16
97.40
96.16
90
88

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SPECIFICATION FOR COPPER-SILICON ALLOY PLATE, SHEET, STRIP, AND ROLLED BAR FOR GENERAL PURPOSES AND PRESSURE VESSELS



SB-96/SB-96M

(Identical with ASTM Specification B96/B96M-20 except yield strength is required.)

Specification for Copper-Silicon Alloy Plate, Sheet, Strip, and Rolled Bar for General Purposes and Pressure Vessels

1. Scope

1.1 This specification establishes the requirements for copper-silicon alloy plate, sheet, strip, and rolled bar for drawing, forming, stamping, bending, and general engineering applications, and for pressure vessel applications. The alloys involved are copper alloys UNS Nos. C65100, C65400, and C65500.

1.2 When product is ordered for *ASME Boiler and Pressure Vessel Code* applications, consult the Code for applicable alloys.

1.3 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, SI units are shown in brackets. 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 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:

B248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar

B248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)

E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)

E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)

E478 Test Methods for Chemical Analysis of Copper Alloys

2.2 ASME Code:

ASME Boiler and Pressure Vessel Code

3. General Requirements

3.1 The following sections of Specification B248 or Specification B248M constitute a part of this specification:

3.1.1 Terminology

3.1.2 Materials and Manufacture

3.1.3 Dimensions, Mass, and Permissible Variations

3.1.4 Workmanship, Finish, and Appearance

3.1.5 Sampling

3.1.6 Number of Tests and Retests

3.1.7 Test Specimens

3.1.8 Test Methods

3.1.9 Significance of Numerical Limits

3.1.10 Inspection

3.1.11 Rejection and Rehearing

3.1.12 Certification

3.1.13 Test Reports

3.1.14 Product Identification

3.1.15 Packing and Package Marking

3.1.16 Supplementary Requirements

3.2 In addition, when a section with a title identical to that referenced in 3.1 above appears in this specification, it contains additional requirements which supplement those appearing in Specification B248 or Specification B248M.

4. Terminology

4.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification, as applicable:

- 5.1.1 ASTM designation and year of issue;
- 5.1.2 Copper [Alloy] UNS No. designation (Section 1);
- 5.1.3 Temper (Section 7);
- 5.1.4 Dimensions, Thickness, Width, and Length (Section 10);
- 5.1.5 How furnished: straight lengths or coils;
- 5.1.6 Quantity—total weight or total length or number of pieces of each size (10.7);
- 5.1.7 Intended application;
- 5.1.8 Finish (11.2); and
- 5.1.9 Type of edge, if required (slit, sheared, sawed, square corners, round corners, rounded edges, or full rounded edges) (10.6).

5.2 The following options are available but may not be included unless specified at the time of placing of the order when required.

- 5.2.1 DELETED
- 5.2.2 DELETED
- 5.2.3 If product is purchased for agencies of the U.S. government (see the Supplementary Requirements section of Specification B248 or Specification B248M for additional requirements, if specified);
- 5.2.4 DELETED
- 5.2.5 DELETED
- 5.2.6 Whether 0.2 % yield strength is required (Tables 1 and 2); and
- 5.2.7 If specification number must be shown on package marking.

6. Chemical Composition

6.1 The material shall conform to the chemical composition requirements in Table 3 for the copper [alloy] UNS No. designation specified in the ordering information.

6.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

6.3 For alloys in which copper is listed as “remainder,” copper is the difference between the sum of results of all elements determined and 100 %. When all elements in Table 3 are determined, the sum of results shall be 99.5 % min.

7. Temper

7.1 The standard tempers for products described in this specification are in Tables 1 and 2 and Tables 4 and 5.

- 7.1.1 Hot rolled temper M20.
- 7.1.2 Hot rolled and rerolled temper M25.
- 7.1.3 Cold rolled tempers H01 to H14.
- 7.1.4 Annealed tempers O50 or O61.

8. Grain Size for Annealed Tempers

8.1 The approximate grain size values for annealed tempers given in Tables 1 and 2 and Tables 4 and 5 are for general information and shall not be used as a basis for product rejection.

9. Mechanical Property Requirements

9.1 Tensile Strength Requirements:

9.1.1 Product furnished under this specification shall conform to the tensile requirements prescribed in Table 1, Table 2, Table 4, or Table 5, when tested in accordance with Test Methods E8/E8M.

9.1.2 DELETED

9.1.3 The tension test specimens shall be taken so the longitudinal axis of the specimens is parallel to the direction of rolling.

9.2 Yield Strength Requirements:

9.2.1 Product furnished under this specification shall conform to the yield strength requirements prescribed in Tables 1 and 2 when tested in accordance with Test Methods E8/E8M. The purchaser must specify at the time of ordering which yield strength method shall be used.

9.3 Elongation Requirements:

9.3.1 Product furnished under this specification shall be capable of conforming to the elongation requirements prescribed in Tables 1 and 2 when tested in accordance with Test Methods E8/E8M.

TABLE 1 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications (Inch-Pound Units)

Temper Designation		Tensile Strength, ksi	Yield Strength at 0.5 % Extension Under Load, ksi min	Yield Strength ^A at 0.2 % offset, min, ksi	Elongation, min % ^B	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Code	Name						
Copper Alloy UNS No. C65500							
O61	Annealed	50–67	18	18	40	70–82	0.110 max ^C

^A See 5.2.6.

^B Elongation in 2 in.

^C No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.

TABLE 2 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values for Pressure Vessel Applications (SI Units)

Temper Designation	Tensile Strength, MPa	Yield Strength at 0.5 % Extension Under Load, MPa min	Yield Strength ^A at 0.2 % offset, min, MPa	Elongation, min % ^B	Approximate Rockwell F Hardness	Approximate Grain Size, mm
Code	Name					
Copper Alloy UNS No. C65500						
O61	Annealed	345–460	125	125	40	70–82
						0.110 max ^C

^A See 5.2.6.^B Elongation in 50 mm.^C No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.**TABLE 3 Chemical Requirements**

Element	Composition, %		
	Copper Alloy UNS No.		
	C65100	C65400	C65500
Copper, incl silver	remainder	remainder	remainder
Silicon	0.8–2.0	2.7–3.4	2.8–3.8
Manganese	0.7 max	...	0.50–1.3
Tin	...	1.2–1.9	...
Chromium	...	0.01–0.12	...
Zinc, max	1.5	0.50	1.5
Iron, max	0.8	...	0.8
Nickel, max ^A	...	...	0.6
Lead, max	0.05	0.05	0.05

^A Incl cobalt.

9.4 Rockwell Hardness Requirement:

9.4.1 The approximate Rockwell hardness values given in Tables 1 and 2 and Tables 4 and 5 are for general information and assistance in testing, and shall not be used as a basis for product rejection.

10. Dimensions, Mass, and Permissible Variation

10.1 The dimensions and tolerances for product described by this specification shall be as specified in Specification B248 or Specification B248M with particular reference to the following tables and related paragraphs (exceptions for ASME Pressure Vessel Code applications are noted):

10.2 Thickness—Table 2.

10.2.1 *Pressure Vessel Code Applications*—The thickness of any plate or sheet shall not be more than 0.01 in. under the thickness specified.

10.3 Width:

10.3.1 *Slit Metal and Slit Metal with Rolled Edges*—Table 4.

10.3.2 *Square Sheared Metal*—Table 5.

10.3.3 *Sawed Metal*—Table 6.

10.4 Length:

10.4.1 *Length Tolerance for Straight Lengths*—Table 7.

10.4.2 *Schedule for Minimum Lengths and Maximum Weights of Ends for Specific Lengths with Ends, and Stock Lengths with Ends*—Table 8.

10.4.3 *Length Tolerances for Square Sheared Metal*—Table 9.

10.4.4 *Length Tolerances for Sawed Metal*—Table 10.

10.5 Straightness:

10.5.1 *Slit Metal or Slit Metal Either Straightened or Edge Rolled*—Table 11.

10.5.2 *Square Sheared Metal*—Table 12.

10.5.3 *Sawed Metal*—Table 13.

10.6 Edges Contours:

10.6.1 *Square Corners*—Table 14.

10.6.2 *Rounded Corners*—Table 15.

10.6.3 *Rounded Edges*—Table 16.

10.6.4 *Full-Rounded Edges*—Table 17.

10.7 Weight:

10.7.1 *Lot Weight Tolerances for Hot-Rolled Sheet and Plate*—Table 18.

10.7.2 *ASME Pressure Vessel Code Applications*—Table 6 of this specification.

11. Workmanship, Finish, and Appearance

11.1 For workmanship and appearance requirements, refer to Specification B248 or Specification B248M.

11.2 *Finish*—The material is supplied regularly in the following finishes:

11.2.1 *Black*—After hot rolling retains all of the oxides.

11.2.2 *Plain Pickled*—Sulfuric acid pickle only, brick red oxide; has cuprous and silicon oxides still adherent.

11.2.3 *Specially Cleaned*—Commercially free of all oxides; has the golden color of the alloy.

11.2.4 *Sand Blasted*—Commercially free of all oxides; has a dull gray color.

12. Sampling

12.1 Refer to sampling section in Specification B248 or Specification B248M.

13. Test Methods

13.1 Chemical Analyses:

13.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published test methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement.

Element	ASTM Test Method
Copper	E478
Silicon	E54; Perchloric acid dehydration
Manganese	E62
Tin	E478; Titrimetric
Chromium	E118
Zinc	E478; Atomic absorption
Iron	E478
Nickel	E478; Photometric
Lead	E478; Atomic absorption

TABLE 4 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values (Inch-Pound Units)

Temper Designation		Tensile Strength, ksi	Approximate Rockwell Hardness		Approximate Grain Size, mm
Code	Name		F Scale	B Scale	
Copper Alloy UNS No. C65100					
O61	Annealed	38–45	45–55	...	0.050–0.120
O50	Light anneal	40–50	50–75	...	0.060 max ^A
H01	Quarter-hard	42–52	...	48–63	...
H02	Half-hard	47–57	...	64–73	...
H04	Hard	60–70	...	74–82	...
H06	Extra-hard	67–76	...	78–85	...
H08	Spring	71–79	...	81–86	...
Copper Alloy UNS Nos. C65500					
O61	Annealed	52–58	70–82	...	0.110 max ^A
O50	Light anneal	55–64	76–93	...	0.055 max ^B
H01	Quarter-hard	60–74	...	65–80	...
H02	Half-hard ^B	72–86	...	79–91	...
H04	Hard ^B	85–99	...	88–96	...
H06	Extra-hard ^B	95–109	...	93–98	...
H08	Spring ^B	102–116	...	94–99	...
M20	As hot-rolled	55–72	72 min	...	...
M25	As hot-rolled and rerolled	58–72	...	60–80	...
Copper Alloy UNS No. C65400			Superficial 30T	B Scale	
O61	Annealed	65–80	...	...	0.040 ^B max
H01	Quarter hard ^B	75–90	64–77	72–91	...
H02	Half hard ^B	86–101	75–79	89–95	...
H03	Three-quarter hard ^B	97–112	77–81	94–97	...
H04	Hard ^B	108–120	80–81	96–98	...
H06	Extra hard ^B	116–126	81–82	97–100	...
H08	Spring ^B	124–133	81–82	99–101	...
H10	Extra spring ^B	131–140	81 min	100–102	...
H14	Super spring ^B	137 min	81 min	101 min	...

^A No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.^B Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.**TABLE 5 Tensile Strength Requirements and Approximate Rockwell Hardness and Grain Size Values (SI Units)**

Temper Designation		Tensile Strength, MPa	Approximate Rockwell Hardness		Approximate Grain Size, mm
Code	Name		F Scale	B Scale	
Copper Alloy UNS No. C65100					
O61	Annealed	260–310	45–55	...	0.050–0.120
O50	Light anneal	275–345	50–75	...	0.060 max ^A
H01	Quarter-hard	290–360	...	48–63	...
H02	Half-hard	325–395	...	64–73	...
H04	Hard	415–485	...	74–82	...
H06	Extra-hard	460–525	...	78–85	...
H08	Spring	490–545	...	81–86	...
Copper Alloy UNS Nos. C65500					
O61	Annealed	360–400	70–82	...	0.110 max ^A
O50	Light anneal	380–440	76–93	...	0.055 max ^B
H01	Quarter-hard	415–510	...	65–80	...
H02	Half-hard ^B	495–595	...	79–91	...
H04	Hard ^B	585–685	...	88–96	...
H06	Extra-hard ^B	655–750	...	93–98	...
H08	Spring ^B	705–800	...	94–99	...
M20	As hot-rolled	380–495	72 min	...	...
M25	As hot-rolled and rerolled	400–495	...	60–80	...
Copper Alloy UNS No. C65400			Superficial 30T	B Scale	
O61	Annealed	450–550	...	...	0.040 ^B max
H01	Quarter hard ^B	515–620	64–77	72–91	...
H02	Half hard ^B	595–695	75–79	89–95	...
H03	Three-quarter hard ^B	670–770	77–81	94–97	...
H04	Hard ^B	745–825	80–81	96–98	...
H06	Extra hard ^B	800–870	81–82	97–100	...
H08	Spring ^B	855–915	81–82	99–101	...
H10	Extra spring ^B	905–965	81 min	100–102	...
H14	Super spring ^B	945 min	81 min	101 min	...

^A No minimum grain size requirement is specified, but all annealed material shall be fully recrystallized.^B Commercially supplied only as strip. The manufacturer should be consulted where these tempers are desired in sheet or plate.

13.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchase order

agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

TABLE 6 Lot Weight Tolerances in Percentage of Theoretical Weight for Pressure Vessel Applications—All Plus

Thickness, in. [mm]	Permissible Excess in Average Weight of Lots, Expressed in Percentage of Normal Weight					
	48 in. [1200 mm] and Under in Width	Over 48 to 60 in. [1200 to 1500 mm] in Width	Over 60 to 72 in. [1500 to 1800 mm] in Width	Over 72 to 96 in. [1800 to 2500 mm] in Width	Over 96 to 120 in. [2500 to 3000 mm] in Width	Over 120 to 132 in. [3000 to 3500 mm] incl in Width
1/8 to 3/16, incl [3.0 to 5.0]	6.5	8	9	11	12	13
Over 3/16 to 1/4, incl [6.0 to 8.0]	6.5	8	9	11	12	13
Over 1/4 to 5/16, incl [8.0 to 10]	6.5	7.75	8.75	11	12	13
Over 5/16 to 3/8, incl [9.0 to 10]	6.25	7.5	8.5	11	12	13
Over 3/8 to 7/16, incl [10 to 12]	6	7.25	8.25	11	12	13
Over 7/16 to 1/2, incl [12 to 14]	6	7	8	10	11	12
Over 1/2 to 5/8, incl [14 to 16]	5.75	6.5	7.5	9	10	11
Over 5/8 to 3/4, incl [16 to 20]	5.5	6	7	8	9	10
Over 3/4 to 1, incl [20 to 25]	5	5	6.25	7	8	9
Over 1 to 2, incl [25 to 50]	3.5	4	5	6	7	8

13.2 Other Tests:

13.2.1 *Mechanical Properties (Tensile Strength, Yield Strength, Elongation, Rockwell Hardness, and Grain Size)*—Refer to the appropriate test method in Specification B248 or Specification B248M.

14. Keywords

14.1 copper-silicon alloy plate; copper-silicon alloy pressure vessels; copper-silicon alloy rolled bar; copper-silicon alloy sheet; copper-silicon alloy strip; UNS No. C65100; UNS No. C65400; UNS No. C65500

SPECIFICATION FOR COPPER-SILICON ALLOY ROD, BAR AND SHAPES



SB-98/SB-98M

(Identical with ASTM Specification B98/B98M-13(2019) except that paras. 4.2.3 and 8.1.1.1 were deleted so that tensile testing rather than Rockwell hardness testing is required to show conformance with mechanical properties.)

Specification for Copper-Silicon Alloy Rod, Bar and Shapes

1. Scope

1.1 This specification establishes requirements for copper-silicon rod, bar, and shapes for UNS Copper Alloys C65100, C65500, and C66100.

NOTE 1—Material for hot forging is covered by Specification B124/B124M.

NOTE 2—DELETED

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, SI units are shown in brackets. 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.

1.3 *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:

B124/B124M Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B249/B249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings
B950 Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys
B601 Classification for Temper Designations for Copper and

Copper Alloys—Wrought and Cast

E8/E8M Test Methods for Tension Testing of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)

E478 Test Methods for Chemical Analysis of Copper Alloys

2.2 *ASME Standard:*

ASME Boiler and Pressure Vessel Code

3. General Requirements

3.1 The following sections of Specification B249/B249M constitute a part of this specification:

- 3.1.1 Terminology;
- 3.1.2 Materials and Manufacture;
- 3.1.3 Workmanship, Finish, and Appearance;
- 3.1.4 Sampling;
- 3.1.5 Number of Tests and Retests;
- 3.1.6 Specimen Preparation;
- 3.1.7 Test Methods;
- 3.1.8 Significance of Numerical Limits;
- 3.1.9 Inspection;
- 3.1.10 Rejection and Rehearing;
- 3.1.11 Certification;
- 3.1.12 Test Reports;
- 3.1.13 Packaging and Package Marking; and
- 3.1.14 Supplementary Requirements.

3.2 In addition, when a section with a title identical to one of those referenced in 3.1 appears in this specification, it contains additional requirements that supplement those which appear in Specification B249/B249M.

4. Ordering Information

4.1 Include the following specified choices when placing orders for product under this specification, as applicable:

- 4.1.1 ASTM Designation and year of issue;

- 4.1.2 Copper Alloy UNS No. designation;
- 4.1.3 Temper designation (see Temper Section 7);
- 4.1.4 Quantity; total weight or length, or number of pieces of each temper, form, or alloy;
- 4.1.5 Dimensions; diameter or distance between parallel surfaces;
- 4.1.6 Type of edge; edge contours;
- 4.1.7 How furnished; specific lengths with or without ends; and
- 4.1.8 Intended application.

4.2 The following options are available but may not be included unless specified at the time of placing of the order when required:

- 4.2.1 DELETED
- 4.2.2 DELETED
- 4.2.3 DELETED

4.2.4 If product is purchased for agencies of the U.S. Government (see Supplementary Requirements in Specification B249/B249M).

5. Material and Manufacture

5.1 *Materials*—The starting material shall be cast billets or rods of Copper Alloy UNS Nos. C65100, C65500, or C66100, and shall be of such soundness and structure as to enable them to be processed into the product specified in the contract or purchase order.

5.2 *Manufacture*—The product shall be manufactured by such hot-working, cold-working, straightening, and annealing processing as to produce a uniform wrought structure and obtain the required finish properties.

6. Chemical Composition

6.1 The material shall conform to the chemical requirements specified in Table 1 for the Copper Alloy UNS No. designated in the ordering information.

6.1.1 For alloys in which copper is listed as “remainder,” copper is the difference between the sum of the results of all elements determined and 100 %.

6.1.2 When all elements listed in Table 1 are determined for the designated alloy, the sum of results shall be 99.5 % min.

TABLE 1 Chemical Requirements

	Composition, % Maximum (Unless Shown as a Range or Minimum)		
	Copper Alloy UNS No.		
	C65100	C65500	C66100
Copper (Includes Silver)	remainder	remainder	remainder
Lead	0.05	0.05	0.20–0.8
Iron	0.8	0.8	0.25
Zinc	1.5	1.5	1.5
Manganese	0.7	0.50–1.3	1.5
Silicon	0.8–2.0	2.8–3.8	2.8–3.5
Nickel (includes cobalt)	...	0.6	...

6.2 These composition limits do not preclude the presence of other elements. Limits may be established and analysis required for unnamed elements by agreement between the manufacturer and the purchaser.

7. Temper

7.1 The standard tempers, as defined in Classification B601, for products described in this specification are given in Tables 2–5.

- 7.1.1 Soft annealed O60,
- 7.1.2 ¼-hard H01,
- 7.1.3 ½-hard H02,
- 7.1.4 Hard H04,
- 7.1.5 Extra-hard H06,
- 7.1.6 As hot rolled M20, and
- 7.1.7 As hot extruded M30.

7.2 Product of bars and shapes in the temper H06 is normally not produced.

8. Mechanical Property Requirements

8.1 Product furnished under this specification shall conform to the tensile and hardness requirements prescribed in Tables 2–5 for the Copper Alloy UNS No. designation specified in the ordering information.

8.1.1 *Rockwell Hardness Requirement*—For the alloys and tempers listed, product 0.5 in. [12 mm] and over in diameter or in the distance between parallel surfaces shall conform with the requirements given in Table 4 and Table 5, when tested in accordance with Test Methods E18.

8.1.1.1 DELETED

8.1.2 *Tensile Strength Requirements*—The product shall conform with the requirements of Table 2 and Table 3 when tested in accordance with Test Methods E8/E8M.

8.1.2.1 The tensile requirements for all alloys and forms of M20 and M30 tempers shall be as agreed upon between the manufacturer and purchaser at the time of order.

9. Dimensions, Mass and Permissible Variations

9.1 Refer to the appropriate paragraphs in Specification B249/B249M with particular reference to the following tables:

9.2 *Diameter or Distance Between Parallel Surfaces:*

9.2.1 *Rod: Round, Hexagonal, Octagonal*—Refer to Table 1 for Alloy C65100 and to Table 2 for Alloys C65500 and C66100.

9.2.2 *Rod: Round M20 Temper*—Refer to Table 6.

9.2.3 *Rod: Round, Hexagonal, Octagonal, M30 Temper*—Refer to Table 5.

9.2.4 *Bar: Rectangular and Square*—Refer to Tables 8 and 10 for Alloy C65100, and Tables 9 and 11 for Alloys C65500 and C66100.

9.2.5 *Bar: M30 Temper*—Refer to Table 5 for thickness and width tolerances.

9.3 *Shapes*—The dimensional tolerance for shapes shall be as agreed upon between the manufacturer and the purchaser, and shall be specified in the order.

TABLE 2 Tensile Requirements, Inch-Pound (see Table 3 for SI)

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^A in.	Tensile Strength min, ksi	Yield Strength at 0.5 % Extension Under Load, min, ksi	Elongation in 4 × Diameter or Thickness of Specimen, min, % ^B
Code	Name				
Copper Alloy UNS No. C65100 Rods, Bars, and Shapes					
O60	Soft anneal	All forms, all sizes	40	12	30
H02	Half-hard	Rods:			
		Up to ½, incl	55	20	11
		Over ½ to 2, incl	55	20	12
		Bars and shapes	<i>c</i>	<i>c</i>	<i>c</i>
H04	Hard	Rods:			
		Up to ½, incl	65	35	8
		Over ½ to 2, incl	65	35	10
		Bars and shapes	<i>c</i>	<i>c</i>	<i>c</i>
H06	Extra-hard	Rods:			
		Up to ½, incl	85	55	6
		Over ½ to 1, incl	75	45	8
		Over 1 to 1½, incl	75	40	8
Copper Alloy UNS Nos. C65500 and C66100 Rectangular Bars					
O60	Soft anneal	All sizes	52	15	35
H04	Hard	Up to 1, incl	65	38	20
		Over 1 to 1½, incl	60	30	25
		Over 1½ to 3, incl	55	24	27
Copper Alloy UNS Nos. C65500 and C66100 Rods, Square Bars, and Shapes					
O60	Soft anneal	All forms, all sizes	52	15	35
H01	Quarter-hard	All forms, all sizes	55	24	25
H02	Half-hard	Rods and square bars:			
		Up to 2, incl	70	38	20
		Shapes	<i>c</i>	<i>c</i>	<i>c</i>
H04	Hard	Rods and square bars:			
		Up to ¼, incl	90	55	8
		Over ¼ to 1, incl	90	52	13
		Over 1 to 1½, incl	80	43	15
		Over 1½ to 3, incl	70	38	17
		Over 3	<i>c</i>	<i>c</i>	<i>c</i>
		Shapes	<i>c</i>	<i>c</i>	<i>c</i>
H06	Extra-hard	Rods: up to ½, incl	100	55	7

^A For rectangular bar, the Distance Between Parallel Surfaces refers to thickness.^B In any case a minimum gage length of 1 in. shall be used.^C As agreed upon between manufacturer and purchaser.

9.4 Length:

9.4.1 Rod, Bar and Shapes—Refer to Tables 13 and 15.

9.5 Straightness:

9.5.1 Rod and Bar—Refer to Table 16.

9.6 Edge Contours:

9.6.1 Rod and Bar—Refer to the section entitled, “Edge Contours” and to Figs. 1, 2, and 3.

10. Test Methods

10.1 In cases of disagreement, test methods for chemical composition shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published test methods some of which are considered by ASTM as no longer viable. These, and others not listed, may be used subject to agreement.

Element	Test Methods
Copper	E478
Lead	E478, Atomic absorption
Manganese	E62
Nickel	E478, Photometric
Silicon	E62
Zinc	E478, Atomic absorption

10.1.1 Test Method(s) to be followed for the determination of elements required by contractual or purchase order agreement shall be as agreed upon between the supplier and purchaser.

10.2 Refer to Specification B249/B249M for other appropriate test methods.

11. Keywords

11.1 copper—rod, bar, shapes; copper-silicon alloy; high silicon bronze A; low silicon bronze B; silicon bronze; UNS No. C65100; UNS No. C65500; UNS No. C66100

TABLE 3 Tensile Requirements, SI (see Table 2 for Inch-Pound)

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^A mm	Tensile Strength min, MPa	Yield Strength at 0.5 % Extension Under Load, min, MPa	Elongation, min, % ^B		
Code	Name						
Copper Alloy UNS No. C65100 Rods, Bars, and Shapes							
O60	Soft anneal	All forms, all sizes	275	85	30		
H02	Half-hard	Rods: Up to 12, incl Over 12 to 50, incl	380 380	140 140	11 12		
H04	Hard	Bars and shapes	<i>C</i>	<i>C</i>	<i>C</i>		
		Rods: Up to 12, incl Over 12 to 50, incl	450 450	240 240	8 10		
		Bars and shapes	<i>C</i>	<i>C</i>	<i>C</i>		
H06	Extra-hard	Rods: Up to 12, incl Over 12 to 25, incl Over 25 to 38, incl	585 515 515	380 310 275	6 8 8		
		Copper Alloy UNS Nos. C65500 and C66100 Rectangular Bars					
		O60	Soft anneal	All sizes	360	105	35
H04	Hard	Up to 25, incl	450	260	20		
		Over 25 to 38, incl	415	205	25		
		Over 38 to 75, incl	380	165	27		
Copper Alloy UNS Nos. C65500 and C66100 Rods, Square Bars, and Shapes							
O60	Soft anneal	All forms, all sizes	360	105	35		
H01	Quarter-hard	All forms, all sizes	380	165	25		
H02	Half-hard	Rods and square bars: Up to 50, incl	485	260	20		
		Shapes	<i>C</i>	<i>C</i>	<i>C</i>		
		H04	Hard	Rods and square bars: Up to 6, incl Over 6 to 25, incl Over 25 to 38, incl Over 38 to 75, incl Over 75	615 615 545 485 <i>C</i>	380 360 295 260 <i>C</i>	8 13 15 17 <i>C</i>
Shapes	<i>C</i>			<i>C</i>	<i>C</i>		
H06	Extra-hard			Rods: up to 12, incl	690	380	7

^A For rectangular bar, the Distance Between Parallel Surfaces refers to thickness.^B Elongation values are based on a gage length of 5.65 times the square root of the area for dimensions greater than 2.5 mm.^C As agreed upon between manufacturer and purchaser.**TABLE 4 Rockwell Hardness Requirements, Inch-Pound^A (see Table 5 for SI)**

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^B in.	Rockwell B Hardness Determined on the Cross Section Midway Between Surface and Center
Code	Name		
Copper Alloy UNS No. C65100 Rods, Bars, and Shapes			
H02	Half-hard	0.5 to 2.0 , incl	60–85
H04	Hard	0.5 to 2.0, incl	65–90
H06	Extra-hard ^C	0.5 to 1.5, incl	75–95
Copper Alloy UNS Nos. C65500 and C66100 Rectangular Bars			
H04	Hard	0.5 to 3.0, incl	60–95
Copper Alloy UNS Nos. C65500 and C66100 Rods, Square Bars, and Shapes			
H02	Half-hard	0.5 to 1.0, incl	75–95
		over 1.0 to 1.5, incl	75–95
		over 1.5 to 3.0, incl	75–95
H04	Hard	0.5 to 1.0, incl	85–100
		over 1.0 to 1.5, incl	80–95
		over 1.5 to 3.0, incl	75–95

^A Rockwell hardness requirements are not established for diameters less than 0.5 in.^B For rectangular bar, the Distance Between Parallel Surfaces refers to thickness.^C Bars and shapes are not produced in the H06 temper.

TABLE 5 Rockwell Hardness Requirements, SI^A (see Table 4 for Inch-Pound)

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^B mm	Rockwell B Hardness Determined on the Cross Section Midway Between Surface and Center
Code	Name		
Copper Alloy UNS No. C65100 Rods, Bars, and Shapes			
H02	Half-hard	12 to 50, incl	60–85
H04	Hard	12 to 50, incl	65–90
H06	Extra-hard ^C	12 to 50, incl	75–95
Copper Alloy UNS Nos. C65500 and C66100 Rectangular Bars			
H04	Hard	12 to 75, incl	60–95
Copper Alloy UNS Nos. C65500 and C66100 Rods, Square Bars, and Shapes			
H02	Half-hard	12 to 25, incl	75–95
		over 25 to 38, incl	75–95
		over 38 to 75, incl	75–95
H04	Hard	12 to 25, incl	85–100
		over 25 to 38, incl	80–95
		over 38 to 75, incl	75–95

^A Rockwell hardness requirements are not established for diameters less than 12 mm.

^B For rectangular bar, the Distance Between Parallel Surfaces refers to thickness.

^C Bars and shapes are not produced in the H06 temper.

SPECIFICATION FOR ALUMINUM-ALLOY PERMANENT MOLD CASTINGS



SB-108/SB-108M

(Identical with ASTM Specification B108/B108M-12¹ except that certification and test reports have been made mandatory, and ASME welding requirements are invoked for repair welding.)

Specification for Aluminum-Alloy Permanent Mold Castings

1. Scope

1.1 This specification covers aluminum-alloy permanent mold castings designated as shown in Table 1.

1.2 This specification is for aluminum-alloy permanent mold castings used in general purpose applications. It may not address the mechanical properties, integrity testing, and verification required for highly loaded or safety critical applications.

1.3 Alloy and temper designations are in accordance with ANSI H35.1/H35.1(M). The equivalent unified numbering system alloy designations are in accordance with Practice E527.

1.4 Unless the order specifies the “M” specification designation, the material shall be furnished to the inch-pound units.

1.5 For acceptance criteria for inclusion of new aluminum and aluminum alloys and their properties in this specification, see Annex A1 and Annex A2.

1.6 *Units*—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.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of casting purchase form a part of this specification to the extent referenced herein:

2.2 ASTM Standards:

- B179 Specification for Aluminum Alloys in Ingot and Molten Forms for Castings from All Casting Processes
- B275 Practice for Codification of Certain Nonferrous Metals and Alloys, Cast and Wrought
- B557 Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products
- B557M Test Methods for Tension Testing Wrought and Cast Aluminum- and Magnesium-Alloy Products (Metric)
- B660 Practices for Packaging/Packing of Aluminum and Magnesium Products
- B881 Terminology Relating to Aluminum- and Magnesium-Alloy Products
- B917/B917M Practice for Heat Treatment of Aluminum-Alloy Castings from All Processes
- D3951 Practice for Commercial Packaging
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E34 Test Methods for Chemical Analysis of Aluminum and Aluminum-Base Alloys
- E94 Guide for Radiographic Examination
- E155 Reference Radiographs for Inspection of Aluminum and Magnesium Castings
- E165 Practice for Liquid Penetrant Examination for General Industry
- E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
- E607 Test Method for Atomic Emission Spectrometric Analysis Aluminum Alloys by the Point to Plane Technique Nitrogen Atmosphere (Withdrawn 2011)

TABLE 1 Chemical Composition Limits^{A,B,C}

Alloy		Composition, %												
ANSI ^D	UNS	Aluminum	Silicon	Iron	Copper	Manga- nese	Magne- sium	Chromium	Nickel	Zinc	Titanium	Tin	Other Elements ^E	
													Each	Total ^F
204.0	A02040	remainder	0.20	0.35	4.2–5.0	0.10	0.15–0.35	...	0.05	0.10	0.15–0.30	0.05	0.05	0.15
242.0	A02420	remainder	0.7	1.0	3.5–4.5	0.35	1.2–1.8	0.25	1.7–2.3	0.35	0.25	...	0.05	0.15
296.0		remainder	2.0–3.0	1.2	4.0–5.0	0.35	0.05	...	0.35	0.50	0.25	...	...	0.35
308.0		remainder	5.0–6.0	1.0	4.0–5.0	0.50	0.10	...	...	1.0	0.25	...	...	0.50
319.0	A03190	remainder	5.5–6.5	1.0	3.0–4.0	0.50	0.10	...	0.35	1.0	0.25	...	...	0.50
332.0 ^G	A03320	remainder	8.5–10.5	1.2	2.0–4.0	0.50	0.50–1.5	...	0.50	1.0	0.25	...	...	0.50
333.0	A03330	remainder	8.0–10.0	1.0	3.0–4.0	0.50	0.05–0.50	...	0.50	1.0	0.25	...	...	0.50
336.0 ^G	A03360	remainder	11.0–13.0	1.2	0.50–1.5	0.35	0.7–1.3	...	2.0–3.0	0.35	0.25	...	0.05	...
354.0	A03540	remainder	8.6–9.4	0.20	1.6–2.0	0.10	0.40–0.6	...	...	0.10	0.20	...	0.05	0.15
355.0	A03550	remainder	4.5–5.5	0.6 ^H	1.0–1.5	0.50 ^H	0.40–0.6	0.25	...	0.35	0.25	...	0.05	0.15
C355.0	A35550	remainder	4.5–5.5	0.20	1.0–1.5	0.10	0.40–0.6	...	...	0.10	0.20	...	0.05	0.15
356.0	A03560	remainder	6.5–7.5	0.6 ^H	0.25	0.35 ^H	0.20–0.45	...	...	0.35	0.25	...	0.05	0.15
A356.0	A13560	remainder	6.5–7.5	0.20	0.20	0.10	0.25–0.45	...	...	0.10	0.20	...	0.05	0.15
357.0		remainder	6.5–7.5	0.15	0.05	0.03	0.45–0.6	...	...	0.05	0.20	...	0.05	0.15
A357.0	A13570	remainder	6.5–7.5	0.20	0.20	0.10	0.40–0.7	...	...	0.10	0.04–0.20	...	0.05 ^I	0.15
E357.0		remainder	6.5–7.5	0.10	0.10	0.10	0.55–0.6	...	...	...	0.10–0.20	...	0.05 ^J	0.15
F357.0		remainder	6.5–7.5	0.10	0.20	0.10	0.40–0.7	...	...	0.10	0.04–0.20	...	0.05 ^J	0.15
359.0	A03590	remainder	8.5–9.5	0.20	0.20	0.10	0.50–0.7	...	...	0.10	0.20	...	0.05	0.15
443.0	A04430	remainder	4.5–6.0	0.8	0.6	0.50	0.05	0.25	...	0.50	0.25	...	...	0.35
B443.0	A24430	remainder	4.5–6.0	0.8	0.15	0.35	0.05	...	...	0.35	0.25	...	0.05	0.15
A444.0	A14440	remainder	6.5–7.5	0.20	0.10	0.10	0.05	...	...	0.10	0.20	...	0.05	0.15
513.0 ^G	A05130	remainder	0.30	0.40	0.10	0.30	3.5–4.5	...	...	1.4–2.2	0.20	...	0.05	0.15
535.0	A05350	remainder	0.15	0.15	0.05	0.10–0.25	6.2–7.5	...	...	...	0.10–0.25	...	0.05 ^K	0.15
705.0	A07050	remainder	0.20	0.8	0.20	0.40–0.6	1.4–1.8	0.20–0.40	...	2.7–3.3	0.25	...	0.05	0.15
707.0	A07070	remainder	0.20	0.8	0.20	0.40–0.6	1.8–2.4	0.20–0.40	...	4.0–4.5	0.25	...	0.05	0.15
711.0 ^G	A07110	remainder	0.30	0.7–1.4	0.35–0.65	0.05	0.25–0.45	...	...	6.0–7.0	0.20	...	0.05	0.15
713.0	A07130	remainder	0.25	1.1	0.40–1.0	0.6	0.20–0.50	0.35	0.15	7.0–8.0	0.25	...	0.10	0.25
850.0	A08500	remainder	0.7	0.7	0.7–1.3	0.10	0.10	...	0.7–1.3	...	0.20	5.5–7.0	...	0.30
851.0 ^G	A08510	remainder	2.0–3.0	0.7	0.7–1.3	0.10	0.10	...	0.3–0.7	...	0.20	5.5–7.0	...	0.30
852.0 ^G	A08520	remainder	0.40	0.7	1.7–2.3	0.10	0.6–0.9	...	0.9–1.5	...	0.20	5.5–7.0	...	0.30

^A When single units are shown, these indicate the maximum amounts permitted.^B Analysis shall be made for the elements for which limits are shown in this table.^C The following applies to all specified limits in this table: For purposes of determining conformance to these limits, an observed value or a calculated value obtained from analysis shall be rounded to the nearest unit in the last right-hand place of figures used in expressing the specified limit in accordance with the rounding method of Practice E29.^D ASTM alloy designations are recorded in Practice B275.^E *Others* includes listed elements for which no specific limit is shown as well as unlisted metallic elements. The producer may analyze samples for trace elements not specified in the specification. However, such analysis is not required and may not cover all metallic *Others* elements. Should any analysis by the producer or the purchaser establish that an *Others* element exceeds the limit of *Each* or that the aggregate of several *Others* elements exceeds the limit of *Total*, the material shall be considered nonconforming.^F *Other Elements*—Total shall be the sum of unspecified metallic elements 0.010 % or more, rounded to the second decimal before determining the sum.^G 336.0 formerly A332.0, 332.0 formerly F332.0, 513.0 formerly A514.0, 711.0 formerly C712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.^H If the iron content exceeds 0.45 %, manganese content shall not be less than one half of the iron.^I Beryllium 0.04–0.07.^J Beryllium 0.002 max.^K Beryllium 0.003–0.007, boron 0.005 max.

E716 Practices for Sampling and Sample Preparation of Aluminum and Aluminum Alloys for Determination of Chemical Composition by Spectrochemical Analysis
 E1251 Test Method for Analysis of Aluminum and Aluminum Alloys by Spark Atomic Emission Spectrometry
 E2422 Digital Reference Images for Inspection of Aluminum Castings
 IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI): The Modern Metric System

2.3 ANSI Standard:

H35.1/H35.1M Alloy and Temper Designation Systems for Aluminum

2.4 Military Standards:

MIL-STD-129 Marking for Shipment and Storage
 MIL-STD-276 Impregnation of Porous Nonferrous Metal Castings
 NAVSEA S9074-AR-GIB-010/278 Requirements for Fabrication Welding and Inspection, and Casting Inspection and Repair for Machinery, Piping, and Pressure Vessels

2.5 AMS Specification:

AMS 2771 Heat Treatment of Aluminum Alloy Castings

2.6 Federal Standard:

Fed Std. No. 123 Marking for Shipment (Civil Agencies)

2.7 Other Standards:

CEN EN 14242 Aluminum and Aluminum Alloys, Chemical Analysis, Inductively Coupled Plasma Optical Emission Spectral Analysis

3. Terminology

3.1 Definitions—Refer to Terminology B881 for definitions of product terms used in this specification.

4. Ordering Information

4.1 Orders for material under this specification shall include the following information (see 1.4 and 1.5):

4.1.1 This specification designation (which includes the number, the year, and the revision letter, if applicable),

NOTE 1—For inch-pound application, specify Specification B108 and for metric application specify Specification B108M. Do not mix units.

4.1.2 Alloy (see Section 7 and Table 1),

4.1.3 Temper (see Section 10 and Table 2 [Table 3]).

TABLE 2 Tensile Requirements^A (Inch-Pound Units)

NOTE 1—For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 0.1 ksi, and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

Alloy		Temper ^B	Tensile Strength, min, ksi	Yield Strength ^C (0.2 % offset), min, ksi	Elongation in 2 in. or 4 × Diameter, min, %	Typical Brinell Hardness ^D 500-kgf load, 10-mm ball
ANSI ^E	UNS					
204.0	A02040	T4 separately cast specimens	48.0	29.0	8.0	...
242.0	A02420	T571	34.0	...	F	105
		T61	40.0	...	F	110
296.0	A02960	T4	33.0	15.0	4.5	75
		T6	35.0	...	2.0	90
		T7	33.0	16.0	3.0	...
308.0	A03080	F	24.0	...	...	70
319.0	A03190	F	27.0	14.0	2.5	95
332.0 ^G	A03320	T5	31.0	...	F	105
333.0	A03330	F	28.0	...	F	90
		T5	30.0	...	F	100
		T6	35.0	...	F	105
		T7	31.0	...	F	90
336.0 ^G	A03360	T551	31.0	...	F	105
		T65	40.0	...	F	125
354.0	A03540	T61				
		separately cast specimens	48.0	37.0	3.0	
		castings, designated area ^H	47.0	36.0	3.0	
		castings, no location designated ^H	43.0	33.0	2.0	
		T62				
		separately cast specimens	52.0	42.0	2.0	
		castings, designated area ^H	50.0	42.0	2.0	
		castings, no location designated ^H	43.0	33.0	2.0	
355.0	A03550	T51	27.0	...	F	75
		T62	42.0	...	F	105
		T7	36.0	...	F	90
		T71	34.0	27.0	F	80
C355.0	A33550	T61				
		separately cast specimens	40.0	30.0	3.0	85–90
		castings, designated area ^H	40.0	30.0	3.0	
		castings, no location designated ^H	37.0	30.0	1.0	85
356.0	A03560	F	21.0	10.0	3.0	
		T6	33.0	22.0	3.0	85
		T71	25.0	...	3.0	70
A356.0	A13560	T61				
		separately cast specimens	38.0	26.0	5.0	80–90
		castings, designated area ^H	33.0	26.0	5.0	
		castings, no location designated ^H	28.0	26.0	3.0	
357.0		T6	45.0	...	3.0	...
A357.0	A13570	T61				
		separately cast specimens	45.0	36.0	3.0	100
		castings, designated area ^H	46.0	36.0	3.0	...
		castings, no location designated ^H	41.0	31.0	3.0	...
E357.0 ^I		T61				
		separately cast specimens	45.0	36.0	3.0	100
		castings, designated area ^H	46.0	36.0	3.0	
		castings, no location designated ^H	41.0	31.0	3.0	
F357.0 ^J		T6	45.0		3.0	
359.0	A03590	T61				
		separately cast specimens	45.0	34.0	4.0	90
		castings, designated area ^H	45.0	34.0	4.0	

TABLE 2 Continued

Alloy		Temper ^B	Tensile Strength, min, ksi	Yield Strength ^C (0.2 % offset), min, ksi	Elongation in 2 in. or 4 x Diameter, min, %	Typical Brinell Hardness ^D 500-kgf load, 10-mm ball
ANSI ^E	UNS					
		castings, no location designated ^H	40.0	30.0	3.0	
		T62				
		separately cast specimens	47.0	38.0	3.0	100
		castings, designated area ^H	47.0	38.0	3.0	
		castings, no location designated ^H	40.0	30.0	3.0	
443.0	A04430	F	21.0	7.0	2.0	45
B443.0	A24430	F	21.0	6.0	2.5	45
A444.0	A14440	T4				
		separately cast specimens	20.0	...	20	...
		castings, designated area ^H	20.0	...	20	...
513.0 ^G	A05130	F	22.0	12.0	2.5	60
535.0	A05350	F	35.0	18.0	8.0	...
705.0	A07050	T1 or T5	37.0	17.0	10.0	
707.0	A07070	T1	42.0	25.0	4.0	
		T7	45.0	35.0	3.0	
711.0 ^G	A07110	T1	28.0	18.0	7.0	70
713.0	A07130	T1 or T5	32.0	22.0	4.0	
850.0	A08500	T5	18.0	...	8.0	
851.0 ^G	A08510	T5	17.0	...	3.0	
		T6	18.0	...	8.0	
852.0 ^G	A08520	T5	27.0	...	3.0	

^A If agreed upon by manufacturer and the purchaser, other mechanical properties may be obtained by other heat treatments such as annealing, aging, or stress relieving.

^B Refer to ANSI H 35.1/H35.1(M) for description of tempers.

^C Yield strength to be evaluated only when specified in contract or purchase order.

^D Hardness values given for information only, not required for acceptance.

^E ASTM alloy designations are recorded in Practice B275.

^F Not required.

^G 332.0 formerly F332.0, 336.0 formerly A332.0, 513.0 formerly A514.0, 711.0 formerly C712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

^H These properties apply only to castings having section thicknesses not greater than 2 in. except that section thicknesses of ¾ in., max, shall apply to Alloy A444.0.

^I Properties copied from A357.0–T61.

^J Properties copied from 357.0–T6.

TABLE 3 Tensile Requirements (SI Units) – [Metric]^{AB}

NOTE 1—For purposes of determining conformance with this specification, each value for tensile strength and yield strength shall be rounded to the nearest 1 MPa and each value for elongation shall be rounded to the nearest 0.5 %, both in accordance with the rounding method of Practice E29.

Alloy		Temper ^C	Tensile Strength, min, MPa ^D	Yield Strength ^E (0.2 % offset), min, MPa ^D	Elongation in 5D, min, %	Typical Brinell Hardness ^F 500-kgf load, 10-mm ball
ANSI ^G	UNS					
204.0	A02040	T4 separately cast specimens	330	200	7.0	...
242.0	A02420	T571	235	...	H	105
		T61	275	...	H	110
296.0	A02960	T4	230	105	4.5	75
		T6	240	...	2.0	90
		T7	230	110	3.0	...
308.0	A03080	F	165	...	...	70
319.0	A03190	F	185	95	2.5	95
332.0 ^I	A03320	T5	215	...	H	105
333.0	A03330	F	195	...	H	90
		T5	205	...	H	100
		T6	240	...	H	105
		T7	215	...	H	90
336.0 ^I	A03360	T551	215	...	H	105
		T65	275	...	H	125
354.0	A03540	T61				
		separately cast specimens	330	255	3.0	
		casting, designated area ^J	325	250	3.0	
		castings, no location designated ^J	295	230	2.0	
		T62				
		separately cast specimens	360	290	2.0	
		castings, designated area ^J	345	290	2.0	
		castings, no location designated ^J	295	230	2.0	
355.0	A03550	T51	185	...	H	75
		T62	290	...	H	105
		T7	250	...	H	90
		T71	235	185	H	80
C355.0	A33550	T61				
		separately cast specimens	275	205	3.0	85–90
		castings, designated area ^J	275	205	3.0	
		castings, no location designated ^J	255	205	1.0	85

TABLE 3 Continued

Alloy		Temper ^C	Tensile Strength, min, MPa ^D	Yield Strength ^E (0.2 % offset), min, MPa ^D	Elongation in 5D, min, %	Typical Brinell Hardness ^F 500-kgf load, 10-mm ball
ANSI ^G	UNS					
356.0	A03560	F	145	70	3.0	
		T6	230	150	3.0	85
		T71	170	...	3.0	70
A356.0	A13560	T61				
		separately cast specimens	260	180	4.0	80–90
		castings, designated area ^J	230	180	4.0	
		castings, no location designated ^J	195	180	3.0	
357.0		T6	310	...	3.0	...
A357.0	A13570	T61				
		separately cast specimens	310	250	3.0	100
		castings, designated area ^J	315	250	3.0	...
		castings, no location designated ^J	285	215	3.0	...
E357.0 ^K		T61				
		separately cast specimens	310	250	3.0	100
		castings, designated area ^J	315	250	3.0	
		castings, no location designated ^J	285	215	3.0	
F357.0 ^L		T6	310		3.0	
359.0	A03590	T61				
		separately cast specimens	310	235	4.0	90
		castings, designated area ^J	310	235	4.0	
		castings, no location designated ^J	275	205	3.0	
		T62				
		separately cast specimens	325	260	3.0	100
		castings, designated area ^J	325	260	3.0	
		castings, no location designated ^J	275	205	3.0	
443.0	A04430	F	145	50	2.0	45
B443.0	A24430	F	145	40	2.5	45
A444.0	A14440	T4				
		separately cast specimens	140	...	18.0	...
		castings, designated area ^J	140	...	18.0	...
513.0 ^I	A05130	F	150	80	2.5	60
535.0	A05350	F	240	125	7.0	...
705.0	A07050	T1 or T5	255	115	9.0	
707.0	A07070	T1	290	170	4.0	
		T7	310	240	3.0	
711.0 ^I	A07110	T1	195	125	6.0	70
713.0	A07130	T1 or T5	220	150	4.0	
850.0	A08500	T5	125	...	7.0	
851.0 ^I	A08510	T5	115	...	3.0	
		T6	125	...	7.0	
852.0 ^I	A08520	T5	185	...	3.0	

^A If agreed upon by manufacturer and the purchaser, other mechanical properties may be obtained by other heat treatments such as annealing, aging, or stress relieving.

^B Guidelines for metric conversion from the "Temperatures for Aluminum and Aluminum Alloys, Metric Edition" (Tan Sheets) Appendix A, were used to convert the tensile and yield values to SI units.⁶

^C Refer to ANSI H 35.1/H35.1(M) for description of tempers.

^D For explanation of the SI Unit "MPa" see Appendix X2.

^E Yield strength to be evaluated only when specified in contract or purchase order.

^F Hardness values given for information only, not required for acceptance.

^G ASTM alloy designations are recorded in Practice B275.

^H Not required.

^I 332.0 formerly F332.0, 336.0 formerly A332.0, 513.0 formerly A514.0, 711.0 formerly C712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.

^J These properties apply only to castings having section thicknesses not greater than 2 in. except that section thicknesses of 19-mm max, shall apply to Alloy A444.0.

^K Properties copied from A357.0–T61.

^L Properties copied from 357.0–T6.

4.1.4 Applicable drawing or part number,

4.1.5 The quantity in either pieces or pounds [kilograms],

4.2 Additionally, orders for material to this specification shall include the following information when required by the purchaser.

4.2.1 Whether foundry control is required (see Section 9),

4.2.2 Whether yield strength tests are required (see 10.1 and Table 2, Footnote C, [Table 4], [Footnote D]),

4.2.3 Whether castings or test bars, or both, are to be artificially aged for Alloys 705.0-T5, 707.0-T5, and 713.0-T5 (see 10.3),

4.2.4 Whether test specimens cut from castings are required in addition to or instead of separately cast specimens (see Sections 10, 12.2, 13.2, and 15),

4.2.5 Whether heat treatment is to be performed in accordance with AMS 2771 (see Section 16),

4.2.6 Whether repairs are permissible (see Section 17),

4.2.7 Whether inspection is required at the producer's works (see Section 18),

4.2.8 DELETED

4.2.9 Whether surface requirements will be checked visually or by observational standards where such standards are established (see 19.1),

TABLE 4 Discontinuity—Level Requirements for Aluminum Castings in Accordance with Film Reference Radiographs E155 or Digital Reference Radiographs E2422

Discontinuity	Grade A ^A	Grade B	Grade C	Grade D			
	Section Thickness, in. (mm)						
	1/4 to 3/4 (6.4 to 19.0)	1/4 (6.4)	3/4 (19.0)	1/4 (6.4)	3/4 (19.0)	1/4 (6.4)	3/4 (19.0)
Gas holes	none	1	1	2	2	5	5
Gas porosity (round)	none	1	1	3	3	7	7
Gas porosity (elongated)	none	1	1	3	4	5	5
Shrinkage cavity	none	1	^B	2	^B	3	^B
Shrinkage porosity or sponge	none	1	1	2	2	4	3
Foreign material (less dense material)	none	1	1	2	2	4	4
Foreign material (more dense material)	none	1	1	2	1	4	3
Segregation	none		none		none		none
Cracks	none		none		none		none
Cold shuts	none		none		none		none
Surface irregularity			not to exceed drawing tolerance				
Core shaft			not to exceed drawing tolerance				

^A Caution should be exercised in requesting grade A because of the difficulty in obtaining this level.

^B No radiographs available. Use 1/4-in. [6-mm] for all thicknesses.

4.2.10 Whether liquid penetrant inspection is required (see 19.2),

4.2.11 Whether radiographic inspection is required and, if so, the radiographic grade of casting required (19.3, Table 4), and

4.2.12 Whether Practices B660 applies and, if so, the levels of preservation, packaging and packing required (see 23.4).

5. Responsibility for Quality Assurance

5.1 Unless otherwise specified in the contract or purchase order, the producer shall be responsible for the performance of all inspections and test requirements specified herein. Unless otherwise agreed upon, the producer may use his own or any other suitable facilities for the performance of the inspection and test requirements specified herein. The purchaser shall have the right to perform any of the inspections and tests set forth in the specification where such inspections are deemed necessary to confirm that the material conforms to prescribed requirements.

6. Manufacture

6.1 The responsibility of furnishing castings that can be laid out and machined to the finished dimensions within the permissible variations specified, as shown on the blueprints or drawings, shall rest with the producer, except where mold equipment is furnished by the purchaser.

7. Chemical Composition

7.1 The product shall conform to the chemical composition limits prescribed in Table 1. Conformance shall be determined by the producer by taking samples at the time castings are poured in accordance with E716 and analyzed in accordance with E607, E1251, E34, or CEN EN 14242. If the producer has determined the composition of the material during casting, they shall not be required to sample and analyze the finished product.

7.2 If it becomes necessary to analyze castings for conformance to chemical composition limits, the method used to sample castings for the determination of chemical composition

shall be by agreement between the producer and the purchaser. Analysis shall be performed in accordance with E716, E607, E1251, E34, or CEN EN 14242 (ICP method).

7.3 Other methods of analysis or in the case of a dispute the method of analysis shall be agreed upon by the producer and the purchaser.

7.4 A sample for determination of chemical composition shall be taken to represent one of the following:

7.4.1 Not more than 4000 lb [2000 kg] of clean castings or a single casting poured from one furnace. The maximum elapsed time between determinations shall be established for each alloy, but in any case the maximum elapsed time shall not exceed 8 hours.

8. Material Requirements—Castings Produced for Governmental and Military Agencies

8.1 Unless otherwise specified, only aluminum alloy conforming to the requirements of Specification B179 or producers foundry scrap, identified as being made from alloy conforming to Specification B179, shall be used in the remelting furnace from which molten metal is taken for pouring directly into castings. Additions of small amounts of modifying and grain refining elements or alloys are permitted.

8.2 Pure materials, recycled materials, and master alloys may be used to make alloys conforming to this specification, provided chemical analysis can be taken and adjusted to conform to Table 1 prior to pouring any castings.

9. Foundry Control—Castings Produced for Governmental or Military Agencies, or Both

9.1 When specified, castings shall be produced under foundry control approved by the purchaser. Foundry control shall consist of examination of castings by radiographic or other approved methods for determining internal discontinuities until the gating, pouring, and other foundry practices have been established to produce castings meeting the quality standards furnished by the purchaser or agreed upon between the purchaser and the producer. When foundry practices have

been so established, the production method shall not be significantly changed without demonstrating to the satisfaction of the purchaser that the change does not adversely affect the quality of the castings. Minor changes in pouring temperature of $\pm 50^\circ\text{F}$ [$\pm 28^\circ\text{C}$] from the established nominal temperature are permissible.

10. Tensile Requirements

10.1 The separately cast tension test specimens representing the castings shall meet the mechanical properties prescribed in Table 2 [Table 3].

10.2 When specified, the tensile strength and elongation of test specimens cut from castings shall be in accordance with Table 2 [Table 3] for Alloys 354.0, C355.0, A356.0, A357.0, E357.0, 359.0, and A444.0. For other alloys a minimum of 75 % of the tensile and yield strength values and not less than 25 % of the elongation values specified in Table 2 [Table 3] are required. The measurement of elongation is not required for test specimens cut from castings if 25% of the specified minimum elongation value published in Table 2 [Table 3] is 0.5 % or less. If grade D quality castings as described in Table 4 are specified, no tensile tests shall be specified nor tensile requirements be met on specimens cut from castings.

10.3 Although Alloys 705.0, 707.0, and 713.0 are most frequently used in the naturally aged condition, by agreement of the producer and the purchaser, the castings may be artificially aged. The producer and the purchaser may also agree to base the acceptance of castings on artificially aged test bars. The conditions of artificial aging shown in Practice B917/B917M or AMS 2771 shall be employed unless other conditions are accepted by mutual consent.

11. Workmanship, Finish, and Appearance

11.1 The finished castings shall be uniform in composition and free of blowholes, cracks, shrinks, and other discontinuities in accordance with standards designated and agreed upon as acceptable by the purchaser.

12. Test Specimens

12.1 Separately cast test specimens shall be cast in iron molds. A recommended gating method is shown in Fig. 1 [Fig. 2]. The test section of the tension test specimen shall be cast to size in accordance with the dimensions shown in Fig. 1 [Fig. 2] and not machined prior to test. Grip ends may be machined to adapt them in such a manner as to ensure axial loading.

12.2 When properties of castings are to be determined, tension test specimens shall be cut from the locations designated on the drawings, unless otherwise negotiated. If no locations are designated, one or more specimens shall be taken to include locations having significant variation in casting thickness, except that specimens shall not be taken from areas directly under risers. The tension test specimens shall be the standard 0.500-in. [12.5-mm] diameter specimens shown in Fig. 9 of Test Methods B557 [B557M] or a round specimen of smaller size proportional to the standard specimens. In no case shall the dimensions of the smallest specimen be less than the following:

	in.	mm
Diameter of reduced section.	0.250	[6.00]
Length of reduced section	1¼	[32]
Radius of fillet	¾	[5]
Diameter of end section	¾	[10]
Overall length:		
With shouldered ends	2¾	[60]
With threaded ends	3	[75]
With plain cylindrical ends	4	[100]

12.3 When necessary, a rectangular specimen may be used proportional to that shown for the 0.500 in. [12.5-mm] wide specimen in Fig. 6 of Test Methods B557 [B557M], but in no case shall its dimensions be less than the following:

	in.	mm
Width of reduced section,	¼	[6]
Length of reduced section,	1¼	[32]
Radius of fillet,	¼	[6]
Overall length,	4	[100]

The specified elongation values shall not apply to tests of rectangular specimens.

12.4 If the castings are to be heat treated and separately cast specimens are to be used, the specimens representing such castings shall be heat treated with the castings they represent. If castings are to be heat treated and tests are to be obtained on the castings, the test specimens shall be taken from the castings after heat treatment.

13. Number of Tests

13.1 Unless otherwise agreed upon by the purchaser and producer, two tension test specimens shall be separately cast and tested to represent the following:

13.1.1 Not more than 4000 lb [2000 kg] of clean castings (gates and risers removed) or a single casting poured from one furnace.

13.1.2 The castings poured continuously from one furnace in not more than eight consecutive hours.

13.2 When tensile properties of castings are to be determined, one per melt-heat combination shall be tested unless otherwise shown on the drawing or specified in the purchase order.

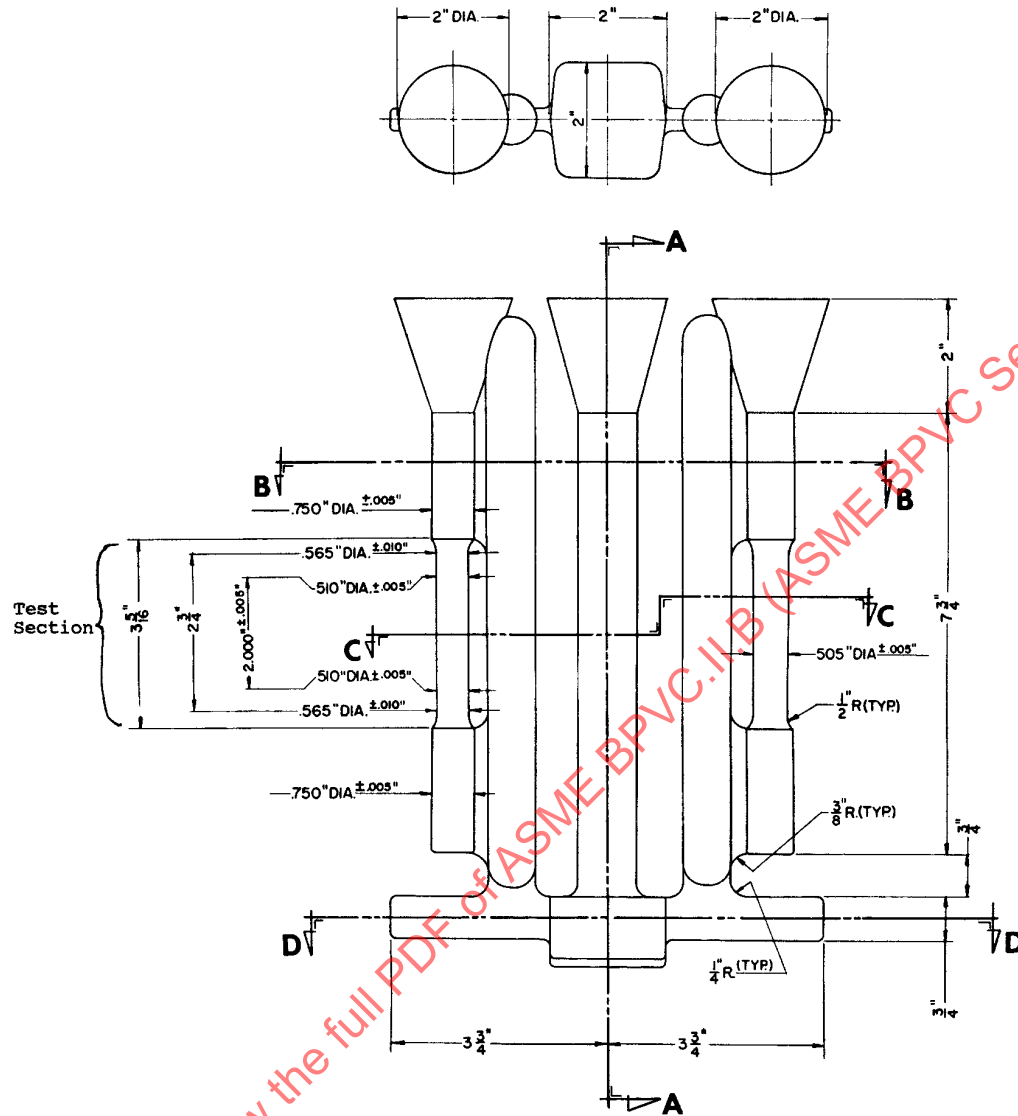
13.3 If any test specimen shows defective machining or flaws, it may be discarded, in which case the purchaser and the producer shall agree upon the selection of a replacement specimen.

14. Test Methods

14.1 The tensile properties shall be determined in accordance with Test Methods B557 [B557M].

15. Retests

15.1 If the results of the tension test do not conform to the requirements prescribed in Table 2 [Table 4], test bars representative of the castings may be retested in accordance with the replacement tests and retest provisions of Test Methods B557 [B557M] and the results of retests shall conform to the requirements as to mechanical properties specified in Table 2 [Table 4].



Nominal draft angle to be 20° on all square or rectangular sections in direction transverse to parting line.

NOTE 1—Test section of test bar: this section to be gradually tapered from the ends towards the center.

FIG. 1 Tension Test Specimen Casting – (Inch Pounds)

16. Heat Treatment

16.1 Heat treatment of castings shall be performed in accordance with Practice B917/B917M.

16.2 When specified, heat treatment shall be in accordance with AMS 2771.

17. Repair of Castings

17.1 Castings may be repaired only by processes approved and agreed upon by the producer and purchaser, such as,

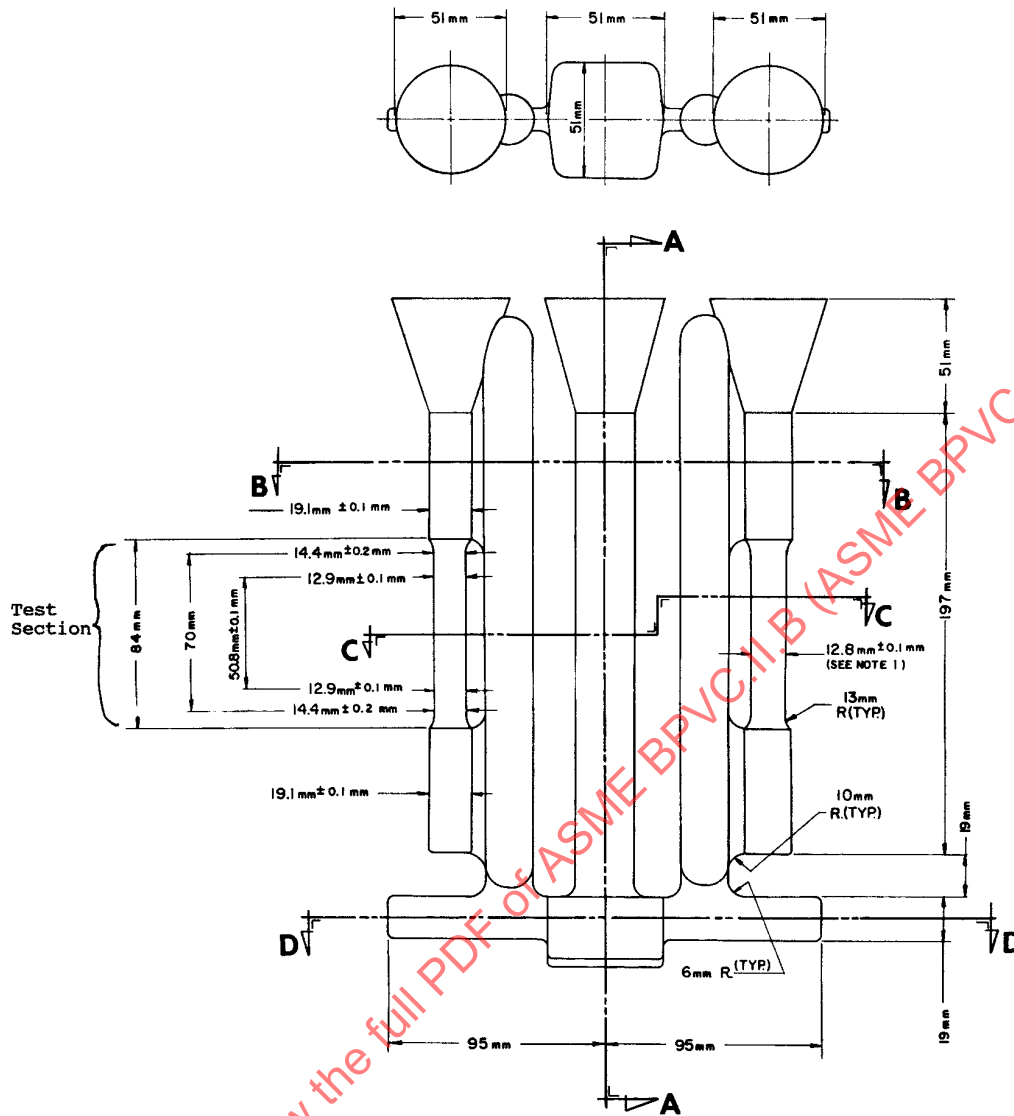
welding, impregnation, peening, blending, soldering, and so forth. Limitations on the extent and frequency of such repairs, and methods of inspection of repaired areas should also be agreed upon.

17.1.1 The welding procedure and welders shall be qualified in accordance with Section IX of the ASME BPVC.

17.2 *Repairing of Castings Produced for Governmental and Military Agencies:*

17.2.1 *Welding:*

17.2.1.1 When welding is permitted, it shall be done by methods suitable for the particular alloy. Welding methods



Nominal draft angle to be 20° on all square or rectangular sections in direction transverse to parting line.

NOTE 1—Test section of test bar: this section to be gradually tapered from the ends towards the center.

FIG. 2 Tension Test Specimen Casting – [Metric]

shall be in accordance with such specifications as are referenced on the applicable drawings, or as are required by the contract or order.

17.2.1.2 All welding shall be done by qualified welders and by methods approved by the purchaser.

17.2.1.3 When castings are to be supplied in the heat treated condition, they shall be heat treated to the required temper after welding, except that small arc welds may be performed without subsequent heat treatment upon approval of the purchaser.

17.2.1.4 Unless otherwise specified, castings that have been repaired by welding shall have the welded areas examined radiographically after all reworking and heat treatment have been completed.

17.2.1.5 All welds shall be free from cracks, lack of fusion, and meet the same quality requirements as the parent material.

17.2.1.6 Welded castings shall be marked with a symbol of three concentric circles with a letter or number designating the welder adjacent to the symbol. The outer circle of the symbol shall be no larger than ¼ in. (6 mm) in outside diameter. All welded areas shall be encircled with a ring or white paint prior to submission for final inspection.

17.2.1.7 Repair welding of castings used in naval shipboard pressure vessels, piping systems, and machinery shall be performed in accordance with requirements for repair of castings specified in NAVSEA Technical Publication S9074-AR-GIB-010/278.

17.3 *Impregnation*—When impregnation is permitted, it shall be to correct general seepage leaks only and shall not be used to correct poor foundry technique or porosity in excess of

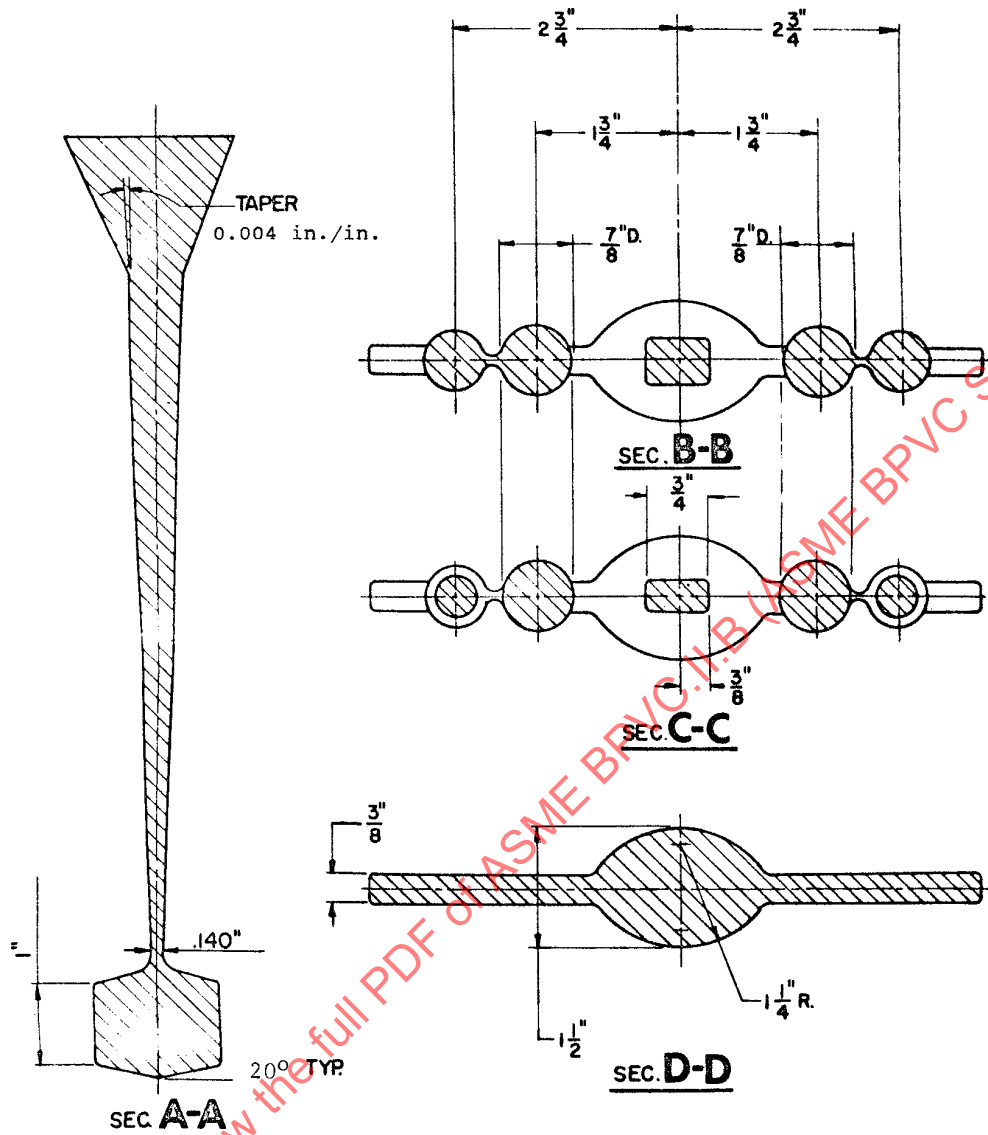


FIG. 8 Tension Test Specimen Casting (Cross Section) – (Inch Pounds)

accepted standards. It shall be accomplished in accordance with MIL-STD-276. Unless otherwise authorized by the purchaser, castings which have been impregnated shall be marked "IMP".

17.4 *Peening*—When peening is permitted, it shall be to correct localized minor seepage leaks and small surface imperfections only, or to disclose subsurface voids for the purpose of inspection. Peening will not be permitted to repair cracks, cold shuts, shrinks, misruns, defects due to careless handling, or other similar major defects. Peening may be accomplished either hot or cold and shall be performed by methods which are acceptable to the purchaser. Peened castings shall be marked with a Maltese cross approximately $\frac{1}{4}$ in. [6-mm] high.

17.5 *Blending*—Blending with suitable grinders or other tools will be permitted for the removal of surface imperfections only, and shall not result in dimensions outside the tolerances shown on the applicable drawings.

18. Source Inspection

18.1 If the purchaser elects to make an inspection of the castings at the producer's works, it shall be so stated in the contract or order.

18.2 If the purchaser elects to have an inspection made at the producer's works, the producer shall afford the inspector all reasonable facilities to satisfy him that the material is being furnished in accordance with this specification. All tests and inspections shall be so conducted as not to interfere unnecessarily with the operation of the works.

19. Foundry Inspection

19.1 Requirements such as surface finish, parting line projections, snagging projections where gates and risers were removed, and so forth, may be checked visually. It is advisable to have agreed upon observational standards representing both acceptable and unacceptable material.

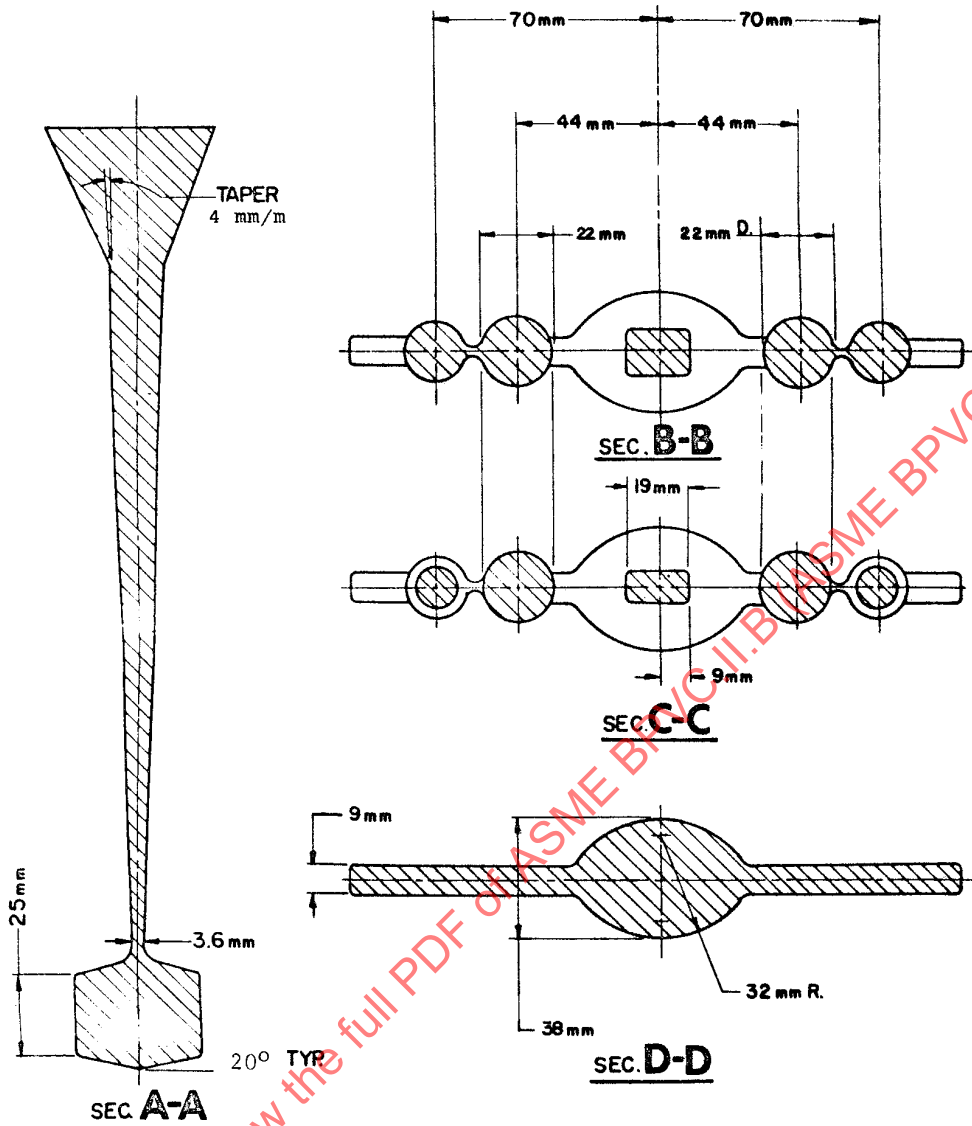


FIG. 4 Tension Test Specimen Casting Cross Section – [Metric]

19.2 Liquid Penetrant Inspection:

19.2.1 When specified, liquid penetrant inspection shall be in accordance with Test Method E165, and the required sensitivity shall be specified.

19.2.2 Acceptance standards for discontinuities shall be agreed upon, including size and frequency per unit area and location.

19.3 Radiographic Inspection:

19.3.1 Radiographic inspection shall be in accordance with Guide E94 and Film Reference Radiographs E155.

19.3.2 When agreed upon between the manufacturer and purchaser, digital radiographic inspection shall be in accordance with Guide E94 and Digital Reference Radiographs E2422.

19.3.3 Radiographic acceptance shall be in accordance with the requirements selected from Table 4. Any modifications of the table and the frequency per unit area and location of discontinuities should also be agreed upon.

19.3.4 The number, film size and orientation of radiographs, and the number of castings radiographically inspected shall be agreed upon by the producer and purchaser.

20. Identification and Repair Marking for Castings Produced for Government and Military Agencies

20.1 *Identification*—Unless otherwise specified, each casting shall be marked with the applicable drawing or part number. The marking shall consist of raised Arabic numbers, and when applicable upper-case letters, cast integral. The

location of the identification marking shall be as specified on the applicable drawing. When the location is not specified on the drawing, the drawing or part number, or both, shall be placed in a location mutually agreeable to the purchaser and producer.

20.2 *Lot Identification*—When practical, each casting shall also be marked with the melt or inspection lot number.

20.3 *Lot*—A lot shall consist of all of the cleaned castings poured from the same heat or melt when subsequent heat treatment is not required.

20.3.1 When the castings consist of alloys that require heat treatment, the lot shall consist of all castings from the same melt or heat that have been heat treated in the same furnace charge, or if heat treated in a continuous furnace, all castings from the same melt or heat that are discharged from the furnace during a 4-hour period.

20.4 *Repair Marking*—All identification markings indicating repairs as specified in 19.1, 19.2, and 19.3 shall be made with a waterproof marking fluid.

21. Rejection and Rehearing

21.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer promptly and in writing. In case of dissatisfaction with the results of the test, the producer may make claim for a rehearing.

22. Certification

22.1 The producer shall furnish to the purchaser a certificate stating that each lot has been sampled, tested, and

inspected in accordance with this specification, and has met the requirements. In addition, all test reports required by this specification shall be supplied with the certification.

23. Packaging, Marking, and Shipping

23.1 The material shall be packaged in such a manner as to prevent damage in ordinary handling and transportation. The type of packaging and gross weight of individual containers shall be left to the discretion of the producer unless otherwise agreed upon. Packaging methods and containers shall be so selected as to permit maximum utility of mechanical equipment in unloading and subsequent handling. Each package or container shall contain only one part number, alloy, and temper of material when packaged for shipment unless otherwise agreed upon.

23.2 Each package or container shall be marked with the purchase order number, part number, quantity, specification number, alloy and temper, gross and net weights, and the name of the producer.

23.3 Packages or containers shall be such as to ensure acceptance by common or other carriers for safe transportation at the lowest rate to the point of delivery.

23.4 When specified in the contract or purchase order, material shall be preserved, packaged, and packed in accordance with the requirement of Practices B660. The applicable levels shall be as specified in the contract or order. Marking for shipment of such material shall be in accordance with Fed. Std. No. 123 or Practice D3951 for civil agencies and MIL-STD-129 for military agencies.

24. Keywords

24.1 aluminum; permanent mold castings

ANNEXES

(Mandatory Information)

A1. BASIS FOR INCLUSION OF PROPERTY LIMITS

A1.1 Limits are established at a level at which a statistical evaluation of the data indicates that 99 % of the population obtained from all standard material meets the limit with 95 % confidence. For the products described, mechanical property limits for the respective size ranges are based on the analyses of at least 100 data from standard production material with no

more than ten data from a given lot. All tests are performed in accordance with the appropriate ASTM test methods. For informational purposes, refer to “Statistical Aspects of Mechanical Property Assurance” in the Related Material section of the *Annual Book of ASTM Standards*, Vol 02.02.

A2. ACCEPTANCE CRITERIA FOR INCLUSION OF NEW ALUMINUM AND ALUMINUM ALLOYS IN THIS SPECIFICATION

A2.1 Prior to acceptance for inclusion in this specification, the composition of wrought or cast aluminum or aluminum alloy shall be registered in accordance with ANSI H35.1/H35.1(M). The Aluminum Association holds the Secretariat of ANSI H35 Committee and administers the criteria and procedures for registration.

A2.2 If it is documented that the Aluminum Association could not or would not register a given composition, an alternative procedure and the criteria for acceptance shall be as follows:

A2.2.1 The designation submitted for inclusion does not utilize the same designation system as described in ANSI H35.1/H35.1(M). A designation not in conflict with other designation systems or a trade name is acceptable.

A2.2.2 The aluminum or aluminum alloy has been offered for sale in commercial quantities within the prior twelve months to at least three identifiable users.

A2.2.3 The complete chemical composition limits are submitted.

A2.2.4 The composition is, in the judgement of the responsible subcommittee, significantly different from that of any other aluminum or aluminum alloy already in this specification.

A2.2.5 For codification purposes, an alloying element is any element intentionally added for any purpose other than grain refinement and for which minimum and maximum limits are specified. Unalloyed aluminum contains a minimum of 99.00 % aluminum.

A2.2.6 Standard limits for alloying elements and impurities are expressed to the following decimal places:

Less than 0.001 %	0.000X
0.001 to but less than 0.01 %	0.00X
0.01 to but less than 0.10 %	
Unalloyed aluminum made by a refining process	0.0XX
Alloys and unalloyed aluminum not made by a refining process	0.0X
0.10 through 0.55 %	0.XX
(It is customary to express limits of 0.30 through 0.55 % as 0.X0 or 0.X5)	
Over 0.55 %	0.X, X.X, etc.
(Except that combined Si + Fe limits for 99.00 % minimum aluminum must be expressed as 0.XX or 1.XX)	

A2.2.7 Standard limits for alloying elements and impurities are expressed in the following sequence: Silicon; Iron; Copper; Manganese; Magnesium; Chromium; Nickel; Zinc; Titanium; (Note A2.1); Other Elements, Each; Other Elements, Total: Aluminum (Note A2.2).

NOTE A2.1—Additional specified elements having limits are inserted in alphabetical order of their chemical symbols between Titanium and Other Elements, Each, or are specified in footnotes.

NOTE A2.2—Aluminum is specified as *minimum* for unalloyed aluminum and as a *remainder* for aluminum alloys.

APPENDICES

(Nonmandatory Information)

X1. PROPERTIES AND CHARACTERISTICS

X1.1 Data in Table X1.1 are approximate and are supplied for general information only.

TABLE X1.1 Properties and Characteristics – (Inch-Pound Units) – (SI Units) – [Metric]

NOTE 1—indicates best of group; 5 indicates poorest of group.

Alloy		Foundry Characteristics							Other Characteristics							
ANSI ^A	UNS	Approximate Melting Range °F ^B [°C]	Resistance to Hot Cracking ^C	Pressure Tightness	Fluidity ^D	Solidification Shrinkage Tendency ^E	Normally Heat-Treated	Resistance to Corrosion ^F	Machining ^G	Polishing ^H	Electroplating ^I	Anodizing (Appearance) ^J	Chemical Oxide Coating (Protection) ^K	Strength at Elevated Temp ^L	Suitability for Welding ^M	Suitable for Brazing ^N
204.0	A02040	985 to 1200 [529-649]	4	3	3	4	yes	4	1	2	1	3	4	1	4	no
242.0	A02420	990 to 1175 [532-635]	4	4	3	4	yes	4	2	2	1	2	3	1	4	no
296.0	A02960	970 to 1170 [521-632]	4	3	3	4	yes	4	1	2	1	3	4	1	4	no
308.0	A03080	970 to 1135 [521-613]	2	2	2	3	yes	4	3	3	2	4	3	3	2	no
319.0	A03190	950 to 1125 [510-607]	2	2	2	3	yes	3	3	3	2	4	3	3	2	no
336.0 ^O	A03360	1080 to 1050 [538-566]	1	2	1	3	yes	3	4	5	4	5	2	2	2	no
332.0 ^O	A03320	970 to 1080 [521-582]	1	2	1	2	aged only	3	3	4	3	5	3	3	2	no
333.0	A03330	960 to 1085 [516-585]	2	2	2	3	no	3	3	3	3	5	3	3	2	no
354.0	A03540	1015 to 1150 [546-621]	1	1	2	2	yes	3	3	3	2	4	2	2	2	no
355.0	A03550	1015 to 1150 [546-621]	1	1	2	2	yes	3	3	3	2	4	2	2	2	no
C355.0	A33550	1015 to 1150 [546-621]	1	1	2	2	yes	3	3	3	2	4	2	2	2	no
356.0	A03560	1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
A356.0	A13560	1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
357.0		1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
A357.0	A13570	1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
E357.0		1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
F357.0		1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
359.0	A03590	1035 to 1135 [557-613]	1	1	2	1	yes	2	3	3	1	4	2	3	2	no
443.0	A04430	1065 to 1170 [574-632]	1	1	1	2	no	3	5	4	2	4	2	4	1	ltd
B443.0	A24430	1065 to 1170 [574-632]	1	1	1	2	no	2	5	4	2	4	2	4	1	ltd
A444.0	A14440	1065 to 1145 [574-618]	1	1	1	1	yes	2	5	4	2	4	2	4	1	ltd
513.0 ^O	A05130	1075 to 1180 [579-638]	4	5	5	4	no	1	1	1	4	1	1	3	5	no
535.0	A05350	1020 to 1165 [549-629]	4	5	5	5	no	1	1	1	5	1	1	3	4	no
705.0	A07050	1105 to 1180 [596-638]	5	4	4	5	aged only	2	1	1	3	1	2	5	4	yes
707.0	A07070	1085 to 1165 [585-629]	5	4	4	5	yes	2	1	1	3	1	2	5	5	yes
711.0 ^O	A07110	1120 to 1190 [604-643]	5	4	4	5	aged only	2	1	1	2	1	2	5	4	yes

TABLE X1.1 Continued

Alloy		Approximate Melting Range °F ^B [°C]	Foundry Characteristics					Other Characteristics								
ANSI ^A	UNS		Resistance to Hot Cracking ^C	Pressure Tight- ness	Fluidity ^D	Solidifi- cation Shrinkage Tendency ^E	Normally Heat- Treated	Resistance to Corrosion ^F	Machin- ing ^G	Polish- ing ^H	Electro- plating ^I	Anodizing (Appear- ance) ^J	Chemical Oxide Coating (Protection) ^K	Strength at Elevated Temp ^L	Suitability for Welding ^M	Suitable for Brazing ^N
713.0	A07130	1100 to 1185 [593-641]	5	4	4	5	aged only	2	1	1	2	1	2	5	4	yes
850.0	A08500	435 to 1200 [224-649]	5	5	5	5	aged only	3	1	1	5	4	5	^P	5	no
851.0 ^O	A08510	440 to 1165 [227-629]	4	4	5	4	yes	3	1	1	5	4	5	^P	5	no
852.0 ^O	A08520	400 to 1175 [204-635]	5	5	5	5	aged	3	1	1	5	4	5	^P	5	no

^A ASTM alloy designations are recorded in Practice B275.^B Temperatures of solidus and liquidus are indicated, pouring temperatures will be higher.^C Ability of alloy to withstand stresses from contraction while cooling through hot-short or brittle temperature range.^D Ability of liquid alloy to flow readily in mold and fill thin sections.^E Decrease in volume accompanying freezing of alloy and measure of amount of compensating feed metal required in form of risers.^F Based on resistance of alloy in standard type salt-spray test.^G Composite rating based on ease of cutting, chip characteristics, quality of finish, and tool life. Ratings, in the case of heat-treatable alloys, based on T6 temper. Other tempers, particularly the annealed temper, may have lower rating.^H Composite rating based on ease and speed of polishing and quality of finish provided by typical polishing procedure.^I Ability of casting to take and hold an electroplate applied by present standard methods.^J Rates of lightness of color, brightness, and uniformity of clear anodized coating applied in sulfuric acid electrolyte.^K Rated on combined resistance of coating and base alloy to corrosion.^L Rating based on tensile and yield strengths at temperatures up to 500°F [260°C], after prolonged heating at testing temperature.^M Based on ability of material to be fusion-welded with filler rod or same alloy.^N Refers to suitability of alloy to withstanding brazing temperatures without excessive distortion or melting.^O 336.0 formerly A332.0, 332.0 formerly F332.0, 513.0 formerly A514.0, 711.0 formerly C712.0, 851.0 formerly A850.0, 852.0 formerly B850.0.^P Not recommended for service at elevated temperatures.

X2. METRIC EQUIVALENTS

X2.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI) (IEEE/ASTM SI 10). The derived SI unit for force is the newton (N), which is defined as that force which when applied to a body having a mass of one kilogram gives it an acceleration of one metre per second squared ($N = \text{kg}\cdot\text{m}/\text{s}^2$). The derived SI unit

for pressure or stress is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

X3. INACTIVE ALLOYS

X3.1 Alloys listed as inactive by the Aluminum Association—208.0 and 222.0. Listing the composition limits, mechanical properties, and characteristics of the alloys is a

method of preserving this data should it be needed at some future date.

TABLE X3.1 Chemical Composition Limits

NOTE 1—All applicable notes and footnotes can be found in Table 1

Alloy		Aluminum	Composition, %										Other Elements	
ANSI	UNS		Silicon	Iron	Copper	Manganese	Magnesium	Chromium	Nickel	Zinc	Titanium	Vanadium	Each	Total
208.0	A02080	remainder	2.5–3.5	1.2	3.5–4.5	0.50	0.10	...	0.35	1.0	0.25	...	...	0.50
222.0	A02220	remainder	2.0	1.5	9.2–10.7	0.50	0.15–0.35	...	0.50	0.8	0.25	...	...	0.35

^ABeryllium 0.002 max

TABLE X3.2 Tensile Requirements (Inch-Pound Units)—Inactive Alloys

NOTE 1—All applicable notes and footnotes can be found in Table 2.

Alloy		Temper	Tensile Strength, min, ksi	Yield Strength (0.2 % offset), min, ksi (MPa)	Elongation in 2 in. or 4 x diameter, min, %	Typical Brinell Hard- ness, 500 kgf, 10 mm
ANSI	UNS					
208.0	A02080	T4	33.0	15.0	4.5	75
		T6	35.0	22.0	2.0	90
		T7	33.0	16.0	3.0	80
222.0	A02220	T551	30.0	...	^A	115
		T65	40.0	...	^A	140

^A Not required.

TABLE X3.3 Tensile Requirements (SI Units)—[Metric]—Inactive Alloys

NOTE 1—All applicable notes and footnotes can be found in Table 3.

Alloy		Temper	Tensile Strength, min, MPa	Yield Strength (0.2 % offset), min, MPa	Elongation in 5D, min, %	Typical Brinell Hard- ness, 500 kgf, 10 mm
ANSI	UNS					
208.0	A02080	T4	230	105	4.5	75
		T6	240	150	2.0	90
		T7	230	110	3.0	80
222.0	A02220	T551	205	...	^A	115
		T65	275	...	^A	140

^A Not required.

TABLE X3.4 Properties and Characteristics—(Inch-Pound Units) – (SI Units) –[Metric]—Inactive Alloys

NOTE 1—1 indicates best of group, 5 indicates poorest of group.

NOTE 2—All applicable notes and footnotes can be found in Table X1.1.

Alloy		Pattern Shrinkage Allowance, ^A in./ft [mm/m]	Approximate Melting Range, °F [°C]	Resistance to Hot Cracking ^E	Pressure Tightness	Fluidity ^B	Solidification Shrinkage Tendency	Normally Heat Treated	Resistance to Corrosion ^C	Machining ^D	Polishing ^F	Electroplating ^G	Anodizing (Appearance) ^H	Chemical Oxide Coating (Protection) ^A	Strength at Elevated Temperature ^B	Suitability for Welding ^C	Suitability for Brazing ^D
ANSI ^F	UNS																
208.0	A02080	5/32 [13]	970-1160 [521-627]	2	2	2	2	yes	4	3	3	2	3	3	3	2	no
222.0	A02220	5/32 [13]	965-1155 [518-624]	3	3	3	3	yes	4	1	2	1	3	4	1	4	no

SPECIFICATION FOR COPPER AND COPPER-ALLOY SEAMLESS CONDENSER TUBES AND FERRULE STOCK



SB-111/SB-111M

(Identical with ASTM Specification B111/B111M-18a except that certification and test reports have been made mandatory.)

Specification for Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock

1. Scope

1.1 This specification establishes the requirements for seamless tube and ferrule stock of copper and various copper alloys up to 3½ in. [80 mm] inclusive, in diameter, for use in surface condensers, evaporators, and heat exchangers. The following coppers and copper alloys are specified:

Copper or Copper Alloy UNS No.	Previously Used Designation	Description
C10100	OFE	Oxygen-free electronic
C10200	OF ^A	Oxygen-free without residual deoxidants
C10300	...	Oxygen-free, extra low phosphorus
C10800	...	Oxygen-free, low phosphorus
C12000	DLP ^A	Phosphorized, low residual phosphorus
C12200	DHP ^A	Phosphorized, high residual phosphorus
C14200	DPA ^A	Phosphorized, arsenical
C15630	...	Nickel Phosphorus
C19200	...	Phosphorized, 1 % iron
C23000	...	Red Brass
C28000	...	Muntz Metal
C44300	...	Admiralty Metals, B, C, and D
C44400	...	...
C44500	...	...
C60800	...	Aluminum Bronze
C61300	...	...
C61400	...	Aluminum Bronze, D
C68700	...	Aluminum Brass, B
C70400	...	95-5 Copper-Nickel
C70600	...	90-10 Copper-Nickel
C70620	...	90-10 Copper-Nickel—Welding Grade
C71000	...	80-20 Copper-Nickel
C71500	...	70-30 Copper-Nickel
C71520	...	70-30 Copper-Nickel—Welding Grade

Copper or Copper Alloy UNS No.	Previously Used Designation	Description
C71640	...	Copper-nickel-iron-manganese
C72200	...	...

^A Designations listed in Classification B224.

1.2 *Units*—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 The following safety hazards caveat pertains only to the test methods portion, Section 19, of this specification: *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. (Warning—Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Use caution when handling mercury and mercury-containing products. See the applicable product Safety Data Sheet (SDS) for additional information. The potential exists that selling mercury or mercury-containing products, or both, is prohibited by local or national law. Users must determine legality of sales in their location.)*

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 The following documents in the current issue of the *Annual Book of ASTM Standards* form a part of this specification to the extent referenced herein:

2.2 ASTM Standards:

B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
 B154 Test Method for Mercurous Nitrate Test for Copper Alloys
 B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes
 B224 Classification of Coppers
 B846 Terminology for Copper and Copper Alloys
 B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
 B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube
 E8/E8M Test Methods for Tension Testing of Metallic Materials
 E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
 E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
 E54 Test Methods for Chemical Analysis of Special Brasses and Bronzes (Withdrawn 2002)
 E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)
 E75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys (Withdrawn 2010)
 E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)
 E112 Test Methods for Determining Average Grain Size
 E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)
 E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
 E255 Practice for Sampling Copper and Copper Alloys for the Determination of Chemical Composition
 E478 Test Methods for Chemical Analysis of Copper Alloys
 E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)
 E2575 Standard Test Method for Determination of Oxygen in Copper and Copper Alloys (Withdrawn 2017)

3. Terminology

3.1 Definitions:

3.1.1 For definitions of terms relating to copper and copper alloys, refer to Terminology B846.

4. Ordering Information

4.1 Include the following specified choices when placing orders for product under this specification, as applicable:

4.1.1 ASTM Designation and year of issue;

4.1.2 Copper or Copper Alloy UNS No. Designation (see Table 1);

4.1.3 Temper (Section 7);

4.1.4 Dimensions, outside diameter, and wall thickness, whether minimum or nominal (Section 14);

4.1.5 How furnished (tube or ferrule stock);

4.1.6 Quantity—total weight or total length or number of pieces of each size; and

4.1.7 Intended application.

4.2 The following options are available but may not be included unless specified at the time of placing of the order when required:

4.2.1 DELETED

4.2.2 Hydrostatic or pneumatic test as an alternative to eddy current test (Section 13).

4.2.3 If the cut ends of the tubes do not need to be deburred (Section 15).

4.2.4 If the product is to be subsequently welded (Table 1, Footnotes G and H).

4.2.5 Residual Stress Test—Ammonia Vapor Test or Mercurous Nitrate Test (Section 12).

4.2.6 For Ammonia Vapor Test, risk level (pH value) if other than 10.

4.2.7 Heat identification or traceability details.

4.2.8 DELETED

4.2.9 DELETED

4.2.10 If a subsequent thermal treatment after straightening is required (Section 7).

4.2.11 If product is purchased for agencies of the U.S. Government (see Supplementary Requirements section of this specification for additional requirements, if required).

5. Materials and Manufacture

5.1 Materials:

5.1.1 The material of manufacture shall be a form of such purity and soundness as to be suitable for processing into the products prescribed herein.

5.1.2 When specified in the contract or purchase order that heat identification or traceability is required, the purchaser shall specify the details desired.

5.2 Manufacture:

5.2.1 The product shall be manufactured by such hot-working, cold-working, annealing, straightening, trimming, and other processes as to produce a uniform seamless tube in the finished product.

5.2.2 The product shall be hot- or cold-worked to the finished size, and subsequently annealed, when required, to meet the temper properties specified.

6. Chemical Composition

6.1 The product shall conform to the chemical composition requirements specified in Table 1.

TABLE 1 Chemical Requirements

Copper or Copper Alloy UNS No.	Composition, %												Other Named Elements
	Copper	Tin	Aluminum	Nickel, incl Cobalt	Lead, max	Iron	Zinc	Manganese	Arsenic	Antimony	Phosphorus	Chromium	
C10100	99.99 min ^A	0.0002 max	...	0.0010 max ^B	0.0005 max	0.0010 max	0.0001 max	0.00005 max	0.0005 max	0.0004 max	0.0003 max	0.0001 max	^C
C10200 ^C	99.95 min ^D	...	...	...	...	...	...	...	...	...	...	...	^C
C10300	99.95 min ^D	...	...	...	...	...	...	...	...	...	0.001–0.005	...	...
C10800	99.95 min ^D	...	...	...	...	...	...	...	...	...	0.005–0.012	...	...
C12000 ^E	99.90 min ^D	...	...	...	...	...	...	...	...	...	0.004–0.012	...	...
C12200	99.9 min ^D	...	...	...	...	...	...	...	...	...	0.015–0.040	...	...
C14200	99.4 min ^D	...	...	...	...	...	...	...	0.15–0.50	...	0.015–0.040	...	...
C15630	remainder	...	...	0.60–0.90 ^B	...	...	...	...	...	...	0.015–0.040	...	...
C19200	98.5 min	...	...	...	...	0.8–1.2	0.20 max	...	...	...	0.01–0.04	...	...
C23000	84.0–86.0	...	...	...	0.05	0.05 max	remainder	...	...	...	...	...	...
C28000	59.0–63.0	...	...	...	0.09	0.07 max	remainder	...	...	...	...	...	...
C44300	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C44400	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	0.02–0.10	...	...	...
C44500	70.0–73.0	0.9–1.2	...	...	0.07	0.06 max	remainder	...	...	...	0.02–0.10	...	...
C60800	remainder ^D	...	5.0–6.5	...	0.10	0.10 max	...	...	0.02–0.35	...	...	...	...
C61300	remainder ^D	0.20–0.50	6.0–7.5	0.15 max	0.01	2.0–3.0	0.10 max	0.20 max	...	...	0.015 max	...	^{F, G}
C61400	remainder ^D	...	6.0–8.0	...	0.01	1.5–3.5	0.20 max	1.0 max	...	...	0.015 max	...	...
C68700	76.0–79.0 ^D	...	1.8–2.5	...	0.07	0.06 max	remainder	...	0.02–0.06	...	...	...	...
C70400	remainder ^D	...	...	4.8–6.2	0.05	1.8–1.7	1.0 max	0.30–0.8	...	...	...	...	...
C70600	remainder ^D	...	...	9.0–11.0	0.05	1.0–1.8	1.0 max	1.0 max	...	...	...	...	...
C70620	86.5 min ^D	...	...	9.0–11.0	0.02	1.0–1.8	0.50 max	1.0 max	...	...	0.02 max	...	C.05 max S.02 max ^H
C71000	remainder ^D	...	...	19.0–23.0	0.05 ^H	0.50–1.0	1.0 max ^H	1.0 max	...	...	^H	...	...
C71500	remainder ^D	...	...	29.0–33.0	0.05	0.40–1.0	1.0 max	1.0 max	...	...	...	...	...
C71520	65.0 min ^D	...	...	29.0–33.0	0.02	0.40–1.0	0.50 max	1.0 max	...	...	0.02 max	...	C.05 max S.02 max
C71640	remainder ^D	...	...	29.0–32.0	0.05 ^H	1.7–2.3	1.0 max ^H	1.5–2.5	...	...	^H	...	C.06 max S.03 max ^H
C72200	remainder ^D	...	...	15.0–18.0	0.05 ^H	0.50–1.0	1.0 max ^H	1.0 max	...	...	^H	0.30–0.70	Si.03 max Ti.03 max ^H

^A This value is exclusive of silver and shall be determined by difference of "impurity total" from 100 %. "Impurity total" is defined as the sum of sulfur, silver, lead, tin, bismuth, arsenic, antimony, iron, nickel, mercury, zinc, phosphorus, selenium, tellurium, manganese, cadmium, and oxygen present in the sample.

^B Not including Cobalt.

^C Additional impurity maximums in percent for alloy C10100 shall be: bismuth 0.0001, cadmium 0.0001, oxygen 0.0005, selenium 0.0003, sulfur 0.0015, tellurium 0.0002, mercury 0.0001. For C10200, oxygen should be 0.0010 max.

^D Copper (including silver).

^E This includes oxygen-free Cu which contains P in an amount agreed upon.

^F Silicon shall be 0.10 % max.

^G When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zinc 0.05 % max, and zirconium 0.05 % max.

^H When the product is for subsequent welding applications, and so specified by the purchaser, zinc shall be 0.50 % max, lead 0.02 % max, phosphorus 0.02 % max, sulfur 0.02 % max, and carbon 0.05 % max.

6.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

6.2.1 *Copper Alloy UNS No. C19200*—Copper is the difference between the sum results of all the elements determined and 100 %. When all the elements in Table 1 are determined, their sum shall be 99.8 % minimum.

6.2.2 For alloys in which copper is listed as “remainder,” copper is the difference between the sum results of all the elements determined and 100 %. When all elements in Table 1 are determined, the sum of the results shall be as follows:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C15630	99.5
C60800	99.5
C61300	99.8
C61400	99.5
C70400	99.5
C70600 & C70620	99.5
C71000	99.5
C71500 & C71520	99.5
C71640	99.5
C72200	99.8

6.2.3 For alloys in which zinc is listed as the remainder, either copper or zinc may be taken as the difference between the sum of all the elements determined and 100 %. When all elements in Table 1 are determined, the sum of the results shall be as follows:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C23000	99.8
C28000	99.7
C44300	99.6
C44400	99.6
C44500	99.6
C68700	99.5

7. Temper

7.1 Tubes shall be furnished in the temper designations identified in Tables 2 and 3.

7.1.1 Drawn tempers H55 and H80.

7.1.2 Annealed temper O61.

7.1.3 Drawn and stress-relieved temper HR50.

7.2 Tubes for ferrule stock shall be annealed sufficiently to be fully recrystallized.

7.3 *Optional Post-Straightening Thermal Treatment*—Some tubes, when subjected to aggressive environments, may have the potential for stress-corrosion cracking failure due to the residual stresses induced during straightening processing. For such applications, it is suggested that tubes of Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 be subjected to a stress-relieving thermal treatment subsequent to straightening. If required, this must be specified on the purchase order or

TABLE 2 Tensile Requirements—Inch-Pound Values

NOTE 1—See Table 3 for tensile requirements—SI values.

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min ksi ^A	Yield Strength, ^B min ksi ^A	Elongation in 2 in., min %
	Code	Name			
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	36	30	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	45	40	...
C15630	O61	annealed	30	8	40
C19200	H55	light-drawn	40	35	...
C19200	H80	hard-drawn	48	43	...
C19200	O61	annealed	38	12	...
C23000	O61	annealed	40	12	...
C28000	O61	annealed	50	20	...
C44300, C44400, C44500	O61	annealed	45	15	...
C60800	O61	annealed	50	19	...
C61300, C61400	O61	annealed	70	30	...
C68700	O61	annealed	50	18	...
C70400	O61	annealed	38	12	...
C70400	H55	light-drawn	40	30	...
C70600, C70620	O61	annealed	40	15	...
C70600, C70620	H55	light-drawn	45	35	...
C71000	O61	annealed	45	16	...
C71500, C71520	O61	annealed	52	18	...
C71500, C71520					
Wall thicknesses up to 0.048 in., incl	HR50	drawn and stress-relieved	72	50	12
Wall thicknesses over 0.048 in.	HR50	drawn and stress-relieved	72	50	15
C71640	O61	annealed	63	25	...
C71640	HR50	drawn and stress relieved	81	58	...
C72200	O61	annealed	45	16	...
C72200	H55	light-drawn	50	45	...

^A ksi = 1000 psi.

^B At 0.5 % extension under load.

TABLE 3 Tensile Requirements—SI Values

NOTE 1—See Table 2 for tensile requirements—inch-pound values.

Copper or Copper Alloy UNS No.	Temper Designation		Tensile Strength, min MPa	Yield Strength, ^A min MPa	Elongation in 50 mm, min %
	Code	Name			
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H55	light-drawn	250	205	...
C10100, C10200, C10300, C10800, C12000, C12200, C14200	H80	hard-drawn	310	275	...
C15630	O61	annealed	205	55	40
C19200	H55	light-drawn	275	240	...
C19200	H80	hard-drawn	330	295	...
C19200	O61	annealed	260	85	...
C23000	O61	annealed	275	85	...
C28000	O61	annealed	345	140	...
C44300, C44400, C44500	O61	annealed	310	105	...
C60800	O61	annealed	345	130	...
C61300, C61400	O61	annealed	480	205	...
C68700	O61	annealed	345	125	...
C70400	O61	annealed	260	85	...
C70400	H55	light-drawn	275	205	...
C70600, C70620	O61	annealed	275	105	...
C70600, C70620	H55	light-drawn	310	240	...
C71000	O61	annealed	310	110	...
C71500, C71520	O61	annealed	360	125	...
C71500, C71520: Wall thicknesses up to 1.2 mm incl	HR50	drawn and stress-relieved	495	345	12
Wall thicknesses over 1.2 mm.	HR50	drawn and stress-relieved	495	345	15
C71640	O61	annealed	435	170	...
C71640	HR50	drawn and stress relieved	560	400	...
C72200	O61	annealed	310	110	...
C72200	H55	light-drawn	345	310	...

^A At 0.5 % extension under load.

contract. Tolerances for roundness and length, and the condition of straightness, for tube so ordered, shall meet the requirements agreed upon by the manufacturer and the purchaser.

8. Mechanical Properties

8.1 Material shall have tensile properties as prescribed in Table 2 or Table 3.

9. Grain Size for Annealed Tempers

9.1 Grain size shall be the standard requirement for all product in the annealed (O61) temper.

9.1.1 Other than Copper Alloy UNS Nos. C19200 and C28000, acceptance or rejection for all annealed products shall depend only on average grain size of the test specimen within the limits of 0.010 to 0.045 mm taken from each of two sample portions, and each specimen shall be within the limits prescribed herein when determined in accordance with Test Methods E112.

10. Performance Requirements

10.1 Expansion Test:

10.1.1 Tube specimens selected for test shall withstand the expansion shown in Table 4 when expanded in accordance with Test Method B153. The expanded tube shall show no cracking or rupture visible to the unaided eye.

10.2 Hard-drawn tubes not end annealed are not subject to this test. When tubes are specified end annealed, this test is required and shall be performed on the annealed ends of the sampled tubes.

10.3 Tubes for ferrule stock are not subject to the expansion test.

11. Flattening Test

11.1 *Test Method*—Each test specimen shall be inspected per Test Method B968/B968M.

11.2 During inspection, the flattened areas of the test-specimen shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

11.3 Tubes for ferrule stock are not subject to flattening test.

12. Residual Stress Test

12.1 A residual stress test, when specified in the purchase order, is required only for Copper Alloy UNS Nos. C23000, C28000, C44300, C44400, C44500, C60800, C61300, C61400, and C68700 and when not supplied in an annealed temper.

12.2 Unless otherwise specified, the producer shall have the option of testing the product to either the mercurous nitrate test, Test Method B154, or the ammonia vapor test, Test Method B858, as prescribed below.

12.2.1 Mercurous Nitrate Test:

12.2.1.1 **Warning**—Mercury is a definite health hazard and therefore equipment for the detection and removal of mercury vapor produced in volatilization is recommended. The use of rubber gloves in testing is advisable.

12.2.1.2 The test specimens, cut 6 in. [150 mm] in length, shall withstand without cracking, an immersion in the standard mercurous nitrate solution prescribed in Test Method B154. The test specimen shall include the finished tube end.

TABLE 4 Expansion Requirements

Temper Designation		Copper or Copper Alloy UNS No.	Expansion of Tube Outside Diameter, in Percent of Original Outside Diameter
Code	Name		
O61	annealed	C15630	40
		C19200	30
		C23000	20
		C28000	15
		C44300, C44400, C44500	20
		C60800	20
		C61300, C61400	20
		C68700	20
		C70400	30
		C70600, C70620	30
		C71000	30
		C71500, C71520	30
		C71640	30
		C72200	30
		C10100, C10200, C10300, C10800, C12000, C12200	20
H55	light-drawn	C14200	20
		C19200	20
		C70400	20
		C70600, C70620	20
		C72200	20
HR50	drawn and stress relieved	C71500, C71520	20
		C71640	20
...	hard-drawn and end annealed	C10100, C10200, C10300, C10800, C12000, C12200, C14200	30

12.2.2 Ammonia Vapor Test:

12.2.2.1 The test specimens, cut 6 in. [150 mm] in length, shall withstand without cracking, the ammonia vapor test as prescribed in Test Method B858. For the purposes of this specification, unless otherwise agreed between purchaser and supplier, the risk level identified in the Annex of Method B858, shall be specified as risk level (pH value) of 10.

13. Nondestructive Testing

13.1 Each tube shall be subjected to the eddy-current test in 13.1.1. Tubes may be tested in the final drawn, annealed, or heat-treated temper or in the drawn temper before the final anneal or heat treatment unless otherwise agreed upon by the supplier and the purchaser. The purchaser may specify either of the tests in 13.1.2 or 13.1.3 as an alternative to the eddy-current test.

13.1.1 *Eddy-Current Test*—Each tube shall be passed through an eddy-current testing unit adjusted to provide information on the suitability of the tube for the intended application. Testing shall follow the procedures of Practice E243.

13.1.1.1 The depth of the round-bottom transverse notches or the diameters of the drilled holes in the calibrating tube used to adjust the sensitivity of the test unit are shown in Tables 5 and 6, and Tables 7 and 8, respectively. Notches of less depth and smaller diameter drilled holes are acceptable to meet this requirement.

13.1.1.2 Tubes that do not actuate the signaling device of the eddy-current tester shall be considered to conform to the requirements of this test. Tubes causing irrelevant signals because of moisture, soil, and like effects may be reconditioned and retested. Such tubes, when retested to the original test parameters, shall be considered to conform if they do not cause output signals beyond the acceptable limits. Tubes causing

TABLE 5 Notch Depth—Inch-Pound Values

NOTE 1—See Table 6 for notch depth—SI values.

Tube Wall Thickness, in.	Tube Outside Diameter, in.		
	Over 1/4 to 3/4, incl	Over 3/4 to 1 1/4, incl	Over 1 1/4 to 3 1/2, incl
Over 0.017–0.032	0.005	0.006	0.007
Incl 0.032–0.049	0.006	0.006	0.0075
Incl 0.049–0.083	0.007	0.0075	0.008
Incl 0.083–0.109	0.0075	0.0085	0.0095
Incl 0.109–0.120	0.009	0.009	0.011

TABLE 6 Notch Depth—SI Values

NOTE 1—See Table 5 for notch depth—inch-pound values.

Tube Wall Thickness, mm	Tube Outside Diameter, mm		
	Over 6 to 19, incl	Over 19 to 32, incl	Over 32 to 80, incl
Over 0.4–0.8	0.13	0.15	0.18
Incl 0.8–1.3	0.15	0.15	0.19
Incl 1.3–2.1	0.18	0.19	0.20
Incl 2.1–2.8	0.19	0.22	0.24
Incl 2.8–3.0	0.23	0.23	0.28

irrelevant signals because of visible and identifiable handling marks may be retested by the hydrostatic test prescribed in 13.1.2, or the pneumatic test prescribed in 13.1.3. Tubes meeting requirements of either test shall be considered to conform if the tube dimensions are within the prescribed limits, unless otherwise agreed upon between the manufacturer and the purchaser.

13.1.2 *Hydrostatic Test*—Each tube shall stand, without showing evidence of leakage, an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi [48 MPa] as determined by the following equation for thin

TABLE 7 Diameter of Drilled Holes—Inch-Pound Values

NOTE 1—See Table 8 for diameter of drilled holes—SI values.

Tube Outside Diameter, in.	Diameter of Drilled Holes, in.	Drill No.
¼ –¾, incl	0.025	72
Over ¾ –1, incl	0.031	68
Over 1 –1¼, incl	0.036	64
Over 1¼ –1½, incl	0.042	58
Over 1½ –1¾, incl	0.046	56
Over 1¾ –2, incl	0.052	55

TABLE 8 Diameter of Drilled Holes—SI Values

NOTE 1—See Table 7 for diameter of drilled holes—inch-pound values.

Tube Outside Diameter, mm	Diameter of Drilled Holes, mm	Drill No.
6.0–19.0, incl	0.65	72
Over 19.0–25.4, incl	0.80	68
Over 25.4–31.8, incl	0.92	64
Over 31.8–38.1, incl	1.1	58
Over 38.1–44.4, incl	1.2	56
Over 44.4–50.8, incl	1.3	55

hollow cylinders under tension. The tube need not be tested at a hydrostatic pressure of over 1000 psi [7.0 MPa] unless so specified.

$$P = 2St/(D - 0.8t)$$

where:

P = hydrostatic pressure, psig [MPa];

t = thickness of tube wall, in. [mm];

D = outside diameter of the tube, in. [mm]; and

S = allowable stress of the material, psi [MPa].

13.1.3 Pneumatic Test—Each tube shall be subjected to an internal air pressure of 60 psig [400 kPa], min, for 5 s without showing evidence of leakage. The test method used shall permit easy visual detection of any leakage, such as by having the tube under water or by the pressure differential method. Any evidence of leakage shall be cause for rejection.

14. Dimensions and Permissible Variations

14.1 Diameter—The outside of the tubes shall not vary from that specified by more than the amounts shown in Table 9 or Table 10 as measured by “go” and “no-go” ring gages.

TABLE 9 Diameter Tolerances—Inch-Pound Values

NOTE 1—See Table 10 for diameter tolerances—SI values.

Outside Diameter, in.	Wall Thickness, in.				
	0.020 ^A	0.032	0.035	0.042	0.049 and Over
	0.022				
	0.025				
	0.028				
Diameter Tolerance, Plus and Minus, in.					
Up to 0.500, incl	0.003	0.0025	0.0025	0.0025	0.0025
Over 0.500–0.740, incl	0.0040	0.004	0.004	0.0035	0.003
Over 0.740–1.000, incl	0.0060	0.006	0.005	0.0045	0.004
Over 1.000–1.250, incl	...	0.009	0.008	0.006	0.0045
Over 1.250–1.375, incl	...	...	...	0.008	0.005
Over 1.375–2.000, incl	...	...	...	...	0.006
Over 2.000–3.125, incl	...	...	...	...	0.0065

^A Tolerances in this column are applicable to light drawn and drawn tempers only. Tolerances for annealed tempers shall be as agreed upon between the manufacturer and the purchaser.

Alternatively, micrometers may be used to ensure outer diameter tolerance at any one point; however, in cases of dispute, ring gauges shall be used for final determination.

14.2 Wall Thickness Tolerances:

14.2.1 Tubes Ordered to Minimum Wall—No tube wall at its thinnest point shall be less than the specified wall thickness. The maximum plus deviation from the specified wall at any point shall not exceed twice the values shown in Tables 11 and 12.

14.2.2 Tubes Ordered to Nominal Wall—The maximum plus and minus deviation from the nominal wall at any point shall not exceed the values shown in Tables 11 and 12.

14.3 Length—The length of the tubes shall not be less than that specified when measured at room temperature, but may exceed the specified value by the amounts given in Tables 13 and 14.

14.4 Squareness of Cut—The departure from squareness of the end of the tube shall not exceed the following:

Tube, Outside Diameter, in. [mm]	Tolerance, in. [mm]
Up to ½ [16], incl	0.010 in. [0.25]
Over ½ [16]	0.016 in./in. [mm/mm] of diameter

14.5 For the purpose of determining conformance with the dimensional requirements prescribed in this specification, any measured value outside the specified limiting values for any dimensions may be cause for rejection.

15. Workmanship, Finish, and Appearance

15.1 Roundness, straightness, uniformity of the wall thickness, and inner and outer surface of the tube shall be such as to make it suitable for the intended application. Unless otherwise specified on the purchase order, the cut ends of the tubes shall be deburred by use of a rotating wire wheel or other suitable tool.

15.2 Annealed-temper or thermally stress-relieved tubes shall be clean and smooth but may have a superficial, dull iridescent film on both the inside and the outside surface. Drawn-temper tubes shall be clean and smooth, but may have a superficial film of drawing lubricant on the surfaces.

TABLE 10 Diameter Tolerances—SI Values

NOTE 1—See Table 9 for diameter tolerances—inch-pound values.

Outside Diameter, mm	Wall Thickness, mm				
	0.508 ^A 0.559 0.635 0.711	0.813	0.889	1.07	1.24 and Over
Diameter Tolerance, Plus and Minus, mm					
Up to 12, incl	0.076	0.064	0.064	0.064	0.064
Over 12–18, incl	0.10	0.10	0.10	0.089	0.076
Over 18–25, incl	0.15	0.15	0.13	0.11	0.10
Over 25–35, incl	...	...	...	0.20	0.13
Over 35–50, incl	...	...	...	...	0.15
Over 50–79, incl	...	...	...	...	0.17

^A Tolerances in this column are applicable to light drawn and drawn tempers only. Tolerances for annealed tempers shall be as agreed upon between the manufacturer and the purchaser.

TABLE 11 Wall Thickness Tolerances, Plus and Minus—Inch-Pound Values

NOTE 1—See Table 12 for SI values.

Wall Thickness, in.	Outside Diameter, in.			
	Over $\frac{1}{8}$ to $\frac{5}{8}$, incl	Over $\frac{5}{8}$ to 1, incl	Over 1 to 2, incl	Over 2 to 3.125, incl
0.020, incl to 0.032	0.003	0.003	...	...
0.032, incl to 0.035	0.003	0.003	0.004	...
0.035, incl to 0.058	0.004	0.0045	0.0045	0.005
0.058, incl to 0.083	0.0045	0.005	0.005	0.0055
0.083, incl to 0.120	0.005	0.0065	0.0065	0.0065
0.120, incl to 0.134	0.007	0.007	0.0075	0.008

TABLE 12 Wall Thickness Tolerances, Plus and Minus—SI Values

NOTE 1—See Table 11 for inch-pound values.

Wall Thickness, mm	Outside Diameter, mm		
	Over 12 to 25, incl	Over 25 to 50, incl	Over 50 to 80, incl
0.50, incl to 0.80	0.08	...	...
0.80, incl to 0.90	0.08	0.10	...
0.90, incl to 1.5	0.11	0.11	0.13
1.5, incl to 2.1	0.13	0.13	0.14
2.1, incl to 3.0	0.17	0.17	0.17
3.0, incl to 3.4	0.18	0.19	0.20

TABLE 13 Length Tolerances—Inch-Pound Values

NOTE 1—See Table 14 for SI values.

Specified Length, ft	Tolerance, all Plus, in.
Up to 15	$\frac{3}{32}$
Over 15–20, incl	$\frac{1}{8}$
Over 20–30, incl	$\frac{5}{32}$
Over 30–60, incl	$\frac{3}{8}$
Over 60–100, incl ^A	$\frac{1}{2}$

^A Condenser tubes in lengths over 100 ft are not in demand at present. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.020, incl. to 0.032 shall be as agreed upon between the manufacturer or supplier and the purchaser.

16. Sampling

16.1 *Sampling*—The lot size, portion size, and selection of sample pieces shall be as follows:

TABLE 14 Length Tolerances—SI Values

NOTE 1—See Table 13 for inch-pound values.

Specified Length, mm	Tolerance, all Plus, mm
Up to 4500	2.4
Over 4500–6000, incl	3.2
Over 6000–10 000, incl	4.0
Over 10 000–18 000, incl	9.5
Over 18 000–30 000, incl ^A	13.0

^A Condenser tubes in lengths over 30 000 mm are not in demand at present. Tolerance values for the lengths will be developed as experience dictates. Tolerance values for lengths in wall thicknesses of 0.5, inclusive to 0.8 shall be as agreed upon between the manufacturer or supplier and the purchaser.

16.1.1 *Lot Size*—600 tubes or 10 000 lb [4550 kg] or fraction of either, whichever constitutes the greater weight.

16.1.2 *Portion Size*—Sample pieces from two individual lengths of finished product.

16.2 Samples taken for the purpose of the tests prescribed in the specification shall be selected in a manner that will represent correctly the material furnished and avoid needless destruction of finished material when samples representative of the material are available from other sources.

16.3 *Chemical Analysis*—Samples for chemical analysis shall be taken in accordance with Practice E255. Drillings, millings, and so forth shall be taken in approximately equal weight from each of the sample pieces selected in accordance with 16.1.2 and combined into one composite sample. The minimum weight of the composite sample that is to be divided into three equal parts shall be 150 g.

16.3.1 Alternatively to sampling procedures in accordance with Practice E255, the manufacturer shall have the option of determining conformance to chemical composition as follows: Conformance shall be determined by the manufacturer by analyzing samples taken at the time the castings are poured or samples taken from the semifinished product. If the manufacturer determines the chemical composition of the material during the course of manufacture, he shall not be required to sample and analyze the finished product. The number of samples taken for determination of chemical composition shall be as follows:

16.3.1.1 When samples are taken at the time the castings are poured, at least one sample shall be taken for each group of castings poured simultaneously from the same source of molten metal.

16.3.1.2 When samples are taken from the semifinished product, a sample shall be taken to represent each 10 000 lb [4550 kg] or fraction thereof, except that not more than one sample shall be required per piece.

16.3.1.3 Because of the discontinuous nature of the processing of castings into wrought products, it is not practical to identify specific casting analysis with a specific quantity of finished material.

16.3.1.4 In the event that heat identification or traceability is required, the purchaser shall specify the details desired at the time of order placement.

17. Number of Tests and Retests

17.1 Test:

17.1.1 *Chemical Analysis*—Chemical composition shall be determined as per the element mean of the results from at least two replicate analyses of the sample(s).

17.1.2 *Other Tests*—For tests specified in Sections 8 – 12 inclusive, specimens shall be taken from each of the pieces selected in accordance with 16.1.2.

17.1.3 If any test specimen representing a lot fails to conform to the requirements of Sections 6 – 12, two additional specimens, at the option of the manufacturer, may be taken as before, and submitted for check analysis or subjected to any tests in which the original specimen failed, but each of these specimens shall conform to the requirements specified.

17.2 Retest:

17.2.1 When requested by the manufacturer or supplier, a retest shall be permitted when results of tests obtained by the purchaser fail to conform to the requirements of the product specification.

17.2.2 The retest shall be as directed in the product specification for the initial test, except the number of test specimens shall be twice that normally required for the specified test.

17.2.3 All test specimens shall conform to the product specification requirement(s) in retest. Failure to conform shall be cause for rejection.

18. Specimen Preparation

18.1 *Flattening Test*—Prepare specimen as per Test Method B968/B968M.

18.2 *Expansion Test*—Prepare specimen as per Test Method B153.

18.3 *Mercurous Nitrate Test*—Prepare specimen as per Test Method B154.

18.4 *Ammonia Vapor Test*—Prepare specimen as per Test Method B858.

18.5 *Chemical Analysis*—Prepare specimens as per Test Method listed (see 19.1).

18.6 *Grain Size*—Prepare specimens per Test Methods E112.

18.6.1 The surface of the test specimen for microscopical examination shall approximate a radial longitudinal section of the tube.

18.7 *Tension Testing*—Tubes selected for test shall be subjected to the tension test which shall, in case of disagreement, be performed in accordance with Test Methods E8/E8M. Tension test specimen shall be of the full section of the tube and shall conform to the requirements of the section, Specimens for Pipe and Tube, of Test Methods E8/E8M, unless the limitations of the testing machine preclude the use of such a specimen. Test specimens conforming to Type No. 1 of Fig. 13, Tension Test Specimens for Large-Diameter Tubular Products, of Test Methods E8/E8M may be used when a full section specimen cannot be tested.

19. Test Methods

19.1 Chemical Analyses:

19.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following published methods, some of which may no longer be viable, which along with others not listed, may be used, subject to agreement:

Test	ASTM Designation
Chemical analysis	B170, ^A E53, E54, E62, E75, E76, E118, E478

^A Reference to Specification B170 is to the suggested chemical methods in the annex thereof. When E01 Committee has tested and published methods for assaying the low-level impurities in copper, the Specification B170 annex will be eliminated.

19.1.2 Test methods to be followed for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

19.2 Other Tests:

19.2.1 The product furnished shall conform to specified requirements when subjected to test in accordance with the following table:

Test	ASTM Designation
Grain size	E112
Expansion (pin test)	B153
Mercurous nitrate	B154
Tension	E8/E8M
Nondestructive test	E243

19.2.2 Whenever tension test results are obtained from both full-size and machined specimens and they differ, the results obtained from full-size test specimens shall be used to determine conformance to the specification requirements.

19.2.3 Tension test results on material covered by this specification are not seriously affected by variations in speed of testing. A considerable range of testing speed is permissible; however, the range of stressing to the yield strength should not exceed 100 ksi/min [690 MPa/min]. Above this yield strength the movement per minute of the testing machine head under load should not exceed 0.5 in./in. [mm/mm] of gage length (or distance between grips for full-section specimens).

20. Significance of Numerical Limits

20.1 For the purpose of determining compliance with the specified limits for requirements of the properties listed in the following table, and for dimensional tolerances, an observed value or a calculated value shall be rounded as indicated in accordance with the rounding method of Practice E29:

Property	Rounded Unit for Observed or Calculated Value
Chemical composition	nearest unit in the last right-hand significant digit used in expressing the limiting value
Tensile strength	nearest ksi, for over 10 to 100 ksi, incl
Yield strength	[nearest 5 MPa]
Elongation	nearest 1 %
Grain size—under 0.060 mm	nearest multiple of 0.005 mm
0.060 mm and over	nearest 0.01 mm

21. Inspection

21.1 The manufacturer, or supplier, shall inspect and make tests necessary to verify the furnished product conforms to specification requirements.

21.2 Source inspection of the product by the purchaser may be agreed upon between the manufacturer, or supplier, and the purchaser as part of the purchase order. In such case, the nature of the facilities needed to satisfy the inspector, representing the purchaser, that the product is being furnished in accordance with the specification shall be included in the agreement. All testing and inspection shall be conducted so as not to interfere unnecessarily with the operation of the works.

21.3 When mutually agreed upon, the manufacturer, or supplier, and the purchaser shall conduct the final inspection simultaneously.

22. Rejection and Rehearing

22.1 Rejection:

22.1.1 Product that fails to conform to the specification requirements when tested by the purchaser or purchaser's agent shall be subject to rejection.

22.1.2 Rejection shall be reported to the manufacturer or supplier promptly. In addition, a written notification of rejection shall follow.

22.1.3 In case of dissatisfaction with results of the test upon which rejection is based, the manufacturer, or supplier, shall have the option to make claim for a rehearing.

22.2 Rehearing:

22.2.1 As a result of product rejection, the manufacturer, or supplier, shall have the option to make claim for a retest to be conducted by the manufacturer, or supplier, and the purchaser. Samples of the rejected product shall be taken in accordance with the product specification and subjected to test by both parties using the test method(s) specified in the product specification, or alternately, upon agreement of both parties, an independent laboratory may be selected for the test(s) using the test method(s) specified in the product specification.

23. Certification

23.1 The purchaser shall be furnished certification that samples representing each lot have been either tested or inspected as directed in this specification and requirements have been met.

23.2 DELETED

24. Test Report

24.1 A report of test results shall be furnished.

25. Packaging and Package Marking

25.1 The material shall be separated by size, composition, and temper, and prepared for shipment in such a manner as to ensure acceptance by common carrier for transportation and to afford protection from the normal hazards of transportation.

25.2 Each shipping unit shall be legibly marked with the purchase order number, metal or alloy designation, temper, size, shape, total length or piece count, or both, and name of supplier. The specification number shall be shown, when specified.

26. Keywords

26.1 condenser tube; copper; copper alloys; evaporator; ferrule stock; heat exchanger; seamless tube; UNS No. C10100; UNS No. C10200; UNS No. C10300; UNS No. C10800; UNS No. C12000; UNS No. C12200; UNS No. C14200; UNS No. C15630; UNS No. C19200; UNS No. C23000; UNS No. C28000; UNS No. C44300; UNS No. C44400; UNS No. C44500; UNS No. C60800; UNS No. C61300; UNS No. C61400; UNS No. C68700; UNS No. C70400; UNS No. C70600; UNS No. C70620; UNS No. C71000; UNS No. C71500; UNS No. C71520; UNS No. C71640; UNS No. C72200

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

S1.1.3 *Military Specification:*

B900 Specification for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

S2. Quality Assurance

S2.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the

purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of ASTM B900.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX

(Nonmandatory Information)

X1. DENSITY OF COPPER AND COPPER ALLOYS

X1.1 The densities of the alloys covered by this specification are given in Table X1.1.

TABLE X1.1 Densities

NOTE 1—This information is for reference only.

Copper or Copper Alloy UNS No.	Density, lb/in. ³	Density, g/cm ³
C10100, C10200, C10300, C10800, C12000, C12200, C14200	0.323	8.94
C15630	0.320	8.87
C19200	0.320	8.86
C23000	0.316	8.75
C28000	0.303	8.39
C44300, C44400, C44500	0.308	8.53
C60800	0.295	8.17
C61300, C61400	0.285	7.89
C68700	0.301	8.33
C70400	0.323	8.94
C70600, C70620	0.323	8.94
C71000	0.323	8.94
C71500, C71520	0.323	8.94
C71640	0.323	8.94
C72200	0.323	8.94

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SPECIFICATION FOR NICKEL-COPPER ALLOY (UNS N04400) PLATE, SHEET, AND STRIP



SB-127

(Identical with ASTM Specification B127-05 (2014) except that certification has been made mandatory.)

SPECIFICATION FOR NICKEL-COPPER ALLOY (UNS N04400) PLATE, SHEET, AND STRIP



SB-127

[Identical with ASTM Specification B 127-05(2014) except that certification has been made mandatory.]

1. Scope

1.1 This specification covers rolled nickel-copper alloy (UNS N04400) plate, sheet, and strip.

1.2 The values stated in inch-pound units are to be regarded as the standard. The other values given are for information only.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

B 906 Specification for General Requirements for Flat-Rolled Nickel and Nickel Alloys Plate, Sheet, and Strip
E 140 Hardness Conversion Tables for Metals
F 155 Test Method for Temper of Strip and Sheet Metals for Electronic Devices (Spring-Back Method)

2.2 Federal Standards:

Fed. Std. No. 102 Preservation, Packaging, and Packing Levels
Fed. Std. No. 123 Marking for Shipment (Civil Agencies)
Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys

2.3 Military Standards:

MIL-STD-129 Marking for Shipment and Storage
MIL-STD-271 Nondestructive Testing Requirements for Metals

3. Terminology

3.1 *Descriptions of Terms Specific to This Standard* — The terms given in Table 1 shall apply.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 906 unless otherwise provided herein.

5. Ordering Information

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

5.1.1 *Alloy* — Name or UNS number (see Table 2).

5.1.2 *ASTM designation*, including year of issue.

5.1.3 *Condition* — See 7.1, 7.2, and Appendix X1.

5.1.4 *Finish* — See Appendix X1.

5.1.5 *Dimensions* — Thickness, width, and length.

TABLE 1
PRODUCT DESCRIPTION

Product	Thickness, in. (mm)
Hot-rolled plate ^A	$\frac{3}{16}$ and over
Hot-rolled sheet ^A	0.018 to 0.250 (0.46 to 6.4), incl
Cold-rolled sheet ^B	0.018 to 0.250 (0.46 to 6.4), incl
Cold-rolled strip ^B	0.005 to 0.250 (0.13 to 6.4), incl

^A Material $\frac{3}{16}$ to $\frac{1}{4}$ in. (4.8 to 6.4 mm), incl, in thickness may be furnished as sheet or plate provided the material meets the specification requirements for the condition ordered.

^B Material under 48 in. (1219 mm) in width may be furnished as sheet or strip provided the material meets the specification requirements for the condition ordered.

TABLE 2
CHEMICAL REQUIREMENTS

Element	Composition, %
	Alloy N04400
Nickel, min ⁴	63.0
Copper	28.0 to 34.0
Iron, max	2.5
Manganese, max	2.0
Carbon, max	0.3
Silicon, max	0.5
Sulfur, max	0.024

⁴ Element shall be determined arithmetically by difference.

5.1.6 Quantity.

5.1.7 Optional Requirements:

5.1.7.1 Sheet and Strip — Whether to be furnished in coil, in cut straight lengths, or in random straight lengths.

5.1.7.2 Strip — Whether to be furnished with commercial slit edge, square edge, or round edge.

5.1.7.3 Plate — Whether to be furnished specially flattened (7.2); also how plate is to be cut (8.2.1 and 8.3.2).

5.1.8 Fabrication Details — Not mandatory but helpful to the manufacturer.

5.1.8.1 Welding or Brazing — Process to be employed.

5.1.8.2 Plate — Whether material is to be hot-formed.

5.1.9 Certification — Certification and a report of test results are required (see Specification B 906, section on Material Test Report and Certification).

5.1.10 Samples for Product (Check) Analysis — Whether samples for product (check) analysis should be furnished (see Specification B 906, section on Sampling).

5.1.11 Purchaser Inspection — If the purchaser wishes to witness the tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (see Specification B 906, section on Inspection).

6. Chemical Composition

6.1 The material shall conform to the requirements as to chemical composition prescribed in Table 2.

6.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations prescribed in Specification B 906.

7. Mechanical and Other Requirements

7.1 Mechanical Properties — The material shall conform to the requirements for mechanical properties prescribed in Table 3.

7.2 Deep-Drawing and Spinning Quality Sheet and Strip — The material shall conform to the requirements for grain size and hardness properties prescribed in Table 4.

7.2.1 The mechanical properties of Table 3 do not apply to deep-drawing and spinning quality sheet and strip.

8. Dimensions and Permissible Variations

8.1 Weight:

8.1.1 For calculations of mass or weight a density of 0.319 lb/in.³ (8.83 g/cm³) shall be used.

8.2 Thickness:

8.2.1 Plate — For plate up to 2 in. (50.8 mm) inclusive, in thickness, the permissible variation, under the specified thickness and permissible excess in overweight shall not exceed the amounts prescribed in Specification B 906, see Permissible Variations in Thickness and Overweight of Rectangular Plates Table.

8.2.2 Plate — For plate over 2 in. (50.8 mm) in thickness, the permissible variations over the specified thickness shall not exceed the amounts prescribed in Specification B 906, see Permissible Variations in Thickness for Rectangular Plates Over 2 in. (51 mm) in Thickness Table.

8.2.3 Sheet and Strip — The permissible variations in thickness of sheet and strip shall be prescribed in Specification B 906, see Permissible Variations in Thickness of Sheet and Strip Table. The thickness of strip and sheet shall be measured with the micrometer spindle $\frac{3}{8}$ in. (9.5 mm) or more from either edge for material 1 in. (25.4 mm) or over in width and at any place on the strip under 1 in. in width.

8.3 Width or Diameter:

8.3.1 Plate — The permissible variations in width of rectangular plates and diameter of circular plates shall be as prescribed in Specification B 906, see Permissible Variations in Width of Sheared, Plasma Torch-Cut, and Abrasive-Cut Rectangular Plate Table and Permissible Variations in Diameter for Circular Plates Table.

8.3.2 Sheet and Strip — The permissible variations in width for sheet and strip shall be as prescribed in Specification B 906, see Permissible Variations in Width of Sheet and Strip Table.

8.4 Length:

8.4.1 Sheet and strip of all sizes may be ordered to cut lengths in which case, a variation of $\frac{1}{8}$ in. (3.2 mm) over the specified length shall be permitted.

8.4.2 Permissible variations in length of rectangular plate shall be as prescribed in Specification B 906, see Permissible Variations in Length of Sheared, Plasma Torch-Cut, and Abrasive-Cut Rectangular Plate Table.

TABLE 3
MECHANICAL PROPERTIES FOR PLATE, SHEET, AND STRIP (ALL THICKNESSES AND SIZES UNLESS OTHERWISE INDICATED)

Condition (Temper)	Tensile Strength, min, psi (MPa)	Yield Strength ^A (0.2% offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, or 4D, min, %	Rockwell Hardness (B Scale) ^{B,C}
Hot-Rolled Plate				
Annealed	70 000 (485)	28 000 (195)	35	...
As-rolled ^{D,E}	75 000 (515)	40 000 (275)	25	...
Hot-Rolled Sheet				
Annealed	70 000 (485)	28 000 (195)	35	...
Cold-Rolled Sheet				
Annealed	70 000 to 85 000 (485 to 585)	28 000 (195)	35	...
Quarter-hard	...	...	...	73 to 83
Half-hard	...	...	...	82 to 90
Hard	100 000 (690)	90 000 (620)	2	...
Cold-Rolled Strip				
Annealed	70 000 to 85 000 (485 to 585) ^F	28 000 (195)	35 ^F	...
Skin hard	...	...	...	68 to 73
Quarter-hard	...	...	...	73 to 83
Half-hard	...	...	...	82 to 90
Three-quarter-hard	...	...	...	89 to 94
Hard	100 000 (690) ^F	90 000 (620)	2 ^F	...
Spring temper	...	...	...	98 min

^A Yield strength requirements do not apply to material under 0.020 in. (0.51 mm) in thickness.

^B For Rockwell or equivalent hardness conversions see Hardness Conversion Tables E 140.

^C Caution should be observed in using the Rockwell test on thin material, as the results may be affected by specimen thickness. For thicknesses under 0.050 in. (1.3 mm), the use of the Rockwell superficial or the Vickers hardness test is suggested.

^D As-rolled plate may be given a stress-relieving heat treatment subsequent to final rolling.

^E As-rolled plate specified "suitable for hot forming" shall be furnished from heats of known good hot-malleability characteristics (see X1.2.2). There are no applicable tensile or hardness requirements for such material.

^F Not applicable for thickness under 0.010 in. (0.25 mm).

8.5 Straightness:

8.5.1 The edgewise curvature (depth of chord) of flat sheet, strip, and plate shall not exceed 0.05 in. multiplied by the length in feet (0.04 mm multiplied by the length in centimetres).

8.5.2 Straightness for coiled material is subject to agreement between the manufacturer and the purchaser.

8.6 Edges:

8.6.1 When finished edges of strip are specified in the contract or purchase order, the following descriptions shall apply:

8.6.1.1 Square-edge strip shall be supplied with finished edges, with sharp, square corners, and without bevel or rounding.

8.6.1.2 Round-edge strip shall be supplied with finished edges, semicircular in form, and the diameter of the circle forming the edge being equal to the strip thickness.

8.6.1.3 When no description of any required form of strip edge is given, it shall be understood that edges such as those resulting from slitting or shearing will be acceptable.

8.6.1.4 Sheet shall have sheared or slit edges.

8.6.1.5 Plate shall have sheared or cut (machined, abrasive-cut, powder-cut, or inert-arc-cut) edges, as specified.

8.7 Squareness (Sheet) — For sheets of all thicknesses, the angle between adjacent sides shall be $90 \pm 0.15^\circ$ ($\frac{1}{16}$ in. in 24 in.) (1.6 mm in 610 mm).

8.8 Flatness:

8.8.1 There shall be no flatness requirements for "deep drawing quality," "spinning quality," or "as-rolled," sheet and strip (see X1.4).

8.8.2 Standard flatness tolerances for plate shall conform to the requirements prescribed in Table 5. "Specially

TABLE 4
GRAIN SIZE AND HARDNESS FOR COLD-ROLLED, DEEP-DRAWING, AND SPINNING QUALITY SHEET AND STRIP

Thickness, in. (mm)	Calculated Diameter of Average Grain Section, max		Corresponding ASTM Micro- Grain Size No.	Rockwell B ^{A,B} Hardness, max
	mm	in.		
Sheet (56 in. (1420 mm) Wide and Under)				
0.050 (1.3) and under	0.075	0.0030	4.5	76
Over 0.050 to 0.250 (1.3 to 6.4), incl	0.110	0.0043	3.5	76
Strip (12 in. (305 mm) Wide and Under) ^C				
0.005 ^D to 0.015 (0.13 to 0.38), incl	0.022	0.0009	8 ^E	76 ^E
Over 0.015 to 0.024 (0.38 to 0.61), incl	0.060	0.0024	5.5	76
Over 0.024 to 0.125 (0.61 to 3.2), incl	0.075	0.0030	4.5	76

^A For Rockwell or equivalent hardness conversions see Hardness Conversion Tables E 140.

^B Caution should be observed in using the Rockwell test on thin material as the results may be affected by specimen thickness. For thicknesses under 0.050 in. (1.3 mm), the use of the Rockwell superficial or the Vickers hardness test is suggested.

^C Sheet requirements in Table 4 apply to strip thicknesses over 0.125 in. (3.2 mm), and for all thicknesses of strip over 12 in. (305 mm) in width.

^D For ductility evaluations for strip under 0.005 in. (0.13 mm) in thickness, the spring-back test such as described in Test Method F 155 is often used and the manufacturer should be consulted.

^E Accurate grain size and hardness determinations are difficult to make on strip under 0.005 in. (0.13 mm) in thickness and are not recommended.

TABLE 5
PERMISSIBLE VARIATIONS FROM FLATNESS OF RECTANGULAR, CIRCULAR, AND SKETCH PLATES

Specified Thickness	Permissible Variations from a Flat Surface for Thickness and Widths Given, in. (mm)								144 (3660) and over
	To 48 (1220), excl	48 to 60 (1220 to 1520), excl	60 to 72 (1520 to 1830), excl	72 to 84 (1830 to 2130), excl	84 to 96 (2130 to 2440), excl	96 to 108 (2440 to 2740), excl	108 to 120 (2740 to 3050), excl	120 to 144 (3050 to 3660), excl	
Inches									
3 ¹ / ₁₆ to 1 ¹ / ₄ , excl	3 ³ / ₄	1 ¹ / ₁₆	1 ¹ / ₄	1 ³ / ₈	1 ⁵ / ₈	1 ⁵ / ₈	...	...	...
1 ¹ / ₄ to 3 ¹ / ₈ , excl	1 ¹¹ / ₁₆	3 ³ / ₄	1 ¹⁵ / ₁₆	1 ¹ / ₈	1 ³ / ₈	1 ⁷ / ₁₆	1 ⁹ / ₁₆	1 ⁷ / ₈	...
3 ¹ / ₈ to 1 ¹ / ₂ , excl	1 ¹ / ₂	9 ¹ / ₁₆	1 ¹ / ₁₆	3 ¹ / ₄	1 ⁵ / ₁₆	1 ¹ / ₈	1 ¹ / ₄	1 ¹ / ₁₆	1 ³ / ₄
1 ¹ / ₂ to 3 ³ / ₄ , excl	1 ¹ / ₂	9 ¹ / ₁₆	5 ⁵ / ₈	1 ¹³ / ₁₆	1 ¹ / ₈	1 ¹ / ₈	1 ¹ / ₈	1 ³ / ₈	1 ³ / ₈
3 ³ / ₄ to 1, excl	1 ¹ / ₂	9 ¹ / ₁₆	5 ⁵ / ₈	5 ⁵ / ₈	3 ³ / ₄	1 ¹³ / ₁₆	1 ¹⁵ / ₁₆	1	1 ¹ / ₈
1 to 2, excl	1 ¹ / ₂	9 ¹ / ₁₆	9 ¹ / ₁₆	9 ¹ / ₁₆	1 ¹¹ / ₁₆	1 ¹¹ / ₁₆	1 ¹¹ / ₁₆	3 ³ / ₄	1
2 to 4, incl	1 ¹ / ₄	5 ¹ / ₁₆	3 ³ / ₈	7 ¹ / ₁₆	1 ¹ / ₂	9 ¹ / ₁₆	5 ⁵ / ₈	3 ³ / ₄	7 ⁷ / ₈
Millimetres									
4.8 to 6.4, excl	19.0	27.0	31.7	34.9	41.3	41.3	...	...	...
6.4 to 9.5, excl	17.5	19.0	23.8	28.6	35.0	36.5	39.7	47.6	...
9.5 to 12.7, excl	12.7	14.3	17.5	19.0	23.8	28.6	31.7	35.0	44.4
12.7 to 19.0, excl	12.7	14.3	15.9	15.9	20.6	28.6	28.6	28.6	34.9
19.0 to 25.4, excl	12.7	14.3	15.9	15.9	19.0	20.6	23.8	25.4	28.6
25.4 to 50.8, excl	12.7	14.3	14.3	14.3	17.5	17.5	17.5	19.0	25.4
50.8 to 101.6, incl	6.4	7.9	9.5	11.1	12.7	14.3	15.9	19.0	22.2

NOTE 1 — Permissible variations apply to plates up to 12 ft (366 cm) in length, or to any 12 ft or longer plates.

NOTE 2 — If the longer dimension is under 36 in. (914 mm), the permissible variation is not greater than 1/4 in. (6.4 mm).

NOTE 3 — The shorter dimension specified is considered the width, and the permissible variation in flatness across the width does not exceed the tubular amount of that dimension.

NOTE 4 — The maximum deviation from a flat surface does not customarily exceed the tabular tolerance for the longer dimension specified.

flattened” plate when so specified, shall have permissible variations in flatness as agreed upon between the manufacturer and the purchaser.

9. Workmanship, Finish, and Appearance

9.1 The material shall be uniform in quality and temper, smooth, commercially straight or flat, and free of injurious imperfections.

9.2 *Sheet, Strip, and Plate* — Sheet, strip, and plate supplied in the conditions and finishes as listed in the appendix may be ground or machined to remove surface imperfections, provided such removal does not reduce the material below the minimum specified dimensions. Surface eliminated depressions shall be faired smoothly into the surrounding material. The removal of a surface imperfection shall be verified by the method originally used to detect the imperfection.

10. Product Marking

10.1 Each plate, sheet, or strip shall be marked on one face with the specification number, alloy, condition (temper), heat number, manufacturer’s identification, and size. The markings shall not have a deleterious effect on the material or its performance and shall be sufficiently stable to withstand normal handling.

10.2 When applicable, each bundle or shipping container shall be marked with the name of the material, condition (temper), this specification number, alloy, size, consignor and consignee address, contract or order number, and such other information as may be defined in the contract or order.

11. Keywords

11.1 N04400; plate; sheet; strip

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein. Federal Standard No. 102, No. 123, No. 182, and Military Standard MIL-STD-129.

S2. Chemical Composition

S2.1 The material shall conform to the composition limits specified in Table 2 except as specified in Table S2.1.

S3. Mechanical Properties

S3.1 Mechanical property requirements for quarter hard cold-rolled strip $\frac{1}{4}$ in. thick and less shall be as specified in Table S3.1.

S4. Nondestructive Tests

S4.1 When specified by the purchaser, each piece of each lot shall be inspected. The purchaser shall specify if one or both tests are required.

TABLE S2.1
CHEMICAL REQUIREMENTS

Element	Composition Limits, %
Carbon	0.2 max.
Sulfur	0.015 max.
Aluminum	0.5 max.
Lead	0.006 max.
Tin	0.006 max.
Zinc	0.02 max.
Phosphorous	0.02 max.

TABLE S3.1
MECHANICAL PROPERTIES FOR QUARTER-HARD
COLD ROLLED STRIP

Tensile Strength, min, psi (MPa)	78 000–85 000 (538–586)
Yield Strength, min, psi (MPa) (0.2% offset)	45,000 (310)
Elongation in 2 in., 50 mm, or 4D, min, %	20

S4.2 Ultrasonic Tests:

S4.2.1 General Requirements:

S4.2.1.1 Ultrasonic testing shall be performed in accordance with MIL-STD-271 as modified by the requirements specified herein.

S4.2.1.2 Acoustic compatibility between the production material and the calibration standard material shall be within 75%. If the acoustic compatibility is within 25%, no gain compensation is required for the examination. If acoustic compatibility difference is between 25% and 75%, a change in the gain or dB controls shall be accomplished to compensate for the differences in acoustic compatibility. This method cannot be used if the ultrasonic noise level exceeds 50% of the rejection value.

S4.2.2 Calibration:

S4.2.2.1 Longitudinal Wave — The longitudinal wave test shall be calibrated on a flat-bottomed reference hole of a given diameter in accordance with Table S4.1 for specified material thickness drilled either into the piece to be tested or into a separate defect-free specimen of the same size (within $\pm \frac{1}{8}$ in. (3.18 mm)), shape, material, and condition, or acoustically similar material. Holes are to be drilled to midsection and the bottom of the hole shall be parallel to the entrant surface. The ultrasonic test instrument shall be adjusted so that the response from the reference hole shall not be less than 25% and not more than 75% of screen height.

S4.2.2.2 Recalibration — During quality conformance inspection, any realignment of the search unit that will cause a decrease in the calibrated sensitivity and resolution, or both, or any change in search unit, couplant, instrument settings, or scanning speed from that used for calibration shall require recalibration. Recalibration shall be performed at least once per 8 h shift.

S4.2.3 Procedure — Paragraph S4.2.3.1 describes the requirements for plate. Sheet and strip shall be excluded from these requirements.

TABLE S4.1
ULTRASONIC TESTING REFERENCE HOLE FOR PLATE

Material Thickness, in. (mm)	Hole Diameter, in. (mm)
Up to and including 4 (102)	$\frac{1}{4}$ (6.4)
Over 4 (102)	$\frac{1}{2}$ (12.7)

S4.2.3.1 Plate — Plate shall be inspected by the longitudinal wave technique using the contact or immersion method. For contact, the scanning shall be on a 24 in. grid and one diagonal in each grid. For immersion, the scanning shall be continuous on a 12 in. grid. For either method, the search shall be expanded to determine the full extent of any rejectable indication if the material is to be offered on a waiver basis.

S4.2.4 Acceptance Criteria:

S4.2.4.1 Longitudinal Wave — Any material that produces indications equal to or larger than the response from the reference hole, or that produces a complete loss of back reflection shall be rejected. Material shall be tested using a square, rectangular, or circular transducer having an effective area of one square inch or less, but no dimension shall be smaller than the diameter of the reference hole. In the event of disagreement on the degree of back reflection loss, it shall be determined by the contact method using a 1 to 1 $\frac{1}{8}$ in. (25.4 to 28.6 mm) diameter transducer or one whose area falls within this range.

S4.2.4.2 Reference Notch Removal — If reference notches or flat-bottomed holes are made in the material to be tested, they shall be so located that their subsequent removal will not impair the suitability of the material for its intended use.

S4.3 Liquid Penetrant Inspection:

S4.3.1 Procedure — Liquid penetrant inspection shall be in accordance with MIL-STD-271.

S4.3.2 Surface Requirements — The surface produced by hot working is not suitable for liquid penetrant testing. Therefore, liquid penetrant testing will not be applicable to products ordered with a hot finished surface.

S4.3.3 Acceptance Criteria — Linear defects revealed by liquid penetrant inspection shall be explored by grinding or other suitable means. Depth of defects shall not exceed the dimensional tolerance of the material.

S5. Quality Assurance

S5.1 Responsibility for Inspection — Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S6. Identification Marking

S6.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 182 except that the ASTM specification number and the alloy number shall be used.

S7. Preparation for Delivery

S7.1 Preservation, Packaging, Packing:

S7.1.1 Military Agencies — The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, or packed, Level A, B, or C as specified in the contract or purchase order.

S7.1.2 Civil Agencies — The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S7.2 Marking:

S7.2.1 Military Agencies — In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S7.2.2 Civil Agencies — In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX

(Nonmandatory Information)

X1. CONDITIONS AND FINISHES

X1.1 Scope

X1.1.1 This appendix lists the conditions and finishes in which plate, sheet, and strip are normally supplied. These are subject to change and the manufacturer should be consulted for the latest information available.

X1.2 Plate, Hot-Rolled

X1.2.1 Annealed — Soft with an oxide surface and suitable for heavy cold forming. Available with a descaled surface, when so specified.

X1.2.2 As-Rolled — With an oxide surface. Available with a descaled surface, when so specified. Suitable for flat work, mild forming, or tube sheets. When intended for tube sheets, specify that plates are to be specially flattened. When intended for hot forming, this should be indicated on the purchase order so that the manufacturer may select appropriate material.

X1.3 Plate, Cold-Rolled

X1.3.1 Annealed — Soft with an oxide surface; available with a descaled surface when so specified.

X1.4 Sheet, Hot-Rolled

X1.4.1 Annealed, and Pickled — Soft with a pickled matte finish. Properties similar to X1.5.1 but with broader thickness tolerances. Not suggested for applications where the finish of a cold-rolled sheet is considered essential, or for deep drawing or spinning.

X1.5 Sheet and Strip, Cold-Rolled

X1.5.1 Annealed — Soft with a pickled or bright annealed finish.

X1.5.2 Deep-Drawing or Spinning Quality — Similar to X1.5.1, except furnished to controlled hardness and grain size and lightly leveled.

X1.5.3 Skin Hard — Similar to X1.5.1 but given a light cold reduction to hardness range shown in Table 3.

X1.5.4 Quarter-Hard — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.5 Half-Hard — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.6 Three-Quarter Hard — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.7 Hard — Cold rolled to the tensile requirements indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.8 Spring Temper — Cold rolled to the minimum hardness indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

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SPECIFICATION FOR SEAMLESS BRASS TUBE



SB-135/SB-135M

(Identical with ASTM Specification B135/B135M-17 except for revisions to para. 8.2 and Note 1. Mechanical property requirements of Note 1 are mandatory.)

Specification for Seamless Brass Tube

1. Scope

1.1 This specification covers seamless round and rectangular including square copper alloy tube in straight lengths. Ten alloys are specified having the following nominal compositions:

Copper Alloy UNS No.	Previously Used Designation ^A	Nominal Composition, %			
		Copper	Zinc	Lead	Tin
C22000	7	90.0	10.0	...	...
C23000	1	85.0	15.0	...	...
C26000	2	70.0	30.0	...	...
C27000	9	65.0	35.0	...	...
C27200	8	63.0	37.0	...	...
C27400	...	62.5	37.5	...	...
C28000	5	60.0	40.0	...	...
C33000	3	66.0	33.5	0.5	...
C33200	4	66.0	32.4	1.6	...
C37000	6	60.0	39.0	1.0	...
C44300	...	71.5	27.5	...	1.00

^A Alloy Designations of Specification B135 – 63, which was published in the 1966 Book of ASTM Standards, Part 5.

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 **Warning**—Mercury has been designated by many regulatory agencies as a hazardous substance that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Safety Data Sheet (SDS) for additional information. Users should be aware that

selling mercury and/or mercury containing products into your state or country may be prohibited by law. (See 10.1.)

1.4 *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.*

1.5 *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:

- B153 Test Method for Expansion (Pin Test) of Copper and Copper-Alloy Pipe and Tubing
- B154 Test Method for Mercurous Nitrate Test for Copper Alloys
- B251/B251M Specification for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
- B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
- B846 Terminology for Copper and Copper Alloys
- B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
- B968/B968M Test Method for Flattening of Copper and Copper-Alloy Pipe and Tube
- E243 Practice for Electromagnetic (Eddy Current) Examination of Copper and Copper-Alloy Tubes
- E527 Practice for Numbering Metals and Alloys in the Unified Numbering System (UNS)

3. Terminology

3.1 For terms related to copper and copper alloys, refer to Terminology B846.

4. Ordering Information

4.1 Orders for material under the specification shall include the following information:

- 4.1.1 Alloy (Section 1),
- 4.1.2 Temper (Section 7),
- 4.1.3 Whether tension tests are required (for drawn tempers only (see 8.1)),
- 4.1.4 Dimensions: diameter or distance between parallel surfaces and wall thickness (see 11.2 and 11.3),
- 4.1.5 Length (see 12.4),
- 4.1.6 Stress Corrosion Resistance Testing, if required (Section 10),
- 4.1.7 Total length of each size,
- 4.1.8 Hydrostatic pressure test, when specified, and
- 4.1.9 Pneumatic test, when specified.

5. General Requirements

5.1 Material furnished under this specification shall conform to the applicable requirements of the current edition of Specification B251/B251M.

5.2 The following sections of Specification B251/B251M constitute a part of this specification:

- 5.2.1 Terminology
- 5.2.2 Materials and Manufacture
- 5.2.3 Dimensions and Permissible Variations
- 5.2.4 Sampling
- 5.2.5 Number of Tests and Retests
- 5.2.6 Specimen Preparation
- 5.2.7 Certification
- 5.2.8 Test Reports

5.3 In addition, when a section with a title identical to that referenced in 5.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B251/B251M.

6. Chemical Composition

6.1 The material shall conform to the chemical requirements specified in Table 1.

6.2 These specification limits do not preclude the presence of other elements. Limits for unnamed elements are to be established by agreement between manufacturer or supplier and purchaser.

6.2.1 For alloys in which zinc is listed as “remainder,” either copper or zinc may be taken as the difference between the sum of results of all other elements determined and 100 %. When all elements in Table 1 are determined, the sum of the results shall be as shown in the following table:

Copper Alloy UNS No.	Copper Plus Named Elements, % min
C22000	99.8
C23000	99.8
C26000	99.7
C27000	99.7
C27200	99.7
C27400	99.7
C28000	99.7
C33000	99.6
C33200	99.6
C37000	99.6
C44300	99.6

7. Temper

7.1 *Drawn Tempers, H*—The tempers of drawn tube shall be designated as light-drawn (H55), drawn (H58), and hard-drawn (H80) (see Tables 2 and 3). Light-drawn (bending) temper is used only when a tube of some stiffness but yet capable of being bent is needed. Drawn temper is for general purposes and is most commonly used where there is no specific requirement for high strength on the one hand or for bending qualities on the other. Hard-drawn temper is used only where there is need for a tube as strong as is commercially feasible for the sizes indicated. For any combination of diameter and wall thickness not covered under hard-drawn temper, the values given for drawn temper shall be used. Rectangular including square tubes shall normally be supplied only in drawn (general-purpose) temper. When there is a need for light-drawn or hard-drawn tempers these are to be supplied as agreed upon between the manufacturer and the purchaser.

7.2 *Annealed Tempers, O*—The tempers of annealed tube shall be designated as light anneal (O50) and soft anneal (O60) (Tables 4 and 5).

NOTE 1—Tube of Copper Alloy UNS No. C23000, shall have in the annealed condition a minimum tensile strength of 40 ksi [275 MPa] and a minimum yield strength of 12 ksi [80 MPa] at 0.5 % extension under load.

TABLE 1 Chemical Requirements

Copper Alloy UNS No.	Composition, %					
	Copper	Lead	Arsenic	Tin	Iron, max	Zinc
C22000	89.0–91.0	0.05 max	...	...	0.05	remainder
C23000	84.0–86.0	0.05 max	...	...	0.05	remainder
C26000	68.5–71.5	0.07 max	...	...	0.05	remainder
C27000	63.0–68.5	0.09 max	...	...	0.07	remainder
C27200	62.0–65.0	0.07 max	...	...	0.07	remainder
C27400	61.0–64.0	0.09 max	...	...	0.05	remainder
C28000	59.0–63.0	0.09 max	...	...	0.07	remainder
C33000	65.0–68.0	0.25 ^A –0.7	...	...	0.07	remainder
C33200	65.0–68.0	1.5–2.5	...	...	0.07	remainder
C37000	59.0–62.0	0.9–1.4	...	...	0.15	remainder
C44300	70.0–73.0	0.07 max	0.02–0.06	0.9–1.2	0.06	remainder

^A In the case of Copper Alloy UNS No. C33000 on tube sizes greater than 5 in. in outside diameter, or distance between outside parallel surfaces, the lead content shall be 0.7 % maximum, no minimum is specified.

TABLE 2 Mechanical Property Requirements of Drawn Temper Tube—Inch-Pound Values

Copper Alloy UNS No.	Temper Designation ^A		Outside Diameter, in. or Major Distance Between Outside Parallel Surfaces, in.	Wall Thickness, in.	Tensile Strength ksi ^B	Rockwell Hardness ^C 30T
	Standard	Former				
C22000	H58	drawn (general purpose)	all	all	40 min	38 min
C23000	H80	hard drawn ^D	up to 1, incl	0.020 to 0.120, incl	52 min	55 min
C22000	H80	hard drawn ^D	over 1 to 2, incl	0.035 to 0.180, incl	52 min	55 min
C22000	H80	hard drawn ^D	over 2 to 4, incl	0.060 to 0.250, incl	52 min	55 min
C23000	H55	light drawn ^D	all	all	44–58	43–75
C23000	H58	drawn (general purpose)	all	all	44 min	43 min
C23000	H80	hard drawn ^D	up to 1, incl	0.020 to 0.120, incl	57 min	65 min
C23000	H80	hard drawn ^D	over 1 to 2, incl	0.035 to 0.180, incl	57 min	65 min
C23000	H80	hard drawn ^D	over 2 to 4, incl	0.0605 to 0.250, incl	57 min	65 min
C26000, C27000, C27200, C27400, C33000, and C33200	H58	drawn (general purpose)	all	all	54 min	53 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^D	up to 1, incl	0.020 to 0.120, incl	66 min	70 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^D	over 1 to 2, incl	0.035 to 0.180, incl	66 min	70 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^D	over 2 to 4, incl	0.060 to 0.250, incl	66 min	70 min
C28000 and C37000	H58	drawn (general purpose)	all	all	54 min	55 min
C44300	H58	drawn (general purpose)	all	all	54 min	53 min
C44300	H80	hard drawn ^D	all	all	66 min	70 min

^A Standard designations defined in Classification B601.^B ksi = 1000 psi.^C Rockwell hardness values shall apply only to tubes having a wall thickness of 0.012 in. or over and to round tubes having an inside diameter of 5/16 in. or over and to rectangular including square tubes having an inside major distance between parallel surfaces of 3/16 in. or over. Rockwell hardness shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the manufacturer and the purchaser.^D Light-drawn and hard-drawn tempers are available in round-tube only.

8. Mechanical Properties

8.1 *Drawn Temper*—Tube shall conform to the mechanical properties prescribed in Tables 2 and 3. Tension tests are required for tubes with a wall thickness under 0.020 in. [50 mm] and for round tubes having an inside diameter under 5/16 in. [8.0 mm] and for rectangular including square tubes having a major distance between inside parallel surfaces under 3/16 in. [5.0 mm]. The tension test for other sizes of tubes need not be made except when indicated by the purchaser at the time of placing the order. A convenient method of indicating that the tension test is required is to specify that “Test procedure ‘T’ is required” (see 4.1.3). When agreement on the Rockwell hardness tests cannot be reached, the tensile strength requirements of Table 2 shall be the basis for acceptance or rejection.

8.2 *Annealed Temper*—The mechanical property requirements of Copper Alloy UNS No. C23000 tube shall be those given in 7-2, Note 1.

9. Expansion Test for Round Tube

9.1 Tube ordered in the annealed (O) condition, selected for test, shall be capable of withstanding in accordance with Test Method B153 an expansion of the outside diameter in the following amount:

Outside Diameter, in.	Expansion of Outside Diameter, %
3/4 and under	20
Over 3/4	15

The expanded tube shall show no cracking or rupture visible to the unaided eye. Tube ordered in the drawn (H) condition is not subject to this test.

NOTE 2—The term “unaided eye,” as used herein, permits the use of corrective spectacles necessary to obtain normal vision.

9.2 As an alternative to the expansion test for tube over 4 in. [100 mm] in diameter in the annealed condition shall be Test Method B968/B968M.

9.3 Drawn temper tube shall not be required to withstand these tests.

10. Mercurous Nitrate Test

10.1 **Warning**—Mercury is a definite health hazard. Use equipment for the detection and removal of mercury vapor. Wear rubber gloves when conducting the test.

10.2 When specifically required, test specimens 6 in. [150 mm] in length of both annealed and drawn tempers shall withstand, after proper cleaning, an immersion for 30 min

TABLE 3 Mechanical Property Requirements of Drawn Temper Tube—SI Values

Copper Alloy UNS No.	Temper Designation ^A		Outside Diameter, mm or Major Distance Between Outside Parallel Surfaces, mm	Wall Thickness, mm	Tensile Strength, MPa	Rockwell Hardness ^B 30T
	Standard	Former				
C22000	H58	drawn (general purpose)	all	all	275 min	38 min
C22000	H80	hard drawn ^C	up to 25, incl	0.050 to 3.0, incl	360 min	55 min
C22000	H80	hard drawn ^C	over 25 to 40, incl	0.090 to 5.50, incl	360 min	55 min
C22000	H80	hard drawn ^C	over 50 to 100, incl	1.5 to 6.0, incl	360 min	55 min
C23000	H55	light drawn ^C	all	all	305–400	43–75
C23000	H58	drawn (general purpose)	all	all	305 min	43 min
C23000	H80	hard drawn ^C	up to 25, incl	0.050 to 3.0, incl	395 min	65 min
C23000	H80	hard drawn ^C	over 25 to 50, incl	0.090 to 5.0, incl	395 min	65 min
C23000	H80	hard drawn ^C	over 50 to 100, incl	1.5 to 6.0, incl	395 min	65 min
C26000, C27000, C27200, C27400, C33000, and C33200	H58	drawn (general purpose)	all	all	370 min	53 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^C	up to 25, incl	0.050 to 3.0, incl	455 min	70 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^C	over 25 to 50, incl	0.090 to 5.0, incl	455 min	70 min
C26000, C27000, C27200, C27400, C33000, and C33200	H80	hard drawn ^C	over 50 to 100, incl	1.5 to 6.0, incl	455 min	70 min
C28000 and C37000	H58	drawn (general purpose)	all	all	370 min	55 min
C44300	H58	drawn (general purpose)	all	all	370 min	53 min
C44300	H80	hard drawn ^C	all	all	455 min	70 min

^A Standard designations defined in Classification B601.

^B Rockwell hardness values shall apply only to tubes having a wall thickness of 0.30 mm or over and to round tubes having an inside diameter of 8.0 mm or over and to rectangular including square tubes having an inside major distance between parallel surfaces of 5.0 mm or over. Rockwell hardness shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified.

^C Light-drawn and hard-drawn tempers are available in round tube only.

without cracking in the standard mercurous nitrate solution prescribed in Test Method B154. Immediately after removal from the solution, the specimen shall be wiped free of excess mercury and examined for cracks.

11. Nondestructive Testing

11.1 Unless nondestructive testing has been waived, tubes shall be subjected to a nondestructive test. The manufacturer shall select the nondestructive test that is most suitable for the tube size and the application.

11.1.1 Eddy-current testing is the standard nondestructive test, and all tubes of appropriate size shall be eddy-current tested in accordance with 11.2.

11.1.2 Tubes that are not of a size suitable for eddy-current test capabilities shall be tested by the hydrostatic test as described in 11.3.1, or by the pneumatic test as described in 11.3.2.

11.2 *Eddy-Current Test*—Each tube up to 3½ in. [79 mm] in outside diameter shall be subjected to an eddy-current test. Testing shall follow the procedure of Practice E243, except the determination of “end effect” is not required. Tubes shall be passed through an eddy-current test unit adjusted to provide information on the suitability of the tube for the intended application.

11.2.1 Notch-depth standards rounded to the nearest 0.001 in. [0.03 mm] shall be 22 % of the nominal wall thickness. The notch-depth tolerance shall be ±0.0005 in.

[±0.01 mm]. Alternatively, if the manufacturer uses speed-insensitive eddy-current units that are equipped so that a fraction of the maximum unbalance signal is able to be selected, the following percent maximum unbalance signals shall be used.

Standard Tube Size, in. [mm]	Maximum Percent Unbalance Signal Magnitude
Up to and including ¾ [12 mm]	0.2
1½ to 2 incl [15 to 54 mm incl]	0.3
Over 2 to 3 incl [54 to 79 mm incl]	0.4

11.2.2 Tubes that do not actuate the signalling device of the eddy-current testers shall be considered as conforming to the requirements of this test. If reexamined or retested, tubes with signals that are found to have been caused by minor mechanical damage, soil, or moisture, shall not be cause for rejection of the tubes provided the tube dimensions are still within prescribed limits and the tube is suitable for its intended application.

11.3 A pressure test shall be specified for tube sizes over 3½ in. [79 mm] in outside diameter or tube of dimensions beyond the capabilities of the eddy-current test apparatus or as an alternative to the eddy-current test. The purchaser shall have the option to specify either a hydrostatic test in 11.3.1 or the pneumatic test in 11.3.2. When, in the case where subsequent testing by the purchaser establishes that the material does not meet these requirements, then the tubes shall be subject to rejection.

TABLE 4 Mechanical Property Requirements of Annealed Temper Tube—Inch-Pound Values

Copper Alloy UNS No.	Temper Designation ^A		Wall Thickness, in.	Rockwell Hardness ^B		Average Grain Size, mm	
	Standard	Former		Scale	Max	Min	Max
C22000	O60	soft anneal	up to 0.045, incl	30T	30	0.025	0.060
C22000	O60	soft anneal	over 0.045	F	70	0.025	0.060
C22000	O50	light anneal	up to 0.045, incl	30T	37	^C	0.035
C22000	O50	light anneal	over 0.045	F	78	^C	0.035
C23000	O60	soft anneal	up to 0.045, incl	30T	36	0.025	0.060
C23000	O60	soft anneal	over 0.045	F	75	0.025	0.060
C23000	O50	light anneal	up to 0.045, incl	30T	39	^C	0.035
C23000	O50	light anneal	over 0.045	F	85	^C	0.035
C26000, C33000, and C33200	O60	soft anneal	up to 0.030, incl	30T	40	0.025	0.060
C26000, C33000, and C33200	O60	soft anneal	over 0.030	F	80	0.025	0.060
C26000, C28000, C33000, C332000, and C37000	O50	light anneal	up to 0.030, incl	30T	60	^C	0.035
C26000, C28000, C33000, C332000, and C37000	O50	light anneal	over 0.030	F	90	^C	0.035
C27000, C27200, and C27400	O60	soft anneal	up to 0.030, incl	30T	40	0.025	0.060
C27000, C27200, and C27400	O60	soft anneal	over 0.030	F	80	0.025	0.060
C27000, C27200, and C27400	O50	light anneal	up to 0.030, incl	30T	60	^C	0.035
C27000, C27200, and C27400	O50	light anneal	over 0.030	F	90	^C	0.035
C44300	O60	soft anneal	up to 0.030, incl	30T	40	0.025	0.060
C44300	O60	soft anneal	over 0.030	F	80	0.025	0.060
C44300	O50	light anneal	up to 0.030, incl	30T	60	^C	0.035
C44300	O50	light anneal	over 0.030	F	90	^C	0.035

^A Standard designations defined in Classification B601.

^B Rockwell hardness values shall apply only to tubes having a wall thickness of 0.015 in. or over and to round tubes having an inside diameter of 5/16 in. or over and to rectangular including square tubes having an inside major distance between parallel surfaces of 3/16 in. or over. For all other tube no Rockwell hardness values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the manufacturer and the purchaser.

^C Although no minimum grain size is specified, the product must nevertheless have a fully recrystallized grain structure.

11.3.1 *Hydrostatic Test*—When specified, the tube shall stand, without showing evidence of leakage an internal hydrostatic pressure sufficient to subject the material to a fiber stress of 7000 psi [48 MPa], determined by the following equation for thin hollow cylinders under tension:

$$P = 2St/(D - 0.8t) \quad (1)$$

where:

P = hydrostatic pressure, psi [MPa];

t = wall thickness of the material, in. [mm];

D = outside diameter of the material, in. [mm]; and

S = allowable stress of the material.

11.3.2 *Pneumatic Test*—When specified, the tube shall be subjected to an internal air pressure of 60 psig [400 kPa] minimum for 5 s without showing evidence of leakage. The test method used shall provide for easy visual detection of any leakage, such as by immersion of the tube under water or by the pressure differential method. Any evidence of leakage shall be cause for rejection.

12. Dimensions and Permissible Variations

12.1 The dimensions and tolerances for material covered by this specification shall be as prescribed in the current edition of

Specification B251/B251M, with particular reference to Section 5 and the following tables of that specification:

12.2 *Wall Thickness Tolerances*—See 5.2, Tables 1 and 6.

12.3 *Tolerances for Diameter or Distance Between Parallel Surfaces*—See 5.3, Tables 2 and 7.

12.4 *Length Tolerances*—See 5.5, Tables 3 and 4.

12.5 *Roundness*—See 5.4.

12.6 *Squareness of Cut*—See 5.6

12.7 *Straightness Tolerances*—For round tubes see 5.7.1, Table 5. For rectangular including square tubes see 5.7.2.

12.8 *Corner Radius for Rectangular Including Square Tubes*—See 5.8, Table 8.

12.9 *Twist Tolerances for Rectangular and Square Tubes*—See 5.9.

13. Sampling for Visual and Dimensional Examination

13.1 Minimum sampling for visual and dimensional examination shall be as follows when specified by the purchaser in the inquiry, contract or order, for agencies of the U.S. Government:

TABLE 5 Mechanical Property Requirements of Annealed Temper Tube—SI Values

Copper Alloy UNS No.	Temper Designation ^A		Wall Thickness, mm	Rockwell Hardness ^B		Average Grain Size, mm	
	Standard	Former		Scale	Max	Min	Max
C22000	O60	soft anneal	up to 1.0, incl	30T	30	0.025	0.060
C22000	O60	soft anneal	over 1.0	F	70	0.025	0.060
C22000	O50	light anneal	up to 1.0, incl	30T	37	^C	0.035
C22000	O50	light anneal	over 1.0	F	78	^C	0.035
C23000	O60	soft anneal	up to 1.0, incl	30T	36	0.025	0.060
C23000	O60	soft anneal	over 1.0	F	75	0.025	0.060
C23000	O50	light anneal	up to 1.0, incl	30T	39	^C	0.035
C23000	O50	light anneal	over 1.0	F	85	^C	0.035
C26000, C33000, and C33200	O60	soft anneal	up to 0.080, incl	30T	40	0.025	0.060
C26000, C33000, and C33200	O60	soft anneal	over 0.080	F	80	0.025	0.060
C26000, C28000, C33000, C33200, and C37000	O50	light anneal	up to 0.080, incl	30T	60	^C	0.035
C26000, C28000, C33000, C33200, and C37000	O50	light anneal	over 0.080	F	90	^C	0.035
C27000, C27200, and C27400	O60	soft anneal	up to 0.080, incl	30T	40	0.025	0.060
C27000, C27200, and C27400	O60	soft anneal	over 0.080	F	80	0.025	0.060
C27000, C27200, and C27400	O50	light anneal	up to 0.080, incl	30T	60	^C	0.035
C27000, C27200, and C27400	O50	light anneal	over 0.080	F	90	^C	0.035
C44300	O60	soft anneal	up to 0.080, incl	30T	40	0.025	0.060
C44300	O60	soft anneal	over 0.080	F	80	0.025	0.060
C44300	O50	light anneal	up to 0.080, incl	30T	60	^C	0.035
C44300	O50	light anneal	over 0.080	F	90	^C	0.035

^A Standard designations defined in Classification B601.

^B Rockwell hardness values shall apply only to tubes having a wall thickness of 0.40 mm or over and to round tubes having an inside diameter of 8.0 mm or over and to rectangular including square tubes having an inside major distance between parallel surfaces of 5.0 mm or over. For all other tube, no Rockwell hardness values shall apply. Rockwell hardness tests shall be made on the inside surface of the tube. When suitable equipment is not available for determining the specified Rockwell hardness, other Rockwell scales and values shall be specified subject to agreement between the manufacturer and the purchaser.

^C Although no minimum grain size is specified, the product must nevertheless have a fully recrystallized grain structure.

Lot Size (Pieces Per Lot)

Sample Size

2 to 8	Entire lot
9 to 90	8
91 to 150	12
151 to 280	19
281 to 500	21
501 to 1200	27
1201 to 3200	35
3201 to 10 000	38
10 001 to 35 000	46

13.2 In all cases, the acceptance number is zero and the rejection number is one. Screening and resubmittal of samples

from rejected lots for visual and dimensional examination is acceptable. All defective items shall be replaced with acceptable items before lot acceptance.

14. Workmanship, Finish, and Appearance

14.1 Annealed tube shall be either bright annealed or acid cleaned after final annealing operations.

15. Keywords

15.1 brass tube; seamless brass tube; seamless tube

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U.S. Government. Supplementary Requirement S5 shall apply only when specified.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

S1.1.1 *ASTM Standard:*

B900, Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

S1.1.2 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 185 Identification Marking of Copper and Copper-Base Alloy Mill Products

S1.1.3 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer shall use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 185 except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, Level A or C, packed, Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of Practice B900.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

S5. Tubes for Voice and Pneumatic Service

S5.1 Tubes ordered to this supplement for voice and pneumatic service shall have dimensions, tolerances, and tempers as specified in Table S5.1. For these tubes, the mercurous nitrate test shall be required and nondestructive testing shall not be required. Copper plus sum of all named elements shall be 98.85 %.

TABLE S5.1 Tubes for Voice and Pneumatic Service

Size	Outside Diameter, in. [mm]	Inside Diameter, in. [mm]	Average Diameter Tolerance, in. [mm]	Wall Thickness, in. [mm]	Temper
A	2.000 [50.8]	...	+0.000 −0.004 [−0.10]	0.049 [1.25]	H-80
B	2.000 [50.8]	...	+0.000 −0.004 [−0.10]	0.109 [2.75]	H-58
C	...	2.000 [50.8]	+0.004 [0.10] −0.000	0.049 [1.25]	H-80
D	2.250 [57.2]	...	+0.000 −0.004 [−0.10]	0.065 [1.65]	H-80
E	...	2.250 [57.2]	+0.004 [0.10] −0.000 [0.00]	0.049 [1.25]	H-80
F	3.000 [76.2]	...	+0.000 −0.004 [−0.10]	0.049 [1.25]	H-80
G	3.000 [76.2]	...	+0.000 −0.004 [−0.10]	0.109 [2.75]	H-58
H	...	3.000 [76.2]	+0.004 [0.10] −0.000	0.049 [1.25]	H-80

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SPECIFICATION FOR ALUMINUM-BRONZE SAND CASTINGS



SB-148

(Identical with ASTM Specification B148-18 except certification and test report have been made mandatory, and weld repair requirements in accordance with ASME Section IX have been added.)

Specification for Aluminum-Bronze Sand Castings

1. Scope

1.1 This specification establishes requirements for sand castings produced from copper-base alloys having the alloy numbers, commercial designations, and nominal compositions shown in Table 1.

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

1.3 *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 The following documents of the issue in effect on date of material purchase form a part of this specification to the extent referenced herein:

2.2 *ASTM Standards:*

B208 Practice for Preparing Tension Test Specimens for Copper Alloy Sand, Permanent Mold, Centrifugal, and Continuous Castings

B824 Specification for General Requirements for Copper Alloy Castings

B846 Terminology for Copper and Copper Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E10 Test Method for Brinell Hardness of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

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

3. Terminology

3.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

4. General Requirements

4.1 Material furnished under this specification shall conform to the applicable requirements of Specification B824.

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification as applicable:

5.1.1 ASTM designation and year of issue,

5.1.2 Copper or Copper Alloy UNS. No. designation,

5.1.3 Temper, must include optional Heat Treatment when needed,

5.1.4 Dimensions, diameter, and wall thickness (For tube or pipe: specify either O.D./I.D., O.D./Wall, or I.D./Wall unless standard size such as type K are ordered; for flat products: thickness, width, and edges; for rod, bar, or shapes: by diameter or distance between parallel surfaces),

5.1.5 Quantity of castings required,

5.1.6 Intended applications,

5.1.7 Specification title, number, and year of issue,

5.1.8 Pattern or drawing number and condition (cast, machined, and so forth),

5.1.9 Analysis of residual elements, if specified in the purchase order (Specification B824),

5.1.10 Pressure test requirements, if specified in the purchase order (Specification B824),

5.1.11 Soundness requirements, if specified in the purchase order (Specification B824),

5.1.12 Certification (Specification B824),

5.1.13 Test report (Specification B824),

5.1.14 Witness inspection, if specified in the purchase order (Specification B824),

TABLE 1 Nominal Compositions

Copper Alloy UNS No.	Old Designation	Commercial Designation	Nominal Composition, %					
			Copper	Nickel	Iron	Aluminum	Silicon	Manganese
C95200	9A	Grade A	88.0	...	3.0	9.0	...	...
C95300 ^A	9B	Grade B	89.0	...	1.0	10.0	...	...
C95400 ^A	9C	Grade C	85.0	...	4.0	11.0	...	...
C95410 ^A	...	...	84.0	2.0	4.0	10.0	...	...
C95500 ^A	9D	Grade D	81.0	4.0	4.0	11.0	...	...
C95520 ^A	...	...	78.5	5.5	5.0	11.0	...	...
C95600	9E	Grade E	91.0	...	...	7.0	2.0	...
C95700	9F	Grade F	75.0	2.0	3.0	8.0	...	12.0
C95800	...	...	81.3	4.5	4.0	9.0	...	1.2
C95820	...	...	79.0	5.2	4.5	9.5	...	1.0
C95900	...	...	87.5	...	4.5	13.0	...	...

^A These grades respond to heat treatment.

5.1.15 Approval of weld procedure and records of repairs, if specified in the purchase order (Section 10),

5.1.16 DELETED

5.1.17 Castings for seawater service (6.2.3), and

5.1.18 Product marking, if specified in the purchase order (Specification B824).

5.2 When material is purchased for agencies of the U.S. Government, the Supplementary Requirements of this specification may be specified.

6. Materials and Manufacture

6.1 Materials:

6.1.1 The material of manufacture shall be sand castings of Copper Alloys, UNS No. C95200, C95300, C95400, C95410, C95500, C95520, C95600, C95700, C95800, C95820, C95900 of such purity and soundness as to be suitable for processing into the products prescribed herein.

6.1.2 When specified in the contract or purchase order, that heat identification or traceability is required, the purchaser shall specify the details desired.

6.2 Manufacture:

6.2.1 As a specified option, Copper Alloy UNS Nos. C95300, C95400, C95410, C95500, and C95520 may be supplied in the heat-treated condition to obtain the higher

TABLE 2 Mechanical Requirements

Classification	Aluminum Bronze			Nickel Aluminum Bronze		Silicon Aluminum Bronze	Manganese-Nickel Aluminum Bronze	Nickel Aluminum Bronze	Aluminum Bronze
	As-Cast		As-Cast	As-Cast					
Copper Alloy UNS No.	C95200	C95300	C95400 and C95410	C95500	C95820	C95600	C95700	C95800 ^A	C95900 ^B
Tensile strength, min, ksi ^C (MPa ^D)	65 (450)	65 (450)	75 (515)	90 (620)	94 (650)	60 (415)	90 (620)	85 (585)	...
Yield strength, ^E min, ksi ^C (MPa ^D)	25 (170)	25 (170)	30 (205)	40 (275)	39 ^F (270) ^F	28 (195)	40 (275)	35 (240)	...
Elongation in 2 in. (50.8 mm), %	20	20	12	6	13	10	20	15	...
Brinell hardness No. ^G (3000-kg load)	110	110	150	190	...	...	...	...	...
Heat-Treated									
Copper Alloy UNS No.		C95300	C95400 and C95410	C95500	C95520 ^H				
Tensile strength, min, ksi ^C (MPa ^D)	...	80 (550)	90 (620)	110 (760)	125 (862)	...	...	...	...
Yield strength, ^E min, ksi ^C (MPa ^D)	...	40 (275)	45 (310)	60 (415)	95 ^F (655) ^F	...	...	...	...
Elongation in 2 in. (50.8 mm), %	...	12	6	5	2	...	...	...	...
Brinell hardness No. ^G (3000-kg load)	...	160	190	200	255 ^I	...	...	...	241 min

^A As cast or temper annealed.

^B Normally supplied annealed between 1100 and 1300 °F for 4 h followed by air cooling.

^C ksi = 1000 psi.

^D See Appendix X1.

^E Yield strength shall be determined as the stress producing an elongation under load of 0.5 %, that is, 0.01 in. (0.254 mm) in a gage length of 2 in. (50.8 mm).

^F Yield strength at 0.2 % offset, min, ksi^C (MPa^D).

^G For information only.

^H Copper Alloy UNS No. C95520 is used in the heat-treated condition only.

^I Sand castings and sand cast test specimens shall be 25 HRC minimum.

mechanical properties shown in Table 2. Suggested heat treatments for these alloys are given in Table 3. Actual practice may vary by manufacturer.

6.2.2 For better corrosion resistance in seawater applications, castings in Copper Alloy UNS No. C95800 may be given a temper anneal heat treatment at 1200 to 1300 °F (650 to 705 °C) for 6 h minimum. Cooling shall be by the fastest means possible that will not cause excessive distortion or cracking. Propeller castings shall be exempt from this requirement.

6.2.3 Copper Alloy UNS No. C95520 is used in the heat-treated condition only.

6.2.4 Copper Alloy UNS No. C95900 is normally supplied annealed between 1100 °F (595 °C) and 1300 °F (705 °C) followed by air cooling.

6.2.5 Copper Alloy UNS No. C95820 is supplied in the as-cast condition.

6.2.6 Separately cast test bar coupons representing castings made in Copper Alloy UNS Nos. C95300HT, C95400HT, C95410HT, C95500HT, C95520HT, C95800 temper annealed, and C95900 annealed shall be heat treated with the castings.

7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements in Table 4 for the copper alloy UNS. No. designation specified in the ordering information.

7.1.1 Results of analysis of the product sample shall conform to the composition requirements within the permitted analytical variance specified in Table 4.

7.1.2 These composition limits do not preclude the presence of other elements. Limits may be established by agreement between manufacturer or supplier and purchaser for the unnamed elements.

7.1.3 For alloys in which Copper is listed as remainder, copper is the difference between the sum of results of all elements determined and 100 %. When all the elements in Table 4 are determined, the sum of results shall be as specified in the following table:

TABLE 3 Suggested Heat Treatments

Copper Alloy UNS No.	Solution Treatment (Not Less than 1 h/in. Followed by Water Quench)	Annealing Treatment (Not Less than 2 h Followed by Air Cool)
C95300	1585–1635 °F (860–890 °C)	1150–1225 °F (620–660 °C)
C95400 C95410	1600–1675 °F (870–910 °C)	1150–1225 °F (620–660 °C)
C95500 C95520	(2 h followed by water quench) 1600–1700 °F (870–925 °C)	925–1000 °F (495–540 °C)
C95800 ^A		1200–1300 °F (650–705 °C), 6 h minimum followed by air cooling

^A Corrosion inhibiting heat treatment, depends on agreement between the manufacturer and buyer.

Copper Alloy UNS Number	Copper Plus Named Elements, min, %
C95200	99.0
C95300	99.0
C95400	99.5
C95410	99.5
C95500	99.5
C95520	99.5
C95600	99.0
C95700	99.5
C95800	99.5
C95820	99.2
C95900	99.5

8. Temper

8.1 The suggested heat treatment (temper) for products described in this specification are given in Table 3.

9. Mechanical Property Requirements

9.1 Tensile Strength Requirements:

9.1.1 The mechanical properties shall be determined from separately cast test bar castings.

9.1.2 Product furnished under this specification shall conform to the mechanical properties requirements specified in Table 2, when tested in accordance with Test Methods E8/E8M.

9.1.3 Acceptance or rejection based upon mechanical properties shall depend on tensile strength, yield strength, and elongation.

9.2 Hardness Requirement:

9.2.1 The approximate Brinell hardness values given in Table 2 are for general information and assistance in testing, and shall not be used as a basis for product rejection.

10. Casting Repair

10.1 Alloys included in this specification are generally weldable. All weld repairs shall be made utilizing procedures qualified in accordance with Section IX of the ASME BPVC, and repair welding shall be done by welders or welding operators in accordance with ASME BPVC Section IX. Weld repairs may be made at the manufacturer's discretion provided each excavation does not exceed 20 % of the casting section or wall thickness or 4 % of the casting surface area.

10.2 Excavations that exceed those described in 10.1 may be made at the manufacturer's discretion except that when required (5.1.15) the weld procedure shall be approved by the purchaser and the following records shall be maintained:

- 10.2.1 A sketch or drawing showing the dimensions, depth, and location of excavations,
- 10.2.2 Postweld heat treatment, when applicable,
- 10.2.3 Weld repair inspection results,
- 10.2.4 Casting identification number,
- 10.2.5 Weld procedure identification number,
- 10.2.6 Welder identification, and
- 10.2.7 Name of inspector.

10.3 The castings shall not be impregnated without approval of the purchaser.

TABLE 4 Chemical Requirements

Classification	Aluminum Bronze				Nickel Aluminum Bronze		Silicon Aluminum Bronze	Manganese- Nickel Aluminum Bronze	Nickel Aluminum Bronze		Aluminum Bronze
Copper Alloy UNS No.	C95200	C95300	C95400	C95410	C95500	C95520 ^A	C95600	C95700	C95800	C95820 ^B	C95900
Composition, %											
Copper	86.0 min	86.0 min	83.0 min	83.0 min	78.0 min	74.5 min	88.0 min	71.0 min	79.0 min	77.5 min	remainder
Aluminum	8.5–9.5	9.0–11.0	10.0–11.5	10.0–11.5	10.0–11.5	10.5–11.5	6.0–8.0	7.0–8.5	8.5–9.5	9.0–10.0	12.0–13.5
Iron	2.5–4.0	0.8–1.5	3.0–5.0	3.0–5.0	3.0–5.0	4.0–5.5	...	2.0–4.0	3.5–4.5 ^C	4.0–5.0	3.0–5.0
Manganese	...	...	0.50 max	0.50 max	3.5 max	1.5 max	...	11.0–14.0	0.8–1.5	1.5 max	1.5 max
Nickel (incl cobalt)	...	...	1.5 max	1.5–2.5	3.0–5.5	4.2–6.0	0.25 max	1.5–3.0	4.0–5.0 ^C	4.5–5.8	0.50 max
Silicon	...	...	...	...	...	0.15 max	1.8–3.2	0.10 max	0.10 max	0.10 max	...
Lead	...	...	...	...	...	0.03 max	...	0.03 max	0.03 max	0.03 max	...

^A Chromium shall be 0.05 max, cobalt 0.20 max, tin 0.25 max, and zinc 0.30 max.

^B Zinc shall be 0.20 max and tin 0.20 max.

^C Iron content shall not exceed the nickel content.

11. Workmanship, Finish, and Appearance

11.1 The product shall be free of defects, but blemishes of a nature that do not interfere with the intended application are acceptable.

12. Sampling

12.1 Test bar castings for the Copper Alloy UNS Nos. in this specification shall be cast to the form and dimensions shown in Figs. 1 or 2 in Practice B208.

12.2 For small remelts the lot size shall not exceed 1000 lb (455 kg) of castings and shall consist of all of the metal from a single master heat poured from an individual melting unit, or group of melting units, operating during the course of one-half shift, not to exceed 5 h.

13. Test Methods

13.1 Chemical Analysis:

13.1.1 In case of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer and the purchaser.

13.2 Other Tests:

13.2.1 Brinell readings shall be taken on the grip end of the tension test bar and shall be made in accordance with Test Method E10, with the exception that a 3000-kg load shall be used.

13.2.2 Rockwell hardness readings shall be taken on the grip end of the tension test bar and shall be made in accordance with Test Methods E18.

13.2.3 Tensile and Yield Strength shall be determined by the extension-under-load method of Test Methods E8/E8M.

13.2.4 When specified in the purchase order, additional hardness testing may be performed on castings. The test location and hardness values shall be agreed upon between the manufacturer and the purchaser.

14. Certification and Test Report

14.1 The purchaser shall be furnished certification that samples representing each lot have been tested and inspected as directed in this specification and requirements have been met. A report of the test results shall be furnished to the purchaser.

14.2 DELETED

15. Keywords

15.1 aluminum-bronze castings; copper alloy castings; copper-base alloy castings; UNS No. C95200; UNS No. C95300; UNS No. C95400; UNS No. C95410; UNS No. C95500; UNS No. C95520; UNS No. C95600; UNS No. C95700; UNS No. C95800; UNS No. C95820; UNS No. C95900

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order for agencies of the U.S. Government.

S1. Scope

S1.1 The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order for agencies of the U.S. Government.

S2. Referenced Documents

S2.1 The following documents of the issue effect on date of material purchase form a part of this specification to the extent referenced herein:

S2.1.1 Federal Standards:

Fed. Std. No. 102 Preservation, Packaging, and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

S2.1.2 Military Standards:

MIL-STD-129 Marking for Shipment and Storage

MIL-STD-248 Welded and Brazing Procedure in Performance Qualification

MIL-STD-271 Requirements for Nondestructive Testing Methods

MIL-STD-278 Welding and Casting Standard

S2.1.3 ASTM Standard:

B900 Practice for Packaging of Copper and Copper Alloy Mill Products for U.S. Government Agencies

S3. First Article Inspection

S3.1 The initial casting shall be radiographically examined in accordance with MIL-STD-271 at locations specified by the purchaser. Subsequent to radiography, samples for mechanical testing shall be removed from the specified locations and tested. The acceptance criteria for all tests and examinations shall be as agreed upon between the manufacturer and the purchaser.

S3.2 Following acceptance of the initial casting by the purchaser, the manufacturer shall not change his basic foundry practice without the specific approval of the purchaser. The manufacturer may be required to perform additional tests or inspections to verify acceptability of any changes made.

S4. Soundness

S4.1 Castings shall meet the soundness requirements of MIL-STD-278 for the category, subcategory, and criticality level specified in the purchase order.

S5. Pressure Test

S5.1 Castings shall meet the pressure test requirements of MIL-STD-278.

S6. Weld Repair

S6.1 All repair welding shall be in accordance with MIL-STD-278 using welders and welding procedures qualified in accordance with MIL-STD-248.

S6.2 Surfaces of the casting that will be in contact with seawater will be identified by the purchaser. Any weld repair made on these surfaces or within 1/4 in. of these surfaces shall be postweld heat treated in accordance with 6.2.3.

S7. Quality Assurance

S7.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

S8. Marking

S8.1 The castings shall be marked in accordance with Specification B824. Additionally, the marking shall include the manufacturer's trademark, specification, and alloy number.

S9. Preparation for Delivery**S9.1 Preservation, Packaging, and Packing:**

S9.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, Level A or C, packed, Level A, B, or C as specified in the contract or purchase order, in accordance with the requirements of Practice B900.

S9.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S9.2 Marking:

S9.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S9.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX**(Nonmandatory Information)****X1. METRIC EQUIVALENTS**

X1.1 The SI unit for strength properties now shown is in accordance with the International System of Units (SI). The derived SI unit for force is the newton (N), which is defined as that force that, when applied to a body having a mass of one kilogram, gives it an acceleration of one metre per second square ($N = \text{kg} \cdot \text{m/s}^2$). The derived SI unit for pressure or stress

is the newton per square metre (N/m^2), which has been named the pascal (Pa) by the General Conference on Weights and Measures. Since $1 \text{ ksi} = 6\,894\,757 \text{ Pa}$, the metric equivalents are expressed as megapascal (MPa), which is the same as MN/m^2 and N/mm^2 .

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SPECIFICATION FOR ALUMINUM BRONZE ROD, BAR, AND SHAPES



SB-150/SB-150M

(Identical with ASTM Specification B150/B150M-12(2017) except that paras. 4.2.2, 4.2.3, 4.2.6, and 8.2.1 have been deleted.)

Specification for Aluminum Bronze Rod, Bar, and Shapes

1. Scope

1.1 This specification establishes the requirements for aluminum bronze rod, bar, and shapes for Copper Alloys UNS Nos. C61300, C61400, C61900, C62300, C62400, C63000, C63020, C63200, C64200, and C64210.

NOTE 1—Product intended for hot forging is described in Specification B124/B124M.

NOTE 2—**Warning**—Mercury has been designated by many regulatory agencies as a hazardous material that can cause serious medical issues. Mercury, or its vapor, has been demonstrated to be hazardous to health and corrosive to materials. Caution should be taken when handling mercury and mercury containing products. See the applicable product Safety Data Sheet (SDS) for additional information. Users should be aware that selling mercury and/or mercury containing products into your state or country may be prohibited by law.

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 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

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:*

B124/B124M Specification for Copper and Copper Alloy Forging Rod, Bar, and Shapes
B154 Test Method for Mercurous Nitrate Test for Copper Alloys
B249/B249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings
B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
B858 Test Method for Ammonia Vapor Test for Determining Susceptibility to Stress Corrosion Cracking in Copper Alloys
E8/E8M Test Methods for Tension Testing of Metallic Materials
E18 Test Methods for Rockwell Hardness of Metallic Materials
E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)
E118 Test Methods for Chemical Analysis of Copper-Chromium Alloys (Withdrawn 2010)
E478 Test Methods for Chemical Analysis of Copper Alloys

3. General Requirements

3.1 The following sections of Specification B249/B249M constitute a part of this specification:

3.1.1 Terminology,
3.1.2 Materials and Manufacture,
3.1.3 Workmanship, Finish, and Appearance,
3.1.4 Sampling,
3.1.5 Number of Tests and Retests,
3.1.6 Specimen Preparation,
3.1.7 Test Methods,
3.1.8 Significance of Numerical Limits,
3.1.9 Inspection,
3.1.10 Rejection and Rehearing,
3.1.11 Certification,
3.1.12 Mill Test Report,
3.1.13 Packaging and Package Marking, Preservation and Delivery, and

3.1.14 Supplementary Requirements.

3.2 In addition, when a section with a title identical to those referenced in 3.1, appears in this specification, it contains additional requirements that supplement those appearing in Specification B249/B249M.

4. Ordering Information

4.1 Include the following information when placing orders for product under this specification, as applicable:

- 4.1.1 Specification designation and year of issue,
- 4.1.2 Copper alloy UNS No. (See Table 1),
- 4.1.3 Temper (see Temper section),
- 4.1.3.1 When Alloy UNS No. C63000 is specified, specify standard strength or high strength temper (See Table 2),
- 4.1.4 Product cross-section (for example round, hexagonal, square, and so forth),
- 4.1.5 Dimensions (diameter or distance between parallel surfaces and length) and permissible variations (Section 10),
- 4.1.5.1 When product of Copper Alloy UNS No. C63020 is specified, the tolerances for diameter, thickness, width, and length shall be part of the contract or purchase order and shall be agreed upon between the supplier and the purchaser.
- 4.1.5.2 *Shapes*—When product is shapes, the dimensional tolerances shall be as agreed upon between the manufacturer and the purchaser and shall be specified.
- 4.1.6 Quantity, total weight, footage, or number of pieces for each size.
- 4.1.7 If product is being purchased for agencies of the U.S. government.
- 4.2 The following options are available and should be specified at the time of placing the order when required:
 - 4.2.1 If Copper Alloy C61300 material is intended for subsequent welding applications (See Note B, Table 2),
 - 4.2.2 DELETED
 - 4.2.3 DELETED

4.2.4 Residual stress test (Performance Requirements section)

- 4.2.4.1 Ammonia Vapor Test or Mercurous Nitrate Test,
- 4.2.4.2 For Ammonia Vapor Test, pH value other than 10.
- 4.2.5 If piston finish or shafting is required, (Performance Requirements and Workmanship sections), and
- 4.2.6 DELETED

5. Materials and Manufacture

5.1 Manufacture:

5.1.1 *Copper Alloy UNS C63020*—Rod and Bar shall be heat-treated to 26 Rockwell hardness (C scale) (HRC) minimum as follows:

5.1.2 Heat to 1550°/1650°F [850/900°C] for 2 h minimum and quenched in water.

5.1.3 Temper at 900°/1000°F [480/540°C] for 2 h minimum and air cool to room temperature.

5.2 *Copper Alloy UNS C63200*—Rod and Bar shall be heat-treated as follows:

5.2.1 Heat to 1550°F [850°C] minimum for 1 h minimum at temperature and quench in water or other suitable medium,

5.2.2 Temper anneal at 1300 ± 25°F [700 ± 15°C] for 3 to 9 h at temperature as required to obtain desired mechanical properties, and

5.2.3 Heat treatment is not mandatory for sections that exceed 12 in. [300 mm] in diameter or thickness.

6. Chemical Composition

6.1 The material shall conform by alloy to the chemical composition requirements in Table 1 for the copper alloy UNS designation specified in the ordering information.

6.2 For alloys in which copper is listed as “remainder,” copper is the difference between the sum of all elements determined and 100 %.

TABLE 1 Chemical Requirements

Elements	Composition, %									
	C61300	C61400	C61900	C62300	Copper Alloy UNS No.		C63020	C63200	C64200	C64210
					C62400	C63000				
Aluminum	6.0–7.5	6.0–8.0	8.5–10.0	8.5–10.0	10.0–11.5	9.0–11.0	10.0–11.0	8.7–9.5	6.3–7.6	6.3–7.0
Copper, incl silver	remainder	remainder	remainder	remainder	remainder	remainder	74.5 min	remainder	remainder	remainder
Iron	2.0–3.0	1.5–3.5	3.0–4.5	2.0–4.0	2.0–4.5	2.0–4.0	4.0–5.5	3.5–4.3 ^A	0.30 max	0.30 max
Nickel, incl cobalt	0.15 max	...	...	1.0 max	...	4.0–5.5	4.2–6.0	4.0–4.8 ^A	0.25 max	0.25 max
Manganese	0.20 max	1.0 max	...	0.50 max	0.30 max	1.5 max	1.5 max	1.2–2.0	0.10 max	0.10 max
Silicon	0.10 max	...	...	0.25 max	0.25 max	0.25 max	...	0.10 max	1.5–2.2	1.5–2.0
Tin	0.20–0.50	...	0.6 max	0.6 max	0.20 max	0.20 max	0.25 max	...	0.20 max	0.20 max
Zinc, max	0.10 ^B	0.20	0.8	...	...	0.30	0.30	...	0.50	0.50
Lead, max	0.01	0.01	0.02	...	...	...	0.03	0.02	0.05	0.05
Arsenic, max	...	...	...	...	...	...	...	...	0.15	0.15
Phosphorus, max	0.015	0.015	...	...	...	...	...	...	...	...
Other named elements ^B	C									

^A Iron content shall not exceed nickel content.

^B When the product is for subsequent welding applications and is so specified by the purchaser, chromium shall be 0.05 % max, cadmium 0.05 % max, zirconium 0.05 % max, and zinc 0.05 % max.

^C Chromium shall be 0.05 max and cobalt shall be 0.20 max.

TABLE 2 Tensile Requirements

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^A in. [mm]	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa], at 0.5 % Extension Under Load	Elongation in 4 × Diameter or Thickness of Specimen min, % ^B
Code	Name				
Copper Alloy UNS No. C61300					
HR50	drawn and stress relieved	<i>rod (round only):</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2.0 [50] incl over 2 [50] to 3 [80], incl	80 [550] 75 [515] 72 [495] 70 [485]	50 [345] 45 [310] 40 [275] 35 [240]	30 30 30 30
HR50	drawn and stress relieved	<i>rod (hexagonal and octagonal) and bar:</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl	80 [550] 75 [515] 70 [485]	40 [275] 35 [240] 32 [220]	30 30 30
Copper Alloy UNS No. C61400					
HR50	drawn and stress relieved	<i>rod (round only):</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	80 [550] 75 [515] 70 [485] 70 [485]	40 [275] 35 [240] 32 [220] 30 [205]	30 30 30 30
Copper Alloy UNS No. C61900					
HR50	drawn and stress relieved	<i>rod (round only):</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	90 [620] 88 [605] 85 [585] 78 [540]	50 [345] 44 [305] 40 [275] 37 [255]	15 15 20 25
M20	as hot rolled	over 3 [80]	75 [515]	30 [205]	20
M20	as hot rolled	} <i>shapes, all sizes</i>	75 [515]	30 [205]	20
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
Copper Alloy UNS No. C62300					
HR50	drawn and stress relieved	<i>rod (round only):</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	90 [620] 88 [605] 84 [580] 76 [525]	50 [345] 44 [305] 40 [275] 37 [255]	12 15 15 20
M20	as hot rolled	} over 3 [80]	75 [515]	30 [205]	20
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
HR50	drawn and stress relieved	<i>rod (hexagonal and octagonal) and bar:</i> 1 [25] and under over 1 [25] to 2 [50], incl	80 [550] 78 [540]	35 [240] 32 [220]	15 15
M20	as hot rolled	over 2 [50]	75 [515]	30 [205]	20
M20	as hot rolled	} <i>shapes, all sizes</i>	75 [515]	30 [205]	20
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
HR50	drawn and stress relieved				
Copper Alloy UNS No. C62400					
HR50	drawn and stress relieved	<i>rod (round only):</i> ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	95 [655] 95 [655] 90 [620] 90 [620]	45 [310] 45 [310] 43 [295] 40 [275]	10 12 12 12
M20	as hot rolled	} over 3 [80] to 5 [125] incl	90 [620]	35 [240]	12
M30	as hot extruded				
O20	hot forged and annealed	} <i>rod (hexagonal and octagonal) and bar:</i> ½ [12] to 5 [125], incl <i>shapes, all sizes</i>	90 [620] 90 [620]	35 [240] 35 [240]	12 12
O25	hot rolled and annealed				
O30	hot extruded and annealed				

TABLE 2 Continued

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^A in. [mm]	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa], at 0.5 % Extension Under Load	Elongation in 4 × Diameter or Thickness of Specimen min, % ^B
Code	Name				
TQ50	quench hardened and temper annealed	rod (round only): over 3 [80] to 5 [125], incl	95 [655]	45 [310]	10
Copper Alloy UNS No. C63000					
HR50	drawn and stress relieved	1—standard strength rod: ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	100 [690] 90 [620] 85 [585]	50 [345] 45 [310] 42.5 [295]	5 6 10
M20	as hot rolled	over 3 [80] to 4 [100], incl over 4 [100]	85 [585] 80 [550]	42.5 [295] 40 [275]	10 12
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
HR50	drawn and stress relieved	bar: ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl	100 [690] 90 [620]	50 [345] 45 [310]	5 6
M20	as hot rolled	over 2 [50] to 4 [100], incl over 4 [100]	85 [585] 80 [550]	42.5 [295] 40 [275]	10 12
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
M20	as hot rolled	shapes, all sizes	85 [585]	42.5 [295]	10
M30	as hot extruded				
O20	hot forged and annealed				
O25	hot rolled and annealed				
O30	hot extruded and annealed				
HR50	drawn and stress relieved				
HR50	drawn and stress relieved	2—high strength rod: 1 [25] and under over 1 [25] to 2 [50], incl	110 [760] 110 [760]	68 [470] 60 [415]	10 10
HR50	drawn and stress relieved	over 2 [50] to 3 [80], incl	105 [725]	55 [380]	10
O26	hot rolled and temper annealed				
TQ50	quench hardened and temper annealed	over 3 [80] to 5 [125], incl	100 [690]	50 [345]	10
O32	hot extruded and temper annealed				
O26	hot rolled and temper annealed				
Copper Alloy UNS No C63020					
TQ30	quenched hardened and tempered	rod and bar: up to 1 [25] incl over 1 [25] to 2 [50], incl over 2 [50] to 4 [100], incl	135 [930] 130 [890] 130 [890]	100 [690] ^C 95 [650] ^C 90 [620] ^C	6 6 6
Copper Alloy UNS No. C63200					
TQ50	quench hardened and temper annealed	rod and bar: up to 3 [80], incl over 3 [80] to 5 [125], incl over 5 [125] to 12 [300], incl	90 [620] 90 [620] 90 [620]	50 [345] 45 [310] 40 [275]	15 15 15
TQ55	quench hardened, temper annealed, drawn, and stress relieved	shapes, all sizes	90 [620]	40 [275]	15
O20	hot forged and annealed	bar and shapes all sizes	90 [620]	40 [275]	15
O25	hot rolled and annealed				
Copper Alloy UNS Nos. C64200 and C64210					
HR50	drawn and stress relieved	rod and bar: ½ [12] and under over ½ [12] to 1 [25], incl over 1 [25] to 2 [50], incl over 2 [50] to 3 [80], incl	90 [620] 85 [585] 80 [550] 75 [515]	45 [310] 45 [310] 42 [290] 35 [240]	9 12 12 15

TABLE 2 Continued

Temper Designation		Diameter or Distance Between Parallel Surfaces, ^A in. [mm]	Tensile Strength, min ksi [MPa]	Yield Strength, min ksi [MPa], at 0.5 % Extension Under Load	Elongation in 4 x Diameter or Thickness of Specimen min, % ^B
Code	Name				
M10	as hot forged—air cooled	over 3 [80] to 4 [100] incl over 4 [100]	70 [485]	30 [205]	15
M20	as hot rolled		70 [485]	25 [170]	15
M30	as hot extruded		70 [485]	30 [205]	15
M30	as hot extruded	shapes, all sizes	70 [485]	30 [205]	15

^A For rectangular bar, the Distance Between Parallel Surfaces as used in this table refers to the thickness.

^B Elongation values are based on 5.65 times the square root of the area for dimensions greater than 0.10 in. [2.5 mm]. In any case, a minimum gage length of 1 in. [25 mm] shall be used.

^C Yield strength at 0.2 % offset.

TABLE 3 Rockwell Hardness Requirements^A

Temper Designation		Diameter or Distance Between Parallel Surfaces, in. [mm]	Rockwell Hardness Determined on the Cross Section Midway Between Surface and Center
Code	Name		
Copper Alloy UNS No. C63020			
TQ30	Quench hardened and tempered	all sizes	C26 min
Copper Alloys UNS Designations C64200 and C64210			
HR50	drawn and stress relieved	0.5 [12] to 1.0 [25], incl. over 1.0 [25] to 2.0 [50], incl. over 2.0 [50] to 3.0 [80], incl.	B80 – 100 B80 – 100 B70 – 95
M30	as hot-extruded	over 3.0 [80] to 4.0 [100], incl. over 4.0 [100] shapes, all sizes	B65 – 95 B65 – 95 B65–95

^A Rockwell hardness requirements are not established for diameters less than 0.5 in. [12 mm].

6.2.1 When all elements in Table 1 are determined, the sum of results shall be 99.5 % minimum for all alloys except C61300 which shall be 99.8 % min.

6.3 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and the purchaser, limits may be established and analysis required for unnamed elements.

7. Temper

7.1 The standard tempers for products described in this specification, and as defined in Classification B601, are given in Tables 2 and 3.

7.1.1 Annealed tempers O20, O25, and O30.

7.1.2 Cold worked and stress relieved temper HR50.

7.1.3 As-manufactured tempers M10, M20, M30.

7.1.4 Heat treated tempers O26, O32, TQ30, TQ50 and TQ55.

NOTE 3—UNS No. C63000 has two available strength levels available in rod, standard strength and high strength.

8. Mechanical Property Requirements

8.1 Product furnished under this specification shall conform to the mechanical property requirements prescribed in Table 2 and Table 3 for the Copper Alloy UNS No. designation specified in the ordering information.

8.2 *Rockwell Hardness Requirement*—For the alloys and tempers listed in Table 3, product 0.5 in. [12 mm] and over in diameter or distance between parallel surfaces shall conform

with the requirements prescribed in Table 3, when tested in accordance with Test Methods E18.

8.2.1 DELETED

8.3 *Tensile Strength Requirements*—Product furnished under this specification shall conform to the tensile requirements in Table 2 when tested in accordance with Test Methods E8/E8M.

9. Performance Requirements

9.1 Residual Stress Test:

9.1.1 When specified in the contract or purchase order, the product shall be tested for residual stress according to the requirements of Test Method B154 or Test Method B858, and show no signs of cracking.

Warning—Mercury is a definite health hazard. With the Mercurous Nitrate Test, equipment for the detection and removal of mercury vapor produced in volatilization, and the use of protective gloves is recommended.

9.1.2 When the ammonia vapor test is used, the test pH value appropriate for the intended application shall be 10 unless otherwise specified by the purchaser.

NOTE 4—A residual stress test provides information about the adequacy of the stress relief of the material. Bar straightening is a method of mechanical stress relief. Stress relief annealing is a method of thermal stress relief.

9.2 *Piston Finish*—When specified, round rod over 0.5 in. [12 mm] in diameter shall be furnished piston finished. Refer to Specification B249/B249M.

10. Dimensions and Permissible Variations

10.1 The dimensions and tolerances for product described by this specification shall be as specified in Specification B249/B249M with particular reference to the following tables and related paragraphs:

10.1.1 *Diameter or Distance between Parallel Surfaces, Rod (Round, Hexagonal, Octagonal)*:

10.1.1.1 *Rod: Cold Drawn Tempers*—Refer to applicable Table 2 on Tolerances for Diameter or Distances Between Parallel Surfaces of Cold-Drawn Rod.

10.1.1.2 *Rod, M30, O30, and O32 tempers*—Refer to Table 4 on Tolerances for Diameter or Distance Between Parallel Surfaces of As-Extruded Rod and Bar.

10.1.1.3 *Round Rod, M20 temper*—Refer to Table 6 on Diameter Tolerances for Hot-Rolled Round Rod.

10.1.1.4 *Piston Finish Rod*—Refer to Table 3 on Diameter Tolerances for Piston-Finished Rod.

10.1.2 *Distance between Parallel Surfaces, Bar (Rectangular and Square)*:

10.1.2.1 *Bar, Drawn Tempers*—Refer to Table 9 on Thickness Tolerances for Rectangular and Square Bar, and Table 11 on Width Tolerances for Rectangular Bar.

10.1.2.2 *Bar, M30, O30, and O32 Tempers*—Refer to Table 4 on Tolerances for Diameter or Distance Between Parallel Surfaces of As-Extruded Rod and Bar.

10.1.3 *Length of Rod, Bar and Shapes*—Refer to Table 13 on Length Tolerances for Rod, Bar, and Shapes, and Table 15 on Schedule of Lengths (Specific and Stock) with Ends for Rod and Bar.

10.1.4 *Straightness*:

10.1.4.1 *Rod and Bar*—Refer to Table 16 on Straightness Tolerances for Rod, Bar, and Shapes.

10.1.4.2 *Shafting Rod*—Refer to Table 17 on Straightness Tolerances for Shafting.

10.1.4.3 *Rod, Bar and Shapes of M20, M30, O30, and O32 Temper*—They shall be of sufficient straightness to meet the requirements of the intended application.

10.1.5 *Edge Contours*—Refer to section entitled, “Edge Contours.”

10.2 *Shapes*—The cross section dimensional tolerances for shapes shall be as agreed upon between the manufacturer and the purchaser.

11. Workmanship, Finish, and Appearance

11.1 When specified in the contract or purchase order, round rod over ½ in. [12 mm] in diameter shall be furnished as piston finish rod or shafting.

12. Test Methods

12.1 *Chemical Analysis*:

12.1.1 In cases of disagreement, determine the composition using the following methods:

Element	ASTM Test Methods
Aluminum	E478, Titrimetric
Arsenic	E62
Copper	E478
Iron	E478, Photometric
Lead	E478, Atomic absorption
Manganese	E62
Nickel	E478, Photometric
Phosphorous	E62
Silicon	E62
Tin	E478, Photometric
Zinc	E478, Atomic absorption
Cadmium	E53
Chromium	E118

12.1.2 Test methods to be followed for the determination of elements resulting from contractual or purchase order agreement shall be as agreed upon between the manufacturer or supplier and the purchaser.

13. Keywords

13.1 aluminum bronze bar; aluminum bronze rod; aluminum bronze shapes; UNS Alloy No. C61300; UNS Alloy No. C61400; UNS Alloy No. C61900; UNS Alloy No. C62300; UNS Alloy No. C62400; UNS Alloy No. C63000; UNS Alloy No. C63020; UNS Alloy No. C63200; UNS Alloy No. C64200; UNS Alloy No. C64210

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SPECIFICATION FOR COPPER-NICKEL-ZINC ALLOY (NICKEL SILVER) AND COPPER-NICKEL ROD AND BAR



SB-151/SB-151M

(Identical with ASTM Specification B151/B151M-20 except paras. 5.2.2 and 5.2.3 have been deleted.)

Specification for Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar

1. Scope

1.1 This specification establishes the requirements for copper-nickel-zinc and copper-nickel rod and bar for general application produced from Copper Alloy UNS Nos. C70600, C70620, C71500, C71520, C74500, C75200, C75700, C76400, C77000, and C79200.

1.1.1 Copper Alloys UNS Nos. C70620 and C71520 are for product intended for welding applications.

1.1.2 *Units*—The values stated in either inch-pound units or SI units are to be regarded separately as standard. Within the text, SI units are shown in brackets. 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.

NOTE 1—Requirements for copper-nickel-zinc alloy wire appear in Specification B206/B206M.

1.2 *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:

B206/B206M Specification for Copper-Nickel-Zinc (Nickel Silver) Wire and Copper-Nickel Alloy Wire
B249/B249M Specification for General Requirements for Wrought Copper and Copper-Alloy Rod, Bar, Shapes and Forgings
B601 Classification for Temper Designations for Copper and Copper Alloys—Wrought and Cast
B846 Terminology for Copper and Copper Alloys
B950 Guide for Editorial Procedures and Form of Product Specifications for Copper and Copper Alloys
E75 Test Methods for Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys (Withdrawn 2010)
E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)
E478 Test Methods for Chemical Analysis of Copper Alloys

3. General Requirements

3.1 The following sections of Specification B249/B249M constitute a part of this specification:

- 3.1.1 Terminology;
- 3.1.2 Material and Manufacture;
- 3.1.3 Workmanship, Finish, and Appearance;
- 3.1.4 Sampling;
- 3.1.5 Number of Tests and Retests;
- 3.1.6 Specimen Preparation;
- 3.1.7 Test Methods;
- 3.1.8 Significance of Numerical Limits;
- 3.1.9 Inspection;
- 3.1.10 Rejection and Rehearing;
- 3.1.11 Certification;
- 3.1.12 Report;
- 3.1.13 Packaging and Package Marking; and
- 3.1.14 Supplementary Requirements.

3.2 In addition, when a section with a title identical to that referenced in 3.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B249/B249M.

4. Terminology

4.1 For definitions of terms related to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification, as applicable:

- 5.1.1 ASTM designation and year of issue;
- 5.1.2 Copper Alloy UNS No. designation (Section 1);
- 5.1.3 Temper (Section 8 and Tables 2-6);
- 5.1.4 Form: cross section such as round, hexagonal, square, and so forth (Section 11);
- 5.1.5 Diameter or distance between parallel surfaces, length (Section 11);
- 5.1.6 Weight: total for each form, size, and temper; and
- 5.1.7 Intended application.

5.2 The following options are available but may not be included unless specified at the time of placing of the order when required:

5.2.1 Heat identification or traceability details (4.1 of Specification B249/B249M),

5.2.2 DELETED

5.2.3 DELETED

5.2.4 When material is purchased for agencies of the U.S. Government (Section 11).

6. Materials and Manufacture

6.1 Material:

6.1.1 The material of manufacture as specified in the contract or purchase order, shall be of one of Copper Alloy UNS Nos. C70600, C70620, C71500, C71520, C74500, C75200, C75700, C76400, C77000, or C79200.

7. Chemical Composition

7.1 The material shall conform to the chemical composition requirements in Table 1 for the Copper Alloy UNS No. designation specified in the ordering information.

7.1.1 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and the purchaser, limits may be established and analysis required for unnamed elements.

7.2 For alloys in which copper is listed as “remainder,” copper is the difference between the sum of results for all elements determined and 100 %.

7.3 For alloys in which zinc is listed as “remainder,” either copper or zinc may be taken as the difference between the sum of all elements determined and 100 %.

7.4 When all elements listed in Table 1 for a specified alloy are determined, the sum of results shall be 99.5 % minimum.

TABLE 2 Grain Size Requirements for OS (Annealed) Temper Rod and Bar

Copper Alloy UNS No.	Temper Designation	Grain Size, mm		
		Nominal	Minimum	Maximum
All alloys	OS015	0.015	...	0.030
All alloys	OS035	0.035	0.025	0.050
C74500, C75200, C75700, C76400, and C77000	OS070	0.070	0.050	0.100

TABLE 3 Tensile Requirements for Copper-Nickel-Zinc Alloy Rod and Bar (Inch-Pound Units)

NOTE 1—SI values are stated in Table 4.

Temper Designation	Diameter or Distance Between Parallel Surfaces, in.	Tensile Strength, ksi			
		Copper Alloy UNS Nos. C75200 and C79200		Copper Alloy UNS Nos. C74500, C75700, C76400, and C77000	
		Min	Max	Min	Max
H01	Rod: round	60	80	75	95
	0.02 to 0.50, incl				
H04	Rod: round, hexagonal, octagonal	80	100	90	110
	0.02 to 0.25, incl				
	Over 0.25 to 0.50, incl				
	Over 0.50 to 1.0, incl				
H04	Bar: square, rectangular	68	88	75	95
	all sizes				

8. Temper

8.1 The standard tempers for products described in this specification and as defined in Classification B601 are: O60, OS015, OS035, OS070, M30, H01, and H04 as given in Tables 2-6.

NOTE 2—The purchaser should confer with the manufacturer or supplier concerning the availability of a specific form and temper.

8.2 Other tempers, and tempers for other products, including shapes, shall be subject to agreement between the manufacturer and the purchaser.

TABLE 1 Chemical Requirements

Composition, % max (unless shown as range or min)									
Copper Alloy UNS No.	Copper, Incl Silver	Nickel, Incl Cobalt	Lead	Iron	Manganese	Zinc	Phosphorous	Sulfur	Carbon
C70600	remainder	9.0-11.0	0.05	1.0-1.8	1.0	1.0	...	...	...
C70620	86.5 min	9.0-11.0	0.02	1.0-1.8	1.0	0.50	0.02	0.02	0.05
C71500	remainder	29.0-33.0	0.05	0.40-1.0	1.0	1.0	...	...	...
C71520	65.0 min	29.0-33.0	0.02	0.40-1.0	1.0	0.50	0.02	0.02	0.05
C74500	63.5-66.5	9.0-11.0	0.05	0.25	0.50	remainder	...	...	...
C75200	63.0-66.5	16.5-19.5	0.05	0.25	0.50	remainder	...	...	...
C75700	63.5-66.5	11.0-13.0	0.05	0.25	0.50	remainder	...	...	...
C76400	58.5-61.5	16.5-19.5	0.05	0.25	0.50	remainder	...	...	...
C77000	53.5-56.5	16.5-19.5	0.05	0.25	0.50	remainder	...	...	...
C79200	59.0-66.5	11.0-13.0	0.8-1.4	0.25	0.50	remainder	...	...	...

TABLE 4 Tensile Requirements for Copper-Nickel-Zinc Alloy Rod and Bar [SI Units]

NOTE 1—Inch-Pound values are stated in Table 3.

Temper Designation	Diameter or Distance Between Parallel Surfaces, mm	Tensile Strength, MPa			
		Copper Alloy UNS Nos. C75200 and C79200		Copper Alloy UNS Nos. C74500, C75700, C76400 and C77000	
		Min	Max	Min	Max
H01	Rod: round				
	0.5 to 10, incl	415	550	515	655
H04	Rod: round, hexagonal				
	0.5 to 6.5 incl	550	690	620	760
	Over 6.5 to 10, incl	485	620	550	690
	Over 10 to 25, incl	450	590	515	655
H04	Bar: square, rectangular				
	all sizes	470	605	515	650

9. Grain Size of Annealed Tempers

9.1 Grain size shall be the standard requirement for all product in the annealed tempers.

9.1.1 Product in the OS temper shall conform to the grain size requirement prescribed in Table 2 for the specified copper alloy and temper.

9.1.2 Grain size shall be the basis for acceptance or rejection for OS temper product produced from Copper Alloy UNS Nos. C74500, C75200, C75700, C76400, C77000, and C79200.

10. Mechanical Property Requirements

10.1 Tensile Strength Requirement:

10.1.1 Product of Copper-Nickel-Zinc Alloys UNS Nos. C74500, C75200, C75700, C76400, C77000, and C79200 in Tempers H01 and H04 furnished under this specification shall conform to the tensile requirements prescribed in Tables 3 and 4 for the specified shape and size. The tensile strength shall be the basis of acceptance or rejection for product in these tempers.

10.1.2 Product of Copper-Nickel Alloys UNS Nos. C70600, C70620, C71500, and C71520 in Tempers H01, H04, M30, and O60 furnished under this specification shall conform to the tensile requirements prescribed in Tables 5 and 6 for the specified shape and size. The tensile properties shall be the basis of acceptance or rejection for all tempers.

11. Purchases for U.S. Government Agencies

11.1 When specified in the contract or purchase order, product purchased for agencies of the U.S. Government shall conform to the special government regulations specified in the Supplementary Requirements section of Specification B249/B249M.

12. Dimensions, Mass, and Permissible Variations

12.1 The dimensions and tolerances for product described by this specification shall be as specified in Specification B249/B249M with particular reference to the following tables and related paragraphs:

12.1.1 Diameter or Distance Between Parallel Surfaces:

12.1.1.1 Rod: round/hexagonal, octagonal—cold-drawn rod, Table 2.

12.1.1.2 Bar: rectangular and square—thickness, width, Tables 9 and 11.

12.1.2 Length—length tolerances, schedule of length, Tables 13 and 15.

12.1.3 Straightness tolerances for rod, bar, and shapes, Table 16.

12.1.4 Edge contours—see identically titled section.

13. Test Methods

13.1 The test methods used for quality control or production control, or both, for the determination of conformance with product property requirements are discretionary.

13.1.1 The test methods used to obtain data for the preparation of certification or test report, or both, shall be made available to the purchaser on request.

13.2 *Chemical Analysis*—In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list of published test methods some of which are considered by ASTM as no longer viable. These, and others not listed, may be used, subject to agreement.

Element	Range, %	Method
Copper	53–90	E478
Iron	0.02–8	E75
Lead	0.05–1.5	E478 (AA)
Manganese	0.05–1.0	E75
Nickel	8–34	E478 (Gravimetric)
Zinc	0–1.0	E478 (AA)
Zinc	2–40	E478 (Titrimetric)
Sulfur	0–0.1	E478 (AA)
Phosphorus	0–1.0	E478 (AA)
Carbon	0.01–1.0	E76

14. Keywords

14.1 copper alloy bar; copper alloy rod; copper-nickel alloy bar; copper-nickel alloy rod; copper-nickel-zinc alloy bar; copper-nickel-zinc alloy rod; cupronickel bar; cupronickel rod; nickel silver bar; nickel silver rod; UNS C70600 bar; UNS C71500 bar; UNS C74500 bar; UNS C75200 bar; UNS C75700 bar; UNS C76400 bar; UNS C77000 bar; UNS C79200 bar; UNS C70600 rod; UNS C71500 rod; UNS C74500 rod; UNS C75200 rod; UNS C75700 rod; UNS C76400 rod; UNS C77000 rod; UNS C79200 rod ; UNS C70620; UNS C71520

TABLE 5 Tensile Requirements for Copper-Nickel Alloy Rod and Bar (Inch-Pound Units)

NOTE 1—SI values are stated in Table 6.

Temper Designation	Diameter or Distance Between Parallel Surfaces, in.		Tensile Strength, min, ksi	Yield Strength at 0.5 % Extension Under Load, min, ksi	Elongation in 4x Diameter or Thickness of Specimen, min, % ^A	
Copper Alloy UNS Nos. C70600 and C70620						
O60, M30 H04	round, hexagonal, and octagonal rods and square bars	all sizes	38	15	30	
	round, hexagonal, and octagonal rods and square bars	up to ⅜, incl	60	38	10	
O60 H04	rectangular bars and shapes	over ⅜ to 1, incl	50	30	15	
		over 1 to 3, incl	40	15	30	
		over 3 to 5, incl	38	15	20	
		all sizes	38	15	30	
		For Thicknesses				
		up to ⅜, incl	55	30	10	
H04	rectangular bars	over ⅜ to ½ incl	50	28	12	
		over ½ to 3	40	17	20	
H04	shapes	all sizes	(As agreed upon between the manufacturer or supplier and the purchaser)			
Copper Alloy UNS Nos. C71500 and C71520						
O60, M30	round, hexagonal, and octagonal rods and square bars	up to ½, incl	52	18	30	
		over ½ to 1, incl	48	18	30	
		over 1	45	18	30	
H01	round, hexagonal, and octagonal rods and square bars	up to ½, incl	65	50	10	
		over ½ to 1, incl	60	45	15	
		over 1 to 3, incl	55	35	20	
		over 3 to 5, incl	45	18	20	
		up to ½, incl	80	60	8	
H04	rectangular bars and shapes	over ½ to 1, incl	75	58	10	
		over 1 to 2, incl	70	55	10	
		all sizes	45	15	30	
		For Thicknesses				
H04	rectangular bars	up to ½, incl	75	55	7	
		over ½ to 1, incl	70	50	10	
H04	shapes	all sizes	(As agreed upon between the manufacturer or supplier and the purchaser)			

^A In any case, a minimum gage length of 1 in. shall be used.

TABLE 6 Tensile Requirements for Copper-Nickel Alloy Rod and Bar [SI Units]

NOTE 1—Inch-pound values are stated in Table 5.

Temper Designation	Diameter or Distance Between Parallel Surfaces, mm		Tensile Strength, min, MPa	Yield Strength at 0.5 % Extension Under Load, min, MPa	Elongation in 4x Diameter or Thickness of Specimen, min, % ^A
Copper Alloy UNS Nos. C70600 and C70620					
O60, M30 H04	round, hexagonal, and octagonal rods and square bars	all sizes	260	105	30
		up to 9.5, incl	415	260	10
		over 9.5 to 25, incl	345	205	15
		over 25 to 80, incl	275	105	30
		over 80 to 125, incl	260	105	20
O60	rectangular bars and shapes	all sizes	260	105	30
For Thicknesses					
H04	rectangular bars	up to 9.5, incl	380	205	10
		over 9.5 to 12, incl	345	195	12
		over 12 to 80, incl	275	115	20
H04	shapes	all sizes	(As agreed upon between the manufacturer or supplier and the purchaser)		
Copper Alloy UNS Nos. C71500 and C71520					
O60, M30	round, hexagonal, and octagonal rods and square bars	up to 12, incl	360	125	30
		over 12 to 25, incl	330	125	30
		over 25	310	125	30
H01	round, hexagonal, and octagonal rods and square bars	up to 12, incl	450	345	10
		over 12 to 25, incl	415	310	15
		over 25 to 80, incl	380	240	20
		over 80 to 125, incl	310	125	20
		up to 12, incl	550	415	8
H04		over 12 to 25, incl	515	400	10
		over 25 to 50, incl	485	380	10
		all sizes	310	105	30
For Thicknesses					
H04	rectangular bars	up to 12, incl	515	380	7
over 12 to 25, incl		485	345	10	
H04	shapes	all sizes	(As agreed upon between the manufacturer or supplier and the purchaser)		

^A In any case, a minimum gage length of 25 mm shall be used.

SPECIFICATION FOR COPPER SHEET, STRIP, PLATE, AND ROLLED BAR



SB-152/SB-152M

(Identical with ASTM Specification B152/B152M-19 except for the deletion of paras. 7.3.1.1 and 10.3.1, and certification and test reports have been made mandatory.)

Specification for Copper Sheet, Strip, Plate, and Rolled Bar

1. Scope

1.1 This specification establishes the requirements for copper sheet, strip, plate, and rolled bar produced from the following coppers.

Copper UNS No. ^A	Previous Designation	Type of Copper
C10100 ^B	OFE	Oxygen-free electronic
C10200 ^B	OF	Oxygen-free without residual deoxidants
C10300	OFXLP	Oxygen-free extra low phosphorus
C10400, C10500, C10700	OFS	Oxygen-free, silver bearing
C10800	OFLP	Oxygen-free low phosphorus
C10910	...	Low oxygen
C11000 ^{B, C}	ETP, TP ^C	Electrolytic tough pitch, ^C Tough pitch ^C
C11300, C11400, C11600 ^B	STP	Silver bearing tough pitch
C12000	DLP	Phosphorized, low residual phos- phorus
C12200 ^B	DHP	Phosphorized, high residual phos- phorus
C12300	DHPS	Phosphorized, silver bearing
C14200	DPA	Phosphorus deoxidized, arsenical
C14420	...	Tin bearing tellurium copper
C14530	...	Tin tellurium bearing copper

^A Except Copper UNS Nos. C10910 (low oxygen), C14200 (phosphorus deoxidized, arsenical), C14420 (tin bearing tellurium), and C14530 (tin tellurium bearing) these types of copper are classified in Classification B224.

^B SAE Specification CA101 conforms to Copper UNS No. C10100; SAE Specification CA102 conforms to the requirements for Copper UNS No. C10200; SAE Specification CA110 conforms to the requirements for Copper UNS No. C11000; SAE Specifications CA113, CA114, and CA116 conform to the requirements for Copper UNS Nos. C11300, C11400, and C11600; SAE Specification CA120 conforms to Copper UNS No. C12000; and SAE Specification CA122 conforms to the requirements for Copper UNS No. C12200.

^C Unless specified in the contract or purchase order the supplier is permitted to provide ETP copper or TP copper.

NOTE 1—Each of the coppers listed has unique properties that can make it suitable for specific applications. The purchaser should consult with the supplier to determine which copper would be best suited for the intended application.

NOTE 2—This specification is not intended to establish requirements for material rolled to ounce-weight thicknesses. Such material is defined in Specification B370.

Flat copper products with finished (rolled or drawn) edges (flat wire and strip) are defined in Specification B272.

1.1.1 When a specific copper is not identified in the contract or purchase order, the supplier may furnish product from any of the listed coppers.

1.2 *Units*—The values stated in either inch-pound units or SI 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.

1.3 The following safety hazard caveat pertains only to the test method(s) described in this specification:

1.3.1 *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.*

1.4 *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:

- B170 Specification for Oxygen-Free Electrolytic Copper—Refinery Shapes
- B193 Test Method for Resistivity of Electrical Conductor Materials
- B216 Specification for Tough-Pitch Fire-Refined Copper—Refinery Shapes
- B224 Classification of Coppers

B248 Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar
 B248M Specification for General Requirements for Wrought Copper and Copper-Alloy Plate, Sheet, Strip, and Rolled Bar (Metric)
 B272 Specification for Copper Flat Products with Finished (Rolled or Drawn) Edges (Flat Wire and Strip)
 B370 Specification for Copper Sheet and Strip for Building Construction
 B577 Test Methods for Detection of Cuprous Oxide (Hydrogen Embrittlement Susceptibility) in Copper
 B846 Terminology for Copper and Copper Alloys
 E3 Guide for Preparation of Metallographic Specimens
 E8/E8M Test Methods for Tension Testing of Metallic Materials
 E53 Test Method for Determination of Copper in Unalloyed Copper by Gravimetry
 E62 Test Methods for Chemical Analysis of Copper and Copper Alloys (Photometric Methods) (Withdrawn 2010)
 E112 Test Methods for Determining Average Grain Size
 E478 Test Methods for Chemical Analysis of Copper Alloys
 2.2 *ASME Standard:*
 ASME Boiler and Pressure Vessel Code

3. General Requirements

3.1 The following sections of Specification B248 or B248M constitute a part of this specification:

- 3.1.1 Terminology
- 3.1.2 Materials and Manufacture
- 3.1.3 Sampling
- 3.1.4 Number of Tests and Retests
- 3.1.5 Specimen Preparation
- 3.1.6 Test Methods
- 3.1.7 Packaging and Package Marking
- 3.1.8 Workmanship, Finish, and Appearance
- 3.1.9 Significance of Numerical Limits
- 3.1.10 Rejection and Rehearing

3.2 In addition, when a section with a title identical to that referenced in 3.1, above, appears in this specification, it contains additional requirements which supplement those appearing in Specification B248 or B248M.

4. Terminology

4.1 *Definitions*—For definitions of terms related to copper and copper alloys, refer to Terminology B846.

5. Ordering Information

5.1 Include the following specified choices when placing orders for product under this specification, as applicable:

- 5.1.1 ASTM designation and year of issue;
- 5.1.2 Copper [Alloy] UNS No. (or other internationally recognized copper [alloy]). With Alloys C10400, C10500, C10700, C11300, C11400, C11600, or C12300, the amount of silver in ounces per ton;
- 5.1.3 Temper (Section 7);
- 5.1.4 Dimensions: thickness, width, and edges (Section 12);
- 5.1.5 How furnished: straight lengths or coils;
- 5.1.6 Quantity – total weight or total length or number of pieces of each size;
- 5.1.7 Length (Section 12); and
- 5.1.8 Weight of coils: coil weights or coil size limitations, if required.

5.2 The following options are available but may not be included unless specified at the time of placing of the order when required:

- 5.2.1 Embrittlement test for the alloys listed in 11.2.
- 5.2.2 DELETED
- 5.2.3 DELETED
- 5.2.4 Resistivity test for alloys listed in Table 5 (see Section 9);
- 5.2.5 If product is purchased for agencies of the U.S. Government (see the Supplemental Requirements section of Specifications B248 and B248M).

6. Chemical Composition

6.1 The materials shall conform to the chemical requirements in Table 1 for the copper [alloy] UNS No. specified in the ordering information.

6.2 These composition limits do not preclude the presence of other elements. By agreement between the manufacturer and purchaser, limits may be established and analysis required for unnamed elements.

7. Temper

7.1 The standard tempers for product described in this specification are given in Tables 2 and 3.

7.1.1 *As Hot Rolled Temper M20:*
 7.1.1.1 Plate not specified for ASME Boiler and Pressure Vessel Code applications are generally available in the M20 temper.

7.1.2 *Cold Rolled Tempers H00 to H10.*
 7.1.3 *Annealed Tempers O25, O60, or O68:*
 7.1.3.1 DELETED

NOTE 3—Any product produced in a temper other than those listed in Table 2, Table 3, or Table 4 will be produced and sold by contract and cannot be said to be produced under this specification.

NOTE 4—Soft-anneal temper is suitable for most industrial users of copper such as forming, spinning, and simple drawing operations in which close control of temper is not essential. Deep drawing anneal temper is especially suited for very severe drawing and forming operations in which maximum ductility and close control of temper is required.

8. Grain Size for Cold Rolled Annealed Tempers

8.1 Grain size shall be standard requirement for all product of the annealed (O60 and O68) tempers.

TABLE 1 Chemical Requirements

Element	Composition, %																	
	Copper UNS No.																	
	C10100 ^A	C10200	C10300	C10400 ^B	C10500 ^B	C10700 ^B	C10800	C10910	C11000	C11300 ^C	C11400 ^C	C11600 ^C	C12000	C12200	C12300 ^D	C14200	C14420	C14530
Copper, min	99.99 ^E	99.95 ^E incl silver	99.95 ^F incl silver	99.95 ^E incl silver	99.95 ^E incl silver	99.95 ^E incl silver	99.95 ^F incl silver	99.95 incl silver	99.90 incl silver	99.90 incl silver	99.90 incl silver	99.90 incl silver	99.90 incl silver	99.9 incl silver	99.90 incl silver	99.4 incl silver	99.90 ^G incl silver	99.90 ^H incl silver
Phosphorus	^A	...	0.001– 0.005	...	...	...	0.005– 0.012	...	...	...	...	...	0.004– 0.012	0.015– 0.040	0.015– 0.040	0.015– 0.040	...	0.001– 0.010
Arsenic	^A	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.15– 0.50	...	...
Oxygen, max	0.0005	0.0010	...	0.0010	0.001	0.001	...	0.005	...	...	...	...	...	...	...	...	...	...
Silver	^A	...	...	8 ^I	10 ^I	25 ^I	...	...	...	8 ^I	10 ^I	25 ^I	...	...	4 ^I	...	...	...
Selenium + tellurium, max	^A	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.023
Tellurium	^A	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.005– 0.05	0.003– 0.023 ^J
Tin	^A	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0.04– 0.15	0.003– 0.023

^A Impurity maximums in ppm of C10100 shall be: antimony 4, arsenic 5, bismuth 1, cadmium 1, iron 10, lead 5, manganese 0.5, nickel 10, phosphorus 3, selenium 3, silver 25, sulfur 15, tellurium 2, tin 2, and zinc 1.

^B C10400, C10500, and C10700 are oxygen-free coppers with the addition of a specified amount of silver. The compositions of these alloys are equivalent to C10200 plus the intentional addition of silver.

^C C11300, C11400, and C11600 are electrolytic tough-pitch copper with silver additions. The compositions of these alloys are equivalent to C11000 plus the intentional addition of silver.

^D Copper UNS No. C12300 is produced by the addition of silver to phosphorus-deoxidized copper.

^E Copper shall be determined by difference between impurity total and 100 %.

^F Includes phosphorus.

^G Includes tellurium + tin.

^H Includes tin + tellurium + selenium.

^I Values are minimum silver Troy oz/Avoirdupois ton (1 oz/ton is equivalent to 0.0034 %).

^J Tellurium or selenium, or both.

TABLE 2 Tensile Strength Requirements and Approximate Hardness Values (Inch-Pound Units)

Temper Designation		Tensile Strength, ksi ^A		Approximate Rockwell Hardness ^B	
Code	Name	Min	Max	F Scale	Superficial 30T
	Cold-rolled tempers:				
H00	Eighth hard	32	40	54–82	up to 49
H01	Quarter hard	34	42	60–84	18–51
H02	Half hard	37	46	77–89	43–57
H03	Three-quarter-hard	41	50	82–91	47–59
H04	Hard	43	52	86–93	54–62
H06	Extra hard	47	56	88–95	56–64
H08	Spring	50	58	91–97	60–66
H10	Extra spring	52	...	92 and over	61 and over
	Hot-rolled tempers:				
M20 ^C	Hot-rolled	30 ^E	38	up to 75	up to 41
O25 ^D	Hot-rolled and annealed	30 ^E	38	up to 65	up to 31

^A ksi = 1000 psi.^B Rockwell values apply as follows: The F scale applies to metal 0.020 in. and over in thickness. The Superficial 30-T scale applies to metal 0.012 in. and over in thickness.^C See 7.1.1.1.^D DELETED^E The minimum yield strength at 0.5 % extension under load or at 0.2 % offset shall be 10 ksi.**TABLE 3 Tensile Strength Requirements and Approximate Hardness Values (SI Units)**

Temper Designation		Tensile Strength, MPa		Approximate Rockwell Hardness ^A	
Code	Name	Min	Max	F Scale	Superficial 30T
	Cold-rolled tempers:				
H00	Eighth hard	220	275	54–82	up to 49
H01	Quarter hard	235	290	60–84	18–51
H02	Half hard	255	315	77–89	43–57
H03	Three-quarter-hard	285	345	82–91	47–59
H04	Hard	295	360	86–93	54–62
H06	Extra hard	325	385	88–95	56–64
H08	Spring	345	400	91–97	60–66
H10	Extra spring	360	...	92 and over	61 and over
	Hot-rolled tempers:				
M20 ^B	Hot-rolled	205 ^D	260	up to 75	up to 41
O25 ^C	Hot-rolled and annealed	205 ^D	260	up to 65	up to 31

^A Rockwell values apply as follows: The F scale applies to metal 0.50 mm and over in thickness. The Superficial 30-T scale applies to metal 0.30 mm and over in thickness.^B See 7.1.1.1.^C DELETED^D The minimum yield strength at 0.5 % extension under load or at 0.2 % offset shall be 70 MPa.**TABLE 4 Grain Size Requirements and Approximate Rockwell Hardness Values for Annealed Product**

Temper Designation		Grain Size, mm		Approximate Rockwell Hardness ^A	
Code	Name	Min	Max	F Scale	
				Min	Max
O60	Soft anneal	^B			65
O68	Deep-drawing anneal	^B	0.050	30	75

^A Rockwell hardness values apply as follows: The F scale applies to metal 0.020 in. or 0.50 mm and over in thickness.^B Although no minimum grain size is required, this material must be fully recrystallized.

8.2 Acceptance or rejection based upon grain size shall depend only on the average grain size of a test specimen taken from each of two sample portions, and each specimen shall be within the limits prescribed in Table 4 when determined in accordance with Test Methods E112.

TABLE 5 Electrical Mass Resistivity Requirements for Copper UNS Nos. C10100, C10200, C10300, C10400, C10500, C10700, C10910, C11000, C11300, C11400, and C11600

Alloy	Temper	Electrical Resistivity max, $\Omega \cdot \text{g}/\text{m}^2$
C10100	Annealed	0.15176
C10100	Cold Rolled	0.15614
C10200, C10300, C10400, C10500, C10700, C10910, C11000, C11300, C11400, C11600	Annealed	0.15328
C10200, C10300, C10400, C10500, C10700, C10910, C11000, C11300, C11400, C11600	Cold Rolled	0.15775

8.3 The test specimen shall be prepared in accordance with Guide E3. The average grain size shall be determined on a plane parallel to the surface of the product.

9. Physical Property Requirements

9.1 Electrical Resistivity Requirement:

9.1.1 When specified in the contract or purchase order on the alloys listed below, the product shall conform to the electrical mass resistivity requirement prescribed in Table 5, when tested in accordance with Test Method B193.

9.1.2 Copper UNS Nos. C10800, C12000, C12200, C12300, C14200, C14420, and C14530 when specified at the time of purchase for electrical conductor use shall meet resistivity requirements as agreed upon between the manufacturer or supplier and the purchaser.

NOTE 5—The International Annealed Copper Standard electrical conductivity equivalents are as follows:

Electrical Resistivity, $\Omega\text{-g/m}^2$	Conductivity, % IACS
0.151 76	101.00
0.153 28	100.00
0.156 14	98.16
0.157 75	97.16

10. Mechanical Property Requirements

10.1 *Tensile Requirements of As Hot-Rolled (M20), and Hot-Rolled and Annealed (O25) Tempers:*

10.1.1 Product furnished under this specification shall conform to the tensile strength requirements prescribed in Tables 2 and 3. Furthermore, Copper [Alloy] UNS Nos. C11000 and C12200 plate shall have 40 % minimum elongation in 2 in. [50 mm] and Copper [Alloy] UNS No. C14200 plate shall have 45 % minimum elongation in 2 in. [50 mm]. The test specimens shall be taken so that the longitudinal axis of the specimen is parallel to the direction of rolling and tested in accordance with Test Methods E8/E8M.

10.1.2 *Plate Item Test*—Five specimens shall be taken either from the excess portion of the plate or from separate pieces produced under the same specification and temper.

10.1.3 DELETED

10.2 *Tensile Requirements of Rolled (R) Tempers:*

10.2.1 Product furnished under this specification shall conform to the tensile strength requirements prescribed in Tables 2 and 3. The test specimens shall be taken so the longitudinal axis of the specimen is parallel to the direction of rolling and tested in accordance with Test Methods E8/E8M.

10.2.2 Acceptance or rejection based upon mechanical properties shall depend only on tensile strength.

10.3 Rockwell Hardness Requirement:

10.3.1 The approximate Rockwell hardness values given in Table 2, Table 3, and Table 4 are for general information and assistance in testing and shall not be used as a basis for product rejection.

NOTE 6—The Rockwell hardness tests offer a quick and convenient method of checking for general conformity to the specification requirements for temper, tensile strength, and grain size.

11. Performance Requirements

11.1 Microscopical Examination:

11.1.1 Samples of Copper [Alloy] UNS Nos. C10100, C10200, C10300, C10400, C10500, C10700, and C12000 shall be substantially free of cuprous oxide as determined by Procedure A of Test Methods B577. In case of a dispute, a referee method in accordance with Procedure C of Test Methods B577 shall be used.

11.1.2 When Copper UNS Nos. C10800, C10910, C11000, C11300, C11400, C11600, C12200, C12300, C14200, C14420, or C14530 are supplied, microscopical examination for cuprous oxide is not required.

11.2 *Hydrogen Embrittlement Susceptibility Test*—Samples of Copper UNS Nos. C10100, C10200, C10300, C10400, C10500, C10700, C10800, C12000, C12200, and C12300 shall be capable of passing the embrittlement test of Procedure B of Test Methods B577. The actual performance of this test is not mandatory under the terms of this specification unless specified in the ordering information. In case of a dispute, a referee method in accordance with Procedure C shall be used.

12. Dimensions, Mass, and Permissible Variation

12.1 The dimensions and tolerances for product described by this specification shall be as specified in Specification B248 or B248M with particular reference to the following tables and related paragraphs:

12.2 Thickness.

12.3 Width:

12.3.1 Slit Metal and Slit Metal with Rolled Edges.

12.3.2 Square Sheared Metal.

12.3.3 Sawed Metal.

12.4 Length:

12.4.1 Length Tolerance for Straight Lengths.

12.4.2 *Schedule for Minimum Lengths and Maximum Weights of Ends for Specific Lengths with Ends, and Stock Lengths with Ends.*

12.4.3 Length Tolerance for Square Sheared Metal.

12.4.4 Length Tolerance for Sawed Metal.

12.5 Straightness:

12.5.1 *Slit Metal or Slit Metal Either Straightened or Edge Rolled.*

12.5.2 Square Sheared Metal.

12.5.3 Sawed Metal.

12.6 Weight—Hot Rolled Sheet and Plate.

12.7 Edges Contours:

12.7.1 Square Corners.

12.7.2 Rounded Corners.

12.7.3 Rounded Edges.

12.7.4 Full-Rounded Edges.

13. Test Methods

13.1 Chemical Analyses:

13.1.1 In cases of disagreement, test methods for chemical analysis shall be subject to agreement between the manufacturer or supplier and the purchaser. The following table is a list

of published methods, some of which may no longer be viable, which along with others not listed, may be used subject to agreement.

Element	ASTM Test Method
Copper	E53
Phosphorus	E62
Selenium	Refer to Annex, Specification B216
Silver	E478
Tellurium	Refer to Annex, Specification B216
Arsenic	E62

13.1.2 Test method(s) to be followed for the determination of element(s) resulting from contractual or purchaser order agreement shall be as agreed upon between the manufacturer or supplier and purchaser.

13.1.3 For Copper [Alloy] UNS No. C10100, refer to the Annex of Specification B170 for test methods for chemical composition.

13.2 Other Tests:

13.2.1 Refer to Specification B248 or B248M for the appropriate mechanical test method.

14. Inspection

14.1 The manufacturer or supplier shall inspect and make tests necessary to verify that the furnished product conforms to specification requirements.

14.2 When mutually agreed upon, the manufacturer or supplier and the purchaser shall conduct the final inspection simultaneously.

15. Certification

15.1 The purchaser shall be furnished certification that samples representing each lot have been tested and inspected as directed in this specification and requirements have been met.

15.2 DELETED

16. Test Report

16.1 A report of test results shall be furnished.

17. Keywords

17.1 annealed; copper bars; copper plate; copper sheet; copper strip; hot-rolled; rolled; UNS No. C10100; UNS No. C10200; UNS No. C10300; UNS No. C10400; UNS No. C10500; UNS No. C10700; UNS No. C10800; UNS No. C10910; UNS No. C11000; UNS No. C11300; UNS No. C11400; UNS No. C11600; UNS No. C12000; UNS No. C12200; UNS No. C12300; UNS No. C14200; UNS No. C14420; UNS No. C14530

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SPECIFICATION FOR NICKEL ROD AND BAR



SB-160

(Identical with ASTM Specification B160-05(2014) except that certification has been made mandatory and editorial correction to maximum carbon value for UNS N02200 in Table 2.)

SPECIFICATION FOR NICKEL ROD AND BAR



SB-160

[Identical with ASTM Specification B 160-05(2014) except that certification has been made mandatory.]

1. Scope

1.1 This specification covers nickel (UNS N02200), low carbon nickel (UNS N02201), and solution strengthened nickel (UNS N02211) in the form of hot-worked and cold-worked rod and bar in the conditions shown in Table 1.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

2. Referenced Documents

2.1 ASTM Standards:

- B 162 Specification for Nickel Plate, Sheet, and Strip
- B 880 Specification for General Requirements for Chemical Check Analysis of Nickel, Nickel Alloys, and Cobalt Alloys
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 140 Hardness Conversion Tables for Metals
- E 1473 Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *bar, n* —material of rectangular (flats), hexagonal, or square solid section up to and including 10 in. (254 mm) in width and $\frac{1}{8}$ in. (3.2 mm) and over in thickness in straight lengths.

NOTE 1 — Hot-worked rectangular bar in widths 10 in. (254 mm) and under may be furnished as hot-rolled plate with sheared or cut edges in accordance with Specification B 162, provided the mechanical property requirements of Specification B 160 are met.

3.1.2 *rod, n* — material of round solid section furnished in straight lengths.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 ASTM designation and year of issue.

4.1.2 UNS number.

4.1.3 *Section* —Rod (round) or bar (square, hexagonal, or rectangular).

4.1.4 *Dimensions* — Dimensions including length.

4.1.5 Condition.

4.1.6 Finish.

4.1.7 *Quantity* — feet or number of pieces.

4.1.8 *Certification* — Certification and a report of test results are required (Section 15).

4.1.9 *Samples for Product (Check) Analysis* — State whether samples for product (check) analysis should be furnished.

4.1.10 *Purchaser Inspection* — If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which test or inspections are to be witnessed.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 2.

5.2 If a product (check) analysis is performed by the purchaser, the material shall be done per Specification B 880 and the material shall conform to the product (check) analysis variations defined in Check Analysis Variation table of Specification B 880.

TABLE 1
MECHANICAL PROPERTIES

Condition and Diameter or Distance Between Parallel Surfaces, in. (mm)	Tensile Strength, min, psi (MPa)	Yield Strength (0.2% offset), min, psi (MPa) ^A	Elongation in 2 in. or 50 mm or 4D, min %
Nickel (UNS N02200)			
Cold-worked (as worked):			
Rounds, 1 (25.4) and under	80 000 (550)	60 000 (415)	10 ^B
Rounds over 1 to 4 (25.4 to 101.6) incl.	75 000 (515)	50 000 (345)	15
Squares, hexagons, and rectangles, all sizes	65 000 (450)	40 000 (275)	25 ^B
Hot-worked:			
All sections, all sizes	60 000 (415)	15 000 (105)	35 ^C
Rings and disks ^D	—	—	—
Annealed:			
Rods and bars, all sizes	55 000 (380)	15 000 (105)	40 ^B
Rings and disks ^E	—	—	—
Forging quality:			
All sizes	F	F	F
Low-Carbon Nickel (UNS N02201) and Solution Strengthened Nickel (UNS N02211)			
Hot-worked:			
All sections, all sizes	50 000 (345)	10 000 (70)	40 ^C
Annealed:			
All products, all sizes	50 000 (345)	10 000 (70)	40 ^B

^A See 12.2.

^B Not applicable to diameters or cross sections under $\frac{3}{32}$ in. (2.4 mm).

^C For hot-worked flats $\frac{5}{16}$ in. (7.9 mm) and under in thickness the elongation shall be 25%, min.

^D Hardness B 45 to B 80, or equivalent.

^E Hardness B 45 to B 70 or equivalent.

^F Forging quality is furnished to chemical requirements and surface inspection only. No tensile properties are required.

TABLE 2
CHEMICAL REQUIREMENTS

Element	Composition Limits, %		
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Solution Strengthened Nickel (UNS N02211)
Nickel, min ^A	99.0	99.0	93.7
Copper, max	0.25	0.25	0.25
Iron, max.	0.40	0.40	0.75
Manganese, max.	0.35	0.35	4.25–5.25
Carbon, max.	0.15	0.02	0.02
Silicon, max.	0.35	0.35	0.15
Sulfur, max.	0.01	0.01	0.015

^A Element shall be determined arithmetically by difference.

6. Mechanical and Other Requirements

6.1 Mechanical Properties — The material shall conform to the mechanical properties specified in Table 1.

7. Dimensions and Permissible Variations

7.1 Diameter, Thickness, or Width — The permissible variations from the specified dimensions as measured on

the diameter or between parallel surfaces of cold-worked rod and bar shall be as prescribed in Table 3, and of hot-worked rod and bar as prescribed in Table 4.

7.2 Out-of-Round — Hot-worked rods and cold-worked rods (except “forging quality”), all sizes, in straight lengths, shall not be out-of-round by more than one half the total permissible variations in diameter shown in Tables 3 and 4, except for hot-worked rods $\frac{1}{2}$ in. (12.7 mm) in diameter and under, which may be out-of-round by the total permissible variations in diameter shown in Table 4.

7.3 Corners — Cold-worked bars will have practically exact angles and sharp corners.

7.4 Machining Allowances for Hot-Worked Materials — When the surfaces of hot-worked products are to be machined, the allowances prescribed in Table 5 are recommended for normal machining operations.

7.5 Length — The permissible variations in length of cold-worked and hot-worked rod and bar shall be as prescribed in Table 6.

7.5.1 Rods and bars ordered to random or nominal lengths will be furnished with either cropped or saw-cut

TABLE 3
PERMISSIBLE VARIATIONS IN DIAMETER OR DISTANCE BETWEEN PARALLEL
SURFACES OF COLD-WORKED ROD AND BAR

Specified Dimension, in. (mm) ⁴	Permissible Variations from Specified Dimensions, in. (mm)	
	+	–
Rounds:		
$\frac{1}{16}$ (1.6) to $\frac{3}{16}$ (4.8), excl	0	0.002 (0.05)
$\frac{3}{16}$ (4.8) to $\frac{1}{2}$ (12.7), excl	0	0.003 (0.08)
$\frac{1}{2}$ (12.7) to $\frac{15}{16}$ (23.8), incl	0.001 (0.03)	0.002 (0.05)
Over $\frac{15}{16}$ (23.8) to $1\frac{15}{16}$ (49.2), incl	0.0015 (0.04)	0.003 (0.08)
Over $1\frac{15}{16}$ (49.2) to $2\frac{1}{2}$ (63.5), incl	0.002 (0.05)	0.004 (0.10)
Over $2\frac{1}{2}$ (63.5) to 3 (76.2), incl	0.0025 (0.06)	0.005 (0.13)
Over 3 (76.2) to 3 (88.9), incl	0.003 (0.08)	0.006 (0.15)
Over $3\frac{1}{2}$ (88.9) to 4 (101.6), incl	0.0035 (0.09)	0.007 (0.18)
Hexagons, squares, rectangles:		
$\frac{1}{2}$ (12.7) and less	0	0.004 (0.10)
Over $\frac{1}{2}$ (12.7) to $\frac{7}{8}$ (22.2), incl	0	0.005 (0.13)
Over $\frac{7}{8}$ (22.2) to $1\frac{1}{4}$ (31.8), incl	0	0.007 (0.18)
Over $1\frac{1}{4}$ (31.8) to $2\frac{1}{4}$ (57.2), incl	0	0.009 (0.23)
Over $2\frac{1}{4}$ (57.2) to 3 (76.2), incl	0	0.011 (0.28)
Over 3 (76.2) to $3\frac{1}{2}$ (88.9), incl	0	0.015 (0.38)
Over $3\frac{1}{2}$ (88.9) to 4 (101.6), incl	0	0.017 (0.43)

⁴ Dimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

TABLE 4
PERMISSIBLE VARIATIONS IN DIAMETER OR DISTANCE BETWEEN
PARALLEL SURFACES OF HOT-WORKED ROD AND BAR

Specified Dimension, in. (mm) ⁴	Permissible Variations from Specified Dimensions, in. (mm)	
	+	–
Rod and bar, hot-worked:		
1 (25.4) and under	0.016 (0.41)	0.016 (0.41)
Over 1 (25.4) to 2 (50.8), incl	0.031 (0.79)	0.016 (0.41)
Over 2 (50.8) to 4 (101.6), incl	0.047 (1.19)	0.031 (0.79)
Over 4 (101.6)	0.125 (3.18)	0.063 (1.60)
Rod, rough-turned or rough-ground:		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0
Forging quality rod:^B		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0

⁴ Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

^B Spot grinding is permitted to remove minor surface imperfections. The depth of these spot ground areas shall not exceed 3% of the diameter of the rod.

TABLE 5
NORMAL MACHINING ALLOWANCES FOR HOT-WORKED MATERIAL

Finished-Machined Dimensions for Finishes as Indicated Below, in. (mm) ^A	Normal Machining Allowance, in. (mm)			
	On Diameter, for Rods	Distance Between Parallel Surface, for Hexagonal and Square Bar	For Rectangular Bar	
			On Thickness	On Width
Hot-worked: ^B				
Up to $\frac{7}{8}$ (22.2), incl	$\frac{1}{8}$ (3.2)	$\frac{1}{8}$ (3.2)	$\frac{1}{8}$ (3.2)	$\frac{3}{16}$ (4.8)
Over $\frac{7}{8}$ to $1\frac{7}{8}$ (22.2 to 47.6), incl	$\frac{1}{8}$ (3.2)	$\frac{3}{16}$ (4.8)	$\frac{1}{8}$ (3.2)	$\frac{3}{16}$ (4.8)
Over $1\frac{7}{8}$ to $2\frac{7}{8}$ (47.6 to 73.0), incl	$\frac{3}{16}$ (4.8)	$\frac{1}{4}$ (6.4)	...	$\frac{3}{16}$ (4.8)
Over $2\frac{7}{8}$ to $3\frac{13}{16}$ (73.0 to 96.8), incl	$\frac{1}{4}$ (6.4)	...	...	$\frac{3}{16}$ (4.8)
Over $3\frac{13}{16}$ (96.8)	$\frac{1}{4}$ (6.4)	...	...	$\frac{3}{8}$ (9.5)
Hot-worked rods:				
Rough-turned or Rough-ground: ^C				
$1\frac{5}{16}$ to 4 (23.8 to 101.6), incl in diameter	$\frac{1}{16}$ (1.6)	...	...	...
Over 4 to 12 (101.6 to 304.8), incl in diameter	$\frac{1}{8}$ (3.2)	...	...	...

^A Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagonal and square bar, and separately to width and thickness of rectangular bar.

^B The allowances for hot-worked material in Table 5 are recommended for rods machined in lengths of 3 ft (0.91 m) or less and for bars machined in lengths of 2 ft (0.61 m) or less. Hot-worked material to be machined longer lengths should be specified showing the finished cross-sectional dimension and the length in which the material will be machined in order that the manufacturer may supply material with sufficient oversize, including allowance for out-of-straightness.

^C Applicable to 3 ft (0.91 m) max length.

TABLE 6
PERMISSIBLE VARIATIONS IN LENGTH OF RODS AND BARS

Random mill lengths:	
Hot-worked	6 to 24 ft (1.83 to 7.31 m) long with not more than 25 weight % between 6 and 9 ft (1.83 and 2.74 m) ^A
Cold-worked	6 to 20 ft (1.83 to 6.1 m) long with not more than 25 weight % between 6 and 10 ft (1.83 and 3.05 m).
Multiple lengths	Furnished in multiples of a specified unit length, within the length limits indicated above. For each multiple, an allowance of $\frac{1}{4}$ in. (6.4 mm) will be made for cutting, unless otherwise specified. At the manufacturer's option, individual specified unit lengths may be furnished.
Nominal lengths	Specified nominal lengths having a range of not less than 2 ft (610 mm) with no short lengths allowed. ^B
Cut lengths	A specified length to which all rods and bars will be cut with a permissible variation of $+\frac{1}{8}$ in. (3.2 mm), -0 for sizes 8 in. (203 mm) and less in diameter or distance between parallel surfaces. For larger sizes, the permissible variation shall be $+\frac{1}{4}$ in. (6.4 mm), -0 .

^A For hot-worked sections weighing over 25 lb/ft (37 kg/m) and for smooth forged products, all sections, short lengths down to 2 ft (610 mm) may be furnished.

^B For cold-worked rods and bars under $\frac{1}{2}$ in. (12.7 mm) in diameter or distance between parallel surfaces ordered to nominal or stock lengths with a 2 ft (610 mm) range, at least 93% of such material shall be within the range specified; the balance may be in shorter lengths but in no case shall lengths less than 4 ft (1220 mm) be furnished.

TABLE 7
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF
COLD-WORKED RODS AND BARS

Specified Diameter or Distance Between Parallel Surfaces, in. (mm) ^A	Permissible Variations in Lengths Indicated, in. (mm)
Rounds: 1/2 (12.7) to 4 (101.6), incl	Depth of Chord: 0.030 (0.76) per ft (305 mm) of length
Hexagons, squares, rectangles: 1/2 (12.7) to 4 (101.6), incl	0.030 (0.76) per ft (305 mm) of length

^A Material under 1/2 in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

ends; material ordered to cut lengths will be furnished with square saw-cut or machined ends.

7.6 Straightness:

7.6.1 The permissible variations in straightness of cold-worked rod and bar as determined by the departure from straightness shall be as prescribed in Table 7.

7.6.2 The permissible variations in straightness of precision straightened cold-worked rod as determined by the departure from straightness shall be as prescribed in Table 8.

7.6.2.1 In determining straightness in the standard 42-in. (1.07-m) distance between supports or, when specified, in determining straightness in lengths not in excess of those shown in Table 8, the rod shall be placed on a precision table equipped with ballbearing rollers and a micrometer or dial indicator. The rod shall then be rotated slowly against the indicator, and the deviation from

straightness in any portion of the rod between the supports shall not exceed the permissible variations prescribed in Table 8. The deviation from straightness (throw in one revolution) is defined as the difference between the maximum and minimum readings of the dial indicator in one complete revolution of the rod.

7.6.3 The permissible variations in straightness of hot-worked rod and bar as determined by the departure from straightness shall be as specified in Table 9.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and condition, smooth, commercially straight or flat, and free of injurious imperfections.

9. Sampling

9.1 Lot—Definition:

9.2 A lot for chemical analysis shall consist of one heat.

9.2.1 A lot for mechanical properties testing shall consist of all material from the same heat, nominal diameter of thickness and condition.

9.2.1.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same size and condition.

9.3 Test Material Selection:

9.3.1 Chemical Analysis — Representative samples from each lot shall be taken during pouring or subsequent processing.

9.3.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

TABLE 8
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF PRECISION-STRAIGHTENED
COLD-WORKED NICKEL (UNS N02200) SHAFTING

Specified Diameter of Shafting, in.	Standard Distance Between Supports	Permissible Variations (Throw in One Revolution) from Straightness, in.
1/2 to 15/16, incl	42 in.	0.005
Over 15/16 to 1 15/16, incl	42 in.	0.006
Over 1 15/16 to 2 1/2, incl	42 in.	0.007
Over 2 1/2 to 4, incl	42 in.	0.008
3/4 to 15/16, incl	Specified lengths of 3 to 10 ft	0.004 + 0.0025 for each foot or fraction thereof in excess of 3 ft.
Over 15/16 to 4, incl	Specified lengths of 20 ft and less	0.005 + 0.0015 for each foot or fraction thereof in excess of 3 ft.
Specified Diameter of Shafting, mm	Standard Distance Between Supports	Permissible Variations (Throw in One Revolution) from Straightness, mm
12.7 to 23.8 incl	1067 mm	0.13
Over 23.8 to 49.2, incl	1067 mm	0.15
Over 49.2 to 63.5, incl	1067 mm	0.18
Over 63.5 to 101.6, incl	1067 mm	0.20
19.1 to 23.8 incl	specified lengths of 914 to 3050 mm	10.2 + 0.2 for each metre or fraction thereof in excess of 914 mm
Over 23.8 to 101.6, incl	specified lengths of 6100 mm and less	12.7 + 0.13 for each metre or fraction thereof in excess of 914 mm

TABLE 9
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF
HOT-WORKED RODS AND BARS^A

Finish	Permissible Variations, in./ft. (mm/m) ^B
Rods and bars, hot-worked	0.050 (4.2) ^C
Rounds—hot-worked, rough-ground, or rough-turned	0.050 (4.2) ^C

^A Not applicable to forging quality.

^B Material under $\frac{1}{2}$ in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

^C The maximum curvature (depth of chord) shall not exceed the values indicated multiplied by the length in feet.

9.3.2 Mechanical Properties — Samples of the material to provide test specimens for mechanical properties shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 Chemical Analysis —One test per lot.

10.2 Tension —One test per lot.

10.3 Hardness —One test per lot.

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition and tested in the direction of fabrication.

11.1.1 All rod and bar shall be tested in full cross-section size when possible. When a full cross-section size test cannot be performed, the largest possible round specimen shown in Test Methods E 8 shall be used. Longitudinal strip specimens shall be prepared in accordance with Test Methods E 8 for rectangular bar up to $\frac{1}{2}$ in. (12.7 mm), inclusive, in thicknesses that are too wide to be pulled full size.

11.2 Hardness test specimens shall be taken from material in the final condition.

11.3 In order that the hardness determinations may be in reasonable close agreement, the following procedure is suggested:

11.3.1 For rod, under $\frac{1}{2}$ in. (12.7 mm) in diameter, hardness readings shall be taken on a flat surface prepared by filing or grinding approximately $\frac{1}{16}$ in. (1.6 mm) from the outside surface of the rod.

11.3.2 For rod, $\frac{1}{2}$ in. (12.7 mm) in diameter and larger, and for hexagonal, square, and rectangular bar, all sizes, hardness readings shall be taken on a cross section midway between the surface and center of the section.

12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical Analysis	E 1473
Tension	E 8
Rockwell Hardness	E 18
Hardness Conversion	E 140
Rounding Procedure	E 29

12.2 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated below, in accordance with the rounding method of Practice E29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in dec- imals)	Nearest unit in the last right-hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5, or a 5 followed only by zeros, choose the one ending in an even digit, with zero defined as an even digit.
Tensile strength and yield strength	Nearest 1000 psi (6.9 MPa)
Elongation	Nearest 1%

13. Inspection

13.1 Inspection of the material shall be made as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

16. Product Marking

16.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: The name of the material or UNS Number, heat number, condition (temper), ASTM Specification B 160, the size, gross, tare, and net weight, consignor and

consignee address, contract or order number, or such other information as may be defined in the contract or order.

17. Keywords

17.1 bar; rod; N02200; N02201; N02211

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APPENDIX

(Nonmandatory Information)

X1. CONDITIONS AND FINISHES

X1.1 The various conditions and finishes in which nickel (UNS N02200) and low-carbon nickel (UNS N02201) rods and bars are procurable are as indicated below.

X1.2 Low-carbon nickel (UNS N02201) is intended essentially for fused caustic and other fused salts and for temperatures above 600°F (316°C). For such applications the manufacturer should be consulted.

X1.2.1 *Hot-Worked* — With a tightly adherent, black, mill oxide surface.

X1.2.2 *Hot-Worked Rough-Ground* — Similar to X1.2.1 except rough-ground.

X1.2.3 *Hot-Worked, Rough-Turned* — Similar to X1.2.1 except rough-turned with a broad-nosed tool similar to a bar peeling operation and thus may not be straight. Intended generally for machining where an overhauled surface is desired, essentially for machined step down shafts or parts machined in short lengths of 3 ft (914 mm) or less.

X1.2.4 *Hot-Worked Forging Quality* — Rough-turned and spot-ground, as necessary, for sizes 1 in.

(25.4 mm) in diameter and over; rough-ground and spot-ground for sizes under 1 in. in diameter. Material is selected from heats of known, good hot malleability.

NOTE X1.1— For sizes 4 in. (101.6 mm) in diameter and less, cold-worked rod may be used also for forging by virtue of the fact such rod have been overhauled for removal of mechanical surface defects prior to cold drawing. In such cases, the user should run pilot forging tests to ensure himself that such material has the desired hot-malleability range.

X1.2.5 *Hot-Worked, Annealed* — Soft with a tightly adherent oxide that may vary from dark to light.

X1.2.6 *Hot-Worked, Annealed and Pickled* — Same as X1.2.5 except descaled for removal of mill oxide. Provides for better surface inspection than does hot-worked material and often employed where welding is involved where removal of mill oxide is desired.

NOTE X1.2— Annealing prior to pickling may be required in order to reduce the mill oxide since uniform pickling of an unreduced oxide is difficult.

X1.2.7 *Cold-Worked, As-worked* — Hot-worked overhauled, cold-worked, and straightened with a smooth bright finish.

X1.2.8 *Cold-worked Annealed* — Hot-worked overhauled, cold-worked, and straightened. Annealed for softness and with a dull matte finish.

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SPECIFICATION FOR NICKEL SEAMLESS PIPE AND TUBE



SB-161

(Identical with ASTM Specification B161-05(2014) except for deletion of 1.1.1. Certification has been made mandatory.)

SPECIFICATION FOR NICKEL SEAMLESS PIPE AND TUBE



SB-161

[Identical with ASTM Specification B 161-05(2014) except for deletion of 1.1.1. Certification has been made mandatory.]

1. Scope

1.1 This specification covers nickel (UNS N02200) and low-carbon nickel (UNS N02201) in the form of cold-worked seamless pipe and tube in the conditions shown in Table 1 and Table X1.1.

1.1.1 DELETED

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations.*

2. Referenced Documents

2.1 ASTM Standards:

B 829 Specification for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube

3. General Requirement

3.1 Material furnished under this specification shall conform to the applicable requirements of Specification B 829 unless otherwise provided herein.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 Alloy name or UNS number.

4.1.2 ASTM designation and year of issue.

4.1.3 Condition (see Appendix X2).

4.1.4 Finish (see Appendix X2).

4.1.5 Dimensions:

4.1.5.1 *Tube* — Specify outside diameter and nominal or minimum wall.

4.1.5.2 *Pipe* — Specify standard pipe size and schedule.

4.1.5.3 *Length* — Cut to length or random.

4.1.6 *Quantity* — Feet or number of pieces.

4.1.7 *Hydrostatic Test or Nondestructive Electric Test* — Specify test (see 6.2).

4.1.8 *Hydrostatic Pressure Requirements* — Specify test pressure if other than required by Specification B 829.

4.1.9 DELETED

4.1.10 *Samples for Product (Check) Analysis* — State whether samples for product (check) analysis should be furnished (see 5.2).

4.1.11 *Purchaser Inspection* — If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed.

4.1.12 *Small-Diameter and Light-Wall Tube (Converter Sizes)* — See Appendix X1.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 2.

TABLE 1
MECHANICAL PROPERTIES

Condition and Size	Tensile Strength, min, psi (MPa)		Yield Strength (0.2 % offset), min, psi (MPa)		Elongation in 2 in. or 50 mm (or 4D), min, %	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Annealed:						
5 in. (127 mm) and under outside diameter	55 000 (380)	50 000 (345)	15 000 (105)	12 000 (80)	35	35
Over 5 in. (127 mm) in outside diameter	55 000 (380)	50 000 (345)	12 000 (80)	10 000 (70)	40	40
Stress-Relieved:						
All sizes	65 000 (450)	60 000 (415)	40 000 (275)	30 000 (205)	15	15

TABLE 2
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Ni, ⁴ min	99.0	99.0
Cu, max	0.25	0.25
Fe, max	0.40	0.40
Mn, max	0.35	0.35
C, max	0.15	...
C, max	...	0.02
Si, max	0.35	0.35
S, max	0.01	0.01

⁴ Element shall be determined arithmetically by difference.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Specification B 829.

6. Mechanical and Other Properties

6.1 Tension Test — The material shall conform to the tensile properties specified in Table 1. The sampling and specimen preparation are as covered in Specification B 829.

6.1.1 Tensile properties for material specified as small-diameter and light-wall tube (converter sizes) shall be as prescribed in Table X1.1.

6.2 Hydrostatic Test or Nondestructive Electric Test — Each pipe or tube shall be subjected to the Nondestructive Electric Test or the Hydrostatic Test. Unless specified by the purchaser, either test may be used at the option of the producer.

7. Dimensions and Permissible Variations

7.1 Permissible variations for material specified as small-diameter and light-wall tube (converter size) shall conform to the permissible variations prescribed in Table X1.2.

8. Number of Tests

8.1 Chemical Analysis — One test per lot.

8.2 Tension — One test per lot.

8.3 Hydrostatic or Nondestructive Electric Test — Each piece in each lot.

9. Test Methods

9.1 Hydrostatic Test — Each pipe or tube with an outside diameter $\frac{1}{8}$ in. (3 mm) and larger and with wall thickness of 0.015 in. (0.38 mm) and over shall be tested in accordance with Specification B 829. The allowable fiber stress, for material in the condition furnished, is as follows:

	UNS N02200	UNS N02201
Annealed:		
5 in. (127 mm) outside diameter and under	10 000 psi (70 MPa)	8000 psi (55 MPa)
Over 5 in. outside diameter	8000 psi (55 MPa)	6700 psi (45 MPa)
Stress-Relieved:		
All sizes	16 200 psi (110 MPa)	15 000 psi (105 MPa)

9.1.1 When so agreed upon by the manufacturer and purchaser, pipe or tube may be tested to $1\frac{1}{2}$ times the allowable fiber stress given above.

9.1.2 If any pipe or tube shows leaks during hydrostatic testing, it shall be rejected.

9.2 Nondestructive Electric Test — Each pipe or tube shall be examined with a nondestructive electric test as prescribed in Specification B 829.

10. Keywords

10.1 seamless pipe; seamless tube; N02200; N02201

APPENDIXES

(Nonmandatory Information)

X1. CONVERTER SIZES

X1.1 Small-diameter and light-wall tube in outside diameters $1\frac{1}{4}$ in. (31.8 mm) and under may be furnished in the conditions listed in Table X1.1 when so specified. The material is furnished in a limited range of sizes and the manufacturer should be consulted as to the various outside diameters and wall thicknesses that may be furnished. Material will have a bright finish. Such material shall conform to the applicable requirements in Table X1.1 and Table X1.2.

X2. CONDITIONS AND FINISHES NORMALLY SUPPLIED**X2.1 Scope**

X2.1.1 This appendix lists the conditions and finishes in which pipe and tube (other than converter sizes) are

normally supplied. These are subject to change, and the manufacturer should be consulted for the latest information available.

X2.2 Nickel (UNS N02200)

X2.2.1 Annealed — Soft, with a dull matte finish.

X2.2.2 Stress-Relieved — Thermally treated below the annealing temperature to relieve the major portion of the internal stresses, with a thin, light to medium-dark surface.

X2.3 Low-Carbon Nickel (UNS N02201)

X2.3.1 Annealed — Similar to X2.2.1.

X2.3.2 Stress-Relieved — Similar to X2.2.2.

TABLE X1.1
MECHANICAL PROPERTIES⁴ OF SMALL-DIAMETER AND LIGHT-WALL TUBING (CONVERTER SIZES)

Condition	Tensile Strength, psi (MPa)	Yield Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, min, %
Nickel UNS N02200			
Annealed ^B	75 000 (515) max	15 000 (105)	33
Half-hard ^C	80 000 (550) min	40 000 (275)	12
Full hard ^D	95 000 (655) min	75 000 (515)	4
Low-Carbon Nickel UNS N02201			
Annealed ^B	70 000 (480) max	12 000 (85)	35
Half-hard ^C	70 000 (480) min	30 000 (205)	12
Full hard ^D	85 000 (585) min	65 000 (450)	4

⁴ Not applicable to outside diameters under $\frac{1}{8}$ in. (3.2 mm) and wall thicknesses under 0.015 in. (0.38 mm).

^B This condition is sometimes designated as "No. 1 Temper."

^C This condition is sometimes designated as "No. 2 Temper."

^D This condition is sometimes designated as "No. 3 Temper."

TABLE X1.2
PERMISSIBLE VARIATIONS FOR SMALL-DIAMETER AND LIGHT-WALL TUBE (CONVERTER SIZES)^{A,B,C,D,E,F}

Specified Outside Diameter, in. (mm)	Outside Diameter		Inside Diameter		Wall Thickness, %	
	Plus	Minus	Plus	Minus	Plus	Minus
Under $\frac{3}{32}$ (2.4)	0.002 (0.05)	0	0	0.002 (0.05)	10	10
$\frac{3}{32}$ to $\frac{3}{16}$ (2.4 to 4.8), excl	0.003 (0.08)	0	0	0.003 (0.08)	10	10
$\frac{3}{16}$ to $\frac{1}{2}$ (4.8 to 12.7), excl	0.004 (0.10)	0	0	0.004 (0.10)	10	10
$\frac{1}{2}$ to $1\frac{1}{4}$ (12.7 to 31.8), incl	0.005 (0.13)	0	0	0.005 (0.13)	10	10

^A *Ovality, Normal Wall Tubes — As Drawn (No. 2 and 3) Tempers* — Ovality will be held within the outside diameter tolerances shown in the table.

Annealed (No. 1) Temper — Ovality will be held within 2% of the theoretical average outside diameter.

^B *Ovality, Light-Wall Tube — As-Drawn (No. 2 and 3) Tempers* — Up to but not including $1\frac{1}{4}$ in. (31.8 mm) in outside diameter, ovality will be held within 2% of the theoretical average outside diameter.

Annealed (No. 1) Temper — Ovality will be held within 3% of the theoretical average outside diameter.

^C *Wall Tolerances, Light-Wall Tube* — The plus and minus wall tolerance shown in the table shall apply down to and including 0.005 in. (0.13 mm) in wall thickness. For wall thicknesses less than 0.005 in. (0.13 mm), the tolerance shall be ± 0.0005 in. (0.013 mm).

^D *Random Lengths:*

Where nominal random lengths on tubing $\frac{1}{8}$ in. (3.2 mm) and larger in outside diameter are specified, a length tolerance of $\pm 3\frac{1}{2}$ ft (1.06 m) applies to the nominal length. This is a total spread of 7 ft (2.10 m).

Random lengths in sizes $\frac{1}{8}$ in. (3.2 mm) and larger in outside diameter shall be subject to a length range of 5 to 24 ft (1.50 to 7.30 m). Long random lengths are subject to a range of 15 to 22 ft (4.57 to 6.70 m).

Random lengths in sizes up to, but not including $\frac{1}{8}$ in. (3.2 mm) in outside diameter, and fragile light-wall tubes over this outside diameter are subject to the length range of 1 to 15 ft (0.30 to 4.57 m).

^E *Straightness* — Round tubing is subject to a straightness tolerance of one part in 600 [equivalent to a depth of arc of 0.030 in. (0.76 mm) in any 3 ft (0.91 m) of length].

^F When specified, the tolerance spreads of this table may be applied as desired. However, when not specified, the tolerances in this table will apply. It should be noted that inside diameter tolerances are based upon the outside diameter range.

SPECIFICATION FOR NICKEL PLATE, SHEET, AND STRIP



SB-162

(Identical with ASTM Specification B162-99(2014) except that certification has been made mandatory.)

SPECIFICATION FOR NICKEL PLATE, SHEET, AND STRIP



SB-162

[Identical with ASTM Specification B 162-99(2014) except that certification has been made mandatory.]

1. Scope

1.1 This specification covers rolled nickel (UNS N02200) and low-carbon nickel (UNS N02201) plate, sheet, and strip.

1.2 The values stated in inch-pound units are to be regarded as the standard. The other values given are for information only.

2. Referenced Documents

2.1 ASTM Standards:

- B 160 Specification for Nickel Rod and Bar
- B 880 General Requirements for Chemical Check Analysis of Nickel, Nickel Alloys, and Cobalt Alloys
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 10 Test Method for Brinell Hardness of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 39 Test Methods for Chemical Analysis of Nickel
- E 112 Test Methods for Determining the Average Grain Size
- E 140 Hardness Conversion Tables for Metals
- F 155 Test Method for Temper of Strip and Sheet Metals for Electronic Devices (Spring-Back Method)

3. Terminology

3.1 Descriptions of Terms Specific to This Standard:

3.1.1 The terms given in Table 1 shall apply.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 Alloy — Name and UNS number. (See Table 2.)

4.1.2 ASTM designation, including year of issue.

4.1.3 Condition (See 6.1, 6.2, and Appendix X1.)

4.1.4 Finish (See Appendix X1.)

4.1.5 Dimensions — Thickness, width, and length.

4.1.6 Quantity.

4.1.7 Optional Requirements:

4.1.7.1 Sheet and Strip — Whether to be furnished in coil, in cut straight lengths, or in random straight lengths.

4.1.7.2 Strip — Whether to be furnished with commercial slit edge, square edge, or round edge.

4.1.7.3 Plate — Whether to be furnished specially flattened (see 7.7.2); also how plate is to be cut (see 7.2.1 and 7.3.2.)

4.1.8 Fabrication Details — Not mandatory but helpful to the manufacturer.

4.1.8.1 Welding or Brazing — Process to be employed.

4.1.8.2 Plate — Whether material is to be hot-formed.

4.1.9 Certification — Certification and a report of test results are required (see Section 15).

4.1.10 Samples for Product (Check) Analysis — Whether samples for product (check) analysis should be furnished (see 5.2).

TABLE 1
PRODUCT DESCRIPTION

Product	Thickness, in. (mm)	Width, in. (mm)
Hot-rolled plate ^A	$\frac{3}{16}$ and over (Tables 5 and 6)	(Table 8) ^B
Hot-rolled sheet ^A	0.018 to 0.250 (0.46 to 6.4), incl (Table 7)	(Table 10)
Cold-rolled sheet ^C	0.018 to 0.250 (0.46 to 6.4), incl (Table 7)	(Table 10)
Cold-rolled strip ^C	0.005 to 0.250 (0.13 to 6.4), incl (Table 7)	(Table 10)

^A Material $\frac{3}{16}$ to $\frac{1}{4}$ in. (4.8 to 6.4 mm), incl, in thickness may be furnished as sheet or plate provided the material meets the specification requirements for the condition ordered.

^B Hot-rolled plate, in widths 10 in. (254 mm) and under, may be furnished as hot-finished rectangles with sheared or cut edges in accordance with Specification B 160, provided the mechanical property requirements of this specification are met.

^C Material under 48 in. (1219 mm) in width may be furnished as sheet or strip provided the material meets the specification requirements for the condition ordered.

TABLE 2
CHEMICAL REQUIREMENTS

Element	Composition, %	
	Nickel (UNS N02200)	Low-Carbon Nickel (UNS N02201)
Nickel, ^A min	99.0	99.0
Copper, max	0.25	0.25
Iron, max	0.40	0.40
Manganese, max	0.35	0.35
Carbon, max	0.15	...
Carbon, min	...	0.02
Silicon, max	0.35	0.35
Sulfur, max	0.01	0.01

^A Element shall be determined arithmetically by difference.

4.1.11 Purchaser Inspection — If the purchaser wishes to witness tests or inspection of material at the place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (see Section 13).

5. Chemical Compositions

5.1 The material shall conform to the requirements as to chemical composition prescribed in Table 2.

5.2 If a product (check) analysis is performed by the purchaser, the material shall be done per ASTM B 880 and the material shall conform to the product (check) analysis variations defined in Table 1 of ASTM B 880.

6. Mechanical and Other Requirements

6.1 Mechanical Properties — The material shall conform to the requirements for mechanical properties prescribed in Table 3.

6.2 Deep-Drawing and Spinning Quality Sheet and Strip — The material shall conform to the requirements for grain size and hardness properties prescribed in Table 4.

6.2.1 The mechanical properties of Table 3 do not apply to deep-drawing and spinning quality sheet and strip.

7. Dimensions and Permissible Variations

7.1 Thickness and Weight:

7.1.1 Plate — For plate up to 2 in. (50.8 mm), inclusive, in thickness, the permissible variation under the specified thickness and permissible excess in overweight shall not exceed the amounts prescribed in Table 5.

7.1.1.1 For use with Table 5, plate shall be assumed to weigh 0.321 lb/in.³ (8.89 g/cm³).

7.1.2 Plate — For plate over 2 in. (50.8 mm) in thickness, the permissible variations over the specified thickness shall not exceed the amounts prescribed in Table 6.

7.1.3 Sheet and Strip — The permissible variations in thickness of sheet and strip shall be as prescribed in Table 7. The thickness of strip and sheet shall be measured with the micrometer spindle $\frac{3}{8}$ in. (9.5 mm) or more from either edge for material 1 in. (25.4 mm) or over in width and at any place on the strip under 1 in. in width.

7.2 Width and Diameter:

7.2.1 Plate — The permissible variations in width of rectangular plates and diameter of circular plates shall be as prescribed in Tables 8 and 9.

7.2.2 Sheet and Strip — The permissible variations in width for sheet and strip shall be as prescribed in Table 10.

7.3 Length:

7.3.1 Sheet and strip of all sizes may be ordered to cut lengths, in which case a variation of $\frac{1}{8}$ in. (3.2 mm) over the specified length shall be permitted.

TABLE 3
MECHANICAL PROPERTIES FOR PLATE, SHEET, AND STRIP (ALL THICKNESSES AND SIZES UNLESS OTHERWISE INDICATED)

Condition (Temper)	Tensile Strength, min, psi (MPa)	Yield ^A Strength (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm, or 4D, min, %	Rockwell Hardness (B Scale) ^{B,C}
Nickel (UNS N02200) Hot-Rolled Plate				
Annealed	55 000 (380)	15 000 (100)	40	...
As-rolled ^{D,E}	55 000 (380)	20 000 (135)	30	...
Nickel (UNS N02200) Hot-Rolled Sheet				
Annealed	55 000 (380)	15 000 (100)	40 ^F	...
Nickel (UNS N02200) Cold-Rolled Sheet				
Annealed	55 000 (380)	15 000 (100)	40 ^F	...
Quarter-hard	...	...	...	70 to 80
Half-hard	...	...	...	79 to 86
Hard	90 000 (620)	70 000 (480)	2	...
Nickel (UNS N02200) Cold-Rolled Strip				
Annealed	55 000 (380) ^G	15 000 (100)	40 ^{F,G}	...
Skin-hard	...	...	...	64 to 70
Quarter-hard	...	...	...	70 to 80
Half-hard	...	...	...	79 to 86
Three-quarter-hard	...	...	...	85 to 91
Hard	90 000 (620) ^G	70 000 (480)	2 ^G	...
Spring temper	...	...	...	95 min
Low-Carbon Nickel (UNS N02201) Hot-Rolled Plate				
Annealed	50 000 (345)	12 000 (80)	40	...
As-rolled ^{D,E}	50 000 (345)	12 000 (80)	30	...
Low-Carbon Nickel (UNS N02201) Hot-Rolled Sheet				
Annealed	50 000 (345)	12 000 (80)	40 ^F	...
Low-Carbon Nickel (UNS N02201) Cold-Rolled Sheet				
Annealed	50 000 (345)	12 000 (80)	40 ^F	...
Low-Carbon Nickel (UNS N02201) Cold-Rolled Strip				
Annealed	50 000 (345) ^G	12 000 (80)	40 ^{F,G}	...

^A Yield strength requirements do not apply to material under 0.020 in. (0.51 mm) in thickness.

^B For Rockwell or equivalent hardness conversions see Hardness Conversion Tables E 140.

^C Caution should be observed in using the Rockwell test on thin material, as the results may be affected by specimen thickness. For thicknesses under 0.050 in. (1.3 mm), the use of the Rockwell superficial or the Vickers hardness test is suggested.

^D As-rolled plate may be given a stress-relieving heat treatment subsequent to final rolling.

^E As-rolled plate specified "suitable for hot forming" shall be furnished from heats of known good hot-malleability characteristics (see X1.2.2). There are no applicable tensile or hardness requirements for such material.

^F Sheet and strip 0.010 to 0.049 in. (0.25 to 1.2 mm), inclusive, in thickness shall have an elongation of 30% minimum. Sheet and strip 0.050 to 0.109 in. (1.3 to 2.7 mm), inclusive, in thickness shall have an elongation of 35% minimum.

^G Not applicable for thickness under 0.010 in. (0.25 mm).

TABLE 4
GRAIN SIZE AND HARDNESS FOR COLD-ROLLED, DEEP-DRAWING, AND SPINNING QUALITY SHEET AND STRIP

Thickness, in. (mm)	Calculated Diameter of Average Grain Section, max		Corresponding ASTM Micro-Grain Size No.	Rockwell B ^{A,B} Hardness, max
	mm	in.		
Nickel (UNS N02200) Sheet [56 in. (1420 mm) Wide and Under] ^C				
0.050 (1.3) and less	0.110	0.0043	3.5	64
Over 0.050 to 0.250 (1.3 to 6.4), incl	0.120	0.0047	3.0	64
Nickel (UNS N02200) Strip [12 in. (305 mm) Wide and Under] ^D				
0.005 ^E to 0.010 (0.13 to 0.25), incl	0.025	0.0010	7.5 ^F	70 ^F
Over 0.010 to 0.024 (0.25 to 0.61), incl	0.065	0.0026	5.0	68
Over 0.024 to 0.125 (0.61 to 3.2), incl	0.110	0.0043	3.5	64
Low-Carbon Nickel (UNS N02201) Strip [12 in. (305 mm) Wide and Under] ^D				
0.005 ^E to 0.010 (0.13 to 0.25), incl	0.030	0.0012	7.0 ^F	66 ^F
Over 0.010 to 0.024 (0.25 to 0.61), incl	0.075	0.0030	4.5	64
Over 0.024 to 0.125 (0.61 to 3.2), incl	0.110	0.0043	3.5	64

^A For Rockwell or equivalent hardness conversions see Hardness Conversion Tables E 140.

^B Caution should be observed in using the Rockwell test on thin material, as the results may be affected by specimen thickness. For thicknesses under 0.050 in. (1.3 mm), the use of the Rockwell superficial or the Vickers hardness test is suggested.

^C There are no applicable grain size requirements for low-carbon nickel (UNS N02201) sheet. The hardness of low-carbon nickel (UNS N02201) sheet shall be not over Rockwell B64, or equivalent.

^D Sheet requirements in Table 4 apply to strip thicknesses over 0.125 in. (3.2 mm), and for all thicknesses of strip over 12 in. (305 mm) in width.

^E For ductility evaluations for strip under 0.005 in. (0.13 mm) in thickness, the spring-back test, such as that described in Test Method F 155, is often used and the manufacturer should be consulted.

^F Accurate grain size and hardness determinations are difficult to make on strip under 0.005 in. (0.13 mm) in thickness and are not recommended.

TABLE 5
PERMISSIBLE VARIATIONS IN THICKNESS AND OVERWEIGHT OF RECTANGULAR PLATES

Specified Thickness, in. (mm)	Permissible Excess in Average Weight, ^{B,C} per Square Foot of Plates for Widths Given in Inches (millimetres) Expressed in Percentage of Nominal Weights									
	Under 48 (1220)	48 to 60 (1220 to 1520), excl	60 to 72 (1520 to 1830), excl	72 to 84 (1830 to 2130), excl	84 to 96 (2130 to 2440), excl	96 to 108 (2440 to 2740), excl	108 to 120 (2740 to 3050), excl	120 to 132 (3050 to 3350), excl	132 to 144 (3350 to 3660), excl	144 to 160 (3660 to 4070), incl
$\frac{3}{16}$ to $\frac{5}{16}$ (4.8 to 7.9), excl	9.0	10.5	12.0	13.5	15.0	16.5	18.0	...	...	...
$\frac{5}{16}$ to $\frac{3}{8}$ (7.9 to 9.5), excl	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	...	...
$\frac{3}{8}$ to $\frac{7}{16}$ (9.5 to 11.1), excl	7.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5
$\frac{7}{16}$ to $\frac{1}{2}$ (11.1 to 12.7), excl	6.0	7.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0
$\frac{1}{2}$ to $\frac{5}{8}$ (12.7 to 15.9), excl	5.0	6.0	7.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5
$\frac{5}{8}$ to $\frac{3}{4}$ (15.9 to 19.0), excl	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5	15.0
$\frac{3}{4}$ to 1 (19.0 to 25.4), excl	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0	13.5
1 to 2 (25.4 to 50.8), incl	4.0	4.0	4.5	5.5	6.0	7.0	7.5	9.0	10.5	12.0

NOTE — All plates shall be ordered to thickness and not to weight per square foot. No plates shall vary more than 0.01 in. (0.25 mm) under the thickness ordered, and the overweight of each lot^A in each shipment shall not exceed the amount given in the table. Spot grinding is permitted to remove surface imperfections, such spots not to exceed 0.01 in. (0.25 mm) under the specified thickness.

^A The term "lot" applied to this table means all of the plates of each group width and each group thickness.

^B The permissible overweight for lots of circular and sketch plates shall be 25% greater than the amounts given in this table.

^C The weight of individual plates shall not exceed the nominal weight by more than $1\frac{1}{4}$ times the amount given in the table and Footnote B.

TABLE 6
PERMISSIBLE VARIATIONS IN THICKNESS FOR RECTANGULAR PLATES OVER 2 in. (50.8 mm) IN THICKNESS

Specified Thickness, in. (mm)	Permissible Variations, in. (mm), over Specified Thickness for Widths Given, in. (mm)					
	To 36 (915), excl	36 to 60 (915 to 1520), excl	60 to 84 (1520 to 2130), excl	84 to 120 (2130 to 3050), excl	120 to 132 (3050 to 3350), excl	132 (3350) and over
Over 2 to 3 (51.0 to 76.0), excl	$\frac{1}{16}$ (1.6)	$\frac{3}{32}$ (2.4)	$\frac{7}{64}$ (2.8)	$\frac{1}{8}$ (3.2)	$\frac{1}{8}$ (3.2)	$\frac{9}{64}$ (3.6)
3 to 4 (76.0 to 102.0), incl	$\frac{5}{64}$ (2.0)	$\frac{3}{32}$ (2.4)	$\frac{7}{64}$ (2.8)	$\frac{1}{8}$ (3.2)	$\frac{1}{8}$ (3.2)	$\frac{9}{64}$ (3.6)

NOTE — Permissible variation under specified thickness, 0.01 in. (0.25 mm).

TABLE 7
PERMISSIBLE VARIATIONS IN THICKNESS OF SHEET AND STRIP [PERMISSIBLE VARIATIONS, PLUS AND MINUS, IN THICKNESS, in. (mm), FOR WIDTHS GIVEN IN in. (mm)]

Specified Thickness, in. (mm)	Sheet ^A			
	Hot-Rolled		Cold-Rolled	
	48 (1220) and Under	Over 48 to 60 (1220 to 1520), incl	48 (1220) and Under	Over 48 to 60 (1220 to 1520), incl
0.018 to 0.025 (0.46 to 0.64), incl	0.003 (0.08)	0.004 (0.10)	0.002 (0.05)	0.003 (0.08)
Over 0.025 to 0.034 (0.64 to 0.86), incl	0.004 (0.10)	0.005 (0.13)	0.003 (0.08)	0.004 (0.10)
Over 0.034 to 0.043 (0.86 to 1.1), incl	0.005 (0.13)	0.006 (0.15)	0.004 (0.10)	0.005 (0.13)
Over 0.043 to 0.056 (1.1 to 1.4), incl	0.005 (0.13)	0.006 (0.15)	0.004 (0.10)	0.005 (0.13)
Over 0.056 to 0.070 (1.4 to 1.8), incl	0.006 (0.15)	0.007 (0.18)	0.005 (0.13)	0.006 (0.15)
Over 0.070 to 0.078 (1.8 to 2.0), incl	0.007 (0.18)	0.008 (0.20)	0.006 (0.15)	0.007 (0.18)
Over 0.078 to 0.093 (2.0 to 2.4), incl	0.008 (0.20)	0.009 (0.23)	0.007 (0.18)	0.008 (0.20)
Over 0.093 to 0.109 (2.4 to 2.8), incl	0.009 (0.23)	0.010 (0.25)	0.007 (0.18)	0.009 (0.23)
Over 0.109 to 0.125 (2.8 to 3.2), incl	0.010 (0.25)	0.012 (0.30)	0.008 (0.20)	0.010 (0.25)
Over 0.125 to 0.140 (3.2 to 3.6), incl	0.012 (0.30)	0.014 (0.36)	0.008 (0.20)	0.010 (0.25)
Over 0.140 to 0.171 (3.6 to 4.3), incl	0.014 (0.36)	0.016 (0.41)	0.009 (0.23)	0.012 (0.30)
Over 0.171 to 0.187 (4.3 to 4.8), incl	0.015 (0.38)	0.017 (0.43)	0.010 (0.25)	0.013 (0.33)
Over 0.187 to 0.218 (4.8 to 5.5), incl	0.017 (0.43)	0.019 (0.48)	0.011 (0.28)	0.015 (0.38)
Over 0.218 to 0.234 (5.5 to 5.9), incl	0.018 (0.46)	0.020 (0.51)	0.012 (0.30)	0.016 (0.41)
Over 0.234 to 0.250 (5.9 to 6.4), incl	0.020 (0.51)	0.022 (0.56)	0.013 (0.33)	0.018 (0.46)
Cold-Rolled Strip ^{A,B}				
Specified Thickness, in. (mm)	Widths 12 in. (305 mm) and under, ±			
Up to 0.050 (1.3), incl	0.0015 (0.04)			
Over 0.050 to 0.093 (1.3 to 2.4), incl	0.0025 (0.06)			
Over 0.093 to 0.125 (2.4 to 3.2), incl	0.004 (0.11)			

^A Measured $\frac{3}{8}$ in. (9.5 mm) or more from either edge except for strip under 1 in. (25.4 mm) in width which is measured at any place.

^B Standard sheet tolerances apply for thicknesses over 0.125 in. (3.2 mm) and for all thicknesses of strip over 12 in. (305 mm) wide.

TABLE 8
PERMISSIBLE VARIATIONS IN WIDTH^A OF SHEARED, PLASMA-TORCH CUT, AND ABRASIVE-CUT RECTANGULAR PLATE^{B,C}

Specified Thickness	Permissible Variations in Widths for Widths Given in in. (mm)									
	Up to 30 (760), incl		Over 30 to 72 (760 to 1830), incl		Over 72 to 108 (1830 to 2740), incl		Over 108 to 144 (2740 to 3660), incl		Over 144 to 160 (3660 to 4070), incl	
	+	−	+	−	+	−	+	−	+	−
Inches										
Sheared: ^D										
$\frac{3}{16}$ to $\frac{5}{16}$, excl	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	...	...
$\frac{5}{16}$ to $\frac{1}{2}$, excl	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$
$\frac{3}{4}$ to 1, excl	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$
1 to $1\frac{1}{4}$, incl	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	1	$\frac{1}{8}$
Abrasive-cut: ^{E,F}										
$\frac{3}{16}$ to $1\frac{1}{4}$, incl	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
Over $1\frac{1}{4}$ to $2\frac{3}{4}$, incl	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$
Plasma-torch-cut: ^G										
$\frac{3}{16}$ to 2, excl	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0
2 to 3, incl	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0
Millimetres										
Sheared: ^D										
4.8 to 7.9, excl	4.8	3.2	6.4	3.2	9.5	3.2	12.7	3.2	...	...
7.9 to 12.7, excl	6.4	3.2	9.5	3.2	9.5	3.2	12.7	3.2	15.9	3.2
12.7 to 19.0, excl	9.5	3.2	9.5	3.2	12.7	3.2	15.9	3.2	19.0	3.2
19.0 to 25.4, excl	12.7	3.2	12.7	3.2	15.9	3.2	19.0	3.2	22.2	3.2
25.4 to 31.8, incl	15.9	3.2	15.9	3.2	19.0	3.2	22.2	3.2	25.4	3.2
Abrasive-cut: ^{E,F}										
4.8 to 31.8, incl	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Over 31.8 to 69.8, incl	4.8	3.2	4.8	3.2	4.8	3.2	4.8	3.2	4.8	3.2
Plasma-torch-cut: ^G										
4.8 to 50.8, excl	12.7	0	12.7	0	12.7	0	12.7	0	12.7	0
50.8 to 76.2, incl	15.9	0	15.9	0	15.9	0	15.9	0	15.9	0

^A Permissible variations in width for powder-cut or inert-arc-cut plate shall be as agreed upon between the manufacturer and the purchaser.

^B Permissible variations in machined, powder-cut, or inert-arc-cut circular plate shall be as agreed upon between the manufacturer and the purchaser.

^C Permissible variations in plasma-torch-cut sketch plates shall be as agreed upon between the manufacturer and the purchaser.

^D The minimum sheared width is 10 in. (254 mm) for material $\frac{3}{4}$ in. (19.0 mm) and under in thickness and 20 in. (508 mm) for material over $\frac{3}{4}$ in. (19.0 mm) in thickness.

^E The minimum abrasive-cut width is 2 in. (50.8 mm) and increases to 4 in. (101.6 mm) for thicker plates.

^F These tolerances are applicable to lengths of 240 in. (6100 mm), max. For lengths over 240 in. (6100 mm), an additional $\frac{1}{16}$ in. (1.6 mm) is permitted, both plus and minus.

^G The tolerance spread shown for plasma-torch-cutting may be obtained all on the minus side, or divided between the plus and minus side if so specified by the purchaser.

TABLE 9
PERMISSIBLE VARIATIONS IN DIAMETER FOR CIRCULAR PLATES

Sheared Plate						
Specified Diameter, in. (mm)		Permissible Variations Over Specified Diameter for Thickness Given in in. (mm) ^A				
		To $\frac{3}{8}$ (9.5), incl				
20 to 32 (508 to 813), excl		$\frac{1}{4}$ (6.4)				
32 to 84 (813 to 2130), excl		$\frac{5}{16}$ (7.9)				
84 to 108 (2130 to 2740), excl		$\frac{3}{8}$ (9.5)				
108 to 140 (2740 to 3580), incl		$\frac{7}{16}$ (11.1)				
Plasma-Torch-Cut Plate ^B						
Specified Diameter, in. (mm)		Permissible Variations in Specified Diameter for Thickness Given in in. (mm) ^C				
		Thickness max, in. (mm)	$\frac{3}{16}$ to 2 (4.76 to 50.8), excl		2 to 3 (50.8 to 76.2), incl	
			+	–	+	–
19 to 20 (483 to 508), excl		3 (76.2)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0
20 to 22 (508 to 559), excl		2 $\frac{3}{4}$ (69.8)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0
22 to 24 (559 to 610), excl		2 $\frac{1}{2}$ (63.5)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0
24 to 28 (610 to 711), excl		2 $\frac{1}{4}$ (57.3)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0
28 to 32 (711 to 812), excl		2 (50.8)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0
32 to 34 (812 to 864), excl		1 $\frac{3}{4}$ (44.5)	$\frac{1}{2}$ (12.7)	0	...	...
34 to 38 (864 to 965), excl		1 $\frac{1}{2}$ (38.1)	$\frac{1}{2}$ (12.7)	0	...	...
38 to 40 (965 to 1020), excl		1 $\frac{1}{4}$ (31.8)	$\frac{1}{2}$ (12.7)	0	...	...
40 to 140 (1020 to 3560), incl		3 (76.2)	$\frac{1}{2}$ (12.7)	0	$\frac{5}{8}$ (15.9)	0

^A No permissible variations under.

^B Permissible variations in plasma-torch-cut sketch plates shall be as agreed upon between the manufacturer and the purchaser.

^C The tolerance spread shown may also be obtained all on the minus side or divided between the plus and minus sides if so specified by the purchaser.

7.3.2 Permissible variations in length of rectangular plate shall be as prescribed in Table 11.

7.4 Straightness:

7.4.1 The edgewise curvature (depth of chord) of flat sheet, strip, and plate shall not exceed 0.05 in. multiplied by the length in feet (0.04 mm multiplied by the length in centimetres).

7.4.2 Straightness for coiled material is subject to agreement between the manufacturer and the purchaser.

7.5 Edges:

7.5.1 When finished edges of strip are specified in the contract or order, the following descriptions shall apply:

7.5.1.1 Square-edge strip shall be supplied with finished edges, with sharp, square corners, and without bevel or rounding.

7.5.1.2 Round-edge strip shall be supplied with finished edges, semicircular in form, and the diameter of the circle forming the edge being equal to the strip thickness.

7.5.1.3 When no description of any required form of strip edge is given, it shall be understood that edges such as those resulting from slitting or shearing will be acceptable.

7.5.1.4 Sheet shall have sheared or slit edges.

7.5.1.5 Plate shall have sheared or cut (machined, abrasive-cut, powder-cut, or inert-arc-cut) edges, as specified.

7.6 Squareness (Sheet) — For sheets of all thicknesses, the angle between adjacent sides shall be $90^\circ \pm 0.15^\circ$ ($\frac{1}{16}$ in. in 24 in.) (1.6 mm in 610 mm).

7.7 Flatness:

7.7.1 There shall be no flatness requirements for “deep drawing quality,” “spinning quality,” or “as rolled,” sheet and strip (see X1.4).

7.7.2 Standard flatness tolerances for plate shall conform to the requirements prescribed in Table 12. “Specially flattened” plate, when so specified, shall have permissible variations in flatness as agreed upon between the manufacturer and the purchaser.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight or flat, and free of injurious imperfections.

8.2 Sheet, Strip, and Plate — Sheet, strip, and plate supplied in the conditions and finishes as listed in the appendix may be ground or machined to remove surface imperfections, provided such removal does not reduce the material below the minimum specified dimensions. Surface

TABLE 10
PERMISSIBLE VARIATIONS IN WIDTH OF SHEET AND STRIP

Specified Thickness, in. (mm)	Specified Width, in. (mm)	Permissible Variations in Specified Width, in. (mm)	
		+	–
Sheet			
Up to 0.250 (6.4)	all	0.125 (3.2)	0
Strip ⁴			
Under 0.075 (1.9)	up to 12 (305), incl	0.007 (0.18)	0.007 (0.18)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0
0.075 to 0.100 (1.9 to 2.5), incl	up to 12 (305), incl	0.009 (0.23)	0.009 (0.23)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0
Over 0.100 to 0.125 (2.5 to 3.2), incl	up to 12 (305), incl	0.012 (0.30)	0.012 (0.30)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0
Over 0.125 to 0.160 (3.2 to 4.1), incl	up to 12 (305), incl	0.016 (0.41)	0.016 (0.41)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0
Over 0.160 to 0.187 (4.1 to 4.7), incl	up to 12 (305), incl	0.020 (0.51)	0.020 (0.51)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0
Over 0.187 to 0.250 (4.7 to 6.4), incl	up to 12 (305), incl	0.062 (1.6)	0.062 (1.6)
	over 12 to 48 (305 to 1219), incl	0.062 (1.6)	0.062 (1.6)

⁴ Rolled-round or square-edge strip in thicknesses of 0.071 to 0.125 in. (1.8 to 3.2 mm), inclusive, in widths 3 in. (76.2 mm) and under, shall have permissible width variations of ± 0.005 in. (± 0.130 mm). Permissible variations for other sizes shall be as agreed upon between the manufacturer and the purchaser.

TABLE 11
PERMISSIBLE VARIATIONS IN LENGTH^A OF SHEARED, PLASMA TORCH-CUT,^B AND ABRASIVE-CUT
RECTANGULAR PLATE^C

Specified Thickness	Permissible Variation in Length for Lengths Given, in. (mm)															
	Up to 60 (1520), incl		Over 60 to 96 (1520 to 2440), incl		Over 96 to 120 (2440 to 3050), incl		Over 120 to 240 (3050 to 6096), incl		Over 240 to 360 (6096 to 9144), incl		Over 360 to 450 (9144 to 11 430), incl		Over 450 to 540 (11 430 to 13 716), incl		Over 540 (13 716)	
	+	-	+	-	+	-	+	-	+	-	+	-	+	-	+	-
Inches																
Sheared: ^D																
$\frac{3}{16}$ to $\frac{5}{16}$, excl	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	...	...
$\frac{5}{16}$ to $\frac{1}{2}$, excl	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	1	$\frac{1}{8}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{11}{8}$	$\frac{1}{8}$	$\frac{13}{8}$	$\frac{1}{8}$
$\frac{3}{4}$ to 1, excl	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{5}{8}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	$\frac{11}{8}$	$\frac{1}{8}$	$\frac{13}{8}$	$\frac{1}{8}$	$\frac{15}{8}$	$\frac{1}{8}$
1 to $1\frac{1}{4}$, incl	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{3}{4}$	$\frac{1}{8}$	$\frac{7}{8}$	$\frac{1}{8}$	$1\frac{1}{8}$	$\frac{1}{8}$	$1\frac{3}{8}$	$\frac{1}{8}$	$1\frac{5}{8}$	$\frac{1}{8}$	...	...
Abrasive-cut: ^E																
$\frac{3}{16}$ to $1\frac{1}{4}$, incl	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	...	...	...	...
Over $1\frac{1}{4}$ to $2\frac{3}{4}$, incl	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	...	...	...	...
Plasma-torch-cut: ^F																
$\frac{3}{16}$ to 2, excl	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0	$\frac{1}{2}$	0
2 to 3, incl	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0	$\frac{5}{8}$	0
Millimetres																
Sheared: ^D																
4.8 to 7.9, excl	4.8	3.2	6.4	3.2	9.5	3.2	12.7	3.2	15.9	3.2	19.0	3.2	22.2	3.2	...	...
7.9 to 12.7, excl	9.5	3.2	12.7	3.2	12.7	3.2	12.7	3.2	15.9	3.2	19.0	3.2	22.2	3.2	25.4	3.2
12.7 to 19.0, excl	12.7	3.2	12.7	3.2	15.9	3.2	15.9	3.2	19.0	3.2	22.2	3.2	28.6	3.2	34.9	3.2
19.0 to 25.4, excl	15.9	3.2	15.9	3.2	15.9	3.2	19.0	3.2	22.2	3.2	28.6	3.2	34.9	3.2	41.2	3.2
25.4 to 31.8, incl	19.0	3.2	19.0	3.2	19.0	3.2	22.2	3.2	28.6	3.2	34.9	3.2	41.2	3.2	...	...
Abrasive-cut: ^E																
4.8 to 31.8, incl	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	...	...	...	...
Over 31.8 to 69.9, incl	4.8	3.2	4.8	3.2	4.8	3.2	4.8	3.2	4.8	3.2	4.8	3.2	...	...	...	...
Plasma-torch-cut: ^F																
4.8 to 50.8, excl	12.7	0	12.7	0	12.7	0	12.7	0	12.7	0	12.7	0	12.7	0	12.7	0
50.8 to 76.2, incl	15.9	0	15.9	0	15.9	0	15.9	0	15.9	0	15.9	0	15.9	0	15.9	0

^A Permissible variations in length for powder-cut or inert-arc-cut plate shall be as agreed upon between the manufacturer and the purchaser.

^B The tolerance spread shown for plasma-torch-cutting may be obtained all on the minus side, or divided between the plus and minus sides if so specified by the purchaser.

^C Permissible variations in machined, powder-cut or inert-arc-cut circular plate shall be as agreed upon between the manufacturer and the purchaser.

^D The minimum sheared length is 10 in. (254 mm).

^E Abrasive cut applicable to a maximum length of 144 to 400 in. (3658 to 10 160 mm) depending on the thickness and width ordered.

^F The tolerance spread shown for plasma-torch-cut sketch plates shall be as agreed upon between the manufacturer and the purchaser.

TABLE 12
PERMISSIBLE VARIATIONS FROM FLATNESS OF RECTANGULAR, CIRCULAR, AND SKETCH PLATES

Specified Thickness	Permissible Variations from a Flat Surface for Thickness and Widths Given in in. (mm)								
	To 48 (1220), excl	48 to 60 (1220 to 1520), excl	60 to 72 (1520 to 1830), excl	72 to 84 (1830 to 2130), excl	84 to 96 (2130 to 2440), excl	96 to 108 (2440 to 2740), excl	108 to 120 (2740 to 3050), excl	120 to 144 (3050 to 3660), excl	144 (3660), and over
Inches									
$\frac{3}{16}$ to $\frac{1}{4}$, excl	$\frac{3}{4}$	$1\frac{1}{16}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{5}{8}$	$1\frac{5}{8}$	...	...	...
$\frac{1}{4}$ to $\frac{3}{8}$, excl	$1\frac{1}{16}$	$\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{1}{8}$	$1\frac{3}{8}$	$1\frac{7}{16}$	$1\frac{9}{16}$	$1\frac{7}{8}$	...
$\frac{3}{8}$ to $\frac{1}{2}$, excl	$\frac{1}{2}$	$\frac{9}{16}$	$1\frac{1}{4}$	$\frac{3}{4}$	$1\frac{5}{16}$	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{7}{16}$	$1\frac{3}{4}$
$\frac{1}{2}$ to $\frac{3}{4}$, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$1\frac{13}{16}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{3}{8}$
$\frac{3}{4}$ to 1, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{3}{4}$	$1\frac{13}{16}$	$1\frac{15}{16}$	1	$1\frac{1}{8}$
1 to 2, excl	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$	$1\frac{11}{16}$	$1\frac{11}{16}$	$1\frac{11}{16}$	$1\frac{3}{4}$	1
2 to 4, incl	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
Millimetres									
4.8 to 6.4, excl	19.0	27.0	31.7	34.9	41.3	41.3	...	...	...
6.4 to 9.5, excl	17.5	19.0	23.8	28.6	35.0	36.5	39.7	47.6	...
9.5 to 12.7, excl	12.7	14.3	17.5	19.0	23.8	28.6	31.7	35.0	44.4
12.7 to 19.0, excl	12.7	14.3	15.9	15.9	20.6	28.6	28.6	28.6	34.9
19.0 to 25.4, excl	12.7	14.3	15.9	15.9	19.0	20.6	23.8	25.4	28.6
25.4 to 50.8, excl	12.7	14.3	14.3	14.3	17.5	17.5	17.5	19.0	25.4
50.8 to 101.6, incl	6.4	7.9	9.5	11.1	12.7	14.3	15.9	19.0	22.2

NOTE 1 — Permissible variations apply to plates up to 12 ft (3.66 m) in length, or to any 12 ft of longer plates.

NOTE 2 — If the longer dimension is under 36 in. (914 mm), the permissible variation is not greater than $\frac{1}{4}$ in. (6.4 mm).

NOTE 3 — The shorter dimension specified is considered the width, and the permissible variation in flatness across the width does not exceed the tabular amount of that dimension.

NOTE 4 — The maximum deviation from a flat surface does not customarily exceed the tabular tolerance for the longer dimension specified.

eliminated depressions shall be faired smoothly into the surrounding material. The removal of a surface imperfection shall be verified by the method originally used to detect the imperfection.

9. Sampling

9.1 Lot — Definition:

9.1.1 A lot for chemical analysis shall consist of one heat.

9.1.2 A lot for mechanical properties, hardness, and grain size testing shall consist of all material from the same heat, nominal thickness, and condition.

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same thickness and condition, except for plates weighing over 500 lb, in which case only one specimen shall be taken.

9.2 Test Material Selection:

9.2.1 Chemical Analysis — Representative samples shall be taken during pouring or subsequent processing.

9.2.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.2.2 Mechanical Properties, Hardness, and Grain Size — Samples of the material to provide test specimens for mechanical properties, hardness, and grain size shall be taken from such locations in each lot as to be representative of that lot. (Hardness and grain size required only on the products as specified in Tables 3 and 4.)

10. Number of Tests

10.1 Chemical Analysis — One test per lot.

10.2 Mechanical Properties — One test per lot.

10.3 Hardness — One test per lot. (Required only as specified in Table 3 and Table 4.)

10.4 Grain Size — One test per lot. (Required only as specified in Table 4.)

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition (temper) and tested transverse to the direction of rolling when width will permit.

11.2 Tension test specimens shall be any of the standard or subsize specimens shown in Test Methods E 8.

11.3 In the event of disagreement, referee specimens shall be as follows:

11.3.1 Full thickness of the material, machined to the form and dimensions shown for the sheet-type specimen in Test Methods E 8 for material under $\frac{1}{2}$ in. (12.7 mm) in thickness.

11.3.2 The largest possible round specimen shown in Test Methods E 8 for material $\frac{1}{2}$ in. (12.7 mm) and over.

12. Test Methods

12.1 Determine the chemical composition, mechanical, and other properties of the material as enumerated in this specification, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical analysis	E 39
Tension	E 8
Brinell hardness	E 10
Rockwell hardness	E 18
Hardness conversion	E 140
Grain size	E 112
Rounding procedure	E 29
Spring-back	F 155

12.2 The measurement of the average grain size may be carried out by the planimetric method, the comparison method, or the intercept method described in Test Methods E 112. In case of dispute, the “referee” method for determining the average grain size shall be the planimetric method.

12.3 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated, in accordance with the rounding method of Practice E 29.

Test	Rounded Unit for Observed Or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	nearest unit in the last right hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5, or a 5 followed only by zeros, choose the one ending in an even digit, with zero defined as an even digit.
Tensile strength and yield strength	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1%
Grain Size:	
0.0024 in. (0.060 mm) or larger	nearest multiple of 0.0002 in. (0.005 mm)
less than 0.0024 in. (0.060 mm)	nearest multiple of 0.0001 in. (0.002 mm)

13. Inspection

13.1 Inspection of the material shall be as agreed upon between the purchaser and the supplier as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

16. Product Marking

16.1 Each plate, sheet, or strip shall be marked on one face with the specification number, alloy, condition (temper), heat number, manufacturer's identification, and size. The markings shall not have a deleterious effect on the material or its performance and shall be sufficiently stable to withstand normal handling.

16.2 When applicable, each bundle or shipping container shall be marked with the name of the material, condition (temper), this specification number, alloy, size, consignor and consignee address, contract or order number, and such other information as may be defined in the contract or order.

APPENDIX

(Nonmandatory Information)

X1. CONDITIONS AND FINISHES

X1.1 Scope

X1.1.1 This appendix lists the conditions and finishes in which plate, sheet, and strip are normally supplied. These are subject to change, and the manufacturer should be consulted for the latest information available.

X1.2 Plate, Hot-Rolled

X1.2.1 *Annealed* — Soft with an oxide surface, and suitable for heavy cold forming. Available with a descaled surface, when so specified.

X1.2.2 *As-Rolled* — With an oxide surface. Available with a descaled surface, when so specified. Suitable for flat work, mild forming or tube sheets. When intended for tube sheets, specify that plates are to be specially flattened. When intended for hot forming, this should be indicated on the purchase order so that the manufacturer may select appropriate material.

X1.3 Plate, Cold-Rolled

X1.3.1 *Annealed* — Soft with an oxide surface; available with a descaled surface when so specified.

X1.4 Sheet, Hot-Rolled

X1.4.1 *Annealed and Pickled* — Soft with a pickled matte finish. Properties similar to X1.5.1 but with broader thickness tolerances. Not suggested for applications where the finish of a cold-rolled sheet is considered essential or for deep drawing or spinning.

X1.5 Sheet and Strip, Cold-Rolled

X1.5.1 *Annealed* — Soft with a pickled or bright annealed finish.

X1.5.2 *Deep-Drawing or Spinning Quality* — Similar to X1.5.1, except furnished to controlled hardness and grain size and lightly leveled.

X1.5.3 *Skin Hard* — Similar to X1.5.1, but given a light cold reduction to hardness range shown in Table 3.

X1.5.4 *Quarter-Hard* — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.5 *Half-Hard* — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.6 *Three-Quarter Hard* — Cold rolled to the hardness range indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.7 *Hard* — Cold rolled to the tensile requirements indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

X1.5.8 *Spring Temper* — Cold rolled to the minimum hardness indicated in Table 3, bright finish. Out-of-flatness must be expected and will vary with temper and thickness.

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SPECIFICATION FOR SEAMLESS NICKEL AND NICKEL ALLOY CONDENSER AND HEAT-EXCHANGER TUBES



SB-163

(Identical with ASTM Specification B163-19 except that certification and test reports have been made mandatory.)

Specification for Seamless Nickel and Nickel Alloy Condenser and Heat- Exchanger Tubes

1. Scope

1.1 This specification covers seamless tubes of nickel and nickel alloys, as shown in Table 1, for use in condenser and heat-exchanger service.

1.2 This specification covers outside diameter and average wall, or outside diameter and minimum wall tube.

1.2.1 The sizes covered by this specification are 3 in. (76.2 mm) and under in outside diameter with minimum wall thicknesses of 0.148 in. (3.76 mm) and under, and with average wall thicknesses of 0.165 in. (4.19 mm) and under.

1.3 Tube shall be furnished in the alloys and conditions as shown in Table 2. For small diameter and light wall tube (converter sizes), see Appendix X2.

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

1.5 The following safety hazards caveat pertains only to the test method portion, Section 12, of this specification. *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 become familiar with all hazards including those identified in the appropriate Safety Data Sheet (SDS) for this product/material as provided by the manufacturer, 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 Recom-

mendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 ASTM Standards:

B829 Specification for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube

B880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys and Cobalt Alloys

E8/E8M Test Methods for Tension Testing of Metallic Materials

E18 Test Methods for Rockwell Hardness of Metallic Materials

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

E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)

E112 Test Methods for Determining Average Grain Size

E140 Hardness Conversion Tables for Metals Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, Scleroscope Hardness, and Leeb Hardness

E1473 Test Methods for Chemical Analysis of Nickel, Cobalt and High-Temperature Alloys

2.2 Federal Standards:

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys

2.3 Military Standard:

MIL-STD-129 Marking for Shipment and Storage

TABLE 1 Chemical Requirements^A

	Composition, %									
	N02200	N02201	N04400	N06025	N06045	N06600	N06601	N06603	N06686	N06690
Nickel	99.0 min ^B	99.0 min ^B	63.0 min ^B	remainder ^B	45.0 min ^B	72.0 min ^B	58.0–63.0	remainder ^B	remainder ^B	58.0 min ^B
Copper	0.25	0.25	28.0–34.0	0.1	0.3	0.5	1.0	0.5	...	0.5
Molybdenum	...	...	...	...	...	...	...	...	15.0–17.0	...
Iron	0.40	0.40	2.5	8.0–11.0	21.0–25.0	6.0–10.0	remainder ^B	8.0–11.0	5.0	7.0–11.0
Manganese	0.35	0.35	2.0	0.15	1.0	1.0	1.0	0.15	0.75	0.5
Carbon	0.15	0.02	0.3	0.15–0.25	0.05–0.12	0.15	0.10	0.20–0.40	0.010	0.05
Silicon	0.35	0.35	0.5	0.5	2.5–3.0	0.5	0.5	0.5	0.08	0.5
Sulfur	0.01	0.01	0.024	0.010	0.010	0.015	0.015	0.010	0.02	0.015
Chromium	...	...	...	24.0–26.0	26.0–29.0	14.0–17.0	21.0–25.0	24.0–26.0	19.0–23.0	27.0–31.0
Aluminum	...	...	...	1.8–2.4	...	...	1.0–1.7	2.4–3.0	...	...
Titanium	...	...	...	0.1–0.2	...	...	...	0.01–0.25	0.02–0.25	...
Phosphorus	...	...	...	0.020	0.020	...	...	0.02	0.04	...
Cerium	...	...	...	...	0.03–0.09	...	...	...	...	...
Zirconium	...	...	...	0.01–0.10	...	...	...	0.01–0.10	...	...
Yttrium	...	...	...	0.05–0.12	...	...	...	0.01–0.15	...	...
Boron	...	...	...	...	...	...	...	...	...	...
Cobalt	...	...	...	...	...	...	...	...	...	...
Columbium (Nb)	...	...	...	...	...	...	...	...	...	...
Tungsten	...	...	...	...	...	...	...	...	3.0–4.4	...
Nitrogen	...	...	...	...	...	...	...	...	...	...

^A Maximum unless range or minimum is given. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.

^B Element shall be determined arithmetically by difference.

TABLE 1 Chemical Requirements^A (continued)

	N06696	N06699	N06845	N08120	N08800	N08801	N08810	N08811	N08825	N08935
Nickel	remainder ^B	remainder ^B	44.0–50.0	35.0–39.0	30.0–35.0	30.0–34.0	30.0–35.0	30.0–35.0	38.0–46.0	34.0–36.0
Copper	1.5–3.0	0.50	2.0–4.0	0.50	0.75	0.50	0.75	0.75	1.5–3.0	0.4
Molybdenum	1.0–3.0	...	5.0–7.0	2.50	...	...	...	...	2.5–3.5	6.1–7.1
Iron	2.0–6.0	2.5	remainder ^B	remainder ^B	39.5 min ^B	39.5 min ^B	39.5 min ^B	39.5 min ^B	22.0 min ^B	remainder ^B
Manganese	1.0	0.50	0.5	1.5	1.5	1.50	1.5	1.5	1.0	1.2
Carbon	0.15	0.005–0.10	0.05	0.02–0.10	0.10	0.10	0.05–0.10	0.06–0.10	0.05	0.030
Silicon	1.0–2.5	0.50	0.5	1.0	1.0	1.00	1.0	1.0	0.5	0.5
Sulfur	0.010	0.01	0.010	0.03	0.015	0.015	0.015	0.015	0.03	0.020
Chromium	28.0–32.0	26.0–30.0	20.0–25.0	23.0–27.0	19.0–23.0	19.0–22.0	19.0–23.0	19.0–23.0	19.5–23.5	26.0–28.0
Aluminum	...	1.9–3.0	...	0.40	0.15–0.60	...	0.15–0.60	0.15–0.60 ^C	0.2	...
Titanium	1.0	0.60	...	0.20	0.15–0.60	0.75–1.5	0.15–0.60	0.15–0.60 ^C	0.6–1.2	...
Phosphorus	...	0.02	...	0.04	...	...	...	...	...	0.030
Cerium	...	...	...	...	...	...	...	...	...	...
Zirconium	...	0.10	...	...	...	...	...	...	...	...
Yttrium	...	...	...	...	...	...	...	...	...	...
Boron	...	0.008	...	0.010	...	...	...	...	...	...
Cobalt	...	...	...	3.0	...	...	...	...	...	...
Columbium (Nb)	...	0.50	...	0.4–0.9	...	...	...	...	...	...
Tungsten	...	...	2.0–5.0	2.50	...	...	...	...	...	...
Nitrogen	...	0.05	...	0.13–0.30	...	...	...	...	...	0.25–0.36

^A Maximum unless range or minimum is given. Where ellipses (...) appear in this table, there is no requirement and analysis for the element need not be determined or reported.

^B Element shall be determined arithmetically by difference.

^C Alloy UNS N08811: Al + Ti, 0.85 – 1.20.

TABLE 2 Alloy and Conditions

Alloy	Condition
Nickel UNS N02200 and low-carbon nickel UNS N02201	annealed or stress-relieved
Nickel-copper alloy UNS N04400	annealed or stress-relieved
Nickel-chromium-iron-aluminum alloy UNS N06603	annealed
Nickel-chromium-iron-copper alloy UNS N06696	annealed
Nickel-chromium-iron-aluminum alloy UNS N06601	annealed
Nickel-chromium-iron alloy UNS N06600	annealed
Low-carbon nickel-chromium-molybdenum-tungsten alloy UNS N06686	annealed
Nickel-chromium-iron alloy UNS N06690	annealed
Nickel-chromium-iron alloy UNS N06045	annealed
Nickel-iron-chromium alloy UNS N08120 ^A	annealed or cold-worked
Nickel-iron-chromium alloy UNS N08800 ^A	annealed or cold-worked
Nickel-iron-chromium alloy UNS N08810 ^A	annealed
Nickel-iron-chromium alloy UNS N08811 ^A	annealed
Nickel-iron-chromium alloy UNS N08801	annealed
Nickel-iron-chromium-molybdenum alloy UNS N08935	annealed
Nickel-iron-chromium-molybdenum-copper alloy UNS N08825	annealed
Nickel-chromium-iron alloy UNS N06025	annealed
Nickel-iron-chromium-molybdenum-copper alloy UNS N06845	annealed
Nickel-chromium-aluminum alloy UNS N06699	annealed

^A Alloy UNS N08800 is normally employed in service temperatures up to and including 1100°F (593°C). Alloys UNS N08810, UNS N08811, and UNS N08120 are normally employed in service temperatures above 1100°F (593°C) where resistance to creep and rupture is required, and it is annealed to develop controlled grain size for optimum properties in this temperature range.

3. Terminology

3.1 Definitions:

3.1.1 *average diameter, n*—average of the maximum and minimum outside diameters, as determined at any one cross section of the tube.

3.1.2 *tube, n*—hollow product of round or any other cross section having a continuous periphery.

4. Ordering Information

4.1 It is the responsibility of the purchaser to specify all requirements that are necessary for the safe and satisfactory performance of material ordered under this specification. Examples of such requirements include, but are not limited to, the following:

4.1.1 *Alloy* (Table 1).

4.1.2 *Condition (Temper)* Table 3 and Appendix X1 and Appendix X2.

4.1.2.1 If annealed ends for stress relieved tubing are desired, state length of end to be annealed and whether or not one end or both ends are to be annealed.

4.1.3 *Finish*.

4.1.4 *Dimensions*—Outside diameter, minimum or average wall thickness (in inches, not gage number), and length.

4.1.5 *Fabrication Operations*:

4.1.5.1 *Cold Bending or Coiling*.

4.1.5.2 *Packing*.

4.1.5.3 *Rolling or Expanding into Tube Sheets*.

4.1.5.4 *Welding or Brazing*—Process to be employed.

4.1.5.5 *Hydrostatic Test or Nondestructive Electric Test*—Specify type of test (6.5).

4.1.5.6 *Pressure Requirements*—If other than required by 6.5.

4.1.5.7 *Ends*—Plain ends cut and deburred will be furnished.

4.1.6 *Supplementary Requirements*—State nature and details.

4.1.7 DELETED

4.1.8 *Samples for Product (Check) Analysis*—Whether samples for product (check) analysis shall be furnished.

4.1.9 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13).

4.1.10 *Small-Diameter and Light-Wall Tube (Converter Sizes)*—See Appendix X2.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 1.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis per Specification B880.

6. Mechanical Properties and Other Requirements

6.1 *Mechanical Properties*—The material shall conform to the mechanical properties specified in Table 3.

6.2 *Hardness*—When annealed ends are specified for tubing in the stress-relieved condition (see Table 3), the hardness of the ends after annealing shall not exceed the values specified in Table 3.

6.3 *Flare*—A flare test shall be made on one end of 1 % of the number of finished tube lengths from each lot. For less than 100 tubes in a lot, a flare test shall be made on one end of one tube length in the lot. In the case of stress relieved tubing with annealed ends, the test shall be made prior to, or subsequent to, annealing of the ends at the option of the manufacturer.

6.3.1 The flare test shall consist of flaring a test specimen with an expanding tool having an included angle of 60° until the specified outside diameter has been increased by 30 %. The flared specimen shall not exhibit cracking through the wall.

6.4 *Grain Size*—A transverse sample representing full-wall thickness of annealed alloys UNS N08120, UNS N08810 and UNS N08811 shall conform to an average grain size of ASTM No. 5 or coarser.

TABLE 3 Mechanical Properties of Tubes

Material and Condition	Tensile Strength, min, ksi (MPa)	Yield Strength (0.2 % Offset), min, ksi (MPa)	Elongation in 2 in. or 50 mm (or 4 D) min, %	Rockwell Hardness (or equivalent) for annealed ends ^A
<i>Nickel</i> UNS N02200:				
Annealed	55 (379)	15 (103)	40	...
Stress-relieved	65 (448)	40 (276)	15	B65 max
<i>Low-carbon nickel</i> UNS N02201:				
Annealed	50 (345)	12 (83)	40	...
Stress-relieved	60 (414)	30 (207)	15	B62 max
<i>Nickel-copper alloy</i> UNS N04400:				
Annealed	70 (483)	28 (193)	35	...
Stress-relieved	85 (586)	55 (379)	15	B75 max
<i>Nickel-chromium-iron alloys:</i>				
Annealed alloy UNS N06600	80 (552)	35 (241)	30	...
Annealed alloy UNS N06601	80 (552)	30 (207)	30	...
Annealed alloy UNS N06690	85 (586)	35 (241)	30	...
Annealed alloy UNS N06045	90 (620)	35 (240)	35	...
Annealed alloy UNS N06025	98 (680)	39 (270)	30	...
Annealed alloy UNS N06603	94 (650)	43 (300)	25	...
Annealed alloy UNS N06696	85 (586)	35 (240)	30	...
<i>Low-carbon nickel-chromium-molybdenum-tungsten alloy:</i>				
Annealed UNS N06686	100 (690)	45 (310)	45	...
<i>Nickel-iron-chromium alloys:</i>				
Annealed alloy UNS N08120	90 (620)	40 (276)	30	...
Annealed alloy UNS N08800	75 (517)	30 (207)	30	...
Annealed alloy UNS N08801	65 (448)	25 (172)	30	...
Cold-worked alloy UNS N08800	83 (572)	47 (324)	30	...
Annealed alloy UNS N08810	65 (448)	25 (172)	30	...
Annealed alloy UNS N08811	65 (448)	25 (172)	30	...
<i>Nickel-iron-chromium-molybdenum alloy:</i>				
Annealed alloy UNS N08935	109 (750)	62 (425)	35	...
<i>Nickel-iron-chromium-molybdenum-copper alloys:</i>				
Annealed UNS N08825	85 (586)	35 (241)	30	...
Annealed UNS N06845	100 (690)	40 (276)	30	...
<i>Nickel-chromium-aluminum alloys:</i>				
Annealed UNS N06699	89 (610)	35 (240)	40	...

^A Rockwell or equivalent hardness values apply only to the annealed ends of stress-relieved tubing. Caution should be observed in using the Rockwell test on thin material, as the results may be affected by the thickness of specimen. For thickness under 0.050 in. (1.27 mm) the use of the Rockwell superficial or the Vickers hardness test is suggested. For hardness conversions for nickel and high-nickel alloys see Hardness Conversion Tables E140.

6.5 Hydrostatic or Nondestructive Electric Test—Each tube shall be subjected to either the hydrostatic test or the nondestructive electric test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

6.5.1 Hydrostatic Test:

6.5.1.1 Each tube with an outside diameter ½ in. (3.2 mm) and larger and tubes with wall thickness of 0.015 in. (0.38 mm) and over shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress calculated in accordance with the following equation does not exceed the allowable fiber stress, S , indicated below. The tube shall show no evidence of leakage.

$$P = 2St/D$$

where:

P = hydrostatic test pressure, psi (MPa),

S = allowable fiber stress for material in the condition furnished, as follows:

t = minimum wall thickness, in. (mm); equal to the specified average wall minus the permissible “minus” wall tolerance, Table 4 and Table X2.2, or the specified minimum wall thickness, and

D = outside diameter of the tube, in. (mm).

	psi	MPa
Annealed low-carbon nickel UNS N02201	8 000	55.2
Stress-relieved low-carbon nickel UNS N02201	15 000	103.4
Annealed nickel UNS N02200	10 000	68.9
Stress-relieved nickel UNS N02200	16 200	111.7
Annealed nickel-copper alloy UNS N04400	17 500	120.6
Stress-relieved nickel-copper alloy UNS N04400	21 200	146.2
Annealed nickel-chromium-aluminum alloy UNS N06699	22 100	152
Annealed nickel-chromium-iron alloy UNS N06600	20 000	137.9
Annealed nickel-chromium-iron alloy UNS N06601	20 000	137.9
Annealed nickel-chromium-iron alloy UNS N06690	21 200	146
Annealed nickel-chromium-iron alloy UNS N06045	22 500	155
Annealed nickel-chromium-iron alloy UNS N06025	24 500	169
Solution annealed low-carbon nickel-chromium-molybdenum-tungsten alloy UNS N06686	25 000	172
Annealed nickel-chromium-iron-aluminum alloy UNS N06603	24 000	165
Annealed nickel-chromium-iron-copper alloy UNS N06696	21 200	146
Annealed nickel-iron-chromium alloy UNS N08120	22 500	155
Annealed nickel-iron-chromium alloy UNS N08800	18 700	128.9
Annealed nickel-iron-chromium alloy UNS N08810	16 600	114.4
Annealed nickel-iron-chromium alloy UNS N08811	16 600	114.4
Annealed nickel-iron-chromium alloy UNS N08801	16 600	114.4
Annealed nickel-iron-chromium-molybdenum alloy UNS N08935	27 200	187.5
Annealed nickel-iron-chromium-molybdenum copper alloy UNS N08825	21 000	144.8
Annealed nickel-iron-chromium-molybdenum-copper alloy UNS N06845	21 200	146.2
Cold-worked nickel-iron-chromium alloy UNS N08800	20 700	142.7

TABLE 4 Permissible Variations in Outside Diameter and Wall Thickness of Condenser and Heat Exchanger Tubes

NOTE 1—The tolerances in the table apply to individual measurements of outside diameter and include out-of-roundness (ovality), and apply to all materials and all conditions, except that for thin wall tubes having a nominal wall of 3 % or less of the outside diameter, the mean outside diameter shall comply with the permissible variations of the above table and individual measurements (including ovality) shall conform to the plus and minus values of the table with the values increased by ½ % of the nominal outside diameter.

NOTE 2—*Eccentricity*—The variation in wall thickness in any one cross section of any one tube shall not exceed plus or minus 10 % of the actual (measured) average wall of that section. The actual average wall is defined as the average of the thickest and thinnest wall of that section.

NOTE 3—For tolerances of small diameter and light wall tube (converter sizes) see Appendix X2 (Table X2.2).

Material	Nominal Outside Diameter, in. (mm)	Permissible Variations ^A					
		Outside Diameter, in. (mm)		Wall Thickness, %			
		+	–	Average Wall		Minimum Wall	
				+	–	+	–
UNS N02200, UNS N02201, and UNS N04400	½ to ⅝ (12.7 to 15.9), excl	0.005 (0.13)	0	12.5	12.5	25.0	0
	⅝ to 1½ (15.9 to 38.1), incl	0.005 (0.13)	0.005 (0.13)	10.0	10.0	20.0	0
	over 1½ to 3 (38.1 to 76.2), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22.0	0
UNS N06600, UNS N06601, UNS N06690, UNS N06045, UNS N06025, UNS N06603, UNS N06696, UNS N08800, UNS N06699, UNS N08810, UNS N08811, UNS N08801, UNS N08935, UNS N08825, UNS N06845, and UNS N08120	½ to ⅝ (12.7 to 15.9), excl	0.005 (0.13)	0.005 (0.13)	12.5	12.5	25.0	0
	⅝ to 1½ (15.9 to 38.1), incl	0.0075 (0.19)	0.0075 (0.19)	10.0	10.0	20.0	0
	over 1½ to 3 (38.1 to 76.2), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22.0	0

^A Wall variations as indicated above are applicable only to the wall as ordered, for instance, to minimum or to average wall, but not to both.

6.5.1.2 When so agreed upon between the manufacturer and the purchaser, tube may be tested to 1½ times the above allowable fiber stress.

6.5.1.3 When stress-relieved tubes with annealed ends are to be tested hydrostatically, such pressure testing shall be done prior to annealing of the ends of the tube.

6.5.2 *Nondestructive Electric Test*—Each tube shall be examined with a nondestructive electric test as prescribed in Specification B829.

7. Dimensions and Permissible Variations

7.1 *Outside Diameter and Wall Thickness*—The permissible variations in the outside diameter and wall thickness of tube shall not exceed those prescribed in Table 4 and Table X2.2, as applicable. (See also Table 5 and Table 6.)

7.2 *Length*—When tube is ordered cut-to-length, the length shall not be less than that specified, but a variation of plus ⅛ in. (3.2 mm) will be permitted, except that for lengths over 30 ft (9.1 m), a variation of plus ¼ in. (6.4 mm) will be permitted.

7.3 *Straightness*—Material shall be reasonably straight and free of bends or kinks.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight, and free of injurious imperfections.

9. Sampling

9.1 *Lot*—Definition:

9.1.1 A lot for chemical analysis shall consist of one heat.

TABLE 5 Alloy,^A Condition, Tube Size, and Bend Radii Limitations

Tube OD, in. (mm)	Average Tube Wall, in. (mm) ^B	Minimum Bend Radius, in. (mm)	
		Annealed Condition	Stress-Relieved Condition
Up to ½ (12.7), incl	0.046 to 0.057 (1.17 to 1.45), incl	1⅜ (30.2)	1¼ (31.8)
Up to ½ (12.7), incl	Over 0.057 to 0.120 (1.45 to 3.05), incl	1 (25.4)	1⅝ (28.6)
Over ½ to ⅝ (12.7 to 15.9), incl	0.037 to 0.057 (0.94 to 1.45), incl	1⅜ (30.2)	1¼ (31.8)
Over ½ to ⅝ (12.7 to 15.9), incl	Over 0.057 to 0.120 (1.45 to 3.05), incl	1 (25.4)	1⅝ (30.2)
Over ⅝ to ¾ (15.9 to 19.0), incl	0.049 to 0.057 (1.24 to 1.45), incl	1¼ (31.8)	1½ (38.1)
Over ⅝ to ¾ (15.9 to 19.0), incl	Over 0.057 to 0.109 (1.45 to 2.77), incl	1⅜ (30.2)	1¼ (31.8)
Over ¾ to 1 (19.0 to 25.4), incl	0.049 to 0.058 (1.24 to 1.47), incl	2 (50.8)	4 (101.6)
Over ¾ to 1 (19.0 to 25.4), incl	Over 0.058 to 0.109 (1.47 to 2.77), incl	1¾ (44.5)	2¼ (57.2)

^A Applies for all alloys except alloy UNS N08810, alloy UNS N08801, and UNS N08811.

^B To determine the bend radius applicable to minimum wall tubing, compute the corresponding average wall from the wall tolerances in Table 4, then use Table 5.

TABLE 6 Alloys, Size Ranges, and Yield Strength for Higher Yield Strength Tubes

Alloys	Size Range, in. (mm)		0.2 % Yield Strength, ksi (MPa)	
	OD	Wall Thickness	Minimum	Maximum
Nickel-chromium-iron Alloy UNS N06600	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)
Nickel-chromium-iron Alloy UNS N06601	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (449)
Nickel-iron-chromium Alloy UNS N08800	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)
Nickel-chromium-iron Alloy UNS N06690	¼ to ⅞ (6.35 to 22.23)	Up to 0.100 (2.54)	40 (276)	65 (448)

9.1.2 A lot for mechanical properties, hardness, flaring, and grain size testing shall consist of all material from the same heat, nominal size (except length), and condition (temper).

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (230 kg) of material in the same condition (temper) and size.

9.2 Test Material Selection:

9.2.1 *Chemical Analysis*—Representative samples shall be taken during pouring or subsequent processing.

9.2.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical Properties, Hardness, and Grain Size*—Samples of the material to provide test specimens for mechanical properties, hardness, and grain size shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Mechanical Properties*—One test per lot.

10.3 *Hardness*—A representative sample consisting of 3 % of each lot of tubes with annealed ends (see 9.1.2).

10.4 *Grain Size*—One test per lot.

10.5 *Flare*—A representative sample consisting of 1 % of the number of tube lengths in each lot, with a minimum of one tube per lot.

11. Specimen Preparation

11.1 Tension Test:

11.1.1 Tension test specimens shall be taken from material in the final condition (temper) and tested in the direction of fabrication.

11.1.2 Whenever possible, all tubes shall be tested in full tubular size. When testing in full tubular size is not possible, longitudinal strip specimens, or the largest possible round specimen, shall be used. In the event of disagreement when full tubular testing is not possible, a longitudinal strip specimen with reduced gage length as contained in Test Methods E8/E8M shall be used.

11.1.3 In the case of stress-relieved tubes furnished with annealed ends, the tension test shall be made on the stress-relieved tubes prior to annealing the ends.

11.2 Hardness Test:

11.2.1 *Stress-Relieved Tubing with Annealed Ends*—The hardness test may be made on the inside of the tube near the end or on a specimen cut from the end, at the option of the manufacturer. The test shall be made on the inside of the specimen.

12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical Analysis	E76, E1473
Tension	E8/E8M
Rounding Procedure	E29
Rockwell Hardness	E18
Grain Size	E112
Hardness Conversion	E140

12.2 The measurement of average grain size may be carried out by the planimetric method, the comparison method, or the intercept method described in Test Methods E112. In case of dispute the “referee” method for determining average grain size shall be the planimetric method.

12.3 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated below, in accordance with the rounding method of Practice E29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	nearest unit in the last right-hand place of figures of the specified limit
Tensile strength, yield strength	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1 %
Grain size:	
0.0024 in. (0.060 mm) or larger	nearest multiple of 0.0002 in. (0.005 mm)
less than 0.0024 in. (0.060 mm)	nearest multiple of 0.0001 in. (0.002 mm)

13. Inspection

13.1 Inspection of the material shall be made as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material not conforming to this specification or to authorized modifications will be subject to rejection.

14.2 Samples tested in accordance with this specification that represent rejected material shall be preserved for not less than three weeks from the date 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.

15. Certification

15.1 A manufacturer’s certification shall be furnished to the purchaser stating that material has been manufactured, tested and inspected in accordance with this specification, and that the test results on representative samples meet specification

requirements. A report of the test results shall be furnished.

16. Product Marking

16.1 Each bundle or shipping container shall be marked with the name of the material; condition (temper); this specification number; the size; gross, tare, and net weight; consignor and consignee address; contract or order number; or such other information as may be defined in the contract or order.

17. Keywords

17.1 seamless tube; UNS N02200; UNS N02201; UNS N04400; UNS N06025; UNS N06045; UNS N06600; UNS N06601; UNS N06603; UNS N06686; UNS N06690; UNS N06696; UNS N06845; UNS N08120; UNS N08800; UNS N08801; UNS N08810; UNS N08811; UNS N08825; UNS N06699; UNS N08935

SUPPLEMENTARY REQUIREMENTS

S1. U-BENT TUBES

The following supplementary requirements shall apply when U-bent tubes are specified by the purchaser in the inquiry, contract, or order.

S1.1 Limitation of Supplementary Requirements for U-Bent Tubes

S1.1.1 The requirements for U-bent tubes included in this supplement are limited to the alloys, conditions (tempers), tube outside diameter (OD), and wall thickness ranges and bend radii listed in Table 5.

S1.2 Permissible Variations in Dimensions (Fig. S1.1)

S1.2.1 *Leg Spacing*—The leg spacing, measured between the points of tangency of the bend to the legs shall not vary from the value ($2R - \text{specified tube OD}$) by more than the amounts shown below where R is the specified centerline bend radius:

Centerline Bend Radius (R), in. (mm)	Tolerance, in. (mm)
Up to 18 (457), incl.	$\frac{1}{16}$ (1.6)
Over 18 to 30 (457 to 762), incl.	$\frac{3}{32}$ (2.4)
Over 30 to 36 (762 to 914), incl.	$\frac{1}{8}$ (3.2)

S1.2.2 *Diameter of Tube in U-Bent Section*—Neither the major, nor the minor outside diameter of the tube at any one cross section included within the points of tangency of the bend shall deviate from the nominal diameter prior to bending by more than 10 %.

S1.2.3 *Wall Thickness of Tube in U-Bent Section*—The wall thickness of the tube at the apex of the U-bent section shall be not less than the value determined by the following equation:

$$TF = T(2R)/(2R + D)$$

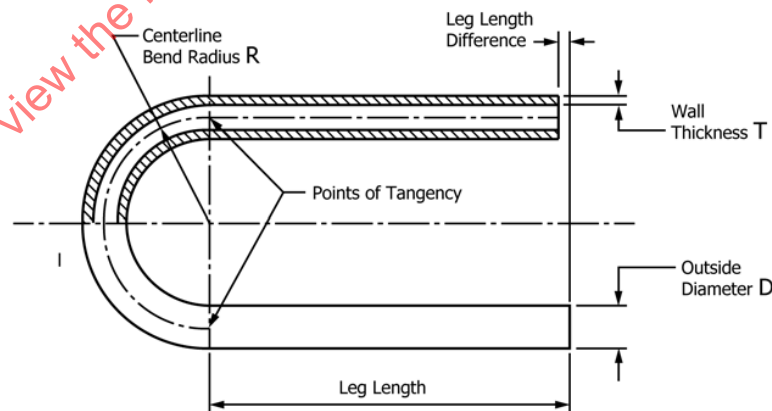


FIG. S1.1 Bent Portion of U-Tube

where:

TF = thickness after bending, in. (mm),
 T = minimum permissible thickness of tube wall prior to bending, in. (mm),
 R = centerline bend radius, in. (mm), and
 D = nominal outside diameter of the tube, in. (mm).

When specified by the purchaser, proof of conformance to this requirement shall be obtained by bending a tube specimen, representative of the material offered, to the scheduled radius of bend, cutting the tube at the apex of the bend, measuring the tube wall at the cross section of this apex section, and comparing the measured value with the calculated value of TF .

S1.2.4 Length of U-Bend Tube Legs—The length of the tube legs as measured from the point of tangency of the bend and the tube leg to the end of the tube leg shall not be less than that specified, but may exceed the specified values by the following amounts:

Specified Length (L), ft (m)	Tolerance (all Plus), in. (mm)
Up to 20 (6.1), incl	$\frac{1}{8}$ (3.2)
Over 20 to 30 (6.1 to 9.1), incl	$\frac{5}{32}$ (4.0)
Over 30 to 60 (9.1 to 18.3), incl	$\frac{1}{4}$ (6.4)
Over 60 (18.3)	$\frac{3}{8}$ (10.0)

S1.2.4.1 The difference in the length of the tube legs shall not be greater than $\frac{1}{8}$ in. (3.2 mm).

S1.2.5 Squareness of Ends—The end of any tube may depart from square by not more than the following amounts:

Tube OD, in. (mm)	Tolerance, in. (mm)
Up to $\frac{5}{8}$ (15.9), incl	0.010 (0.25)
Over $\frac{5}{8}$ (15.9)	0.016 (0.41)

S1.3 Hydrostatic Test

S1.3.1 When specified by the purchaser, the hydrostatic test shall be performed after bending. The minimum holding time at pressure shall be 5 s.

S1.3.1.1 When hydrostatic testing is performed after bending, such testing will not be required on straight length tubes prior to bending.

S1.3.1.2 The required fiber stress for computing hydrostatic test pressure shall be 26 600 psi (183.3 MPa).

S2. HIGH YIELD STRENGTH TUBES

The following supplementary requirements shall apply when high yield strength tubes are specified by the purchaser in the inquiry, contract, or purchase order.

S2.1 Limitations of Supplementary Requirements for High Yield Strength Tubes

S2.1.1 The requirements for higher yield strength tubes included in this supplement are limited to the alloys, tube outside diameter (OD), and wall thickness ranges listed in Table 6.

S2.2 Higher Yield Strength

S2.2.1 The 0.2 % yield strength shall be as listed in Table 6. All other mechanical properties shall be as listed in Table 3.

S2.3 Degree of Cold Work

S2.3.1 No additional cold working over and above that normally required for these alloys shall be used in order to meet the higher yield strength.

S2.4 Annealing

S2.4.1 Tubing is to be furnished in the annealed condition. In order to meet the higher yield strength requirement, it may be necessary to control the final annealing parameters so as to preclude large grain sizes.

S2.5 Marking Requirements

S2.5.1 In addition to the marking requirements of SB-163, the marking shall include the letters HYS signifying higher yield strength.

S3. COILED OR UNSTRAIGHTENED TUBING

The following supplementary requirements shall apply when coiled or unstraightened tubing is specified by the purchaser in the inquiry, contract, or purchase order.

S3.1 Unstraightened Tubing

S3.1.1 When the purchaser specifies coiled or unstraightened tubing after final heat treatment, the tensile specimens may be machine straightened prior to testing.

S3.1.2 On the certification and wherever the grade designation for unstraightened tubing appears, it shall be identified with the suffix letter "U" (for example, UNS N06600-U).

S4. U.S. GOVERNMENT

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order for agencies of the U.S. Government.

S4.1 Referenced Documents

S4.1.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein: Fed. Std. No. 102, Fed. Std. No. 123, Fed. Std. No. 182, and MIL-STD-129.

S4.2 Quality Assurance

S4.2.1 *Responsibility for Inspection:*

S4.2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements.

S4.3 Identification Marking

S4.3.1 The material shall be properly marked for identification in accordance with Fed. Std. No. 182 except that the ASTM specification number and the alloy number shall be used.

S4.4 Preparation for Delivery

S4.4.1 *Preservation, Packaging, Packing:*

S4.4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade or class and shall be preserved and packaged, level A or C, packed level A, B, or C as specified in the contract or purchase order.

S4.4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.4.2 *Marking:*

S4.4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIXES

(Nonmandatory Information)

X1. CONDITION AND FINISHES NORMALLY SUPPLIED

X1.1 Scope

X1.1.1 This appendix lists the conditions and finishes in which tube (other than converter sizes) are normally supplied. These are subject to change and the manufacturer should be consulted for the latest information available.

X1.2 Nickel UNS N02200

X1.2.1 *Annealed*—Soft, with a dull matte finish.

X1.2.2 *Stress Relieved*—Thermally treated below the annealing temperature to relieve the major portion of the internal stresses, with a thin, light to medium-dark surface.

X1.2.3 *Stress Relieved with Annealed Ends*—Same as X1.2.2 except with annealed ends.

X1.3 Low-Carbon Nickel UNS N02201

X1.3.1 *Annealed*—Similar to X1.2.1.

X1.3.2 *Stress Relieved*—Similar to X1.2.2.

X1.3.3 *Stress-Relieved With Annealed Ends*—Same as X1.3.2 except with annealed ends.

X1.4 Nickel-Copper Alloy UNS N04400

X1.4.1 *Annealed*—Soft with a dull matte finish.

X1.4.2 *Stress Relieved*—Thermally treated below the annealing temperature to relieve the major portion of the internal stresses resulting from cold drawing, with a thin, light to medium-dark surface.

X1.4.3 *Stress-Relieved With Annealed Ends*—Same as X1.4.2 except with annealed ends.

X1.5 Nickel-Chromium-Aluminum Alloy UNS N06699, Nickel-Chromium-Iron Alloy UNS N06600, Nickel-Chromium-Iron Alloy UNS N06601, Nickel-Chromium-Iron Alloy UNS N06690, Nickel-Chromium-Iron Alloy UNS N06045, Nickel-Chromium-Iron Alloy UNS N06025, Nickel-Iron-Chromium Alloys (UNS N08120, UNS N08800, UNS N08810, UNS N08811, and UNS N08801), Nickel-Iron-Chromium-Molybdenum Alloy N08935, and Nickel-Iron-Chromium-Molybdenum-Copper Alloys UNS N08825 and UNS N06845

X1.5.1 *Annealed and Ground Outside Diameter*—The inside diameter may have a bright finish when material is annealed in protective atmosphere; otherwise, the inside diameter is supplied descaled as necessary.

X1.5.2 *Annealed and Pickled (Not Ground)*—Outside and inside diameter will have dull, matte (pickled) surfaces.

X2. CONVERTER SIZES

X2.1 Small diameter and light wall tube in outside diameters 1¼ in. (31.8 mm) and under all wall thicknesses may be furnished in the following conditions or tempers when so specified. The material is furnished in a limited range of sizes and the manufacturer should be consulted as to the various

outside diameters and wall thicknesses that may be furnished. Material shall be clean and scale-free. Such material shall conform to the applicable requirements indicated in Table X2.1 and Table X2.2.

TABLE X2.1 Mechanical Properties^A of Small Diameter and Light Wall Tube

Material	Tensile Strength, ksi (MPa)	Yield Strength (0.2 % offset), ^B min, ksi (MPa)	Elongation in 2 in. or 50 mm, min, %	Rockwell Hardness ^C (Scale as Indicated)
<i>Nickel UNS N02200:</i>				
Annealed ^D	80 (552) max	15 (103)	33	B75, max
Half-hard ^E	80 (552) min	40 (276)	12	B75 to B90
Full hard ^F	95 (655) min	75 (517)	4	B90 to C30
<i>Low-carbon nickel UNS N02201:</i>				
Annealed ^D	70 (483) max	12 (83)	35	B62, max
Half-hard ^E	70 (483) min	30 (207)	12	B70 to B85
Full hard ^F	85 (586) min	65 (448)	4	B80 to B95
<i>Nickel-copper alloy UNS N04400:</i>				
Annealed ^D	90 (621) max	28 (193)	32	B80, max
Half-hard ^E	85 (586) min	55 (379)	12	B75 to B97
Full hard ^F	110 (758) min	90 (621)	3	B95 to C27
<i>Nickel-chromium-iron alloy UNS N06600:</i>				
Annealed ^{D,G}	80 (552) to 110 (758)	35 (241)	30	B92, max
Half-hard ^E	105 (724) min	55 (379)	13	B90 to B98
Full-hard ^F	130 (896) min	105 (724)	4	C19 to C34
<i>UNS N06601:</i>				
Annealed ^{D,G}	80 (552) to 110 (758)	30 (207)	30	B92 max
Half-hard ^E	105 (724) min	55 (379)	13	B90 to B98
Full-hard ^F	130 (896) min	105 (724)	4	C19 to C34
<i>UNS N06690:</i>				
Annealed ^{D,G}	85 (586) to 115 (793)	35 (241)	30	B92 max
Half-hard ^E	105 (724) min	55 (379)	13	B90 to B98
Full-hard ^F	130 (896) min	105 (724)	4	C19 to C34
<i>Nickel-iron chromium alloy UNS N08800:</i>				
Annealed ^{D,G}	75 (517) to 100 (689)	30 (207)	30	B95, max
Half-hard ^E	105 (724)	60 (414)	13	B93 to C26
Full hard ^F	130 (896)	105 (724)	4	C24 to C38
<i>Nickel-iron chromium- molybdenum-copper alloy UNS N08825:</i>				
Annealed ^{D,G}	85 (586) to 115 (793)	35 (241)	30	B90 max
Half-hard ^E	105 (724) min	75 (517)	15	B90 to C25
Full-hard ^F	125 (862) min	100 (689)	5	C25 to C35

^A Not applicable to outside diameters under 1/8 in. (3.2 mm) and to wall thicknesses under 0.015 in. (0.38 mm).

^B See 12.3.

^C Hardness values, indicative of tensile strength, are shown for information only. All tests are subject to confirmation by tension tests. For hardness conversions, see Hardness Conversion Tables E140.

^D This condition is sometimes designated as "No. 1 Temper."

^E This condition is sometimes designated as "No. 2 Temper."

^F This condition is sometimes designated as "No. 3 Temper."

^G The minimum tensile strength value applies only to tubing in straight lengths.

TABLE X2.2 Permissible Variations for Small Diameter and Light Wall Tube (Converter Sizes)

NOTE 1—Ovality, *Normal Wall Tube*:

As-Drawn (No. 2 and 3) Tempers—Ovality will be held within the outside diameter tolerances shown in the table.

Annealed (No. 1) Temper—Ovality will be held within 2 % of the theoretical average outside diameter.

NOTE 2—Ovality *Light Wall Tube*:

As-Drawn (No. 2 and 3) Tempers—Ovality will be held within 2 % of the theoretical average outside diameter.

Annealed (No. 1) Temper—Ovality will be held within 3 % of the theoretical average outside diameter.

NOTE 3—*Wall Tolerances, Light Wall Tube*—The plus and minus wall tolerance shown in the table shall apply down to and including 0.005 in. (0.13 mm) in wall thickness. For wall thicknesses less than 0.005 in. the tolerance shall be plus and minus 0.0005 in.

NOTE 4—Random Lengths:

(a) Where nominal random lengths on tubing $\frac{1}{8}$ in. and larger in outside diameter are specified, a length tolerance of plus and minus 3½ ft (1.1 m) applies to the nominal length. This is a total spread of 7 ft. (2.1 m).

(b) Random lengths in sizes $\frac{1}{8}$ in. (3.2 mm) and larger in outside diameter shall be subject to a length range from 5 to 24 ft (1.5 to 7.3 m). Long random lengths are subject to a range from 15 to 22 ft (4.6 to 6.7 m).

(c) Random lengths in sizes up to, but not including, $\frac{1}{8}$ in. in outside diameter, and fragile light wall tubes over this outside diameter are subject to the length range from 1 to 15 ft (0.3 to 4.6 m).

NOTE 5—*Cut Lengths*—Tolerances on cut lengths shall be as follows:

NOTE 6—*Straightness*—Round tubing is subject to a straightness tolerance of one part in 600 (equivalent to a depth of arc of 0.030 in. (0.76 mm) in any 3 ft (0.9 m) of length).

NOTE 7—*Eccentricity*—Eccentricity (as defined in Table 4, Note 2) shall be limited to plus or minus 10 % of the specified wall or calculated average wall.

NOTE 8—When specified, the tolerance spread may be applied as desired. However, when not specified the tolerances shown below will apply. It should be noted that inside diameter tolerances are based upon the outside diameter range.

Length, ft	Tube Size, in.	Permissible Variations, in.				
		Over	Under			
U.S. Customary Units						
Under 1	Up to 1.250, incl	1/32	0			
1 to 4, incl	Up to 1.250, incl	1/16	0			
Over 4 to 10, incl	Up to 1.250, incl	3/32	0			
Over 10	Up to 1.250, incl	3/16	0			
Metric Units						
Length, m	Tube Size, mm	Permissible Variations, mm				
		Over	Under			
Under 0.3	Up to 31.75, incl	0.794	0			
0.3 to 1.2, incl	Up to 31.75, incl	1.59	0			
1.2 to 3.0, incl	Up to 31.75, incl	2.38	0			
Over 3.0	Up to 31.75, incl	4.76	0			
Specified Outside Diameter, in.	Outside Diameter, in.		Inside Diameter, in.		Wall Thickness,%	
	+	—	+	—	+	—
U.S. Customary Units						
Under 3/32	0.002	0	0	0.002	10	10
to 3/16 (0.1875), excl	0.003	0	0	0.003	10	10
3/16 to 1/2 (0.500), excl	0.004	0	0	0.004	10	10
1/2 to 1 1/4 (1.250), incl	0.005	0	0	0.005	10	10
Millimetres						
Under 2.38	0.051	0	0	0.051	10	10
2.38 to 4.76, excl	0.076	0	0	0.076	10	10
4.76 to 12.70, excl	0.102	0	0	0.102	10	10
12.70 to 31.8, incl	0.127	0	0	0.127	10	10

SPECIFICATION FOR NICKEL-COPPER ALLOY ROD, BAR, AND WIRE



SB-164

(Identical with ASTM Specification B164-03(2014) except that certification and reporting have been made mandatory and lot definition is revised.)

SPECIFICATION FOR NICKEL-COPPER ALLOY ROD, BAR, AND WIRE



SB-164

[Identical with ASTM Specification B 164-03(2014) except that certification and reporting have been made mandatory and lot definition is revised.]

1. Scope

1.1 This specification covers nickel-copper alloys UNS N04400 and N04405 in the form of hot-worked and cold-worked rod and bar in the conditions shown in Table 1 and cold-worked wire in the conditions shown in Table 2.

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are for information only.

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet for this product/material as provided by the manufacturer, to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

- B 127 Specification for Nickel-Copper Alloy (UNS N04400) Plate, Sheet, and Strip
- B 880 Specification for General Requirements for Chemical Check Analysis Limits for Nickel, Nickel Alloys, and Cobalt Alloys
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E 76 Test Methods for Chemical Analysis of Nickel-Copper Alloys
- E 140 Hardness Conversion Tables for Metals
- E 1473 Test Methods for Chemical Analysis of Nickel, Cobalt, and High-Temperature Alloys

2.2 Military Standards:

- MIL-STD-129 Marking for Shipment and Storage
- MIL-STD-271 Nondestructive Testing Requirements for Metals

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 bar — material of rectangular (flats), hexagonal, or square solid section up to and including 10 in. (254 mm) in width and $\frac{1}{8}$ in. (3.2 mm) and over in thickness in straight lengths.

3.1.2 rod — material of round solid section furnished in straight lengths.

3.1.3 wire — a cold-worked solid product of uniform round cross section along its whole length, supplied in coiled form.

NOTE 1 — Hot-worked rectangular bar in widths 10 in. and under may be furnished as hot-rolled plate with sheared or cut edges in accordance with Specification B 127, provided the mechanical property requirements of Specification B 164 are met.

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. Examples of such requirements include, but are not limited to, the following:

4.1.1 ASTM designation and year of issue.

4.1.2 UNS number.

4.1.3 Section — Rod (round) or bar (square, hexagonal, or rectangular) or wire (round).

4.1.4 Dimensions — Dimensions including length.

TABLE 1
MECHANICAL PROPERTIES OF ROD AND BAR

Condition and Diameter or Distance Between Parallel Surfaces, in. (mm)	Tensile Strength min, psi (MPa)	Yield Strength (0.2% offset) ^A min., psi (MPa)	Elongation in 2 in. or 50 mm (or 4D), min, %	Rockwell Hard- ness (or equivalent)
UNS N04400				
<i>Cold-worked (as worked):</i>				
Rounds under 1/2 (12.7)	110 000 (760)	85 000 (585)	8 ^B	...
Squares, hexagons, and rectangles under 1/2 (12.7)	85 000 (585)	55 000 (380)	10 ^B	...
<i>Cold-worked (stress-relieved):</i>				
Rounds under 1/2 (12.7)	84 000 (580)	50 000 (345)	10 ^B	...
Rounds, 1/2 to 3 1/2 (12.7 to 88.9), incl	87 000 (600)	60 000 (415)	20	...
Rounds, over 3 1/2 to 4 (88.9 to 101.6), incl	84 000 (580)	55 000 (380)	20	...
Squares, hexagons and rectangles, 2 (50.8) and under	84 000 (580)	50 000 (345)	20 ^{B,C}	...
Squares, hexagons and rectangles, over 2 (50.8) to 3 1/2 (79.4), incl	80 000 (552)	50 000 (345)	20	...
<i>Hot-worked (as worked or stress-relieved):</i>				
Rounds, squares, and rectangles up to 12 (305), incl, and hexagons 2 1/8 (54) and under	80 000 (552)	40 000 (276)	30 ^D	...
Rounds, squares, and rectangles over 12 (305) to 14 (356), incl	75 000 (517)	40 000 (276)	30	...
Hexagons over 2 1/8 (54) to 4 (102), incl	75 000 (517)	30 000 (207)	25	...
Rings and disks	...	...	...	B 75 to B 95
<i>Hot-worked (annealed) or cold-worked (annealed):</i>				
Rod and bar, all sizes	70 000 (480)	25 000 (170)	35	...
Rings and disks	...	...	...	B 60 to B 75
<i>Forging quality:</i> ^E				
All sizes	...	...	...	...
UNS N04405				
<i>Cold-worked (as worked or stress-relieved):</i>				
Rounds, under 1/2 (12.7)	85 000 (585)	50 000 (345)	8 ^B	...
Rounds, 1/2 (12.7) to 3 (76.2), incl	85 000 (585)	50 000 (345)	15	...
Rounds, over 3 (76.2) to 4 (101.6), incl	80 000 (552)	50 000 (345)	15	...
Hexagons and squares 2 (50.8) and under	85 000 (585)	50 000 (345)	15 ^{B,C}	...
Hexagons and squares over 2 (50.8) to 3 1/2 (79.4), incl	80 000 (552)	45 000 (310)	15	...
<i>Hot-worked (as hot-worked or stress-relieved):</i>				
Rounds 3 (76.2) and less	75 000 (517)	35 000 (241)	30	...
Hexagons and squares, 2 1/8 (54) and less	75 000 (517)	35 000 (241)	30	...
Hexagons and squares, over 2 1/8 (54) to 4 (101.6), incl	70 000 (480)	30 000 (207)	25	...
<i>Hot-worked (annealed) or cold-worked (annealed):</i>				
Rod and Bar, All sizes	70 000 (480)	25 000 (170)	35	...

^A See 12.2.

^B Not applicable to diameters or cross sections under 3/32 in. (2.4 mm).

^C For sections under 1/2 in. (12.7 mm), the elongation shall be 10% min.

^D For hot-worked flats 5/16 in. (7.9 mm) and under in thickness the elongation shall be 20% min.

^E Forging quality is furnished to chemical requirements and surface inspection only. No tensile properties are required.

TABLE 2
MECHANICAL PROPERTIES OF COLD-WORKED WIRE IN COIL⁴

Alloy Condition and Size, in. (mm)	Tensile Strength, psi (MPa)		Wrapping Test
	Min	Max	
UNS N04400 and N04405:			
Annealed, all sizes	70 000 (483)	85 000 (586)	All wire shall wrap around a rod of the same diameter as the wire without cracking
No. 0 temper, under $\frac{1}{2}$ (12.7)	80 000 (552)	95 000 (655)	
No. 1 temper, under $\frac{1}{2}$ (12.7)	90 000 (621)	110 000 (758)	
UNS N04400			
Regular temper, under $\frac{1}{2}$ (12.7)	110 000 (758)	140 000 (965)	All wire up to 0.2294 in. (5.84 mm) inclusive, shall wrap around a rod of the same diameter as the wire without cracking. Wire over 0.2294 in. (5.84 mm) diameter shall wrap around a rod of twice the wire diameter without cracking.
Regular temper, $\frac{1}{2}$ (12.7) and over	90 000 (621)	130 000 (896)	
Spring temper			
0.028 (0.71) and less	165 000 (1138)	...	
Over 0.028 (0.71) to 0.057 (1.45), incl	160 000 (1103)	...	
Over 0.057 (1.45) to 0.114 (2.90), incl	150 000 (1034)	...	
Over 0.114 (2.90) to 0.312 (7.92), incl	140 000 (965)	...	
Over 0.312 (7.92) to 0.375 (9.53), incl	135 000 (931)	...	
Over 0.375 (9.53) to 0.500 (12.7), incl	130 000 (896)	...	
Over 0.500 (12.7) to 0.563 (14.3), incl	120 000 (827)	...	

⁴ Properties are not applicable to wire after straightening and cutting.

TABLE 3
CHEMICAL REQUIREMENTS

Element	Composition Limits, %	
	UNS N04400	UNS N04405
Nickel ⁴	63.0 min	63.0 min
Copper	28.0 min	28.0 min
	34.0 max	34.0 max
Iron	2.5 max	2.5 max
Manganese	2.0 max	2.0 max
Carbon	0.3 max	0.3 max
Silicon	0.5 max	0.5 max
Sulfur	0.024 max	0.025 min
		0.060 max

⁴ Element shall be determined arithmetically by difference.

4.1.5 Condition.

4.1.6 Finish.

4.1.7 Quantity — feet or number of pieces.

4.1.8 Certification — Certification and reporting per para. 15 are mandatory.

4.1.9 Samples for Product (Check) Analysis — State whether samples for product (check) analysis should be furnished.

4.1.10 Purchaser Inspection — If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which test or inspections are to be witnessed.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 3.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Specification B 880.

6. Mechanical Properties

6.1 Mechanical Properties — The material shall conform to the mechanical properties specified in Table 1 for rod or bar, or in Table 2 for wire.

7. Dimensions and Permissible Variations

7.1 Diameter, Thickness, or Width — The permissible variations from the specified dimensions as measured on the diameter or between parallel surfaces of cold-worked rod and bar shall be as prescribed in Table 4, and of hot-worked rod and bar as prescribed in Table 5. The permissible variations in diameter of cold-worked wire shall be as prescribed in Table 6.

7.2 Out-of-Round — Hot-worked rods and cold-worked rods (except “forging quality”) all sizes, in straight lengths, shall not be out-of-round by more than one half the total permissible variations in diameter shown in Table 4 and Table 5, except for hot-worked rods $\frac{1}{2}$ in. (12.7 mm) in diameter and under, which may be out-of-round by the total permissible variations in diameter shown in Table 5. Wire shall not be out-of-round by more than one-half the total permissible variations shown in Table 6.

7.3 Corners — Cold-worked bars will have practically exact angles and sharp corners.

7.4 Machining Allowances for Hot-Worked Materials — When the surfaces of hot-worked products are to be machined, the allowances prescribed in Table 7 are

TABLE 4
PERMISSIBLE VARIATIONS IN DIAMETER OR DISTANCE BETWEEN PARALLEL SURFACES OF COLD-WORKED ROD AND BAR

Specified Dimension, in. (mm) ⁴	Permissible Variations from Specified Dimension, in. (mm)	
	+	–
Rounds:		
$\frac{1}{16}$ (1.6) to $\frac{3}{16}$ (4.8), excl	0	0.002 (0.05)
$\frac{3}{16}$ (4.8) to $\frac{1}{2}$ (12.7), excl	0	0.003 (0.08)
$\frac{1}{2}$ (12.7) to $1\frac{5}{16}$ (23.8), incl	0.001 (0.03)	0.002 (0.05)
over $1\frac{5}{16}$ (23.8) to $1\frac{15}{16}$ (49.2), incl	0.0015 (0.04)	0.003 (0.08)
over $1\frac{15}{16}$ (49.2) to $2\frac{1}{2}$ (63.5), incl	0.002 (0.05)	0.004 (0.10)
over $2\frac{1}{2}$ (63.5) to 3 (76.2), incl	0.0025 (0.06)	0.005 (0.13)
over 3 (76.2) to $3\frac{1}{2}$ (88.9), incl	0.003 (0.08)	0.006 (0.15)
over $3\frac{1}{2}$ (88.9) to 4 (101.6), incl	0.0035 (0.09)	0.007 (0.18)
Hexagons, squares, rectangles:		
$\frac{1}{2}$ (12.7) and less	0	0.004 (0.10)
over $\frac{1}{2}$ (12.7) to $\frac{7}{8}$ (22.2), incl	0	0.005 (0.13)
over $\frac{7}{8}$ (22.2) to $1\frac{1}{4}$ (31.8), incl	0	0.007 (0.18)
over $1\frac{1}{4}$ (31.8) to $2\frac{1}{4}$ (57.2), incl	0	0.009 (0.23)
over $2\frac{1}{4}$ (57.2) to 3 (76.2), incl	0	0.011 (0.28)
over 3 (76.2) to $3\frac{1}{2}$ (88.9), incl	0	0.015 (0.38)
over $3\frac{1}{2}$ (88.9) to 4 (101.6), incl	0	0.017 (0.43)

⁴ Dimensions apply to diameter of rounds, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

TABLE 5
PERMISSIBLE VARIATIONS IN DIAMETER OR DISTANCE BETWEEN PARALLEL SURFACES OF HOT-WORKED ROD AND BAR

Specified Dimension, in. (mm) ⁴	Permissible Variations from Specified Dimensions, in. (mm)	
	+	–
Rod and bar, hot-worked:		
1 (25.4) and under	0.016 (0.41)	0.016 (0.41)
over 1 (25.4) to 2 (50.8), incl	0.031 (0.79)	0.016 (0.41)
over 2 (50.8) to 4 (101.6), incl	0.047 (1.19)	0.031 (0.79)
over 4 (101.6)	0.125 (3.18)	0.063 (1.60)
Rod, rough-turned or ground:		
under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0
Forging quality rod:^B		
Under 1 (25.4)	0.005 (0.13)	0.005 (0.13)
1 (25.4) and over	0.031 (0.79)	0

⁴ Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagons and squares, and separately to width and thickness of rectangles.

^B Spot grinding is permitted to remove minor surface imperfections. The depth of these spot ground areas shall not exceed 3% of the diameter of the rod.

TABLE 6
PERMISSIBLE VARIATIONS IN DIAMETER OF COLD-WORKED WIRE

Diameter, in. (mm)	Permissible Variations, in. (mm), ±
Under 0.0044 (0.11)	0.0002 (0.005)
0.0044 (0.11) to 0.0079 (0.20), incl	0.00025 (0.006)
Over 0.0079 (0.20) to 0.0149 (0.38), incl	0.0003 (0.008)
Over 0.0149 (0.38) to 0.0199 (0.51), incl	0.0004 (0.010)
Over 0.0199 (0.51) to 0.031 (0.79), incl	0.0005 (0.013)
Over 0.031 (0.79) to 0.045 (1.14), incl	0.0006 (0.015)
Over 0.045 (1.14) to 0.079 (2.01), incl	0.0007 (0.018)
Over 0.079 (2.01) to 0.1875 (4.76), incl	0.001 (0.025)
Over 0.1875 (4.76) to 0.3125 (7.93), incl	0.002 (0.051)
Over 0.3125 (7.93)	0.003 (0.076)

TABLE 7
NORMAL MACHINING ALLOWANCES FOR HOT-WORKED MATERIAL

Finished-Machined Dimensions for Finishes as Indicate Below in. (mm) ^A	Normal Machining Allowance, in. (mm)			
	On Diameter, for Rods	Distance Between Parallel Surfaces, for Hexagonal and Square Bar	For Rectangular Bar	
			On Thickness	On Width
Hot-worked: ^B				
Up to 7/8 (22.2), incl	1/8 (3.2)	1/8 (3.2)	1/8 (3.2)	3/16 (4.8)
Over 7/8 to 1 7/8 (22.2 to 47.6), incl	1/8 (3.2)	3/16 (4.8)	1/8 (3.2)	3/16 (4.8)
Over 1 7/8 to 2 7/8 (47.6 to 73.0), incl	3/16 (4.8)	1/4 (6.4)	...	3/16 (4.8)
Over 2 7/8 to 3 13/16 (73.0 to 96.8), incl	1/4 (6.4)	...	...	3/16 (4.8)
Over 3 13/16 (96.8)	1/4 (6.4)	...	...	3/8 (9.5)
Hot-worked rods:				
Rough-turned or rough-ground: ^C				
1 5/16 to 4 (23.8 to 101.6), incl, in diameter	1/16 (1.6)	...	...	...
Over 4 to 12 (101.6 to 304.8), incl, in diameter	7/8 (3.2)	...	...	...

^A Dimensions apply to diameter of rods, to distance between parallel surfaces of hexagonal and square bar, and separately to width and thickness of rectangular bar.

^B The allowances for hot-worked material in Table 5 are recommended for rods machined in lengths of 3 ft (0.91 m) or less and for bars machined in lengths of 2 ft (0.61 m) or less. Hot-worked material to be machined in longer lengths should be specified showing the finished cross-sectional dimension and the length in which the material will be machined in order that the manufacturer may supply material with sufficient oversize, including allowance for out-of-straightness.

^C Applicable to 3 ft (0.91 m) max length.

recommended for normal machining operations.

7.5 Length — The permissible variations in length of cold-worked and hot-worked rod and bar shall be as prescribed in Table 8.

7.5.1 Rods and bars ordered to random or nominal lengths will be furnished with either cropped or saw-cut ends; material ordered to cut lengths will be furnished with square saw-cut or machined ends.

7.6 Straightness:

7.6.1 The permissible variations in straightness of cold-worked rod and bar as determined by the departure from straightness shall be as prescribed in Table 9.

7.6.2 The permissible variations in straightness of precision straightened cold-worked rod as determined by

the departure from straightness shall be as prescribed in Table 10.

7.6.2.1 In determining straightness in the standard 42-in. (1.07-m) distance between supports or, when specified, in determining straightness in lengths not in excess of those shown in Table 10, the rod shall be placed on a precision table equipped with ball-bearing rollers and a micrometer or dial indicator. The rod shall then be rotated slowly against the indicator, and the deviation from straightness in any portion of the rod between the supports shall not exceed the permissible variations prescribed in Table 10. The deviation from straightness (throw in one revolution) is defined as the difference between the maximum and minimum readings of the dial indicator in one complete revolution of the rod.

TABLE 8
PERMISSIBLE VARIATIONS IN LENGTH OF RODS AND BAR

Random mill lengths:	
Hot-worked	6 to 24 ft (1.83 to 7.31 m) long with not more than 25 weight % between 6 and 9 ft (1.83 and 2.74 m) ^A
Cold-worked	6 to 20 ft (1.83 to 6.1 m) long with not more than 25 weight % between 6 and 10 ft (1.83 and 3.05 m).
Multiple lengths	Furnished in multiples of a specified unit length, within the length limits indicated above. For each multiple, an allowance of $\frac{1}{4}$ in. (6.4 mm) will be made for cutting, unless otherwise specified. At the manufacturer's option, individual specified unit lengths may be furnished.
Nominal lengths	Specified nominal lengths having a range of not less than 2 ft (610 mm) with no short lengths allowed ^B
Cut lengths	A specified length to which all rods and bars will be cut with a permissible variation of plus $\frac{1}{8}$ in. (3.2 mm), minus 0 for sizes 8 in. (203 mm) and less in diameter or distance between parallel surfaces. For larger sizes, the permissible variation shall be $+\frac{1}{4}$ in. (6.4 mm), -0.

^A For hot-worked sections weighing over 25 lb/ft (37 kg/m) and for smooth forged products, all sections, short lengths down to 2 ft (610 mm) may be furnished.

^B For cold-worked rods and bars under $\frac{1}{2}$ in. (12.7 mm) in diameter or distance between parallel surfaces ordered to nominal or stock lengths with a 2-ft (610-mm) range, at least 93% of such material shall be within the range specified; the balance may be in shorter lengths but in no case shall lengths less than 4 ft (1220 mm) be furnished.

TABLE 9
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF COLD-WORKED RODS AND BARS

Specified Diameter or Distance Between Parallel Surfaces, in. (mm) ⁴	Permissible Variations in Lengths Indicated, in. (mm)
Rounds: ½ (12.7) to 4 (101.6), incl	Depth of Chord: 0.030 (0.76) per ft (305 mm) of length
Hexagons, Squares, Rectangles: ½ (12.7) to 4 (101.6), incl	0.030 (0.76) per ft (305 mm) of length

⁴ Material under ½ in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

7.6.3 The permissible variations in straightness of hot-worked rod and bar as determined by the departure from straightness shall be as specified in Table 11.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and condition, smooth, commercially straight or flat, and free of injurious imperfections.

9. Sampling

9.1 Lot—Definition:

9.1.1 A lot for chemical analysis shall consist of one heat.

9.1.2 A lot for mechanical properties testing shall consist of all material from the same heat, nominal diameter or thickness, and condition.

9.1.2.1 DELETED

9.2 Test Material Selection:

9.2.1 Chemical Analysis —Representative samples from each lot shall be taken during pouring or subsequent processing.

9.2.1.1 Product (check) analysis shall be wholly the responsibility of the purchaser.

9.2.2 Mechanical Properties —Samples of the material to provide test specimens for mechanical properties shall be taken from such locations in each lot as to be representative of that lot.

10. Number of Tests

10.1 Chemical Analysis — One test per lot.

10.2 Tension — One test per lot.

10.3 Hardness — One test per lot.

10.4 Wrapping — One test per lot.

11. Specimen Preparation

11.1 Tension test specimens shall be taken from material in the final condition and tested in the direction of fabrication.

11.1.1 All rod, bar, and wire shall be tested in full cross-section size when possible. When a full cross-section size test cannot be performed, the largest possible round specimen shown in Test Methods E 8 shall be used. Longitudinal strip specimens shall be prepared in accordance with Test Methods E 8 for rectangular bar up to ½ in. (12.7 mm) inclusive, in thicknesses that are too wide to be pulled full size.

11.2 Hardness test specimens shall be taken from material in the final condition.

11.3 In order that the hardness determinations may be in reasonably close agreement, the following procedure is suggested:

11.3.1 For rod and wire under ½ in. (12.7 mm) in diameter, hardness readings shall be taken on a flat surface prepared by filing or grinding approximately ¼ in. (1.6 mm) from the outside surface of the rod.

11.3.2 For rod and wire ½ in. in diameter and larger, and for hexagonal, square, and rectangular bar, all sizes, hardness readings shall be taken on a cross section midway between the surface and center of the section.

12. Test Methods

12.1 The chemical composition, mechanical, and other properties of the material as enumerated in this specification shall be determined, in case of disagreement, in accordance with the following methods:

Test	ASTM Designation
Chemical Analysis	E 76, E 1473
Tension	E 8
Rockwell Hardness	E 18
Hardness Conversion	E 140
Rounding Procedure	E 29

TABLE 10
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF PRECISION-STRAIGHTENED COLD-WORKED SHAFTING UNS N04400 ONLY

Specified Diameter of Shafting, in.	Standard Distance Between Supports	Permissible Variations (Throw in One Revolution) from Straightness, in.
$\frac{1}{2}$ to $\frac{15}{16}$, incl	42 in.	0.005
Over $\frac{15}{16}$ to $1\frac{15}{16}$, incl	42 in.	0.006
Over $1\frac{15}{16}$ to $2\frac{1}{2}$, incl	42 in.	0.007
Over $2\frac{1}{2}$ to 4, incl	42 in.	0.008
$\frac{3}{4}$ to $\frac{15}{16}$, incl	Specified lengths of 3 to 10 ft.	0.004 plus 0.0025 for each foot or fraction thereof in excess of 3 ft
Over $\frac{15}{16}$ to 4, incl	Specified lengths of 20 ft and less	0.005 plus 0.0015 for each foot or fraction thereof in excess of 3 ft
Specified Diameter of Shafting, mm	Standard Distance Between Supports	Permissible Variations (Throw in One Revolution) from Straightness, mm
12.7 to 23.8, incl	1067 mm	0.13
Over 23.8 to 49.2, incl	1067 mm	0.15
Over 49.2 to 63.5, incl	1067 mm	0.18
Over 63.5 to 101.6, incl	1067 mm	0.20
19.1 to 23.8, incl	specified lengths of 914 to 3050 mm	10.2 plus 0.2 for each metre or fraction thereof in excess of 914 mm
Over 23.8 to 101.6, incl	specified lengths of 6100 mm and less	12.7 plus 0.13 for each metre or fraction thereof in excess of 914 mm

12.2 For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value or a calculated value shall be rounded as indicated below, in accordance with the rounding method of Practice E 29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition, hardness, and tolerances (when expressed in decimals)	Nearest unit in the last right-hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5, or a 5 followed only by zeros, choose the one ending in an even digit, with zero defined as an even digit.
Tensile strength and yield strength	Nearest 1000 psi (6.9 MPa)
Elongation	Nearest 1%

13. Inspection

13.1 Inspection of the material shall be made as agreed upon between the manufacturer and the purchaser as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material, tested by the purchaser, that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 A producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with

TABLE 11
PERMISSIBLE VARIATIONS IN STRAIGHTNESS OF
HOT-WORKED RODS AND BARS^A

Finish	Permissible Variations, in./ft (mm/m) ^B
Rods and bars, hot-worked	0.050 (4.2) ^C
Round—hot worked, rough-ground, or rough-turned	0.050 (4.2) ^C

^A Not applicable to forging quality.

^B Material under $\frac{1}{2}$ in. (12.7 mm) shall be reasonably straight and free of sharp bends and kinks.

^C The maximum curvature (depth of chord) shall not exceed the values indicated multiplied by the length in feet.

this specification and has been found to meet the requirements. A report of the test results shall be furnished.

16. Product Marking

16.1 The following information shall be marked on the material or included on the package, or on a label or tag attached thereto: The name of the material or UNS Number, heat number, condition (temper), ASTM B 164, the size, gross, tare, and net weight, consignor and consignee address, contract or order number, or such other information as may be defined in the contract or order.

17. Keywords

17.1 bar; rod; wire; N04400

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Scope

S1.1 The requirements for annealed, hot finished, and cold rolled and stress relieved rod and bar shall apply for shapes in the same conditions except as modified herein for chemistry and ultrasonic inspection.

S2. Referenced Documents

S2.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein:

S2.1.1 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys

S2.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

S3. Chemical Composition

S3.1 The material shall conform to the composition limits specified in Table 3 except as specified in Table S3.1 or Table S3.2.

S4. Mechanical Properties

S4.1 UNS N04400 cold worked bar and rod shall be supplied in the stress relieved condition.

S5. Number of Tests

S5.1 For wire, the number of samples for tension and wrapping tests shall be as specified in Table S5.1.

TABLE S3.1
CHEMICAL REQUIREMENTS

Element	Composition Limits, %
	UNS N04400
Carbon	0.2 max.
Sulfur	0.015 max.
Aluminum	0.5 max.
Lead	0.006 max.
Tin	0.006 max.
Zinc	0.02 max.
Phosphorus	0.02 max.

S6. Specimen Preparation

S6.1 Tensile specimens for rod and bar up to 1½ in. in diameter or minimum thickness shall coincide with the central axis of the piece. Tensile specimens for rod and bar 1½ in. and over in diameter or thickness shall be located midway between the center and the rolled or drawn surface of the piece.

S6.2 Tensile specimens for wire shall be of the full cross section and not less than 15 in. in length. Specimens shall be free from sharp bends or kinks. The distance between the jaws of the testing machine, with the specimen in place ready for testing, shall be not less than 10 in.

S7. Nondestructive Tests

S7.1 When specified by the purchaser, each piece of each lot shall be inspected. The purchaser shall specify if one or both tests are required.

TABLE S3.2
CHEMICAL REQUIREMENTS

Element	Composition Limits, %
	UNS N04405
Aluminum	0.5 max.
Lead	0.006 max.
Tin	0.006 max.
Zinc	0.02 max.
Phosphorus	0.02 max.

TABLE S5.1
REQUIRED SAMPLES FOR TENSION AND WRAPPING TESTS OF WIRE

Lot Size, lbs	Number of Samples for Each Test
¼ in. diameter and less:	
180 and under	1
181 to 500	2
501 to 800	3
801 to 1300	5
1301 to 3200	7
3201 to 5000	10
Over ¼ in. diameter:	
For each 500 lbs. or fraction thereof	1

TABLE S7.1
ULTRASONIC TESTING REFERENCE HOLE FOR ROD
AND BAR

Material Thickness, in. (mm)	Hole Diameter, in. (mm)
Up to and including 6 (152)	$\frac{1}{8}$ (3.18)
Over 6 (152) and including 16 (406)	$\frac{1}{4}$ (6.4)
Over 16 (406)	As agreed upon

S7.2 Ultrasonic Tests:

S7.2.1 General Requirements:

S7.2.1.1 Ultrasonic testing shall be performed in accordance with MIL-STD-271 as modified by the requirements specified herein. Testing shall be done by a longitudinal wave or shear wave technique as specified herein.

S7.2.1.2 Acoustic compatibility between the production material and the calibration standard material shall be within 75%. If the acoustic compatibility is within 25%, no gain compensation is required for the examination. If acoustic compatibility difference is between 25% and 75%, a change in the gain or dB controls shall be accomplished to compensate for the differences in acoustic compatibility. This method cannot be used if the ultrasonic noise level exceeds 50% of the rejection value.

S7.2.2 Calibration:

S7.2.2.1 Shear Wave — The shear wave test shall be calibrated on two notches, one notch cut into the inside and one into the outside surface. The notches shall be cut axially and shall have a depth of 5% of the material thickness or $\frac{1}{4}$ in. (6.4 mm), whichever is less. Notch length shall not exceed 1 in. (25.4 mm). Notches shall be made either in the piece to be examined or in a separate defect-free specimen of the same size (within $\pm \frac{1}{8}$ in. (3.18 mm)), shape, material, and condition, or acoustically similar material. The position and amplitude of the response from each notch shall be marked on the instrument screen or a transparent overlay, and these marks shall be used as the evaluation reference. Indications that appear between these points shall be evaluated on the basis of a straight line joining the two peak amplitudes.

S7.2.2.2 Longitudinal Wave — The longitudinal wave test shall be calibrated on a flatbottomed reference hole of a given diameter in accordance with Table S7.1 for specified material thickness drilled either into the piece to be tested or into a separate defect-free specimen of the same size (within $\pm \frac{1}{8}$ in. (3.18 mm)), shape, material, and condition, or acoustically similar material. Holes are to be drilled to midsection and the bottom of the hole shall be parallel to the entrant surface. The ultrasonic test instrument shall be adjusted so that the response from the reference hole shall not be less than 25% and not more than 75% of screen height.

S7.2.2.3 Recalibration — During quality conformance inspection, any realignment of the search unit that will cause a decrease in the calibrated sensitivity and resolution, or both, or any change in search unit, couplant, instrument settings, or scanning speed from that used for calibration shall require recalibration. Recalibration shall be performed at least once per 8 h shift.

S7.2.3 Procedure — S7.2.3.1 and S7.2.3.2 describe the requirements for rod and bar. Wire shall be excluded from these requirements. Shapes other than those listed below shall be tested to the extent set forth in the approved procedure.

S7.2.3.1 Rod — Rod shall be tested using the longitudinal wave technique. The scanning path shall be circumferential or helical with the beam directed along a radius of the rod.

S7.2.3.2 Bar — Bar shall be tested using the longitudinal wave technique through one side of each pair of parallel sides (thickness and width only).

S7.2.4 Acceptance Criteria:

S7.2.4.1 Shear Wave — Any material that produces indications equal to or larger than the response from the reference notch or higher than the straight line joining the two peak amplitudes shall be rejected.

S7.2.4.2 Longitudinal Wave — Any material that produces indications equal to or larger than the response from the reference hole, or that produces a complete loss of back reflection shall be rejected. Material shall be tested using a square, rectangular, or circular transducer having an effective area of one square inch or less, but no dimension shall be smaller than the diameter of the reference hole. In the event of disagreement on the degree of back reflection loss, it shall be determined by the contact method using a 1 to $1\frac{1}{8}$ in. (25.4 to 28.6 mm) diameter transducer or one whose area falls within this range.

S7.2.4.3 Reference Notch Removal — If reference notches or flatbottomed holes are made in the material to be tested, they shall be so located that their subsequent removal will not impair the suitability of the material for its intended use.

S7.3 Liquid Penetrant Inspection:

S7.3.1 Procedure — Liquid penetrant inspection shall be in accordance with MIL-STD-271.

S7.3.2 Surface Requirements — The surface produced by hot working is not suitable for liquid penetrant testing. Therefore, liquid penetrant testing will not be applicable to products ordered with a hot finished surface.

S7.3.3 Acceptance Criteria — Linear defects revealed by liquid penetrant inspection shall be explored by grinding or other suitable means. Depth of defects shall not exceed the dimensional tolerance of the material.

S8. Quality Assurance**S8.1 Responsibility for Inspection:**

S8.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to ensure that the material conforms to prescribed requirements:

S9. Identification Marking

S9.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 182, except that the ASTM Specification number and the alloy number shall be used.

S10. Preparation for Delivery**S10.1 Preservation, Packaging, Packing:**

S10.1.1 Military Agencies — The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, level A or C, packed level A, B, or C as specified in the contract or purchase order.

S10.1.2 Civil Agencies — The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S10.2 Marking:

S10.2.1 Military Agencies — In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S10.2.2 Civil Agencies — In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIX

(Nonmandatory Information)

X1. CONDITIONS AND FINISHES NORMALLY SUPPLIED

X1.1 The various conditions and finishes in which rod and bar are procurable are as follows:

X1.1.1 *Hot-Worked* — With a tightly adherent, black, mill oxide surface.

X1.1.2 *Hot-Worked, Rough-Ground* — Similar to X1.1.1 except rough-ground.

X1.1.3 *Hot-Worked, Rough-Turned* — Similar to X1.1.1 except rough turned with a broad nosed tool similar to a bar peeling operation and thus may not be straight. Intended generally for machining where an over-hauled surface is desired, essentially for machined step down shafts or parts machined in short lengths of 3 ft (910 mm) or less.

X1.1.3.1 Where material is intended for shafting for diameters over 4 in. (101.6 mm) the “stress-relieved” temper is recommended.

X1.1.4 *Hot-Worked, Forging Quality* — Rough turned and spot ground, as necessary, for sizes 1 in. in diameter and over; rough ground and spot ground for sizes under 1 in. (25.4 mm) in diameter. Material is selected from heats of known, good hot malleability.

NOTE X1.1— For sizes 4 in. in diameter and less, cold-worked rod may be used also for forging by virtue of the fact such rod has been overhauled for removal of mechanical surface defects prior to cold-working. In such cases, the user should run pilot forging tests to ensure himself that such material has the desired hot malleability range.

X1.1.5 *Forging Quality, Bolt Tolerance* — Hot-worked, of known good hot malleability, but not overhauled prior to skin pass, cold-working to tolerances specified herein, which tolerances conform to the major diameter

tolerances of Class 3 fit of American Standard screw threads. No mechanical properties are offered since material is to be subsequently hot worked. Intended primarily for hot heated bolts but is of somewhat inferior quality, as to surface seams and cracks compared to forging quality, see X1.1.4.

X1.1.6 *Hot-Worked, Annealed* — Soft with a tightly adherent oxide that may vary from dark to light.

X1.1.7 *Hot-Worked, Annealed, and Pickled* — Same as X1.1.6 except descaled for removal of mill oxide. Provides for better surface inspection than does hot-worked material and often employed where welding is involved where removal of mill oxide is desired.

NOTE X1.2— Annealing prior to pickling may be required in order to reduce the mill oxide since uniform pickling of an unreduced oxide is difficult.

X1.1.8 *Cold-Worked, Stress-Relieved* — Hot worked, overhauled, cold-worked, and straightened. Material is thermally treated to relieve the major portion of the internal stresses resulting from cold-working and may have a very thin light to medium oxide. Intended primarily for shafting and for machined parts where minimum “walking” or distortion after metal removal is desired.

X1.1.9 *Cold-Worked, Annealed* — Hot-worked, overhauled, cold-worked, and straightened. Annealed for softness and with a dull matte finish.

NOTE X1.3— *UNS N04405 Material*—This is the machining grade and is preferred generally to UNS N04400 for intricately machined parts, particularly for parts that are to be machined on automatics or require drilling.

SPECIFICATION FOR NICKEL-COPPER ALLOY SEAMLESS PIPE AND TUBE



SB-165

(Identical with ASTM Specification B165-19 except for deletion of 1.1.1.)

Specification for Nickel-Copper Alloy Seamless Pipe and Tube

1. Scope

1.1 This specification covers nickel-copper alloy UNS N04400 in the form of cold-worked seamless pipe and tube in the conditions shown in Table 1 and Table X1.1.

1.1.1 DELETED

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

1.3 *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 become familiar with all hazards including those identified in the appropriate Material Safety Data Sheet (MSDS) for this product/material as provided by the manufacturer, to establish appropriate safety, health, and environmental practices, and determine the applicability of regulatory limitations prior to use.*

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:

- B829 Specification for General Requirements for Nickel and Nickel Alloys Seamless Pipe and Tube
- E8 Test Methods for Tension Testing of Metallic Materials [Metric] E0008_E0008M
- E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
- E76 Test Methods for Chemical Analysis of Nickel-Copper Alloys (Withdrawn 2003)

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *average diameter, n*—average of the maximum and minimum outside diameters, as determined at any one cross-section of the pipe or tube.

3.1.2 *pipe, n*—tube conforming to the particular dimensions commercially known as pipe sizes, see Table X2.1.

3.1.3 *seamless pipe or tube, n*—pipe or tube produced with a continuous periphery in all stages of the operations.

3.1.4 *tube, n*—hollow product of round or any other cross-section having a continuous periphery.

4. Ordering Information

4.1 Orders for material to this specification shall include information with respect to the following:

- 4.1.1 Alloy name or UNS number.
- 4.1.2 ASTM designation and year of issue.
- 4.1.3 Condition (see Appendix X3).
- 4.1.4 Finish (see Appendix X3).
- 4.1.5 Dimensions:
 - 4.1.5.1 *Tube*—Specify outside diameter and nominal or minimum wall.
 - 4.1.5.2 *Pipe*—Specify standard pipe size and schedule.
 - 4.1.5.3 *Length*—Cut to length or random.
- 4.1.6 *Quantity*—Feet or number of pieces.
- 4.1.7 *Hydrostatic Test or Nondestructive Electric Test*—Specify type of test (see 6.2).
- 4.1.8 *Hydrostatic Pressure Requirements*—Specify test pressure if other than required by 12.3.1.

TABLE 1 Mechanical Properties of Pipe and Tube

Condition and Size	Tensile Strength, min, psi (MPa)	Yield Strength, min. (0.2 % offset), min, psi (MPa)	Elongation in 2 in. or 50 mm (or 4 D), min, %
Annealed:			
5 in. (127 mm) outside diameter and under	70 000 (480)	28 000 (195)	35
Over 5 in. (127 mm) outside diameter	70 000 (480)	25 000 (170)	35
Stress-Relieved: All sizes	85 000 (585)	55 000 (380)	15

4.1.9 *Samples for Product (Check) Analysis*—State whether samples for product (check) analysis should be furnished (see 5.2).

4.1.10 *Purchaser Inspection*—If purchaser wishes to witness tests or inspection of material at place of manufacture, the purchase order must so state indicating which tests or inspections are to be witnessed (Section 13).

4.1.11 *Small-Diameter Tube and Tube with Specified Wall Thickness 3 % or Less of the Specified Outside Diameter (Converter Sizes)*—See Appendix X1.

5. Chemical Composition

5.1 The material shall conform to the composition limits specified in Table 2.

5.2 If a product (check) analysis is performed by the purchaser, the material shall conform to the product (check) analysis variations in Table 2.

6. Mechanical and Other Requirements

6.1 *Tension Test*—The material shall conform to the tensile properties specified in Table 1.

6.1.1 Tensile properties for material specified as small-diameter tube and tube with specified wall thickness 3 % or less of the specified outside diameter (converter sizes) shall be in accordance with Table X1.1.

6.2 *Hydrostatic or Nondestructive Electric Test*—Each pipe or tube shall be subjected to either the hydrostatic test or the nondestructive electric test. The type of test to be used shall be at the option of the manufacturer, unless otherwise specified in the purchase order.

TABLE 2 Chemical Requirements

Element	Composition Limits, %	Product (Check) Analysis Variations, under min or over max, of the Specified Limit of Element
Ni ^a	63.0 min	0.45
Cu	28.0 min 34.0 max	0.15 0.20
Fe	2.5 max	0.05
Mn	2.0 max	0.04
C	0.3 max	0.02
Si	0.5 max	0.03
S	0.024 max	0.005

^a Element shall be determined arithmetically by difference.

7. Dimensions and Permissible Variations

7.1 *Diameter and Wall Thickness*—The permissible variations in the outside diameter and wall thickness shall conform to the permissible variations prescribed in Table 3.

7.2 *Length*—When material is ordered cut-to-length, the length shall conform to the permissible variations prescribed in Table 4.

7.3 *Straightness*—Material shall be reasonably straight and free of bends and kinks.

7.4 *Ends*—Ends shall be plain cut and deburred.

7.5 Permissible variations for material specified as small-diameter tube and tube with specified wall thickness 3 % or less of the specified outside diameter (converter size) shall conform to the permissible variations prescribed in Table X1.2.

8. Workmanship, Finish, and Appearance

8.1 The material shall be uniform in quality and temper, smooth, commercially straight, and free of injurious imperfections.

9. Sampling

9.1 *Lot Definition*:

9.1.1 A lot for chemical analysis shall consist of one heat.

9.1.2 A lot for all other testing shall consist of all material from the same heat, nominal size (excepting length), and condition.

9.1.2.1 Where material cannot be identified by heat, a lot shall consist of not more than 500 lb (227 kg) of material in the same condition and nominal size (excepting length).

9.2 *Test Material Selection*:

9.2.1 *Chemical Analysis*—Representative samples from each lot shall be taken during pouring or subsequent processing.

9.2.1.1 Product (Check) Analysis shall be wholly the responsibility of the purchaser.

9.2.2 *Mechanical and other Properties*—Samples of the material to provide test specimens for mechanical and other properties shall be taken from such locations in each lot as to be representative of that lot. Test specimens shall be taken from material in the final condition.

10. Number of Tests

10.1 *Chemical Analysis*—One test per lot.

10.2 *Tension*—One test per lot.

10.3 *Hydrostatic or Nondestructive Electric Test*—Each piece in each lot.

11. Specimen Preparation

11.1 *Room Temperature Tensile Specimen*—Material shall be tested in the direction of fabrication. Whenever possible, all pipe and tube shall be tested in full tubular size. When testing in full tubular size is not possible, longitudinal strip specimens, or the largest possible round specimen, shall be used. In the event of disagreement when full tubular testing is not possible, a longitudinal strip specimen with reduced gauge length as contained in Test Methods E8 shall be used.

TABLE 3 Permissible Variations for Outside Diameter and Wall Thickness of Seamless Cold Worked Pipe and Tube^{A,B}

Nominal Outside diameter, in. (mm)	Permissible Variations				% of Thickness of Specified Minimum Wall	
	Outside Diameter, in. (mm)		% of Thickness of Specified Nominal Wall			
	+	−	+	−	+	−
Over 0.400 (10) to 5⁄8 (16), excl	0.005 (0.13)	0.005 (0.13)	15.0	15.0	30	0
5⁄8 (16) to 1½ (38), incl	0.0075 (0.19)	0.0075 (0.19)	10.0	10.0	22	0
Over 1½ (38) to 3 (76), incl	0.010 (0.25)	0.010 (0.25)	10.0	10.0	22	0
Over 3 (76) to 4½ (114), incl	0.015 (0.38)	0.015 (0.38)	10.0	10.0	22	0
Over 4½ (114) to 6 (152), incl	0.020 (0.51)	0.020 (0.51)	12.5	12.5	28	0
Over 6 (152) to 6¾ (168), incl	0.025 (0.64)	0.025 (0.64)	12.5	12.5	28	0
Over 6¾ (168) to 8¾ (219), incl	0.031 (0.79)	0.031 (0.79)	12.5	12.5	28	0

^A *Ovality*—The permissible variations in this table apply to individual measurements, including out-of-roundness (ovality) except for the following:

For pipe and tube having a nominal wall thickness of 3 % or less of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements (including ovality) shall conform to the plus and minus values of the table, with the values increased by 0.5 % of the nominal outside diameter.

For pipe and tube over 4 1/2 in. (114 mm) in outside diameter with a nominal wall thickness greater than 3 % of the nominal outside diameter, the mean outside diameter shall conform to the permissible variations of this table and individual measurements shall not exceed twice the permissible variations of the table.

^B *Eccentricity*—The permissible variations in this table apply to individual measurements including eccentricity.

TABLE 4 Permissible Variations in Length^A

Outside Diameter, in. (mm)	Cut Length, in. (mm)	
	Over	Under
Under 2 (50.8)	1/8 (3.2)	0
2 (50.8) and over	3/16 (4.8)	0

^A These permissible variations in length apply to pipe or tube in straight lengths. They apply to cut lengths up to and including 24 ft (7.3 m). For lengths over 24 ft, an additional over-tolerance of 1/8 in. (3.2 mm) for each 10 ft (3.0 m) or fraction thereof shall be permissible up to a maximum additional over-tolerance of 1/2 in. (12.7 mm).

12. Test Methods

12.1 *Chemical Composition*—In case of disagreement, the chemical composition shall be determined in accordance with Test Methods E76.

12.2 *Tension Test*—Tension testing shall be conducted in accordance with Test Methods E8.

12.3 *Hydrostatic or Nondestructive Electric Test*—Each pipe or tube with an outside diameter 1/8 in. (3 mm) and larger and with wall thickness of 0.015 in. (0.38 mm) and over shall be tested by the manufacturer to an internal hydrostatic pressure of 1000 psi (6.9 MPa) provided that the fiber stress calculated in accordance with the following equation does not exceed the allowable fiber stress, S , indicated below:

$$P = 2St/D \quad (1)$$

where:

P = hydrostatic test pressure, psi (or MPa)

S = allowable fiber stress, for material in the condition (temper) furnished as follows:

<i>Annealed:</i>	
5 in. (127 mm) outside diameter and under	17 500 psi (120 MPa)
Over 5 in. (127 mm) outside diameter	16 700 psi (115 MPa)
<i>Stress-relieved:</i>	
All sizes	21 200 psi (145 MPa)

t = minimum wall thickness, in. (or mm), equal to the specified nominal wall minus the permissible minus wall tolerance, or the specified minimum wall thickness, and,
 D = outside diameter of the pipe or tube, in. (or mm).

12.3.1 When so agreed upon between the manufacturer and purchaser, pipe or tube may be tested to 1 1/2 times the allowable fiber stress given above.

12.3.2 If any pipe or tube shows leaks during hydrostatic testing, it shall be rejected.

12.4 *Nondestructive Electric Test*—Each pipe or tube shall be examined with a nondestructive electric test in accordance with Specification B829.

12.5 *Rounding Method*—For purposes of determining compliance with the specified limits for requirements of the properties listed in the following table, an observed value, or a calculated value, shall be rounded as indicated below, in accordance with the rounding method of Practice E29:

Test	Rounded Unit for Observed or Calculated Value
Chemical composition and tolerances (when expressed in decimals)	nearest unit in the last right-hand place of figures of the specified limit. If two choices are possible, as when the digits dropped are exactly a 5 or a 5 followed only by zeros, choose the one ending in an even digit with zero defined as an even digit.
Tensile strength, yield strength	nearest 1000 psi (6.9 MPa)
Elongation	nearest 1 %

13. Inspection

13.1 Inspection of the material shall be agreed upon between the purchaser and the supplier as part of the purchase contract.

14. Rejection and Rehearing

14.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection should be reported to the producer or supplier promptly and in writing. In case of dissatisfaction with the results of the test, the producer or supplier may make claim for a rehearing.

15. Certification

15.1 A manufacturer's certification shall be furnished to the purchaser stating that material has been manufactured, tested, and inspected in accordance with this specification, and that the test results on representative samples meet specification requirements. A report of the test results shall be furnished.

16. Product Marking

16.1 The following information shall be marked on the material or included on the package, or on a label or tag

attached thereto: The name of the material or UNS number, heat number, condition (temper), this specification number, the size, gross, tare and net weight, consignor and consignee address, contract or order number, or such other information as may be defined in the contract or order.

17. Keywords

17.1 seamless pipe; seamless tube; N04400

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the inquiry, contract, or order, for agencies of the U. S. Government.

S1. Referenced Documents

S1.1 The following documents of the issue in effect on date of material purchased form a part of this specification to the extent referenced herein:

S1.1.1 *Federal Standards:*

Fed. Std. No. 102 Preservation, Packaging and Packing Levels

Fed. Std. No. 123 Marking for Shipment (Civil Agencies)

Fed. Std. No. 182 Continuous Identification Marking of Nickel and Nickel-Base Alloys

S1.1.2 *Military Standard:*

MIL-STD-129 Marking for Shipment and Storage

S2. Quality Assurance

S2.1 *Responsibility for Inspection:*

S2.1.1 Unless otherwise specified in the contract or purchase order, the manufacturer is responsible for the performance of all inspection and test requirements specified. Except as otherwise specified in the contract or purchase order, the manufacturer may use his own or any other suitable facilities for the performance of the inspection and test requirements unless disapproved by the purchaser at the time the order is

placed. The purchaser shall have the right to perform any of the inspections or tests set forth when such inspections and tests are deemed necessary to assure that the material conforms to prescribed requirements.

S3. Identification Marking

S3.1 All material shall be properly marked for identification in accordance with Fed. Std. No. 182, except that the ASTM specification number and the alloy number shall be used.

S4. Preparation for Delivery

S4.1 *Preservation, Packaging, Packing:*

S4.1.1 *Military Agencies*—The material shall be separated by size, composition, grade, or class and shall be preserved and packaged, level A or C, packed level A, B, or C as specified in the contract or purchase order.

S4.1.2 *Civil Agencies*—The requirements of Fed. Std. No. 102 shall be referenced for definitions of the various levels of packaging protection.

S4.2 *Marking:*

S4.2.1 *Military Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with MIL-STD-129.

S4.2.2 *Civil Agencies*—In addition to any special marking required by the contract or purchase order, marking for shipment shall be in accordance with Fed. Std. No. 123.

APPENDIXES

(Nonmandatory Information)

X1. CONVERTER SIZES

X1.1 Small-diameter tube and tube with specified wall thickness 3 % or less of the specified outside diameter in outside diameters 1¼ in. (31.8 mm) and under may be furnished in the conditions listed in Table X1.1 when so specified. The material is furnished in a limited range of sizes and the manufacturer should be consulted as to the various outside diameters and wall thicknesses that may be furnished. Material will have a bright finish. Such material shall conform to the applicable requirements in Table X1.1 and Table X1.2.

TABLE X1.1 Mechanical Properties^A of Small-Diameter Tube and Tube with Specified Wall Thickness 3 % or Less of the Specified Outside Diameter (Converter Sizes)

Condition	Tensile Strength, psi (MPa)	Yield Strength (0.2 % offset) min, psi (MPa)	Elongation in 2 in. or 50 mm, (or 4 <i>D</i>), min %
Annealed ^B	85 000 (585) max	28 000 (195)	32
Half-hard ^C	85 000 (585) min	55 000 (380)	12
Full hard ^D	110 000 (760) min	90 000 (620)	3

^A Not applicable to outside diameters under ⅛ in. (3.2 mm) and wall thicknesses under 0.015 in. (0.38 mm).

^B This condition is sometimes designated as "No. 1 Temper."

^C This condition is sometimes designated as "No. 2 Temper."

^D This condition is sometimes designated as "No. 3 Temper."

TABLE X1.2 Permissible Variations for Small-Diameter Tube and Tube with Specified Wall Thickness $\leq 3\%$ of the Specified Outside Diameter (Converter Sizes)^{A,B,C,D,E,F,G}

Specified Outside Diameter, in. (mm)	Outside Diameter		Inside Diameter, in. (mm)		Wall Thickness, %	
	+	−	+	−	+	−
Under $\frac{3}{32}$ (2.4)	0.002 (0.05)	0 (0)	0 (0)	0.002 (0.05)	10	10
$\frac{3}{32}$ to $\frac{3}{16}$ (2.4 to 4.8), excl	0.003 (0.08)	0 (0)	0 (0)	0.003 (0.08)	10	10
$\frac{3}{16}$ to $\frac{1}{2}$ (4.8 to 12.7), excl	0.004 (0.10)	0 (0)	0 (0)	0.004 (0.10)	10	10
$\frac{1}{2}$ to $1\frac{1}{4}$ (12.7 to 31.8), incl	0.005 (0.13)	0 (0)	0 (0)	0.005 (0.13)	10	10

^A *Ovality, Tube with Specified Wall Thickness $> 3\%$ of the Specified Outside Diameter—As-Drawn (No. 2 and 3) Tempers—Ovality will be held within the outside diameter tolerances shown in the table.*

Annealed (No. 1) Temper—Ovality will be held within 2% of the theoretical average outside diameter.

^B *Ovality, Tube with Specified Wall Thickness $\leq 3\%$ of the Specified Outside Diameter—As-Drawn (No. 2 and 3) Tempers—Up to but not including $1\frac{1}{4}$ in. (31.8 mm) in outside diameter, ovality will be held within 2% of the theoretical average outside diameter.*

Annealed (No. 1) Temper—Ovality will be held within 3% of the theoretical average outside diameter.

^C *Wall Tolerances, Tube with Specified Wall Thickness $\leq 3\%$ of the Specified Outside Diameter—The plus and minus wall tolerance shown in the table shall apply down to and including 0.005 in. (0.13 mm) in wall thickness. For wall thicknesses less than 0.005 in. (0.13 mm), the tolerance shall be ± 0.0005 in. (0.013 mm).*

^D *Random Lengths:*

Where nominal random lengths on tubing $\frac{1}{8}$ in. (3.2 mm) and larger in outside diameter are specified, a length tolerance of $\pm 3\frac{1}{2}$ ft (106 cm) applies to the nominal length. This is a total spread of 7 ft (210 cm).

Random lengths in sizes $\frac{1}{8}$ in. (3.2 mm) and larger in outside diameter shall be subject to a length range of 5 to 24 ft (150 to 730 cm). Long random lengths are subject to a range of 15 to 22 ft (457 to 670 cm).

Random lengths in sizes up to, but not including $\frac{1}{8}$ in. (3.2 mm) in outside diameter, and fragile tubes with specified wall thickness $\leq 3\%$ of the specified outside diameter over this outside diameter are subject to the length range of 1 to 15 ft (30 to 457 cm).

^E *Cut Lengths—Tolerances on cut lengths shall be in accordance with Table X1.3.*

^F *Straightness—Round tubing is subject to a straightness tolerance of one part in 600 (equivalent to a depth of arc of 0.030 in. (0.76 mm) in any 3 ft (91 cm) of length).*

^G When specified, the tolerance spreads of this table may be applied as desired. However, when not specified, the tolerances in this table will apply. It should be noted that inside diameter tolerances are based upon the outside diameter range.

TABLE X1.3 Tolerances on Cut Lengths of Tube with Specified Wall Thickness $\leq 3\%$ of the Specified Outside Diameter

Length, ft (cm)	Tube Size, in. (mm)	Permissible Variations, in. (mm)	
		Over	Under
Under 1 (30)	up to 1.250 (31.8), incl	$\frac{1}{32}$ (0.8)	0 (0)
1 to 4 (30 to 122), incl	up to 1.250 (31.8), incl	$\frac{1}{16}$ (1.6)	0 (0)
Over 4 to 10 (122 to 300), incl	up to 1.250 (31.8), incl	$\frac{3}{32}$ (2.4)	0 (0)
Over 10 (300)	up to 1.250 (31.8), incl	$\frac{3}{16}$ (4.8)	0 (0)

X2. PIPE SCHEDULES

X2.1 The schedules of pipe shown in Table X2.1 are regularly available. Other schedules may be furnished, and the manufacturer should be consulted. Table X2.1 is published for information only.

TABLE X2.1 Pipe Schedules^A

Nominal Pipe Size in.	Outside Diameter in. (mm)	Nominal Wall Thickness, in. (mm)			
		Schedule No. 5 in. (mm)	Schedule No. 10 in. (mm)	Schedule No. 40 in. (mm)	Schedule No. 80 in. (mm)
$\frac{1}{8}$	0.405 (10.3)	...	0.049 (1.2)	0.068 (1.7)	0.095 (2.4)
$\frac{1}{4}$	0.540 (13.7)	...	0.065 (1.6)	0.088 (2.2)	0.119 (3.0)
$\frac{3}{8}$	0.675 (17.1)	...	0.065 (1.6)	0.091 (2.3)	0.126 (3.2)
$\frac{1}{2}$	0.840 (21.3)	0.065 (1.6)	0.083 (2.1)	0.109 (2.8)	0.147 (3.7)
$\frac{3}{4}$	1.050 (26.7)	0.065 (1.6)	0.083 (2.1)	0.113 (2.8)	0.154 (3.9)
1	1.315 (33.4)	0.065 (1.6)	0.109 (2.8)	0.133 (3.4)	0.179 (4.5)
$1\frac{1}{4}$	1.660 (42.2)	0.065 (1.6)	0.109 (2.8)	0.140 (3.6)	0.191 (4.8)
$1\frac{1}{2}$	1.900 (48.3)	0.065 (1.6)	0.109 (2.8)	0.145 (3.7)	0.200 (5.1)
2	2.375 (60.3)	0.065 (1.6)	0.109 (2.8)	0.154 (3.9)	0.218 (5.5)
$2\frac{1}{2}$	2.875 (73.0)	0.083 (2.1)	0.120 (3.0)	0.203 (5.2)	0.276 (7.0)
3	3.500 (88.9)	0.083 (2.1)	0.120 (3.0)	0.216 (5.5)	0.300 (7.6)
$3\frac{1}{2}$	4.000 (101.6)	0.083 (2.1)	0.120 (3.0)	0.226 (5.7)	0.318 (8.1)
4	4.500 (114.3)	0.083 (2.1)	0.120 (3.0)	0.237 (6.0)	0.337 (8.6)
5	5.563 (141.3)	0.109 (2.8)	0.134 (3.4)	0.258 (6.5)	0.375 (9.5)
6	6.625 (168.3)	0.109 (2.8)	0.134 (3.4)	0.280 (7.1)	0.432 (10.9)
8	8.625 (219.1)	...	...	0.322 (8.2)	0.500 (12.7)

^A The pipe schedules shown above conform with standards adopted by the American National Standards Institute.

X3. CONDITIONS AND FINISHES NORMALLY SUPPLIED

X3.1 This appendix lists the conditions and finishes in which pipe and tube (other than converter sizes) are normally supplied. These are subject to change, and the manufacturer should be consulted for the latest information available.

X3.2.2 *Stress-Relieved*—Thermally treated below the annealing temperature to relieve the major portion of the internal stresses, with a thin, light- to medium-dark surface.

X3.2 Nickel-Copper Alloy (UNS N04400)

X3.2.1 *Annealed*—Soft, with a dull matte finish.

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**SPECIFICATION FOR NICKEL-CHROMIUM-ALUMINUM
ALLOY, NICKEL-CHROMIUM-IRON ALLOYS, NICKEL-
CHROMIUM-COBALT-MOLYBDENUM ALLOY, NICKEL-
IRON-CHROMIUM-TUNGSTEN ALLOY, AND NICKEL-
CHROMIUM-MOLYBDENUM-COPPER ALLOY, ROD,
BAR, AND WIRE**



SB-166

(Identical with ASTM Specification B166-19 except for the addition of UNS N06617 heat treatment requirements.
Certification and test reports have been made mandatory.)