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ASME B31.1-2001

(Revision of ASME B31.1-1998)

POWER PIPING

ASME CODE FOR PRESSURE PIPING, B31

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POWER PIPING

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Date of Issuance: December 10, 2001
Mandatory Date: June 10, 2002

This Edition was approved by the American National Standards Institute and designated ASME B31.1-2001 on July 2, 2001

The 2001 Edition of this Code is being issued with an automatic update service that includes Addenda, Interpretations, and Cases. The next Edition is scheduled for publication in 2004.

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FOREWORD

The general *philosophy* underlying this Power Piping Code is to parallel those provisions of Section I, Power Boilers, of the ASME Boiler and Pressure Vessel Code, as they can be applied to power piping systems. The Allowable Stress Values for power piping are generally consistent with those assigned for power boilers. This Code is more conservative than some other piping codes, reflecting the need for long service life and maximum reliability in power plant installations.

The Power Piping Code as currently written does not differentiate between the design, fabrication, and erection requirements for *critical and noncritical piping systems,* except for certain stress calculations and mandatory nondestructive tests of welds for heavy wall, high temperature applications. The *problem involved* is to try to reach agreement on how to evaluate criticality, and to avoid the inference that noncritical systems do not require competence in design, fabrication, and erection. Some day such levels of quality may be definable, so that the need for the many different piping codes will be overcome.

There are many instances where the Code serves to *warn a designer,* fabricator, or erector against possible pitfalls; but the Code is *not a handbook,* and cannot substitute for education, experience, and sound engineering judgment.

Nonmandatory Appendices are included in the Code. Each contains information on a specific subject, and is maintained current with the Code. Although written in mandatory language, these Appendices are offered for application at the user's discretion.

The Code *never intentionally puts a ceiling limit on conservatism.* A designer is free to specify more rigid requirements as he feels they may be justified. *Conversely, a designer who is capable* of a more rigorous analysis than is specified in the Code may justify a less conservative design, and still satisfy the basic intent of the Code.

The Power Piping Committee strives to keep abreast of the current technological improvements in new materials, fabrication practices, and testing techniques; and endeavors to keep the Code updated to permit the use of acceptable new developments.

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INTRODUCTION

The ASME B31 Code for Pressure Piping consists of a number of individually published Sections, each an American National Standard, under the direction of ASME Committee B31, Code for Pressure Piping.

Rules for each Section have been developed considering the need for application of specific requirements for various types of pressure piping. Applications considered for each Code Section include:

B31.1 Power Piping: piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems;

B31.3 Process Piping: piping typically found in petroleum refineries, chemical, pharmaceutical, textile, paper, semiconductor, and cryogenic plants, and related processing plants and terminals;

B31.4 Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids: piping transporting products which are predominately liquid between plants and terminals and within terminals, pumping, regulating, and metering stations;

B31.5 Refrigeration Piping: piping for refrigerants and secondary coolants;

B31.8 Gas Transportation and Distribution Piping Systems: piping transporting products which are predominately gas between sources and terminals, including compressor, regulating, and metering stations; and gas gathering pipelines;

B31.9 Building Services Piping: piping typically found in industrial, institutional, commercial, and public buildings, and in multi-unit residences, which does not require the range of sizes, pressures, and temperatures covered in B31.1;

B31.11 Slurry Transportation Piping Systems: piping transporting aqueous slurries between plants and terminals and within terminals, pumping, and regulating stations.

This is the B31.1 Power Piping Code Section. Hereafter, in this Introduction and in the text of this Code Section B31.1, where the word *Code* is used without specific identification, it means this Code Section.

It is the owner's responsibility to select the Code Section which most nearly applies to a proposed piping installation. Factors to be considered by the owner include: limitations of the Code Section; jurisdictional requirements; and the applicability of other codes and standards. All applicable requirements of the selected Code Section shall be met. For some installations, more than one Code Section may apply to different parts of the installation. The owner is also responsible for imposing requirements supplementary to those of the selected Code Section, if necessary, to assure safe piping for the proposed installation.

Certain piping within a facility may be subject to other codes and standards, including but not limited to:

ASME Boiler and Pressure Vessel Code, Section III: nuclear power piping;

ANSI Z223.1 National Fuel Gas Code: piping for fuel gas from the point of delivery to the connection of each fuel utilization device;

NFPA Fire Protection Standards: fire protection systems using water, carbon dioxide, halon, foam, dry chemical, and wet chemicals;

NFPA 99 Health Care Facilities: medical and laboratory gas systems;

NFPA 8503 Standard for Pulverized Fuel Systems: piping for pulverized coal from the coal mills to the burners;

Building and plumbing codes, as applicable, for potable hot and cold water, and for sewer and drain systems.

The Code sets forth engineering requirements deemed necessary for safe design and construction of pressure piping. While safety is the basic consideration, this factor alone will not necessarily govern the final specifications for any piping system. The designer is cautioned that the Code is not a design handbook; it does not do away with the need for the designer or for competent engineering judgment.

To the greatest possible extent, Code requirements for design are stated in terms of basic design principles and formulas. These are supplemented as necessary with specific requirements to assure uniform application of principles and to guide selection and application of piping elements. The Code prohibits designs and practices known to be unsafe and contains warnings where caution, but not prohibition, is warranted.

The specific design requirements of the Code usually revolve around a simplified engineering approach to a subject. It is intended that a designer capable of applying

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more complete and rigorous analysis to special or unusual problems shall have latitude in the development of such designs and the evaluation of complex or combined stresses. In such cases the designer is responsible for demonstrating the validity of his approach.

This Code Section includes:

(1) references to acceptable material specifications and component standards, including dimensional requirements and pressure-temperature ratings;

(2) requirements for design of components and assemblies, including pipe supports;

(3) requirements and data for evaluation and limitation of stresses, reactions, and movements associated with pressure, temperature changes, and other forces;

(4) guidance and limitations on the selection and application of materials, components, and joining methods;

(5) requirements for the fabrication, assembly, and erection of piping; and

(6) requirements for examination, inspection, and testing of piping.

It is intended that this Edition of Code Section B31.1 and any subsequent Addenda not be retroactive. Unless agreement is specifically made between contracting parties to use another issue, or the regulatory body having jurisdiction imposes the use of another issue, the latest Edition and Addenda issued at least 6 months prior to the original contract date for the first phase of activity covering a piping system or systems shall be the governing document for all design, materials, fabrication, erection, examination, and testing for the piping until the completion of the work and initial operation.

Users of this Code are cautioned against making use of revisions without assurance that they are acceptable to the proper authorities in the jurisdiction where the piping is to be installed.

Code users will note that clauses in the Code are not necessarily numbered consecutively. Such discontinuities result from following a common outline, insofar as practicable, for all Code Sections. In this way, corresponding material is correspondingly numbered in most Code Sections, thus facilitating reference by those who have occasion to use more than one Section.

The Code is under the direction of ASME Committee B31, Code for Pressure Piping, which is organized and operates under procedures of The American Society of Mechanical Engineers which have been accredited by the American National Standards Institute. The Committee is a continuing one, and keeps all Code Sections current with new developments in materials, construction, and industrial practice. Addenda are issued periodically. New editions are published at intervals of three to five years.

When no Section of the ASME Code for Pressure Piping, specifically covers a piping system, at his discretion the user may select any Section determined to be generally applicable. However, it is cautioned that supplementary requirements to the Section chosen may be necessary to provide for a safe piping system for the intended application. Technical limitations of the various Sections, legal requirements, and possible applicability of other codes or standards are some of the factors to be considered by the user in determining the applicability of any Section of this Code.

The Committee has established an orderly procedure to consider requests for interpretation and revision of Code requirements. To receive consideration, inquiries must be in writing and must give full particulars (see Mandatory Appendix H covering preparation of technical inquiries). The Committee will not respond to inquiries requesting assignment of a Code Section to a piping installation.

The approved reply to an inquiry will be sent directly to the inquirer. In addition, the question and reply will be published as part of an Interpretation Supplement issued to the applicable Code Section.

A Case is the prescribed form of reply to an inquiry when study indicates that the Code wording needs clarification or when the reply modifies existing requirements of the Code or grants permission to use new materials or alternative constructions. Proposed Cases are published in *Mechanical Engineering* for public review. In addition, the Case will be published as part of a Case Supplement issued to the applicable Code Section.

A case is normally issued for a limited period after which it may be renewed, incorporated in the Code, or allowed to expire if there is no indication of further need for the requirements covered by the Case. However, the provisions of a Case may be used after its expiration or withdrawal, provided the Case was effective on the original contract date or was adopted before completion of the work; and the contracting parties agree to its use.

Materials are listed in the Stress Tables only when sufficient usage in piping within the scope of the Code has been shown. Materials may be covered by a Case. Requests for listing shall include evidence of satisfactory usage and specific data to permit establishment of allowable stresses, maximum and minimum temperature limits, and other restrictions. Additional criteria can be found in the guidelines for addition of new materials

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in the ASME Boiler and Pressure Vessel Code, Section II and Section VIII, Division 1, Appendix B. (To develop usage and gain experience, unlisted materials may be used in accordance with Para. 123.1.)

Requests for interpretation and suggestions for revision should be addressed to the Secretary, ASME B31 Committee, Three Park Avenue, New York, NY 10016-5990.

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SUMMARY OF CHANGES

Changes given below are identified on the pages by a margin note, **01**, placed next to the affected area.

Page	*Location*	*Change*
vi, viii	Contents	Updated to reflect 01
1, 4	100.1.2	Subparagraph (B) deleted
4	100.1.3	Subparagraph (B) revised
18	104.1.2	Subparagraph (C.1) revised
22	104.3.1	First equation in subparagraph (D.2.2) revised
29, 30	104.8.1	First paragraph revised
	104.8.2	Nomenclature for M_B revised
	104.8.3	First sentence revised
31, 32	105.3	Subparagraph (E) revised
34	108.6.1	Subparagraph (E) added
	108.6.2	Subparagraph (C) revised
37	Table 112	Under Gaskets, Item (f)(2) revised
40	Table 114.2.1	Note (1) redesignated as General Note
44	119.10.1	Nomenclature for E_c corrected by Errata
45	121.2	Subparagraph (A) revised
52	122.1.7	First paragraph of subparagraph (A.3) revised
56, 57	122.4	(1) Subparagraph (A.8) revised (2) Subparagraph (A.10) added
58	Fig. 122.4	Art revised and General Note added
61, 62	122.8.2	Subparagraph (C.3) revised
65, 66	123	Revised through 123.1.2
	123.1.6	Added
72, 73	Table 126.1	(1) MSS Standard Practices revised (2) Under ASME Codes and Standards, B16.48 added
84	127.5.4	Added
88–92	Table 132	General Notes renumbered from (I)(A), (I)(B), etc., (II)(A), (II)(B), etc., to (A)(1), (A)(2), etc., (B)(1), (B)(2), etc.

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Page	*Location*	*Change*
97	Table 136.4	(1) In column headings, *Piping Service Conditions etc.* revised to read *Piping Design Condtions etc.* (2) Under General Notes, (D) deleted; (E) and (F) redesignated as new (D) and (E)
104	Table A-1	Under Seamless Pipe and Tube, reference to Note (1) added to A 333 6
106–114, 118	Table A-1	On even-numbered pages, references to Notes (16) to (24) renumbered as (15) to (23), respectively
107	Table A-1	Under Electric Resistance Welded Pipe and Tube, second Grade of A 178 corrected by Errata
115	Table A-1	Under Plate, both stress values at 800°F for A 299 corrected by Errata
119	Table A-1	Notes (16) to (24) renumbered as (15) to (23), respectively
120–130	Table A-2	On even-numbered pages, references to Notes (12) to (21) renumbered as (11) to (20), respectively
128	Table A-2	Under Forgings, Nominal Composition for A 182 F1 corrected by Errata
133, 134	Table A-2	Notes (12) to (21) renumbered as (11) to (20), respectively
140	Table A-3	Under Seamless Pipe and Tube, Austenitic, reference to Note (32) added to last two A 312 entries
142	Table A-3	Under Seamless Pipe and Tube, Ferritic/Martensitic, reference to Note (32) added to A 268 TPXM27, TP446-1, and TPXM33 and A 731 TPXM27 and TPXM33
144, 154, 156 166–172	Table A-3	On even-numbered pages, references to Notes (18) to (27) renumbered as (17) to (26), respectively, and (29) to (33) as (27) to (31), respectively
146	Table A-3	Under Welded Pipe and Tube — Without Filler Metal, Austenitic, reference to Note (32) added to last two A 249 entries
150	Table A-3	Under Welded Pipe and Tube — Without Filler Metal: (1) Under Austenitic, reference to Note (32) added to last two A 312 entries

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Page	*Location*	*Change*
150	Table A-3	(2) Under Ferritic/Martensitic, reference to Note (32) added to A 268 TP446-1, TPXM27, and TPXM33 and A 731 TPXM27 and TPXM33
154	Table A-3	Under Welded Pipe — Filler Metal Added, Austenitic, reference to Note (32) added to last four A 358 entries
158	Table A-3	(1) Under Plate, Sheet, and Strip: (a) Under Austenitic, reference to Note (32) added to last two A 240 entries (b) Under Ferritic/Martensitic, reference to Note (32) added to A 240 XM27 and XM33 (2) Under Forgings, Austenitic, reference to Note (32) added to A 182 F44 in two places
175	Table A-3	(1) Notes (18) through (27) renumbered as (17) through (26), respectively (2) Notes (29) through (33) rennumbered as (27) through (31), respectively (3) Note (32) added
176	Table A-4	Under Seamless Pipe and Tube, reference to Note (13) added to B 622 N06022 in two places and B 690 N08367 in two places
178	Table A-4	Under Welded Pipe and Tube, reference to Note (13) added to B 675 N08367 in two places, B 676 N08367 in two places, and B 804 N08367 in two places
180, 182	Table A-4	(1) Under Plate, Sheet, and Strip, reference to Note (13) added to B 688 N08367 in six places (2) Under Bars, Rods, Shapes, Forgings, reference to Note (13) added to both B 564 N08367 entries and both B 691 N08367 entries (3) Under Seamless Fittings, reference to Note (13) added to B 366 N06022 in two places and N08367 in two places and B 462 N08367 in two places (4) Under Welded Fittings, reference to Note (13) added to B 366 N06022 in two places
183	Table A-4	Note (13) added
188, 189	Table A-6	Under Seamless Pipe and Tube, B 280 added
213–215	Table B-1	Thermal Expansion Data designated as Table B-1 and revised

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Page	*Location*	*Change*
216–219	Table B-1 (SI)	Thermal Expansion Data (SI) designated as Table B-1 (SI) and revised
222	Table C-1 (SI)	Revised
223, 224	Table C-2	(1) Note (1) reference moved from main title to column head for *E* (2) First column head revised (3) Under High Nickel Alloys: (a) Stress value at 1100°F revised for N06002(X) (b) Note (2) reference added to N08800 (800) and N08810 (800H) (4) Under Aluminum and Aluminum Alloys, stress value at 500°F revised for third bracketed group (5) Unalloyed Titanium heading revised (6) Note (2) added
225, 226	Table C-2 (SI)	Revised
236	Appendix F	(1) MSS Standard Practices revised (2) Under ASME Codes and Standards, B16.48 added
238	Apppendix G	Under Paragraph References for *A*, 104.3.1 added
287	III-5.1.3	Second line of subparagraph (B.4.B) corrected by Errata
323	Index	Updated to reflect 01

NOTES:

(1) The interpretations to ASME B31.1 issued between January 1, 2000, and June 30, 2000, follow the last page of this Addenda as a separate supplement, Interpretations No. 35. The interpretations to ASME B31.1 issued between July 1, 2000, and December 31, 2000, follow the last page of Interpretations No. 35 as a separate supplement, Interpretations No. 36.

(2) After the Interpretations, a separate supplement, Cases No. 27, follows.

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CHAPTER I
SCOPE AND DEFINITIONS

100 GENERAL

This Power Piping Code is one of several Sections of the American Society of Mechanical Engineers Code for Pressure Piping, B31. This Section is published as a separate document for convenience.

Standards and specifications specifically incorporated by reference into this Code are shown in Table 126.1. It is not considered practical to refer to a dated edition of each of the standards and specifications in this Code. Instead, the dated edition references are included in an Addenda which will be revised yearly.

100.1 Scope

Rules for this Code Section have been developed considering the needs for applications which include piping typically found in electric power generating stations, in industrial and institutional plants, geothermal heating systems, and central and district heating and cooling systems.

100.1.1 This Code prescribes requirements for the design, materials, fabrication, erection, test, and inspection of piping systems.

Piping as used in this Code includes pipe, flanges, bolting, gaskets, valves, relief devices, fittings, and the pressure containing portions of other piping components, whether manufactured in accordance with Standards listed in Table 126.1 or specially designed. It also includes hangers and supports and other equipment items necessary to prevent overstressing the pressure containing components.

Rules governing piping for miscellaneous appurtenances, such as water columns, remote water level indicators, pressure gages, gage glasses etc., are included within the scope of this Code, but the requirements for boiler appurtenances shall be in accordance with Section I of the ASME Boiler and Pressure Vessel Code, PG-60.

The users of this Code are advised that in some areas legislation may establish governmental jurisdiction over the subject matter covered by this Code. However, any such legal requirement shall not relieve the owner of his inspection responsibilities specified in para. 136.1.

100.1.2 Power piping systems as covered by this Code apply to all piping and their component parts except as excluded in para. 100.1.3. They include but are not limited to steam, water, oil, gas, and air services. 01

(A) This Code covers boiler external piping as defined below for power boilers and high temperature, high pressure water boilers in which: steam or vapor is generated at a pressure of more than 15 psig [100 kPa (gage)]; and high temperature water is generated at pressures exceeding 160 psig [1103 kPa (gage)] and/or temperatures exceeding 250°F (120°C).

Boiler external piping shall be considered as that piping which begins where the boiler proper terminates at:

(1) the first circumferential joint for welding end connections; or

(2) the face of the first flange in bolted flanged connections; or

(3) the first threaded joint in that type of connection; and which extends up to and including the valve or valves required by para. 122.1.

The terminal points themselves are considered part of the boiler external piping. The terminal points and piping external to power boilers are illustrated by Figs. 100.1.2(A), 100.1.2(B), and 100.1.2(C).

Piping between the terminal points and the valve or valves required by para. 122.1 shall be provided with Data Reports, inspection, and stamping as required by Section I of the ASME Boiler and Pressure Vessel Code. All welding and brazing of this piping shall be performed by manufacturers or contractors authorized to use the appropriate symbol shown in Figs. PG-105.1 through PG-105.3 of Section I of the ASME Boiler and Pressure Vessel Code. The installation of boiler external piping by mechanical means may be performed by an organization not holding a Code symbol stamp. However, the holder of a valid S, A, or PP Certificate of Authorization shall be responsible for the documentation and hydrostatic test, regardless of the method of assembly. The quality control system requirements of

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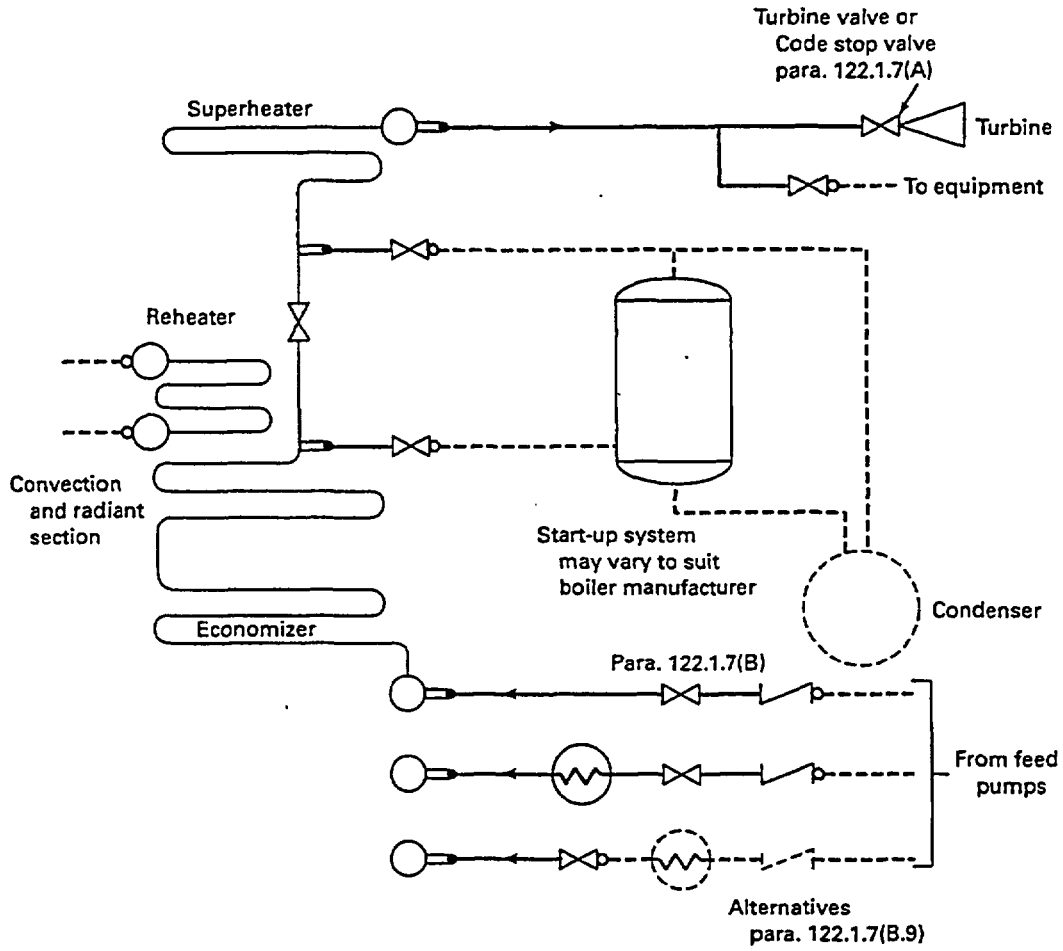

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC Section I Preamble.

•——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble, fifth, sixth, and seventh paragraphs and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o----- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(A) CODE JURISDICTIONAL LIMITS FOR PIPING — FORCED FLOW STEAM GENERATOR WITH NO FIXED STEAM AND WATER LINE

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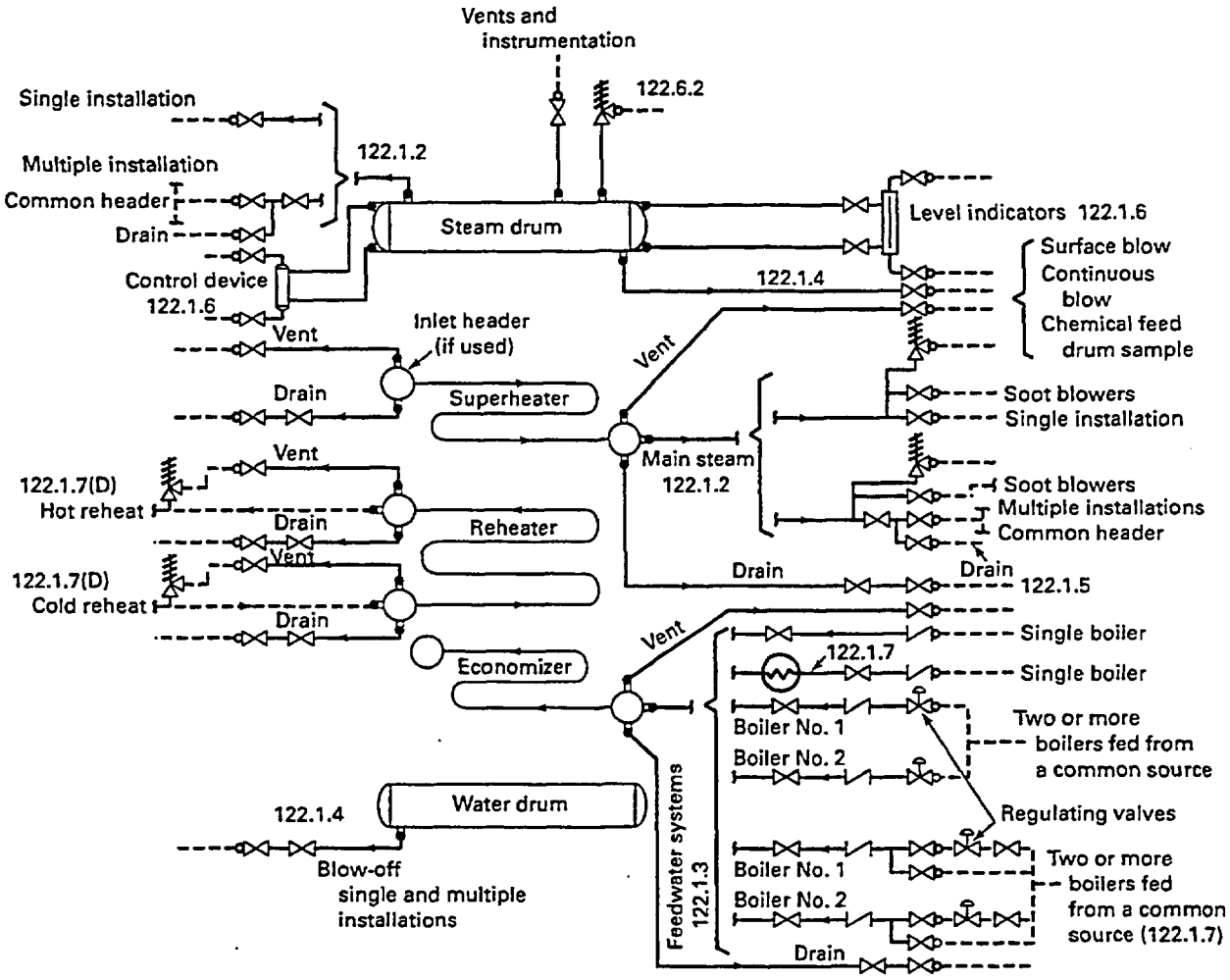

Administrative Jurisdiction and Technical Responsibility

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o----- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(B) CODE JURISDICTIONAL LIMITS FOR PIPING — DRUM TYPE BOILERS

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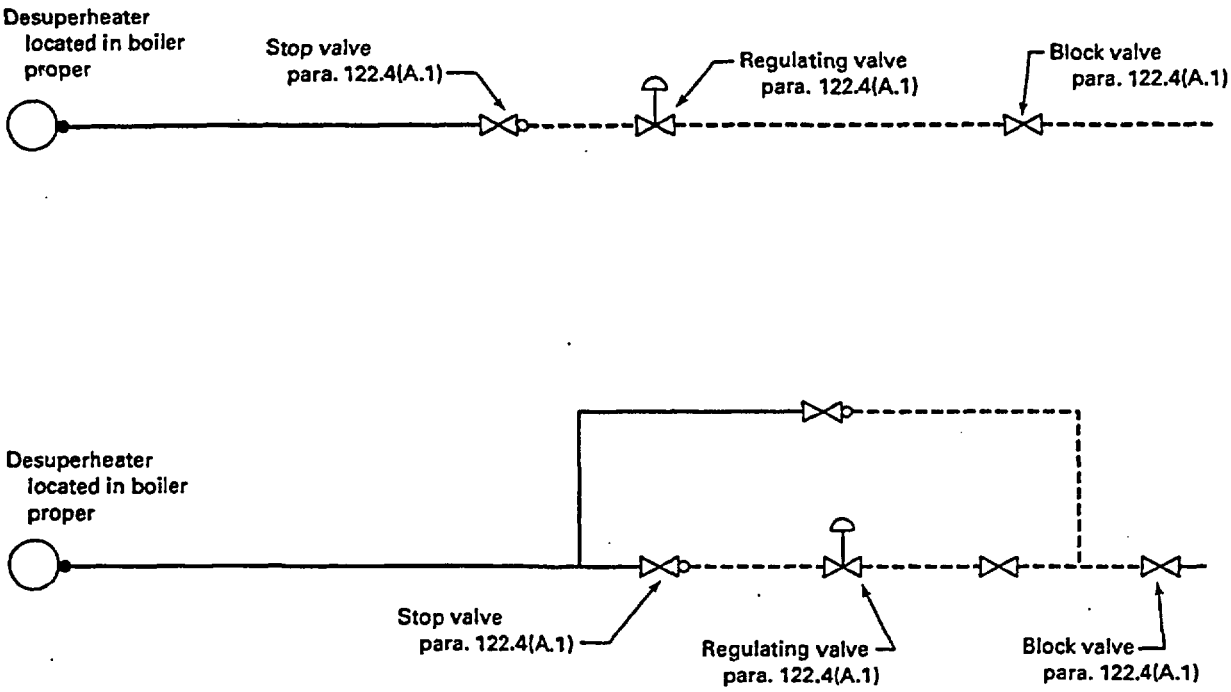

Administrative Jurisdiction and Technical Responsibility

——— Boiler Proper — The ASME Boiler and Pressure Vessel Code (ASME BPVC) has total administrative jurisdiction and technical responsibility. Refer to ASME BPVC *Section 1 Preamble*.

●——— Boiler External Piping and Joint (BEP) — The ASME BPVC has total administrative jurisdiction (mandatory certification by Code Symbol stamping, ASME Data Forms, and Authorized Inspection) of BEP. The ASME Section Committee B31.1 has been assigned technical responsibility. Refer to ASME BPVC Section I Preamble and ASME B31.1 Scope, para. 100.1.2(A). Applicable ASME B31.1 Editions and Addenda are referenced in ASME BPVC Section I, PG-58.3.

o---- Nonboiler External Piping and Joint (NBEP) — The ASME Code Committee for Pressure Piping, B31, has total administrative and technical responsibility.

FIG. 100.1.2(C) CODE JURISDICTIONAL LIMITS FOR PIPING — SPRAY TYPE DESUPERHEATER

Section I of the ASME Boiler and Pressure Vessel Code shall apply. These requirements are shown in Appendix J of this Code.

The valve or valves required by para. 122.1 are part of the boiler external piping, but do not require ASME Boiler and Pressure Vessel Code, Section I inspection and stamping except for safety, safety relief, and relief valves, see para. 107.8.2. Refer to PG-11.

Pipe connections meeting all other requirements of this Code but not exceeding NPS ½ may be welded to pipe or boiler headers without inspection and stamping required by Section I of the ASME Boiler and Pressure Vessel Code.

Nonboiler external piping includes all the piping covered by this Code except for that portion defined above as boiler external piping.

100.1.3 This Code does not apply to the following:

(A) economizers, heaters, pressure vessels, and components covered by Sections of the ASME Boiler and Pressure Vessel Code;

(B) building heating and distribution steam and condensate piping designed for 15 psig [100 kPa(gage)] or less, or hot water heating systems designed for 30 psig [200 kPa (gage)] or less; 01

(C) piping for hydraulic or pneumatic tools and their

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components downstream of the first block or stop valve off the system distribution header;

(D) piping for marine or other installations under Federal control;

(E) towers, building frames, tanks, mechanical equipment, instruments, and foundations;

100.2 Definitions

Some commonly used terms relating to piping are defined below. Terms related to welding generally agree with AWS A3.0. Some welding terms are defined with specified reference to piping. For welding terms used in this Code, but not shown here, definitions of AWS A3.0 apply.

anchor: a rigid restraint providing substantially full fixation, permitting neither translatory nor rotational displacement of the pipe.

annealing: see *heat treatments.*

arc welding: a group of welding processes wherein coalescence is produced by heating with an electric arc or arcs, with or without the application of pressure and with or without the use of filler metal.

assembly: the joining together of two or more piping components by bolting, welding, caulking, brazing, soldering, cementing, or threading into their installed location as specified by the engineering design.

automatic welding: welding with equipment which performs the entire welding operation without constant observation and adjustment of the controls by an operator. The equipment may or may not perform the loading and unloading of the work.

backing ring: backing in the form of a ring that can be used in the welding of piping.

ball joint: a component which permits universal rotational movement in a piping system.

base metal: the metal to be welded, brazed, soldered, or cut.

branch connection: the attachment of a branch pipe to the run of a main pipe with or without the use of fittings.

braze welding: a method of welding whereby a groove, fillet, plug, or slot weld is made using a nonferrous filler metal having a melting point below that of the base metals, but above 800°F (425°C). The filler metal is not distributed in the joint by capillary action. (Bronze welding, formerly used, is a misnomer for this term.)

brazing: a metal joining process wherein coalescence is produced by use of a nonferrous filler metal having a melting point above 800°F (425°C) but lower than that of the base metals joined. The filler metal is distributed between the closely fitted surfaces of the joint by capillary action.

butt joint: a joint between two members lying approximately in the same plane.

component: component as used in this Code is defined as consisting of but not limited to items such as pipe, piping subassemblies, parts, valves, strainers, relief devices, fittings, etc.

standard component: a component manufactured in accordance with one or more of the standards listed in Table 126.1.

specially designed component: a component designed in accordance with para. 104.7.2.

defect: a flaw (imperfection or unintentional discontinuity) of such size, shape, orientation, location, or properties as to be rejectable.

discontinuity: a lack of continuity or cohesion; an interruption in the normal physical structure of material or a product.

employer: the owner, manufacturer, fabricator, contractor, assembler, or installer responsible for the welding, brazing, and NDE performed by his organization including procedure and performance qualifications.

engineering design: the detailed design developed from process requirements and conforming to Code requirements, including all necessary drawings and specifications, governing a piping installation.

equipment connection: an integral part of such equipment as pressure vessels, heat exchangers, pumps, etc., designed for attachment of pipe or piping components.

erection: the complete installation of a piping system, including any field assembly, fabrication, testing, and inspection of the system.

examination: denotes the procedures for all nondestructive examination. Refer to para. 136.1 and the definition for visual examination.

expansion joint: a flexible piping component which absorbs thermal and/or terminal movement.

fabrication: primarily, the joining of piping components into integral pieces ready for assembly. It includes bending, forming, threading, welding, or other opera-

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tions upon these components, if not part of assembly. It may be done in a shop or in the field.

face of weld: the exposed surface of a weld on the side from which the welding was done.

filler metal: metal to be added in welding, soldering, brazing, or braze welding.

fillet weld: a weld of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, tee joint, corner joint, or socket weld.

fire hazard: situation in which a material of more than average combustibility or explosibility exists in the presence of a potential ignition source.

flaw: an imperfection or unintentional discontinuity which is detectable by a nondestructive examination.

full fillet weld: a fillet weld whose size is equal to the thickness of the thinner member joined.

fusion: the melting together of filler metal and base metal, or of base metal only, which results in coalescence.

gas welding: a group of welding processes wherein coalescence is produced by heating with a gas flame or flames, with or without the application of pressure, and with or without the use of filler metal.

groove weld: a weld made in the groove between two members to be joined.

heat affected zone: that portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding or cutting.

heat treatments

annealing, full: heating a metal or alloy to a temperature above the critical temperature range and holding above the range for a proper period of time, followed by cooling to below that range. (A softening treatment is often carried out just below the critical range which is referred to as a subcritical anneal.)

normalizing: a process in which a ferrous metal is heated to a suitable temperature above the transformation range and is subsequently cooled in still air at room temperature.

postweld heat treatment: any heat treatment subsequent to welding.

preheating: the application of heat to a base metal immediately prior to a welding or cutting operation.

stress-relieving: uniform heating of a structure or portion thereof to a sufficient temperature to relieve the major portion of the residual stresses, followed by uniform cooling.

imperfection: a condition of being imperfect; a departure of a quality characteristic from its intended condition.

indication: the response or evidence from the application of a nondestructive examination.

inert gas metal arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc between a metal electrode and the work. Shielding is obtained from an inert gas, such as helium or argon. Pressure may or may not be used and filler metal may or may not be used.

inspection: denotes verifying the performance of examination and tests by an Inspector.

joint design: the joint geometry together with the required dimensions of the welded joint.

joint penetration: the minimum depth of a groove weld extends from its face into a joint, exclusive of reinforcement.

low energy capacitor discharge welding: a resistance welding process wherein coalescence is produced by the rapid discharge of stored electric energy from a low voltage electrostatic storage system.

manual welding: welding wherein the entire welding operation is performed and controlled by hand.

maximum allowable stress: the maximum stress value that may be used in the design formulas for a given material and design temperature.

maximum allowable working pressure (MAWP): the pressure at the coincident temperature to which a boiler or pressure vessel can be subjected without exceeding the maximum allowable stress of the material or pressure-temperature rating of the equipment. For the purposes of this Code, the term MAWP is as defined in the ASME Boiler and Pressure Vessel Code, Sections I and VIII.

may: may is used to denote permission, neither a requirement nor a recommendation.

mechanical joint: a joint for the purpose of mechanical strength or leak resistance, or both, where the mechanical strength is developed by threaded, grooved, rolled, flared, or flanged pipe ends, or by bolts, pins, and compounds, gaskets, rolled ends, caulking, or machined

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and mated surfaces. These joints have particular application where ease of disassembly is desired.

miter: two or more straight sections of pipe matched and joined on a line bisecting the angle of junction so as to produce a change in direction.

nominal thickness: the thickness given in the product material specification or standard to which manufacturing tolerances are applied.

normalizing: see *heat treatments.*

oxygen cutting: a group of cutting processes wherein the severing of metals is effected by means of the chemical reaction of oxygen with the base metal at elevated temperatures. In the case of oxidation-resistant metals, the reaction is facilitated by use of a flux.

oxygen gouging: an application of oxygen cutting wherein a chamfer or groove is formed.

peening: the mechanical working of metals by means of hammer blows.

pipe and tube: the fundamental difference between pipe and tube is the dimensional standard to which each is manufactured.

A pipe is a tube with a round cross section conforming to the dimensional requirements for nominal pipe size as tabulated in ANSI B36.10, Tables 2 and 4, and ANSI B36.19, Table 1. For special pipe having a diameter not listed in these Tables, and also for round tube, the nominal diameter corresponds with the outside diameter.

A tube is a hollow product of round or any other cross section having a continuous periphery. Round tube size may be specified with respect to any two, but not all three, of the following: outside diameter, inside diameter, wall thickness; types K, L, and M copper tube may also be specified by nominal size and type only. Dimensions and permissible variations (tolerances) are specified in the appropriate ASTM or ASME standard specifications.

Types of pipe, according to the method of manufacture, are defined as follows:

(A) electric resistance welded pipe: pipe produced in individual lengths or in continuous lengths from coiled skelp and subsequently cut into individual lengths, having a longitudinal butt joint wherein coalescence is produced by the heat obtained from resistance of the pipe to the flow of electric current in a circuit of which the pipe is a part, and by the application of pressure.

(B) furnace butt welded pipe

(B.1) furnace butt welded pipe, bell welded: pipe produced in individual lengths from cut length skelp, having its longitudinal butt joint forge welded by the mechanical pressure developed in drawing the furnace heated skelp through a cone shaped die (commonly known as a "welding bell") which serves as a combined forming and welding die.

(B.2) furnace butt welded pipe, continuous welded: pipe produced in continuous lengths from coiled skelp and subsequently cut into individual lengths, having its longitudinal butt joint forge welded by the mechanical pressure developed in rolling the hot formed skelp through a set of round pass welding rolls.

(C) electric fusion welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced in the performed tube by manual or automatic electric arc welding. The weld may be single (welded from one side), or double (welded from inside and outside) and may be made with or without the use of filler metal. Spiral welded pipe is also made by the electric fusion welded process with either a butt joint, a lap joint, or a lock seam joint.

(D) electric flash welded pipe: pipe having a longitudinal butt joint wherein coalescence is produced, simultaneously over the entire area of abutting surfaces, by the heat obtained from resistance to the flow of electric current between the two surfaces, and by the application of pressure after heating is substantially completed. Flashing and upsetting are accompanied by expulsion of metal from the joint.

(E) double submerged arc welded pipe: pipe having a longitudinal butt joint produced by the submerged arc process, with at least two passes, one of which is on the inside of the pipe.

(F) seamless pipe: pipe produced by one or more of the following processes:

(F.1) rolled pipe: pipe produced from a forged billet which is pierced by a conical mandrel between two diametrically opposed rolls. The pierced shell is subsequently rolled and expanded over mandrels of increasingly larger diameter. Where closer dimensional tolerances are desired, the rolled pipe is cold or hot drawn through dies, and machined.

One variation of this process produces the hollow shell by extrusion of the forged billet over a mandrel in a vertical, hydraulic piercing press.

(F.2) forged and bored pipe: pipe produced by boring or trepanning of a forged billet.

(F.3) extruded pipe: pipe produced from hollow or solid round forgings, usually in a hydraulic extrusion press. In this process the forging is contained in a cylindrical die. Initially a punch at the end of the

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extrusion plunger pierces the forging. The extrusion plunger then forces the contained billet between the cylindrical die and the punch to form the pipe, the latter acting as a mandrel.

(F.4) centrifugally cast pipe: pipe formed from the solidification of molten metal in a rotating mold. Both metal and sand molds are used. After casting, the pipe is machined, to sound metal, on the internal and external diameters to the surface roughness and dimensional requirements of the applicable material specification.

One variation of this process utilizes autofrettage (hydraulic expansion) and heat treatment, above the recrystallization temperature of the material, to produce a wrought structure.

(F.5) statistically cast pipe: pipe formed by the solidification of molten metal in a sand mold.

pipe supporting elements: pipe supporting elements consist of hangers, supports, and structural attachments.

hangers and supports: hangers and supports include elements which transfer the load from the pipe or structural attachment to the supporting structure or equipment. They include hanging type fixtures, such as hanger rods, spring hangers, sway braces, counterweights, turnbuckles, struts, chains, guides, and anchors, and bearing type fixtures, such as saddles, bases, rollers, brackets, and sliding supports.

structural attachments: structural attachments include elements which are welded, bolted, or clamped to the pipe, such as clips, lugs, rings, clamps, clevises, straps, and skirts.

porosity: cavity-type discontinuities formed by gas entrapment during metal solidification.

postweld heat treatment: see *heat treatments.*

preheating: see *heat treatments.*

pressure: an application of force per unit area; fluid pressure (an application of internal or external fluid force per unit area on the pressure boundary of piping components).

Procedure Qualification Record (PQR): a record of the welding data used to weld a test coupon. The PQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

readily accessible: for visual examination, readily accessible inside surfaces are defined as those inside surfaces which can be examined without the aid of optical devices. (This definition does not prohibit the use of optical devices for a visual examination; however, the selection of the device should be a matter of mutual agreement between the owner and the fabricator or erector.)

Reid vapor pressure: the vapor pressure of a flammable or combustible liquid as determined by ASTM Standard Test Method D 323 Vapor Pressure of Petroleum Products (Reid Method).

reinforcement of weld: weld metal on the face of a groove weld in excess of the metal necessary for the specified weld size.

restraint: any device which prevents, resists, or limits movement of a piping system.

root opening: the separation between the members to be joined, at the root of the joint.

root penetration: the depth a groove weld extends into the root opening of a joint measured on the center line of the root cross section.

seal weld: a weld used on a pipe joint primarily to obtain fluid tightness as opposed to mechanical strength.

semiautomatic arc welding: arc welding with equipment which controls only the filler metal feed. The advance of the welding is manually controlled.

shall: "shall" or "shall not" is used to indicate that a provision or prohibition is mandatory.

shielded metal arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc between a covered metal electrode and the work. Shielding is obtained from decomposition of the electrode covering. Pressure is not used and filler metal is obtained from the electrode.

should: "should" or "it is recommended" is used to indicate that a provision is not mandatory but recommended as good practice.

size of weld

groove weld: the joint penetration (depth of chamfering plus the root penetration when specified).

fillet weld: for equal leg fillet welds, the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section.

slag inclusion: nonmetallic solid material entrapped in weld metal or between weld metal and base metal.

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soldering: a metal joining process wherein coalescence is produced by heating to suitable temperature and by using a nonferrous alloy fusible at temperatures below 800°F (425°C) and having a melting point below that of the base metals being joined. The filler metal is distributed between closely fitted surfaces of the joint by capillary action. In general, solders are lead-tin alloys and may contain antimony, bismuth, silver, and other elements.

steel: an alloy of iron and carbon with no more than 2% carbon by weight. Other alloying elements may include manganese, sulfur, phosphorus, silicon, aluminum, chromium, copper, nickel, molybdenum, vanadium, and others depending upon the type of steel. For acceptable material specifications for steel refer to Chapter III, Materials.

stress-relieving: see *heat treatments.*

submerged arc welding: an arc welding process wherein coalescence is produced by heating with an electric arc or arcs between a bare metal electrode or electrodes and the work. The welding is shielded by a blanket of granular, fusible material on the work. Pressure is not used and filler metal is obtained from the electrode and sometimes from a supplementary welding rod.

supplementary steel: steel members which are installed between existing members for the purpose of installing supports for piping or piping equipment.

swivel joint: a component which permits single-plane rotational movement in a piping system.

tack weld: a weld made to hold parts of a weldment in proper alignment until the final welds are made.

throat of a fillet weld

theoretical: the distance from the beginning of the root of the joint perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the fillet weld cross section.

actual: the shortest distance from the root of a fillet weld to its face.

toe of weld: the junction between the face of the weld and the base metal.

tube: refer to *pipe and tube.*

tungsten electrode: a nonfiller metal electrode used in arc welding, consisting of a tungsten wire.

undercut: a groove melted into the base metal adjacent to the toe of a weld and not filled with weld metal.

visual examination: the observation of whatever portions of components, joints, and other piping elements that are exposed to such observation either before, during, or after manufacture, fabrication, assembly, erection, inspection, or testing. This examination may include verification of the applicable requirements for materials, components, dimensions, joint preparation, alignment, welding or joining, supports, assembly, and erection.

weld: a localized coalescence of metal which is produced by heating to suitable temperatures, with or without the application of pressure, and with or without the use of filler metal. The filler metal shall have a melting point approximately the same as the base metal.

welder: one who is capable of performing a manual or semiautomatic welding operation.

Welder/Welding Operator Performance Qualification (WPQ): demonstration of a welder's ability to produce welds in a manner described in a welding procedure specification that meets prescribed standards.

welding operator: one who operates machine or automatic welding equipment.

Welding Procedure Specification (WPS): a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

weldment: an assembly whose component parts are joined by welding.

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CHAPTER II
DESIGN

PART 1
CONDITIONS AND CRITERIA

101 DESIGN CONDITIONS

101.1 General

These design conditions define the pressures, temperatures and various forces applicable to the design of power piping systems. Power piping systems shall be designed for the most severe condition of coincident pressure, temperature and loading, except as herein stated. The most severe condition shall be that which results in the greatest required pipe wall thickness and the highest flange rating.

101.2 Pressure

All pressures referred to in this Code are expressed in pounds per square inch and kilopascals above atmospheric pressure, i.e., psig [kPa (gage)], unless otherwise stated.

101.2.2 Internal Design Pressure. The internal design pressure shall be not less than the maximum sustained operating pressure (MSOP) within the piping system including the effects of static head.

101.2.4 External Design Pressure. Piping subject to external pressure shall be designed for the maximum differential pressure anticipated during operating, shutdown, or test conditions.

101.3 Temperature

101.3.1 All temperatures referred to in this Code, unless otherwise stated, are the average metal temperatures of the respective materials expressed in degrees Fahrenheit, i.e., °F (Celsius, i.e., °C).

101.3.2 Design Temperature

(A) The piping shall be designed for a metal temperature representing the maximum sustained condition expected. The design temperature shall be assumed to be the same as the fluid temperature unless calculations or tests support the use of other data, in which case the design temperature shall not be less than the average of the fluid temperature and the outside wall temperature.

(B) Where a fluid passes through heat exchangers in series, the design temperature of the piping in each section of the system shall conform to the most severe temperature condition expected to be produced by the heat exchangers in that section of the system.

(C) For steam, feedwater, and hot water piping leading from fired equipment (such as boiler, reheater, superheater, economizer, etc.), the design temperature shall be based on the expected continuous operating condition plus the equipment manufacturers guaranteed maximum temperature tolerance. For operation at temperatures in excess of this condition, the limitations described in para. 102.2.4 shall apply.

(D) Accelerated creep damage, leading to excessive creep strains and potential pipe rupture, caused by extended operation above the design temperature shall be considered in selecting the design temperature for piping to be operated above 800°F.

101.4 Ambient Influences

101.4.1 Cooling Effects on Pressure. Where the cooling of a fluid may reduce the pressure in the piping to below atmospheric, the piping shall be designed to withstand the external pressure or provision shall be made to break the vaccum.

101.4.2 Fluid Expansion Effects. Where the expansion of a fluid may increase the pressure, the piping system shall be designed to withstand the increased pressure or provision shall be made to relieve the excess pressure.

101.5 Dynamic Effects

101.5.1 Impact. Impact forces caused by all external and internal conditions shall be considered in the piping design. One form of internal impact force is due to the propagation of pressure waves produced by sudden changes in fluid momentum. This phenomena is often called water or steam "hammer." It may be caused by the rapid opening or closing of a valve in the system.

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The designer should be aware that this is only one example of this phenomena and that other causes of impact loading exist.

101.5.2 Wind. Exposed piping shall be designed to withstand wind loadings, using meteorological data to determine wind forces. Where state or municipal ordinances covering the design of building structures are in effect and specify wind loadings, these values shall be considered the minimum design values.

101.5.3 Earthquake. The effect of earthquakes, where applicable, shall be considered in the design of piping, piping supports, and restraints, using data for the site as a guide in assessing the forces involved. However, earthquakes need not be considered as acting concurrently with wind.

101.5.4 Vibration. Piping shall be arranged and supported with consideration of vibration (see paras. 120.1(c) and 121.7.5).

101.6 Weight Effects

The following weight effects combined with loads and forces from other causes shall be taken into account in the design of piping. Piping shall be carried on adjustable hangers or properly leveled rigid hangers or supports, and suitable springs, sway bracing, vibration dampeners, etc., shall be provided where necessary.

101.6.1 Live Load. The live load consists of the weight of the fluid transported. Snow and ice loads shall be considered in localities where such conditions exist.

101.6.2 Dead Load. The dead load consists of the weight of the piping components, insulation, protective lining and coating, and other superimposed permanent loads.

101.6.3 Test or Cleaning Fluid Load. The test or cleaning fluid load consists of the weight of the test or cleaning fluid.

101.7 Thermal Expansion and Contraction Loads

101.7.1 General. The design of piping systems shall take account of the forces and moments resulting from thermal expansion and contraction, and from the effects of expansion joints.

Thermal expansion and contraction shall be provided for preferably by pipe bends, elbows, offsets or changes in direction of the pipeline.

Hangers and supports shall permit expansion and contraction of the piping between anchors.

101.7.2 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Joints of the corrugated bellows, slip, sleeve, ball, or swivel types and flexible metal hose assemblies may be used if their materials conform to this Code, their structural and working parts are of ample proportions, and their design prevents the complete disengagement of working parts while in service. However, flexible metal hose assemblies, and expansion joints of the corrugated bellows, slip, or sleeve type shall not be used in any piping system connecting the boiler and the first stop valve in that system.

102 DESIGN CRITERIA

102.1 General

These criteria cover pressure-temperature ratings for standard and specially designed components, allowable stresses, stress limits, and various allowances to be used in the design of piping and piping components.

102.2 Pressure-Temperature Ratings for Piping Components

102.2.1 Components Having Specific Ratings. Pressure-temperature ratings for certain piping components have been established and are contained in some of the standards listed in Table 126.1.

Where piping components have established pressure-temperature ratings which do not extend to the upper material temperature limits permitted by this Code, the pressure-temperature ratings between those established and the upper material temperature limit may be determined in accordance with the rules of this Code, but such extensions are subject to restrictions, if any, imposed by the standards.

Standard components may not be used at conditions of pressure and temperature which exceed the limits imposed by this Code.

102.2.2 Components Not Having Specific Ratings. Some of the Standards listed in Table 126.1, such as those for buttwelding fittings, specify that components shall be furnished in nominal thicknesses. Unless limited elsewhere in this Code, such components shall be rated

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for the same allowable pressures as seamless pipe of the same nominal thickness, as determined in paras. 103 and 104 for material having the same allowable stress.

Piping components, such as pipe, for which allowable stresses have been developed in accordance with para. 102.3, but which do not have established pressure ratings, shall be rated by rules for pressure design in para. 104, modified as applicable by other provisions of this Code.

Should it be desired to use methods of manufacture or design of components not covered by this Code or not listed in referenced standards, it is intended that the manufacturer shall comply with the requirements of paras. 103 and 104 and other applicable requirements of this Code for design conditions involved. Where components other than those discussed above, such as pipe or fittings not assigned pressure-temperature ratings in an American National Standard, are used, the manufacturer's recommended pressure-temperature rating shall not be exceeded.

102.2.3 Ratings: Normal Operating Condition. A piping system shall be considered safe for operation if the maximum sustained operating pressure and temperature which may act on any part or component of the system does not exceed the maximum pressure and temperature allowed by this Code for that particular part or component. The design pressure and temperature shall not exceed the pressure-temperature rating for the particular component and material as defined in the applicable specification or standard listed in Table 126.1.

102.2.4 Ratings: Allowance for Variation From Normal Operation. The maximum internal pressure and temperature allowed shall include considerations for occasional loads and transients of pressure and temperature.

It is recognized that variations in pressure and temperature inevitably occur, and therefore the piping system, except as limited by component standards referred to in para. 102.2.1 or by manufacturers of components referred to in para. 102.2.2, shall be considered safe for occasional short operating periods at higher than design pressure or temperature. For such variations, either pressure or temperature, or both, may exceed the design values if the computed circumferential pressure stress does not exceed the maximum allowable stress from Appendix A for the coincident temperature by:

(A) 15% if the event duration occurs for no more than 8 hr at any one time and no more than 800 hr/year; or

(B) 20% if the event duration occurs for no more than 1 hr at any one time and no more than 80 hr/year.

102.2.5 Ratings at Transitions. Where piping systems operating at different design conditions are connected, a division valve shall be provided having a pressure-temperature rating equal to or exceeding the more severe conditions. See para. 122 for design requirements pertaining to specific piping systems.

102.3 Allowable Stress Values and Other Stress Limits for Piping Components

102.3.1 Allowable Stress Values

(A) Allowable stress values to be used for the design of power piping systems are given in the Tables in Appendix A, also referred to in this Code Section as the Allowable Stress Tables. These Tables list allowable stress values for commonly used materials at temperatures appropriate to power piping installations. In every case the temperature is understood to be the metal temperature. Where applicable, weld joint efficiency factors and casting quality factors are included in the tabulated values. Thus, the tabulated values are values of *S*, *SE*, or *SF*, as applicable.

(B) Allowable stress values in shear shall not exceed 80% of the values determined in accordance with the rules of para. 102.3.1(A). Allowable stress values in bearing shall not exceed 160% of the determined values.

(C) The basis for establishing the allowable stress values in this Code Section are the same as those in the ASME Boiler and Pressure Vessel Code, Section II, Part D, Appendix 1; except that allowable stresses for cast iron and ductile iron are in accordance with Section VIII, Division 1, Appendix P for Tables UCI-23 and UCD-23, respectively.

102.3.2 Limits of Calculated Stresses Due to Sustained Loads and Thermal Expansion

(A) Internal Pressure Stress. The calculated stress due to internal pressure shall not exceed the allowable stress values given in the Allowable Stress Tables in Appendix A. This criterion is satisfied when the wall thickness of the piping component, including any reinforcement, meets the requirements of para. 104.1 through 104.7, excluding para. 104.1.3 but including the consideration of allowances permitted by paras. 102.2.4, 102.3.3(B), and 102.4.

(B) External Pressure Stress. Piping subject to external pressure shall be considered safe when the wall thickness and means of stiffening meet the requirements of para. 104.1.3.

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TABLE 102.3.2(C)
STRESS RANGE REDUCTION FACTORS

Number of Equivalent Full Temperature Cycles N	f
7,000 and less	1.0
7,000–14,000	0.9
14,000–22,000	0.8
22,000–45,000	0.7
45,000–100,000	0.6
100,000 and over	0.5

(C) Allowable Stress Range for Expansion Stresses. Except as permitted in para. 102.3.2(D), the thermal expansion stress range S_E (see paras. 104.8.3 and 119.6.4) shall not exceed the allowable stress range S_A given by the following formula:

$$S_A = f(1.25S_c + 0.25S_h) \quad (1)$$

where

S_c = basic material allowable stress at minimum (cold) temperature from the Allowable Stress Tables

S_h = basic material allowable stress at maximum (hot) temperature from the Allowable Stress Tables

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

In determining the basic material allowable stresses, S_c and S_h, joint efficiencies need not be applied. The values of allowable stress in the Allowable Stress Tables for welded pipe may be divided by the weld joint factors listed in para. 102.4.3.

Stress reduction factors apply essentially to noncorrosive service and to corrosion resistant materials where employed to minimize the reduction in cyclic life caused by corrosive action.

If the range of temperature change varies, equivalent full temperature cycles may be computed as follows:

$$N = N_E + r_1^5 N_1 + r_2^5 N_2 + \ldots + r_n^5 N_n \quad (2)$$

where

N_E = number of cycles at full temperature change ΔT_E for which expansion stress S_E has been calculated

$N_1, N_2, \ldots, N_n$ = number of cycles at lesser temperature changes $\Delta T_1, \Delta T_2, \ldots, \Delta T_n$

$r_1, r_2, \ldots, r_n$ = ratio of lesser temperature cycles to that for any which the expansion stress S_E has been calculated
= $\Delta T_1/\Delta T_E, \Delta T_2/\Delta T_E, \ldots, \Delta T_n/\Delta T_E$

(D) Longitudinal Stresses. The sum of the longitudinal stresses S_L due to pressure, weight, and other sustained loads shall not exceed the allowable stress in the hot condition S_h. Where the sum of these stresses is less than S_h, the difference may be used as an additional thermal expansion allowance, which is the second term on the right side of Eq. (13) of para. 104.8.3.

The longitudinal pressure stress S_{lp} shall be determined by either of the following equations:

$$S_{lp} = \frac{PD_o}{4t_n}$$

or

$$S_{lp} = \frac{Pd_n^2}{D_n^2 - d_n^2}$$

102.3.3 Limits of Calculated Stresses due to Occasional Loads

(A) During Operation. The sum of the longitudinal stresses produced by internal pressure, live and dead loads and those produced by occasional loads, such as the temporary supporting of extra weight, may exceed the allowable stress values given in the Allowable Stress Tables by the amounts and durations of time given in para. 104.8.2.

(B) During Test. During pressure tests performed in accordance with para. 137, the circumferential (hoop) stress shall not exceed 90% of the yield strength (0.2% offset) at test temperature. In addition, the sum of longitudinal stresses due to test pressure and live and dead loads at the time of test, excluding occasional loads, shall not exceed 90% of the yield strength at test temperature.

102.4 Allowances

102.4.1 Corrosion or Erosion. When corrosion or erosion is expected, an increase in wall thickness of the piping shall be provided over that required by other

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design requirements. This allowance in the judgment of the designer shall be consistent with the expected life of the piping.

102.4.2 Threading and Grooving. The calculated minimum thickness of piping (or tubing) which is to be threaded shall be increased by an allowance equal to thread depth; dimension *h* of ASME B1.20.1 or equivalent shall apply. For machined surfaces or grooves, where the tolerance is not specified, the tolerance shall be assumed to be $\frac{1}{64}$ in. (0.40 mm) in addition to the specified depth of cut. The requirements of para. 104.1.2(C) shall also apply.

102.4.3 Weld Joint Efficiency Factors. The use of joint efficiency factors for welded pipe is required by this Code. The factors in Table 102.4.3 are based on full penetration welds. These factors are included in the allowable stress values given in Appendix A. The factors in Table 102.4.3 apply to both straight seam and spiral seam welded pipe.

102.4.4 Mechanical Strength. Where necessary for mechanical strength to prevent damage, collapse, excessive sag, or buckling of pipe due to superimposed loads from supports or other causes, the wall thickness of the pipe should be increased; or, if this is impractical or would cause excessive local stresses, the superimposed loads or other causes shall be reduced or eliminated by other design methods. The requirements of para. 104.1.2(C) shall also apply.

102.4.5 Bending. The minimum wall thickness at any point in a completed bend shall not be less than required by Formulas (3) or (3A) of para. 104.1.2(A).

(A) Table 102.4.5 is a guide to the designer who must specify wall thickness for ordering pipe. In general it has been the experience that when good shop practices are employed, the minimum thicknesses of straight pipe shown in Table 102.4.5 should be sufficient for bending, and still meet the minimum thickness requirements of para. 104.1.2(A).

(B) The bend thinning allowance in Table 102.4.5 may be provided in all parts of the cross section of the pipe circumference without any detrimental effects being produced.

102.4.6 Casting Quality Factors

(A) General. The use of a casting quality factor is required for all cast components which use the allowable stress values of Appendix A as the design basis. A factor of 0.80 is included in the allowable stress values for all castings given in Appendix .A.

This required factor does not apply to component standards listed in Table 126.1, if such standards define allowable pressure-temperature ratings or provide the allowable stresses to be used as the design basis for the component.

(B) For steel materials, a casting quality factor not exceeding 1.0 may be applied when the following requirements are met.

(B.1) All steel castings having a nominal body thickness of $4\frac{1}{2}$ in. (114 mm) or less (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

(B.1.1) All critical areas, including the junctions of all gates, risers, and abrupt changes in section or direction and area of weld end preparation shall be radiographed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 446 Reference Radiographs for Steel Castings up to 2 in. (50 mm) in Thickness or E 186 Reference Radiographs for Heavy Walled [2 to $4\frac{1}{2}$ in. (50 to 114 mm)] Steel Castings, depending upon the section thickness. The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6(B.1.1).

(B.1.2) All surfaces of each casting, including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III, and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference Photographs for Magnetic Particle Indications on Ferrous Castings, are not acceptable and shall be removed.

(B.1.3) Where more than one casting of a particular design is produced, each of the first five castings shall be inspected as above. Where more than five castings are being produced, the examination shall be performed on the first five plus one additional casting to represent each five additional castings. If this additional casting proves to be unacceptable, each of the remaining castings in the group shall be inspected.

(B.1.4) Any discontinuities in excess of the maximum permitted in (B.1.1) and (B.1.2) above shall be removed, and the casting may be repaired by welding after the base metal has been inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).] The completed repair shall be subject to

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TABLE 102.4.3
LONGITUDINAL WELD JOINT EFFICIENCY FACTORS

No.	Type of Joint	Type of Seam	Examination	Factor E
1	Furnace butt weld, continuous weld	Straight	As required by listed specification	0.60 [Note (1)]
2	Electric resistance weld	Straight or spiral	As required by listed specification	0.85 [Note (1)]
3	Electric fusion weld			
	(a) Single butt weld (without filler metal)	Straight or spiral	As required by listed specification	0.85
			Additionally 100% radiographed	1.00 [Note (2)]
	(b) Single butt weld (with filler metal)	Straight or spiral	As required by listed specification	0.80
			Additionally 100% radiographed	1.00 [Note (2)]
	(c) Double butt weld (without filler metal)	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
	(d) Double butt weld (with filler metal)	Straight or spiral	As required by listed specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]
4	API 5L Submerged arc weld (SAW) Gas metal arc weld (GMAW) Combined GMAW, SAW	Straight with one or two seams Spiral	As required by specification	0.90
			Additionally 100% radiographed	1.00 [Note (2)]

NOTES:
(1) It is not permitted to increase the longitudinal weld joint efficiency factor by additional examination for joint 1 or 2.
(2) Radiography shall be in accordance with the requirements of para. 136.4.5 or the material specification as applicable.

reinspection by the same method as was used in the original inspection and shall be reinspected after any required postweld heat treatment.

(B.2) All steel castings having a nominal body thickness greater than 4½ in. (114 mm) (other than pipe flanges, flanged valves and fittings, and butt welding end valves, all complying with ASME B16.5 or B16.34) shall be inspected as follows.

(B.2.1) All surfaces of each casting including machined gasket seating surfaces, shall be examined by the magnetic particle or dye penetrant method after heat treatment. The examination techniques shall be in accordance with Article 6 or 7, as applicable, and with Article 9 of Section V of the ASME Boiler and Pressure Vessel Code. Magnetic particle or dye penetrant indications exceeding degree 1 of Type I, degree 2 of Type II, and degree 3 of Type III and exceeding degree 1 of Types IV and V of ASTM E 125, Standard Reference

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TABLE 102.4.5

Radius of Bends	Min. Thickness Recommended Prior to Bending
6 pipe diameters or greater	$1.06t_m$
5 pipe diameters	$1.08t_m$
4 pipe diameters	$1.14t_m$
3 pipe diameters	$1.25t_m$

GENERAL NOTES:

(a) Interpolation is permissible for bending to intermediate radii.

(b) t_m is determined by Formula (3) or (3A) of para. 104.1.2(A).

(c) Pipe diameter is the nominal diameter as tabulated in ASME B36.10M, Tables 2 and 4, and ASME B36.19M, Table 1. For piping with a diameter not listed in these Tables, and also for tubing, the nominal diameter corresponds with the outside diameter.

Photographs for Magnetic Particle Indications on Ferrous Castings, shall be removed.

(B.2.2) All parts of castings shall be subjected to complete radiographic inspection in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, and the radiographs shall conform to the requirements of ASTM E 280, Reference Radiographs for Heavy Walled [4½ to 12 in. (114 to 305 mm)] Steel Castings.

The maximum acceptable severity level for a 1.0 quality factor shall be as listed in Table 102.4.6 (B.2.2).

(B.2.3) Any discontinuities in excess of the maximum permitted in (B.2.1) and (B.2.2) above shall be removed and may be repaired by welding after the base metal has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities. [Refer to para. 127.4.11(A).]

(B.2.4) All weld repairs of depth exceeding 1 in. (25 mm) or 20% of the section thickness, whichever is the lesser, shall be inspected by radiography in accordance with (B.2.2) above and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 in. (25 mm), whichever is the lesser, and all weld repairs of section which cannot be effectively radiographed shall be examined by magnetic particle or dye penetrant inspection of the first layer, of each ¼ in. (6 mm) thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

(C) For cast iron and nonferrous materials, no increase of the casting quality factor is allowed except when special methods of examination, prescribed by the material specification, are followed. If such increase is specifically permitted by the material specification, a factor not exceeding 1.0 may be applied.

PART 2
PRESSURE DESIGN OF PIPING COMPONENTS

103 CRITERIA FOR PRESSURE DESIGN OF PIPING COMPONENTS

The design of piping components shall consider the effects of pressure and temperature, in accordance with paras. 104.1 through 104.7, including the consideration of allowances permitted by paras. 102.2.4 and 102.4. In addition, the mechanical strength of the piping system shall be determined adequate in accordance with para. 104.8 under other applicable loadings, including but not limited to those loadings defined in para. 101.

104 PRESSURE DESIGN OF COMPONENTS

104.1 Straight Pipe

104.1.2 Straight Pipe Under Internal Pressure

(A) Minimum Wall Thickness. The minimum thickness of pipe wall required for design pressures and for temperatures not exceeding those for the various materials listed in the Allowable Stress Tables, including allowances for mechanical strength, shall not be less than that determined by Formula (3) or (3A), as follows:

$$t_m = \frac{PD_o}{2(SE + Py)} + A \qquad (3)^1$$

$$t_m = \frac{Pd + 2SEA + 2yPA}{2(SE + Py - P)} \qquad (3A)^1$$

Design pressure shall not exceed

$$P = \frac{2SE(t_m - A)}{D_o - 2y(t_m - A)} \qquad (4)^1$$

$$P = \frac{2SE(t_m - A)}{d - 2y(t_m - A) + 2t_m} \qquad (4A)^1$$

[1] *SF* shall be used in place of *SE* where casting quality factors are intended. See definition of *SE*. Units of *P* and *SE* must be identical. Appendix A values must be converted to kPa when the design pressure is in kPa.

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TABLE 102.4.6(B.1.1)

Discontinuity Category Designation	Severity Level ≤1 in. (25 mm) Thick	Severity Level >1 in. (25 mm) Thick	Discontinuity Category Designation	Severity Level
For E 446 [Castings up to 2 in. (50 mm) Thickness]			For E 186 [Castings 2 to 4½ in. (50 to 114 mm) Thickness]	
A	1	2	A, B, and Types 1 and 2 of C	2
B	2	3	Type 3 of C	3
C Types 1, 2, 3, and 4	1	3	D, E, and F	None acceptable
D, E, F, and G	None acceptable	None acceptable		

TABLE 102.4.6(B.2.2)

Discontinuity Category Designation	Severity Level
A, B, and Types 1,2, and 3 of C	2
D, E, and F	None acceptable

where the nomenclature used above are:

(A.1) t_m = minimum required wall thickness, in. (mm)

(A.1.1) If pipe is ordered by its nominal wall thickness, the manufacturing tolerance on wall thickness must be taken into account. After the minimum pipe wall thickness t_m is determined by Formula (3) or (3A), this minimum thickness shall be increased by an amount sufficient to provide the manufacturing tolerance allowed in the applicable pipe specification or required by the process. The next heavier commercial wall thickness shall then be selected from thickness schedules such as contained in ASME B36.10M or from manufacturers' schedules for other than standard thickness.

(A.1.2) To compensate for thinning in bends, refer to para. 102.4.5.

(A.1.3) For cast piping components, refer to para. 102.4.6.

(A.1.4) Where ends are subject to forming or machining for jointing, the wall thickness of the pipe, tube, or component after such forming or machining shall not be less than t_m minus the amount provided for removal by para. 104.1.2 (A.6.1).

(A.2) P = internal design pressure, psig [kPa (gage)]

NOTE: When computing the design pressure for a pipe of a definite minimum wall thickness by Formula (4) or (4A), the value of P obtained by these Formulas may be rounded out to the next higher unit of 10. For cast iron pipe, see para. 104.1.2(B).

(A.3) D_o = outside diameter of pipe, in. (mm). For design calculations, the outside diameter of pipe as given in tables of standards and specifications shall be used in obtaining the value of t_m. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured outside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

(A.4) d = inside diameter of pipe, in. (mm). For design calculations, the inside diameter of pipe is the maximum possible value allowable under the purchase specification. When calculating the allowable working pressure of pipe on hand or in stock, the actual measured inside diameter and actual measured minimum wall thickness at the thinner end of the pipe may be used to calculate this pressure.

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TABLE 104.1.2(A)
VALUES OF y

Temperature, °F	900 and Below	950	1000	1050	1100	1150	1200	1250 and Above
Temperature, °C	482 and Below	510	538	566	593	621	649	677 and Above
Ferritic steels	0.4	0.5	0.7	0.7	0.7	0.7	0.7	0.7
Austenitic steels	0.4	0.4	0.4	0.4	0.5	0.7	0.7	0.7
Nickel Alloys UNS Nos. N08800, N08810, N08825	0.4	0.4	0.4	0.4	04	0.4	0.5	0.7

GENERAL NOTES:

(a) The value of y may be interpolated between the 50°F (27.8°C) values shown in the Table. For cast iron and nonferrous materials, y equals 0.4.

(b) For pipe with a D_o/t_m ratio less than 6, the value of y for ferritic and austenitic steels designed for temperatures of 900°F (480°C) and below shall be taken as:

$$y = \frac{d}{d + D_o} \quad (5)$$

(A.5) SE or *SF* = maximum allowable stress in material due to internal pressure and joint efficiency (or casting quality factor) at the design temperature, psi (kPa). The value of *SE* or *SF* shall not exceed that given in Appendix A, for the respective material and design temperature. These values include the weld joint efficiency *E*, or the casting factor *F*.

(A.6) A = additional thickness, in. (mm):

(A.6.1) to compensate for material removed in threading, grooving, etc., required to make a mechanical joint, refer to para. 102.4.2;

(A.6.2) to provide for mechanical strength of the pipe, refer to para. 102.4.4 (not intended to provide for extreme conditions of misapplied external loads or for mechanical abuse);

(A.6.3) to provide for corrosion and/or erosion, refer to para. 102.4.1;

(A.6.4) for cast iron pipe the following values of *A* shall apply:

Centrifugally cast . . . . . 0.14 in. (3.56 mm)
Statically cast . . . . . 0.18 in. (4.57 mm)

(A.7) y = coefficient having values as given in Table 104.1.2(A)

(B) The thickness of gray and ductile iron pipe and fittings conveying liquids may be determined from ANSI/AWWA C110/A21.10, ANSI/AWWA C115/A21.15, ANSI/AWWA C150/A21.50, ANSI/AWWA C151/A21.51, or Federal Specification WW-P-421, using the class of pipe for the pressure next higher than the desired internal design pressure in psi (kPa). These thickness include allowances for foundry tolerances and water hammer. Where the thickness of ductile iron pipe for liquid service is calculated, the methods of ANSI/AWWA C115/A21.15, or ANSI/AWWA C150/A21.50 may be used.

Where cast gray and ductile iron pipe is used for steam service, the thickness shall be calculated in accordance with Formula (3) or (3A) using the allowable stress value from the Allowable Stress Tables.

(C) While the thickness determined from Formula (3) or (3A) are theoretically ample for both bursting pressure and material removed in threading, the following minimum requirements are mandatory to furnish added mechanical strength.

(C.1) Where steel pipe is threaded and used for steam service at pressure above 250 psi (1750 kPa) or for water service above 100 psi (700 kPa) with water temperature above 220°F (105°C), the pipe shall be seamless having the minimum ultimate tensile strength of 48,000 psi (330 MPa) and a weight at least equal to Schedule 80 of ASME B36.10M. 01

(C.2) Where threaded brass or copper pipe is used for the services described in (C.1) above, it shall comply with pressure and temperature classifications permitted for these materials by other paragraphs of this Code and shall have a wall thickness at least equal to that specified above for steel pipe of corresponding size.

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(C.3) Plain end nonferrous pipe or tube shall have minimum wall thicknesses as follows.

For nominal sizes smaller than NPS ¾, the thickness shall not be less than that specified for Type K of ASTM B 88.

For nominal sizes NPS ¾ and larger, the wall thickness shall not be less than 0.049 in. (1.25 mm). The wall thickness shall be further increased, as required, in accordance with para. 102.4.

104.1.3 Straight Pipe Under External Pressure. For determining wall thickness and stiffening requirements for straight pipe under external pressure, the procedures outlined in UG-28, UG-29, and UG-30 of Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code shall be followed.

104.2 Curved Segments of Pipe

104.2.1 Pipe Bends. Pipe bends shall be subject to the following limitations.

(A) The minimum wall thickness shall meet the requirements of para. 102.4.5 and the fabrication requirements of para. 129.

(B) For ferrous material, when the radius of a bend is 5 nominal pipe diameters or greater, and the nominal wall thickness of the pipe is schedule 40 or thicker, the difference between maximum and minimum diameters shall not exceed 8% of average measured outside diameter of the pipe before bending.

(C) Greater flattening may be permitted or less flattening may be required by the design, depending upon the service, the material, and the stress level involved.

104.2.2 Elbows. Elbows manufactured in accordance with the standards listed in Table 126.1 are suitable for use at the pressure-temperature ratings specified by such standards, subject to the requirements of para. 106.

104.3 Intersections

104.3.1 Branch Connections

(A) This paragraph gives rules governing the design of branch connections to sustain internal and external pressure in cases where the axes of the branch and the run intersect, and the angle between the axes of the branch and of the run is between 45 deg and 90 deg, inclusive.

Branch connections in which the smaller angle between the axes of the branch and the run is less than 45 deg or branch connections where the axes of the branch and the run do not intersect impose special design and fabrication problems. The rules given herein may be used as a guide, but sufficient additional strength must be provided to assure safe service. Such branch connections shall be designed to meet the requirement of para. 104.7.

(B) Branch connections in piping may be made from materials listed in Appendix A by the use of the following:

(B.1) fittings, such as tees, laterals, and crosses made in accordance with the applicable standards listed in Table 126.1 where the attachment of the branch pipe to the fitting is by butt welding, socket welding, brazing, soldering, threading, or by a flanged connection;

(B.2) weld outlet fittings, such as cast or forged nozzles, couplings and adaptors, or similar items where the attachment of the branch pipe to the fitting is by butt welding, socket welding, threading, or by a flanged connection. Such weld outlet fittings are attached to the run by welding similar to that shown in Fig. 127.4.8(E). Couplings are restricted to a maximum of NPS 3.

(B.3) extruded outlets at right angles to the run pipe, in accordance with (G) below, where the attachment of the branch pipe is by butt welding;

(B.4) piping directly attached to the run pipe by welding in accordance with para. 127.4.8 or by socket welding or threading as stipulated below:

(B.4.1) socket welded right angle branch connections may be made by attaching the branch pipe directly to the run pipe provided:

(B.4.1.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run, whichever is smaller;

(B.4.1.2) the depth of the socket measured at its minimum depth in the run pipe is at least equal to that shown in ASME B16.11. If the run pipe wall does not have sufficient thickness to provide the proper depth of socket, an alternate type of construction shall be used.

(B.4.1.3) the clearance between the bottom of the socket and the end of the inserted branch pipe is in accordance with Fig. 127.4.4(C);

(B.4.1.4) the size of the fillet weld is not less than 1.09 times the nominal wall thickness of the branch pipe.

(B.4.2) threaded right angle branch connections may be made by attaching the branch pipe directly to the run provided:

(B.4.2.1) the nominal size of the branch does not exceed NPS 2 or one-fourth of the nominal size of the run whichever is smaller;

(B.4.2.2) the minimum thread engagement is: 6 full threads for NPS ½ and NPS ¾ branches; 7 for NPS 1, NPS 1¼, and NPS 1½ branches; and 8 for NPS 2

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branches. If the run pipe wall does not have sufficient thickness to provide the proper depth for thread engagement, an alternative type of construction shall be used.

(C) Branch Connections Not Requiring Reinforcement. A pipe having a branch connection is weakened by the opening that must be made in it. Unless the wall thickness of the branch and/or run pipe is sufficiently in excess of that required to sustain the pressure, it is necessary to provide additional material in order to meet the reinforcement requirements of (D) and (E) below. However, there are certain branch connections for which supporting calculations are not required. These are as follows:

(C.1) branch connections made by the use of a fitting (tee, lateral, cross, or branch weld-on fitting), manufactured in accordance with a standard listed in Table 126.1, and used within the limits of pressure-temperature ratings specified in that standard;

(C.2) branch connections made by welding a coupling or half coupling directly to the run pipe in accordance with Fig. 127.4.8(E) provided the nominal diameter of the branch does not exceed NPS 2 or one-fourth the nominal diameter of the run, whichever is less. The minimum wall thickness of the coupling anywhere in the reinforcement zone (if threads are in the zone, wall thickness is measured from the root of the thread to the minimum O.D.) shall not be less than that of the unthreaded branch pipe. In no case shall the thickness of the coupling be less than extra heavy or Class 3000 rating.

Small branch connections NPS 2 or smaller as shown in Fig. 127.4.8(F) may be used provided t_w is not less than the thickness of schedule 160 pipe of the branch size.

(C.3) integrally reinforced fittings welded directly to the run pipe when the reinforcements provided by the fitting and the deposited weld metal meets the requirements of (D) below.

(C.4) integrally reinforced extruded outlets in the run pipe. The reinforcement requirements shall be in accordance with (G) below.

(D) Branch Connections Subject to Internal Pressure Requiring Reinforcement

(D.1) Reinforcement is required when it is not provided inherently in the components of the branch connection. This paragraph gives rules covering the design of branch connections to sustain internal pressure in cases where the angle between the axes of the branch and of the run is between 45 deg and 90 deg Subparagraph (E) below gives rules governing the design of connections to sustain external pressure.

(D.2) Figure 104.3.1(D) illustrates the notations used in the pressure-temperature design conditions of branch connections but does not illustrate the allowances for mill tolerance or any other wall thickness allowance. The designer shall make proper allowances for the effects of corrosion or erosion, threading and grooving, and mechanical strength as specified in paras. 102.4.1, 102.4.2, and 102.4.4 in order that the required minimum reinforcement is assured over the design life of the piping system. These notations are as follows:

α = angle between axes of branch and run, deg

b = subscript referring to branch

D_o = outside diameter of pipe, in. (mm)

d_1 = inside center line longitudinal dimension of the finished branch opening in the run of the pipe, in. (mm)
= $[D_{ob} - 2(T_b - A)]/\sin\alpha$

d_2 = "half width" of reinforcing zone, in. (mm)
= the greater of d_1 or $(T_b - A) + (T_h - A) + d_1/2$ but in no case more than D_{oh}, in. (mm)

h = subscript referring to run or header

L_4 = altitude of reinforcement zone outside of run, in. (mm)
= $2.5(T_b - A) + t_r$ or $2.5(T_h - A)$, whichever is smaller

t_r = thickness of attached reinforcing pad, in Example B, in. (mm); or height of the largest 60 deg right triangle supported by the run and branch outside diameter projected surfaces and lying completely within the area of integral reinforcement, in Example C, in. (mm)

T_b, T_h = actual (by measurement), or minimum wall thickness of the branch or header pipe, in. (mm), permissible under purchase specification

t_{mb}, t_{mh} = required minimum wall thickness, in. (mm), of the branch or header pipe as determined by use of Formula (3) or (3A) in para. 104.1.2(A)

(D.2.1) If the run pipe contains a longitudinal seam which is not intersected by the branch, the stress value of seamless pipe of comparable grade may be used to determine the value of t_{mh} for the purpose of reinforcement calculations only. If the branch intersects a longitudinal weld in the run, or if the branch contains a weld, the weld joint efficiency for either or both shall enter the calculations. If the branch and run both contain longitudinal welds, care shall be taken to ensure that the two welds do not intersect each other.

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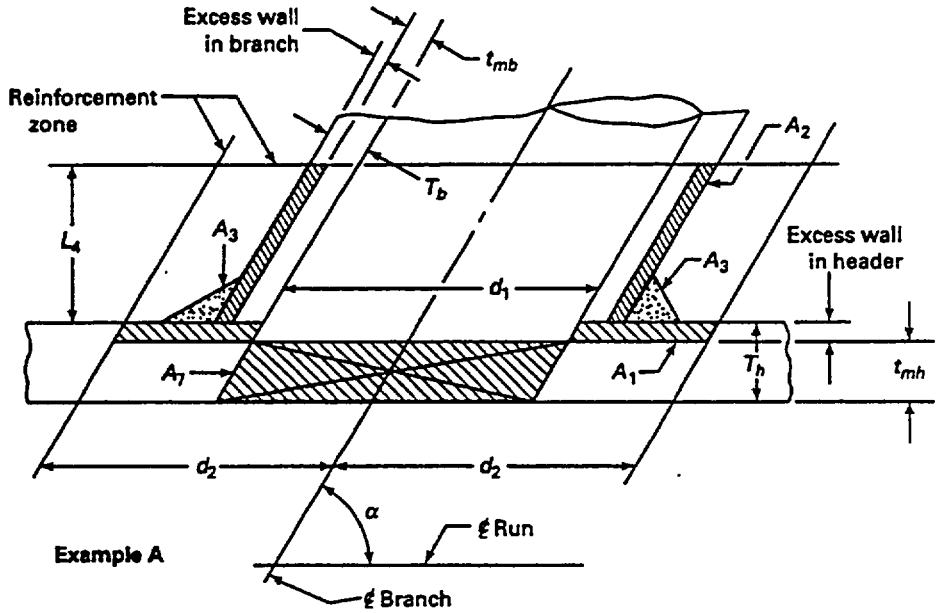
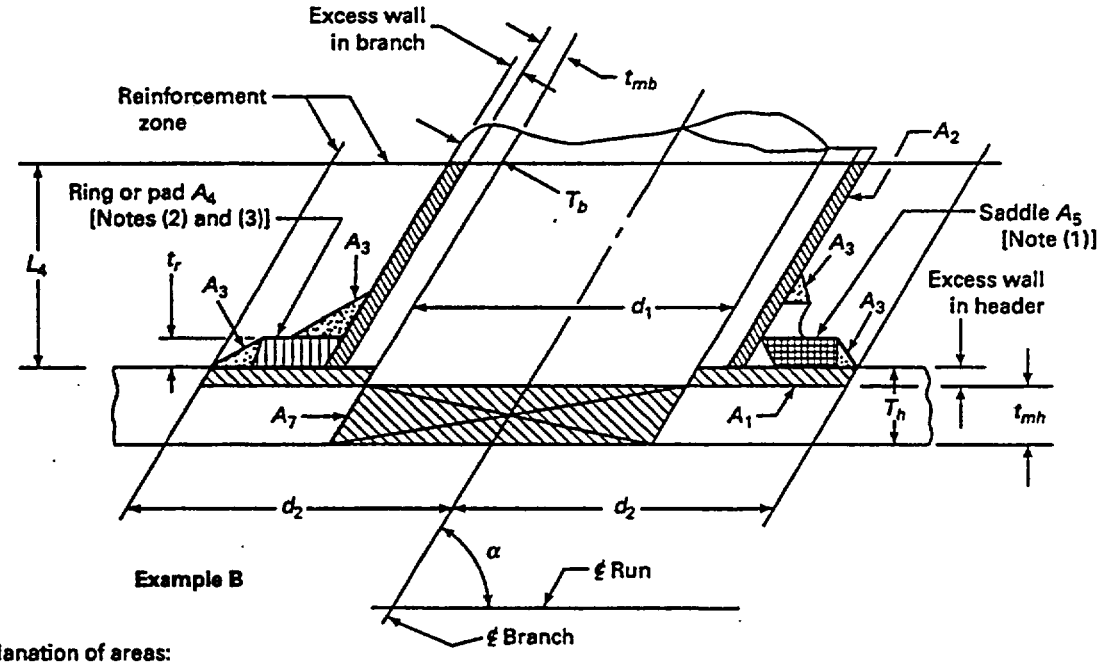
required reinforcement = $(t_{mh})(d_1)(2 - \sin \alpha) = A_7$.

reinforcement areas = A_1, A_2, A_3, A_4, and A_5





Explanation of areas:

- Area A_7 — required reinforcement area
- Area A_1 — excess wall in header
- Area A_2 — excess wall in branch
- Area A_3 — fillet weld metal
- Area A_4 — metal in ring, pad, or integral reinforcement
- Area A_5 — metal in saddle along run

FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS

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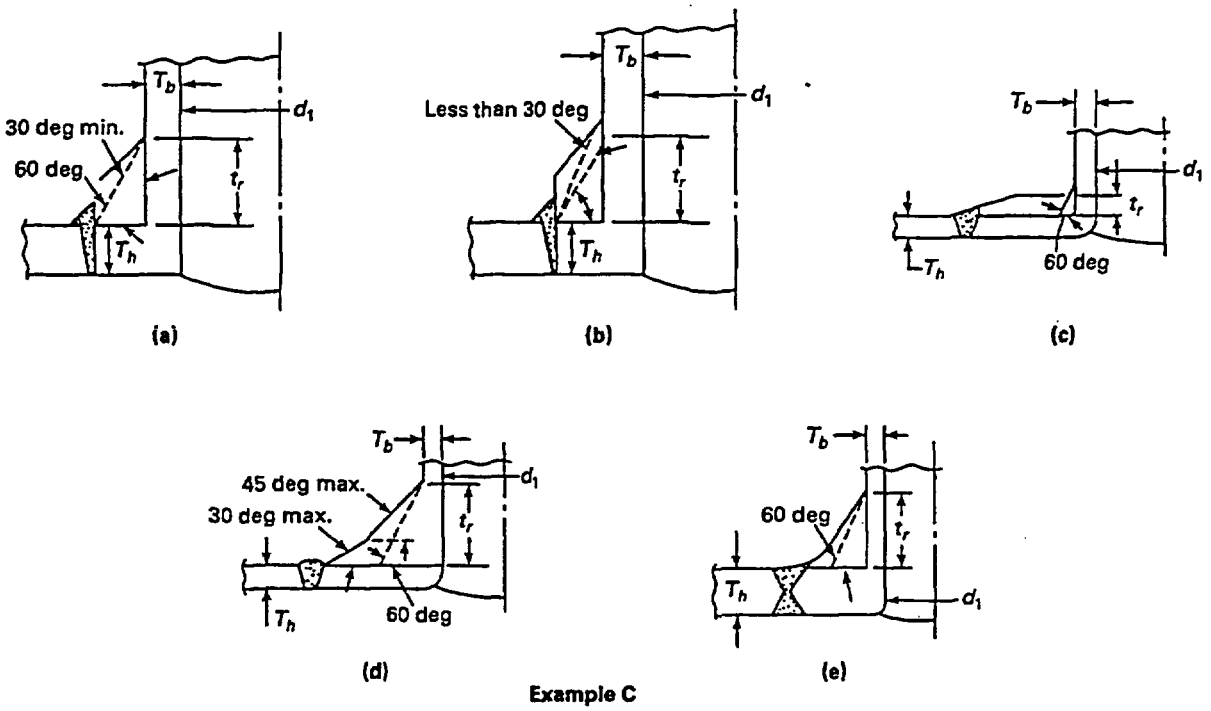

Example C

NOTES:

(1) Reinforcing saddles are limited to use on 90 deg branches.

(2) When a ring or pad is added as reinforcement (Example B), the value of reinforcing area may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, header pipe, and ring or pad. Typical acceptable methods of welding that meet the above requirement are shown in Fig. 127.4.8(D), examples (c) and (d).

(3) Width to height of rings and pads shall be reasonably proportioned, preferably on a ratio as close to 4:1 as the available horizontal space within the limits of the reinforcing zone along the run and the O.D. of the branch will permit, but in no case may the ratio be less than 1:1.

FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS (CONT'D)

01 *(D.2.2)* The required reinforcement area in square inches (square millimeters) for branch connections shall be the quantity

$$A_7 = (t_{mh} - A)d_1\,(2 - \sin\alpha)$$

For right angle connections the required reinforcement becomes

$$A_7 = t_{mh}d_1$$

The required reinforcement must be within the limits of the reinforcement zone as defined in (D.2.4) below.

(D.2.3) The reinforcement required by (D.2) shall be that provided by any combination of areas A_1, A_2, A_3, A_4, and A_5, as defined below and illustrated in Fig. 104.3.1 (D) where

A_1 = area provided by excess pipe wall in the run
= $(2d_2 - d_1)(T_h - t_{mh})$

A_2 = area, in.^{2} (mm^2), provided by excess pipe wall in the branch for a distance L_4 above the run
= $2L_4\,(T_b - t_{mb})/\sin\alpha$

A_3 = area provided by deposited weld metal beyond the outside diameter of the run and branch, and for fillet weld attachments of rings, pads, and saddles

A_4 = are provided by a reinforcing ring, pad, or integral reinforcement. The value of A_4 may be taken in the same manner in which excess header metal is considered, provided the weld completely fuses the branch pipe, run pipe, and ring or pad, or integral reinforcement. For welding branch connections refer to para. 127.4.8.

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A_5 = area provided by a saddle on right angle connections
= (O.D. of saddle − D_{ob})t_r

Portions of the reinforcement area may be composed of materials other than those of the run pipe, but if the allowable stress of these materials is less than that for the run pipe, the corresponding calculated reinforcement area provided by this material shall be reduced in the ratio of the allowable stress being applied to the reinforcement area. No additional credit shall be taken for materials having higher allowable stress values than the run pipe.

(D.2.4) Reinforcement Zone. The reinforcement zone is a parallelogram whose width shall extend a distance d_2 on each side of the center line of the branch pipe, and whose altitude shall start at the inside surface of the run pipe and extend to a distance L_4 from the outside surface of the run pipe.

(D.2.5) Reinforcement of Multiple Openings. It is preferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirement shall be met. The two or more openings shall be reinforced in accordance with (D.2), with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for the separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

When more than two adjacent openings are to be provided with a combined reinforcement, the minimum distance between centers of any two of these openings should preferably be at least 1½ times their average diameter, and the area of reinforcement between them shall be at least equal to 50% of the total required for these two openings.

(D.2.6) Rings, Pads, and Saddles. Reinforcement provided in the form of rings, pads, or saddles shall not be appreciably narrower at the side than at the crotch.

A vent hole shall be provided at the ring, pad, or saddle to provide venting during welding and heat treatment. Refer to para. 127.4.8(E).

Rings, pads, or saddles may be made in more than one piece, provided the joints between pieces have full thickness welds, and each piece is provided with a vent hole.

(D.2.7) Other Designs. The adequacy of designs to which the reinforcement requirements of para. 104.3 cannot be applied shall be proven by burst or proof tests on scale models or on full size structures, or by calculations previously substantiated by successful service of similar design.

(E) Branch Connections Subject to External Pressure Requiring Reinforcement. The reinforcement area in square inches (square millimeters) required for branch connections subject to external pressure shall be

$$0.5 t_{mh} d_1 (2 - \sin \alpha)$$

Procedures established heretofore for connections subject to internal pressure shall apply for connections subject to external pressure provided that D_{oh}, D_{ob}, and t_r are reduced to compensate for external corrosion, if required by design conditions.

(F) Branch Connections Subject to External Forces and Moments. The requirements of the preceding paragraphs are intended to assure safe performance of a branch connection subjected only to pressure. However, when external forces and moments are applied to a branch connection by thermal expansion and contraction, by dead weight of piping, valves, and fittings, covering and contents, or by earth settlement, the branch connection shall be analyzed considering the stress intensification factors as specified in Appendix D. Use of ribs, gussets, and clamps designed in accordance with para. 104.3.4 is permissible to stiffen the branch connection, but their areas cannot be counted as contributing to the required reinforcement area of the branch connection.

(G) Extruded Outlets Integrally Reinforced

(G.1) The following definitions, modifications, notations, and requirements are specifically applicable to extruded outlets. The designer shall make proper wall thickness allowances in order that the required minimum reinforcement is assured over the design life of the system.

(G.2) Definition. An extruded outlet header is defined as a header in which the extruded lip at the outlet has an altitude above the surface of the run which is equal to or greater than the radius of curvature of the external contoured portion of the outlet; i.e., $h_o \geq r_o$. See nomenclature and Fig. 104.3.1(G).

(G.3) These rules apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(G.4) The notation used herein is illustrated in Fig. 104.3.1(G). All dimensions are in inches (millimeters).

d = outside diameter of branch pipe
d_b = corroded internal diameter of branch pipe
D = outside diameter of run

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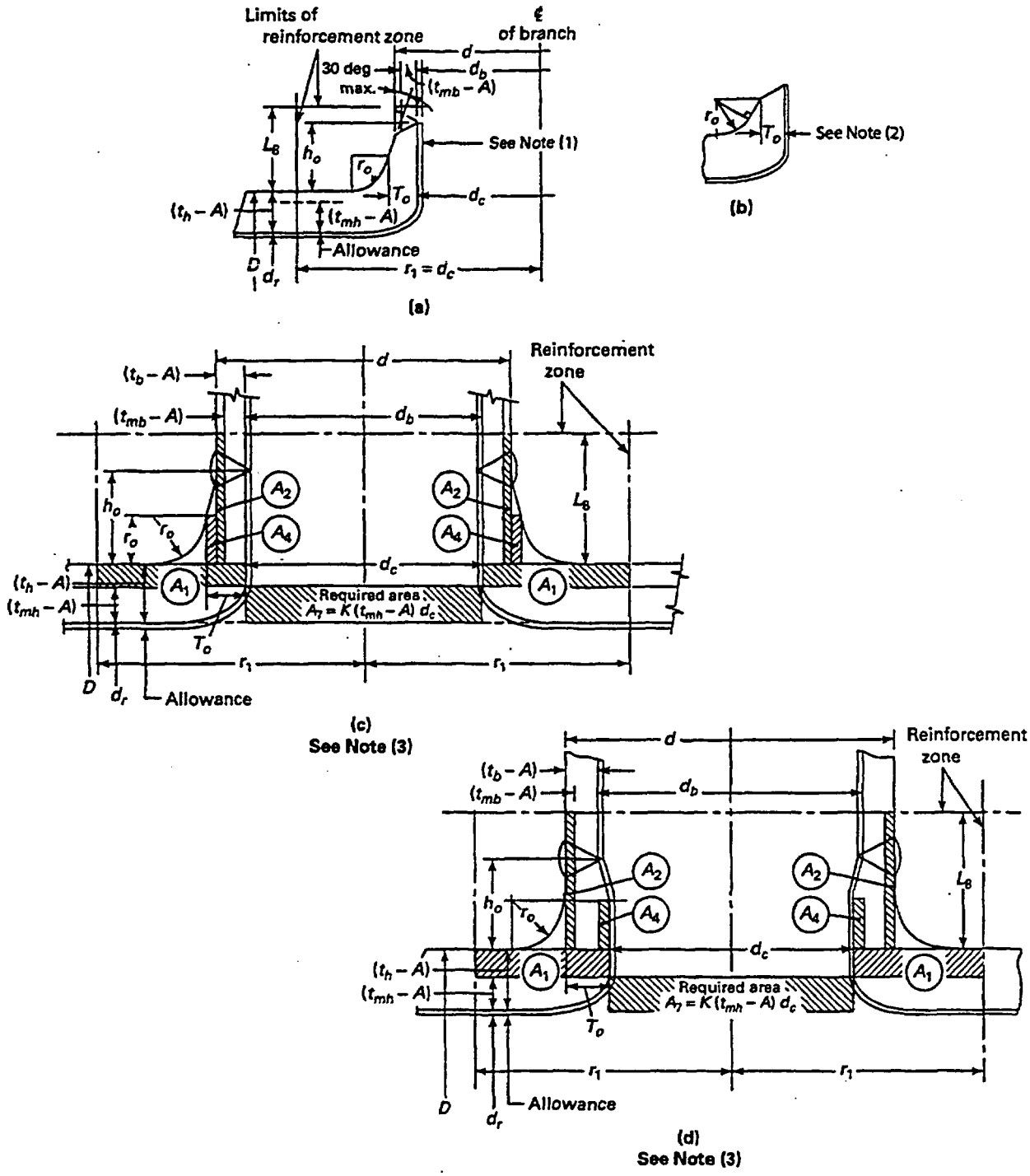

NOTES:
(1) Taper bore inside diameter (if required) to match branch pipe 1:3 maximum taper.
(2) Sketch to show method of establishing T_o when the taper encroaches on the crotch radius.
(3) Sketch is drawn for condition where $k = 1.00$.

FIG. 104.3.1(G) REINFORCED EXTRUDED OUTLETS

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d_r = corroded internal diameter of run

d_c = corroded internal diameter of extruded outlet measured at the level of the outside surface of the run

h_o = height of the extruded lip. This must be equal to or greater than r_o except as shown in (G.4.2) below.

L_8 = altitude of reinforcement zone
= $0.7\sqrt{dT_o}$

$t_{mb} - A$ = required thickness of branch pipe according to wall thickness Formula (3) or (3A) in para. 104.1.2(A), but not including any thickness for corrosion

$t_b - A$ = actual thickness of branch wall not including corrosion allowance

$t_{mh} - A$ = required thickness of the run according to the Formula (3) or (3A) in para. 104.1.2(A), but not including any allowance for corrosion

$t_h - A$ = actual thickness of run wall, not including the corrosion allowance

T_o = corroded finished thickness of extruded outlet measured at a height equal to r_o above the outside surface of the run

r_1 = half width of reinforcement zone (equal to d_c)

r_o = radius of curvature of external contoured portion of outlet measured in the plane containing the axes of the run and branch. This is subject to the following limitations.

(G.4.1) Minimum Radius. This dimension shall not be less than $0.05d$ except that on branch diameters larger than NPS 30, it need not exceed 1.50 in. (38 mm).

(G.4.2) Maximum Radius. For outlet pipe sizes 6 in. nominal and larger, this dimension shall not exceed $0.10d + 0.50$ in. ($0.10d + 12.7$ mm). For outlet pipe sizes less than NPS 6, this dimension shall not be greater than 1.25 in. (32 mm).

(G.4.3) When the external contour contains more than one radius, the radius of any arc sector of approximately 45 deg shall meet the requirements of (G.4.1) and (G.4.2) above. When the external contour has a continuously varying radius, the radius of curvature at every point on the contour shall meet the requirements of (G.4.1) and (G.4.2) above.

(G.4.4) Machining other than grinding for weld cleanup shall not be employed in order to meet the above requirements.

(G.5) Required Area. The required area is defined as

$$A_7 = K\,(t_{mh} - A)\,d_c$$

where K shall be taken as follows.

For d/D greater than 0.60,

$$K = 1.00$$

For d/D greater than 0.15 and not exceeding 0.60,

$$K = 0.6 + \tfrac{2}{3}\,d/D$$

For d/D equal to or less than 0.15,

$$K = 0.70$$

The design must meet criteria that the reinforcement area defined in (G.6) below is not less than the required area.

(G.6) Reinforcement Area. The reinforcement area shall be the sum of areas

$$A_1 + A_2 + A_4$$

as defined below.

(G.6.1) Area A_1 is the area lying within the reinforcement zone resulting from any excess thickness available in the run wall.

$$A_1 = d_c(t_h - t_{mh})$$

(G.6.2) Area A_2 is the area lying within the reinforcement zone resulting from any excess thickness available in the branch pipe wall.

$$A_2 = 2L_8(t_b - t_{mb})$$

(G.6.3) Area A_4 is the area lying within the reinforcement zone resulting from excess thickness available in the extruded outlet lip.

$$A_4 = 2r_o\,[T_o - (t_b - A)]$$

(G.7) Reinforcement of Multiple Openings. It is pre-

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ferred that multiple branch openings be spaced so that their reinforcement zones do not overlap. If closer spacing is necessary, the following requirements shall be met. The two or more openings shall be reinforced in accordance with (G) with a combined reinforcement that has a strength equal to the combined strength of the reinforcement that would be required for separate openings. No portion of the cross section shall be considered as applying to more than one opening, or be evaluated more than once in a combined area.

(G.8) In addition to the above, the manufacturer shall be responsible for establishing and marking on the section containing extruded outlets, the design pressure and temperature. The manufacturer's name or trademarks shall be marked on the section.

104.3.3 Miters. Miter joints, and the terminology related thereto, are described in Appendix D. A widely spaced miter with

$$\theta < 9\sqrt{\frac{t_n}{r}}\ \text{deg}$$

shall be considered to be equivalent to a girth buttwelded joint, and the rules of this paragraph do not apply. Miter joints, and fabricated pipe bends consisting of segments of straight pipe welded together, with θ equal to or greater than this calculated value may be used within the limitations described below.

(A) Pressure shall be limited to 10 psi (70 kPa) under the following conditions:

(A.1) the assembly includes a miter weld with $\theta >$ 22.5 deg, or contains a segment which has a dimension

$$B < 6t_n$$

(A.2) the thickness of each segment of the miter is not less than that determined in accordance with para. 104.1;

(A.3) the contained fluid is nonflammable, nontoxic, and incompressible, except for gaseous vents to atmosphere;

(A.4) the number of full pressure cycles is less than 7000 during the expected lifetime of the piping system; and

(A.5) full penetration welds are used in joining miter segments.

(B) Pressure shall be limited to 100 psi (700 kPa) under the conditions defined in (A.2), (A.3), (A.4), and (A.5) above, in addition to the following:

(B.1) the angle θ does not exceed 22.5 deg; and

(B.2) the assembly does not contain any segment which has a dimension

$$B < 6t_n$$

(C) Miters to be used in other services or at design pressures above 100 psi (700 kPa) shall meet the requirements of para. 104.7.

(C.1) When justification under para. 104.7 is based on comparable service conditions, such conditions must be established as comparable with respect to cyclic as well as static loadings.

(C.2) When justification under para. 104.7 is based on an analysis, that analysis and substantiating tests shall consider the discontinuity stresses which exist at the juncture between segments; both for static (including brittle fracture) and cyclic internal pressure.

(C.3) The wall thickness t_s of a segment of a miter shall not be less than specified in (C.3.1) or (C.3.2) below, depending on the spacing.

(C.3.1) For closely-spaced miter bends (see Appendix D for definition)

$$t_s = t_m \frac{2 - r/R}{2(1 - r/R)}$$

(C.3.2) For widely-spaced miters (see Appendix D for definition)

$$t_s = t_m(1 + 0.64\sqrt{r/t_s}\tan\theta)$$

(the above equation requires an iterative or quadratic solution for t_s).

104.3.4 Attachments. External and internal attachments to piping shall be designed so as not to cause flattening of the pipe, excessive localized bending stresses, or harmful thermal gradients in the pipe wall. It is important that such attachments be designed to minimize stress concentrations in applications where the number of stress cycles, due either to pressure or thermal effect, is relatively large for the expected life of the equipment.

104.4 Closures

104.4.1 General. Closures for power piping systems shall meet the applicable requirements of this Code and shall comply with the requirements described in (A) or (B) below. Closures may be made:

(A) by use of closure fittings, such as threaded or welded plugs, caps, or blind flanges, manufactured in

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accordance with standards listed in Table 126.1, and used within the specified pressure-temperature ratings; or

(B) in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, Power Boilers, PG-31, or Section VIII, Pressure Vessels, Division 1, UG-34 and UW-13, calculated from

$$t_m = t + A$$

where

t = pressure design thickness, calculated for the given closure shape and direction of loading using appropriate equations and procedures in Section I or Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code

The definition of A and the symbols used in determining t shall have the definitions shown herein, instead of those given in the ASME Boiler and Pressure Vessel Code.

Attachment of a welded flat permanent closure with only a single fillet weld is not permitted.

104.4.2 Openings in Closures. Openings in closures may be made by welding, extruding, or threading. Attachment to the closure shall be in accordance with the limitations provided for such connections in para. 104.3.1 for branch connections. If the size of the opening is greater than one-half of the inside diameter of the closure, the opening shall be designed as a reducer in accordance with para. 104.6.

Other openings in closures shall be reinforced in accordance with the requirements of reinforcement for a branch connection. The total cross-sectional area required for reinforcement in any plane passing through the center of the opening and normal to the surface of the closure shall not be less than the quantity of d_5t, where

d_5 = diameter of the finished opening, in. (mm), and t as defined in (B) above

104.5 Pressure Design of Flanges and Blanks

104.5.1 Flanges — General

(A) Flanges of sizes NPS 24 and smaller, that are manufactured in accordance with ASME B16.1 and B16.5, shall be considered suitable for use at the primary service ratings (allowable pressure at service temperature) except the slip-on flanges to ASME B16.5 shall be limited in application to no higher than Class 300 primary pressure service rating. Refer to para. 127.4.4.

For flanges larger than NPS 24, and manufactured in accordance with the Specifications and Standards listed in Table 126.1, the designer is cautioned about the dimensionally different designs that are available, as well as the limitations of their application.

Flanges not made in accordance with the Specifications and Standards listed in Table 126.1 shall be designed in accordance with Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, except that the requirements for fabrication, assembly, inspection, and testing, and the pressure and temperature limits for materials of this Code for Pressure Piping shall govern. Certain notations used in the ASME Code, namely, P, S_a, S_b, and S_f, shall have the meanings described below instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

P = design pressure, psi (kPa) (see paras. 101.2.2 and 101.2.4)

S_a = bolt design stress at atmospheric temperature, psi (kPa)

S_b = bolt design stress at design temperature, psi (kPa)

S_f = allowable stress for flange material or pipe, psi (kPa) (see para. 102.3.1 and Allowable Stress Tables) (stress values converted from MPa to kPa)

For certain specific applications see the limitations of paras. 122.1.1 (F), (G), and (H).

(B) These flange design rules are not applicable to flat face designs employing full face gaskets which extend beyond the bolts.

(C) The bolt design stress in (A) above shall be as established in Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code, Appendix P for ferrous materials.

(D) Application of bolting materials for flanged joints is covered in para. 108.5.

104.5.2 Blind Flanges

(A) Blind flanges manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use at the pressure-temperature rating specified by such Standards.

(B) The required thickness of blind flanges not manufactured in accordance with standards in Table 126.1 shall be calculated from Formula (6).

$$t_m = t + A \qquad (6)$$

where

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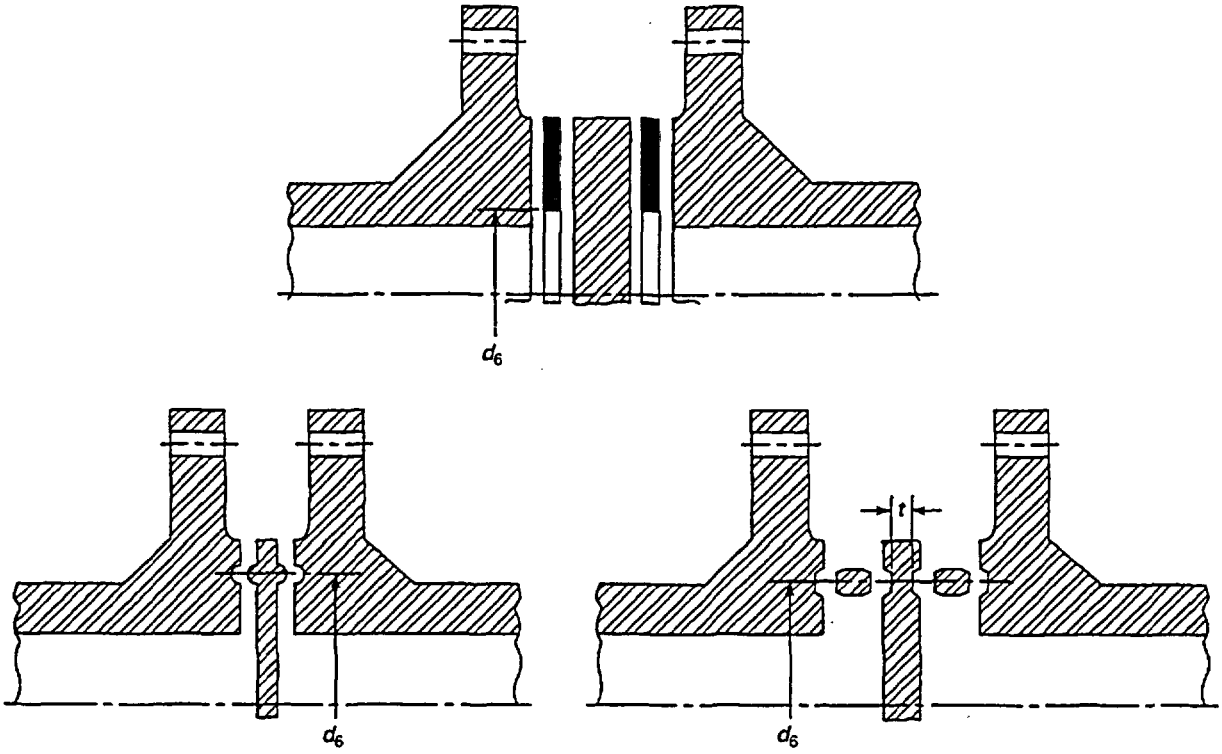

FIG. 104.5.3 TYPES OF PERMANENT BLANKS

t = pressure design thickness as calculated for the given style of blind flange from the appropriate equations for bolted flat cover plates in Section 1 of the ASME Boiler and Pressure Vessel Code. Certain notations used in these equations, namely, P and SE [see para. 104.1.2(A), footnote 1], shall be considered to have the meanings described in para. 104.1.2(A) instead of those given in the ASME Code. All other notations shall be as defined in the ASME Code.

104.5.3 Blanks

(A) The required thickness of permanent blanks (see Fig. 104.5.3) shall be calculated from the formula

$$t_m = t + A$$

where

t = pressure design thickness as calculated from Formula (7)

$$= d_6\sqrt{\frac{3P}{16SE}} \quad (7)$$

See para. 104.1.2(A), footnote 1.

d_6 = inside diameter of gasket for raised or flat (plain) face flanges, or the gasket pitch diameter for retained gasketed flanges, in. (mm)

(B) Blanks to be used for test purposes only shall have a minimum thickness not less than the pressure design thickness t specified above except that P shall be not less than the test pressure and SE [see para. 104.1.2(A), footnote 1] may be taken as the specified minimum yield strength of the blank material if the test fluid is incompressible.

(C) Attachment of a welded flat permanent blank with only a single fillet weld is not permitted.

104.6 Reducers

Flanged reducer fittings manufactured in accordance with the Standards listed in Table 126.1 shall be considered suitable for use at the specified pressure-temperature ratings. Where butt welding reducers are

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made to a nominal pipe thickness, the reducers shall be considered suitable for use with pipe of the same nominal thickness.

104.7 Other Pressure-Containing Components

104.7.1 Pressure-containing components manufactured in accordance with the standards listed in Table 126.1 shall be considered suitable for use under normal operating conditions at or below the specified pressure-temperature ratings. However, the user is cautioned that where certain standards or manufacturers may impose more restrictive allowances for variation from normal operation than those established by this Code, the more restrictive allowances shall apply.

104.7.2 Specially Designed Components. The pressure design of components not covered by the standards listed in Table 126.1 or for which design formulas and procedures are not given in this Code shall be based on calculations consistent with the design criteria of this Code. These calculations shall be substantiated by one or more of the means stated in (A), (B), (C), and (D) below:

(A) extensive, successful service experience under comparable conditions with similarly proportioned components of the same or similar material:

(B) experimental stress analysis, such as described in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 2, Appendix 6;

(C) proof test in accordance with either ASME B16.9, MSS SP-97, or the ASME Boiler and Pressure Vessel Code, Section I. A-22; and

(D) detailed stress analysis, such as finite element method, in accordance with the ASME Boiler and Pressure Vessel Code, Division 2, Appendix 4, except that the basic material allowable stress from the Allowable Stress Tables of Appendix A shall be used in place of S_m.

For any of (A) through (D) above, it is permissible to interpolate between sizes, wall thicknesses, and pressure classes and to determine analogies among related materials.

Calculations and documentation showing compliance with this paragraph shall be available for the owner's approval, and, for boiler external piping, they shall be available for the Authorized Inspector's review.

104.8 Analysis of Piping Components

To validate a design under the rules in this paragraph, the complete piping system must be analyzed between anchors for the effects of thermal expansion, weight, other sustained loads, and other occasional loads. Each component in the system must meet the limits in this paragraph. For pipe and fittings, the pressure term in Eqs. (11) and (12) may be replaced with the alternative term for S_{lp} as defined in para. 102.3.2(D). The pressure term in Eqs. (11) and (12) may not apply for bellows and expansion joints. When evaluating stresses in the vicinity of expansion joints, consideration must be given to actual cross-sectional areas that exist at the expansion joint.

104.8.1 Stress due to Sustained Loads. The effects of pressure, weight, and other sustained mechanical loads shall meet the requirements of Eq. (11). 01

English units

$$S_L = \frac{PD_o}{4t_n} + \frac{0.75\,iM_A}{Z} \le 1.0\,S_h \qquad (11A)$$

Metric units

$$S_L = \frac{PD_o}{4t_n} + \frac{1000\,(0.75i)M_A}{Z} \le 1.0\,S_h \qquad (11B)$$

where

M_A = resultant moment loading on cross section due to weight and other sustained loads, in-lb (mm-N) (see para. 104.8.4)

Z = section modulus, in.^{3} (mm^3) (see para. 104.8.4)

i = stress intensification factor (see Appendix D). The product $0.75i$ shall never be taken as less than 1.0.

S_L = sum of the longitudinal stresses due to pressure, weight, and other sustained loads

104.8.2 Stress due to Occasional Loads. The effects of pressure, weight, other sustained loads, and occasional loads including earthquake must meet the requirements of Eq. (12). 01

English units

$$\frac{PD_o}{4t_n} + \frac{0.75iM_A}{Z} + \frac{0.75iM_B}{Z} \le k\,S_h \qquad (12A)$$

Metric units

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$$\frac{PD_o}{4t_n} + \frac{1000(0.75i)M_A}{Z} + \frac{1000(0.75i)M_B}{Z} \le k\,S_h \quad (12B)$$

Terms same as para. 104.8.1 except

k = 1.15 for occasional loads acting for no more than 8 hr at any one time and no more than 800 hr/year [see para. 102.3.3(A)]

k = 1.2 for occasional loads acting for no more than 1 hr at any one time and no more than 80 hr/year [see para. 102.3.3(A)]

M_B = resultant moment loading on cross section due to occasional loads [see para. 102.3.3(A)], such as thrusts from relief/safety valve loads, from pressure and flow transients, and earthquake (see para. 104.8.4). If calculation of moments due to earthquake is required, use only one-half the earthquake moment range. Effects of anchor displacement due to earthquake may be excluded from Eq. (12) if they are included in Eq. (13), in.-lb.

01 **104.8.3 Thermal Expansion Stress Range.** The effects of thermal expansion shall meet the requirements of Eq. (13).

English units

$$S_E = \frac{iM_C}{Z} \le S_A + f(S_h - S_L) \quad (13A)$$

Metric units

$$S_E = \frac{1000(iM_c)}{Z} \le S_A + f(S_h - S_L) \quad (13B)$$

Terms same as para. 104.8.1 except

M_C = range of resultant moments due to thermal expansion. Also include moments effects of anchor displacement due to earthquake if anchor displacement effects were omitted from Eq. (12) (see para. 104.8.4).

f = stress range reduction factor for cyclic conditions for total number N of full temperature cycles over total number of years during which system is expected to be in operation, from Table 102.3.2(C)

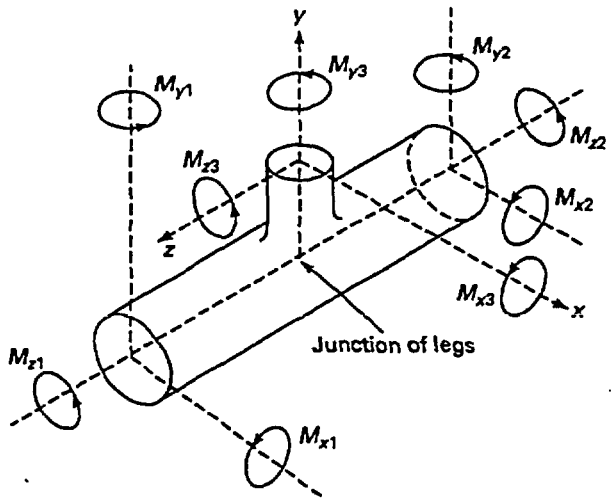

FIG. 104.8.4

104.8.4 Moments and Section Modulus

(A) For purposes of Eqs. (11), (12), and (13), the resultant moments for straight through components, curved pipe, or welding elbows may be calculated as follows:

$$M_j = (M_{xj}^2 + M_{yj}^2 + M_{zj}^2)^{1/2}$$

where

j = A, B, or C as defined in paras. 104.8.1, 104.8.2, and 104.8.3

Z = section modulus of piping, in.^{3} (mm^3)

(B) For full outlet branch connections, calculate the resultant moment of each leg separately in accordance with (A) above. Use Z, section modulus, in Eqs. (11) through (13) as applicable to branch or run pipe. Moments are taken at the junction point of the legs. See Fig. 104.8.4.

(C) For reduced outlets, calculate the resultant moment of each leg separately in accordance with (A) above. Moments are to be taken at the junction point of the legs, unless the designer can demonstrate the validity of a less conservative method. See Fig. 104.8.4. For the *reduced outlet branch*, except for branch connections covered by Fig. D-1:

$$M_A,\ M_B,\ M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

$Z = \pi r_b^2 t_e$ (effective section modulus)

r_b = branch mean cross-sectional radius, in. (mm)

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t_e = effective branch wall thickness, in. (mm)
= lesser of t_{nh} or it_{nb} in Eq. (13) or lesser of t_{nh} or $0.75it_{nb}$, where $0.75i \geq 1.0$, in Eqs. (11) and (12)

For the *reduced outlet branch connections covered by Fig. D-1:*

$$M_A, M_B, M_C = \sqrt{M_{x3}^2 + M_{y3}^2 + M_{z3}^2}$$

and

$$Z = \pi r'^2_m T_b$$

If L_1 in Fig. D-1 sketches (a), (b), and (c) equals or exceeds $0.5\sqrt{r_i T_b}$, then r'_m can be taken as the radius to the center of T_b when calculating the section modulus and the stress intensification factor. For such a case the transition between branch pipe and nozzle must be evaluated separately from the branch connection.

For the *main run outlets:*

$$M_A, M_B, M_C = \sqrt{M_{x1}^2 + M_{y1}^2 + M_{z1}^2}$$

and

$$M_A, M_B, M_C = \sqrt{M_{x2}^2 + M_{y2}^2 + M_{z2}^2}$$

and

Z = section modulus of pipe, in.^{3} (mm^3)

PART 3
SELECTION AND LIMITATIONS OF PIPING COMPONENTS

105 PIPE

105.1 General

Pipe conforming to the standards and specifications listed in Appendix A shall be used within the range of temperatures for which allowable stresses are given within the limitations specified herein.

105.2 Metallic Pipe

105.2.1 Ferrous Pipe

(A) Furnace butt welded steel pipe shall not be used for flammable, combustible or toxic fluids.

(B) Cast iron pipe may be used for design pressures within the ratings established by the standards and specifications listed in Tables 126.1 and A-5 and Notes thereto, and the limitations herein and in para. 124.4. Cast iron pipe shall not be used for flammable, combustible, or toxic fluids.

105.2.2 Nonferrous Pipe

(A) Copper and brass pipe for water and steam service may be used for design pressures up to 250 psi (1750 kPa) and for design temperatures to 406°F (208°C).

(B) Copper and brass pipe for air may be used in accordance with the allowable stresses given in the Allowable Stress Tables.

(C) Copper tubing may be used for dead-end instrument service with the limitations stated in para. 122.3.2(D).

(D) Copper, copper alloy, or aluminum alloy pipe or tube may be used under the conditions stated in para. 124.7. Copper, copper alloy, or aluminum pipe or tube shall not be used for flammable, combustible, or toxic fluids except as permitted in paras. 122.7 and 122.8.

105.3 Nonmetallic Pipe 01

(A) Plastic pipe may be used for water and nonflammable liquids where experience or tests have demonstrated that the plastic pipe is suitable for the service conditions, and the pressure and temperature conditions are within the manufacturer's recommendations. Until such time as mandatory rules are established for these materials, pressure shall be limited to 150 psi (1000 kPa) and temperature to 140°F (60°C) for water service. Pressure and temperature limits for other services shall be based on the hazards involved, but in no application shall they exceed 150 psi (1000 kPa) and 140°F (60°C). For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

(B) Reinforced thermosetting resin pipe may be used, in addition to the services listed in para. 105.3(A), in buried flammable and combustible liquid service subject to the limitations described in para. 122.7.3(F).

(C) Reinforced concrete pipe may be used in accordance with the specifications listed in Table 126.1 for water service up to 150°F (65°C).

(D) A flexible nonmetallic pipe or tube assembly may be used in applications where:

(a) satisfactory service experience exists;

(b) the pressure and temperature conditions are within the manufacturer's recommendations; and

(c) the conditions described in paras. 104.7, 124.7, and 124.8 are met.

(E) Polyethylene pipe may be used, in addition to

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the service listed in para. 105.3(A), in buried flammable and combustible liquid and gas service subject to the limitations described in paras. 122.7.2(D) and 122.8.1(B.4).

106 FITTINGS, BENDS, AND INTERSECTIONS

106.1 Fittings

(A) Threaded, flanged, grooved and shouldered socket-welding, buttwelding, compression, and solder-joint fittings made in accordance with the applicable standards in Table 126.1 may be used in power piping systems within the material, size, pressure, and temperature limitations of those standards, and within any further limitations specified in this Code. Material for fittings in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

(B) Fittings not covered by the Standards listed in Table 126.1 may be used if they conform to para. 104.7.

(C) Cast buttwelding steel fittings not covered by the dimensional standards listed in Table 126.1 may be used up to the manufacturer's pressure and temperature ratings, provided they are radiographed in accordance with the method of ASTM E 142 and meet the acceptance requirements of ASTM E 446, E 186, and E 280 as applicable for the thickness being radiographed.

(D) Fabricated ends for grooved and shouldered type joints are acceptable, provided they are attached by full penetration welds, double fillet welds, or by threading. Fabricated ends attached by single fillet welds are not acceptable.

106.1.1 Bell and Spigot Fittings. Bell and spigot fittings complying with applicable standards listed in Table 126.1 may be used for cold water and drainage service.

106.2 Bends and Intersections

Bends and extruded branch connections may be used when designed in accordance with the provisions of paras. 104.2 and 104.3, respectively. Miters may be used within the limitations of para. 104.3.3.

106.3 Pipe Couplings

(A) Cast iron and malleable iron pipe couplings shall be limited in application as referenced in paras. 124.4 and 124.5, respectively.

(B) Straight thread couplings shall not be used.

106.4 Flexible Metal Hose Assembly

(A) Flexible metal hose assemblies may be used to provide flexibility in a piping system, to isolate or control vibration, or to compensate for misalignment. The design conditions shall be in accordance with para. 101 and within the limitations of the assembly as recommended by the manufacturer. The basis for their application shall include the following service conditions: thermal cycling, bend radius, cycle life, and the possibility of corrosion and erosion. Installation shall be limited to a single-plane bend, free from any torsion effects during service conditions and nonoperating periods. Type of end-connector components shall be consistent with the requirements of this Code.

(B) A flexible metal hose assembly, consisting of one continuous length of seamless or butt welded tube with helical or annular corrugations, is not limited as to application in piping systems which are within the scope of this Code, provided that the conditions described in (A) above are met. For application subject to internal pressure the flexible element shall be contained within one or more separate layers of braided metal permanently attached at both coupling ends by welding or brazing. For application in toxic fluid systems, it is recommended that the designer also review the standards published by the relevant fluid industry for any additional safety and materials requirements that may be necessary.

(C) A flexible metal hose assembly consisting of wound interlocking metal strips may be applied to atmospheric vent systems only and shall not be used in systems which convey high temperature, flammable, toxic, or searching-type fluids. Where applicable, as determined by the designer and within the limitations described in para. 122.6 and those imposed by the manufacturer, this type of hose assembly may be used at pressure relieving devices.

107 VALVES

107.1 General

(A) Valves complying with the standards and specifications listed in Table 126.1 shall be used within the specified pressure-temperature ratings.

(B) Valves not complying with (A) above shall be of a design, or equal to the design, which the manufacturer recommends for the service as stipulated in para. 102.2.2.

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(C) Some valves are capable of sealing simultaneously against a pressure differential between an internal cavity of the valve and the adjacent pipe in both directions. Where liquid is entrapped in such a valve and is subsequently heated, a dangerous rise in pressure can result. Where this condition is possible, the Owner shall provide means in design, installation, and/or operation to assure that the pressure in the valve shall not exceed the rated pressure for the attained temperature. A relief device used solely for the over-pressure protection from such entrapped fluid and conforming to (A) or (B) above need not comply with the requirements of para. 107.8. Any penetration of the pressure retaining wall of the valve shall meet the requirements of this Code.

(D) Only valves designed such that the valve stem is retained from blow-out by an assembly which functions independently of the stem seal retainer shall be used.

(E) Materials used for pressure retention for valves in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

107.2 Marking

Each valve shall bear the manufacturer's name or trademark and reference symbol to indicate the service conditions for which the manufacturer guarantees the valve. The marking shall be in accordance with ASME B16.5 and B16.34.

107.3 Ends

Valves may be used with flanged, threaded, butt welding, socket welding, or other ends in accordance with applicable standards as specified in para. 107.1(A).

107.4 Stem Threads

Stem threads of valves may be internal or external with reference to the valve bonnet. Outside screw and yoke design shall be used for valves NPS 3 and larger for pressures above 600 psi (4150 kPa).

107.5 Bonnet Joints

Bonnet joints may be of flanged, welded, pressure seal, union type, or other design, except that screwed bonnet connections in which the seal depends on a steam tight threaded joint shall not be permitted as source valves in steam service at pressures above 250 psi (1750 kPa).

107.6 Bypasses

Sizes of bypasses shall be in accordance with MSS SP-45 as a minimum standard. Pipe for bypasses shall be at least schedule 80 seamless, and of a material of the same nominal chemical composition and physical properties as that used for the main line. Bypasses may be integral or attached.

107.8 Safety, Safety Relief, and Relief Valves

107.8.1 General. Safety, safety relief, and relief valves shall conform to the requirements specified in this Code for flanges, valves, and fittings for the pressures and temperatures to which they may be subjected.

107.8.2 Safety, Safety Relief, and Relief Valves on Boiler External Piping. Safety, safety relief, and relief valves on boiler external piping shall be in accordance with para. 122.1.7(D.1) of this Code.

107.8.3 Safety, Safety Relief, and Relief Valves on Nonboiler External Piping. Safety, safety relief, and relief valves on nonboiler external piping (except for reheat safety valves) shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, UG-126 through UG-133. Reheat safety valves shall be in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section I, PG-67 through PG-73.

107.8.4 Nonmandatory Appendix. For nonmandatory rules for the design of safety valve installations, see Appendix II of this Code.

108 PIPE FLANGES, BLANKS, FLANGE FACINGS, GASKETS, AND BOLTING

108.1 Flanges

Flanges shall conform to the design requirements of para. 104.5.1 or to the standards listed in Table 126.1. They may be integral or shall be attached to pipe by threading, welding, brazing, or other means within the applicable standards specified in Table 126.1.

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108.2 Blanks

Blanks shall conform to the design requirements of para. 104.5.3.

108.3 Flange Facings

Flange facings shall be in accordance with the applicable standards listed in Tables 126.1 and 112. When bolting Class 150 standard steel flanges to flat face cast iron flanges, the steel flange shall be furnished with a flat face. Steel flanges of Class 300 raised face standard may be bolted to Class 250 raised face cast iron.

108.4 Gaskets

Gaskets shall be made of materials which are not injuriously affected by the fluid or by temperature. They shall be in accordance with Table 112.

108.5 U. S. Customary Bolting

108.5.1 General

(A) Bolts, bolt studs, nuts, and washers shall comply with applicable standards and specifications listed in Table 126.1 and Table 112. Bolts and bolt studs shall extend completely through the nuts.

(B) Washers, when used under nuts, shall be of forged or rolled material with steel washers being used under steel nuts and bronze washers under bronze nuts.

(C) Nuts shall be provided in accordance with the requirements of the specification for the bolts and bolt studs.

(D) Alloy steel bolt studs shall be either threaded full length or provided with reduced shanks of a diameter not less than that at the root of the threads. They shall have ASME heavy hexagonal nuts. Headed alloy bolts shall not be used with other than steel or stainless steel flanges.

(E) All alloy steel bolt studs and carbon steel bolts or bolt studs and accompanying nuts shall be threaded in accordance with ASME B1.1 Class 2A for external threads and Class 2B for internal threads. Threads shall be the coarse-thread series except that alloy steel bolting $1\frac{1}{8}$ in. and larger in diameter shall be the 8-pitch-thread series.

(F) Carbon steel headed bolts shall have square, hex, or heavy hex heads (ANSI B18.2.1) and shall be used with hex or heavy hex nuts (ASME B18.2.2). For bolt sizes smaller than $\frac{3}{4}$ in., square or heavy hex heads and heavy hex nuts are recommended. For bolt sizes larger than $1\frac{1}{2}$ in., bolt studs with a hex or heavy hex nut on each end are recommended. For cast iron or bronze flanges using $\frac{3}{4}$ in. and larger carbon steel headed bolts, square nuts may be used.

108.5.2 For the various combinations of flange materials, the selection of bolting materials and related rules concerning flange faces and gaskets shall be in accordance with para. 108 and Table 112.

108.5.3 Bolting requirements for components not covered by para. 108.5.2 shall be in accordance with para. 102.2.2

108.6 Metric Bolting

108.6.1 General. The use of metric bolts, bolt studs, nuts, and washers shall conform to the general requirements of para. 108.5, but the following are allowed. 01

(A) Threads shall be in accordance with ASME B1.13M, M profile, with tolerance Class 6g for external threads and Class 6H for internal threads.

(B) Threads shall be the coarse-thread series for size M68 and smaller, and 6 mm fine-pitch for M70 and larger sizes, except that alloy steel bolting M30 and larger shall be the 3 mm fine-pitch.

(C) Nuts shall be heavy hex in accordance with ASME B18.2.4.6M. Headed bolts shall be either hex or heavy hex in accordance with ASME B18.2.3.5M and B18.2.3.6M, respectively. Heavy hex heads are recommended for headed bolt sizes M18 and smaller.

(D) Bolt studs are recommended in lieu of headed bolts for sizes M39 and larger.

(E) Metric bolting is not approved for boiler external piping applications.

108.6.2 Responsibilities When Specifying or Allowing Metric Bolting 01

(A) The piping designer is responsible for specifying the metric bolt size to be used with each class and size of flange.

(B) The designer shall ensure that the selected metric size will fit within the flange bolt holes, and that adequate space exists for bolt heads, nuts, and the assembly tool.

(C) In those instances where the selected metric bolt size is smaller in root thread area than the corresponding U.S. Customary size, the designer shall ensure that the selected size is capable of the required assembly torque and of producing the required gasket loading to adequately seal at design pressure. Further, the designer shall ensure sufficient contact area exists between the flange metal and both the nut and bolt head to withstand the required bolt loading. If not, larger bolting or a higher flange class shall be selected.

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PART 4
SELECTION AND LIMITATIONS OF PIPING JOINTS

110 PIPING JOINTS

The type of piping joint used shall be suitable for the design conditions and shall be selected with consideration of joint tightness, mechanical strength, and the nature of the fluid handled.

111 WELDED JOINTS

111.1 General

Welded joints may be used in any materials allowed by this Code for which it is possible to qualify WPSs, welders, and welding operators in conformance with the rules established in Chapter V.

All welds shall be made in accordance with the applicable requirements of Chapter V.

111.2 Butt Welds

111.2.1 Design of Butt Welds. The design of butt welds shall include the evaluation of any expected joint misalignment [para. 127.3(C)], which may result from specification of joint geometries at variance with the recommendations of this Code.

111.2.2 Backing Rings for Butt Welds. If backing rings are used in services where their presence will result in severe corrosion or erosion, the backing ring shall be removed and the internal surface ground smooth. In such services, where it is impractical to remove the backing ring, consideration shall be given to welding the joint without a backing ring, or with a consumable type insert ring.

111.3 Socket Welds

111.3.1 Restrictions on size of socket welded components are given in paras. 104.3.1(B.4), 122.1.1(H), and 122.8.2(C). Special consideration should be given to further restricting the use of socket welded piping joints where temperature or pressure cycling or severe vibration is expected to occur or where the service may accelerate crevice corrosion.

111.3.2 Dimensions for sockets of socket welding components shall conform to ASME B16.5 for flanges and ASME B16.11 for fittings. Assembly of socket welded joints shall be made in accordance with para. 127.3(E).

111.3.3 A branch connection socket welded directly into the wall of the run pipe shall be in accordance with requirements of para. 104.3.1(B.4).

111.3.4 Drains and bypasses may be attached to a fitting or valve by socket welding, provided the socket depth, bore diameter, and shoulder thickness conform to the requirements of ASME B16.11.

111.4 Fillet Welds

Fillet welds shall have dimensions not less than the minimum dimensions shown in Figs. 127.4.4(B), 127.4.4(C), and 127.4.8(D).

111.5 Seal Welds

Seal welding of connections, including threaded joints, may be used to avoid joint leakage but the welding shall not be considered as contributing any strength to the joint. Also see para. 127.4.5. Seal welded threaded joints are subject to the limitations of para. 114.

112 FLANGED JOINTS

Flanged joints shall conform to paras. 108 and 110 and Table 112.

113 EXPANDED OR ROLLED JOINTS

Expanded or rolled joints may be used where experience or test has demonstrated that the joint is suitable for the design conditions and where adequate provisions are made to prevent separation of the joint.

114 THREADED JOINTS

Threaded joints may be used within the limitations specified in para. 106 and within the other limitations specified herein.

114.1

All threads on piping components shall be taper pipe threads in accordance with the applicable Standards listed in Table 126.1. Threads other than taper pipe threads may be used for piping components where tightness of the joint depends on a seal weld or a seating surface other than the threads, and where experience or test has demonstrated that such threads are suitable.

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(a)	Class 25 cast iron	Class 25 cast iron	(a)(1) "Low strength" [Notes (1), (2), and (5)]	(a)(1) Flat	(a)(1) Flat ring nonmetallic to ASME B16.21, Table 1
			(a)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(a)(2) Flat	(a)(2) Full face nonmetallic to ASME B16.21, Table 1
(b)	Class 125 cast iron	Class 125 cast iron, Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	"Low strength" [Notes (1), (2), and (5)]	Flat	Flat ring; nonmetallic to ASME B16.21, Table 2
(c)	Class 125 cast iron, Class 150 bronze, MSS SP-51 stainless steel, or nonmetallic	Class 125 cast iron, Class 150 bronze, Class 150 steel and stainless steel (including MSS SP-51), Class 150 ductile iron, or nonmetallic	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 2 [Notes (8), (9)]
(d)	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	Class 150 steel and stainless steel (excluding MSS SP-51), or Class 150 ductile iron	(d)(1) "Low strength" [Notes (1), (2), and (5)]	(d)(1) Raised or flat on one or both flanges	(d)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(d)(2) "Higher strength" [Notes (3), (4), and (5)]	(d)(2) Raised or flat on one or both flanges	(d)(2) Ring style to ASME B16.5, Annex E, Groups Ia and Ib, Fig. E3 [Notes (10) and (11)]
			(d)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(d)(3) Flat	(d)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material
(e)	Class 150 steel and stainless steel (excluding MSS SP-51)	Class 150 steel and stainless steel (excluding MSS SP-51)	"Higher strength" [Notes (3), (4), and (5)]	Ring joint	Ring joint to ASME B16.20

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(f)	Class 250 cast iron	Class 250 cast iron, Class 300 steel and stainless steel, or Class 300 ductile iron	(f)(1) "Low strength" [Notes (1), (2), and (5)]	(f)(1) Raised or flat on one or both flanges	(f)(1) Flat ring nonmetallic to ASME B16.21, Table 3
			(f)(2) "Higher strength" or "low strength" [Notes (1) through (5)]	(f)(2) Flat	(f)(2) Full face nonmetallic to ASME B16.21 Table 6 (Class 300)
(g)	Class 300 bronze	Class 250 cast iron, Class 300 bronze, Class 300 steel and stainless steel, or Class 300 ductile iron	"Higher strength" or "low strength" [Notes (1) through (7)]	Flat	Full face nonmetallic to ASME B16.21, Table 11 [Note (8)]
(h)	Class 300 ductile iron	Class 300 steel and stainless steel, or Class 300 ductile iron	(h)(1) "Low strength" [Notes (1), (2), and (5)]	(h)(1) Raised or flat on one or both flanges	(h)(1) Flat ring nonmetallic to ASME B16.5, Annex E, Group Ia, Fig. E3 [Note (11)]
			(h)(2) "Higher strength" [Notes (3), (4) and (5)]	(h)(2) Raised or flat on one or both flanges	(h)(2) Ring style to ASME B16.5, Annex E [Notes (10) and (11)]
			(h)(3) "Higher strength" or "low strength" [Notes (1) through (5)]	(h)(3) Flat	(h)(3) Full face nonmetallic to ASME B16.5, Annex E, Group Ia material [Note (11)]

(continued)

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TABLE 112
PIPING FLANGE BOLTING, FACING, AND GASKET REQUIREMENTS (CONT'D)
Refer to Paras. 108, 110, and 112

Item	Flange A Mating With Flange B		Bolting	Flange Facings	Gaskets
	Flange A	Flange B			
(l)	Class 300 and higher classes, steel and stainless steel	Class 300 and higher classes, steel and stainless steel	(l)(1) "Low strength" [Notes (1), (2), and (5)]	(l)(1) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(l)(1) Flat ring nonmetallic to ASME B16.5, Para. 6.11 and Annex E, Group Ia material [Note (11)]
			(l)(2) "Higher strength" [Notes (3), (4), and (5)]	(l)(2) Raised or flat on one or both flanges; large or small male and female; large or small tongue and groove	(l)(2) Ring style to ASME B16.5, Para. 6.11 and Annex E [Notes (10) and (11)]
			(l)(3) "Higher strength" [Notes (3), (4), and (5)]	(l)(3) Ring joint	(l)(3) Ring joint to ASME B16.20
(j)	Class 800 cast iron	Class 800 cast iron	"Low strength" [Notes (1), (2), and (5)]	Raised or large male and female	Flat ring nonmetallic to ASME B16.21, Table 4

GENERAL NOTES:

(a) Bolting (including nuts), flange facing, and gasket selection (materials, dimensions, bolt stress, gasket factor, seating stress, etc.) shall be suitable for the flanges, service conditions, and hydrostatic tests. There shall be no overstressing of the gasket or flanges from the expected bolt loading or external bending loads.

(b) Unless otherwise stated, the flange facing described applies to both flanges A and B.

(c) For flanges other than to ASME B16.1, in sizes larger than NPS 24 (NPS 12 in Class 2500), gasket dimensions should be verified against the flanges specified (e.g., MSS SP-44 and API 605).

(d) The effective seating of a full face gasket shall extend to the outside edge of the flange. For flat or raised face flanges, a flat ring or ring style gasket shall be self-centering, extending to the inner edge of the bolt holes or bolts. Where the joint contains a cast iron, bronze, nonmetallic, or MSS SP-51 stainless steel flange, the effective gasket seating shall extend to the outside diameter of the gasket.

(e) Unconfined nonmetallic gaskets shall not be used on flat or raised face flanges if the expected normal operating pressure exceeds 720 psi (4950 kPa) or the temperature exceeds 750°F (400°C). Metal gaskets, spiral wound gaskets of metal with nonmetallic filler, and confined nonmetallic gaskets are not limited as to pressure or temperature provided the gasket materials are suitable for the maximum fluid temperatures.

(continued)

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TABLE 112 (CONT'D)

NOTES:

(1) "Low strength" bolting shall conform to ASTM:

A 193, Grade B8A, B8CA, B8MA, or B8TA
A 193, Class 1, Grade B8, B8C, B8M, or B8T
A 307, Grade B [Bolting to A 307, Grade B shall not be used at temperatures greater than 400°F (200°C)]
A 320, Class 1, Grade B8, B8C, B8M, or B8T

(2) Nuts for "low strength" bolting shall conform to the grade of ASTM A 194 or A 563 as required by the bolting specification.

(3) "Higher strength" bolting shall conform to ASTM:

A 193, Grade B5, B6, B6X, B7, B7M, or B16
A 193, Class 2, Grade B8, B8C, B8M, or B8T
A 320, Grade L7, L7A, L7B, L7C, or L43
A 320, Class 2, Grade B8, B8C, B8F, B8M, or B8T
A 354, Grade BC or BD
A 437, Grade B4B, B4C, or B4D
A 453, Grade 651 or 660

(4) Nuts for "higher strength" bolting shall conform to the grade of ASTM A 194, A 437, A 453, A 563, or A 564, as required by the bolting specification.

(5) For temperatures below –20°F (–29°C), bolting conforming to the ASTM A 320 classes and grades listed, respectively, in Note (3) "higher strength" and Note (1) "low strength" shall be used. For this bolting to ASTM A 320, Grades L7, L7A, L7B, L7C, and L43, the nuts shall conform to ASTM A 194, Grade 4 or 7 with impact requirements of A 320. For bolting to the other grades of A 320, the nuts shall conform to A 320.

(6) Additionally, for joints containing bronze flanges, nonferrous bolting conforming to the following may be used:

ASTM B 98, UNS C65100, C65500, and C66100; half hard; to 350°F (177°C) maximum
ASTM B 150, UNS C61400, to 500°F (260°C) maximum
ASTM B 150, UNS C63000 and C64200, to 550°F (288°C) maximum
ASTM B 164, UNS N04400 and N04405; hot finish; 550°F (288°C) maximum
ASTM B 164, UNS N04400, cold drawn, cold drawn and stress relieved, or cold drawn and stress equalized; and N04405, cold drawn, to 500°F (260°C) maximum

(7) Where a flanged joint contains dissimilar materials (e.g., bronze flanges with steel bolting) and has a design temperature exceeding 300°F (149°C), the differences in coefficients of expansion shall be considered.

(8) For bronze flanges where "low strength" or nonferrous bolting is used, nonmetallic gaskets having seating stresses greater than 1600 psi shall not be used.

(9) For stainless steel flanges to MSS SP-51 and for nonmetallic flanges, preference shall be given to gasket materials having the lower minimum design seating stress as listed in ASME B16.5, Fig. E1, Group 1a.

(10) For items (d)(2), and (l)(2), where two flat face flanges are used in a joint and the gasket seating width (considering both the gasket and the flanges) is greater than that of an ASME B16.5 flange having a standard raised face, the gasket material shall conform to ASME B16.5, Annex E, Group 1a.

(11) Where asbestos sheet, fiber or filler material for gaskets is specified in ASME B16.5, this limitation shall not apply to ASME B31.1 applications. Any nonmetallic material suitable for the operating conditions may be used in lieu of asbestos provided the requirements of Table 112 are met.

01

TABLE 114.2.1

Maximum Nominal Size, in.	Maximum Pressure psi	Maximum Pressure kPa
3	400	2 750
2	600	4 150
1	1200	8 300
¾ and smaller	1500	10 350

GENERAL NOTE: For instrument, control and sampling lines, refer to para. 122.3.6(A.5)

114.2.1 Threaded joints shall not be used where severe erosion, crevice corrosion, shock, or vibration is expected to occur, nor at temperatures over 925°F (495°C). Size limits for steam and hot water service [above 220°F (105°C)] shall be as listed in Table 114.2.1.

114.2.2 Threaded access holes with plugs, which serve as openings for radiographic inspection of welds, are not subject to the limitations of para. 114.2.1 and Table 114.2.1, provided their design and installation meets the requirement of para. 114.1. A representative type of access hole and plug is shown in PFI ES-16.

114.2.3 Threaded connections for insertion type fluid temperature determination, flow measurement, and sampling devices are not subject to the temperature limitation stated in para. 114.2.1 nor the pressure limitations stated in Table 114.2.1 provided that design and installation meet the requirements of paras. 104.3.1 and 114.1. At temperatures greater than 925°F (495°C) or at pressures greater than 1500 psi (10 350 kPa), these threaded connections shall be seal welded in accordance with para. 127.4.5. The design and installation of insertion type fluid temperature determination, flow measurement, and sampling devices shall be adequate to withstand the effects of the fluid characteristics, fluid flow, and vibration.

114.3

Pipe with a wall thickness less than that of standard weight of ASME B36.10M steel pipe shall not be threaded, regardless of service. For additional threading limitations for pipe used in:

(A) steam service over 250 psi (1750 kPa); or

(B) water service over 100 psi (700 kPa) and 220°F (105°C).

See para. 104.1.2(C.1).

115 FLARED, FLARELESS, AND COMPRESSION JOINTS

Flared, flareless, and compression type tubing fittings may be used for tube sizes not exceeding 2 in. (50 mm) O.D. within the limitations of applicable standards and specifications listed in Table 126.1.

In the absence of standards, specifications, or allowable stress values for the material used to manufacture the fitting, the designer shall determine that the type and the material of the fitting selected is adequate and safe for the design conditions in accordance with the following requirements.

(A) The pressure design shall meet the requirements of para. 104.7.

(B) A suitable quantity of the type, size, and material of the fittings to be used shall meet successful performance tests to determine the safety of the joint under simulated service conditions. When vibration, fatigue, cyclic conditions, low temperature, thermal expansion, or hydraulic shock are expected, the applicable conditions shall be incorporated in the test.

115.1

Fittings and their joints shall be compatible with the tubing with which they are to be used and shall conform to the range of wall thicknesses and method of assembly recommended by the manufacturer.

115.2

Fittings shall be used at pressure-temperature ratings not exceeding the recommendations of the manufacturer. Service conditions, such as vibration and thermal cycling, shall be considered in the application.

115.3

See para. 114.1 for requirements of threads on piping components.

115.4

Flareless fittings shall be of a design in which the gripping member or sleeve shall grip or bite into the outer surface of the tube with sufficient strength to hold the tube against pressure, but without appreciably distorting the inside tube diameter. The gripping member shall also form a pressure seal against the fitting body.

When using bite type fittings, a spot check shall be made for adequate depth of bite and condition of tubing by disassembling and reassembling selected joints.

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Grip type fittings that are tightened in accordance with manufacturer's instructions need not be disassembled for checking.

116 CAULKED JOINTS

116.1

Caulked or leaded joints of the bell and spigot type which are caulked with lead and packing material may be used for cold water service.

116.2

Caulked joints may be used at pressures permitted for the pipe to which they are applied where provisions are made to prevent disengagement of the joints at bends and dead ends, and to support lateral reactions produced by branch connections or other causes.

117 BRAZED AND SOLDERED JOINTS

117.1

Brazed socket-type joints shall be made with suitable brazing alloys. The minimum socket depth shall be sufficient for the intended service. Brazing alloy shall either be end-fed into the socket or shall be provided in the form of a preinserted ring in a groove in the socket. The brazing alloy shall be sufficient to fill completely the annular clearance between the socket and the pipe or tube. The limitations of paras. 117.3(A) and (D) shall apply.

117.2

Soft soldered socket-type joints made in accordance with applicable standards listed in Table 126.1 may be used within their specified pressure-temperature ratings. The limitations in paras. 117.3 and 122.3.2(E.2.3) for instrument piping shall apply. The allowances of para. 102.2.4 do not apply.

117.3 Limitations

(A) Brazed socket-type joints shall not be used on systems containing flammable or toxic fluids in areas where fire hazards are involved.

(B) Soldered socket-type joints shall be limited to systems containing nonflammable and nontoxic fluids.

(C) Soldered socket-type joints shall not be used in piping subject to shock or vibration.

(D) Brazed or soldered joints depending solely upon a fillet, rather than primarily upon brazing or soldering material between the pipe and sockets, are not acceptable.

118 SLEEVE COUPLED AND OTHER PROPRIETARY JOINTS

Coupling type, mechanical gland type, and other proprietary joints may be used where experience or tests have demonstrated that the joint is safe for the operating conditions, and where adequate provision is made to prevent separation of the joint.

PART 5
EXPANSION, FLEXIBILITY, AND SUPPORTING

119 EXPANSION AND FLEXIBILITY

119.1 General

In addition to the design requirements for pressure, weight, and other loadings, power piping systems subject to thermal expansion or contraction or to similar movements imposed by other sources shall be designed in accordance with the requirements for the evaluation and analysis of flexibility and stresses specified herein.

119.2 Stress Range

Stresses caused by thermal expansion, when of sufficient initial magnitude, relax in the hot condition as a result of local yielding or creep. A stress reduction takes place and usually appears as a stress of reversed sign when the component returns to the cold condition. This phenomenon is designated as self-springing of the line and is similar in effect to cold springing. The extent of self-springing depends on the material, the magnitude of the initial expansion and fabrication stress, the hot service temperature and the elapsed time. While the expansion stress in the hot condition tends to diminish with time, the sum of the expansion strains for the hot and cold conditions during any one cycle remains substantially constant. This sum is referred to as the strain range; however, to permit convenient association with allowable stress, stress range is selected as the criterion for the thermal design of piping. The allowable stress range shall be determined in accordance with para. 102.3.2(C).

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119.3 Local Overstrain

All the commonly used methods of piping flexibility analysis assume elastic behavior of the entire piping system. This assumption is sufficiently accurate for systems where plastic straining occurs at many points or over relatively wide regions, but fails to reflect the actual strain distribution in unbalanced systems where only a small portion of the piping undergoes plastic strain, or where, in piping operating in the creep range, the strain distribution is very uneven. In these cases, the weaker or higher stressed portions will be subjected to strain concentrations due to elastic follow-up of the stiffer or lower stressed portions. Unbalance can be produced:

(A) by use of small pipe runs in series with larger or stiffer pipe, with the small lines relatively highly stressed;

(B) by local reduction in size or cross section, or local use of a weaker material; or

(C) in a system of uniform size, by use of a line configuration for which the neutral axis or thrust line is situated close to the major portion of the line itself, with only a very small offset portion of the line absorbing most of the expansion strain.

Conditions of this type should preferably be avoided, particularly where materials of relatively low ductility are used; if unavoidable, they may be mitigated by the judicious application of cold spring.

It is recommended that the design of piping systems of austentic steel materials be approached with greater over-all care as to inspection, material selection, fabrication quality, erection, and elimination of local stress raisers.

119.5 Flexibility

Power piping systems shall be designed to have sufficient flexibility to prevent pipe movements from causing failure from overstress of the pipe material or anchors, leakage at joints, or detrimental distortion of connected equipment resulting from excessive thrusts and moments. Flexibility shall be provided by changes of direction in the piping through the use of bends, loops, or offsets; or provisions shall be made to absorb thermal movements by utilizing expansion, swivel, or ball joints, corrugated pipe, or flexible metal hose assemblies.

119.5.1 Expansion, Swivel, or Ball Joints, and Flexible Metal Hose Assemblies. Except as stated in para. 101.7.2, these components may be used where experience or tests have demonstrated that they are suitable for expected conditions of pressure, temperature, service, and cyclic life.

Restraints and supports shall be provided, as required, to limit movements to those directions and magnitudes permitted for specific joint or hose assembly selected.

119.6 Properties

Thermal expansion data and moduli of elasticity shall be determined from Appendix B and Appendix C, Tables C-1 and C-2, which cover more commonly used piping materials. For materials not included in these Tables, reference shall be to authoritative source data such as publications of the National Institute of Standards and Technology.

119.6.1 Thermal Expansion Range. The thermal expansion range shall be determined from Appendix B as the difference between the unit expansion shown for the highest metal temperature and that for the lowest metal temperature resulting from operating or shutdown conditions.

119.6.2 Moduli of Elasticity. The cold and hot moduli of elasticity E_c and E_h shall be as shown in Appendix C, Table C-1 for ferrous materials and Table C-2 for nonferrous materials, based on the temperatures established in para. 119.6.1.

119.6.3 Poisson's Ratio. Poisson's ratio, when required for flexibility calculations, shall be taken as 0.3 at all temperatures for all materials.

119.6.4 Stresses. Calculations for the stresses shall be based on the least cross section area of the component, using nominal dimensions at the location of local strain. Calculations for the thermal expansion stress range S_E shall be based on the modulus of elasticity E_c at room temperature.

119.7 Analysis

119.7.1 Method of Analysis. All piping shall meet the following requirements with respect to thermal expansion and flexibility:

(A) It shall be the designer's responsibility to perform an analysis unless the system meets one of the following criteria.

(A.1) The piping system duplicates a successfully operating installation or replaces a system with a satisfactory service record.

(A.2) The piping system can be adjudged adequate by comparison with previously analyzed systems.

(A.3) The piping system is of uniform size, has not

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more than two anchors and no intermediate restraints, is designed for essentially noncyclic service (less than 7000 total cycles), and satisfies the following approximate criterion:

(a) English Units

$$\frac{DY}{(L-U)^2} \le 0.03$$

(b) SI Units

$$\frac{DY}{(L-U)^2} \le 208.3$$

where

D = nominal pipe size, in. (mm)
Y = resultant of movements to be absorbed by pipe lines, in. (mm)
L = developed length of line axis, ft (m)
U = anchor distance (length of straight line joining anchors), ft (m)

WARNING: No general proof can be offered that this equation will yield accurate or consistently conservative results. It was developed for ferrous materials and is not applicable to systems used under severe cyclic conditions. It should be used with caution in configurations such as unequal leg U-bends (L/U > 2.5), or near straight "saw-tooth" runs, or for large diameter thin-wall pipe, or where extraneous displacements (not in the direction connecting anchor points) constitute a large part of the total displacement. There is no assurance that terminal reactions will be acceptably low, even if a piping system falls within the above limitations.

(B) All systems not meeting the above criteria, or where reasonable doubt exists as to adequate flexibility of the system, shall be analyzed by simplified, approximate, or comprehensive methods of analysis that are appropriate for the specific case.

(C) Approximate or simplified methods may be applied only if they are used for the range of configurations for which their adequate accuracy has been demonstrated.

(D) Acceptable comprehensive methods of analysis include: analytical, model tests, and chart methods which provide an evaluation of the forces, moments and stresses caused by bending and torsion from the simultaneous consideration of terminal and intermediate restraints to thermal expansion of the entire piping system under consideration, and including all external movements transmitted to the piping by its terminal and intermediate attachments. Correction factors shall be applied for the stress intensification of curved pipe and branch connections, as provided by the details of these rules, and may be applied for the increased flexibility of such component parts.

119.7.3 Basic Assumptions and Requirements. In calculating the flexibility of a piping system between anchor points, the system between anchor points shall be treated as a whole. The significance of all parts of the line and of all restraints, such as supports or guides, including intermediate restraints introduced for the purpose of reducing moments and forces on equipment or small branch lines, shall be considered.

Flexibility calculations shall take into account stress intensifying conditions found in components and joints. Credit may be taken when extra flexibility exists in such components. In the absence of more directly applicable data, the flexibility factors and stress-intensification factors shown in Appendix D may be used.[2]

Dimensional properties of pipe and fittings used in flexibility calculations shall be based on nominal dimensions.

The total expansion range as determined from para. 119.6.1 shall be used in all calculations, whether or not the piping is cold sprung. Not only the expansion of the line itself, but also linear and angular movements of the equipment to which it is attached shall be considered.

Where simplifying assumptions are used in calculations or model tests, the likelihood of attendant underestimates of forces, moments, and stresses, including the effects of stress-intensification shall be evaluated.

119.8 Movements

Movements caused by thermal expansion and loadings shall be determined for consideration of obstructions and design of proper supports.

119.9 Cold Spring

The beneficial effect of judicious cold springing in assisting a system to attain its most favorable position sooner is recognized. Inasmuch as the life of a system under cyclic conditions depends on the stress range rather than the stress level at any one time, no credit for cold spring is allowed with regard to stresses. In

[2] The stress-intensification factors in Appendix D have been developed from fatigue tests of representative commercially available, matching product forms and assemblies manufactured from ductile ferrous materials. The allowable stress-range is based on tests of carbon and stainless steels. Caution should be exercised when applying Figs. (1) and (13) for the allowable stress-range for certain nonferrous materials (e.g., copper and aluminum alloys) for other than low cycle applications.

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calculating end thrusts and moments acting on equipment, the actual reactions at any one time, rather than their range, are significant. Credit for cold springing is accordingly allowed in the calculation of thrusts and moments, provided an effective method of obtaining the designed cold spring is specified and used.

119.10 Reactions

01 **119.10.1 Computing Hot and Cold Reactions.** In a piping system with no cold spring or an equal percentage of cold springing in all directions, the reactions (forces and moments) of R_h and R_c, in the hot and cold conditions, respectively, shall be obtained from the reaction R derived from the flexibility calculations based on the modulus of elasticity at room temperature E_c, using Eqs. (9) and (10).

$$R_h = \left(1 - \tfrac{2}{3}C\right)\left(\frac{E_h}{E_c}R\right) \tag{9}$$

$$R_c = -CR, \text{ or}$$

$$= -\left[1 - \frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)}\right]R \tag{10}$$

whichever is greater, and with the further condition that

$$\frac{(S_h)}{(S_E)} \cdot \frac{(E_c)}{(E_h)} < 1$$

where

C = cold spring factor varying from zero for no cold spring to 1.00 for 100% cold spring

S_E = computed thermal expansion stress range, psi (MPa)

E_c = modulus of elasticity in the cold condition, psi (MPa)

E_h = modulus of elasticity in the hot condition, psi (MPa)

R = maximum reaction for full expansion range based on E_c which assumes the most severe condition (100% cold spring, whether such is used or not), lb and in-lb (N and mm-N)

R_c, R_h = maximum reactions estimated to occur in the cold and hot conditions, respectively, lb and in.-lb (N and mm-N)

If a piping system is designed with different percentages of cold spring in various directions, Eqs. (9) and (10) are not applicable. In this case, the piping system shall be analyzed by a comprehensive method. The calculated hot reactions shall be based on theoretical cold springs in all directions not greater than two-thirds of the cold springs as specified or measured.

119.10.2 Reaction Limits. The reactions computed shall not exceed limits which the attached equipment can sustain. Equipment allowable reaction limits (forces and moments) on piping connections are normally established by the equipment manufacturer.

120 LOADS ON PIPE SUPPORTING ELEMENTS

120.1 General

(A) The broad terms "Supporting Elements" or "Supports" as used herein shall encompass the entire range of the various methods of carrying the weight of pipe lines, insulation, and the fluid carried. It therefore includes "hangers" which are generally considered as those elements which carry the weight from above, with the supporting members being mainly in tension. Likewise, it includes "supports" which on occasion are delineated as those which carry the weight from below, with the supporting members being mainly in compression. In many cases a supporting element may be a combination of both of these.

(B) In addition to the weight effects of piping components, consideration shall be given in the design of pipe supports to other load effects introduced by service pressure, wind, earthquake, etc., as defined in para. 101. Hangers and supporting elements shall be fabricated and assembled to permit the free movement of piping caused by thermal expansion and contraction. The design of elements for supporting or restraining piping systems, or components thereof, shall be based on all the concurrently acting loads transmitted into the supporting elements.

(C) Where the resonance with imposed vibration and/or shock occurs during operation, suitable dampeners, restraints, anchors, etc., shall be added to remove these effects.

120.2 Supports, Anchors, and Guides

120.2.1 Rigid Type Supports

(A) The required strength of all supporting elements shall be based on the loadings as given in para. 120.1, including the weight of the fluid transported or the fluid used for testing, whichever is heavier. The allow-

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able stress in supporting equipment shall be as specified in para. 121.2.

(B) Exceptions may be made in the case of supporting elements for large size gas or air piping, exhaust steam, relief or safety valve relief piping, but only under the conditions where the possibility of the line becoming full of water or other liquid is very remote.

120.2.2 Variable and Constant Supports. Load calculations for variable and constant supports, such as springs or counterweights, shall be based on the design operating conditions of the piping. They shall not include the weight of the hydrostatic test fluid. However, the support shall be capable of carrying the total load under test conditions, unless additional support is provided during the test period.

120.2.3 Anchors or Guides. Where anchors or guides are provided to restrain, direct, or absorb piping movements, their design shall take into account the forces and moments at these elements caused by internal pressure and thermal expansion.

120.2.4 Supplementary Steel. Where it is necessary to frame structural members between existing steel members, such supplementary steel shall be designed in accordance with American Institute of Steel Construction specifications, the Uniform Building Code, or similar recognized structural design standards. Increases of allowable stress values for short duration loading, such as outlined in para. 121.2(I), are not permitted.

121 DESIGN OF PIPE SUPPORTING ELEMENTS

121.1 General

Design of standard pipe supporting elements shall be in accordance with the rules of MSS SP-58. Allowable stress values and other design criteria shall be in accordance with this paragraph. Supporting elements shall be capable of carrying the sum of all concurrently acting loads as listed in para. 120. They shall be designed to provide the required supporting effort and allow pipeline movement with thermal changes without causing overstress. The design shall also prevent complete release of the piping load in the event of spring failure or misalignment. All parts of the supporting equipment shall be fabricated and assembled so that they will not be disengaged by movement of the supported piping. The maximum safe loads for bolts, threaded hanger rods, and all other threaded members shall be based on the root area of the threads.

121.2 Allowable Stress Values 01

(A) Allowable stress values tabulated in MSS SP-58 or in Appendix A of this Code Section may be used for the base materials of all parts of pipe supporting elements.

(B) Where allowable stress values for a material specification listed in Table 126.1 are not tabulated in Appendix A or in MSS SP-58, allowable stress values from Section II, Part D, Tables 1A and 1B of the ASME Boiler and Pressure Vessel Code may be used, provided the requirements of para. 102.3.1(B) are met. Where there are no stress values given in Section II, Part D, Tables 1A and 1B, an allowable stress value of 25% of the minimum tensile strength given in the material specification may be used, for temperatures not exceeding 650°F (345°C).

(C) For a steel material of unknown specification, or of a specification not listed in Table 126.1 or MSS SP-58, an allowable stress value of 30% of yield strength (0.2% offset) at room temperature may be used at temperatures not exceeding 650°F (345°C). The yield strength shall be determined through a tensile test of a specimen of the material and shall be the value corresponding to 0.2% permanent strain (offset) of the specimen. The allowable stress values for such materials shall not exceed 9500 psi (65.5 MPa).

(D) The allowable shear stress shall not exceed 80% of the values determined in accordance with the rules of (A), (B), and (C) above.

(E) The allowable compressive stress shall not exceed the value as determined in accordance with the rules of (A), (B), or (C) above. In addition, consideration shall be given to structural stability.

(F) The allowable bearing stress shall not exceed 160% of the value as determined in accordance with the rules of (A), (B), or (C) above.

(G) The allowable base material tensile stress determined from (A), (B), or (C) above shall be reduced 25% for threaded hanger rods.

(H) The allowable stress in welds in support assemblies shall be reduced 25% from those determined in accordance with (A), (B), (C), or (D) above for the weaker of the two metals joined.

(I) Increases in the allowable stress values shall be permitted as follows:

(1) an increase of 20% for short time overloading during operation;

(2) an increase to 80% of the minimum yield strength at room temperature during hydrostatic testing. Where the material allowable stress has been established in accordance with the rules of (C) above, the allowable

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stress value during hydrostatic testing shall not exceed 16,000 psi (110.3 MPa).

121.3 Temperature Limitations

Parts of supporting elements which are subjected principally to bending or tension loads and which are subjected to working temperatures for which carbon steel is not recommended shall be made of suitable alloy steel, or shall be protected so that the temperature of the supporting member will be maintained within the appropriate temperature limits of the material.

121.4 Hanger Adjustments

Hangers used for the support of piping, NPS 2½ and larger, shall be designed to permit adjustment after erection while supporting the load. Screwed adjustments shall have threaded parts to conform to ASME B1.1.

Class 2 fit turnbuckles and adjusting nuts shall have the full length of thread in engagement. Means shall be provided for determining that full thread length is in engagement. All screw and equivalent adjustments shall be provided with suitable locking devices.

121.5 Hanger Spacing

Supports for piping with the longitudinal axis in approximately a horizontal position shall be spaced to prevent excessive sag, bending and shear stresses in the piping, with special consideration given where components, such as flanges and valves, impose concentrated loads. Where calculations are not made, suggested maximum spacing of supports for standard and heavier pipe are given in Table 121.5. Vertical supports shall be spaced to prevent the pipe from being overstressed from the combination of all loading effects.

121.6 Springs

The springs used in variable or constant effort type supports shall be designed and manufactured in accordance with MSS SP-58.

121.7 Fixtures

121.7.1 Anchors and Guides

(A) Anchors, guides, pivots, and restraints shall be designed to secure the desired points of piping in relatively fixed positions. They shall permit the piping to expand and contract freely in directions away from the anchored or guided point and shall be structurally suitable to withstand the thrusts, moments, and other loads imposed.

TABLE 121.5
SUGGESTED PIPE SUPPORT SPACING

Nominal Pipe Size, NPS	Suggested Maximum Span			
	Water Service		Steam, Gas, or Air Service	
	ft	m	ft	m
1	7	2.1	9	2.7
2	10	3.0	13	4.0
3	12	3.7	15	4.6
4	14	4.3	17	5.2
6	17	5.2	21	6.4
8	19	5.8	24	7.3
12	23	7.0	30	9.1
16	27	8.2	35	10.7
20	30	9.1	39	11.9
24	32	9.8	42	12.8

GENERAL NOTES:

(a) Suggested maximum spacing between pipe supports for horizontal straight runs of standard and heavier pipe at maximum operating temperature of 750°F (400°C).

(b) Does not apply where span calculations are made or where there are concentrated loads between supports, such as flanges, valves, specialties, etc.

(c) The spacing is based on a fixed beam support with a bending stress not exceeding 2300 psi (15.86 MPa) and insulated pipe filled with water or the equivalent weight of steel pipe for steam, gas, or air service, and the pitch of the line is such that a sag of 0.1 in. (2.5 mm) between supports is permissible.

(B) Rolling or sliding supports shall permit free movement of the piping, or the piping shall be designed to include the imposed load and frictional resistance of these types of supports, and dimensions shall provide for the expected movement of the supported piping. Materials and lubricants used in sliding supports shall be suitable for the metal temperature at the point of sliding contact.

(C) Where corrugated or slip-type expansion joints, or flexible metal hose assemblies are used, anchors and guides shall be provided where necessary to direct the expansion into the joint or hose assembly. Such anchors shall be designed to withstand the force specified by the manufacturer for the design conditions at which the joint or hose assembly is to be used. If this force is otherwise unknown, it shall be taken as the sum of the product of the maximum internal area times the design pressure plus the force required to deflect the joint or hose assembly. Where expansion joints or flexible metal hose assemblies are subjected to a combination of longitudinal and transverse movements, both movements shall be considered in the design and application of the joint or hose assembly.

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TABLE 121.7.2(A)
CARRYING CAPACITIES OF THREADED ASTM A 36, A 575, AND A 576 HOT ROLLED CARBON STEEL

Nominal Rod Diameter, in.	Root Area of Coarse Thread		Max. Safe Load at Rod Temp. of 650°F (345°C)	
	sq in.	sq mm	lb	kg
3/8	0.068	43.87	610	276
1/2	0.126	81.29	1,130	512
5/8	0.202	130.3	1,810	821
3/4	0.302	194.8	2,710	1 229
7/8	0.419	270.3	3,770	1 710
1	0.552	356.1	4,960	2 250
1 1/4	0.889	573.5	8,000	3 629
1 1/2	1.293	834.2	11,630	5 275
1 3/4	1.744	1 125	15,690	7 117
2	2.292	1 479	20,690	9 385
2 1/4	3.021	1 949	27,200	12 338
2 1/2	3.716	2 397	33,500	15 195
2 3/4	4.619	2 980	41,600	18 869
3	5.621	3 626	50,600	22 952
3 1/4	6.720	4 335	60,500	27 442
3 1/2	7.918	5 108	71,260	32 323
3 3/4	9.214	5 945	82,900	37 640
4	10.608	6 844	95,500	43 360
4 1/4	12.100	7 806	108,900	49 440
4 1/2	13.690	8 832	123,200	55 930
4 3/4	15.379	9 922	138,400	62 830
5	17.165	11 074	154,500	70 140

GENERAL NOTE: Tabulated loads are based on an allowable tensile stress of 12,000 psi (82.7 MPa) reduced by 25% using the root thread area as a base. [Refer to para. 121.2(A).]

Flexible metal hose assemblies, applied in accordance with para. 106.4, shall be supported in such a manner as to be free from any effects due to torsion and undue strain as recommended by the manufacturer.

121.7.2 Other Rigid Types

(A) Hanger Rods. Safe loads for threaded hanger rods shall be based on the root area of the threads and allowable stress of the material. In no case shall hanger rods less than 3/8 in. (9.5 mm) diameter be used for support of pipe NPS 2 and smaller, or less than 1/2 in. (12.5 mm) diameter rod for supporting pipe NPS 2 1/2 and larger. See Table 121.7.2(A) for carbon steel rods.

Pipe, straps, or bars of strength and effective area equal to the equivalent hanger rod may be used instead of hanger rods.

Hanger rods, straps, etc., shall be designed to permit the free movement of piping caused by thermal expansion and contraction.

(B) Welded link chain of 3/16 in. (5.0 mm) or larger diameter stock, or equivalent area, may be used for pipe hangers with a design stress of 9000 psi (62 MPa) maximum.

(C) Cast iron in accordance with ASTM A 48 may be used for bases, rollers, anchors, and parts of supports where the loading will be mainly compression. Cast iron parts shall not be used in tension.

(D) Malleable iron castings in accordance with ASTM A 47 may be used for pipe clamps, beam clamps, hanger flanges, clips, bases, swivel rings, and parts of pipe supports, but their use shall be limited to temperatures not in excess of 450°F (230°C). This material is

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not recommended for services where impact loads are anticipated.

(E) Brackets shall be designed to withstand forces and moments induced by sliding friction in addition to other loads.

121.7.3 Variable Supports

(A) Variable spring supports shall be designed to exert a supporting force equal to the load, as determined by weight balance calculations, plus the weight of all hanger parts (such as clamp, rod, etc.) that will be supported by the spring at the point of attachment to the pipe.

(B) Variable spring supports shall be provided with means to limit misalignment, buckling, eccentric loading, or to prevent overstressing of the spring.

(C) It is recommended that all hangers employing springs be provided with means to indicate at all times the compression of the spring with respect to the approximate hot and cold positions of the piping system, except where they are used either to cushion against shock or where the operating temperature of the piping system does not exceed 250°F (120°C).

(D) It is recommended that the support be designed for a maximum variation in supporting effort of 25% for the total travel resulting from thermal movement.

121.7.4 Constant Supports. On high temperature and critical service piping at locations subject to appreciable movement with thermal changes, the use of constant support hangers, designed to provide a substantially uniform supporting force throughout the range of travel, is recommended.

(A) Constant support hangers shall have a support variation of no more than 6% throughout the total travel range.

(B) Counterweight type supports shall be provided with stops, and the weights shall be positively secured. Chains, cables, hanger and rocker arm details, or other devices used to attach the counterweight load to the piping, shall be subject to requirements of para. 121.7.2.

(C) Hydraulic type supports utilizing a hydraulic head may be installed to give a constant supporting effort. Safety devices and stops shall be provided to support the load in case of hydraulic failure.

(D) Boosters may be used to supplement the operation of constant support hangers.

121.7.5 Sway Braces. Sway braces or vibration dampeners shall be used to control the movement of piping due to vibration.

121.7.6 Shock Suppressors. For the control of piping due to dynamic loads, hydraulic or mechanical types of shock suppressors are permitted. These devices do not support pipe weight.

121.8 Structural Attachments

121.8.1 Nonintegral Type

(A) Nonintegral attachments include clamps, slings, cradles, saddles, straps, and clevises.

(B) When clamps are used to support vertical lines, it is recommended that shear lugs be welded to the pipe to prevent slippage. The provisions of para. 121.8.2(B) shall apply.

(C) In addition to the provision of (B) above, clamps to support vertical lines should be designed to support the total load on either arm in the event the load shifts due to pipe and/or hanger movement.

121.8.2 Integral Type

(A) Integral attachments include ears, shoes, lugs, cylindrical attachments, rings, and skirts which are fabricated so that the attachment is an integral part of the piping component. Integral attachments shall be used in conjunction with restraints or braces where multiaxial restraint in a single member is to be maintained. Consideration shall be given to the localized stresses induced into the piping component by the integral attachments. Where applicable, the conditions of para. 121.8.1(C) are to apply.

(B) Integral lugs, plates, angle clips, etc., used as part of an assembly for the support or guiding of pipe may be welded directly to the pipe provided the materials are compatible for welding and the design is adequate for the temperature and load. The design of hanger lugs for attachment to piping for high temperature service shall be such as to provide for differential expansion between the pipe and the attached lug.

Welds shall be proportioned so that the shear stresses do not exceed either 0.8 times the applicable S values for the pipe material shown in the Allowable Stress Tables, or the allowable stress values determined in accordance with para. 121.2(A), (B), or (C). If materials for attachments have different allowable stress values than the pipe, the lower allowable stress value of the two shall be used.

121.9 Loads and Supporting Structures

121.9.1 Considerations shall be given to the load carrying capacity of equipment and the supporting structure. This may necessitate closer spacing of hangers on lines with extremely high loads.

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121.10 Requirements for Fabricating Pipe Supports

121.10.1 Pipe supports shall be fabricated in accordance with the requirements of para. 130.

PART 6
SYSTEMS

122 DESIGN REQUIREMENTS PERTAINING TO SPECIFIC PIPING SYSTEMS

Except as specifically stated otherwise in this Part 6, all provisions of the Code apply fully to the piping systems described herein.

122.1 Boiler External Piping; in Accordance With Para. 100.1.2(A) — Steam, Feedwater, Blowoff, and Drain Piping

122.1.1 General. The minimum pressure and temperature and other special requirements to be used in the design for steam, feedwater, blowoff, and drain piping from the boiler to the valve or valves required by para. 122.1 shall be as specified in the following paragraphs. Design requirements for desuperheater spray piping connected to desuperheaters located in the boiler proper are provided in para. 122.4.

(A) It is intended that the design pressure and temperature be selected sufficiently in excess of any expected operating conditions, not necessarily continuous, to permit satisfactory operation without operation of the overpressure protection devices. Also, since the operating temperatures of fired equipment can vary, the expected temperature at the connection to the fired equipment shall include the manufacturer's maximum temperature tolerance.

(B) In a forced flow steam generator with no fixed steam and waterline, it is permissible to design the external piping, valves, and fittings attached to the pressure parts for different pressure levels along the path through the steam generator of water-steam flow. The values of design pressure and the design temperature to be used for the external piping, valves, and fittings shall be not less than that required for the expected maximum sustained operating pressure and temperature to which the abutted pressure part is subjected except when one or more of the overpressure protection devices covered by PG-67.4 of Section I of the ASME Boiler and Pressure Vessel Code is in operation. The steam piping shall comply with the requirements for the maximum sustained operating conditions as used in (A) above, or for the design throttle pressure plus 5%, whichever is greater.

(C) Provision shall be made for the expansion and contraction of piping connected to boilers to limit forces and moments transmitted to the boiler, by providing substantial anchorage at suitable points, so that there shall be no undue strain transmitted to the boiler. Steam reservoirs shall be used on steam mains when heavy pulsations of the steam currents cause vibration.

(D) Piping connected to the outlet of a boiler for any purpose shall be attached by:

(D.1) welding to a nozzle or socket welding fitting;

(D.2) threading into a tapped opening with a threaded fitting or valve at the other end;

(D.3) screwing each end into tapered flanges, fittings, or valves with or without rolling or peening;

(D.4) bolted joints including those of the Van Stone type;

(D.5) blowoff piping of firetube boilers shall be attached in accordance with (D.2) above if exposed to products of combustion or in accordance with (D.2), (D.3), or (D.4) above if not so exposed.

(E) Nonferrous pipe or tubes shall not exceed NPS 3 in diameter.

(F) American National Standard slip-on flanges shall not exceed NPS 4. Attachment of slip-on flanges shall be by double fillet welds. The throats of the fillet welds shall not be less than 0.7 times the thickness of the part to which the flange is attached.

(G) Hub-type flanges shall not be cut from plate material.

(H) American National Standard socket welded flanges may be used in piping or boiler nozzles provided the dimensions do not exceed NPS 3 for Class 600 and lower and NPS $2\frac{1}{2}$ in Class 1500.

122.1.2 Steam Piping

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For steam piping connected to the steam drum or to the superheater inlet header up to the first stop valve in each connection, the value of P shall be not less than the lowest pressure at which any drum safety valve is set to blow, and the S value shall not exceed that permitted for the corresponding saturated steam temperature.

(A.2) For steam piping connected to the superheater outlet header up to the first stop valve in each connection, the design pressure, except as otherwise provided in (A.4) below shall be not less than the lowest pressure at which any safety valve on the superheater is set to blow, or not less than 85% of the lowest pressure at

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which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.3) For steam piping between the first stop valve and the second valve, when one is required by para. 122.1.7, the design pressure shall be not less than the expected maximum sustained operating pressure or 85% of the lowest pressure at which any drum safety valve is set to blow, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature.

(A.4) For boilers installed on the unit system (i.e., one boiler and one turbine or other prime mover) and provided with automatic combustion control equipment responsive to steam header pressure, the design pressure for the steam piping shall be not less than the design pressure at the throttle inlet plus 5%, or not less than 85% of the lowest pressure at which any drum safety valve is set to blow, or not less than the expected maximum sustained operating pressure at any point in the piping system, whichever is greater, and the S value for the material used shall not exceed that permitted for the expected steam temperature at the superheater outlet. For forced-flow steam generators with no fixed steam and waterline, the design pressure shall also be no less than the expected maximum sustained operating pressure.

(A.5) The design pressure shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material.

122.1.3 Feedwater Piping

(A) The value of P to be used in the formulas in para. 104 shall be as follows.

(A.1) For piping from the boiler to and including the required stop valve and the check valve, the minimum value of P except as permitted in para. 122.1.3(A.4) shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa), whichever is the lesser. For an installation with an integral economizer without valves between the boiler and economizer, this paragraph shall apply only to the piping from the economizer inlet header to and including the required stop valve and the check valve.

(A.2) For piping between the required check valve and the globe or regulating valve, when required by para. 122.1.7(B), and including any bypass piping up to the shutoff valves in the bypass, the value of P shall be not less than the pressure required to feed the boiler.

(A.3) The value of P in the formula shall not be taken at less than 100 psig [700 kPa (gage)] for any condition of service or material, and shall never be less than the pressure required to feed the boiler.

(A.4) In a forced flow steam generator with no fixed steam and waterline, the value of P for feedwater piping from the boiler to and including the required stop valve may be in accordance with the requirements of para. 122.1.1(B).

(B) The S value used, except as permitted in (A.4) above, shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(C) The size of the feed piping between the boiler and the first required valve [para. 122.1.7(B)] or the branch feed connection [para. 122.1.7(B.4)] shall, as a minimum, be the same as the boiler connection.

122.1.4 Blowoff and Blowdown Piping. Blowoff and blowdown piping are defined as piping connected to a boiler and provided with valves or cocks through which the water in the boiler may be blown out under pressure. This definition is not intended to apply to (i) drain piping, and (ii) piping such as used on water columns, gage glasses, or feedwater regulators, etc., for the purpose of determining the operating condition of the equipment. Requirements for (i) and (ii) are described in paras. 122.1.5 and 122.1.6. Blowoff systems are operated intermittently to remove accumulated sediment from equipment and/or piping, or to lower boiler water level in a rapid manner. Blowdown systems are primarily operated continuously to control the concentrations of dissolved solids in the boiler water.

(A) Blowoff piping systems from water spaces of a boiler, up to and including the blowoff valves, shall be designed in accordance with (A.1) to (A.4) below. Two shutoff valves are required in the blowoff system; specific valve requirements and exceptions are given in para. 122.1.7(C).

(A.1) The value of P to be used in the formulas in para. 104 shall exceed the maximum allowable working pressure of the boiler by either 25% or 225 psi (1550 kPa) whichever is less, but shall not be less than 100 psig [700 kPa (gage)].

(A.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(A.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowoff piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable

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iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(A.4) The size of blowoff piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3 and PEB-12.

(B) The blowdown piping system from the boiler, to and including the shutoff valve, shall be designed in accordance with (B.1) through (B.4) below. Only one shutoff valve is required in the blowdown system.

(B.1) The value of P to be used in the formulas in para. 104 shall be not less than the lowest set pressure of any safety valve on the boiler drum.

(B.2) The allowable stress value for the piping materials shall not exceed that permitted for the temperature of saturated steam at the maximum allowable working pressure of the boiler.

(B.3) All pipe shall be steel. Galvanized steel pipe and fittings shall not be used for blowdown piping. When the value of P does not exceed 100 psig [700 kPa (gage)], the fittings shall be bronze, cast iron, malleable iron, ductile iron, or steel. When the value of P exceeds 100 psig [700 kPa (gage)], the fittings shall be steel and the thickness of pipe and fittings shall not be less than that of Schedule 80 pipe.

(B.4) The size of blowdown piping shall be not less than the size of the connection on the boiler, and shall be in accordance with the rules contained in the ASME Boiler and Pressure Vessel Code, Section I, PG-59.3.

(C) The blowoff and blowdown piping beyond the required valves described in (A) and (B) above are classified as nonboiler external piping. The requirements are given in para. 122.2.

122.1.5 Boiler Drains

(A) Complete drainage of the boiler and attached piping shall be provided to the extent necessary to ensure proper operation of the steam supply system. The pipe, fittings, and valves of any drain line shall not be smaller than the drain connection.

(B) If the drain lines are intended to be used both as drains and as blowoffs, then two valves are required and all conditions of paras. 122.1.4, 122.1.7(C), and 122.2 shall be met.

(C) When a drain is intended for use only when the boiler is not under pressure (pressurizing the boiler for rapid drainage is an exception), a single shutoff valve is acceptable under the following conditions: either the valve shall be a type that can be locked in the closed position or a suitable flanged and bolted connection that accepts a blank insert shall be located on the downstream side of the valve. When a single valve is used, it need not be designed for blowoff service.

(D) Drain piping from the drain connection, including the required valve(s) or the blanked flange connection, shall be designed for the temperature and pressure of the drain connection. The remaining piping shall be designed for the expected maximum temperature and pressure. Static head and possible choked flow conditions shall be considered. In no case shall the design pressure and temperature be less than 100 psig [700 kPa (gage)] and 220°F (104°C), respectively.

122.1.6 Boiler External Piping — Miscellaneous Systems

(A) Materials, design, fabrication, examination, and erection of piping for miscellaneous accessories, such as water level indicators, water columns, gage cocks, and pressure gages, shall be in accordance with the applicable sections of this Code.

(B) The value of P to be used in the Formulas in para. 104 shall be not less than the maximum allowable working pressure of the boiler except as provided by para. 122.1.1(B).

(C) Valve requirements for water level indicators or water columns, special gage glass and gage cock requirements, minimum line sizes, and special piping configurations required specifically for cleaning, access, or reliability shall be in accordance with PG-60 of Section I of the ASME Boiler and Pressure Vessel Code.

122.1.7 Valves and Fittings. The minimum pressure and temperature rating for all valves and fittings in steam, feedwater, blowoff, and miscellaneous piping shall be equal to the pressure and temperature specified for the connected piping on the side that has the higher pressure, except that in no case shall the pressure be less than 100 psig [700 kPa (gage)], and for pressures not exceeding 100 psig [700 kPa (gage)] in feedwater and blowoff service, the valves and fittings shall be equal at least to the requirements of the ASME standards for Class 125 cast iron or Class 150 steel.

(A) Steam Stop Valves. Each boiler discharge outlet, except safety valve or safety relief valve connections, or reheater inlet and outlet connections, shall be fitted with a stop valve located at an accessible point in the steam-delivery line and as near to the boiler nozzle as is convenient and practicable.

(A.1) Boiler stop valves shall provide bidirectional shutoff at design conditions. The valve or valves shall meet the requirements of para. 107. Valves with resilient

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(nonmetallic) seats shall not be used where the boiler maximum allowable working pressure exceeds 1035 kPa (150 psig) or where the system design temperature exceeds 186°C (366°F). Valves of the outside screw and yoke, rising stem style are preferred. Valves other than those of the outside screw and yoke, rising stem style shall meet the following additional requirements.

(A.1.A) Each valve shall be equipped with a position indicator to visually indicate from a distance whether the valve is open or closed.

(A.1.B) Quarter turn valves shall be equipped with a slow operating mechanism to minimize dynamic loadings on the boiler and attached piping.

(A.2) In the case of a single boiler and prime mover installation, the stop valve required herein may be omitted provided the prime mover throttle valve is equipped with an indicator to show whether it is opened or closed, and it is designed to withstand the required boiler hydrostatic test.

01 *(A.3)* When two or more boilers are connected to a common header, or when a single boiler is connected to a header having another steam source, the connection from each boiler having a man-hole opening shall be fitted with two stop valves having an ample free-blow drain between them. The preferred arrangement consists of one stop-check valve (located closest to the boiler) and one valve of the style and design described in (A.1) above. Alternatively, both valves may be of the style and design described in (A.1) above.

When a second stop valve is required, it shall have a pressure rating at least equal to that required for the expected steam pressure and temperature at the valve, or a pressure rating at least equal to 85% of the lowest set pressure of any safety valve on the boiler drum at the expected temperature of the steam at the valve, whichever is greater.

(A.4) All valves and fittings on steam lines shall have a pressure rating of at least 100 psig [700 kPa (gage)] in accordance with the applicable ASME Standard.

(B) Feedwater Valves

(B.1) The feedwater piping for all boilers, except for high temperature water boilers complying with the requirements of (B.8) below, and for forced flow steam generators with no fixed steam and water line complying with the requirements of (B.9) below, shall be provided with a check valve and a stop valve or cock between the check valve and the boiler. The stop valve or cock shall comply with the requirements of (C.5) below.

(B.2) The relative locations of the check and stop (or cock) valves, as required in (B.1) above, may be reversed on a single boiler-turbine unit installation.

(B.3) If a boiler is equipped with a duplicate feed arrangement, each such arrangement shall be equipped as required by these rules.

(B.4) When the supply line to a boiler is divided into branch feed connections and all such connections are equipped with stop and check valves, the stop and check valves in the common source may be omitted.

(B.5) When two or more boilers are fed from a common source, there shall also be a globe or regulating valve in the branch to each boiler located between the check valve and the source of supply. A typical arrangement is shown in Fig. 100.1.2(B). Wherever globe style valves are used on feed piping, the inlet shall be under the disk of the valve.

(B.6) A combination stop and check valve in which there is only one seat and disk, and in which a valve stem is provided to close the valve, shall be considered only as a stop valve, and a check valve shall be installed as otherwise provided.

(B.7) Where an economizer or other feedwater heating device is connected directly to the boiler without intervening valves, the feed valves and check valves required shall be placed on the inlet of the economizer or feedwater heating device.

(B.8) The recirculating return line for a high temperature water boiler shall be provided with the same stop valve, or valves, required by (B.1) and (B.3) above. The use of a check valve in the recirculating return line is optional. A check valve shall not be a substitute for a stop valve.

(B.9) The feedwater boiler external piping for a forced flow steam generator with no fixed steam and water line may terminate up to and including the stop valve(s) and omitting the check valve(s) provided that a check valve having a pressure rating no less than the boiler inlet design pressure is installed at the discharge of each boiler feed pump or elsewhere in the feedline between the feed pump and the stop valve(s).

(C) Blowoff Valves

(C.1) Ordinary globe valves as shown in Fig. 122.1.7(C) sketch (1), and other types of valves that have dams or pockets where sediment can collect, shall not be used on blowoff connections.

(C.2) Y-type globe valves as shown in Fig. 122.1.7(C) sketch (2) or angle valves may be used in vertical pipes, or they may be used in horizontal runs of piping provided they are so constructed or installed that the lowest edge of the opening through the seat is at least 25% of the inside diameter below the center line of the valve.

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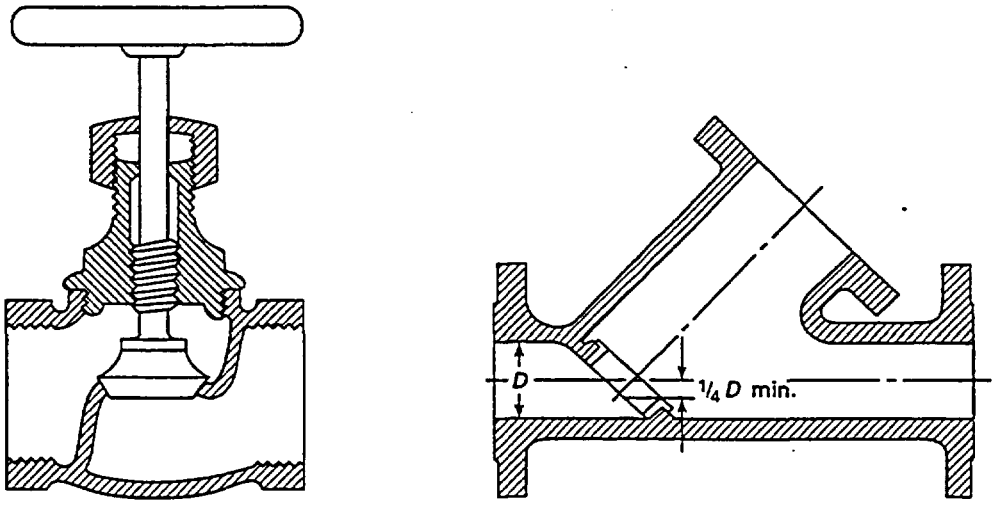

FIG. 122.1.7(C) TYPICAL GLOBE VALVES

(C.3) The blowoff valve or valves, the pipe between them, and the boiler connection shall be of the same size except that a larger pipe for the return of condensate may be used.

(C.4) For all boilers [except electric steam boilers having a normal water content not exceeding 100 gal (380 l), traction-purpose, and portable steam boilers; see (C.11) and (C.12) below] with allowable working pressure in excess of 100 psig [700 kPa (gage)], each bottom blowoff pipe shall have two slow-opening valves, or one quick-opening valve or cock, at the boiler nozzle followed by a slow-opening valve. All valves shall comply with the requirements of (C.5) and (C.6) below.

(C.5) When the value of P required by para. 122.1.4(A.1) does not exceed 250 psig [1750 kPa (gage)], the valves or cocks shall be bronze, cast iron, ductile iron, or steel. The valves or cocks, if of cast iron, shall not exceed NPS $2\frac{1}{2}$ and shall meet the requirements of the applicable ASME Standard for Class 250, as given in Table 126.1, and if of bronze, steel, or ductile iron construction, shall meet the requirements of the applicable standards as given in Table 126.1 or para. 124.6.

(C.6) When the value of P required by para. 122.1.4(A.1) is higher than 250 psig [1750 kPa (gage)], the valves or cocks shall be of steel construction equal at least to the requirements of Class 300 of the applicable ASME Standard listed in Table 126.1. The minimum pressure rating shall be equal to the value of P required by para. 122.1.4(A.1).

(C.7) If a blowoff cock is used, the plug shall be held in place by a guard or gland. The plug shall be distinctly marked in line with the passage.

(C.8) A slow-opening valve is a valve which requires at least five 360 deg turns of the operating mechanism to change from fully closed to fully opened.

(C.9) On a boiler having multiple blowoff pipes, a single master valve may be placed on the common blowoff pipe from the boiler, in which case only one valve on each individual blowoff is required. In such a case, either the master valve or the individual valves or cocks shall be of the slow-opening type.

(C.10) Two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, may be combined in one body and may be used provided the combined fitting is the equivalent of two independent slow-opening valves, or a slow-opening valve and a quick-opening valve or cock, and provided further that the failure of one to operate cannot affect the operation of the other.

(C.11) Only one blowoff valve, which shall be either a slow-opening or quick-opening blowoff valve or a cock, is required on traction and/or portable boilers.

(C.12) Only one blowoff valve, which shall be of a slow-opening type, is required on forced circulation and electric steam boilers having a normal water content not exceeding 100 gal (380 liter).

(D) Safety Valves

(D.1) Safety valves, relief valves, and safety relief valves shall conform to the requirements of PG-67,

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TABLE 122.2

Boiler or Vessel Pressure		Design Pressure		Design Temperature	
psig	kPa (gage)	psig	kPa (gage)	°F	°C
Below 250	1 750	Note (1)		...	...
250–600	1 750–4 150	250	1750	410	210
601–900	4 151–6 200	400	2750	450	230
901–1500	6 201–10 300	600	4150	490	255
1501 and higher	10 301 and higher	900	6200	535	280

NOTE:

(1) For boiler or vessel pressure(s) below 250 psig [1750 kPa (gage)], the design pressure shall be determined in accordance with para. 122.1.4(B.1) but need not exceed 250 psig [1750 kPa (gage)].

PG-68, PG-69, PG-70, PG-71, PG-72, and PG-73 of Section I of the ASME Boiler and Pressure Vessel Code.

122.2 Blowoff and Blowdown Piping in Nonboiler External Piping

(A) From Boilers

(A.1) Blowoff piping, located between the valves described in para. 122.1.4(A) and the blowoff tank or other point where the pressure is reduced approximately to atmospheric pressure and cannot be increased by closing a valve, shall be designed for saturated steam at the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(A.3) shall apply.

(A.2) Blowdown piping, located after the valve described in para. 122.1.4(B) in which the pressure cannot be increased by closing a valve, shall be designed for the appropriate pressure and temperature in accordance with Table 122.2. The provisions of para. 122.1.4(B.3) shall apply.

(A.3) When design pressure of Table 122.2 can be exceeded due either to closing of a downstream valve, calculated pressure drop, or other means, the entire blowoff or blowdown piping system shall be designed in accordance with para. 122.1.4(A) or (B), respectively.

(B) From Pressure Vessels Other Than Boilers

(B.1) The design pressure and temperature of the blowoff piping from the pressure vessel to and including the blowoff valve(s) shall not be less than the vessel design conditions.

122.3 Instrument, Control, and Sampling Piping

(A) The requirements of this Code, as supplemented by para. 122.3, shall apply to the design of instrument, control, and sampling piping for safe and proper operation of the piping itself.

(B) The term "Instrument Piping" shall apply to all valves, fittings, tubing, and piping used to connect instruments to main piping or to other instruments or apparatus or to measuring equipment as used within the classification of para. 100.1.

(C) The term "Control Piping" shall apply to all valves, fittings, tubing, and piping used to interconnect pneumatically or hydraulically operated control apparatus, also classified in accordance with para. 100.1, as well as to signal transmission systems used to interconnect instrument transmitters and receivers.

(D) The term "Sampling Piping" shall apply to all valves, fittings, tubing, and piping used for the collection of samples, such as steam, water, oil, gas, and chemicals.

(E) Paragraph 122.3 does not apply to tubing used in permanently closed systems, such as fluid-filled temperature responsive devices, or the temperature responsive devices themselves.

(F) Paragraph 122.3 does not apply to the devices, apparatus, measuring, sampling, signalling, transmitting, controlling, receiving, or collecting instruments to which the piping is connected.

122.3.1 Materials and Design. The materials utilized for valves, fittings, tubing, and piping shall meet the particular conditions of service and the requirements of the applicable specifications listed under general paras. 105, 106, 107, and 108 with allowable stresses in accordance with the Allowable Stress Tables in Appendix A.

The materials for pressure retention components used for piping specialities such as meters, traps, and strainers in flammable, combustible, or toxic fluid systems shall in addition conform to the requirements of paras. 122.7 and 122.8.

122.3.2 Instrument Piping

(A) Takeoff Connections

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(A.1) Takeoff connections at the source, together with attachment bosses, nozzles, and adapters, shall be made of material at least equivalent to that of the pipe or vessel to which they are attached. The connections shall be designed to withstand the source design pressure and temperature and be capable of withstanding loadings induced by relative displacement and vibration. The nominal size of the takeoff connections shall not be less than NPS ½ for service conditions not in excess of either 900 psi (6200 kPa) or 800°F (425°C), and NPS ¾ (for adequate physical strength) for design conditions which exceed either of these limits. Where the size of the main is smaller than the limits given above, the takeoff connection shall not be less than the size of the main line.

(A.2) To prevent thermal shock to the main steam line by contact with the colder condensate return from the instrument, steam meter or instrument takeoff connections shall be lagged in with the steam main. For temperature in excess of 800°F (425°C), they may also be arranged to make metallic contact lengthwise with the steam main.

(B) Valves

(B.1) Shutoff Valves. Shutoff valves shall be provided at takeoff connections. They shall be capable of withstanding the design pressure and temperature of the pipe or vessel to which the takeoff adapters or nipples are attached.

(B.2) Blowdown Valves

(B.2.1) Blowdown valves at or near the instrument shall be of the gradual opening type. For subcritical pressure steam service, the design pressure for blowdown valves shall be not less than the design pressure of the pipe or vessel; the design temperature shall be the corresponding temperature of saturated steam. For all other services, blowdown valves shall meet the requirements of (B.1) above.

(B.2.2) When blowdown valves are used, the valves at the instrument as well as any intervening fittings and tubing between such blowdown valves and the meter shall be suitable at 100°F (40°C) for at least 1½ times the design pressure of the piping system, but the rating of the valve at the instrument need not exceed the rating of the blowdown valve.

(B.2.3) When blowdown valves are not used, instrument valves shall conform to the requirements of (B.2.1) above.

(C) Reservoirs or Condensers. In dead end steam service, the condensing reservoirs and connecting nipples, which immediately follow the shutoff valves, shall be made of material suitable for the saturated steam temperature corresponding to the main line design pressure.

(D) Materials for Lines Between Shutoff Valves and Instruments

(D.1) Copper, copper alloys, and other nonferrous materials may be used in dead end steam or water services up to the design pressure and temperature conditions used for calculating the wall thickness in accordance with para. 104 provided that the temperature within the connecting lines for continuous services does not exceed 406°F (208°C).

Where water temperature in the reservoir of condensers is above 406°F (208°C), a length of uninsulated steel tubing at least 5 ft (1.5 m) long shall immediately follow the condenser ahead of the connecting copper tubing to the instrument.

(D.2) The minimum size of the tubing or piping is a function of its length, the volume of fluid required to produce full scale deflections of the instrument, and the service of the instrument. When required to prevent plugging as well as to obtain sufficient mechanical strength, the inside diameter of the pipe or tube should not be less than 0.36 in. (9.14 mm), with a wall thickness of not less than 0.049 in. (1.25 mm). When these requirements do not apply, smaller sizes with wall thickness in due proportions may be used. In either case, wall thickness of the pipe or tube shall meet the requirements of (D.3) below.

(D.3) The piping or tubing shall be designed in accordance with para. 104 with consideration for water hammer.

(E) Fittings and Joints

(E.1) For dead end steam service and for water above 150°F (65°C), fittings of the. flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for the header pressure and corresponding saturated steam temperature or water temperature, whichever applies. For supercritical pressure conditions the fittings shall be suitable for the design pressure and temperature of the main fluid line.

(E.2) For water, oil and similar instrument services, any of the following types may be used, within the pressure-temperature limitations of each.

(E.2.1) For main line hydraulic pressures above 500 psi (3450 kPa) and temperatures up to 150°F (65°C), steel fittings either of the flared, flareless, socket welded, fusion welded, or silver brazed socket type shall be used.

(E.2.2) For main line pressures up to 500 psi (3450 kPa) and temperatures up to 150°F (65°C), the fittings may be: (E.2.2.1) flared or silver brazed socket type,

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inverted flared or flareless compression type, all of brass or bronze.

(E.2.3) For pressures up to 175 psi (1200 kPa) or temperatures up to 250°F (120°C), soldered type fittings may be used with water-filled or air-filled tubing under adjusted pressure-temperature ratings. These fittings are not recommended where mechanical vibration, hydraulic shock, or thermal shock are encountered.

122.3.3 Control Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(C) Materials

(C.1) The same materials may be used for control lines as for instrument lines, except that the minimum inside diameter shall be 0.178 in. (4.52 mm) with a minimum wall thickness of 0.028 in. (0.71 mm), provided that this wall thickness is not less than that required by para. 122.3.2(D.3). If a control device has a connection smaller than ¼ in. (6.0 mm), the size reduction from the control tubing to the control device shall be made as close to the control device as possible.

(D) Fittings and Joints

(D.1) Fittings and joints shall be in accordance with para. 122.3.2(E.2).

122.3.4 Sampling Piping

(A) Takeoff Connections

(A.1) Takeoff connections shall be in accordance with para. 122.3.2(A.1).

(B) Valves

(B.1) Shutoff valves shall be in accordance with para. 122.3.2(B.1).

(B.2) Blowdown valves shall be of the gradual opening type and shall be suitable for main line design pressure and temperature.

(C) Materials

(C.1) The materials to be used for sampling lines shall conform to minimum requirements for the main line to which they connect.

(D) Fittings and Joints

(D.1) For subcritical and supercritical pressure steam, and for water above 150°F (65°C), fittings of the flared, flareless, or socket welding type, or other suitable type of similar design shall be used. The fittings shall be suitable for main line design pressure and temperature.

(D.2) For water below 150°F (65°C), fittings and joints shall be suitable for main line design pressure and temperature and shall be in accordance with para. 122.3.2(E.2).

122.3.6 Fittings and Joints

(A) All fittings shall be in accordance with standards and specifications listed in Table 126.1.

(A.1) Socket welded joints shall comply with the requirements of para. 111.3.

(A.2) Flared, flareless, and compression type fittings and their joints shall comply with the requirements of para. 115.

(A.3) Silver brazed socket type joints shall comply with the requirements of paras. 117.1 and 117.3.

(A.4) Solder type joints shall comply with the requirements of paras. 117.2 and 117.3.

(A.5) The use of taper threaded joints up to and including NPS ½ is permitted at pressures up to 5000 psi (34 500 kPa) in dead end service from outlet end and downstream of shutoff valve located at instrument, at control apparatus, or at discharge of sample cooler.

122.3.7 Special Safety Provisions

(A) Connecting piping subject to clogging from solids or deposits shall be provided with suitable connections for cleaning.

(B) Connecting piping handling air and gases containing moisture or other extraneous materials shall be provided with suitable drains or settling chambers or traps.

(C) Connecting piping which may contain liquids shall be protected from damage due to freezing by heating or other adequate means.

122.3.8 Supports. Supports shall be furnished as specified in para. 121 not only for safety but also to protect the piping against detrimental sagging, external mechanical injury abuse, and exposure to unusual service conditions.

122.3.9 Installations

(A) Instrument, control, and sampling piping shall be inspected and tested in accordance with paras. 136 and 137.

(B) The inside of all piping, tubing, valves, and fittings shall be smooth, clean, and free from blisters, loose mill scale, sand, and dirt when erected. All lines shall be cleaned after installation and before placing in service.

122.4 Spray Type Desuperheater Piping for Use on Steam Generators and Reheat Piping 01

(A) Valves and Piping Arrangement

(A.1) Each spraywater pipe connected to a desuper-

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heater shall be provided with a stop valve and a regulating (spray control) valve. The regulating valve shall be installed upstream of the stop valve. In addition, if the steam generator supplies steam to a steam turbine, a power-operated block valve[3] shall be installed upstream of the regulating valve.

(A.2) A bypass valve around the regulating valve is permitted.

(A.3) A bypass valve around the power-operated block valve is prohibited.

(A.4) On a reheater desuperheater, a drain valve shall be installed between the power-operated block valve and the regulating valve.

(A.5) If the spraywater supply is from the boiler feedwater system and its source is not downstream of the feedwater check valve required by para. 122.1.7, a check valve shall be provided in the spraywater piping between the desuperheater and the spraywater source.

(A.6) It is recommended that the valves and piping be arranged to provide a head of water on the downstream side of the stop valve.

(A.7) A typical arrangement is shown in Fig. 122.4.

(A.8) Provisions shall be made to both steam and water systems to accommodate the operating conditions associated with this service including: water hammer, thermal shock and direct water impingement. The connection for the spraywater pipe should be located per the requirements established by the manufacturer so that complete flow mixing is achieved prior to any bends, elbows, or other flow directional changes being encountered.

(A.9) Insertable-type desuperheaters, which include an integral stop and spraywater regulating valve, may be used within the limitations established by the manufacturer. If this type is used, the individual stop and regulating valves shown in Fig. 122.4 may be omitted. All other requirements described in para. 122.4 shall apply.

(A.10) For Desuperheaters Located Within Reheat Piping. The steam system to be desuperheated shall be provided with proper drainage during all water flow conditions. The drainage system shall function both manually and automatically.

(B) Design Requirements

(B.1) The value of P to be used in the formulas of para. 104 shall be as follows.

(B.1.1) For piping from the desuperheater back to the stop valve required by (A.1) above, the value of P shall be equal to or greater than the maximum allowable working pressure of the desuperheater.

(B.1.2) For the remainder of the spraywater piping system, the value of P shall be not less than the maximum sustained pressure exerted by the spraywater.

(B.2) The stop valve required by (A.1) above shall be designed for the pressure requirement of (B.1.1) above or the maximum sustained pressure exerted by the spraywater, whichever is greater.

(B.3) The S value used for the spraywater piping shall not exceed that permitted for the expected temperature.

NOTE: The temperature varies from that of the desuperheater to that of the spraywater source and is highly dependent on the piping arrangement. It is the responsibility of the designer to determine the design temperature to be used for the various sections of the piping system.

122.5 Pressure Reducing Valves

122.5.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

122.5.2 Bypass Valves. Hand controlled bypass valves having a capacity no greater than the reducing valve may be installed around pressure reducing valves if the downstream piping is protected by relief valves as required in para. 122.5.1 or if the design pressure of the downstream piping system and equipment is at least as high as the upstream pressure.

122.5.3 Design of Valves and Relief Devices. Pressure reducing and bypass valves, and relief devices, shall be designed for inlet pressure and temperature conditions. Safety and relief valves shall be in accordance with the requirements of para. 107.8 of this Code.

122.6 Pressure Relief Piping

Pressure relief piping within the scope of this Code shall be supported to sustain reaction forces, and shall conform to the following requirements.

[3] For information on the prevention of water damage to steam turbines used for electric power generation, see ASME TDP-1.

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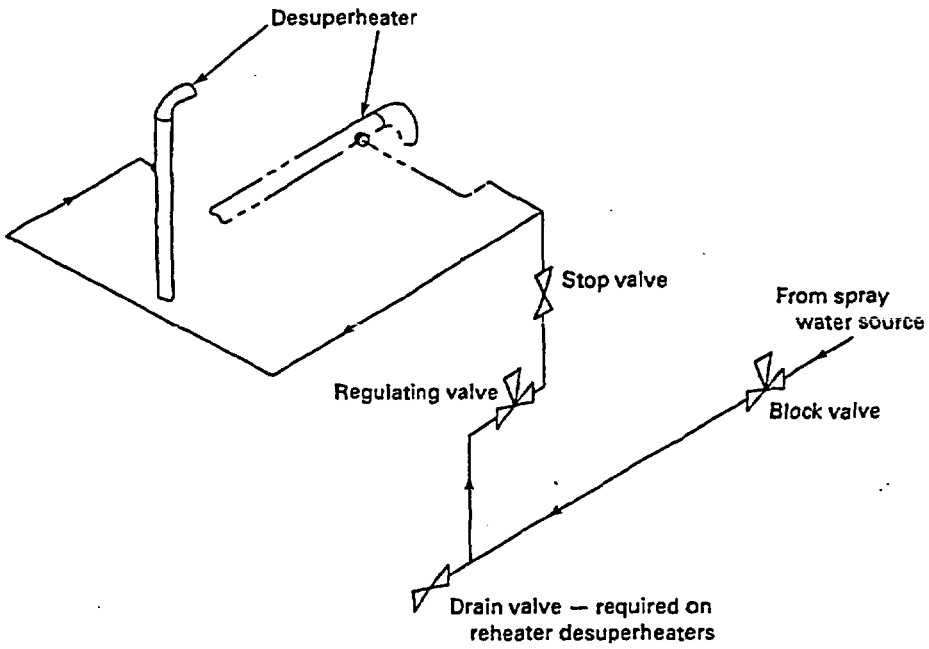

GENERAL NOTE: This figure is a schematic only and is not intended to show equipment layout or orientation.

01 FIG. 122.4 DESUPERHEATER SCHEMATIC ARRANGEMENT

122.6.1 Piping to Pressure-Relieving Safety Devices

(A) There shall be no intervening stop valve(s) between piping being protected and the protective device(s).

(B) Diverter or changeover valves designed to allow servicing of redundant protective devices without system depressurization may be installed between the piping to be protected and the required protective devices under the following conditions.

(B.1) Diverter or changeover valves are prohibited on boiler external piping or reheat piping.

(B.2) One hundred percent (100%) of the required relieving capacity shall be continuously available any time the system is in service.

(B.3) Positive position indicators shall be provided on diverter or changeover valves.

(B.4) Positive locking mechanisms and seals shall be provided on diverter or changeover valves to preclude unauthorized or accidental operation.

(B.5) Diverter or changeover valves shall be designed for the most severe conditions of pressure, temperature, and loading to which they are exposed, and shall be in accordance with para. 107.

(B.6) Provision shall be made to safely bleed off the pressure between the isolated protective device and the diverter or changeover valve.

122.6.2 Discharge Piping From Pressure Relieving Safety Devices

(A) There shall be no intervening stop valve between the protective device or devices and the point of discharge.

(B) When discharging directly to the atmosphere, discharge shall not impinge on other piping or equipment and shall be directed away from platforms and other areas used by personnel.

(C) It is recommended that individual discharge lines be used, but if two or more reliefs are combined, the discharge piping shall be designed with sufficient flow area to prevent blowout of steam or other fluids. Sectional areas of a discharge pipe shall not be less than the full area of the valve outlets discharging thereinto and the discharge pipe shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

(D) Discharge lines from pressure-relieving safety devices within the scope of this Code shall be designed to facilitate drainage.

(E) When the umbrella or drip pan type of connection

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is used, the discharge piping shall be so designed as to prevent binding due to expansion movements.

(F) Drainage shall be provided to remove water collected above the safety valve seat.

(G) Carbon steel materials listed in Appendix A may be used for discharge piping which is subjected to temperatures above 800°F (427°C) only during operation of pressure relieving safety devices provided that:

(G.1) the duration of pressure relieving safety device operation is self-limiting;

(G.2) the piping discharges directly to atmosphere;

(G.3) material allowable stresses at temperatures above 800°F (427°C) shall be taken from Section II, Part D, Tables 1A and 1B for materials applicable to Section I and Section VIII, Division 1 of the ASME Boiler and Pressure Vessel Code.

122.7 Piping for Flammable or Combustible Liquids

122.7.1 General. Piping for flammable or combustible liquids including fuel and lubricating oils is within the scope of this Code. Piping for synthetic lubricants having no flash or fire point need not meet the requirements of para. 122.7.

The designer is cautioned that, among other criteria, static electricity may be generated by the flowing fluid. Additionally, the designer is cautioned of the extreme chilling effect of a liquefied gas flashing to vapor during loss of pressure. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials. Consideration shall also be given to the pressure rise that may occur as a cold fluid absorbs heat from the surroundings.

122.7.2 Materials

(A) Seamless steel or nickel alloy piping materials shall be used in all areas where the line is within 25 ft (7.6 m) of equipment or other lines having an open flame or exposed parts with an operating temperature above 400°F (204°C). Seamless steel or nickel alloy pipe shall also be used for fuel oil systems located downstream of burner shutoff valve(s). The burner shutoff valve(s) shall be located as close to the burner as is practical.

(B) In all other areas, piping systems may include pipe or tube of steel, nickel alloy, ductile iron, copper, or brass construction. Copper tubing shall have a thickness not less than that required by para. 104.1.2(C.3), regardless of pressure. Refer also to paras. 105, 124.6, and 124.7(A)

Wherever materials other than steel or nickel alloy are used, they shall be so located that any spill resulting from the failure of these materials will not unduly expose persons, buildings, or structures, or can be readily controlled by remote valves.

(C) For lubricating oil systems, steel tubing is an acceptable alternative to steel pipe.

(D) Polyethylene (PE) and reinforced thermosetting resin (RTR) pipe may be used for flammable or combustible liquids in buried installations only. The fluid temperatures shall not exceed 140°F (60°C) and pressures shall be limited to 150 psi (1000 kPa). Where such PE or RTR pipe is used in flammable or combustible liquid service, the rules of Appendix III shall be considered mandatory. Where jurisdictional requirements mandate that double containment pipe be used, the rules of Appendix III shall be applied to both the inner and outer pipe.

Particular care must be exercised to prevent damage to RTR piping at the connection to the main or other facility. Precautions shall be taken to prevent crushing or shearing of RTR piping due to external loading or settling of backfill and to prevent damage or pull out from the terminal connection resulting from thermal expansion or contraction.

RTR piping may terminate above ground and outside a building, provided that:

(1) the above ground portion of the RTR pipe is completely enclosed in a conduit or casing of sufficient strength to provide protection from external damage and deterioration. Where a flexible conduit is used, the top of the riser must be attached to a solid support. The conduit or casing shall extend a minimum of 6 in. below grade.

(2) the RTR pipe is not subjected to excessive stresses due to external loading.

122.7.3 Piping Joints

(A) Welded joints shall be used between steel or nickel alloy piping components where practicable. Where bolted flanged joints are necessary, the gasket material shall be suitable for the service. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(A.1) in piping of a thickness no less than extra strong regardless of pressure;

(A.2) limited as prescribed in para. 114; and

(A.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B) Threaded joints in copper or brass pipe shall be subject to the same limitations as for steel pipe in (A.1), (A.2), and (A.3), above.

(C) Copper tubing shall be assembled with flared, flareless, or compression type joints as prescribed in

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para. 115, or brazed in accordance with para. 117. Soft solder type joints are prohibited.

(D) RTR pipe shall be adhesive bonded in accordance with the pipe manufacturer's recommended procedures.

(E) Pipe joints dependent on the friction characteristics or resiliency of combustible materials for mechanical or leak tightness of piping shall not be used inside buildings.

(F) Steel tubing shall be assembled with fittings in accordance with para. 115, or with socket weld fittings.

122.7.4 Valves and Specialties. Valves, strainers, meters, and other specialties shall be of steel or nickel alloy construction. As an alternative, ductile or malleable iron or copper alloy valves and specialties may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

122.8 Piping for Flammable Gases, Toxic Gases or Liquids, or Nonflammable Nontoxic Gases

Although some gases are liquefied for storage or transport, they shall be considered as gases if their Reid vapor pressure is greater than 40 psia [2068.6 mm Hg (absolute)] at 100°F (37.8°C).

122.8.1 Flammable Gas

(A) Some of the common flammable gases are acetylene, ethane, ethylene, hydrogen, methane, propane, butane, and natural or manufactured gas used for fuel. It shall be the designers' responsibility to determine the limiting concentrations (upper and lower explosive limits) and the properties of the gas under consideration. The use of explosive concentrations shall be avoided, or the piping shall be designed to withstand explosive forces.

The designer is further cautioned of the extreme chilling effect of gas during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the possibility of brittle fracture of materials.

(B) Materials. Steel piping, subject to the limitations in para. 105, shall be used for all flammable gases, except as otherwise permitted in (B.2), (B.3), and (B.4) below.

(B.1) Pipe joints shall be welded where practicable, except bolted flanged joints with suitable gaskets may be used where necessary. Threaded joints, where unavoidable for connecting to equipment, valves, specialties, or instruments, shall be:

(B.1.1) in piping of a thickness no less than extra strong regardless of pressure or material;

(B.1.2) limited as prescribed in para. 114, except threaded joints and compression fittings to maximum nominal size of NPS $\frac{3}{4}$ (DN 20) for pressure to 5000 psi (34,000 kPa) are permitted at the connection to the refillable storage containers pressure regulators; and

(B.1.3) assembled with extreme care to assure leak tightness, using thread sealant suitable for the service.

(B.2) For hydrogen systems, the following alternative materials may be used:

(B.2.1) seamless steel tubing with welded joints;

(B.2.2) seamless copper or brass pipe or tubing with brazed, threaded, or compression fitting joints. Threaded fittings shall not exceed NPS $\frac{3}{4}$ (DN 20). For protection against damage, tubing shall be installed in a guarded manner that will prevent damage during construction, operation, or service. Valves with suitable packing, gages, regulators, and other equipment may also consist of copper alloy materials. Safety relief devices shall be vented individually, and connected vent piping shall be designed to convey the fluid, without pockets, to the outside atmosphere; and then directed away from equipment ventilation systems, and vents from other systems.

(B.3) For fuel gas instrumentation and control, seamless copper tubing subject to the following restrictions may be used:

(B.3.1) the design pressure shall not exceed 100 psi (690 kPa);

(B.3.2) tubing shall not exceed $\frac{5}{8}$ in. (15.9 mm) nominal outside diameter;

(B.3.3) all joints shall be made with compression or flared fittings;

(B.3.4) copper tubing shall not be used if the fuel gas contains more than 0.3 grains (19.4 mg) of hydrogen sulfide per 100 cu ft/min (47 liters/sec) of gas at standard conditions;

(B.3.5) consideration shall be given in the design to the lower strength and melting point of copper compared to steel. Adequate support and protection from high ambient temperatures and vibration shall be provided.

(B.3.6) tubing shall be installed in a guarded manner that will prevent damage during construction, operation, and service.

(B.4) Polyethylene (PE) pipe may be used for natural gas service in buried installations only. The fluid temperatures shall not exceed 140°F (60°C), nor be below –20°F (–30°C) and pressures shall be limited to 100 psi (690 kPa). Pipe joints shall be heat fused in accordance with manufacturer's recommended procedures. Where PE pipe is used in flammable gas service, the rules of Appendix III shall be considered mandatory.

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(C) Valves and Specialties. Valves, strainers, meters, and other specialities shall be of steel or nickel alloy construction. As as alternative, ductile iron or copper alloy valves and specialities may be used, subject to the restrictions in paras. 124.6 and 124.7, where metal temperatures do not exceed 400°F (204°C).

(D) For in-plant fuel gas distribution system(s) where the use of a full-relieving-capacity relief valve(s) as described in para. 122.5 could create an undue venting hazard, an alternative pressure limiting design may be substituted. The alternative design shall include all provisions below:

(D.1) Tandem Gas Pressure Reducing Valves. To protect the low pressure system, two gas pressure reducing valves capable of independent operation shall be installed in series. Each shall have the capability of closing off against the maximum upstream pressure, and of controlling the pressure on the low pressure side at or below the design pressure of the low pressure system, in the event that the other valve fails open. Control lines must be suitably protected, designed, and installed so that damage to any one control line will not result in over pressurizing the downstream piping.

(D.2) Trip Stop Valve. A fail-safe trip stop valve shall be installed to automatically close, in less than 1 sec, at or below the design pressure of the downstream piping. It shall be a manually reset design. The pressure switch for initiating closure of the trip stop valve shall be hardwired directly to the valve tripping circuit. The pressure switch shall be mounted directly on the low pressure piping without an intervening isolation valve. The trip stop valve shall be located so that it is accessible and protected from mechanical damage and from weather or other ambient conditions which could impair its proper functioning. It may be located upstream or downstream of the tandem gas pressure reducing valves. The trip stop valve and all upstream piping shall be designed for the maximum upstream supply pressure. The trip stop valve may also serve as the upstream isolation valve of a double-block and vent gas supply isolation system. Provision shall be made to safely bleed off the pressure downstream of the trip stop valve.

(D.3) Safety Relief Device. The low pressure system shall be protected from any leakage through the pressure reducing valves, when closed, by a safety relief device(s) constructed and designed in accordance with paras. 107.8.3 and 122.5.3, and sized for the possible leakage rate.

01 **122.8.2 Toxic Fluids (Gas or Liquid)**

(A) For the purpose of this Code, a toxic fluid is one that may be lethal, or capable of producing injury and/or serious illness through contact, inhalation, ingestion, or absorption through any body surface. It shall be the designers' responsibility to adopt the safety precautions published by the relevant fluid industry which may be more stringent than those described in this Code for toxic fluids. In addition, the piping shall be installed in such a manner that will minimize the possibility of damage from external sources.

TABLE 122.8.2(B)
MINIMUM WALL THICKNESS REQUIREMENTS FOR TOXIC FLUID PIPING

	Carbon & Low Alloy Steel (App. A, Tables A-1 & A-2)	Stainless & Nickel Alloy Steel (App. A, Tables A-3 & A-4)
DN 50 (NPS 2) & smaller	Extra strong	Sch. 10S
Larger than DN 50 (NPS 2)	Standard weight	Sch. 5S

(B) Preferably, pipe and pipe fittings should be seamless steel. Wall thickness shall not be less than that in Table 122.8.2(B).

If the fluid is known to be corrosive to the steels in Table 122.8.2(B), the materials and wall thickness selected shall be suitable for the service. (Refer to para. 104.1.2.)

(C) Piping joints shall be made by welding, or by steel socket welding or welding neck flanges with suitable gaskets. Socket welded joints shall not be larger than DN 65 (NPS 2½). Backing rings used for making girth butt welds shall be removed after welding. Miter welds are not permitted. Fabricated branch connections (branch pipe welded directly to run pipe) are not permitted. Threaded joints, where unavoidable, may be used provided that all of the following requirements are met.

(C.1) The pipe thickness shall not be less than extra strong regardless of pressure or type of material.

(C.2) The requirements of para. 114 shall be met except that threaded joints to a maximum nominal size of DN 20 (NPS ¾) for pressure to 34,500 kPa [gage] (5000 psig), or to a maximum nominal size of DN 50 (NPS 2) for pressure to 345 kPa [gage] (50 psig) are permitted at the connections to the refillable storage containers and their associated pressure regulators, shut-off valves, pumps, and meters.

(C.3) Threaded joints are assembled with extreme care to assure leak tightness. The requirements of para.

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135.5 shall be met. A thread sealant, suitable for the service, shall be used, except where the joint is to be seal welded.

(D) Steel valves shall be used. Bonnet joints with tapered threads are not permitted. Special consideration shall be given to valve design to prevent stem leakage to the environment. Bonnet or cover plate closures and other body joints shall be one of the following types:

(D.1) union;

(D.2) flanged with suitable gasketing and secured by at least four bolts;

(D.3) proprietary, attached by bolts, lugs, or other substantial means, and having a design that increases gasket compression as fluid pressure increases;

(D.4) threaded with straight threads sufficient for mechanical strength, metal-to-metal seats, and a seal weld made in accordance with para. 127.4.5, all acting in series.

(E) Tubing not larger than $\frac{5}{8}$ in. (16 mm) O.D. with socket welding fittings may be used to connect instruments to the process line. An accessible root valve shall be provided at the process lines to permit isolating the tubing from the process piping. The layout and mounting of tubing shall minimize vibration and exposure to possible damage.

(F) The provisions of para. 102.2.4 are not permitted. The simplified rules for analysis in para. 119.7.1 (A.3) are not permitted. The piping system shall be designed to minimize impact and shock loads. Suitable dynamic analysis shall be made where necessary to avoid or minimize vibration, pulsation, or resonance effects in the piping. The designer is cautioned to consider the possibility of brittle fracture of the steel material selected over the entire range of temperatures to which it may be subjected.

(G) For dry chlorine service between –29°C (–20°F) and 149°C (300°F), the pipe material shall not be less in thickness than seamless extra strong steel.

(H) Toxic fluid piping shall be pneumatic leak tested in accordance with para. 137.5. Alternatively, mass spectrometer or halide leak testing in accordance with para. 137.6, and a hydrostatic test in accordance with para. 137.3 may be performed.

122.8.3 Nonflammable Nontoxic Gas

(A) Piping for nonflammable and nontoxic gases, such as air, oxygen, carbon dioxide, and nitrogen, shall comply with the requirements of this Code, except as otherwise permitted in (B) (below). The designer is cautioned of the extreme chilling effect during rapid expansion. This is a factor for determining the lowest expected service temperature relative to the brittle fracture of the material selected.

(B) Threaded joints with or without compression fittings to a maximum nominal size of NPS $\frac{3}{4}$ for pressures to 5000 psi (34,500 kPa) are permitted at the connection to the refillable storage containers, pressure regulators, shutoff valves, and meters. Refer to Para. 114.

122.9 Piping for Corrosive Liquids and Gases

Where it is necessary to use special material, such as glass and plastics, not listed in Table 126.1, for conveying corrosive or hazardous liquids and gases, the design shall meet the requirements of para. 104.7.

122.10 Temporary Piping Systems

Prior to test and operation of the power plant and its included piping systems, most power and auxiliary service piping are subjected to flushing or chemical cleaning to remove internal foreign material such as rust particles, scale, welding or brazing residue, dirt, etc., which may have accumulated within the piping during the construction period. The flushing or cleaning operation may be accomplished by blowing out with steam or air, by hot oil circulation of oil systems, by acid or caustic fluid circulation, or by other flushing or cleaning methods. Temporary piping, that is piping attached to the permanent piping system whose function is to provide means for introducing and removing the fluids used in the flushing or cleaning operations, shall be designed and constructed to withstand the operating conditions during flushing and cleaning. The following minimum requirements shall apply to temporary piping systems.

(A) Each such system shall be analyzed for compliance with para. 103.

(B) Connections for temporary piping to the permanent piping systems which are intended to remain, shall meet the design and construction requirements of the permanent system to which they are attached.

(C) The temporary systems shall be supported such that forces and moments due to static, dynamic and expansion loadings will not be transferred in an unacceptable manner to the connected permanent piping system. Paragraphs 120 and 121 shall be used as guidance for the design of the temporary piping systems supporting elements.

(D) The temporary systems shall be capable of withstanding the cyclic loadings which occur during the flushing and cleaning operations. Particular attention

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shall be given to the effects of large thrust forces which may be generated during high velocity blowing cycles. Where steam piping is to be subjected to high velocity blowing operations, continuous or automatic draining of trapped or potentially trapped water within the system shall be incorporated. Supports at the exhaust terminals of blowdown piping shall provide for restraint of potential pipe whip.

(E) Where necessary, temporary systems containing cast iron or carbon steel material subject to chemical cleaning shall be prewarmed to avoid the potential for brittle failure of the material.

(F) Where temporary piping has been installed and it does not comply with the requirements of this Code for permanent piping systems, it shall be physically removed or separated from the permanent piping to which it is attached prior to testing of the permanent piping system and prior to plant startup.

122.11 Steam Trap Piping

122.11.1 Drip Lines. Drip lines from piping or equipment operating at different pressures shall not be connected to discharge through the same trap.

122.11.2 Discharge Piping. Trap discharge piping shall be designed to the same pressure as the inlet piping unless the discharge is vented to atmosphere, or is operated under low pressure and has no stop valves. In no case shall the design pressure of trap discharge piping be less than the maximum discharge pressure to which it may be subjected. Where two or more traps discharge into the same header, a stop valve shall be provided in the discharge line from each trap. Where the pressure in the discharge piping can exceed the pressure in the inlet piping, a check valve shall be provided in the trap discharge line. A check valve is not required if either the stop valve or the steam trap is designed to automatically prevent reverse flow and is capable of withstanding a reverse differential pressure equal to the design pressure of the discharge piping.

122.12 Exhaust and Pump Suction Piping

Exhaust and pump suction lines for any service and pressure shall have relief valves of suitable size unless the lines and attached equipment are designed for the maximum pressure to which they may accidentally or otherwise be subjected, or unless a suitable alarm indicator, such as a whistle or free blowing relief valve, is installed where it will warn the operator.

122.13 Pump Discharge Piping

Pump discharge piping from the pump up to and including the valve normally used for isolation or flow control shall be designed for the maximum sustained pressure exerted by the pump and for the highest coincident fluid temperature, as a minimum. Variations in pressure and temperature due to occasional inadvertent operation are permitted as limited in para. 102.2.4 under any of the following conditions:

(A) during operation of overpressure relief devices designed to protect the piping system and the attached equipment;

(B) during a short period of abnormal operation, such as pump overspeed; or

(C) during uncontrolled transients of pressure or temperature.

122.14 District Heating and Steam Distribution Systems

122.14.1 General. Where pressure reducing valves are used, one or more relief devices or safety valves shall be provided on the low pressure side of the system. Otherwise, the piping and equipment on the low pressure side of the system shall be designed to withstand the upstream design pressure. The relief or safety devices shall be located adjoining or as close as practicable to the reducing valve. The combined relieving capacity provided shall be such that the design pressure of the low pressure system will not be exceeded if the reducing valve fails open.

122.14.2 Alternative Systems. In district heating and steam distribution systems where the steam pressure does not exceed 400 psi (2750 kPa) and where the use of relief valves as described in para. 122.14.1 is not feasible (e.g., because there is no acceptable discharge location for the vent piping), alternative designs may be substituted for the relief devices. In either case, it is recommended that alarms be provided which will reliably warn the operator of failure of any pressure reducing valve.

(A) Tandem Steam Pressure Reducing Valves. Two or more steam pressure reducing valves capable of independent operation may be installed in series, each set at or below the safe working pressure of the equipment and piping system served. In this case, no relief device is required.

Each pressure reducing valve shall have the capability of closing off against full line pressure, and of controlling the reduced pressure at or below the design pressure

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of the low pressure system, in the event that the other valve fails open.

(B) Trip Stop Valves. A trip stop steam valve set to close at or below the design pressure of the low pressure system may be used in place of a second reducing valve or a relief valve.

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CHAPTER III
MATERIALS

01 ## 123 General Requirements

Chapter III contains limitations and required qualifications for materials based on their inherent properties. Use of these materials in piping systems is also subject to requirements and limitations in other parts of this Code.

123.1 Materials and Specifications

123.1.1 Listed Materials. Material meeting the following requirements shall be considered listed and acceptable materials.

(A) Materials for which allowable stress values are listed in Appendix A or which have been approved by the procedure established by (C) below.

(B) A material conforming to a specification for which allowable stresses are not listed in Appendix A is acceptable provided its use is not specifically prohibited by this Code Section and it satisfies one of the following requirements.

(B.1) It is referenced in a standard listed in Table 126.1. Such a material shall be used only within the scope of and in the product form covered by the referencing standard listed in Table 126.1.

(B.2) It is referenced in other parts of this Code Section and shall be used only within the scope of and in the product form permitted by the referencing text.

(C) Where it is desired to use materials which are not currently acceptable under the rules of this Code Section, written application shall be made to the Committee fully describing the proposed material and the contemplated use. Such material shall not be considered listed and not used as a listed material until it has been approved by the Committee and allowable stress values have been assigned. Details of information which should be included in such applications are given in Appendix VI. See para. 123.1.2.

(D) Materials conforming to ASME SA or SB specifications may be used interchangeably with material specified to the listed ASTM A or B specifications of the same number, except where the requirements of para. 123.2.2 apply.

123.1.2 Unlisted Materials Materials other than those meeting the requirements of para. 123.1.1 shall be considered unlisted materials. Such unlisted materials may only be used for nonboiler external piping provided they satisfy all of the following requirements:

(A) Unlisted materials are certified by the material manufacturer to satisfy the requirements of a specification listed in any Code Section of the ASME B31 Code for Pressure Piping, the ASME Boiler and Pressure Vessel Code, Section II, Part D, or to a published specification covering chemistry, physical and mechanical properties, method and process of manufacture, heat treatment, and quality control.

(B) The allowable stresses of the unlisted materials shall be determined in accordance with the rules of para. 102.3.1(C).

(C) Unlisted materials shall be qualified for service within a stated range of minimum and maximum temperatures based upon data associated with successful experience, tests, or analysis; or a combination thereof.

(D) The designer shall document the owner's acceptance for use of unlisted material.

(E) All other requirements of this Code are satisfied.

123.1.5 Size or Thickness. Materials outside the limits of size or thickness given in the title or scope clause of any specification listed in Table 126.1 may be used if the material is in compliance with the other requirements of the specification, and no other similar limitation is given in the rules for construction.

123.1.6 Marking of Materials or Products. Materials or products marked as meeting the requirements for more than one grade, type, or alloy of a material specification or multiple specifications, are acceptable provided: 01

(A) one of the markings includes the material specification, grade, class, and type or alloy of the material permitted by this Code and the material meets all the requirements of that specification;

(B) the appropriate allowable stress for the specified grade, type, or alloy of a material specification from Appendix A is used;

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(C) all other requirements of this Code are satisfied for the material permitted.

123.2 Piping Components

123.2.1 General. Materials which do not comply with the rules of para. 123.1 may be used for flared, flareless, and compression type tubing fittings, provided that the requirements of para. 115 are met.

123.2.2 Boiler External Piping

(A) Materials for boiler external piping, as defined in para. 100.1.2(A), shall be specified in accordance with ASME SA, SB, or SFA specifications. Material produced under an ASTM specification may be used, provided that the requirements of the ASTM specification are identical or more stringent than the ASME specification for the Grade, Class, or Type produced. The material manufacturer or component manufacturer shall certify, with evidence acceptable to the Authorized Inspector, that the ASME specification requirements have been met. Materials produced to ASME or ASTM material specifications are not limited as to country of origin.

(B) Materials which are not fully identified shall comply with PG-10 of Section I of the ASME Boiler and Pressure Vessel Code.

123.3 Pipe Supporting Elements

Except as permitted by paras. 121.7.2(C) and (D), steel materials shall be used for pipe supporting elements. Steel materials which do not comply with the rules of para. 123.1 may be used for pipe supporting elements, provided the rules of para. 121.2(C) are met.

124 LIMITATIONS ON MATERIALS

124.1 General

The materials listed in the Allowable Stress Tables A-1 through A-9, Appendix A, shall not be used at design temperatures above those for which stress values are given except as permitted by para. 122.6.2(G).

124.2 Steel

(A) Upon prolonged exposure to temperatures above 775°F (415°C), the carbide phase of plain carbon steel, plain nickel alloy steel, carbon-manganese alloy steel, manganese-vanadium alloy steel, and carbon-silicon steel may be converted to graphite.

(B) Upon prolonged exposure to temperatures above 875°F (470°C), the carbide phase of alloy steels, such as carbon-molybdenum, manganese-molybdenum-vanadium, manganese-chromium-vanadium, and chromium-vanadium, may be converted to graphite.

(C) Carbon or alloy steel having carbon content of more than 0.35% shall not be used in welded construction or be shaped by oxygen cutting process or other thermal cutting processes.

(D) Where low alloy (3% chromium or less) steels are used at temperatures above 850°F, the carbon content of the base material and weld filler metal shall be 0.05% or higher.

124.4 Cast Gray Iron

The low ductility of cast gray iron may result in sudden failure if shock loading (pressure, temperature or mechanical) should occur. Possible shock loadings and consequences of failure must be considered before specifying the use of such material. Cast iron components may be used within the nonshock pressure-temperature ratings established by the standards and specifications herein and in para. 105.2.1(B). Castings to ASME SA-278 and ASTM A 278 shall have maximum limits of 250 psig [1725 kPa (gage)] and 450°F (230°C).

The following referenced paragraphs prohibit or restrict the use of gray cast iron for certain applications or to certain pressure-temperature ratings:

Pipe Supports	121.7.2(C)
BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
BEP Valves and Fittings	122.1.7
Blowoff Valves	122.1.7(C.5) & (C.6)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3
Flammable Gases	122.8.1(B)
Toxic Gases or Liquids	122.8.2

124.5 Malleable Iron

Certain types of malleable iron have low ductility characteristics and may be subject to brittle fracture. Malleable iron may be used for design conditions not to exceed 350 psig [2415 kPa (gage)] or 450°F (230°C).

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The following referenced paragraphs prohibit or restrict the use of malleable iron for certain applications or to certain pressure-temperature ratings:

Pipe Supports	121.7.2(D)
BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3(C)
Flammable Gases	122.8.1(B)
Toxic Gases or Liquids	122.8.2

124.6 Ductile (Nodular) Iron

Ductile (nodular) iron components conforming to ANSI B16.42 may be used under the following conditions.

(A) Components for boiler external piping shall be used only within the following limitations.

(A.1) Only ASME SA-395 material may be used.

(A.2) Design pressure shall not exceed 350 psig [2415 kPa (gage)].

(A.3) Design temperature shall not exceed 450°F (230°C).

(B) Welding shall not be used, either in fabrication of the components or in their assembly as a part of a piping system.

(C) The following referenced paragraphs prohibit or restrict the use of ductile iron for certain applications or to certain pressure-temperature ratings:

BEP Blowoff	122.1.4(A.3)
BEP Blowdown	122.1.4(B.3)
BEP Blowoff Valves	122.1.7(C.5)&(C.6)
Non-BEP Blowoff	122.2(A.1)
Non-BEP Blowdown	122.2(A.2)
Flammable or Combustible Liquids	122.7.3(B)
Flammable Gases	122.8.1(D)
Toxic Gases or Liquids	122.8.2
Pipe Supports	123.3

124.7 Nonferrous Metals

Nonferrous metals may be used in piping systems under the following conditions.

(A) The melting points of copper, copper alloys, aluminum, and aluminum alloys must be considered particularly where there is a fire hazard.

(B) The Designer shall consider the possibility of galvanic corrosion when combinations of dissimilar metals, such as copper, aluminum, and their alloys, are used in conjunction with each other or with steel or other metals in the presence of an electrolyte.

(C) Threaded Connections. A suitable thread compound shall be used in making up threaded joints in aluminum pipe to prevent seizing which might cause leakage and perhaps prevent disassembly. Pipe in the annealed temper should not be threaded.

124.8 Nonmetallic Pipe

This Code recognizes the existence of a wide variety of nonmetallic piping materials which may be used on corrosive (either internal or external) or other specialized applications. Extreme care must be taken in their selection as their design properties vary greatly and depend upon the material, type and grade. Particular consideration shall be given to the possibility of:

(A) destruction where fire hazard is involved;

(B) decrease in tensile strength at slight increase in temperature; and

(C) effects of toxicity. Another consideration is that of providing adequate support for the flexible pipe.

For nonmandatory rules for nonmetallic piping, see Appendix III of this Code.

124.9 Deterioration of Materials in Service

It is the responsibility of the engineer to select materials suitable for the intended application. Some guideline for selection of protective coatings for metallic piping are provided in Appendix IV.

125 MATERIALS APPLIED TO MISCELLANEOUS PARTS

125.1 Gaskets

Limitations on gasket materials are covered in para. 108.4.

125.2 Bolting

Limitations on bolting materials are covered in para. 108.5.

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CHAPTER IV
DIMENSIONAL REQUIREMENTS

126 MATERIAL SPECIFICATIONS AND STANDARDS FOR STANDARD AND NONSTANDARD PIPING COMPONENTS

126.1 Standard Piping Components

Dimensions of standard piping components shall comply with the standards and specifications listed in Table 126.1 in accordance with para. 100.

126.2 Nonstandard Piping Components

When nonstandard piping components are designed in accordance with para. 104, adherence to dimensional standards of ANSI and ASME is strongly recommended when practicable.

126.3 Referenced Documents

The documents listed in Table 126.1 may contain references to codes, standards, or specifications not listed in this Table. Such unlisted codes, standards, or specifications are to be used only in the context of the listed documents in which they appear.

Where documents listed in Table 126.1 contain design rules which are in conflict with this Code, the design rules of this Code shall govern.

The fabrication, assembly, examination, inspection, and testing requirements of Chapters V and VI apply to the construction of piping systems. These requirements are not applicable to piping components manufactured in accordance with the documents listed in Table 126.1 unless specifically so stated.

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TABLE 126.1
SPECIFICATIONS AND STANDARDS

ASTM Ferrous Material Specifications

Bolts, Nuts, and Studs

A 193	Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
A 194	Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service
A 307	Carbon Steel Bolts and Studs, 60,000 psi Tensile Strength
A 320	Alloy-Steel Bolting Materials for Low-Temperature Service
A 354	Quenched and Tempered Alloy Steel Bolts, Studs and Other Externally-Threaded Fasteners
A 437	Alloy-Steel Turbine-Type Bolting Material Specially Heat Treated for High Temperature Service
A 449	Quenched and Tempered Steel Bolts and Studs
A 453	Bolting Materials, High-Temperature, 50 to 120 ksi Yield Strength, With Expansion Coefficients Comparable to Austenitic Steels

Castings

A 47	Ferritic Malleable Iron Castings
A 48	Gray Iron Castings
A 126	Gray Iron Castings for Valves, Flanges, and Pipe Fittings
A 197	Cupola Malleable Iron
A 216	Steel Castings, Carbon Suitable for Fusion Welding for High Temperature Service
A 217	Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts Suitable for High-Temperature Service
A 278	Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650°F
A 351	Steel Castings, Austenitic, for High-Temperature Service
A 389	Steel Castings, Alloy, Specially Heat-Treated for Pressure-Containing Parts Suitable for High-Temperature Service
A 395	Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures
A 536	Ductile Iron Castings

Forgings

A 105	Forgings, Carbon Steel, for Piping Components
A 181	Forgings, Carbon Steel for General Purpose Piping
A 182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
A350	Forgings, Carbon and Low-Alloy Steel, Requiring Notch Toughness Testing for Piping Components

Cast Pipe

A 377	Ductile Iron Pressure Pipe
A 426	Centrifugally Cast Ferritic Alloy Steel Pipe for High-Temperature Service
A 451	Centrifugally Cast Austenitic Steel Pipe for High-Temperature Service
A 452	Centrifugally Cast Austenitic Steel Cold-Wrought Pipe for High-Temperature Service

Seamless Pipe and Tube

A 106	Seamless Carbon Steel Pipe for Hight-Temperature Service
A 179	Seamless Cold-Drawn Low-Carbon Steel Heat-Exchanger and Condenser Tubes
A 192	Seamless Carbon Steel Boiler Tubes for High-Pressure Service
A 199	Seamless Cold-Drawn Intermediate Alloy-Steel Heat-Exchanger and Condenser Tubes
A 210	Seamless Medium-Carbon Steel Boiler and Superheater Tubes
A 213	Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat-Exchanger Tubes
A 335	Seamless Ferritic Alloy Steel Pipe for High-Temperature Service
A 369	Carbon and Ferritic Alloy Steel Forged and Bored Pipe for High-Temperature Service
A 376	Seamless Austenitic Steel Pipe for High-Temperature Central-Station Service
A 430	Austenitic Steel Forged and Bored Pipe for High-Temperature Service

Seamless and Welded Pipe and Tube

A 53	Pipe, Steel, Black and Hot-Dipped, Zinc-Coated Welded and Seamless
A 268	Seamless and Welded Ferritic Stainless Steel Tubing for General Service
A 312	Seamless and Welded Austenitic Stainless Steel Pipe
A 333	Seamless and Welded Steel Pipe for Low-Temperature Service
A 450	General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
A 530	General Requirements for Specialized Carbon and Alloy Steel Pipe
A 714	High-Strength Low-Alloy Welded and Seamless Steel Pipe

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Ferrous Material Specifications (Cont'd)

Welded Pipe and Tube

A 134	Pipe, Steel, Electric-Fusion (ARC)-Welded (Sizes NPS 16 and Over)
A 135	Electric-Resistance-Welded Steel Pipe
A 139	Electric-Fusion (ARC)-Welded Steel Pipe (NPS 4 in. and Over)
A 178	Electric-Resistance-Welded Carbon Steel Boiler Tubes
A 211	Spiral Welded-Steel or Iron Pipe
A 214	Electric-Resistance-Welded Carbon Steel Heat-Exchanger and Condenser Tubes
A 226	Electric-Resistance-Welded Carbon Steel Boiler and Superheater Tubes for High-Pressure Service
A 249	Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes
A 254	Copper Brazed Steel Tubing
A 358	Electric-Fusion-Welded Austenitic Chromium-Nickel Alloy Steel Pipe for High-Temperature Service
A 409	Welded Large Diameter Austenitic Steel Pipe for Corrosive or High-Temperature Service
A 587	Electric-Welded Low-Carbon Steel Pipe for the Chemical Industry
A 671	Electric-Fusion-Welded Steel Pipe for Atmospheric and Lower Temperatures
A 672	Electrc-Fusion-Welded Steel Pipe for High-Pressure Service at Moderate Temperatures
A 691	Carbon and Alloy Steel Pipe, Electric-Fusion-Welded for High-Pressure Service at High Temperatures

Fittings

A 234	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and Elevated Temperatures
A 403	Wrought Austenitic Stainless Steel Piping Fittings
A 420	Piping Fittings of Wrought Carbon Steel and Alloy Steel for Low-Temperature Service

Plate, Sheet, and Strip

A 240	Heat-Resistant Chromium and Chromium-Nickel Stainless Steel Plate Sheet and Strip for Pressure Vessels
A 283	Low and Intermediate Tensile Strength Carbon Steel Plates
A 285	Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength
A 299	Pressure Vessel Plates, Carbon Steel, Managanese-Silicon
A 387	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum
A 515	Pressure Vessel Plates, Carbon Steel for Intermediate- and Higher-Temperature Service
A 516	Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service

Rods, Bars, and Shapes

A 276	Stainless and Heat Resisting Steel Bars and Shapes
A 322	Steel Bars, Alloy, Standard Grades
A 479	Stainless and Heat-Resisting Steel Wire, Bars, and Shapes for Use in Boilers and Other Pressure Vessels
A 564	Hot-Rolled and Cold-Finished Age-Hardening Stainless and Heat-Resisting Steel Bars, Wire, and Shapes
A 575	Steel Bars, Carbon, Merchant Quality, M-Grades
A 576	Steel Bars, Carbon, Hot-Wrought, Special Quality

Structural Components

A 36	Structural Steel
A 125	Steel Springs, Helical, Heat Treated
A 229	Steel Wire, Oil-Tempered for Mechanical Springs
A 242	High-Strength Low Alloy Structural Steel

ASTM Nonferrous Material Specifications

Castings

B 26	Aluminum-Alloy Sand Castings
B 61	Steam or Valve Bronze Castings
B 62	Composition Bronze or Ounce Metal castings
B 108	Aluminum-Alloy Permanent Mold Castings
B 148	Aluminum-Bronze Castings
B 367	Titanium and Titanium Alloy Castings
B 584	Copper Alloy Sand Castings

Forgings

B 247	Aluminum and Aluminum-Alloy Die, Hand, and Rolled Ring Forgings
B 283	Copper and Copper-Alloy Die Forgings (Hot Pressed)
B 381	Titanium and Titanium Alloy Forgings
B 462	UNS N08020, UNS N08024, UNS N08026, and UNS N08367 Alloy Pipe Flanges, Forged Fittings and Valves and Parts for Corrosive High-Temperature Service
B 564	Nickel and Alloy Forgings

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Nonferrous Material Specifications (Cont'd)

Seamless Pipe and Tube

B 42	Seamless Copper Pipe, Standard Sizes
B 43	Seamless Red Brass Pipe, Standard Sizes
B 68	Seamless Copper Tube, Bright Annealed
B 75	Seamless Copper Tube
B 88	Seamless Copper Water Tube
B 111	Copper and Copper-Alloy Seamless Condenser Tubes and Ferrule Stock
B 161	Nickel Seamless Pipe and Tube
B 163	Seamless Nickel and Nickel-Alloy Condenser and Heat-Exchanger Tubes
B 165	Nickel-Copper Alloy (UNS N04400) Seamless Pipe and Tube
B 167	Nickel-Chromium-Iron Alloy (UNS N06600–N06690) Seamless Pipe and Tube
B 210	Aluminum Alloy Drawn Seamless Tubes
B 234	Aluminum and Aluminum-Alloy Drawn Seamless Tubes for Condensers and Heat Exchangers
B 241	Aluminum-Alloy Seamless Pipe and Seamless Extruded Tube
B 251	General Requirements for Wrought Seamless Copper and Copper-Alloy Tube
B 280	Seamless Copper Tube for Air Conditioning and Refrigeration Field Service
B 302	Threadless Copper Pipe
B 315	Seamless Copper Alloy Pipe and Tube
B 407	Nickel-Iron-Chromium Alloy Seamless Pipe and Tube
B 423	Nickel-Iron-Chromium-Molybdenum-Copper Alloy (UNS N08825 and N08821) Seamless Pipe and Tube
B 466	Seamless Copper-Nickel Pipe and Tube
B 677	UNS N08904, UNS N08925, and UNS N08926 Seamless Pipe and Tube
B 729	Seamless UNS N08020, UNS N08026, and UNS N08024 Nickel-Alloy Pipe and Tube

Seamless and Welded Pipe and Tube

B 337	Seamless and Welded Titanium and Titanium-Alloy Pipe
B 338	Seamless and Welded Titanium and Titanium Alloy Tubes for Condensers and Heat Exchangers

Welded Pipe and Tube

B 464	Welded Chromium-Nickel-Iron-Molybdenum-Copper-Colombium Stablized Alloy (UNS N08020) Pipe
B 467	Welded Copper-Nickel Pipe
B 468	Welded Chromium-Nickel-Iron-Molybdenum-Copper-Columbium Stabilized Alloy (UNS N08020) Tubes

Welded Pipe and Tube (Cont'd)

B 547	Aluminum-Alloy Formed and Arc-Welded Round Tube
B 603	Welded Copper-Alloy Pipe
B 673	UNS N08904, UNS N08925, and UNS N08926 Welded Pipe
B 674	UNS N08904, UNS N08925, and UNS N08926 Welded Tube

Fittings

B 361	Factory-Made Wrought Aluminum and Aluminum-Alloy Welding Fittings
B 366	Nickel Alloy Fittings

Plate, Sheet, and Strip

B 168	Nickel-Chromium-Iron Alloy (UNS N06600–N06690) Plate, Sheet, and Strip
B 209	Aluminum and Aluminum-Alloy Sheet and Plate
B 265	Titanium and Titanium-Alloy Strip, Sheet, and Plate
B 402	Copper-Nickel Alloy Plate and Sheet for Pressure Vessels
B 409	Nickel-Iron-Chromium Alloy Plate, Sheet, and Strip
B 424	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Plate, Sheet, and Strip
B 463	Chromium-Nickel-Iron-Molybdenum-Copper-Columbium Stabilized Alloy (UNS N08020) Plate, Sheet, and Strip
B 625	UNS N08904, UNS N08925, and UNS N08031, UNS N08932, and UNS N08926 Plate, Sheet, and Strip

Rods, Bars, and Shapes

B 150	Aluminum Bronze Rod, Bar, and Shape
B 151	Copper-Nickel-Zinc Alloy (Nickel Silver) and Copper-Nickel Rod and Bar
B 221	Aluminum Alloy Extruded Bars, Rods, Wire, Shapes, and Tubes
B 348	Titanium and Titanium Alloy Bars and Billets
B 408	Nickel-Iron-Chromium Alloy Rod and Bar
B 425	Ni-Fe-Cr-Mo-Cu Alloy (UNS N08825 and N08221) Rod and Bar
B 473	UNS N08020, UNS N08024, and UNS N08026 Nickel Alloy Bar and Wire
B 649	Ni-Fe-Cr-Mo-Cu Low-Carbon Alloy (N08904) and Ni-Fe-Cr-Mo-Cu-N Low Carbon Alloys (UNS N08925, UNS N08031, and UNS N08926) Bar and Wire

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

ASTM Nonferrous Material Specifications (Cont'd)

Solder

B 32	Solder Metal

API Specifications

Seamless and Welded Pipe

5L	Line Pipe

American National Standards

B1.20.3	Dryseal Pipe Threads (Inch)
B16.18	Cast Copper Alloy Solder-Joint Pressure Fittings
B18.2.1	Square and Hex Bolts and Screws — Inch Series
B18.2.4.6M	Metric Heavy Hex Nuts
B18.22M	Metric Plain Washers
B18.22.1[2]	Plain Washers
Z223.1	National Fuel Gas Code (NFPA 54)

MSS Standard Practices

SP-6	Standard Finishes for Contact Faces of Pipe Flanges and Connecting-End Flanges of Valves and Fittings
SP-9	Spot-Facing for Bronze, Iron & Steel Flanges
SP-25	Standard Marking System for Valves, Fittings, Flanges and Unions
SP-42[1]	Class 150 Corrosion Resistant Gate, Globe, Angle and Check Valves With Flanged and Buttweld Ends
SP-43	Wrought Stainless Steel Butt-Welding Fittings
SP-45	Bypass & Drain Connection
SP-51	Class 150 LW Corrosion Resistant Cast Flanges and Flanged Fittings
SP-53	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Magnetic Particle Examination Method
SP-54	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Radiographic Examination Method
SP-55	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Visual Method for Evaluation of Surface Irregularities.
SP-58	Pipe Hangers & Supports, Materials, Design, and Manufacture
SP-61	Hydrostatic Testing Steel Valves
SP-67[1]	Butterfly Valves
SP-69	Pipe Hangers & Supports — Selection and Application
SP-75	Specification for High Test Wrought Butt-Welding Fittings
SP-79	Socket Welding Reducer Inserts
SP-80	Bronze Gate, Globe, Angle & Check Valve
SP-89	Pipe Hangers and Supports — Fabrication and Installation Practices
SP-93	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Liquid Penetrant Examination Method
SP-94	Quality Standard for Steel Castings and Forgings for Valves, Flanges, and Fittings and Other Piping Components — Ultrasonic Examination Method
SP-97	Integrally Reinforced Forged Branch Outlet Fittings — Socket Welding, Threaded and Buttwelding Ends
SP-105	Instrument Valves for Code Applications

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

01

ASME Codes and Standards

...	ASME Boiler and Pressure Vessel Code
B1.1	Unified Inch Screw Threads
B1.13M	Metric Screw Threads — M Profile
B1.20.1	Pipe Threads, General Purpose (Inch)
B16.1	C.I. Pipe Flanges and Flanged Fittings — 25, 125, 250 & 800 Classes
B16.3	M.I. Thd. Fittings
B16.4	G.I. Thd. Fittings
B16.5	Pipe Flanges & Flanged Fittings
B16.9	Wrought Steel Butt Welding Fittings
B16.10	Face-to-Face and End-to-End Dimensions of Valves
B16.11	Forged Steel Fittings, S.W. & Threaded
B16.14	Ferrous Plugs, Bushings & Locknuts with Pipe Threads
B16.15	Cast Bronze Threaded Fittings, Classes 125 and 250
B16.20	Metallic Gaskets for Pipe Flanges — Ring Joint, Spiral Wound, & Jacketed
B16.21	Non-Metallic Flat Gaskets for Pipe Flanges
B16.22	Wrought Copper & Copper Alloy Solder Joint Pressure Fittings
B16.24	Cast Copper Alloy Pipe Flanges & Flanged Fittings — Class 150, 300, 400, 600, 900, 1500, and 2500
B16.25	Butt Welding Ends
B16.28	Wrought Steel Butt Welding Short Radius Elbows and Returns
B16.34	Valves — Flanged, Threaded, and Welding End
B16.42	Ductile Iron Pipe Flanges and Flanged Fittings — Classes 150 and 300
B16.47	Large Diameter Steel Flanges
B16.48	Steel Line Blanks
B18.2.2	Square and Hex Nuts (Inch Series)
B18.2.3.5M	Metric Hex Bolts
B18.2.3.6M	Metric Heavy Hex Bolts
B18.21.1	Lock Washers (Inch Series)
B31.3	Process Piping
B31.4	Liquid Transportation Systems for Hydrocarbons, Liquid Petroleum Gas, Anhydrous Ammonia, and Alcohols
B31.8	Gas Transmission & Distribution Piping Systems
B36.10M	Welded and Seamless Wrought Steel Pipe
B36.19M	Stainless Steel Pipe
TDP-1	Recommended Practices for the Prevention of Water Damage to Steam Turbines Used for Electric Power Generation — Fossil Fueled Plants

ASNT Specifications

CP-189	ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel
SNT-TC-1A	Personnel Qualification and Certification in Nondestructive Testing

AWS Specifications

A3.0	Standard Welding Terms and Definitions
QC1	Qualification and Certification of Welding Inspectors

AWWA and ANSI/AWWA Standards

C-110/ A21.10	C.I. Fittings 2" thru 48"
C-111/ A21.11	Rubber Gasketed Joint for C.I. Pipe and Fittings
C-115/ A21.15	Flanged .C.I. Pipe with Thread Flanges
C-150/ A21.50	Thickness Design of Ductile-Iron Pipe
C-151/ A21.51	Ductile Iron Pipe Centrifugally Cast in metal or Sandlined Molds
C-200	Fabricated Electrically Welded Steel Pipe
C-207	Steel Pipe Flanges
C-208	Dimensions for Steel Water Pipe Fittings
C-300	Reinforced Concrete Water Pipe-Steel Cylinder Type Not Prestressed
C-301	Reinforced Concrete Water Pipe-Steel Cylinder Type Prestressed
C-302	Reinforced Concrete Water Pipe-Non Cylinder Type — Not Prestressed
C-500	Gate Valves for Ordinary Water Works Service
C-504[1]	Rubber Seated Butterfly Valves
C-600	Installation of C.I. Water Mains
C-606	Grooved and Shouldered Type Joints

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TABLE 126.1
SPECIFICATIONS AND STANDARDS (CONT'D)

National Fire Codes

NFPA 8503	Standard for Pulverized Fuel Systems
NFPA 1963	Screw Threads and Gaskets for Fire Hose Connections

PFI Standards

ES-16	Access Holes and Plugs for Radiographic Inspection of Pipe Welds

GENERAL NOTES:
(a) For boiler external piping application, see para. 123.2.2.
(b) For all other piping, materials conforming to an ASME SA or SB specification may be used interchangeably with material specified to an ASTM A or B spefication of the same number listed in Table 126.1.
(c) The approved year of issue of the specifications and standards is not given in this Table. This information is given in Appendix F of this Code.
(d) The addresses and phone numbers of organizations whose specifications and standards are listed in this Table are given at the end of Appendix F.
(e) Abbreviations which are used in this Table are:

B.W.	Butt welding	H.T.	High temperature	S.W.	Socket welding
C.I.	Cast iron	L.T.	Low temperature	Temp.	Temperature
Engr.	Engineering	M.I.	Malleable iron	Thd.	Threaded
Gen.	General	Serv.	Service(s)	T.S.	Tensile strength
G.I.	Gray iron	S.S.	Stainless steel		

NOTES:
(1) See para. 107.1(D) for valve stem retention requirements.
(2) ANSI B18.22.1 is nonmetric.

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CHAPTER V
FABRICATION, ASSEMBLY, AND ERECTION

127 WELDING

127.1 General

Piping systems shall be constructed in accordance with the requirements of this Chapter and of materials that have been manufactured in accordance with the requirements of Chapter IV. These requirements apply to all fabrication, assembly, and erection operations, whether performed in a shop or at a construction site. The following applies essentially to the welding of ferrous materials. The welding of aluminum, copper, etc., requires different preparations and procedures.

127.1.1 The welding processes that are to be used under this part of this Code shall meet all the test requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

127.2 Material

127.2.1 Filler Metal. All filler metal, including consumable insert material, shall comply with the requirements of Section IX, ASME Boiler and Pressure Vessel Code. A filler metal not incorporated in Section IX may be used if a procedure qualification test is first successfully made in accordance with Section IX. Filler metals with less than 0.05% carbon content shall not be used for high temperature applications (above 850°F) in low alloy steels due to reduced creep rupture properties.

127.2.2 Backing Rings. Backing rings, when used, shall conform to the following requirements:

(A) Ferrous Rings. Ferrous metal backing rings which become a permanent part of the weld shall be made from material of weldable quality, compatible with the base material and the sulfur content shall not exceed 0.05%.

(A.1) Backing rings may be of the continuous machined or split band type.

(A.2) If two abutting surfaces are to be welded to a third member used as a backing ring and one or two of the three members are ferritic and the other member or members are austenitic, the satisfactory use of such materials shall be determined by the WPS qualified as required in para. 127.5.

(A.3) Backing strips used at longitudinal welded joints shall be removed.

(B) Nonferrous and Nonmetallic Rings. Backing rings of nonferrous or nonmetallic materials may be used for backing provided they are included in a WPS as required in para. 127.5. Nonmetallic or nonfusing rings shall be removed.

127.2.3 Consumable Inserts. Consumable inserts may be used provided they are made from material compatible with the chemical and physical properties of the base material. Qualification of the WPS shall be as required by para. 127.5.

127.3 Preparation for Welding

(A) End Preparation

(A.1) Oxygen or arc cutting is acceptable only if the cut is reasonably smooth and true, and all slag is cleaned from the flame cut surfaces. Discoloration which may remain on the flame cut surface is not considered to be detrimental oxidation.

(A.2) Butt-welding end preparation dimensions contained in ASME B16.25 or any other end preparation which meets the WPS are acceptable.

(A.3) If piping component ends are bored, such boring shall not result in the finished wall thickness after welding less than the minimum design thickness. Where necessary, weld metal of the appropriate analysis may be deposited on the inside or outside of the piping component to provide sufficient material for machining to insure satisfactory fitting of rings.

(A.4) If the piping component ends are upset, they may be bored to allow for a completely recessed backing ring, provided the remaining net thickness of the finished ends is not less than the minimum design thickness.

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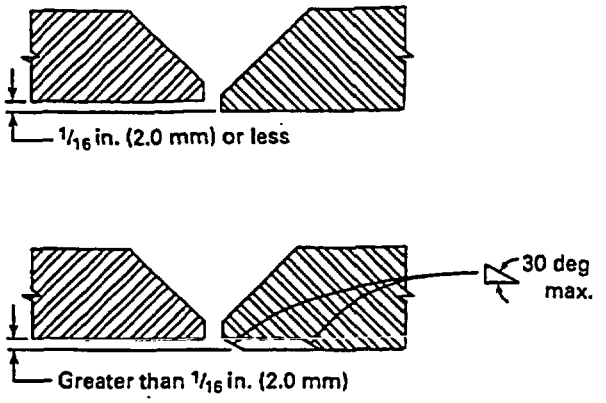

FIG 127.3 BUTT WELDING OF PIPING COMPONENTS WITH INTERNAL MISALIGNMENT

(B) Cleaning. Surfaces for welding shall be clean and shall be free from paint, oil, rust, scale, or other material which is detrimental to welding.

(C) Alignment. The inside diameters of piping components to be butt welded shall be aligned as accurately as is practicable within existing commercial tolerances on diameters, wall thicknesses, and out-of-roundness. Alignment shall be preserved during welding. The internal misalignment of the ends to be joined shall not exceed 1/16 in. (2.0 mm) unless the piping design specifically states a different allowable misalignment.

When the internal misalignment exceeds the allowable, it is preferred that the component with the wall extending internally be internally trimmed per Fig. 127.3. However, trimming shall result in a piping component thickness not less than the minimum design thickness and the change in contour shall not exceed 30 deg (see Fig. 127.3).

(D) Spacing. The root opening of the joint shall be as given in the WPS.

(E) Socket Weld Assembly. In assembly of the joint before welding, the pipe or tube shall be inserted into the socket to the maximum depth and then withdrawn approximately 1/16 in. (2.0 mm) away from contact between the end of the pipe and the shoulder of the socket [see Figs. 127.4.4(B) and (C)]. In sleeve type joints without internal shoulder, there shall be a distance of approximately 1/16 in. (2.0 mm) between the butting ends of the pipe or tube.

The fit between the socket and the pipe shall conform to applicable standards for socket weld fittings and in no case shall the inside diameter of the socket or sleeve exceed the outside diameter of the pipe or tube by more than 0.080 in. (2.0 mm).

127.4 Procedure

127.4.1 General

(A) Qualification of the WPS to be used, and of the performance of welders and operators, is required, and shall comply with the requirements of para. 127.5.

(B) No welding shall be done if there is impingement of rain, snow, sleet, or high wind on the weld area.

(C) Tack welds permitted to remain in the finished weld shall be made by a qualified welder. Tack welds made by an unqualified welder shall be removed. Tack welds which remain shall be made with an electrode and WPS which is the same as or equivalent to the electrode and WPS to be used for the first pass. The stopping and starting ends shall be prepared by grinding or other means so that they can be satisfactorily incorporated into the final weld. Tack welds which have cracked shall be removed.

(D) CAUTION: Arc strikes outside the area of the intended weld should be avoided on any base metal.

127.4.2 Girth Butt Welds

(A) Girth butt welds shall be complete penetration welds and shall be made with a single vee, double vee, or other suitable type of groove, with or without backing rings or consumable inserts. The depth of the weld measured between the inside surface of the weld preparation and the outside surface of the pipe shall not be less than the minimum thickness required by Chapter II for the particular size and wall of pipe used.

(B) In order to avoid abrupt transitions in the contour of the finished weld, the requirements of (B.1) through (B.4) below shall be met.

(B.1) When components with different outside diameters or wall thicknesses are welded together, the welding end of the component with the larger outside diameter shall fall within the envelope defined by solid lines in Fig. 127.4.2. The weld shall form a gradual transition not exceeding a slope of 30 deg from the smaller to the larger diameter component. This condition may be met by adding welding filler material, if necessary, beyond what would otherwise be the edge of the weld.

(B.2) When both components to be welded (other than pipe to pipe) have a transition from a thicker section to the weld end preparation, the included angle between the surface of the weld and the surface of either of the components shall not be less than 150 deg Refer to para. 119.3(B) for additional concerns related to this design.

(B.3) When welding pipe to pipe, the surface of the

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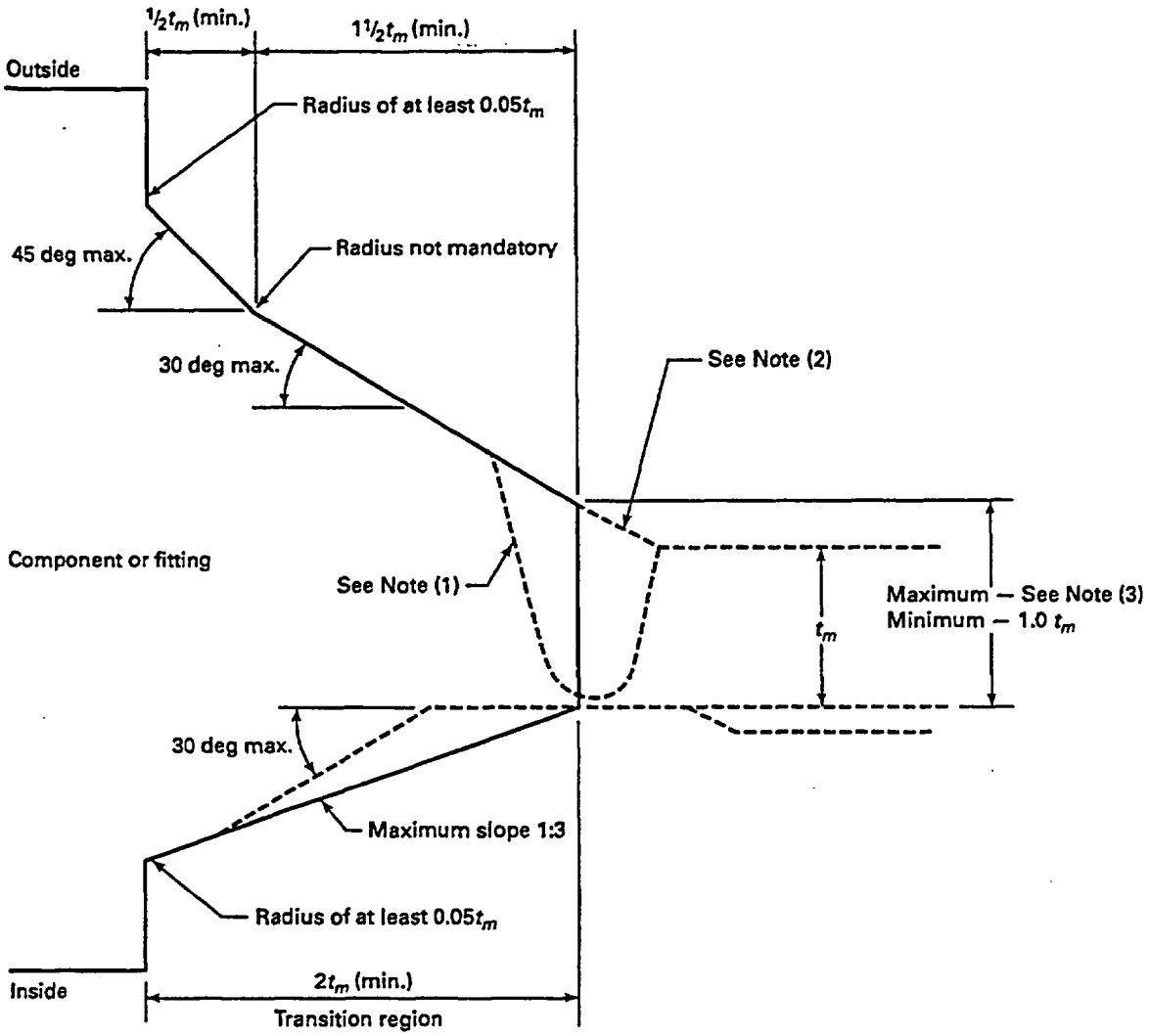

GENERAL NOTES:

(a) The value of t_m is whichever of the following is applicable:
  (1) as defined in para. 104.1.2(A);
  (2) the minimum ordered wall thickness of the cylindrical welding end of a component or fitting (or the thinner of the two) when the joint is between two components.

(b) The maximum envelope is defined by solid lines.

NOTES:

(1) Weld is shown for illustration only.

(2) The weld transition and weld reinforcement shall comply with paras. 127.4.2(B) and (C.2) and may be outside the maximum envelope.

(3) The maximum thickness at the end of the component is:
  (a) the greater of (t_m + 0.15 in.) or $1.15t_m$ when ordered on a minimum wall basis;
  (b) the greater of (t_m + 0.15 in.) or $1.10t_{nom}$ when ordered on a nominal wall basis.

FIG. 127.4.2 WELDING END TRANSITION — MAXIMUM ENVELOPE

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TABLE 127.4.2
REINFORCEMENT OF GIRTH AND LONGITUDINAL BUTT WELDS

Thickness of Base Metal, in. (mm)	Maximum Thickness of Reinforcement for Design Temperature					
	> 750°F (400°C)		350°F–750°F (175°C–400°C)		< 350°F (175°C)	
	in.	mm	in.	mm	in.	mm
Up to 1/8 (3.0), incl.	1/16	2.0	3/32	2.5	3/16	5.0
Over 1/8 to 3/16 (3.0 to 5.0), incl.	1/16	2.0	1/8	3.0	3/16	5.0
Over 3/16 to 1/2 (5.0 to 13.0), incl.	1/16	2.0	5/32	4.0	3/16	5.0
Over 1/2 to 1 (13.0 to 25.0), incl.	3/32	2.5	3/16	5.0	3/16	5.0
Over 1 to 2 (25.0 to 50.0), incl.	1/8	3.0	1/4	6.0	1/4	6.0
Over 2 (50.0)	5/32	4.0	The greater of 1/4 in. (6 mm) or 1/8 times the width of the weld in inches (millimeters).			

GENERAL NOTES:
(a) For double welded butt joints, this limitation on reinforcement given above shall apply separately to both inside and outside surfaces of the joint.
(b) For single welded butt joints, the reinforcement limits given above shall apply to the outside surface of the joint only.
(c) The thickness of weld reinforcement shall be based on the thickness of the thinner of the materials being joined.
(d) The weld reinforcement thicknesses shall be determined from the higher of the abutting surfaces involved.
(e) Weld reinforcement may be removed if so desired.

weld shall, as a minimum, be flush with the outer surface of the pipe, except as permitted in para. 127.4.2(B.4).

(B.4) For welds made without the addition of filler metal, concavity shall be limited to 1/32 in. (1 mm) below the outside surface of the pipe, but shall not encroach upon minimum required thickness.

(C) As-welded surfaces are permitted; however, the surface of welds shall be sufficiently free from coarse ripples, grooves, overlaps, abrupt ridges, and valleys to meet the following.

(C.1) The surface condition of the finished welds shall be suitable for the proper interpretation of radiographic and other nondestructive examinations when nondestructive examinations are required by Table 136.4. In those cases where there is a question regarding the surface condition on the interpretation of a radiographic film, the film shall be compared to the actual weld surface for interpretation and determination of acceptability.

(C.2) Reinforcements are permitted in accordance with Table 127.4.2.

(C.3) Undercuts shall not exceed 1/32 in. (1.0 mm) and shall not encroach on the minimum required section thickness.

(C.4) If the surface of the weld requires grinding to meet the above criteria, care shall be taken to avoid reducing the weld or base material below the minimum required thickness.

(C.5) Concavity on the root side of a single welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two sections being joined and the contour of the concavity is smooth without sharp edges. The internal condition of the root surface of a girth weld, which has been examined by radiography, is acceptable only when there is a gradual change in the density, as indicated in the radiograph. If a girth weld is not designated to be examined by radiography, a visual examination may be performed at welds which are readily accessible.

127.4.3 Longitudinal Butt Welds. Longitudinal butt welds not covered by the applicable material specifications listed in Table 126.1 shall meet the requirements for girth butt welds in para. 127.4.2.

127.4.4 Fillet Welds. In making fillet welds, the weld metal shall be deposited in such a way as to secure adequate penetration into the base metal at the root of the weld.

Fillet welds may vary from convex to concave. The size of a fillet weld is determined as shown in Fig. 127.4.4(A). Typical minimum fillet weld details for slip-on flanges and socket-welding components are shown in Figs. 127.4.4(B) and (C).

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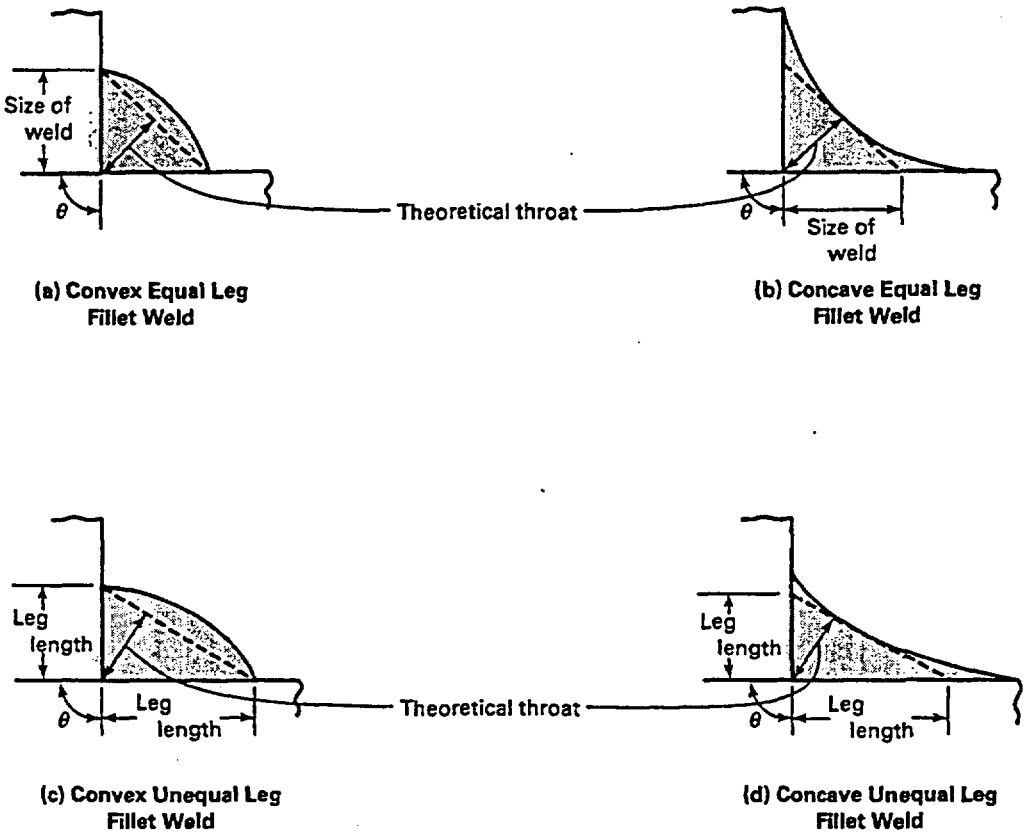

(a) Convex Equal Leg Fillet Weld

(b) Concave Equal Leg Fillet Weld

(c) Convex Unequal Leg Fillet Weld

(d) Concave Unequal Leg Fillet Weld

GENERAL NOTES:

(a) The "size" of an equal leg fillet weld shall be described by the leg length of the largest inscribed isoceles triangle.

(b) The "size" of an unequal leg fillet weld shall be described using both leg lengths and their location on the members to be joined.

(c) Angle θ, as noted in the above figures, may vary from the 90 deg angle as shown based on the angle between the surfaces to be welded.

(d) For an equal leg fillet weld where the angle θ between the members being joined is 90 deg, the theoretical throat shall be 0.7 × leg length. For other fillet welds, the theoretical throat shall be based on the leg lengths and the angle θ between the members to be joined.

(e) For all fillet welds, particularly unequal leg fillet welds with angle θ less than 90 deg, the theoretical throat shall lie within the cross section of the deposited weld metal and shall not be less than the minimum distance through the weld.

FIG. 127.4.4(A) FILLET WELD SIZE

127.4.5 Seal Welds. Where seal welding of threaded joints is performed, threads shall be entirely covered by the seal weld. Seal welding shall be done by qualified welders.

127.4.8 Welded Branch Connections

(A) Welded branch connections shall be made with full penetration welds, except as allowed in para. 127.4.8(F). Figures 127.4.8(A), (B), and (C) show typical details of branch connections with and without added reinforcement. No attempt has been made to show all acceptable types of construction and the fact that a certain type of construction is illustrated does not indicate that it is recommended over other types not illustrated.

(B) Figure 127.4.8(D) shows basic types of weld attachments used in the fabrication of branch connections. The location and minimum size of these attach-

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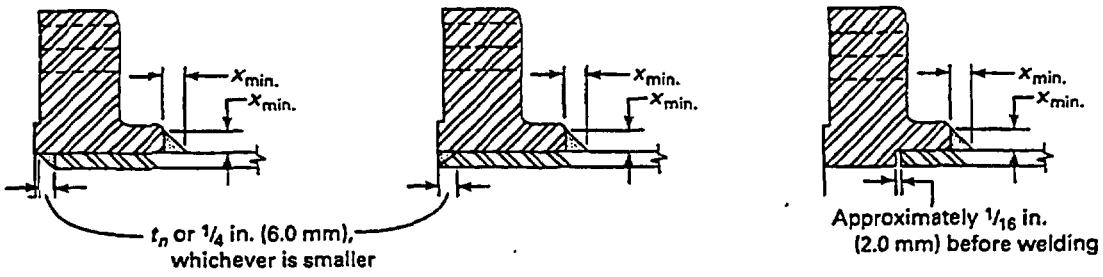

(a) Front and Back Weld [See Notes (1) and (2)]

(b) Face and Back Welds [See Notes (1) and (2)]

(c) Socket Welding Flange [See Notes (2) and (3)]

t_n = nominal pipe wall thickness
$x_{min.}$ = 1.09t_n or thickness of the hub, whichever is smaller

NOTES:
(1) Refer to para. 122.1.1(F) for limitations of use.
(2) Refer to para. 104.5.1 for limitations of use.
(3) Refer to para. 122.1.1(H) for limitations of use.

FIG. 127.4.4(B) WELDING DETAILS FOR SLIP-ON AND SOCKET-WELDING FLANGES; SOME ACCEPTABLE TYPES OF FLANGE ATTACHMENT WELDS

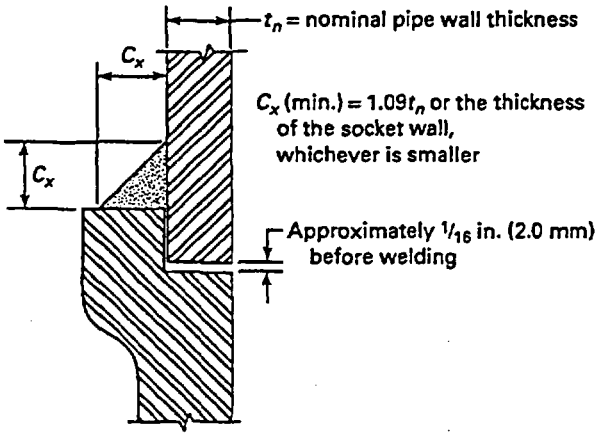

FIG. 127.4.4(C) MINIMUM WELDING DIMENSIONS REQUIRED FOR SOCKET WELDING COMPONENTS OTHER THAN FLANGES

ment welds shall conform to the requirements of para. 127.4.8. Welds shall be calculated in accordance with para. 104.3.1 but shall not be less than the sizes shown in Fig. 127.4.8(D).

The notations and symbols used in this paragraph and in Fig. 127.4.8(D) are as follows:

t_c = the smaller of 1/4 in. (6.0 mm) or 0.7t_{nb}

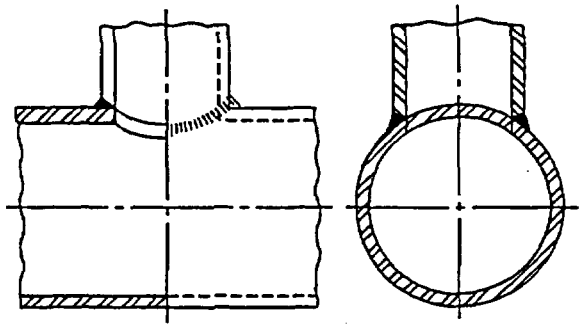

FIG. 127.4.8(A) TYPICAL WELDED BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

t_{nr} = nominal thickness of reinforcing element (ring or saddle), in. (mm)
t_{min} = the smaller of t_{nb} or t_{nr}
t_{nb} = nominal thickness of branch wall, in. (mm)
t_{nh} = nominal thickness of header wall, in. (mm)

(C) Figure 127.4.8(E) shows branch connections made by welding half couplings or adapters directly to the run pipe.

These branch connections and specially made integrally reinforced branch connection fittings which abut the outside surface of the run wall, or which are inserted through an opening cut in the run wall, shall have

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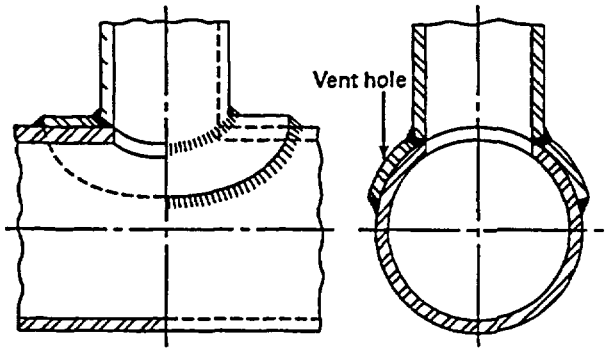

FIG. 127.4.8(B) TYPICAL WELDED BRANCH CONNECTION WITH ADDITIONAL REINFORCEMENT

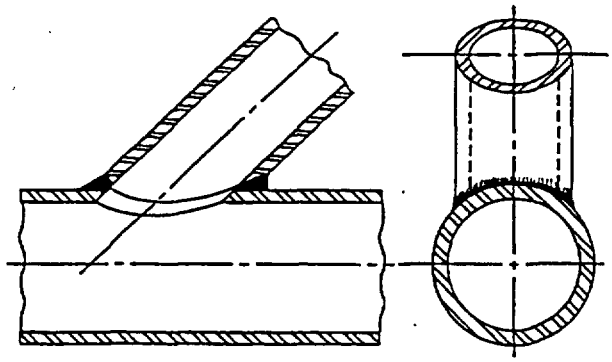

FIG. 127.4.8(C) TYPICAL WELDED ANGULAR BRANCH CONNECTION WITHOUT ADDITIONAL REINFORCEMENT

opening and branch contour to provide a good fit and shall be attached by means of full penetration groove welds except as otherwise permitted in (F) below.

The full penetration groove welds shall be finished with cover fillet welds and meet the requirements of para. 104. The cover fillet welds shall have a minimum throat dimension not less than that shown in Fig. 127.4.8(E).

(D) In branch connections having reinforcement pads or saddles, the reinforcement shall be attached by welds at the outer edge and at the branch periphery as follows.

(D.1) If the weld joining the added reinforcement to the branch is a full penetration groove weld, it shall be finished with a cover fillet weld having a minimum throat dimension not less than t_c; the weld at the outer edge, joining the added reinforcement to the run, shall be a fillet weld with a minimum throat dimension of $0.5t_{nr}$.

(D.2) If the weld joining the added reinforcement to the branch is a fillet weld, the throat dimension shall not be less than $0.7t_{min}$. The weld at the outer edge joining the outer reinforcement to the run shall also be a fillet weld with a minimum throat dimension of $0.5t_{nr}$.

(E) When rings or saddles are used, a vent hole shall be provided (at the side and not at the crotch) in the ring or saddle to reveal leakage in the weld between branch and main run and to provide venting during welding and heat treating operations. Rings or saddles may be made in more than one piece if the joints between the pieces have strength equivalent to ring or saddle parent metal and if each piece is provided with a vent hole. A good fit shall be provided between reinforcing rings or saddles and the parts to which they are attached.

(F) Branch connections NPS 2 and smaller which do not require reinforcements (see para. 104.3) may be constructed as shown in Fig. 127.4.8(F). The groove welds shall be finished with cover fillet welds with a minimum throat dimension not less than that shown in Fig. 127.4.8(F). This construction shall not be used at design temperatures greater than 750°F (400°C) nor at design pressures greater than 1025 psi (7100 kPa).

127.4.9 Attachment Welds. Structural attachments may be made by complete penetration, partial penetration, or fillet welds.

(A) Low energy capacitor discharge welding may be used for the welding of temporary attachments directly to pressure parts, provided that they be removed prior to subjecting the piping system to operating pressure or temperature. After their removal, the affected areas shall be examined in accordance with para. 136.4. Performance and procedure qualifications are not required.

This method of welding may also be used for the permanent attachment of nonstructural items, such as strain gages or thermocouples, provided that:

(A.1) a welding procedure specification is prepared describing the capacitor discharge equipment, the materials to be joined, and the techniques of application; the qualification of the procedure is not required;

(A.2) the minimum thickness of the material to which the attachment is to be made is 0.090 in. (2.3 mm);

(A.3) the power input is limited to less than 125 W-sec.

127.4.10 Heat Treatment. Preheat and postweld heat treatment for welds shall be in accordance with para. 131 or 132 as applicable.

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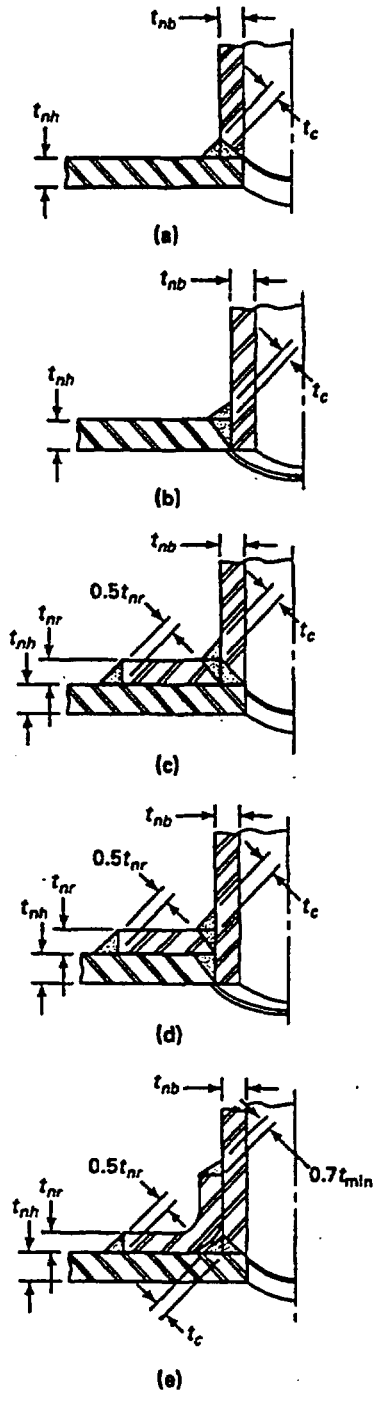

GENERAL NOTE: Weld dimensions may be larger than the minimum values shown here.

FIG. 127.4.8(D) SOME ACCEPTABLE TYPES OF WELDED BRANCH ATTACHMENT DETAILS SHOWING MINIMUM ACCEPTABLE WELDS

127.4.11 Repair Welding

(A) Defect Removal. All defects in welds or base materials requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. Preheating may be required for flame or arc gouging on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface.

(B) Repair Welds. Repair welds shall be made in accordance with a WPS using qualified welders or welding operators (see para. 127.5), recognizing that the cavity to be repair welded may differ in contour and dimension from a normal joint preparation and may present different restraint conditions. The types, extent, and methods of examination shall be in accordance with Table 136.4. For repairs to welds the minimum examination shall be the same method that revealed the defect in the original weld. For repairs to base material, the minimum examination shall be the same as required for butt welds.

127.5 Qualification

127.5.1 General. Qualification of the WPS to be used, and of the performance of welders and welding operators, is required, and shall comply with the requirements of the ASME Boiler and Pressure Vessel Code (Section IX) except as modified herein.

Certain materials listed in Appendix A do not appear in ASME Section IX P-Number groups. Where these materials have been assigned P-Numbers in Appendix A, they may be welded under this Code for nonboiler external piping only without separate qualification as if they were listed in ASME Section IX.

127.5.2 Welding Responsibility. Each employer (see para. 100.2) shall be responsible for the welding performed by his organization and the performance of welders or welding operators employed by that organization.

127.5.3 Qualification Responsibility

(A) Procedures. Each employer shall be responsible for qualifying any WPS that he intends to have used by personnel of his organization. However, to avoid duplication of effort, and subject to approval of the owner, a WPS qualified by a technically competent group or agency may be used:

(A.1) if the group or agency qualifying the WPS meets all of the procedure qualification requirements of this Code;

(A.2) if the fabricator accepts the WPS thus qualified;

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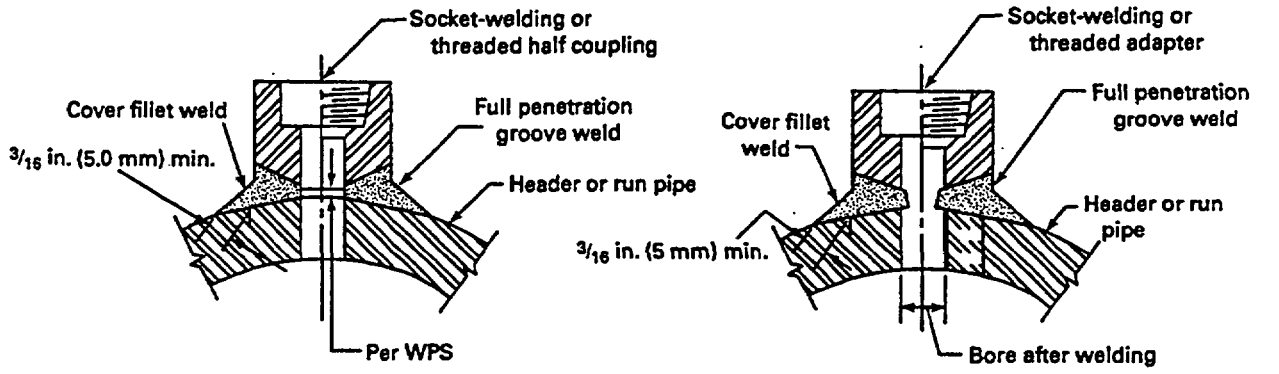

(a) Branch Connection Using ASME B16.11 Forged Steel Socket-Welding or Threaded Half Coupling [See Note (1)]

(b) Branch Connection Using Forged Steel Socket-Welding or Threaded Adapter for Pressure and Temperature Conditions Greater Than Permitted for ASME B16.11 Forged Steel Fittings

NOTE:
(1) Refer to para. 104.3.1(C.2) for branch connections not requiring reinforcement calculations.

FIG. 127.4.8(E) TYPICAL FULL PENETRATION WELD BRANCH CONNECTIONS FOR NPS 3 AND SMALLER HALF COUPLINGS OR ADAPTERS

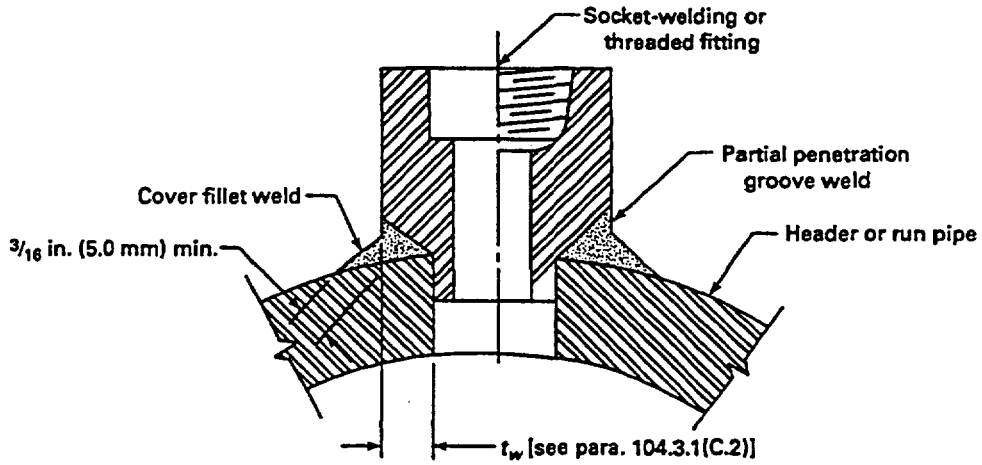

FIG. 127.4.8(F) TYPICAL PARTIAL PENETRATION WELD BRANCH CONNECTION FOR NPS 2 AND SMALLER FITTINGS

(A.3) if the user of the WPS has qualified at least one welder using the WPS;

(A.4) if the user of the WPS assumes specific responsibility for the procedure qualification work done for him by signing the records required by para. 127.6.

All four of the above conditions shall be met before a WPS thus qualified may be used.

(B) Welders and Welding Operators. Each employer shall be responsible for qualifying all the welders and welding operators employed by him.

However, to avoid duplication of effort, he may accept a Welder/Welding Operator Performance Qualification (WPQ) made by a previous employer (subject to the approval of the owner or his agent) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX,

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ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by a previous employer shall obtain a copy (from the previous employer) of the WPQ, showing the name of the employer by whom the welders or welding operators were qualified, the dates of such qualification, and evidence that the welder or welding operator has maintained qualification in accordance with QW-322 of Section IX, ASME Boiler and Pressure Vessel Code. The employer shall then prepare and sign the record required in para. 127.6 accepting responsibility for the ability of the welder or welding operator.

01 **127.5.4 Standard Welding Procedure Specifications.** Standard Welding Procedure Specifications published by the American Welding Society and listed in Appendix E of Section IX of the ASME Boiler and Pressure Vessel Code are permitted for Code construction within the limitations established by Article V of ASME Section IX.

127.6 Welding Records

The employer shall maintain a record (WPS and/or WPQ) signed by him, and available to the purchaser or his agent and the inspector, of the WPSs used and the welders and/or welding operators employed by him, showing the date and results of procedure and performance qualification.

The WPQ shall also show the identification symbol assigned to the welder or welding operator employed by him, and the employer shall use this symbol to identify the welding performed by the welder or welding operator. This may be accomplished by the application of the symbol on the weld joint in a manner specified by the employer. Alternatively, the employer shall maintain records which identify the weld(s) made by the welder or welding operator.

128 BRAZING

128.1 General

128.1.1 The brazing processes that are to be used under this part of the Code shall meet all the test requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

128.2 Materials

128.2.1 Filler Metal. The filler metal shall melt and flow freely within the desired temperature range and, in conjunction with a suitable flux or controlled atmosphere, shall wet and adhere to the surfaces to be joined.

128.2.2 Flux. Fluxes that are fluid and chemically active at the brazing temperature shall be used when necessary to prevent oxidation of the filler metal and the surfaces to be joined and to promote free flowing of the filler metal.

128.3 Preparation

128.3.1 Surface Preparation. The surfaces to be brazed shall be clean and free from grease, oxides, paint, scale, dirt, or other material that is detrimental to brazing. A suitable chemical or mechanical cleaning method can be used to provide a clean wettable surface for brazing.

128.3.2 Joint Clearance. The clearance between surfaces to be joined shall be no larger than is necessary to complete capillary distribution of the filler metal.

128.4 Procedure

128.4.1 General

(A) Qualification of the brazing procedures to be used and of the performance of the brazer and brazing operators is required and shall comply with the requirements of para. 128.5.

(B) No brazing shall be done if there is impingement of rain, snow, sleet, or high wind on the area to be brazed.

128.4.2 Heating. The joint shall be brought to brazing temperature in as short a time as possible to minimize oxidation.

128.5 Qualification

128.5.1 General. The qualification of the brazing procedure and of the performance of brazers and brazing operators shall be in accordance with the requirements of Part QB, Section IX, ASME Boiler and Pressure Vessel Code, except as modified herein.

128.5.2 Brazing Responsibility. Each employer (see para. 100.2) shall be responsible for the brazing performed by his organization and the performance of brazers or brazing operators employed by that organization.

128.5.3 Qualification Responsibility

(A) Procedures. Each employer shall be responsible for qualifying any Brazing Procedure Specification

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(BPS) that he intends to have used by personnel of his organization. However, to avoid duplication of effort, and subject to approval of the owner, a BPS qualified by a technically competent group or agency may be used:

(A.1) if the group or agency qualifying the procedures meets all of the procedure qualification requirements of this Code;

(A.2) if the fabricator accepts the procedure thus qualified;

(A.3) if the user of the procedure has qualified at least one brazer using the BPS;

(A.4) if the user of the procedure assumes specific responsibility for the procedure qualification work done by him by signing the records required by para. 128.6.

All four of the above conditions shall be met before a procedure thus qualified may be used.

(B) Brazers and Brazing Operators. Each employer shall be responsible for qualifying all the brazers and brazing operators employed by him.

However, to avoid duplication of effort, he may accept a Brazer/Brazing Operator Performance Qualification (BPQ) made by a previous employer (subject to the approval of the owner or his agent) on piping using the same or an equivalent procedure wherein the essential variables are within the limits established in Section IX, ASME Boiler and Pressure Vessel Code. An employer accepting such qualification tests by a previous employer shall obtain a copy (from the previous employer) of the BPQ, showing the name of the employer by whom the brazers or brazing operators were qualified, the dates of such qualification, and the date the brazer last brazed pressure piping components under such qualification. The employer shall then prepare and sign the record required in para. 128.6 accepting responsibility for the ability of the brazer or brazing operator.

128.6 Brazing Records

The employer shall maintain a record signed by him and available to the purchaser or his agent and the inspector, showing the date and results of procedure and performance qualification.

The BPQ shall also show the identification symbol assigned to the brazer or brazing operator employed by him, and the employer shall use this symbol to identify the brazing performed by the brazer or brazing operator. This may be accomplished by the application of the symbol on the braze joint in a manner specified by the employer. Alternatively, the employer shall maintain records which identify the braze joints(s) made by the brazer or brazing operator.

TABLE 129.3.2
APPROXIMATE LOWER CRITICAL TEMPERATURES

Material	Approximate Lower Critical Temperature (1), °F (°C)
Carbon Steel (P-No. 1)	1340 (725)
Carbon Molybdenum Steel (P-No. 3)	1350 (730)
1Cr–½Mo (P-No 4, Gr. No. 1)	1375 (745)
1¼Cr–½Mo (P-No. 4, Gr. No. 2)	1430 (775)
2¼Cr–1Mo, 3Cr–1Mo (P-No. 5A)	1480 (805)
5Cr–½Mo (P-No. 5B, Gr. No. 1)	1505 (820)
9Cr–½Mo (P-No. 5B, Gr. No. 2)	1490 (810)

NOTE:
(1) These values are intended for guidance only. The user may apply values obtained for the specific material in lieu of these values.

129 BENDING AND FORMING

129.1 Bending

Pipe may be bent by any hot or cold method and to any radius which will result in a bend surface free of cracks, as determined by a method of inspection specified in the design, and substantially free of buckles. Such bends shall meet the design requirements of paras. 102.4.5 and 104.2.1. This shall not prohibit the use of bends designed as creased or corrugated.

129.2 Forming

Piping components may be formed (swedging, lapping, or upsetting of pipe ends, extrusion of necks, etc.) by any suitable hot or cold working method, provided such processes result in formed surfaces which are uniform and free of cracks or other defects, as determined by method of inspection specified in the design.

129.3 Heat Treatment of Bends and Formed Components

129.3.1 Hot bending or forming is performed at a temperature above T_{crit} – 100°F (56°C) where T_{crit} is the lower critical temperature of the material. Cold bending or forming is performed at a temperature below T_{crit} – 100°F (56°C). (See Table 129.3.2 for lower critical temperatures.)

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129.3.2 A postbending or postforming heat treatment at the time and temperature cycles listed for postweld heat treatment in Table 132 is required on all carbon steel (P-No. 1) materials with a nominal wall thickness in excess of $^3/_4$ in. (19.0 mm) unless the bending or forming operations are performed and completed at temperatures of 1650°F (900°C) or greater.

129.3.3 A postforming or postbending heat treatment as defined below is required for all ferritic alloy steel (excluding P-No. 1) materials with a nominal pipe size 4 in. and larger or with a nominal thickness of $^1/_2$ in. (13.0 mm) or greater.

(A) If hot bending or forming is performed, the material shall receive a full anneal, normalize and temper, or tempering heat treatment as specified by the designer.

(B) If cold bending or forming is performed, a heat treatment is required at the time and temperature cycle listed for the material in Table 132.

129.3.4 Postbending or postforming heat treatment of other materials including austenitic stainless steel is neither required nor prohibited. If a postbending or postforming heat treatment is to be performed, the designer shall fully describe the procedure to be used.

130 REQUIREMENTS FOR FABRICATING AND ATTACHING PIPE SUPPORTS

130.1

Standard pipe hangers and supports shall be fabricated in accordance with the requirements of MSS SP-58. Welders, welding operators, and WPSs shall be qualified in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section IX.

130.2

Special hangers, supports, anchors, and guides, not defined as standard types of hanger components in MSS SP-58, shall be welded in accordance with the requirements of para. 127 (Paragraph 132 is not applicable except as required by the weld procedure used.) and inspected in accordance with the requirement of para. 136.4.2.

130.3

Welds attaching hangers, supports, guides, and anchors to the piping system shall conform to the requirements of Chapters V and VI of this Code.

131 WELDING PREHEAT

131.1

The preheat requirements listed herein are mandatory minimum values.

The base metal temperature prior to welding shall be at or above the specified minimum temperature in all directions from the point of welding for a distance of 3 in. or 1.5 times the base metal thickness (as defined in para. 131.4.1), whichever is greater.

The base metal temperature for tack welds shall be at or above the specified minimum temperature for a distance not less than 1 in. in all directions from the point of welding.

131.2

When welding two different P-Number materials, the minimum preheat temperature required shall be the higher temperature for the material to be welded.

131.3

The preheat temperature shall be checked by use of temperature-indicating crayons, thermocouple pyrometers, or other suitable methods to assure that the required preheat temperature is obtained prior to and uniformly maintained during the welding operation.

131.4 Preheat Temperature

The minimum preheat for all materials shall be 50°F (10°C) unless stated otherwise in the following paragraphs.

131.4.1 Thickness referred to is the greater of the nominal thicknesses at the weld of the parts to be joined.

131.4.2 P-No. 1. 175°F (80°C) for material which has both a specified maximum carbon content in excess of 0.30% and a thickness at the joint in excess of 1 in. (25.0 mm). Preheat may be based on the actual carbon content as determined from a ladle or product analysis in accordance with the material specification in lieu of the maximum carbon content specified in the material specification.

131.4.3 P-No. 3. 175°F (80°C) for material or product form which has either a specified minimum tensile strength in excess of 60,000 psi (413.7 MPa) or a thickness at the joint in excess of $^1/_2$ in. (13.0 mm).

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131.4.4 P-No. 4. 250°F (120°C) for all materials.

131.4.5 P-Nos. 5A and 5B

(A) 400°F (200°C) for material which has either a specified minimum tensile strength in excess of 60,000 psi (413.7 MPa), or has both a specified minimum chromium content above 6.0% and a thickness at the joint in excess of ½ in. (13.0 mm);

(B) 300°F (150°C) for all other materials having this P-Number.

131.4.6 P-No. 6. 400°F (200°C) for all materials.

131.4.7 P-Nos. 9A and 9B

(A) 250°F (120°C) for P-No. 9A materials;

(B) 300°F (150°C) for P-No. 9B materials.

131.4.8 P-No. 10I. 300°F (150°C) with an interpass temperature of 450°F (230°C) maximum.

131.5

For inert gas tungsten arc root pass welding, a lower preheat temperature in accordance with the temperature established in the WPS may be used.

131.6 Interruption of Welding

131.6.1 After welding commences, the minimum preheat temperature shall be maintained until any required PWHT is performed on P-Nos. 3, 4, 5A, 5B, and 6, except when all of the following conditions are satisfied.

(A) A minimum of at least ⅜ in. thickness of weld is deposited or 25% of the welding groove is filled, whichever is less (the weldment shall be sufficiently supported to prevent overstressing the weld if the weldment is to be moved or otherwise loaded).

(B) For P-Nos. 3, 4, and 5A (with a chromium content of 3.0% maximum) materials, the weld is allowed to cool slowly to room temperature.

(C) For P-No. 5B (with a chromium content greater than 3.0%) and P-No. 6 materials, the weld is subjected to an adequate intermediate heat treatment with a controlled rate of cooling.

(D) After cooling and before welding is resumed, visual examination of the weld shall be performed to assure that no cracks have formed.

(E) Required preheat shall be applied before welding is resumed.

132 POSTWELD HEAT TREATMENT

132.1

Before applying the detailed requirements and exemptions in these paragraphs, satisfactory qualification of the WPS to be used shall be performed in accordance with the essential variables of the ASME Boiler and Pressure Vessel Code, Section IX including the conditions of postweld heat treatment or lack of postweld heat treatment and including other restrictions listed below. Except as otherwise provided in paras. 132.2 and 132.3, all welds in materials included in the P-Numbers listed in Table 132 shall be given a postweld heat treatment within the temperature range specified in Table 132. (The range specified in Table 132 may be modified by Table 132.1 for the lower limit and para. 132.2 for the upper limit.) The materials in Table 132 are listed in accordance with the material P-Number grouping of Appendix A. Welds of materials not included in Table 132 shall be heat treated in accordance with the WPS.

132.2

Heat treatment may be accomplished by a suitable heating method which will provide the desired heating and cooling rates, the required metal temperature, temperature uniformity, and temperature control.

(A) The upper limit of the PWHT temperature range in Table 132 is a recommended value which may be exceeded provided the actual temperature does not exceed the lower critical temperature of either material (see Table 129.3.2).

(B) When parts of two different P-Numbers are joined by welding, the postweld heat treatment shall be that specified for the material requiring the higher PWHT temperature. When a nonpressure part is welded to a pressure part and PWHT is required for either part, the maximum PWHT temperature shall not exceed the maximum temperature acceptable for the pressure retaining part.

(C) Caution is necessary to preclude metallurgical damage to some materials or welds not intended or qualified to withstand the PWHT temperatures required.

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TABLE 132
POSTWELD HEAT TREATMENT

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 1 Gr. Nos. 1, 2, 3	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT of P-No. 1 materials is not mandatory, provided that all of the following conditions are met:
(1) the nominal thickness, as defined in para. 132.4.1, is $\frac{3}{4}$ in. (19.0 mm) or less;
(2) a minimum preheat of 200°F (95°C) is applied when the nominal material thickness of either of the base metals exceeds 1 in. (25.0 mm).

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 3 Gr. Nos. 1, 2	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT of P-No. 3 materials is not mandatory, provided all of the following conditions are met:
(1) the nominal thickness, as defined in para. 132.4.1, is $\frac{5}{8}$ in. (16.0 mm) or less;
(2) a minimum preheat of 200°F (95°C) is applied when the nominal material thickness of either of the base metals exceeds $\frac{5}{8}$ in. (16.0 mm);
(3) the specified carbon content of the P-No. 3 base material is 0.25% or less.

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1.

132.3 Exemptions to Mandatory PWHT Requirements

132.3.1 Postweld heat treatment is not required for the following conditions:

(A) welds in nonferrous materials;

(B) welds exempted in Table 132;

(C) welds subject to temperatures above the lower critical temperature (see Table 129.3.2) during fabrication provided the WPS has been qualified with PWHT (see para. 132.1) at the temperature range to be reached during fabrication.

132.3.2 The postweld heat treatment exemption of Table 132 may be based on the actual chemical composition as determined by a ladle or product analysis in accordance with the material specification in lieu of the specified or maximum specified chemical composition limits.

132.4 Definition of Thickness Governing PWHT

132.4.1 The term *nominal thickness* as used in Table 132 and Notes is the lesser thickness of (A) or (B) as follows:

(A) the thickness of the weld;

(B) the thicker of the materials being joined at the weld.

132.4.2 Thickness of the weld, which is a factor in determining the nominal thickness, is defined as follows:

(A) groove welds (girth and longitudinal)—the thicker of the two abutting ends after weld preparation, including I.D. machining;

(B) fillet welds—the throat thickness of the weld;

(C) partial penetration welds—the depth of the weld groove;

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 4 Gr. Nos. 1, 2	1300 (700) to 1375 (750)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:

(A) PWHT is not mandatory for P-No. 4 material under the following conditions:

(1) welds in pipe or attachment welds to pipe complying with all of the following conditions:

(A) a nominal material thickness of $\frac{1}{2}$ in. (13.0 mm) or less;

(B) a specified carbon content of the material to be welded of 0.15% or less;

(C) application of 250°F (120°C) minimum preheat during welding.

(2) for seal welding of threaded or other mechanical joints provided:

(A) the seal weld has a throat thickness of $\frac{3}{8}$ in. (9.0 mm) or less;

(B) a minimum preheat of 250°F (120°C) is maintained during welding.

(3) Attachment welds for non-load-carrying attachments provided in addition to (A)(2) and (A)(3) above:

(A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;

(B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.

(C) if SMAW is used, the electrode shall be the low hydrogen type;

(D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;

(E) the attachment weld has a throat thickness of $\frac{3}{16}$ in. or less.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 5A Gr. No. 1	1300 (700) to 1400 (760)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:

(A) PWHT is not mandatory for P-No. 5A material under the following conditions:

(1) welds in pipe or attachment welds to pipe complying with all of the following conditions:

(A) a nominal material thickness of $\frac{1}{2}$ in. (13.0 mm) or less;

(B) a specified carbon content of the material to be welded of 0.15% or less;

(C) a minimum preheat of 300°F (150°C) is maintained during welding.

(2) attachment welds for non-load-carrying attachments provided in addition to (A)(2) and (A)(3) above:

(A) stud welds or fillet welds made by the SMAW or GTAW process shall be used;

(B) the hardened portion of the heat affected zone (HAZ) shall not encroach on the minimum wall thickness of the pipe, as determined by welding procedure qualification using the maximum welding heat input. The depth of the HAZ shall be taken as the point where the HAZ hardness does not exceed the average unaffected base metal hardness by more than 10%.

(C) if SMAW is used, the electrode shall be the low hydrogen type;

(D) the thickness of the test plate used in making the welding procedure qualification of Section IX shall not be less than that of the material to be welded;

(E) the attachment weld has a throat thickness of $\frac{3}{16}$ in. or less.

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 5B Gr. Nos. 1, 2	1300 (700) to 1400 (760)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 6 Gr. Nos. 1, 2, 3	1400 (760) to 1475 (800)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTE:
(A) PWHT is not mandatory for P-No. 6 Type 410 material provided all of the following conditions are met:
(1) the specified carbon content is not more than 0.08%;
(2) the nominal material thickness is $\frac{3}{8}$ in. (10 mm) or less;
(3) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 7 Gr. Nos. 1, 2	1350 (730) to 1425 (775)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:
(A) In lieu of the cooling rate described in para. 132.5, P-No. 7 material cooling rate shall be not greater than 100°F (55°C) per hr in the range above 1200°F (650°C) after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(B) PWHT is not mandatory for P-No. 7 Type 405 material provided all of the following conditions are met:
(1) the specified carbon content is not more than 0.08%;
(2) the nominal material thickness is $\frac{3}{8}$ in. (10 mm) or less;
(3) the weld is made with A-No. 8, A-No. 9, or F-No. 43 filler metal.

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 8 Gr. Nos. 1, 2, 3, 4	None	None	None

GENERAL NOTE:
(A) PWHT is neither required nor prohibited for joints between P-No. 8 austenitic stainless steels.

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9A Gr. No. 1	1100 (600) to 1200 (650)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT is not mandatory for P-No. 9A material when welds on pipe or attachment welds to pipe comply with all of the following conditions:
(1) a nominal material thickness of ½ in. (13.0 mm) or less;
(2) a specified carbon content of the material to be welded of 0.15% or less;
(3) a minimum preheat of 250°F (120°C) is maintained during welding.

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1 but the minimum PWHT shall not be less than 1000°F (550°C).

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 9B Gr. No. 1	1100 (600) to 1175 (630)	1 hr/in. (25 mm) 15 min minimum	2 hr plus 15 min for each additional inch over 2 in. (50 mm)

GENERAL NOTES:

(A) PWHT of P-No. 9B material is not mandatory for a nominal material thickness of ⅝ in. (16.0 mm) or less provided the Welding Procedure Qualification has been made using material of thickness equal to or greater than the production weld.

(B) When it is impractical to PWHT at the temperature range specified in Table 132, it is permissible to perform the PWHT of this material at lower temperatures for longer periods of time in accordance with Table 132.1, but the minimum PWHT temperature shall not be less than 1000°F (550°C).

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10H Gr. No. 1	...	...	...

GENERAL NOTE:

(A) Postweld heat treatment is neither required nor prohibited. If any heat treatment is performed after forming or welding, it shall be performed within the temperature range listed below for the particular alloy, followed by a rapid cool:

Alloy S31803	1870°F–2010°F
Alloy S32550	1900°F–2050°F
Alloy S32750	1880°F–2060°F
All others	1800°F–1900°F

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TABLE 132
POSTWELD HEAT TREATMENT (CONT'D)

P-Number from Appendix A	Holding Temperature Range, °F (°C)	Holding Time Based on Nominal Thickness	
		Up to 2 in. (50 mm)	Over 2 in. (50 mm)
P-No. 10I Gr. No. 1	1350 (730) to 1500 (815)	1 hr/in. (25 mm) 15 min minimum	1 hr/in. (25 mm)

GENERAL NOTES:
(A) In lieu of the cooling rate described in para. 132.5, the P-No. 10I material cooling rate shall be not greater than 100°F/hr in the range above 1200°F (650°C), after which the cooling rate shall be sufficiently rapid to prevent embrittlement.
(B) Postweld heat treatment is neither required nor prohibited for a nominal thickness of ½ in. or less.

(D) material repair welds—the depth of the cavity to be repaired;

(E) branch welds—the weld thickness is the dimension existing in the plane intersecting the longitudinal axes and is calculated as indicated for each detail using:

t_c = the smaller of ¼ in. or $0.7t_{nb}$

(1) for welds described in Fig. 127.4.8(D):

Detail (a)

$$\text{weld thickness} = t_{nb} + t_c$$

Detail (b)

$$\text{weld thickness} = t_{nh} + t_c$$

Detail (c)

$$\text{weld thickness} = \text{greater of } t_{nr} + t_c \text{ or } t_{nb} + t_c$$

Detail (d)

$$\text{weld thickness} = t_{nh} + t_{nr} + t_c$$

Detail (e)

$$\text{weld thickness} = t_{nb} + t_c$$

(2) for welds described in Figs. 127.4.8(E) and (F):

$$\text{weld thickness} = \text{depth of groove weld} + \text{throat thickness of cover fillet}$$

132.4.3 The term *nominal material thickness* as used in Table 132 is the thicker of the materials being joined at the weld.

132.5 PWHT Heating and Cooling Requirements

Above 600°F (315°C), the rate of heating and cooling shall not exceed 600°F (335°C) per hr divided by ½ the maximum thickness of material in inches at the weld but in no case shall the rate exceed 600°F (335°C) per hr. (See Table 132 for cooling rate requirements for P-Nos. 7 and 10I materials.)

132.6 Furnace Heating

(A) Heating an assembly in a furnace should be used when practical; however, the size or shape of the unit or the adverse effect of a desired heat treatment on one or more components where dissimilar materials are involved, may dictate alternative procedures such as heating a section before assembly, or by applying local heating in accordance with para. 132.7.

(B) An assembly may be postweld heat treated in more than one heat in a furnace provided there is at least a 1 ft (300 mm) overlap of the heated sections and the portion of the assembly outside the furnace is shielded so that the temperature gradient is not harmful.

(C) Direct impingement of flame on the assembly is prohibited.

132.7 Local Heating

Welds may be locally PWHT by heating a circumferential band around the entire component with the weld located in the center of the band. The width of the band heated to the PWHT temperature for girth welds shall be at least three times the wall thickness at the weld of the thickest part being joined. For nozzle and attachment welds, the width of the band heated to the PWHT temperature shall extend beyond the nozzle weld or attachment weld on each side at least two

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TABLE 132.1
ALTERNATE POSTWELD HEAT TREATMENT REQUIREMENTS FOR CARBON AND LOW ALLOY STEELS

Decrease in Temperatures Below Minimum Specified Temperature, °F (°C)	Minimum Holding Time at Decreased Temperature, hr [Note (2)]
50 (28)	2
100 (56)	4
150 (84) [Note (1)]	10
200 (112) [Note (1)]	20

GENERAL NOTE:
Postweld heat treatment at lower temperatures for longer periods of time, in accordance with this Table, shall be used only where permitted in Table 132.

NOTES:
(1) A decrease of more than 100°F (56°C) below the minimum specified temperature is allowable only for P-No. 1, Gr. Nos. 1 and 2 materials.
(2) Times shown apply to thicknesses up to 1 in. (25 mm). Add 15 min/in. (15 min/25 mm) of thicknesses for thicknesses greater than 1 in. (25 mm).

times the header thickness and shall extend completely around the header.

133 STAMPING

Stamping, if used, shall be performed by a method that will not result in sharp discontinuities. In no case shall stamping infringe on the minimum wall thickness or result in dimpling or denting of the material being stamped.

CAUTIONARY NOTE: Detrimental effects can result from stamping of material which will be in operation under long term creep or creep fatigue conditions.

135 ASSEMBLY

135.1 General

The assembly of the various piping components, whether done in a shop or as field erection, shall be done so that the completely erected piping conforms with the requirements of the engineering design.

135.2 Alignment

135.2.1 Equipment Connections. When making connections to equipment, such as pumps or turbines or other piping components which are sensitive to externally induced loading, forcing the piping into alignment is prohibited if this action introduces end reactions which exceed those permitted by design.

135.2.2 Cold Springs. Before assembling joints in piping to be cold sprung, an examination shall be made of guides, supports, and anchors for obstructions which might interfere with the desired movement or result in undesired movement. The gap or overlap of piping prior to assembly shall be checked against the design specifications and corrected if necessary.

135.3 Bolted Flanged Connections

135.3.1 Fit Up. All flanged joints shall be fitted up so that the gasket contact surfaces bear uniformly on the gasket and then shall be made up with relatively uniform bolt stress.

135.3.2 Gasket Compression. When bolting gasketed flange joints, the gasket shall be properly compressed in accordance with the design principles applicable to the type of gasket being used.

135.3.3 Cast Iron to Steel Joints. Cast iron to steel flanged joints in accordance with para 108.3 shall be assembled with care to prevent damage to the cast iron flange.

135.3.4 Bolt Engagement. All bolts shall be engaged so that there is visible evidence of complete threading through the nut or threaded attachment.

135.3.5 Nonmetallic Lined Joints. When assembling nonmetallic lined joints, such as plastic lined steel pipe, consideration should be given to maintaining electrical continuity between flanged pipe sections where required.

135.4 Packed Joints and Caulked Joints

Care shall be used to assure adequate engagement of joint members. Where packed joints are used to absorb thermal expansion, proper clearance shall be provided at the bottom of the sockets to permit movement.

135.5 Threaded Piping

135.5.1 Thread Compound. Any compound or lubricant used in threaded joints shall be suitable for the service conditions, and shall be compatible with the piping material and the service fluid.

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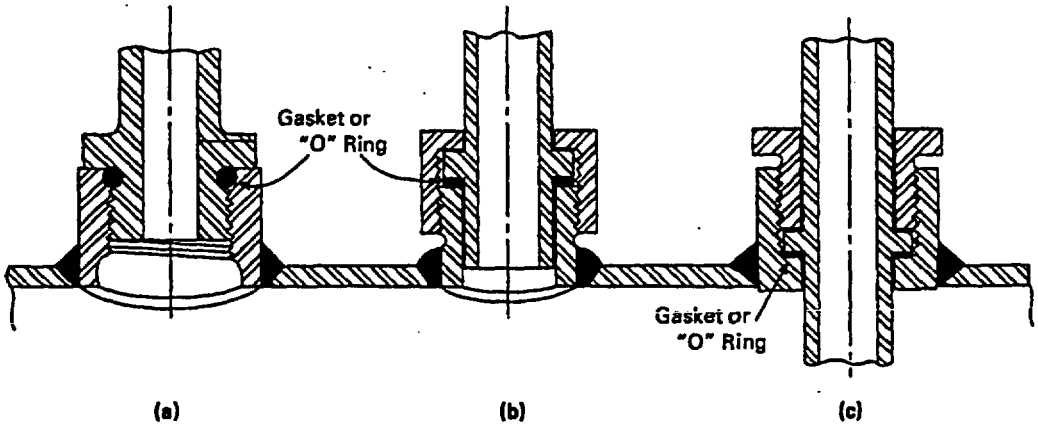

GENERAL NOTE: Threads are ASME B1.1 straight threads.

FIG. 135.5.3 TYPICAL THREADED JOINTS USING STRAIGHT THREADS

135.5.2 Joints for Seal Welding. Threaded joints which are intended to be seal welded in accordance with para. 127.4.5 *should* be made up without any thread compound.

135.5.3 Joints Using Straight Threads. Some joints using straight threads, with sealing at a surface other than threads, are shown in Fig. 135.5.3. Care shall be used to avoid distorting the seal when incorporating such joints into piping assemblies by welding or brazing.

135.5.4 Backing Off. Backing off threaded joints to allow for alignment is prohibited.

135.6 Tubing Joints

135.6.1 Flared. The sealing surface shall be free of injurious defects before installation.

135.6.2 Flareless and Compression. Flareless and compression joints shall be assembled in accordance with manufacturer's recommendations.

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CHAPTER VI
INSPECTION, EXAMINATION, AND TESTING

136 INSPECTION AND EXAMINATION

136.1 Inspection

136.1.1 General. This Code distinguishes between "examination" and "inspection." Inspection is the responsibility of the Owner and may be performed by employees of the Owner or a party authorized by the Owner, except for the inspections required by para. 136.2. Prior to initial operation, a piping installation shall be inspected to assure compliance with the engineering design and with the material, fabrication, assembly, examination, and test requirements of this Code.

136.1.2 Verification of Compliance. Compliance with the requirements of this Code shall be verified by an Authorized Inspector when a Code stamp is required by Section I of the ASME Boiler and Pressure Vessel Code. The rules of this Code and the quality control system requirements of Appendix A-300 of Section I of the ASME Boiler and Pressure Vessel Code shall apply. The quality control system requirments are shown in Appendix J of this Code. The duty of the Inspector shall be as defined in PG-90, Section I, of the ASME Boiler and Pressure Vessel Code. Data Report Forms are included in the Appendix of ASME Section I for use in developing the necessary inspection records. The Inspector shall assure himself/herself that the piping has been constructed in accordance with the applicable requirements of this Code.

136.1.3 Rights of Inspectors. Inspectors shall have access to any place where work concerned with the piping is being performed. This includes manufacture, fabrication, heat treatment, assembly, erection, examination, and testing of the piping. They shall have the right to audit any examination, to inspect the piping using any appropriate examination method required by the engineering design or this Code, and to review all certifications and records necessary to satisfy the Owner's responsibility as stated in para. 136.1.1.

136.1.4 Qualifications of the Owner's Inspector

(A) The Owner's Inspector shall be designated by the Owner and shall be an employee of the Owner, an employee of an engineering or scientific organization, or of a recognized insurance or inspection company acting as the Owner's agent. The Owner's Inspector shall not represent nor be an employee of the piping manufacturer, fabricator, or erector unless the Owner is also the manufacturer, fabricator, or erector.

(B) The Owner's Inspector shall have not less than 10 years experience in the design, manufacture, erection, fabrication, or inspection of power piping. Each year of satisfactorily completed work toward an engineering degree recognized by the Accreditation Board for Engineering and Technology shall be considered equivalent to 1 year of experience, up to 5 years total.

(C) In delegating the performance of inspections, the Owner is responsible for determining that a person to whom an inspection function is delegated is qualified to perform that function.

136.2 Inspection and Qualification of Authorized Inspector for Boiler External Piping

136.2.1 Piping for which inspection and stamping is required as determined in accordance with para. 100.1.2(A) shall be inspected during construction and after completion and at the option of the Authorized Inspector at such stages of the work as he/she may designate. For specific requirements see the applicable parts of Section I of the ASME Boiler and Pressure Vessel Code, PG-104 through PG-113. Each manufacturer, fabricator, or assembler is required to arrange for the services of Authorized Inspectors.

136.2.1.1 The inspections required by this Section shall be performed by an Inspector employed by an ASME accredited Authorized Inspection Agency.

136.2.2 Certification by stamping and Data Reports, where required, shall be as per PG-104, PG-105, PG-109, PG-110, PG-111, and PG-112 of Section I of the ASME Boiler and Pressure Vessel Code.

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136.3 Examination

136.3.1 General. Examination denotes the functions performed by the manufacturer, fabricator, erector, or a party authorized by the Owner which include nondestructive examinations (NDE), such as visual, radiography, ultrasonic, eddy current, liquid penetrant, and magnetic particle methods. The degree of examination and the acceptance standards beyond the requirements of this Code shall be a matter of prior agreement between the manufacturer, fabricator, or erector and the Owner.

136.3.2 Qualification of NDE Personnel. Personnel who perform nondestructive examination of welds shall be qualified and certified for each examination method in accordance with a program established by the employer of the personnel being certified, which shall be based on the following minimum requirements:

(A) instruction in the fundamentals of the nondestructive examination method;

(B) on-the-job training to familiarize the NDE personnel with the appearance and interpretation of indications of weld defects. The length of time for such training shall be sufficient to assure adequate assimilation of the knowledge required;

(C) an eye examination performed at least once each year to determine optical capability of NDE personnel to perform the required examinations;

(D) upon completion of (A) and (B) above, the NDE personnel shall be given an oral or written examination and performance examination by the employer to determine if the NDE personnel are qualified to perform the required examinations and interpretation of results;

(E) certified NDE personnel whose work has not included performance of a specific examination method for a period of 1 year or more shall be recertified by successfully completing the examination of (D) above and also passing the visual examination of (C) above. Substantial changes in procedures or equipment shall require recertification of the NDE personnel.

The following may be used as alternatives to the preceding program, as applicable: SNT-TC-1A or CP-189; and personnel qualified to AWS QC-1 may be used for the visual examination of welds.

136.4 Examination Methods of Welds

136.4.1 Nondestructive Examination. Nondestructive examinations shall be performed in accordance with the requirements of this Chapter. The types and extent of mandatory examinations for pressure welds and welds to pressure retaining components are specified in Table 136.4. For welds other than those covered by Table 136.4, only visual examination is required. Welds requiring nondestructive examination shall comply with the applicable acceptance standards for indications as specified in paras. 136.4.2 through 136.4.6. As a guide, the detection capabilities for the examination method are shown in Table 136.4.1. Welds not requiring examination (i.e., RT, UT, MT, or PT) by this Code or the engineering design shall be judged acceptable if they meet the examination requirements of para. 136.4.2 and the pressure test requirements specified in para. 137.

136.4.2 Visual Examination. Visual examination as defined in para. 100.2. shall be performed, as necessary, during the fabrication and erection of piping components to provide verification that the design and WPS requirements are being met. In addition, visual examination shall be performed to verify that all completed welds in pipe and piping components comply with the acceptance standards specified in (A) below or with the limitations on imperfections specified in the material specification under which the pipe or component was furnished.

(A) Acceptance Standards. The following indications are unacceptable:

(A.1) cracks—external surface;

(A.2) undercut on surface which is greater than $\frac{1}{32}$ in. (1.0 mm) deep;

(A.3) weld reinforcement greater than specified in Table 127.4.2;

(A.4) lack of fusion on surface;

(A.5) incomplete penetration (applies only when inside surface is readily accessible);

(A.6) any other linear indications greater than $\frac{3}{16}$ in. (5.0 mm) long;

(A.7) surface porosity with rounded indications having dimensions greater than $\frac{3}{16}$ in. (5.0 mm) or four or more rounded indications separated by $\frac{1}{16}$ in. (2.0 mm) or less edge to edge in any direction. Rounded indications are indications which are circular or elliptical with their length less than three times their width.

136.4.3 Magnetic Particle Examination. Whenever required by this Chapter (see Table 136.4), magnetic particle examination shall be performed in accordance with the methods of Article 7, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by the retention of the examination medium. All indications are not necessarily defects; however,

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TABLE 136.4
MANDATORY MINIMUM NONDESTRUCTIVE EXAMINATIONS FOR PRESSURE WELDS OR WELDS TO PRESSURE RETAINING COMPONENTS

	Piping Design Conditions and Nondestructive Examination		
Type Weld	Temperatures Over 750°F (400°C) and at All Pressures	Temperatures Between 350°F (175°C) and 750°F (400°C) Inclusive With All Pressures Over 1025 psig [7100 kPa (gage)]	All Others
Butt welds (girth and longitudinal) [Note (1)]	RT or UT for over NPS 2. MT or PT for NPS 2 and less [Note (2)]	RT or UT for over NPS 2 with thickness over $\frac{3}{4}$ in. (19.0 mm). VT for all sizes with thickness $\frac{3}{4}$ in. (19.0 mm) or less.	Visual for all sizes and thicknesses
Welded branch connections (size indicated is branch size) [Notes (3) and (4)]	RT or UT for over NPS 4. MT or PT for NPS 4 and less [Note (2)]	RT or UT for branch over NPS 4 and thickness of branch over $\frac{3}{4}$ in. (19.0 mm) MT or PT for branch NPS 4 and less with thickness of branch over $\frac{3}{4}$ in. (19 mm) VT for all sizes with branch thickness $\frac{3}{4}$ in. (19.0 mm) or less	VT for all sizes and thicknesses
Fillet, socket, attachment, and seal welds	PT or MT for all sizes and thicknesses [Note (5)]	VT for all sizes and thicknesses	VT for all sizes and thicknesses

GENERAL NOTES:

(A) All welds shall be given a visual examination in addition to the type of specific nondestructive examination specified.

(B) NPS — nominal pipe size.

(C) RT — radiographic examination; UT — ultrasonic examination; MT — magnetic particle examination; PT — liquid penetrant examination; VT — visual examination.

(D) For nondestructive examinations of the pressure retaining component, refer to the standards listed in Table 126.1 or manufacturing specifications.

(E) Acceptance standards for nondestructive examinations performed are as follows: MT — see para. 136.4.3; PT — see para. 136.4.4; VT — see para. 136.4.2; RT — see para. 136.4.5; UT — see para. 136.4.6.

NOTES:

(1) The thickness of butt welds is defined as the thicker of the two abutting ends after end preparation.

(2) RT may be used as an alternative to PT or MT when it is performed in accordance with para. 136.4.5.

(3) RT or UT of branch welds shall be performed before any nonintegral reinforcing material is applied.

(4) In lieu of volumetric examination (RT, UT) of welded branch connections when required above, surface examination (PT, MT) is acceptable and, when used, shall be performed at the lesser of one-half of the weld thickness or each $\frac{1}{2}$ in. (12.5 mm) of weld thickness and all accessible final weld surfaces.

(5) Fillet welds not exceeding $\frac{1}{4}$ in. (6 mm) throat thickness which are used for the permanent attachment of nonpressure retaining parts are exempt from the PT or MT requirements of the above Table.

TABLE 136.4.1
WELD IMPERFECTIONS INDICATED BY VARIOUS TYPES OF EXAMINATION

Imperfection	Visual	Magnetic Particle	Liquid Penetrant	Radiography	Ultrasonic
Crack — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	X
Crack — internal	...	...	...	X	X
Undercut — surface	X [Note (1)]	X [Note (1)]	X [Note (1)]	X	...
Weld reinforcement	X [Note (1)]	...	...	X	...
Porosity	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	...
Slag inclusion	X [Note (2)]	X [Note (2)]	X [Note (2)]	X	X
Lack of fusion (on surface)	X [Notes (1), (2)]	X [Notes (1), (2)]	X [Notes (1), (2)]	X	X
Incomplete penetration	X [Note (3)]	X [Note (3)]	X [Note (3)]	X	X

NOTES:
(1) Applies when the outside surface is accessible for examination and/or when the inside surface is readily accessible.
(2) Discontinuities are detectable when they are open to the surface.
(3) Applies *only* when the inside surface is readily accessible.

certain metallurgical discontinuities and magnetic permeability variations may produce similar indications which are not relevant to the detection of unacceptable discontinuities.

(A.2) Any indication which is believed to be nonrelevant shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications which would mask indications of defects are unacceptable.

(A.3) Relevant indications are those which result from unacceptable mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

(B) Acceptance Standards. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications;

(B.2) rounded indications with dimensions greater than $^3/_{16}$ in. (5.0 mm);

(B.3) four or more rounded indications in a line separated by $^1/_{16}$ in. (2.0 mm) or less edge to edge;

(B.4) Ten or more rounded indications in any 6 sq in. (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated.

136.4.4 Liquid Penetrant Examination. Whenever required by this Chapter (see Table 136.4), liquid penetrant examination shall be performed in accordance with the methods of Article 6, Section V, of the ASME Boiler and Pressure Vessel Code.

(A) Evaluation of Indications

(A.1) Mechanical discontinuities at the surface will be indicated by bleeding out of the penetrant; however, localized surface imperfections, such as may occur from machining marks or surface conditions, may produce similar indications which are nonrelevant to the detection of unacceptable discontinuities.

(A.2) Any indication which is believed to be nonrelevant shall be regarded as a defect and shall be reexamined to verify whether or not actual defects are present. Surface conditioning may precede the reexamination. Nonrelevant indications and broad areas of pigmentation which would mask indications of defects are unacceptable.

(A.3) Relevant indications are those which result from mechanical discontinuities. Linear indications are those indications in which the length is more than three times the width. Rounded indications are indications which are circular or elliptical with the length less than three times the width.

(A.4) An indication of a discontinuity may be larger

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than the discontinuity that causes it; however, the size of the indication and not the size of the discontinuity is the basis of acceptance or rejection.

(B) Acceptance Standards. Indications whose major dimensions are greater than 1/16 in. (2.0 mm) shall be considered relevant. The following relevant indications are unacceptable:

(B.1) any cracks or linear indications;

(B.2) rounded indications with dimensions greater than 3/16 in. (5.0 mm);

(B.3) four or more rounded indications in a line separated by 1/16 in. (2.0 mm) or less edge to edge;

(B.4) ten or more rounded indications in any 6 sq in. (3870 mm^2) of surface with the major dimension of this area not to exceed 6 in. (150 mm) with the area taken in the most unfavorable location relative to the indications being evaluated.

136.4.5 Radiography. When required by this Chapter (see Table 136.4), radiographic examination shall be performed in accordance with Article 2 of Section V of the ASME Boiler and Pressure Vessel Code, except that the requirements of T-285 are to be used as a guide but not for the rejection of radiographs unless the geometrical unsharpness exceeds 0.07 in. (2.0 mm).

(A) Acceptance Standards. Welds that are shown by radiography to have any of the following types of discontinuities are unacceptable:

(A.1) any type of crack or zone of incomplete fusion or penetration;

(A.2) any other elongated indication which has a length greater than:

(A.2.1) 1/4 in. (6.0 mm) for t up to 3/4 in. (19.0 mm), inclusive;

(A.2.2) 1/3t for t from 3/4 in. (19.0 mm) to 2 1/4 in. (57.0 mm), incl.;

(A.2.3) 3/4 in. (19.0 mm) for t over 2 1/4 in. (57.0 mm) where t is the thickness of the thinner portion of the weld.

NOTE: t referred to in (A.2.1), (A.2.2), and (A.2.3) above pertains to the thickness of the weld being examined; if a weld joins two members having different thickness at the weld, t is the thinner of these two thickness.

(A.3) any group of indications in line that have an aggregate length greater than t in a length of 12t, except where the distance between the successive indications exceeds 6L where L is the longest indication in the group;

(A.4) porosity in excess of that shown as acceptable in Appendix A-250 of Section I of the ASME Boiler and Pressure Vessel Code;

(A.5) root concavity when there is an abrupt change in density, as indicated on the radiograph.

136.4.6 Ultrasonic Examination. When required by this Chapter (see Table 136.4), ultrasonic examination (UT) shall be performed in accordance with the ASME Boiler and Pressure Vessel Code, Section V, Article 5 and the following additional requirements.

(A) The following criteria shall also be met when performing ultrasonic examinations.

(A.1) The nominal thickness of the material being examined shall be greater that 1/2 in (12.5 mm).

(A.2) The equipment used to perform the examination shall be capable of recording the UT data including the scanning positions.

(A.3) NDE personnel collecting and analyzing UT data shall have demonstrated their ability to perform an acceptable examination using written procedures. The procedure shall have been demonstrated to perform acceptably on a qualification block with imbedded flaws.

(B) Acceptance Standards. Welds that are shown by ultrasonic examination to have discontinuities which produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (B.1) and (B.2) below.

(B.1) Discontinuities evaluated as being cracks, lack of fusion, or incomplete penetration are unacceptable regardless of length.

(B.2) Other discontinuities are unacceptable if the indication exceeds the reference level and their length exceeds the following:

(B.2.1) 1/4 in. (6.0 mm) for t up to 3/4 in. (19.0 mm);

(B.2.2) 1/3t for t from 3/4 in. (19.0 mm) to 2 1/4 in. (57.0 mm)

(B.2.3) 3/4 in. (19.0 mm) for t over 2 1/4 in. (57.0 mm) where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

137 PRESSURE TESTS

137.1 General Requirements

137.1.1 Subassemblies. When conducted in accordance with the requirements of this Code, the pressure testing of piping systems to ensure leak tightness shall

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be acceptable for the determination of any leaks in piping subassemblies.

137.1.2 Temperature of Test Medium. The temperature of the test medium shall be that of the available source unless otherwise specified by the Owner. The test pressure shall not be applied until the system and the pressurizing medium are approximately at the same temperature. When conducting pressure tests at low metal temperatures, the possibility of brittle fracture shall be considered.

137.1.3 Personnel Protection. Suitable precautions in the event of piping system rupture shall be taken to eliminate hazards to personnel in the proximity of lines being tested.

137.1.4 Maximum Stress During Test. At no time during the pressure test shall any part of the piping system be subjected to a stress greater than that permitted by para. 102.3.3(B).

137.1.5 Testing Schedule. Pressure testing shall be performed following the completion of postweld heat treatment, required by para. 132, nondestructive examinations required by Table 136.4, and all other fabrication, assembly and erection activities required to provide the system or portions thereof subjected to the pressure test with pressure retaining capability.

137.2 Preparation for Testing

137.2.1 Exposure of Joints. All joints including welds not previously pressure tested shall be left uninsulated and exposed for examination during the test. By prior agreement the complete system or portions thereof subject to test may be insulated prior to the test period provided an extended holding time pressurization of the system is performed to check for possible leakage through the insulation barrier.

137.2.2 Addition of Temporary Supports. Piping systems designed for vapor or gas shall be provided with additional temporary supports if necessary to support the weight of the test liquid. Such supports shall meet the requirements for testing and system cleanup procedures described in para. 122.10.

137.2.3 Restraint or Isolation of Expansion Joints. Expansion joints shall be provided with temporary restraint if required for the additional pressure load under test, or they shall be isolated during the system test.

137.2.4 Isolation of Equipment and Piping Not Subjected to Pressure Test. Equipment that is not to be subjected to the pressure test shall be either disconnected from the system or isolated by a blank or similar means. Valves may be used for this purpose provided that valve closure is suitable for the proposed test pressure. Owner shall be aware of the limitations of pressure and temperature for each valve subject to test conditions and as further described in para. 107.1(C). Isolated equipment and piping must be vented.

137.2.5 Treatment of Flanged Joints Containing Blanks. Flanged joints at which blanks are inserted to blank off other equipment during the test need not be tested after removal of the blank provided the requirements of para. 137.7.1 are subsequently performed.

137.2.6 Precautions Against Test Medium Expansion. If a pressure test is to be maintained for a period of time during which the test medium in the system is subject to thermal expansion, precautions shall be taken to avoid excessive pressure. A pressure relief device set at $1\frac{1}{3}$ times the test pressure is recommended during the pressure test provided the requirements of paras. 137.1.4, 137.4.5, and 137.5.5 are not exceeded.

137.3 Requirements for Specific Piping Systems

137.3.1 Boiler External Piping. Boiler external piping [see para. 100.1.2(A)] shall be hydrostatically tested in accordance with PG-99 of Section I of the ASME Boiler and Pressure Vessel Code. The test shall be conducted in the presence of the Authorized Inspector.

137.3.2 Nonboiler External Piping. All nonboiler external piping shall be hydrostatically tested in accordance with para. 137.4. As an alternative, when specified by the owner, the piping may be leak tested in accordance with para. 137.5, 137.6, or 137.7. Lines open to the atmosphere, such as vents or drains downstream of the last shutoff valve, need not be tested.

137.4 Hydrostatic Testing

137.4.1 Material. When permitted by the Material Specification, a system hydrostatic test may be performed in lieu of the hydrostatic test required by the material specifications for material used in the piping subassembly or system provided the minimum test pressure required for the piping system is met.

137.4.2 Provision of Air Vents at High Points. Vents shall be provided at all high points of the piping system in the position in which the test is to be

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conducted to purge air pockets while the component or system is filling. Venting during the filling of the system may be provided by the loosening of flanges having a minimum of four bolts or by the use of equipment vents.

137.4.3 Test Medium. Water shall normally be used as the test medium unless otherwise specified by the Owner. Test water shall be clean and shall be of such quality as to minimize corrosion of the materials in the piping system. Further recommended precautions on the quality of test water used for hydrotesting of austenitic (300 series) and ferritic (400 series) stainless steels are contained in Appendix IV, para. IV-3.4.

137.4.4 Check of Test Equipment Before Applying Pressure. The test equipment shall be examined before pressure is applied to ensure that it is tightly connected. All low-pressure filling lines and all other items not subject to the test pressure shall be disconnected or isolated by valves or other suitable means.

137.4.5 Required Hydrostatic Test Pressure. The hydrostatic test pressure at any point in the piping system shall not be less than 1.5 times the design pressure, but shall not exceed the maximum allowable test pressure of any nonisolated components, such as vessels, pumps, or valves, nor shall it exceed the limits imposed by para. 102.3.3(B). The pressure shall be continuously maintained for a minimum time of 10 minutes and may then be reduced to the design pressure and held for such time as may be necessary to conduct the examinations for leakage. Examinations for leakage shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no visual evidence of weeping or leaking.

137.5 Pneumatic Testing

137.5.1 General. Except for preliminary testing in accordance with para. 137.5.4, pneumatic testing shall not be used unless the Owner specifies pneumatic testing or permits its use as an alternative. It is recommended that pneumatic testing be used only when one of the following conditions exists:

(A) when piping systems are so designed that they cannot be filled with water;

(B) when piping systems are to be used in services where traces of the testing medium cannot be tolerated.

137.5.2 Test Medium. The gas used as the test medium shall be nonflammable and nontoxic. Since compressed gas may be hazardous when used as a testing medium, it is recommended that special precautions for protection of personnel be observed when a gas under pressure is used as the test medium.

137.5.3 Check of Test Equipment Before Applying Pressure. The test equipment shall be examined before pressure is applied to ensure that it is tightly connected. All items not subjected to the test pressure shall be disconnected or isolated by valves or other suitable means.

137.5.4 Preliminary Test. A preliminary pneumatic test not to exceed 25 psig [175 kPa (gage)] may be applied, prior to other methods of leak testing, as a means of locating major leaks. If used, the preliminary pneumatic test shall be performed in accordance with the requirements of paras. 137.5.2 and 137.5.3.

137.5.5 Required Pneumatic Test Pressure. The pneumatic test pressure shall be not less than 1.2 nor more than 1.5 times the design pressure of the piping system. The test pressure shall not exceed the maximum allowable test pressure of any nonisolated component, such as vessels, pumps, or valves, in the system. The pressure in the system shall gradually be increased to not more than one-half of the test pressure, after which the pressure shall be increased in steps of approximately one-tenth of the test pressure until the required test pressure has been reached. The pressure shall be continuously maintained for a minimum time of 10 minutes. It shall then be reduced to the lesser of design pressure or 100 psig [700 kPa (gage)] and held for such time as may be necessary to conduct the examination for leakage. Examination for leakage detected by soap bubble or equivalent method shall be made of all joints and connections. The piping system, exclusive of possible localized instances at pump or valve packing, shall show no evidence of leaking.

137.6 Mass-Spectrometer and Halide Testing

137.6.1 When specified by the Owner, systems with conditions of operation and design that require testing methods having a greater degree of sensitivity than can be obtained by a hydrostatic or pneumatic test shall be tested by a method, such as helium mass-spectrometer test or halide test, which has the required sensitivity.

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137.6.2 When a mass-spectrometer or halide test is performed, it shall be conducted in accordance with the instructions of the manufacturer of the test equipment. In all cases a calibrated reference leak, with a leak rate not greater than the maximum permissible leakage from the system, shall be used. The equipment shall be calibrated against the reference leak in such a way that the system leakage measured by the equipment can be determined to be not greater than the leak rate of the reference leak.

137.7 Initial Service Testing

137.7.1 When specified by the owner, an initial service test and examination is acceptable when other types of tests are not practical or when leak tightness is demonstrable due to the nature of the service. One example is piping where shut-off valves are not available for isolating a line and where temporary closures are impractical. Others may be systems where during the course of checking out of pumps, compressors, or other equipment, ample opportunity is afforded for examination for leakage prior to full scale operation. An initial service test is not applicable to boiler external piping.

137.7.2 When performing an initial service test, the piping system shall be gradually brought up to normal operating pressure and continuously held for a minimum time of 10 minutes. Examination for leakage shall be made of all joints and connections. The piping system exclusive of possible localized instances at pump or valve packing shall show no visual evidence of weeping or leaking.

137.8 Retesting After Repair or Additions

137.8.1 Repairs may be made to the pressure parts of boiler external piping after the hydrostatic test required by para. 137.3.1, provided the requirements of PW-54.2 of Section I of the ASME Boiler and Pressure Vessel Code are met.

137.8.2 Nonpressure parts may be welded to the pressure parts of boiler external piping after the hydrostatic test required by para. 137.3.1, provided the requirements of PW-54.3 of Section I of the ASME Boiler and Pressure Vessel Code are met.

137.8.3 In the event repairs or additions to nonboiler external piping are made following a test, the affected piping shall be retested in accordance with the provisions of para. 137.3.2. However, a system need not be retested after seal welding or after attachments of lugs, brackets, insulation supports, nameplates, or other nonpressure retaining attachments provided:

(A) the attachment fillet weld does not exceed $\frac{3}{8}$ in. (10.0 mm) thickness or, if a full penetration weld is used, the material attached does not exceed the nominal thickness of the pressure retaining member or $\frac{1}{2}$ in. (12.0 mm), whichever is less;

(B) welds shall be preheated as required by para. 131;

(C) welds shall be examined as required by Table 136.4;

(D) seal welds shall be examined for leakage after system startup.

137.8.4 All weld defect repairs shall be made in accordance with para. 127.4.11.

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APPENDIX A

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TABLE A-1
CARBON STEEL

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Seamless Pipe and Tube								
A 53	A	S	C	1	(2)	48	30	1.00
	B	S	C–Mn	1	(2)	60	35	1.00
A 106	A	...	C–Si	1	(2)	48	30	1.00
	B	...	C–Si	1	(2)	60	35	1.00
	C	...	C–Si	1	(2)	70	40	1.00
A 179	...	...	C	1	(1)(2)(5)	(47)	26	1.00
A 192	...	...	C–Si	1	(2)(5)	(47)	26	1.00
A 210	A1	...	C–Si	1	(2)	60	37	1.00
	C	...	C–Mn–Si	1	(2)	70	40	1.00
A 333	1	...	C–Mn	1	(1)	55	30	1.00
	6	...	C–Mn–Si	1	(1)	60	35	1.00
A 369	FPA	...	C–Si	1	(2)	48	30	1.00
	FPB	...	C–Mn	1	(2)	60	35	1.00
API-5L	A	...	C	1	(1)(2)(14)	48	30	1.00
	B	...	C–Mn	1	(1)(2)(14)	60	35	1.00
Furnace Butt Welded Pipe								
A 53	...	F	C	1	(4)	48	30	0.60
API-5L	A25	I & II	C	1	(1)(4)(14)	45	25	0.60
Electric Resistance Welded Pipe and Tube								
A 53	A	E	C	1	(2)	48	30	0.85
	B	E	C–Mn	1	(2)	60	35	0.85
A 135	A	...	C	1	(1)(2)	48	30	0.85
	B	...	C–Mn	1	(1)(2)	60	35	0.85

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TABLE A-1
CARBON STEEL

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
											Seamless Pipe and Tube	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	A 53
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	A 106
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C	
...	...	...	...	...	...	...	11.8	11.5	10.6	9.2	...	A 179
...	...	...	...	...	...	...	11.8	11.5	10.7	9.0	...	A 192
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	A1	A 210
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C	
...	...	...	...	...	...	...	13.8	...	...	...	1	A 333
...	...	...	...	...	...	...	15.0	14.4	...	...	6	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	FPA	A 369
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	FPA	
...	...	...	...	...	...	...	12.0	11.7	10.7	9.0	A	API-5L
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B	
											Furnace Butt Welded Pipe	
...	...	...	...	...	...	...	7.2	7.0	...	...	...	A 53
6.8	6.8	6.8	6.8	...	...	...	...	...	...	...	A 25	API-5L
											Electric Resistance Welded Pipe and Tube	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.7	A	A 53
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.9	A	A 135
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Resistance Welded Pipe and Tube (Cont'd)								
A 178	A	...	C	1	(2)(5)	(47)	26	0.85
	C	...	C	1	(2)	60	37	0.85
A 214	...	...	C	1	(1)(2)(5)	(47)	26	0.85
A 226	...	...	C–Si	1	(2)(5)	(47)	26	0.85
A 333	1	...	C–Mn	1	(1)	55	30	0.85
	6	...	C–Mn–Si	1	...	60	35	0.85
API-5L	A25	I & II	C	1	(1)(14)	45	25	0.85
	A	...	C	1	(1)(2)(14)	48	30	0.85
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.85
A 587	...	...	C	1	(1)(2)	48	30	0.85
Electric Fusion Welded Pipe — Filler Metal Added								
A 134	A283A	...	C	1	(1)(7)	45	24	0.80
	A283B	...	C	1	(1)(7)	50	27	0.80
	A283C	...	C	1	(1)(7)	55	30	0.80
	A283D	...	C	1	(1)(7)	60	33	0.80
A 134	A285A	...	C	1	(1)(2)(8)	45	24	0.80
	A285B	...	C	1	(1)(2)(8)	50	27	0.80
	A285C	...	C	1	(1)(2)(8)	55	30	0.80
A 139	A	...	C	1	(1)(2)(14)	48	30	0.80
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.80
API-5L	A	...	C	1	(1)(2)(14)	48	30	0.90
	B	...	C–Mn	1	(1)(2)(14)	60	35	0.90
A 211	A570-30	...	C	1	(1)(7)(14)(16)	49	30	0.75
	A570-33	...	C	1	(1)(7)(14)(16)	52	33	0.75
	A570-40	...	C	1	(1)(7)(14)(16)	55	40	0.75

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TABLE A-1
CARBON STEEL (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
											Electric Resistance Welded Pipe and Tube (Cont'd)	
...	...	...	...	...	...	...	10.0	9.8	9.1	7.7	A	A 178
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	C	
...	...	...	...	...	...	...	10.0	9.8	9.1	7.8	...	A 214
...	...	...	...	...	...	...	10.0	9.8	9.1	7.8	...	A 226
...	...	...	...	...	...	...	11.7	...	...	...	1	A 333
...	...	...	...	...	...	...	12.8	12.2	...	...	6	
9.5	9.5	9.5	9.5	...	...	...	...	...	...	...	A25	API-5L
...	...	...	...	...	...	...	10.2	9.9	9.1	7.7	A	
...	...	...	...	...	...	...	12.8	12.2	11.0	9.2	B	
...	...	...	...	...	...	...	10.2	9.9	9.1	7.9	...	A 587
											Electric Fusion Welded Pipe — Filler Metal Added	
...	...	...	...	...	...	...	9.0	...	...	...	A283A	A 134
...	...	...	...	...	...	...	10.0	...	...	...	A283B	
...	...	...	...	...	...	...	11.0	...	...	...	A283C	
...	...	...	...	...	...	...	12.0	...	...	...	A283D	
...	...	...	...	...	...	...	9.0	8.8	8.2	7.2	A285A	A 134
...	...	...	...	...	...	...	10.0	9.7	9.0	7.7	A285B	
...	...	...	...	...	...	...	11.0	10.6	9.7	8.2	A285C	
...	...	...	...	...	...	...	9.6	9.4	8.6	7.2	A	A 139
...	...	...	...	...	...	...	12.0	11.5	10.4	8.6	B	
...	...	...	...	...	...	...	10.8	10.5	9.6	8.1	A	API-5L
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B	
9.2	9.2	...	...	...	...	...	...	...	...	...	A570-30	A 211
9.8	9.8	...	...	...	...	...	...	...	...	...	A570-33	
10.3	10.3	...	...	...	...	...	...	...	...	...	A570-40	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 671	CA55	10,13	C	1	(1)(2)(15)	55	30	0.90
	CA55	11,12	C	1	(1)(2)(15)	55	30	1.00
	CA55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	CA55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 671	CB60	10,13	C–Si	1	(1)(2)(15)	60	32	0.90
	CB60	11,12	C–Si	1	(1)(2)(15)	60	32	1.00
	CB60	20,23,30,33	C–Si	1	(1)(2)	60	32	0.90
	CB60	21,22,31,32	C–Si	1	(1)(2)	60	32	1.00
A 671	CB65	10,13	C–Si	1	(1)(2)(15)	65	35	0.90
	CB65	11,12	C–Si	1	(1)(2)(15)	65	35	1.00
	CB65	20,23,30,33	C–Si	1	(1)(2)	65	35	0.90
	CB65	21,22,31,32	C–Si	1	(1)(2)	65	35	1.00
A 671	CB70	10,13	C–Si	1	(1)(2)(15)	70	38	0.90
	CB70	11,12	C–Si	1	(1)(2)(15)	70	38	1.00
	CB70	20,23,30,33	C–Si	1	(1)(2)	70	38	0.90
	CB70	21,22,31,32	C–Si	1	(1)(2)	70	38	1.00
A 671	CC60	10,13	C–Mn–Si	1	(1)(2)(15)	60	32	0.90
	CC60	11,12	C–Mn–Si	1	(1)(2)(15)	60	32	1.00
	CC60	20,23,30,33	C–Mn–Si	1	(1)(2)	60	32	0.90
	CC60	21,22,31,32	C–Mn–Si	1	(1)(2)	60	32	1.00
A 671	CC65	10,13	C–Mn–Si	1	(1)(2)(15)	65	35	0.90
	CC65	11,12	C–Mn–Si	1	(1)(2)(15)	65	35	1.00
	CC65	20,23,30,33	C–Mn–Si	1	(1)(2)	65	35	0.90
	CC65	21,22,31,32	C–Mn–Si	1	(1)(2)	65	35	1.00
A 671	CC70	10,13	C–Mn–Si	1	(1)(2)(15)	70	38	0.90
	CC70	11,12	C–Mn–Si	1	(1)(2)(15)	70	38	1.00
	CC70	20,23,30,33	C–Mn–Si	1	(1)(2)	70	38	0.90
	CC70	21,22,31,32	C–Mn–Si	1	(1)(2)	70	38	1.00
A 671	CK75	10,13	C–Mn–Si	1	(1)(2)(15)	75	42	0.90
	CK75	11,12	C–Mn–Si	1	(1)(2)(15)	75	42	1.00
	CK75	20,23,30,33	C–Mn–Si	1	(1)(2)	75	40	0.90
	CK75	21,22,31,32	C–Mn–Si	1	(1)(2)	75	40	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)												
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	CA55	A 671
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	CA55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	CA55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	CA55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CB60	A 671
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CB60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CB60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CB60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CB65	A 671
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CB65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CB65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CB65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CB70	A 671
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CB70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CB70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CB70	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CC60	A 671
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CC60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	CC60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	CC60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CC65	A 671
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CC65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	CC65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	CC65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CC70	A 671
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CC70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	CC70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	CC70	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CK75	A 671
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CK75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CK75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CK75	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 671	CD70	10,13	C-Mn-Si	1	(1)(2)(15)	70	50	0.90
	CD70	11,12	C-Mn-Si	1	(1)(2)(15)	70	50	1.00
	CD70	20,23,30,33	C-Mn-Si	1	(1)(3)	70	50	0.90
	CD70	21,22,31,32	C-Mn-Si	1	(1)(3)	70	50	1.00
A 671	CD80	10,13	C-Mn-Si	1	(1)(15)	80	60	0.90
	CD80	11,12	C-Mn-Si	1	(1)(15)	80	60	1.00
	CD80	20,23	C-Mn-Si	1	(1)(3)	80	60	0.90
	CD80	21,22	C-Mn-Si	1	(1)(3)	80	60	1.00
A 672	A45	10,13	C	1	(1)(2)(15)	45	24	0.90
	A45	11,12	C	1	(1)(2)(15)	45	24	1.00
	A45	20,23,30,33	C	1	(1)(2)	45	24	0.90
	A45	21,22,31,32	C	1	(1)(2)	45	24	1.00
A 672	A50	10,13	C	1	(1)(2)(15)	50	27	0.90
	A50	11,12	C	1	(1)(2)(15)	50	27	1.00
	A50	20,23,30,33	C	1	(1)(2)	50	27	0.90
	A50	21,22,31,32	C	1	(1)(2)	50	27	1.00
A 672	A55	10,13	C	1	(1)(2)(15)	55	30	0.90
	A55	11,12	C	1	(1)(2)(15)	55	30	1.00
	A55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	A55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	B55	10,13	C	1	(1)(2)(15)	55	30	0.90
	B55	11,12	C	1	(1)(2)(15)	55	30	1.00
	B55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	B55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	B60	10,13	C	1	(1)(2)(15)	60	32	0.90
	B60	11,12	C	1	(1)(2)(15)	60	32	1.00
	B60	20,23,30,33	C	1	(1)(2)	60	32	0.90
	B60	21,22,31,32	C	1	(1)(2)	60	32	1.00
A672	B65	10,13	C	1	(1)(2)(15)	65	35	0.90
	B65	11,12	C	1	(1)(2)(15)	65	35	1.00
	B65	20,23,30,33	C	1	(1)(2)	65	35	0.90
	B65	21,22,31,32	C	1	(1)(2)	65	35	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
											Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CD70	A 671
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CD70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CD70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CD70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CD80	A 671
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CD80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CD80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CD80	
...	...	...	...	...	...	...	10.2	9.9	9.3	8.1	A45	A 672
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A45	
...	...	...	...	...	...	...	10.2	9.9	9.3	8.1	A45	
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A45	
...	...	...	...	...	...	...	11.3	10.9	10.1	8.6	A50	A 672
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	A50	
...	...	...	...	...	...	...	11.3	10.9	10.1	8.6	A50	
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	A50	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	A55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	A55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	A55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	A55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	B55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	B55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	B55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	B55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B60	A 672
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	B60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	B60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	B65	A 672
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	B65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	B65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	B65	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 672	B70	10,13	C	1	(1)(2)(15)	70	38	0.90
	B70	11,12	C	1	(1)(2)(15)	70	38	1.00
	B70	20,23,30,33	C	1	(1)(2)	70	38	0.90
	B70	21,22,31,32	C	1	(1)(2)	70	38	1.00
A 672	C55	10,13	C	1	(1)(2)(15)	55	30	0.90
	C55	11,12	C	1	(1)(2)(15)	55	30	1.00
	C55	20,23,30,33	C	1	(1)(2)	55	30	0.90
	C55	21,22,31,32	C	1	(1)(2)	55	30	1.00
A 672	C60	10,13	C	1	(1)(2)(15)	60	32	0.90
	C60	11,12	C	1	(1)(2)(15)	60	32	1.00
	C60	20,23,30,33	C	1	(1)(2)	60	32	0.90
	C60	21,22,31,32	C	1	(1)(2)	60	32	1.00
A 672	C65	10,13	C	1	(1)(2)(15)	65	35	0.90
	C65	11,12	C	1	(1)(2)(15)	65	35	1.00
	C65	20,23,30,33	C	1	(1)(2)	65	35	0.90
	C65	21,22,31,32	C	1	(1)(2)	65	35	1.00
A 672	C70	10,13	C	1	(1)(2)(15)	70	38	0.90
	C70	11,12	C	1	(1)(2)(15)	70	38	1.00
	C70	20,23,30,33	C	1	(1)(2)	70	38	0.90
	C70	21,22,31,32	C	1	(1)(2)	70	38	1.00
A 672	D70	10,13	C–Mn–Si	1	(1)(15)	70	50	0.90
	D70	11,12	C–Mn–Si	1	(1)(15)	70	50	1.00
	D70	20,23,30,33	C–Mn–Si	1	(1)(3)	70	50	0.90
	D70	21,22,31,32	C–Mn–Si	1	(1)(3)	70	50	1.00
A 672	D80	10,13	C–Mn–Si	1	(1)(15)	80	60	0.90
	D80	11,12	C–Mn–Si	1	(1)(15)	80	60	1.00
	D80	20,23	C–Mn–Si	1	(1)(3)	80	60	0.90
	D80	21,22	C–Mn–Si	1	(1)(3)	80	60	1.00
A 672	N75	10,13	C–Mn–Si	1	(1)(2)(15)	75	42	0.90
	N75	11,12	C–Mn–Si	1	(1)(2)(15)	75	42	1.00
	N75	20,23,30,33	C–Mn–Si	1	(1)(2)	75	40	0.90
	N75	21,22,31,32	C–Mn–Si	1	(1)(2)	75	40	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)												
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	B70	A 672
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	B70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	B70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	B70	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	C55	A 672
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C55	
...	...	...	...	...	...	...	12.4	12.0	10.9	9.2	C55	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C55	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	C60	A 672
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	C60	
...	...	...	...	...	...	...	13.5	13.0	11.7	9.7	C60	
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	C60	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	C65	A 672
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	C65	
...	...	...	...	...	...	...	14.7	14.0	12.5	10.3	C65	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	C65	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	C70	A 672
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C70	
...	...	...	...	...	...	...	15.8	14.9	13.3	10.8	C70	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	C70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	D70	A 672
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	D70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	D70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	D70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	D80	A 672
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	D80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	D80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	D80	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	N75	A 672
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	N75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	N75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	N75	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 691	CMSH70	10,13	C-Mn-Si	1	(1)(15)	70	50	0.90
	CMSH70	11,12	C-Mn-Si	1	(1)(15)	70	50	1.00
	CMSH70	20,23,30,33	C-Mn-Si	1	(1)(3)	70	50	0.90
	CMSH70	21,22,31,32	C-Mn-Si	1	(1)(3)	70	50	1.00
A 691	CMSH80	10,13	C-Mn-Si	1	(1)(15)	80	60	0.90
	CMSH80	11,12	C-Mn-Si	1	(1)(15)	80	60	1.00
	CMSH80	20,23	C-Mn-Si	1	(1)(3)	80	60	0.90
	CMSH80	21,22	C-Mn-Si	1	(1)(3)	80	60	1.00
A 691	CMS75	10,13	C-Mn-Si	1	(1)(2)(15)	75	42	0.90
	CMS75	11,12	C-Mn-Si	1	(1)(2)(15)	75	42	1.00
	CMS75	20,23,30,33	C-Mn-Si	1	(1)(2)	75	40	0.90
	CMS75	21,22,31,32	C-Mn-Si	1	(1)(2)	75	40	1.00
Copper Brazed Tubing								
A 254	...	...	C	...	(1)(9)(10)	42	25	1.00
Plate								
A 36	...	...	C-Mn-Si	1	(1)(7)(21)	58	36	0.92
A 283	A	...	C	1	(1)(7)	45	24	0.92
	B	...	C	1	(1)(7)	50	27	0.92
	C	...	C	1	(1)(7)	55	30	0.92
	D	...	C	1	(1)(7)	60	33	0.92
A 285	A	...	C	1	(2)	45	24	1.00
	B	...	C	1	(2)	50	27	1.00
	C	...	C	1	(2)	55	30	1.00
A 299	...	...	C-Mn-Si	1	(2)(23)	75	40	1.00
	...	...	C-Mn-Si	1	(2)(22)	75	42	1.00
A 515	55	...	C-Si	1	(2)	55	30	1.00
	60	...	C-Si	1	(2)	60	32	1.00
	65	...	C-Si	1	(2)	65	35	1.00
	70	...	C-Si	1	(2)	70	38	1.00

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TABLE A-1
CARBON STEEL (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
							Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)					
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CMSH70	A 691
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CMSH70	
15.8	15.8	15.8	15.7	15.7	15.7	15.5	...	...	...	...	CMSH70	
17.5	17.5	17.5	17.4	17.4	17.4	17.2	...	...	...	...	CMSH70	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CMSH80	A 691
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CMSH80	
18.0	18.0	18.0	17.8	17.8	17.8	17.8	...	...	...	...	CMSH80	
20.0	20.0	20.0	19.8	19.8	19.8	19.8	...	...	...	...	CMSH80	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CMS75	A 691
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CMS75	
...	...	...	...	...	...	...	16.9	15.9	14.1	11.3	CMS75	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	CMS75	
											Copper Brazed Tubing	
6.0	5.5	4.8	3.0	...	...	...	...	...	...	...	...	A 254
											Plate	
...	...	...	...	...	...	...	12.7	...	...	...	...	A 36
...	...	...	...	...	...	...	10.4	...	...	...	A	A 283
...	...	...	...	...	...	...	11.5	...	...	...	B	
...	...	...	...	...	...	...	12.7	...	...	...	C	
...	...	...	...	...	...	...	13.8	...	...	...	D	
...	...	...	...	...	...	...	11.3	11.0	10.3	9.0	A	A 285
...	...	...	...	...	...	...	12.5	12.1	11.2	9.6	B	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	C	
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	...	A 299
...	...	...	...	...	...	...	18.8	17.7	15.7	12.6	...	
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	55	A 515
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	60	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	65	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.6	70	

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Plate (Cont'd)								
A 516	55	...	C–Si	1	(2)	55	30	1.00
	60	...	C–Mn–Si	1	(2)	60	32	1.00
	65	...	C–Mn–Si	1	(2)	65	35	1.00
	70	...	C–Mn–Si	1	(2)	70	38	1.00
Forgings								
A 105	...	...	C–Si	1	(2)	70	36	1.00
A 181	...	60	C–Si	1	(2)	60	30	1.00
	...	70	C–Si	1	(2)	70	36	1.00
Wrought Fittings (Seamless and Welded)								
A 234	WPB	...	C–Si	1	(2)	60	35	1.00
	WPC	...	C–Si	1	(2)	70	40	1.00
Castings								
A 216	WCA	...	C–Si	1	(2)(6)	60	30	0.80
	WCB	...	C–Si	1	(2)(6)	70	36	0.80
	WCC	...	C–Mn–Si	1	(2)(6)	70	40	0.80
Bars and Shapes								
A 36	...	...	C–Mn–Si	1	(1)(2)	58	36	1.00
Bolts, Nuts, and Studs								
A 193	...	...	...	...	(11)	...	...	...
A 194	1,2,2H	...	...	...	(12)	...	...	...

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TABLE A-1
CARBON STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
-20 to 100	200	300	400	500	600	650	-20 to 650	700	750	800	Grade	Spec. No.
												Plate (Cont'd)
...	...	...	...	...	...	...	13.8	13.3	12.1	10.2	55	A 516
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	60	
...	...	...	...	...	...	...	16.3	15.5	13.9	11.4	65	
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	70	
												Forgings
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	...	A 105
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	...	A 181
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	...	
												Wrought Fittings (Seamless and Welded)
...	...	...	...	...	...	...	15.0	14.4	13.0	10.8	WPB	A 234
...	...	...	...	...	...	...	17.5	16.6	14.8	12.0	WPC	
												Castings
...	...	...	...	...	...	...	12.0	11.5	10.4	8.6	WCA	A 216
...	...	...	...	...	...	...	14.0	13.3	11.8	9.6	WCB	
...	...	...	...	...	...	...	14.0	13.3	11.8	9.6	WCC	
												Bars and Shapes
...	...	...	...	...	...	...	14.5	13.9	12.6	10.5	...	A 36
												Bolts, Nuts, and Studs
...	...	...	...	...	...	...	...	...	...	...	...	A 193
...	...	...	...	...	...	...	...	...	...	...	1,2,2H	A 194

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TABLE A-1
CARBON STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bolts, Nuts, and Studs (Cont'd)								
A 307	B	...	C	...	(1)(13)(21)	60	...	...
A 449	...	...	C	...	(1)(17)(18)	120	...	...
	...	...	C	...	(1)(17)(19)	105	...	...
	...	...	C	...	(1)(17)(20)	90	...	...

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM, except API-5L. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.

(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.

(c) The P-Numbers indicated in this Table are identical to those adopted by ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code (Section IX) except as modified by para. 127.5.

(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."

(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given except as permitted by para. 122.6.2(G).

(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.

(g) Pressure–temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

(h) All the materials listed are classifed as ferritic [see Table 104.1.2(A)].

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR CONSTRUCTION OF PRESSURE RETAINING PARTS OF BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).

(2) Upon prolonged exposure to temperatures above 775°F, the carbide phase of carbon steel may be converted to graphite.

(3) The allowable stress values given are for pipe fabricated from plate not exceeding $2^1/_2$ in. in thickness.

(4) This material shall not be used for flammable fluids. Refer to para. 105.2.1(A).

(5) Tensile value in parentheses is expected minimum.

(6) The 0.80 material quality factor for casting may be increased in accordance with para. 102.4.6.

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TABLE A-1
CARBON STEEL (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding												
−20 to 100	200	300	400	500	600	650	−20 to 650	700	750	800	Grade	Spec. No.
											Bolts, Nuts, and Studs (Cont'd)	
7.0	7.0	7.0	7.0	...	...	...	...	...	...	...	B	A 307
23.0	23.0	23.0	23.0	23.0	23.0	23.0	...	...	...	...	...	A 449
23.0	20.3	20.3	20.3	20.3	20.3	20.3	...	...	...	...	...	
14.5	14.5	14.5	14.5	14.5	14.5	14.5	...	...	...	...	...	

NOTES (CONT'D)

(7) The stress values for structural quality plate include a material quality factor of 0.92. The allowable stresses for A 283 Grade D and A 36 plate have been limited to 12.7 ksi.
(8) These stress values are permitted only if killed or semikilled steels are used.
(9) A 254 is copper brazed (not welded) steel pipe.
(10) For saturated steam at 250 psi (406°F), the values given for 400°F may be used.
(11) For A 193 alloy and stainless steel bolts for use with carbon steel piping, see Tables A-2 and A-3.
(12) This is a product specification. Allowable stresses are not necessary. Limitations on metal temperature for materials covered by this specification for use under B31.1 are:

Grades 1 and 2	−20°F to 600°F
Grade 2H	−20°F to 800°F

(13) This material shall not be used above 400°F. The allowable stress value is 7000 psi.
(14) This material is not listed in the ASME Boiler and Pressure Vessel Code, Section IX. However, weld procedures shall be qualified in accordance with the P-Number shown. See para. 127.5.1.
(15) This material shall not be used in nominal wall thicknesses exceeding $^3/_4$ in.
(16) These allowable stress values are for pipe made using a butt-welded joint process. Pipe made by other processes shall not be used.
(17) These allowable stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange, bolts, and corresponding relaxation properties.
(18) These allowable stress values apply to bolting materials less than or equal to 1 in. diameter.
(19) These allowable stress values apply to bolting materials greater than 1 in. diameter and less than or equal to $1^1/_2$ in.
(20) These allowable stress values apply to bolting materials greater than $1^1/_2$ in. diameter and less than or equal to 3 in. diameter.
(21) The allowable stress values listed in MSS SP-58 for this material may be used for pipe supporting elements designed in accordance with MSS SP-58.
(22) These values apply to material less than or equal to 1 in. thick.
(23) These values apply to material greater than 1 in. thick.

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube								
A 199	T5	...	5Cr–$^1/_2$ Mo	5B	(1)(5)	60	25	1.00
	T9	...	9Cr–1Mo	5B	(1)(5)	60	25	1.00
A 199	T11	...	1$^1/_4$Cr–$^1/_2$ Mo	4	(1)	60	25	1.00
	T21	...	3Cr–1Mo	5A	(1)	60	25	1.00
	T22	...	2$^1/_4$Cr–1Mo	5A	(1)(17)	60	25	1.00
A 213	T2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	60	30	1.00
	T5	...	5Cr–$^1/_2$ Mo	5B	(5)	60	30	1.00
	T5b	...	5Cr–$^1/_2$ Mo–1$^1/_2$ Si	5B	(5)	60	30	1.00
A 213	T5c	...	5Cr–$^1/_2$ Mo–Ti	5B	(5)	60	30	1.00
	T9	...	9Cr–1Mo	5B	(5)	60	30	1.00
	T11	...	1$^1/_4$Cr–$^1/_2$ Mo	4	...	60	30	1.00
A 213	T12	...	1Cr–$^1/_2$ Mo	4	...	60	30	1.00
	T21	...	3Cr–1Mo	5A	...	60	30	1.00
	T22	...	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	T91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	T91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
A 333	3	...	3$^1/_2$Ni	9B	(1)	65	35	1.00
	4	...	$^3/_4$Cr–$^3/_4$Ni–Cu–Al	4	(1)	60	35	1.00
	7	...	2$^1/_2$Ni	9A	(1)	65	35	1.00
	9	...	2Ni–1Cu	9A	(1)(5)	63	46	1.00
A 335	P1	...	C–$^1/_2$ Mo	3	(2)	55	30	1.00
	P2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	55	30	1.00
	P5	...	5Cr–$^1/_2$ Mo	5B	(5)	60	30	1.00
	P5b	...	5Cr–$^1/_2$ Mo–1$^1/_2$ Si	5B	(5)	60	30	1.00
A 335	P5c	...	5Cr–$^1/_2$ Mo–Ti	5B	(5)	60	30	1.00
	P9	...	9Cr–1Mo	5B	(5)	60	30	1.00
	P11	...	1$^1/_4$Cr–$^1/_2$ Mo–Si	4	...	60	30	1.00
A 335	P12	...	1Cr–$^1/_2$ Mo	4	...	60	32	1.00
	P21	...	3Cr–1Mo	5A	...	60	30	1.00
	P22	...	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	P91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	P91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
-20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Seamless Pipe and Tube	
...	13.3	13.1	12.9	12.8	12.4	12.1	11.6	10.9	8.0	5.8	4.2	2.9	2.0	1.3	T5	A 199
...	13.3	13.1	12.9	12.8	12.4	12.1	11.6	11.0	10.3	7.4	5.0	3.3	2.2	1.5	T9	
14.0	13.5	13.1	12.8	12.6	12.3	12.0	11.7	11.3	9.3	6.3	4.2	2.8	1.9	1.2	T11	A 199
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	2.7	1.5	T21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	2.4	1.4	T22	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.7	9.2	5.9	...	...	...	...	T2	A 213
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5b	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	T5c	A 213
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	T9	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	T11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	T12	A 213
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	T21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	T22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	T91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	T91	
16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	...	3	A 333
15.0	15.0	15.0	15.0	...	...	...	...	...	...	...	...	...	...	...	4	
16.3	16.3	16.3	16.3	...	...	...	...	...	...	...	...	...	...	...	7	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.1	...	...	...	...	...	...	...	P1	A 335
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.3	9.2	5.9	...	...	...	...	P2	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5b	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	P5c	A 335
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	P9	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	P11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	P12	A 335
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	P21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	P22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	P91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	P91	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)								
A 369	FP1	...	C-$^1/_2$Mo	3	(2)	55	30	1.00
	FP2	...	$^1/_2$Cr-$^1/_2$Mo	3	...	55	30	1.00
	FP5	...	5Cr-$^1/_2$Mo	5B	(5)	60	30	1.00
A 369	FP9	...	9Cr-1Mo	5B	(5)	60	30	1.00
	FP11	...	1$^1/_4$Cr-$^1/_2$Mo-Si	4	...	60	30	1.00
A 369	FP12	...	1Cr-$^1/_2$Mo	4	...	60	32	1.00
	FP21	...	3Cr-1Mo	5A	...	60	30	1.00
	FP22	...	2$^1/_4$Cr-1Mo	5A	(17)	60	30	1.00
A 714	V	...	2Ni-1Cu	9A	(1)(5)	65	46	1.00
Centrifugally Cast Pipe								
A 426	CP1	...	C-$^1/_2$Mo	3	(1)(2)(3)(4)(7)	65	35	0.85
	CP2	...	$^1/_2$Cr-$^1/_2$Mo	3	(1)(3)(4)(7)	60	30	0.85
	CP5	...	5Cr-$^1/_2$Mo	5B	(1)(3)(4)(5)(7)	90	60	0.85
	CP5B	...	5Cr-$^1/_2$Mo-Si	5B	(1)(3)(4)(5)(7)	60	30	0.85
A 426	CP9	...	9Cr-1Mo	5B	(1)(3)(4)(5)(7)	90	60	0.85
	CP11	...	1$^1/_4$Cr-$^1/_2$Mo	4	(1)(3)(4)(7)	70	40	0.85
A 426	CP12	...	1Cr-$^1/_2$Mo	4	(1)(3)(4)(7)	60	30	0.85
	CP21	...	3Cr-1Mo	5A	(1)(3)(4)(5)(7)	60	30	0.85
	CP22	...	2$^1/_4$Cr-1Mo	5A	(1)(3)(4)(5)(7)(17)	70	40	0.85
Electric Resistance Welded Pipe								
A 333	3	...	3$^1/_2$Ni	9B	(1)	65	35	0.85
	7	...	2$^1/_2$Ni	9A	(1)	65	35	0.85
	9	...	2Ni-1Cu	9A	(1)(5)	63	46	0.85
A 714	V	E	2Ni-Cu	9A	(1)(5)	65	46	0.85

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
–20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Seamless Pipe and Tube (Cont'd)	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	...	...	...	...	...	...	...	FP1	A 369
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.3	9.2	5.9	...	...	...	...	FP2	
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	FP5	
...	14.4	14.2	13.9	13.7	13.2	12.8	12.1	11.4	10.6	7.4	5.0	3.3	2.2	1.5	FP9	A 369
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	FP11	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	14.0	11.3	7.2	4.5	2.8	...	...	FP12	A 369
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	FP21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	FP22	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714
															Centrifugally Cast Pipe	
13.9	13.9	13.9	13.9	13.9	13.8	13.4	13.0	...	...	...	...	...	...	...	CP1	A 426
12.8	12.8	12.8	12.8	12.8	12.6	12.2	11.9	11.6	7.8	5.0	...	...	...	...	CP2	
...	18.4	18.1	17.8	17.4	16.8	16.2	12.1	9.2	6.8	4.9	3.6	2.5	1.5	0.85	CP5	
...	12.2	12.1	11.8	11.6	11.2	10.9	10.3	9.3	6.8	4.9	3.6	2.5	1.5	0.85	CP5b	
...	18.4	18.1	17.7	17.4	16.8	16.2	15.5	14.0	9.4	6.3	4.3	2.8	1.9	1.3	CP9	A 426
14.9	14.9	14.9	14.9	14.9	14.9	14.9	14.5	11.6	7.9	5.4	3.6	2.4	...	...	CP11	
12.8	12.8	12.8	12.8	12.6	12.4	12.2	11.9	11.6	9.6	6.1	3.8	2.4	...	...	CP12	A 426
...	12.3	12.3	12.3	12.3	12.3	11.8	11.2	10.2	7.7	6.0	4.7	3.4	...	...	CP21	
...	14.3	14.3	14.2	14.1	13.7	13.3	12.8	12.1	9.7	6.6	4.3	2.7	...	...	CP22	
															Electric Resistance Welded Pipe	
13.8	13.8	13.8	13.8	...	...	...	...	...	...	...	...	...	...	...	3	A 333
13.8	13.8	13.8	13.8	...	...	...	...	...	...	...	...	...	...	...	7	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	9	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	V	A 714

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added								
A 672	L65	20,23,30,33,40,43	C–½ Mo	3	(1)	65	37	0.90
	L65	21,22,31,32,41,42	C–½ Mo	3	(1)	65	37	1.00
A 672	L70	20,23,30,33,40,43	C–½ Mo	3	(1)	70	40	0.90
	L70	21,22,31,32,41,42	C–½ Mo	3	(1)	70	40	1.00
A 672	L75	20,23,30,33,40,43	C–½ Mo	3	(1)	75	43	0.90
	L75	21,22,31,32,41,42	C–½ Mo	3	(1)	75	43	1.00
A 691	CM65	20,23,30,33,40,43	C–½ Mo	3	(1)	65	37	0.90
	CM65	21,22,31,32,41,42	C–½ Mo	3	(1)	65	37	1.00
A 691	CM70	20,23,30,33,40,43	C–½ Mo	3	(1)	70	40	0.90
	CM70	21,22,31,32,41,42	C–½ Mo	3	(1)	70	40	1.00
A 691	CM75	20,23,30,33,40,43	C–½ Mo	3	(1)	75	43	0.90
	CM75	21,22,31,32,41,42	C–½ Mo	3	(1)	75	43	1.00
A 691	½ Cr	20,23	½ Cr–½ Mo	3	(1)(11)	55	33	0.90
	½ Cr	21,22	½ Cr–½ Mo	3	(1)(11)	55	33	1.00
	½ Cr	20,23,30,33,40,43	½ Cr–½ Mo	3	(1)(12)	70	45	0.90
	½ Cr	21,22,31,32,41,42	½ Cr–½ Mo	3	(1)(12)	70	45	1.00
A 691	1Cr	20,23	1Cr–½ Mo	4	(1)(11)	55	33	0.90
	1Cr	21,22	1Cr–½ Mo	4	(1)(11)	55	33	1.00
	1Cr	20,23,30,33,40,43	1Cr–½ Mo	4	(1)(12)	65	40	0.90
	1Cr	21,22,31,32,41,42	1Cr–½ Mo	4	(1)(12)	65	40	1.00
A 691	1¼ Cr	20,23	1¼ Cr–½ Mo–Si	4	(1)(11)	60	35	0.90
	1¼ Cr	21,22	1¼ Cr–½ Mo–Si	4	(1)(11)	60	35	1.00
	1¼ Cr	20,23,30,33,40,43	1¼ Cr–½ Mo–Si	4	(1)(12)	75	45	0.90
	1¼ Cr	21,22,31,32,41,42	1¼ Cr–½ Mo–Si	4	(1)(12)	75	45	1.00
A 691	2¼ Cr	20,23	2¼ Cr–1Mo	5A	(1)(11)(17)	60	30	0.90
	2¼ Cr	21,22	2¼ Cr–1Mo	5A	(1)(11)(17)	60	30	1.00
	2¼ Cr	20,23,30,33,40,43	2¼ Cr–1Mo	5A	(1)(5)(12)(17)	75	45	1.00
	2¼ Cr	21,22,31,32,41,42	2¼ Cr–1Mo	5A	(1)(5)(12)(17)	75	45	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added																
14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.8	...	...	...	...	...	...	...	L65	A 672
16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.3	...	...	...	...	...	...	...	L65	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.4	...	...	...	...	...	...	...	L70	A 672
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	L70	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	...	...	...	...	...	...	...	L75	A 672
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	...	...	...	...	...	...	...	L75	
14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.8	...	...	...	...	...	...	...	CM65	A 691
16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.3	...	...	...	...	...	...	...	CM65	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.4	...	...	...	...	...	...	...	CM70	A 691
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	CM70	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	...	...	...	...	...	...	...	CM75	A 691
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	...	...	...	...	...	...	...	CM75	
12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.1	11.5	8.3	5.3	...	...	...	...	½Cr	A 691
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	½Cr	
15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.8	15.2	8.3	5.3	...	...	...	...	½Cr	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	½Cr	
12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.1	11.5	10.2	6.5	4.1	2.5	...	...	1Cr	A 691
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.9	11.3	7.2	4.5	2.8	...	...	1Cr	
14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.2	13.6	10.2	6.5	4.1	2.5	...	...	1Cr	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.2	11.3	7.2	4.5	2.8	...	...	1Cr	
13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.1	12.3	8.4	5.7	3.8	2.5	...	...	1¼Cr	A 691
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	13.7	9.3	6.3	4.2	2.8	...	...	1¼Cr	
16.9	16.9	16.9	16.9	16.9	16.9	16.9	16.5	12.3	8.4	5.7	3.8	2.5	...	...	1¼Cr	
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	13.7	9.3	6.3	4.2	2.8	...	...	1¼Cr	
13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0	12.2	9.7	7.2	5.1	3.4	...	...	2¼Cr	A 691
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	2¼Cr	
...	16.1	16.0	15.9	15.8	15.5	15.2	14.8	14.2	10.3	7.0	4.6	2.9	...	...	2¼Cr	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	2¼Cr	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)								
A 691	3Cr	20,23	3Cr–1Mo	5A	(1)(11)	60	30	0.90
	3Cr	21,22	3Cr–1Mo	5A	(1)(11)	60	30	1.00
	3Cr	20,23,30,33,40,43	3Cr–1Mo	5A	(1)(5)(12)	75	45	0.90
	3Cr	21,22,31,32,41,42	3Cr–1Mo	5A	(1)(5)(12)	75	45	1.00
A 691	5Cr	20,23	5Cr–$^1/_2$Mo	5B	(1)(5)(11)	60	30	0.90
	5Cr	21,22	5Cr–$^1/_2$Mo	5B	(1)(5)(11)	60	30	1.00
	5Cr	20,23,30,33,40,43	5Cr–$^1/_2$Mo	5B	(1)(5)(12)	75	45	0.90
	5Cr	21,22,31,32,41,42	5Cr–$^1/_2$Mo	5B	(1)(5)(12)	75	45	1.00
A 691	91	40,43,50,53	9Cr–1Mo–V	5B	(1)(5)(12)(17)	85	60	0.90
	91	41,42,52,53	9Cr–1Mo–V	5B	(1)(5)(12)(17)	85	60	1.00
Plate								
A 387	2	1	$^1/_2$Cr–$^1/_2$Mo	3	...	55	33	1.00
	2	2	$^1/_2$Cr–$^1/_2$Mo	3	(1)...	70	45	1.00
	5	1	5Cr–$^1/_2$Mo	5B	(5)	60	30	1.00
	5	2	5Cr–$^1/_2$Mo	5B	(1)(5)	75	45	1.00
A 387	11	1	1$^1/_4$Cr–$^1/_2$Mo–Si	4	...	60	35	1.00
	11	2	1$^1/_2$Cr–$^1/_2$Mo–Si	4	...	75	45	1.00
	12	1	1Cr–$^1/_2$Mo	4	...	55	33	1.00
	12	2	1Cr–$^1/_2$Mo	4	...	65	40	1.00
A 387	21	1	3Cr–1Mo	5A	...	60	30	1.00
	21	2	3Cr–1Mo	5A	(5)	75	45	1.00
	22	1	2$^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	22	2	2$^1/_4$Cr–1Mo	5A	(5)(17)	75	45	1.00
A 387	91	2	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	91	2	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
Forgings								
A 182	F1	...	C–$^1/_2$Mo	3	(2)	70	40	1.00
	F2	...	$^1/_2$Cr–$^1/_2$Mo	3	...	70	40	1.00
	F5	...	5Cr–$^1/_2$Mo	5B	(5)	70	40	1.00
	F5a	...	5Cr–$^1/_2$Mo	5B	(5)	90	65	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
Electric Fusion Welded Pipe — Filler Metal Added (Cont'd)																
13.5	13.5	13.5	13.5	13.3	13.1	12.5	11.9	10.8	8.1	6.3	5.0	3.6	...	...	3Cr	A 691
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	3Cr	
...	16.1	16.0	15.9	15.8	15.5	15.2	14.8	11.8	8.6	6.1	4.4	2.9	...	...	3Cr	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	3Cr	
...	13.0	12.7	12.5	12.3	11.9	11.5	10.9	9.8	7.2	5.2	3.8	2.6	1.6	0.90	5Cr	A 691
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5Cr	
...	16.2	15.9	15.7	15.4	14.9	14.4	13.6	9.8	7.2	5.2	3.8	2.6	1.6	0.90	5Cr	
...	18.0	17.7	17.4	17.1	16.5	16.0	15.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5Cr	
...	18.9	18.7	18.4	18.0	17.4	16.8	16.0	15.0	13.9	12.8	11.6	8.6	6.3	3.8	91	A 691
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	91	
Plate																
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.8	9.2	5.9	...	...	...	...	2	A 387
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	2	
...	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5	
...	18.0	17.7	17.4	17.1	16.5	16.0	15.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	5	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.6	13.7	9.3	6.3	4.2	2.8	...	...	11	A 387
18.8	18.8	18.8	18.8	18.8	18.8	18.8	18.3	13.7	9.3	6.3	4.2	2.8	...	...	11	
13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.4	12.9	11.3	7.2	4.5	2.8	...	...	12	
16.3	16.3	16.3	16.3	16.3	16.3	16.3	15.8	15.2	11.3	7.2	4.5	2.8	...	...	12	
15.0	15.0	15.0	15.0	14.8	14.5	13.9	13.2	12.0	9.0	7.0	5.5	4.0	...	...	21	A 387
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	91	A 387
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	91	
Forgings																
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	...	...	...	...	...	...	...	F1	A 182
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	16.9	9.2	5.9	...	...	...	...	F2	
...	16.8	16.5	16.3	16.0	15.4	14.9	14.1	10.8	8.0	5.8	4.2	2.9	1.8	1.0	F5	
...	21.6	21.3	20.9	20.5	19.8	19.1	14.3	10.9	8.0	5.8	4.2	2.9	1.8	1.0	F5a	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd)								
A 182	F9	...	9Cr–1Mo	5B	(5)	85	55	1.00
	F91	...	9Cr–1Mo–V	5B	(5)	85	60	1.00
	F11	Class 1	$1^1/_2$Cr–$^1/_2$Mo–Si	4	...	60	30	1.00
	F11	Class 2	$1^1/_4$Cr–$^1/_4$Mo–Si	4	...	70	40	1.00
	F12	Class 1	1Cr–$^1/_2$Mo	4	...	60	30	1.00
	F12	Class 2	1Cr–$^1/_2$Mo	4	...	70	40	1.00
	F21	...	3Cr–1Mo	5A	(5)	75	45	1.00
	F22	Class 1	$2^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	F22	Class 3	$2^1/_4$Cr–1Mo	5A	(5)(17)	75	45	1.00
A 336	F11	Class 1	$1^1/_4$Cr–$^1/_2$Mo–Si	4	...	60	30	1.00
	F11	Class 2	$1^1/_4$Cr–$^1/_2$Mo–Si	4	...	70	40	1.00
	F12	...	1Cr–$^1/_2$Mo	4	...	70	40	1.00
	F22	Class 1	$2^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	F22	Class 3	$2^1/_4$Cr–1Mo	5A	(5)(17)	75	45	1.00
	F91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	F91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00
A 350	LF3	...	$3^1/_2$Ni	9B	(1)	70	40	1.00
	LF4	...	$^3/_4$Cr–$^3/_4$Ni–Cu–Al	4	(1)	60	...	1.00
	LF5	Class 1	$1^1/_2$Ni	9A	(1)(5)	60	30	1.00
	LF5	Class 2	$1^1/_2$Ni	9A	(1)(5)	70	37	1.00
	LF9	...	2Ni–1Cu	9A	(1)(5)	63	46	1.00
Wrought Fittings (Seamless and Welded)								
A 234	WP1	...	C–$^1/_2$Mo	3	(2)	55	30	1.00
	WP5	...	5Cr–$^1/_2$Mo	5B	...	60	30	1.00
	WP11	...	$1^1/_4$Cr–$^1/_2$Mo	4	...	60	30	1.00
	WP12	(1)	1Cr–$^1/_2$Mo	4	(6)	60	30	1.00
A 234	WP22	...	$2^1/_4$Cr–1Mo	5A	(17)	60	30	1.00
	WP91	...	9Cr–1Mo–V	5B	(5)(19)	85	60	1.00
	WP91	...	9Cr–1Mo–V	5B	(5)(20)	85	60	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
															Forgings (Cont'd)	
...	20.4	20.1	19.7	19.4	18.7	18.1	17.1	16.2	11.0	7.4	5.0	3.3	2.2	1.5	F9	A 182
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	F91	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	F11	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	13.7	9.3	6.3	4.2	2.8	...	...	F11	
15.0	15.0	15.0	15.0	14.8	14.6	14.3	14.0	13.6	11.3	7.2	4.5	2.8	...	...	F12	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.0	16.4	11.3	7.2	4.5	2.8	...	...	F12	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	13.1	9.5	6.8	4.9	3.2	...	...	F21	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	F22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	F22	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	F11	A 336
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.1	13.7	9.3	6.3	4.2	2.8	...	...	F11	
17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.0	16.4	11.3	7.2	4.5	2.8	...	...	F12	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	F22	
...	17.9	17.8	17.7	17.5	17.2	16.9	16.4	15.8	11.4	7.8	5.1	3.2	...	...	F22	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	F91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	F91	
17.5	17.5	17.5	17.5	...	...	...	...	...	...	...	...	...	...	...	LF3	A 350
15.0	15.0	15.0	15.0	...	...	...	...	...	...	...	...	...	...	...	LF4	
...	13.4	...	...	...	...	...	...	...	...	...	...	...	...	...	LF5	
...	15.6	...	...	...	...	...	...	...	...	...	...	...	...	...	LF5	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	LF9	
															Wrought Fittings (Seamless and Welded)	
13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	...	...	...	...	...	...	...	WP1	A 234
14.4	14.4	14.1	13.9	13.7	13.2	12.8	12.1	10.9	8.0	5.8	4.2	2.9	1.8	1.0	WP5	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	WP11	
15.0	15.0	15.0	15.0	15.0	14.8	14.4	14.0	13.6	9.3	6.3	4.2	2.8	...	...	WP12	
15.0	15.0	15.0	15.0	15.0	15.0	15.0	14.4	13.6	10.8	8.0	5.7	3.8	...	...	WP22	A 234
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	10.3	7.0	4.3	WP91	
...	21.1	20.8	20.5	20.0	19.4	18.7	17.8	16.7	15.5	14.3	12.9	9.6	7.0	4.3	WP91	

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Spec. No.	Grade	Type or Class	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Castings								
A 217	WC1	...	C–½Mo	3	(2)(3)(4)	65	35	0.80
	WC4	...	1Ni–½Cr–½Mo	4	(3)(4)	70	40	0.80
	WC5	...	¾Ni–1Mo–¾Cr	4	(3)(4)	70	40	0.80
	WC6	...	1¼Cr–½Mo	4	(3)(4)	70	40	0.80
A 217	WC9	...	2¼Cr–1Mo	5A	(3)(4)(5)	70	40	0.80
	C5	...	5Cr–½Mo	5B	(3)(4)(5)	90	60	0.80
	C12	...	9Cr–1Mo	5B	(3)(4)(5)	90	60	0.80
	C12A	...	9Cr–1Mo–V	5B	(3)(4)(5)	85	...	0.80
Bolts, Nuts, and Studs								
A 193	B5	...	5Cr–½Mo	...	(8)(9)(13)	100	80	1.00
	B7	...	1Cr–⅕Mo	...	(14)	125	105	1.00
	B7	...	1Cr–⅕Mo	...	(15)	115	95	1.00
	B7	...	1Cr–⅕Mo	...	(16)	100	75	1.00
	B7M	...	1Cr–⅕Mo	...	(1)(14)	100	80	1.00
A 193	B16	...	1Cr–½Mo–V	...	(14)	125	105	1.00
	B16	...	1Cr–½Mo–V	...	(15)	110	95	1.00
	B16	...	1Cr–½Mo–V	...	(16)	100	85	1.00
A 194	3	...	5Cr–½Mo–V	...	(10)	...	...	...
	4	...	C–Mo	...	(2)(10)	...	...	...
	7	...	Cr–Mo	...	(10)	...	...	...
A 320	L7	...	1Cr–⅕Mo	...	(1)(8)(18)	125	105	1.00
	L7M	...	1Cr–⅕Mo	...	(1)(14)	100	80	1.00
	L43	...	1¾Ni–¾Cr–¼Mo	...	(1)(8)(18)	125	105	1.00
A 354	BC	...	Alloy Steel	...	(8)(9)(14)	125	109	1.00
	BC	...	Alloy Steel	...	(8)(9)(15)	115	99	1.00
	BD	...	Alloy Steel	...	(8)(9)(14)	150	130	1.00
	BD	...	Alloy Steel	...	(8)(9)(15)	140	120	1.00

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TABLE A-2
LOW AND INTERMEDIATE ALLOY STEEL (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																
−20 to 400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Grade	Spec. No.
																Castings
13.0	13.0	13.0	13.0	13.0	13.0	12.6	12.2	...	...	...	...	...	...	...	WC1	A 217
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	12.0	7.4	4.7	...	...	...	...	WC4	
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	13.0	8.8	5.5	3.7	2.2	...	...	WC5	
14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.7	11.0	7.4	5.0	3.4	2.2	...	...	WC6	
...	13.4	13.4	13.4	13.3	12.9	12.6	12.0	11.4	9.1	6.2	4.1	2.6	...	...	WC9	A 217
...	17.3	17.0	16.7	16.4	15.8	15.3	11.4	8.7	6.4	4.6	3.4	2.3	1.4	0.80	C5	
...	17.3	17.0	16.7	16.4	15.8	15.3	14.6	13.2	8.8	5.9	4.0	2.6	1.7	1.2	C12	
...	15.4	15.0	14.7	14.5	14.2	13.8	13.4	12.9	12.4	11.4	9.1	7.0	5.2	3.4	C12A	
																Bolts, Nuts, and Studs
20.0	20.0	20.0	20.0	20.0	20.0	18.5	14.5	10.4	7.6	5.6	4.2	3.1	2.0	1.3	B5	A 193
25.0	25.0	25.0	25.0	25.0	23.5	21.0	17.0	12.5	8.5	4.5	...	...	...	...	B7	
23.0	23.0	23.0	23.0	23.0	22.2	20.0	16.3	12.5	8.5	4.5	...	...	...	...	B7	
18.8	18.8	18.8	18.8	18.8	18.8	18.0	16.3	12.5	8.5	4.5	...	...	...	...	B7	
20.0	20.0	20.0	20.0	20.0	20.0	13.5	16.2	12.5	8.5	4.5	...	...	...	...	B7M	
25.0	25.0	25.0	25.0	25.0	25.0	25.0	23.5	20.5	16.0	11.0	6.3	2.8	...	...	B16	A 193
22.0	22.0	22.0	22.0	22.0	22.0	22.0	21.0	18.5	15.3	11.0	6.3	2.8	...	...	B16	
20.0	20.0	20.0	20.0	20.0	20.0	20.0	18.8	16.7	14.3	11.0	6.3	2.8	...	...	B16	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	7	
25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	L7	A 320
20.0	20.0	20.0	20.0	20.0	20.0	18.5	16.2	12.5	8.5	4.5	...	...	...	...	L7M	
25.0	25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	L43	
25.0	25.0	25.0	25.0	...	...	...	...	...	...	...	...	...	...	...	BC	A 354
23.0	23.0	23.0	23.0	...	...	...	...	...	...	...	...	...	...	...	BC	
30.0	30.0	30.0	30.0	...	...	...	...	...	...	...	...	...	...	...	BD	
28.0	28.0	28.0	28.0	...	...	...	...	...	...	...	...	...	...	...	BD	

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TABLE A-2 (CONT'D)

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.
(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.
(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5
(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."
(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.
(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.
(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.
(h) All the materials listed are classifed as ferritic [see Table 104.1.2(A)].

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).
(2) Upon prolonged exposure to temperature above 875°F, the carbide phase of carbon-molybdenum steel may be converted to graphite.
(3) These allowable stress values apply to normalized and tempered material only.
(4) The material quality factors and allowable stress values for these materials may be increased in accordance with para. 102.4.6.
(5) At 400°F and below, the following allowable stress values apply:

Spec. No.	Grade	Type or Class	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F	Metal Temperature, °F: −20 to 100	200	300	400
A 182	F5	...	70	40	1.00	17.5	17.5	17.0	16.8
	F5a	...	90	65	1.00	22.5	22.4	21.8	21.6
	F9	...	85	55	1.00	21.3	21.2	20.6	20.4
A 182	F21	...	75	45	1.00	18.8	18.8	18.3	18.0
	F22	Class 3	75	45	1.00	18.8	18.8	18.3	18.0
	F91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 199	T5	...	60	25	1.00	15.0	14.1	13.6	13.4
	T9	...	60	25	1.00	15.0	14.1	13.6	13.4
A 213	T5	...	60	30	1.00	15.0	15.0	14.5	14.4
	T5b	...	60	30	1.00	15.0	15.0	14.5	14.4
	T5c	...	60	30	1.00	15.0	15.0	14.5	14.4
A 213	T9	...	60	30	1.00	15.0	15.0	14.5	14.4
	T91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 217	WC9	...	70	40	0.80	14.0	14.0	13.8	13.5
	C5	...	90	60	0.80	18.0	17.9	17.4	17.3
	C12	...	90	60	0.80	18.0	17.9	17.4	17.3
	C12A	...	85	...	0.80	17.0	17.0	16.5	15.9
A 333	9	Seamless	63	46	1.00	15.8	...	...	...
	9	Welded	63	46	0.85	13.4	...	...	...
A 335	P5	...	60	30	1.00	15.0	15.0	14.5	14.4
	P5b	...	60	30	1.00	15.0	15.0	14.5	14.4
	P5c	...	60	30	1.00	15.0	15.0	14.5	14.4
	P9	...	60	30	1.00	15.0	15.0	14.5	14.4
	P91	...	85	60	1.00	21.3	21.3	21.2	21.2
A 336	F22	Class 3	75	45	1.00	18.8	18.8	18.3	18.0
	F91	...	85	60	1.00	21.3	21.3	21.2	21.2

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TABLE A-2 (CONT'D)

01

NOTES (CONT'D):

Spec. No.	Grade	Type or Class	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F	Metal Temperature, °F: −20 to 100	200	300	400
A 350	LF5	Class 1	60	30	1.00	15.0	14.4	13.7	13.4
	LF5	Class 2	70	37	1.00	17.5	16.8	16.0	15.6
	LF9	...	63	46	1.00	15.8	...	...	...
A 369	FP5	...	60	30	1.00	15.0	15.0	14.5	14.4
	FP9	...	60	30	1.00	15.0	15.0	14.5	14.4
A 387	5	1	60	30	1.00	15.0	15.0	14.5	14.4
	5	2	75	45	1.00	18.8	18.7	18.2	18.0
	21	2	75	45	1.00	18.8	18.8	18.3	18.0
	22	2	75	45	1.00	18.8	18.8	18.3	18.0
A 387	91	2	85	60	1.00	21.3	21.3	21.2	21.2
	91	2	85	60	0.90	19.1	19.1	19.0	19.0
A 426	CP5	...	90	60	0.85	19.1	19.0	18.5	18.4
	CP5b	...	60	30	0.85	12.8	12.8	12.3	12.2
	CP9	...	90	60	0.85	19.1	19.0	18.5	18.4
	CP21	...	60	...	0.85	12.8	12.8	12.5	12.3
	CP22	...	70	40	0.85	14.9	14.9	14.7	14.4
A 691	$2^1/_4$Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.9	16.5	16.2
	$2^1/_4$Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.8	18.3	18.0
A 691	3Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.9	16.5	16.2
	3Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.8	18.3	18.0
A 691	5Cr	20,23	60	30	0.90	13.5	13.5	13.1	13.0
	5Cr	21,22	60	30	1.00	15.0	15.0	14.5	14.4
	5Cr	20,23,30,33,40,43	75	45	0.90	16.9	16.8	16.4	16.2
	5Cr	21,22,31,32,41,42	75	45	1.00	18.8	18.7	18.2	18.0
A 714	V	S	65	46	1.00	15.8	...	...	...
	V	E	65	46	0.85	13.4	...	...	...

(6) If A 234 Grade WP-12 fittings are made from A 387 Grade 12 annealed plate, the allowable stress values shall be reduced by the ratio of 55 divided by 60 in the temperature range −20°F through 850°F. At 900°F through 1100°F, the values shown may be used.

(7) The mutual quality factor for centrifugally cast pipe (0.85) is based on all surfaces being machined, after heat treatment, to a surface finish of 250 μin. arithmetic average deviation or better.

(8) These allowable stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(9) Between temperatures of −20°F and 400°F, allowable stress values equal to the lower of the following may be used: 20% of the specified tensile strength, or 25% of the specified yield strength.

(10) This is a product specification. Allowable stress values are not necessary. Limitations on metal temperature for materials covered by this specification for use under ASME B31.1 are:

Grade 3	−20°F to 1100°F
Grade 4	−20°F to 900°F

(11) These allowable stress values are for pipe fabricated from ASTM A 387 Class 1 plate in the annealed condition.

(12) These allowable stress values are for pipe fabricated from ASTM A 387 Class 2 plate.

(13) These allowable stress values apply to bolting materials 4 in. in diameter and smaller.

(14) These allowable stress values apply to bolting materials $2^1/_2$ in. but not larger than 4 in. in diameter.

(15) These allowable stress values apply to bolting materials larger than $2^1/_2$ in. but not larger than 4 in. in diameter.

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01 TABLE A-2 (CONT'D)

NOTES (CONT'D):

(16) These allowable stress values apply to bolting materials larger than 4 in. but not larger than 7 in. in diameter.
(17) For use at temperatures above 850°F, the carbon content of the base material and, where applicable, weld filler metal shall be 0.05% or higher. See para. 124.2(D).
(18) Minimum tempering temperature shall be 800°F.
(19) These allowable stress values apply to thickness less than 3 in.
(20) These allowable stress values apply to thickness 3 in. or greater.

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APPENDIX A, TABLE A-3

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TABLE A-3
STAINLESS STEELS

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube									
Austenitic									
A 213	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 213	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 213	TP309H		S30909	23Cr–12Ni	8	(9)	75	30	1.00
	TP309H		S30909	23Cr–12Ni	8	...	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	(9)	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	...	75	30	1.00
A 213	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 213	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 213	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 213	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 213	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 213
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	TP304L	A 213
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.6	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 213
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 213
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	TP316L	A 213
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 213
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 213
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 213
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)									
A 312	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 312	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 312	TP309H		S30909	23Cr–12Ni	8	(9)	75	30	1.00
	TP309H		S30909	23Cr–12Ni	8	...	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	(9)	75	30	1.00
	TP310H		S31009	25Cr–20Ni	8	...	75	30	1.00
A 312	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 312	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 312	TP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(10)	75	30	1.00
	TP317	...	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 312	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 312
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	TP304L	A 312
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 312
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.8	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 312
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	TP316L	A 312
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP317	A 312
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	TP317	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 312
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)									
A 312	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 312	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)	75	30	1.00
	TPXM15	...	S38100	18Cr–18Ni–2Si	8	(1)(9)	75	30	1.00
	TPXM19	...	S20910	22Cr–13Ni–5Mn	8	(1)	100	35	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
A 376	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 376	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 376	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	1.00
A 376	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	1.00
A 376	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 312
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.5	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	...	...	...	...	TPXM15	A 312
18.8	17.7	16.6	16.1	15.9	15.9	15.9	15.9	15.5	15.1	14.9	14.6	14.3	13.7	...	...	...	...	TPXM15	
21.3	21.2	20.1	19.3	19.0	18.6	18.5	18.4	18.2	18.0	17.8	17.5	17.2	16.9	16.6	...	...	...	TPXM19	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 376
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 376
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 376
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 376
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.7	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 376
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Seamless Pipe and Tube (Cont'd)									
Austenitic (Cont'd)									
A 430	FP304	...	S30400	18Cr–8Ni	8	(10)(11)	70	30	1.00
	FP304	...	S30400	18Cr–8Ni	8	(9)(10)(11)	70	30	1.00
	FP304H	...	S30409	18Cr–8Ni	8	...	70	30	1.00
	FP304H	...	S30409	18Cr–8Ni	8	(9)	70	30	1.00
	FP304N	...	S30451	18Cr–8Ni–N	8	(10)	75	35	1.00
	FP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	75	35	1.00
A 430	FP316	...	S31600	16Cr–12Ni–2Mo	8	(10)(11)	70	30	1.00
	FP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(11)	70	30	1.00
	FP316H	...	S31609	16Cr–12Ni–2Mo	8	...	70	30	1.00
	FP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	70	30	1.00
	FP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	75	35	1.00
	FP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	75	35	1.00
A 430	FP321	...	S32100	18Cr–10Ni–Ti	8	(10)(11)	70	30	1.00
	FP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)(11)	70	30	1.00
	FP321H	...	S32109	18Cr–10Ni–Ti	8	...	70	30	1.00
	FP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	70	30	1.00
A 430	FP347	...	S34700	18Cr–10Ni–Cb	8	(10)(11)	70	30	1.00
	FP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)(11)	70	30	1.00
	FP347H	...	S34709	18Cr–10Ni–Cb	8	...	70	30	1.00
	FP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	70	30	1.00
Ferritic/Martensitic									
A 268	TP405	...	S40500	12Cr–Al	7	(3)	60	30	1.00
	TP410	...	S41000	13Cr	6	...	60	30	1.00
	TP429	...	S42900	15Cr	6	(3)	60	35	1.00
	TP430	...	S43000	17Cr	7	(3)	60	35	1.00
	TPXM27	...	S44627	26Cr–1Mo	10I	(1)(2)(32)	65	40	1.00
	TP446-1	...	S44600	27Cr	10I	(32)	70	40	1.00
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	68	45	1.00
A 731	TPXM27	...	S44627	27Cr–1Mo	10I	(2)(32)	65	40	1.00
	TPXM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	65	40	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Seamless Pipe and Tube (Cont'd) Austenitic (Cont'd)	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	FP304	A 430
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	FP304	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	FP304H	
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	FP304H	
18.8	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	FP304N	
18.8	18.8	17.8	17.1	16.7	16.3	16.2	16.1	15.9	15.8	15.6	15.4	15.1	14.5	12.4	9.8	7.7	6.1	FP304N	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	FP316	A 430
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	FP316	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	FP316H	
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	FP316H	
18.8	18.8	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	FP316N	
18.8	18.8	18.0	17.6	17.4	17.4	17.4	17.4	17.4	17.3	17.1	17.0	16.7	16.3	15.7	12.4	9.8	7.4	FP316N	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	FP321	A 430
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	FP321	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	FP321H	
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	FP321H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	FP347	A430
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	FP347	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	FP347H	
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	FP347H	
																		Ferritic/Martensitic	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP405	A 268
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP410	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP429	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	TP430	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM27	
17.5	16.6	16.1	15.6	15.0	14.5	14.3	...	...	...	...	...	...	...	...	...	...	...	TP446-1	
17.0	17.0	16.8	16.6	16.4	16.1	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM27	A 731
16.3	16.3	16.1	15.9	15.7	15.4	15.2	...	...	...	...	...	...	...	...	...	...	...	TPXM33	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Centrifugally Cast Pipe									
Austenitic									
A 451	CPF8	...	J92600	18Cr–8Ni	8	(1)(8)(10)(26)	70	30	0.85
	CPF8	...	J92600	18Cr–8Ni	8	(1)(8)(9)(10)(26)	70	30	0.85
	CPF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(8)(10)(26)	70	30	0.85
	CPF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(8)(9)(10)(26)	70	30	0.85
	CPF8M	...	J92900	18Cr–9Ni–2Mo	8	(1)(8)(13)(26)	70	30	0.85
	CPF8M	...	J92900	18Cr–9Ni–2Mo	8	(1)(8)(9)(13)(26)	70	30	0.85
A 451	CPH8	...	J93400	25Cr–12Ni	8	(1)(8)(10)(26)	65	28	0.85
	CPH8	...	J93400	25Cr–12Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
	CPH10	...	J93410	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
	CPH10	...	J93410	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
A 451	CPH20	...	J93402	25Cr–12Ni	8	(1)(6)(8)(10)(26)	(70)	30	0.85
	CPH20	...	J93402	25Cr–12Ni	8	(1)(6)(8)(9)(10)(26)	(70)	30	0.85
	CPK20	...	J94202	25Cr–20Ni	8	(1)(8)(10)(26)	65	28	0.85
	CPK20	...	J94202	25Cr–20Ni	8	(1)(8)(9)(10)(26)	65	28	0.85
A 452	TP304H	...	J92590	18Cr–8Ni	8	(1)(8)(26)	75	30	0.85
	TP304H	...	J92590	18Cr–8Ni	8	(1)(8)(9)(26)	75	30	0.85
	TP316H	...	J92920	16Cr–12Ni–2Mo	8	(1)(8)(26)	75	30	0.85
	TP316H	...	J92920	16Cr–12Ni–2Mo	8	(1)(8)(9)(26)	75	30	0.85
	TP347H	...	J92660	18Cr–10Ni–Cb	8	(1)(8)(26)	75	30	0.85
	TP347H	...	J92660	18Cr–10Ni–Cb	8	(1)(8)(9)(26)	75	30	0.85
Welded Pipe and Tube — Without Filler Metal									
Austenitic									
A 249	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	0.85
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	0.85
A 249	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	0.85
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Centrifugally Cast Pipe Austenitic	
14.9	13.3	11.9	11.0	10.3	9.7	9.5	9.4	9.2	8.9	8.8	8.6	8.4	8.1	7.7	6.4	4.9	3.8	CPF8	A 451
14.9	14.0	12.8	12.8	12.6	12.6	12.6	12.6	12.5	12.4	12.2	12.0	11.4	10.2	8.2	6.4	4.9	3.8	CPF8	
14.9	14.1	13.0	12.2	11.8	11.4	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.1	9.5	8.9	6.8	4.2	CPF8C	
14.9	14.1	13.0	12.2	11.8	11.6	11.6	11.6	11.6	11.6	11.6	11.6	11.5	11.2	10.2	8.8	6.8	4.2	CPF8C	
14.9	13.7	12.4	11.3	10.5	10.0	9.8	9.6	9.4	9.4	9.3	9.2	9.1	9.0	8.6	8.0	6.8	5.1	CPF8M	
14.9	14.9	14.5	14.3	14.3	14.3	14.1	13.9	13.6	13.4	13.3	13.2	13.1	12.7	10.2	8.0	6.8	5.1	CPF8M	
13.9	12.7	12.1	11.7	11.2	10.6	10.4	10.1	9.9	9.7	9.4	9.3	9.2	8.4	7.2	5.5	4.3	3.2	CPH8	A 451
13.9	12.7	12.1	11.7	11.5	11.3	11.2	11.1	11.1	11.1	10.9	10.6	10.0	8.9	7.2	5.5	4.3	3.2	CPH8	
14.9	13.7	13.0	12.6	12.0	11.4	11.1	10.8	10.6	10.4	10.1	9.9	9.5	8.7	7.2	5.5	4.3	3.2	CPH10	
14.9	13.7	13.0	12.6	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.3	10.6	8.9	7.2	5.5	4.0	3.2	CPH10	
14.9	13.7	13.0	12.6	12.0	11.4	11.1	10.8	10.6	10.4	10.1	9.9	9.5	8.7	7.2	5.5	4.3	3.2	CPH20	A 451
14.9	13.7	13.0	12.6	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.3	10.6	8.9	7.2	5.5	4.0	3.2	CPH20	
13.9	12.7	12.1	11.7	11.2	10.6	10.4	10.1	9.9	9.7	9.4	9.3	9.0	8.8	8.3	7.2	6.2	5.1	CPK20	
13.9	12.7	12.1	11.7	11.5	11.3	11.2	11.1	11.1	11.1	10.9	10.6	10.1	9.4	8.3	7.2	6.2	5.1	CPK20	
16.0	13.3	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	A 452
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	
16.0	13.8	12.4	11.4	10.6	10.0	9.9	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	13.2	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.3	10.5	8.3	6.3	TP316H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	...	...	...	...	TP347H	
16.0	15.2	13.9	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.2	...	...	...	...	TP347H	
																		Welded Pipe and Tube – Without Filler Metal Austenitic	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304	A 249
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	
13.3	11.4	10.2	9.3	8.7	8.3	8.1	8.0	7.8	7.7	...	...	...	...	...	...	...	...	TP304L	A 249
13.3	13.3	13.0	12.5	12.3	11.9	11.7	11.5	11.3	11.1	...	...	...	...	...	...	...	...	TP304L	
17.0	15.2	13.3	12.0	11.1	10.5	10.4	10.1	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.3	6.5	5.1	TP304N	
17.0	17.0	16.2	15.6	15.1	14.8	14.7	14.6	14.4	14.2	13.9	13.5	13.3	12.8	10.5	8.3	6.5	5.1	TP304N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe and Tube — Without Filler Metal (Cont'd)									
Austenitic (Cont'd)									
A 249	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	0.85
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	0.85
A 249	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	0.85
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	0.85
A 249	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.85
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	0.85
A 249	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(10)	75	30	0.85
	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	0.85
A 249	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	TP348	...	S34800	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP348	...	S34800	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 249	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	0.85
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	0.85
A 312	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	0.85
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	0.85
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Welded Pipe and Tube – Without Filler Metal (Cont'd) Austenitic (Cont'd)	
16.0	16.0	15.9	15.6	15.2	14.9	14.7	14.5	14.3	14.1	13.7	13.3	12.8	11.7	8.8	6.5	4.7	3.4	TP309H	A 249
16.0	15.0	13.7	12.8	12.0	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	8.8	6.5	4.7	3.4	TP309H	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316	A 249
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316H	
13.3	11.3	10.1	9.2	8.5	8.0	7.8	7.6	7.5	7.3	7.2	...	...	...	...	...	...	...	TP316L	A 249
13.3	13.3	13.3	13.2	12.3	11.5	11.1	10.9	10.7	10.5	10.3	...	...	...	...	...	...	...	TP316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	TP316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	13.4	10.5	8.3	6.3	TP316N	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP317	A 249
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP317	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	7.8	5.9	4.3	3.1	TP321	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.8	8.2	5.9	4.3	3.1	TP321	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.6	7.5	5.9	4.6	TP321H	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.9	10.0	7.7	5.9	4.6	TP321H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP347	A 249
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP347	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP347H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP347H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP348	A 249
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP348	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP348H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP348H	
20.0	20.0	18.2	16.9	15.7	15.2	15.0	14.9	14.7	...	...	...	...	...	...	...	...	...	S31254	A 249
20.0	20.0	19.0	18.1	17.4	17.1	16.9	16.9	16.8	...	...	...	...	...	...	...	...	...	S31254	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304	A312
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304	
16.0	13.3	12.0	11.0	10.5	9.7	9.5	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.6	6.5	5.2	TP304H	
16.0	15.1	14.1	13.8	13.5	13.5	13.5	13.5	13.2	12.9	12.7	12.5	12.2	11.7	10.4	8.3	6.5	5.2	TP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe and Tube — Without Filler Metal (Cont'd)									
Austenitic (Cont'd)									
A 312	TP304L	...	S30403	18Cr–8Ni	8	(1)	70	25	0.85
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)	70	25	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	0.85
	TP304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	0.85
A 312	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	0.85
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	0.85
	TP310H	...	S31009	23Cr–20Ni	8	(9)	75	30	0.85
	TP310H	...	S31009	23Cr–20Ni	8	...	75	30	0.85
A 312	TP316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	0.85
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	0.85
	TP316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	0.85
A 312	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.85
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	0.85
	TP316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	0.85
A 312	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(10)	75	30	0.85
	TP317	...	S31700	19Cr–13Ni–3Mo	8	(1)(9)(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	0.85
	TP321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	...	75	30	0.85
	TP321H	...	S32109	18Cr–10Ni–Ti	8	(9)	75	30	0.85
A 312	TP347	...	S34700	18Cr–10Ni–Cb	8	(10)	75	30	0.85
	TP347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	...	75	30	0.85
	TP347H	...	S34709	18Cr–10Ni–Cb	8	(9)	75	30	0.85
A 312	TP348	...	S34800	18Cr–10Ni–Cb	8	(1)(10)	75	30	0.85
	TP348	...	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(1)	75	30	0.85
	TP348H	...	S34809	18Cr–10Ni–Cb	8	(1)(9)	75	30	0.85

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Welded Pipe and Tube – Without Filler Metal (Cont'd)																			
Austenitic (Cont'd)																			
13.3	11.4	10.2	9.3	8.7	8.3	8.1	8.0	7.8	7.7	...	...	...	...	...	...	...	...	TP304L	A 312
13.3	13.3	13.0	12.5	12.3	11.9	11.7	11.5	11.3	11.1	...	...	...	...	...	...	...	...	TP304L	
17.0	15.2	13.3	12.0	11.1	10.5	10.4	10.1	10.0	9.8	9.6	9.4	9.2	9.0	8.8	8.3	6.5	5.1	TP304N	
17.0	17.0	16.2	15.6	15.1	14.8	14.7	14.6	14.4	14.2	13.9	13.5	13.3	12.8	10.5	8.3	6.5	5.1	TP304N	
16.0	16.0	15.9	15.6	15.2	14.9	14.7	14.5	14.3	14.0	13.7	13.3	12.8	9.7	8.8	6.5	4.7	3.4	TP309H	A 312
16.0	15.0	13.7	12.8	12.0	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	8.8	6.5	4.7	3.4	TP309H	
16.0	15.6	15.0	14.8	14.8	14.8	14.8	14.8	14.6	14.5	14.2	13.9	13.5	11.7	8.8	6.5	4.7	3.4	TP310H	
16.0	15.0	13.7	12.8	12.2	11.6	11.5	11.3	11.1	11.0	10.8	10.6	10.5	10.3	8.8	6.5	4.7	3.4	TP310H	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316	A 312
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP316H	
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP316H	
13.3	11.3	10.1	9.2	8.5	8.0	7.8	7.6	7.5	7.3	7.2	...	...	...	...	...	...	...	TP316L	A 312
13.3	13.3	13.3	13.2	12.3	11.5	11.2	10.9	10.7	10.5	10.3	...	...	...	...	...	...	...	TP316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	TP316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	13.4	10.5	8.3	6.3	TP316N	
16.0	13.8	12.4	11.4	10.6	10.1	9.8	9.6	9.5	9.4	9.3	9.2	9.1	9.0	8.9	8.8	7.9	6.3	TP317	A 312
16.0	16.0	15.6	15.4	15.3	14.5	14.2	13.9	13.7	13.5	13.4	13.2	13.1	13.0	12.3	10.6	8.4	6.3	TP317	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.8	7.8	5.9	4.3	3.1	TP321	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.8	8.2	5.9	4.3	3.1	TP321	
16.0	13.5	12.1	11.0	10.2	9.7	9.5	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.6	7.5	5.9	4.6	TP321H	
16.0	15.6	14.7	14.6	14.6	13.9	13.7	13.5	13.3	13.2	13.1	13.0	12.9	11.9	10.0	7.7	5.9	4.6	TP321H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP347	A 312
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP347	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP347H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP347H	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.1	7.8	5.2	3.8	TP348	A 312
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	11.9	10.3	7.8	5.2	3.8	TP348	
16.0	14.7	13.7	12.8	12.0	11.4	11.2	11.0	10.9	10.8	10.8	10.7	10.7	10.7	10.6	10.3	8.9	6.7	TP348H	
16.0	15.2	14.0	13.2	12.7	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.4	12.3	12.0	11.1	8.9	6.7	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Welded Pipe and Tube — Without Filler Metal (Cont'd)									
Austenitic (Cont'd)									
A 312	TPXM15	...	S38100	18Cr-18Ni-2Si	8	(1)	75	30	0.85
	TPXM15	...	S38100	18Cr-18Ni-2Si	8	(1)(9)	75	30	0.85
	...	...	S31254	20Cr-18Ni-6Mo	8	(1)(32)	94	44	0.85
	...	...	S31254	20Cr-18Ni-6Mo	8	(1)(9)(32)	94	44	0.85
Ferritic/Martensitic									
A 268	TP405	...	S40500	12Cr-Al	7	...	60	30	0.85
	TP410	...	S41000	13Cr	6	...	60	30	0.85
	TP429	...	S42900	15Cr	6	...	60	35	0.85
	TP430	...	S43000	17Cr	7	...	60	35	0.85
	TP446-1	...	S44600	27Cr	10I	(1)(32)	70	40	0.85
	TPXM27	...	S44627	26Cr-1Mo	10I	(1)(2)(32)	65	40	0.85
	TPXM33	...	S44626	27Cr-1Mo-Ti	10I	(2)(32)	68	45	0.85
A 731	TPXM27	...	S44627	27Cr-1Mo	10I	(2)(32)	65	40	0.85
	TPXM33	...	S44626	27Cr-1Mo-Ti	10I	(2)(32)	65	40	0.85
Welded Pipe — *Filler Metal Added*									
Austenitic									
A 358	304	1 & 3	S30400	18Cr-8Ni	8	(1)(10)(11)	75	30	1.00
	304	2	S30400	18Cr-8Ni	8	(1)(10)(11)	75	30	0.90
	304	1 & 3	S30400	18Cr-8Ni	8	(1)(9)(10)(11)	75	30	1.00
	304	2	S30400	18Cr-8Ni	8	(1)(9)(10)(11)	75	30	0.90
A 358	304L	1 & 3	S30403	18Cr-8Ni	8	(1)	70	25	1.00
	304L	2	S30403	18Cr-8Ni	8	(1)	70	25	0.90
	304L	1 & 3	S30403	18Cr-8Ni	8	(1)(9)	70	25	1.00
	304L	2	S30403	18Cr-8Ni	8	(1)(9)	70	25	0.90
A 358	304N	1 & 3	S30451	18Cr-8Ni-N	8	(1)(10)	80	35	1.00
	304N	2	S30451	18Cr-8Ni-N	8	(1)(10)	80	35	0.90
	304N	1 & 3	S30451	18Cr-8Ni-N	8	(1)(9)(10)	80	35	1.00
	304N	2	S30451	18Cr-8Ni-N	8	(1)(9)(10)	80	35	0.90

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Welded Pipe and Tube – Without Filler Metal (Cont'd)	
																		Austenitic (Cont'd)	
15.9	13.3	11.9	11.0	10.3	9.7	9.5	9.4	9.2	8.9	8.8	8.6	8.4	8.3	...	...	...	...	TPXM15	A 312
15.9	15.1	14.1	13.7	13.5	13.5	13.5	13.5	13.2	12.8	12.7	12.4	12.2	11.6	...	...	...	...	TPXM15	
20.0	20.0	18.2	16.9	15.7	15.2	15.0	14.9	14.7	...	...	...	...	...	...	...	...	...	...	
20.0	20.0	19.0	18.1	17.4	17.1	16.9	16.9	16.8	...	...	...	...	...	...	...	...	...	...	
																		Ferritic/Martensitic	
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP405	A 268
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP410	
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP429	
12.8	12.2	11.8	11.3	10.9	10.6	10.4	10.3	...	...	...	...	...	...	...	...	...	...	TP430	
14.9	14.2	13.7	13.3	12.8	12.3	12.2	12.0	...	...	...	...	...	...	...	...	...	...	TP446-1	
13.8	13.8	13.5	13.5	13.5	13.5	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM27	
14.5	14.5	14.3	14.1	13.9	13.7	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
13.8	13.8	13.5	13.5	13.5	13.5	13.5	...	...	...	...	...	...	...	...	...	...	...	TPXM27	A 731
13.9	13.9	13.7	13.5	13.3	13.1	12.9	...	...	...	...	...	...	...	...	...	...	...	TPXM33	
																		Welded Pipe – Filler Metal Added	
																		Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	304	A358
16.9	14.1	12.7	11.7	11.0	10.3	10.2	10.0	9.7	9.5	9.4	9.2	9.0	8.8	8.6	8.0	6.9	5.5	304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	304	
16.9	16.0	14.9	14.6	14.3	14.3	14.3	14.3	14.0	13.7	13.4	13.2	13.0	12.4	11.0	8.8	6.9	5.5	304	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	304L	A 358
14.1	12.1	10.8	9.9	9.3	8.7	8.6	8.5	8.3	8.2	...	...	...	...	...	...	...	...	304L	
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
14.1	14.1	13.8	13.2	13.0	12.6	12.3	12.2	12.0	11.7	...	...	...	...	...	...	...	...	304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.1	10.8	10.5	10.3	9.7	7.7	6.0	304N	A 358
18.0	16.1	14.1	12.7	11.7	11.2	11.0	10.7	10.5	10.4	10.2	10.0	9.7	9.5	9.3	8.7	6.9	5.4	304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	304N	
18.0	18.0	17.1	16.5	16.0	15.7	15.6	15.4	15.2	14.9	14.7	14.3	14.0	13.5	11.2	8.7	6.9	5.4	304N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified *Minimum* Tensile, ksi	Specified *Minimum* Yield, ksi	*E* or *F*
Welded Pipe — Filler Metal Added (Cont'd) Austenitic (Cont'd)									
A 358	309	1 & 3	S30900	23Cr–12Ni	8	(1)(10)	75	30	1.00
	309	2	S30900	23Cr–12Ni	8	(1)(10)	75	30	0.90
	309	1 & 3	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	1.00
	309	2	S30900	23Cr–12Ni	8	(1)(9)(10)	75	30	0.90
A 358	310	1 & 3	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	0.90
	310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	0.90
A 358	310	1 & 3	S31000	25Cr–20Ni	8	(2)(10)(15)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	0.90
	310	1 & 3	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
	310	2	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	0.90
A358	316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	1.00
	316	2	S31600	16Cr–12Ni–2Mo	8	(1)(10)(11)	75	30	0.90
	316	1 & 3	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	1.00
	316	2	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(11)	75	30	0.90
A 358	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)	70	25	0.90
	316L	1 & 3	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	1.00
	316L	2	S31603	16Cr–12Ni–2Mo	8	(1)(9)	70	25	0.90
A 358	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(10)	80	35	0.90
	316N	1 & 3	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	1.00
	316N	2	S31651	16Cr–12Ni–2Mo–N	8	(1)(9)(10)	80	35	0.90
A 358	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(10)(11)	75	30	0.90
	321	1 & 3	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	1.00
	321	2	S32100	18Cr–10Ni–Ti	8	(1)(9)(10)(11)	75	30	0.90
A 358	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	347	1 & 3	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	347	2	S34700	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Welded Pipe – Filler Metal Added (Cont'd) Austenitic (Cont'd)																			
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	309	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.1	9.2	7.7	5.9	4.5	3.4	309	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	309	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.5	7.7	5.9	4.5	3.4	309	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	310	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.3	9.7	8.8	7.7	6.6	5.4	310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	310	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.9	8.8	7.7	6.6	5.4	310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	310	A 358
16.9	15.2	14.3	13.4	12.7	12.1	11.8	11.4	11.3	11.0	10.7	10.5	10.0	8.9	6.4	4.5	3.2	2.3	310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	310	
16.9	15.5	14.8	14.3	14.0	13.8	13.7	13.6	13.5	13.4	13.1	12.5	11.3	9.9	6.4	4.5	3.2	2.3	310	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	316	A 358
16.9	14.6	13.1	12.1	11.3	10.6	10.4	10.2	10.1	9.9	9.8	9.7	9.6	9.5	9.5	9.3	8.4	6.7	316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	316	
16.9	16.9	16.6	16.3	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.1	11.2	8.8	6.7	316	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	316L	A 358
14.1	12.0	10.7	9.7	9.0	8.5	8.3	8.1	7.9	7.7	7.6	...	...	...	...	...	...	...	316L	
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	316L	
14.1	14.1	14.1	14.0	13.0	12.2	11.9	11.6	11.3	11.2	10.9	...	...	...	...	...	...	...	316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	316N	A 358
18.0	17.5	16.0	14.9	13.9	13.1	12.8	12.5	12.2	12.0	11.8	11.5	11.3	11.2	11.0	10.5	8.8	6.7	316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	316N	
18.0	18.0	17.3	16.9	16.7	16.7	16.7	16.7	16.7	16.6	16.5	16.3	16.0	15.7	14.2	11.2	8.8	6.7	316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	321	A 358
16.9	14.3	12.8	11.6	10.8	10.3	10.1	9.9	9.8	9.7	9.6	9.5	9.5	9.4	8.3	6.2	4.5	3.2	321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	321	
16.9	16.6	15.6	15.4	15.4	14.8	14.5	14.2	14.1	14.0	13.9	13.8	13.7	12.4	8.6	6.2	4.5	3.2	321	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	347	A 358
16.9	15.6	14.5	13.5	12.7	12.1	11.9	11.6	11.5	11.4	11.4	11.3	11.3	11.3	10.7	8.2	5.5	4.0	347	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	347	
16.9	16.1	14.8	14.0	13.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	12.6	10.9	8.2	5.5	4.0	347	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Welded Pipe — Filler Metal Added (Cont'd)									
Austenitic (Cont'd)									
A 358	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	0.90
	348	1 & 3	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
	348	2	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	0.90
A 358	...	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	2	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	0.90
	...	1 & 3	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
	...	2	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	0.90
A 409	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(29)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(30)	75	30	0.90
	TP304	...	S30400	18Cr–8Ni	8	(1)(10)(31)	75	30	0.80
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(29)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(30)	75	30	0.90
	TP304	...	S30400	18Cr–8Ni	8	(1)(9)(10)(31)	75	30	0.80
A 409	TP304L	...	S30403	18Cr–8Ni	8	(1)(29)	76	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(30)	76	25	0.90
	TP304L	...	S30403	18Cr–8Ni	8	(1)(31)	76	25	0.80
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)(29)	76	25	1.00
	TP304L	...	S30403	18Cr–8Ni	8	(1)(9)(30)	76	25	0.90
	TP304L	...	S30400	18Cr–8Ni	8	(1)(9)(31)	76	25	0.80
A 409	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(29)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(30)	75	30	0.90
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(10)(31)	75	30	0.80
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(29)	75	30	1.00
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(30)	75	30	0.90
	TP316	...	S31600	16Cr–12Ni–2Mo	8	(1)(9)(10)(31)	75	30	0.80
A 409	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(29)	76	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(30)	76	25	0.90
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(31)	76	25	0.80
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(29)	76	25	1.00
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(30)	76	25	0.90
	TP316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)(31)	76	25	0.80

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
Welded Pipe – Filler Metal Added (Cont'd) Austenitic (Cont'd)																			
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	348	A 358
16.9	15.6	14.5	13.5	12.7	12.1	11.9	11.6	11.5	11.4	11.4	11.3	11.3	11.3	10.7	8.2	5.5	4.0	348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	348	
16.9	16.1	14.8	14.0	13.4	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	12.6	10.9	8.2	5.5	4.0	348	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	A 358
18.0	18.0	16.4	15.2	14.1	13.7	13.5	13.4	13.2	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
18.0	18.0	17.1	16.3	15.7	15.4	15.2	15.2	15.1	...	...	...	...	...	...	...	...	...	...	
18.8	16.7	15.0	13.8	12.9	12.1	12.0	11.8	11.5	11.2	11.0	10.9	10.6	10.4	10.1	9.8	7.7	6.1	TP304	A 409
16.9	15.0	13.5	12.4	11.6	10.9	10.8	10.6	10.4	10.1	9.9	9.8	9.5	9.4	9.1	8.8	6.9	5.5	TP304	
15.0	13.4	12.0	11.0	10.3	9.7	9.6	9.4	9.2	9.0	8.8	8.7	8.5	8.3	8.1	7.8	6.2	4.9	TP304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	14.1	12.4	9.8	7.7	6.1	TP304	
16.9	16.0	14.9	14.6	14.3	14.3	14.3	14.3	14.0	13.7	13.4	13.2	13.0	12.7	11.2	8.8	6.9	5.5	TP304	
15.0	14.2	13.3	13.0	12.7	12.7	12.7	12.7	12.5	12.2	11.9	11.8	11.5	11.3	9.9	7.8	6.2	4.9	TP304	
16.7	14.3	12.8	11.7	10.9	10.3	10.1	10.0	9.8	9.7	...	...	...	...	...	...	...	...	TP304L	A 409
15.0	12.9	11.5	10.5	9.8	9.3	9.1	9.0	8.8	8.7	...	...	...	...	...	...	...	...	TP304L	
13.4	11.4	10.2	9.4	8.7	8.2	8.1	8.0	7.8	7.8	...	...	...	...	...	...	...	...	TP304L	
16.7	16.5	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
15.0	14.9	13.8	13.2	13.0	12.6	12.3	12.2	12.0	11.7	...	...	...	...	...	...	...	...	TP304L	
13.4	13.2	12.2	11.8	11.5	11.2	11.0	10.8	10.6	10.4	...	...	...	...	...	...	...	...	TP304L	
18.8	17.7	15.6	14.3	13.3	12.6	12.3	12.1	11.9	11.7	11.6	11.5	11.4	11.3	11.2	11.0	9.8	7.4	TP316	A 409
16.9	15.9	14.0	12.9	12.0	11.3	11.1	10.9	10.7	10.5	10.4	10.4	10.3	10.2	10.1	9.9	8.8	6.7	TP316	
15.0	14.2	12.5	11.4	10.6	10.1	9.8	9.7	9.5	9.4	9.3	9.2	9.1	9.0	9.0	8.8	7.8	5.9	TP316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	15.1	12.4	9.8	7.4	TP316	
16.9	16.9	16.6	16.3	16.2	15.3	15.0	14.7	14.5	14.3	14.1	14.0	13.9	13.8	13.6	11.2	8.8	6.7	TP316	
15.0	15.0	14.7	14.5	14.4	13.6	13.4	13.0	12.9	12.7	12.6	12.5	12.3	12.2	12.1	9.9	7.8	5.9	TP316	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	...	...	...	...	...	...	...	TP316L	A 409
15.0	12.7	11.4	10.5	9.8	9.4	9.2	9.0	8.8	8.6	8.5	...	...	...	...	...	...	...	TP316L	
13.4	11.3	10.2	9.4	8.7	8.3	8.2	8.0	7.8	7.7	7.5	...	...	...	...	...	...	...	TP316L	
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	...	...	...	...	...	...	...	TP316L	
15.0	15.0	14.4	14.0	13.3	12.6	12.4	12.2	11.9	11.7	11.4	...	...	...	...	...	...	...	TP316L	
13.4	13.4	12.8	12.5	11.8	11.2	11.0	10.8	10.6	10.4	10.2	...	...	...	...	...	...	...	TP316L	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Plate, Sheet, and Strip Austenitic									
A 240	304	...	S30400	18Cr-8Ni	8	(10)(11)	75	30	1.00
	304	...	S30400	18Cr-8Ni	8	(9)(10)(11)	75	30	1.00
	304L	...	S30403	18Cr-8Ni	8	(1)	70	25	1.00
	304L	...	S30403	18Cr-8Ni	8	(1)(9)	70	25	1.00
	304N	...	S30451	18Cr-8Ni-N	8	(1)(10)	80	35	1.00
	304N	...	S30451	18Cr-8Ni-N	8	(1)(9)(10)	80	35	1.00
A 240	309H	...	S30909	23Cr-12Ni	8	(9)(11)(27)	75	30	1.00
	309H	...	S30909	23Cr-12Ni	8	(11)(27)	75	30	1.00
	309S	...	S30908	23Cr-12Ni	8	(1)(10)	75	30	1.00
	309S	...	S30908	23Cr-12Ni	8	(1)(9)(10)	75	30	1.00
A 240	310H	...	S31009	25Cr-20Ni	8	(9)	75	30	1.00
	310H	...	S31009	25Cr-20Ni	8	...	75	30	1.00
	310S	...	S31008	25Cr-20Ni	8	(10)(11)(14)	75	30	1.00
	310S	...	S31008	25Cr-20Ni	8	(9)(10)(11)(14)	75	30	1.00
	310S	...	S31008	25Cr-20Ni	8	(10)(11)(15)	75	30	1.00
	310S	...	S31008	25Cr-20Ni	8	(9)(10)(11)(15)	75	30	1.00
A 240	316	...	S31600	16Cr-12Ni-2Mo	8	(10)(11)	75	30	1.00
	316	...	S31600	16Cr-12Ni-2Mo	8	(9)(10)(11)	75	30	1.00
	316L	...	S31603	16Cr-12Ni-2Mo	8	(1)	70	25	1.00
	316L	...	S31603	16Cr-12Ni-2Mo	8	(1)(9)	70	25	1.00
	316N	...	S31651	16Cr-12Ni-2Mo-N	8	(10)	80	35	1.00
	316N	...	S31651	16Cr-12Ni-2Mo-N	8	(9)(10)	80	35	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
–20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Plate, Sheet, and Strip Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	304	A 240
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	304	
15.6	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	304L	
15.7	15.7	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.0	10.8	10.5	10.3	9.7	7.7	6.0	304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	304N	
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	309H	A 240
18.8	17.6	16.1	15.1	14.1	13.9	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	309H	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	309S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	309S	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	310H	A 240
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	310H	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	310S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	310S	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	310S	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	310S	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	316	A 240
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	316	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	9.2	8.9	8.8	8.0	7.9	6.5	6.4	316L	
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	12.4	12.0	11.9	10.8	10.2	8.8	6.4	316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	316N	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Plate, Sheet, and Strip (Cont'd)									
Austenitic (Cont'd)									
A 240	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(10)(11)	75	30	1.00
	317	...	S31700	18Cr–13Ni–3Mo	8	(1)(9)(10)(11)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)	75	30	1.00
	317L	...	S31703	18Cr–13Ni–3Mo	8	(1)(9)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(10)(11)	75	30	1.00
	321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)(11)	75	30	1.00
A 240	347	...	S34700	18Cr–10Ni–Cb	8	(10)(11)	75	30	1.00
	347	...	S34700	18Cr–10Ni–Cb	8	(9)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(10)(11)	75	30	1.00
	348	...	S34800	18Cr–10Ni–Cb	8	(1)(9)(10)(11)	75	30	1.00
A 240	XM15	...	S38100	18Cr–8Ni–2Si	8	(1)	75	30	1.00
	XM15	...	S38100	18Cr–8Ni–2Si	8	(1)(9)	75	30	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	...	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00
Ferritic/Martensitic									
A 240	405	...	S40500	12Cr–1Al	7	(3)	60	25	1.00
	410	...	S41000	13Cr	6	(1)	65	30	1.00
	410S	...	S41008	13Cr	7	(1)	60	30	1.00
	429	...	S42900	15Cr	6	(1)(3)	65	30	1.00
A 240	430	...	S43000	17Cr	7	(1)(3)	65	30	1.00
	XM27	...	S44627	26Cr–1Mo	10I	(1)(3)(32)	65	40	1.00
	XM33	...	S44626	27Cr–1Mo–Ti	10I	(2)(32)	68	45	1.00
Forgings									
Austenitic									
A 182	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)(32)	94	44	1.00
	F44	...	S31254	20Cr–18Ni–6Mo	8	(1)(9)(32)	94	44	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Plate, Sheet, and Strip (Cont'd) Austenitic (Cont'd)	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	317	A 240
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	317	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	...	...	...	...	...	...	...	317L	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	...	...	...	...	...	...	...	317L	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	321	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	347	A 240
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	348	
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	...	...	...	...	XM15	A 240
18.8	17.7	16.6	16.1	15.9	15.9	15.9	15.9	15.5	15.1	14.9	14.6	14.3	13.7	...	...	...	...	XM15	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	...	
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	...	
																		Ferritic/Martensitic	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	...	...	...	...	...	...	...	...	...	...	405	A 240
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	8.8	6.4	4.4	2.9	1.8	1.0	410	
15.0	14.3	13.8	13.3	12.9	12.4	12.3	12.1	11.7	11.1	10.4	9.7	8.4	6.4	4.4	2.9	1.8	1.0	410S	
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	9.2	6.5	4.5	3.2	2.4	1.8	429	
16.3	15.5	15.0	14.4	13.9	13.5	13.3	13.1	12.7	12.0	11.3	10.5	9.2	6.5	4.5	3.2	2.4	1.8	430	A 240
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	XM27	
17.0	17.0	16.8	16.6	16.4	16.1	15.9	...	...	...	...	...	...	...	...	...	...	...	XM33	
																		Forgings Austenitic	
23.5	23.5	21.4	19.9	18.5	17.9	17.7	17.5	17.3	...	...	...	...	...	...	...	...	...	F44	A 182
23.5	23.5	22.4	21.3	20.5	20.1	19.9	19.9	19.8	...	...	...	...	...	...	...	...	...	F44	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd) Austenitic (Cont'd)									
A 182	F304	...	S30400	18Cr–8Ni	8	(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)(12)	70	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	F304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
A 182	F304H	...	S30409	18Cr–8Ni	8	(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)(12)	70	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	F304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00
A 182	F304L	...	S30403	18Cr–8Ni	8	(1)	65	25	1.00
	F304L	...	S30403	18Cr–8Ni	8	(1)(9)	65	25	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(10)	80	35	1.00
	F304N	...	S30451	18Cr–8Ni–N	8	(9)(10)	80	35	1.00
A 182	F310	...	S31000	25Cr–20Ni	8	(1)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(14)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(10)(15)	75	30	1.00
	F310	...	S31000	25Cr–20Ni	8	(1)(9)(10)(15)	75	30	1.00
A 182	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)(12)	70	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(10)	75	30	1.00
	F316	...	S31600	16Cr–12Ni–2Mo	8	(9)(10)	75	30	1.00
A 182	F316H	...	S31609	16Cr–12Ni–2Mo	8	(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)(12)	70	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	...	75	30	1.00
	F316H	...	S31609	16Cr–12Ni–2Mo	8	(9)	75	30	1.00
A 182	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)	65	25	1.00
	F316L	...	S31603	16Cr–12Ni–2Mo	8	(1)(9)	65	25	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(10)	80	35	1.00
	F316N	...	S31651	16Cr–12Ni–2Mo–N	8	(9)(10)	80	35	1.00
A 182	F321	...	S32100	18Cr–10Ni–Ti	8	(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(12)	70	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(10)	75	30	1.00
	F321	...	S32100	18Cr–10Ni–Ti	8	(9)(10)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Forgings (Cont'd) Austenitic (Cont'd)	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304	A 182
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	F304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	F304	
17.5	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304H	A 182
17.5	16.6	15.5	15.1	14.8	14.8	14.8	14.8	14.7	14.6	14.4	14.2	13.9	13.4	12.0	9.7	7.7	6.1	F304H	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	F304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	F304H	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	F304L	A 182
15.5	15.4	14.2	13.6	13.4	13.3	13.2	13.1	13.0	12.9	...	...	...	...	...	...	...	...	F304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	F304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	F304N	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	F310	A 182
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	F310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	F310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	F310	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316	A 182
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	F316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	F316	
17.5	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316H	A 182
17.5	17.5	17.1	16.8	16.8	16.8	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.0	14.1	12.4	9.8	7.4	F316H	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	F316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	F316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	F316L	A 182
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	F316L	
17.0	16.5	15.1	14.0	13.1	12.4	12.1	11.8	11.6	11.3	11.1	10.9	10.7	10.5	10.4	9.9	8.3	6.3	F316N	
17.0	17.0	16.3	16.0	15.8	15.8	15.8	15.8	15.7	15.6	15.6	15.4	15.1	14.8	12.4	10.5	8.3	6.3	F316N	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	F321	A 182
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	F321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	F321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	F321	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Forgings (Cont'd)									
Austenitic (Cont'd)									
A 182	F321H	...	S32109	18Cr-10Ni-Ti	8	(12)	70	30	1.00
	F321H	...	S32109	18Cr-10Ni-Ti	8	(9)(12)	70	30	1.00
	F321H	...	S32109	18Cr-10Ni-Ti	8	...	75	30	1.00
	F321H	...	S32109	18Cr-10Ni-Ti	8	(9)	75	30	1.00
A 182	F347	...	S34700	18Cr-10Ni-Cb	8	(12)	70	30	1.00
	F347	...	S34700	18Cr-10Ni-Cb	8	(9)(12)	70	30	1.00
	F347	...	S34700	18Cr-10Ni-Cb	8	(10)	75	30	1.00
	F347	...	S34700	18Cr-10Ni-Cb	8	(9)(10)	75	30	1.00
A 182	F347H	...	S34709	18Cr-10Ni-Cb	8	(12)	70	30	1.00
	F347H	...	S34709	18Cr-10Ni-Cb	8	(9)(12)	70	30	1.00
	F347H	...	S34709	18Cr-10Ni-Cb	8	...	75	30	1.00
	F347H	...	S34709	18Cr-10Ni-Cb	8	(9)	75	30	1.00
A 182	F348	...	S34800	18Cr-10Ni-Cb	8	(12)	70	30	1.00
	F348	...	S34800	18Cr-10Ni-Cb	8	(9)(12)	70	30	1.00
	F348	...	S34800	18Cr-10Ni-Cb	8	(10)	75	30	1.00
	F348	...	S34800	18Cr-10Ni-Cb	8	(9)(10)	75	30	1.00
A 182	F348H	...	S34809	18Cr-10Ni-Cb	8	(12)	70	30	1.00
	F348H	...	S34809	18Cr-10Ni-Cb	8	(9)(12)	70	30	1.00
	F348H	...	S34809	18Cr-10Ni-Cb	8	...	75	30	1.00
	F348H	...	S34809	18Cr-10Ni-Cb	8	(9)	75	30	1.00
Ferritic/Martensitic									
A 182	FXM-27b	...	S44627	27Cr-1Mo	10I	(2)	60	35	1.00
A 336	FXM-27Cb	...	S44627	27Cr-1Mo	10I	(2)	60	35	1.00
Fittings (Seamless and Welded)									
Austenitic									
A 403	WP304	...	S30400	18Cr-8Ni	8	(1)(4)(7)(10)(11)	75	30	1.00
	WP304	...	S30400	18Cr-8Ni	8	(1)(4)(7)(9)(10)(11)	75	30	1.00
	WP304H	...	S30409	18Cr-8Ni	8	(1)(4)(7)(11)	75	30	1.00
	WP304H	...	S30409	18Cr-8Ni	8	(1)(4)(7)(9)(11)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																			
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200	Type or Grade	Spec. No.
																		Forgings (Cont'd)	
																		Austenitic (Cont'd)	
17.5	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	F321H	A 182
17.5	17.2	16.2	16.0	16.0	16.0	16.0	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	F321H	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	F321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	F321H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F347	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	F347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F347	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	F347	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F347H	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	F347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	F347H	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F348	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.2	12.0	9.1	6.1	4.4	F348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	F348	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	F348	
17.5	16.7	15.3	14.4	13.9	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F348H	A 182
17.5	16.7	15.3	14.4	13.9	13.7	13.7	13.7	13.7	13.7	13.7	13.7	13.6	13.5	13.2	12.5	10.5	7.9	F348H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	F348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	F348H	
																		Ferritic/Martensitic	
15.0	15.0	14.6	14.2	14.2	14.2	14.2	...	...	...	...	...	...	...	...	...	...	...	FXM-27b	A 182
15.0	15.0	14.6	14.2	14.2	14.2	14.2	...	...	...	...	...	...	...	...	...	...	...	FXM 27Cb	A 336
																		Fittings (Seamless and Welded)	
																		Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	WP304	A 403
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.5	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	WP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	WP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.5	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	WP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Fittings (Seamless and Welded) (Cont'd)									
Austenitic (Cont'd)									
A 403	WP304L	...	S30403	18Cr-8Ni	8	(1)(7)(11)	70	25	1.00
	WP304L	...	S30403	18Cr-8Ni	8	(1)(7)(9)(11)	70	25	1.00
	WP304N	...	S30451	18Cr-8Ni-N	8	(1)(4)(7)(10)	80	35	1.00
	WP304N	...	S30451	18Cr-8Ni-N	8	(1)(4)(7)(9)(10)	80	35	1.00
A 403	WP309	...	S30900	23Cr-12Ni	8	(1)(7)(10)(11)	75	30	1.00
	WP309	...	S30900	23Cr-12Ni	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(9)(10)(11)(14)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(10)(11)(15)	75	30	1.00
	WP310	...	S31000	23Cr-20Ni	8	(1)(7)(9)(10)(11)(15)	75	30	1.00
A 403	WP316	...	S31600	16Cr-12Ni-2Mo	8	(4)(7)(10)(11)	75	30	1.00
	WP316	...	S31600	16Cr-12Ni-2Mo	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP316H	...	S31609	16Cr-12Ni-2Mo	8	(4)(7)(11)	75	30	1.00
	WP316H	...	S31609	16Cr-12Ni-2Mo	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP316L	...	S31603	16Cr-12Ni-2Mo	8	(1)(7)(11)	65	25	1.00
	WP316L	...	S31603	16Cr-12Ni-2Mo	8	(1)(7)(9)(11)	65	25	1.00
	WP316N	...	S31651	16Cr-12Ni-2Mo-N	8	(1)(7)(10)	80	35	1.00
	WP316N	...	S31651	16Cr-12Ni-2Mo-N	8	(1)(7)(9)(10)	80	35	1.00
A 403	WP317	...	S31700	18Cr-13Ni-3Mo	8	(1)(7)(10)(11)	75	30	1.00
	WP317	...	S31700	18Cr-13Ni-3Mo	8	(1)(7)(9)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr-10Ni-Ti	8	(4)(7)(10)(11)	75	30	1.00
	WP321	...	S32100	18Cr-10Ni-Ti	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP321H	...	S32109	18Cr-10Ni-Ti	8	(4)(7)(11)	75	30	1.00
	WP321H	...	S32109	18Cr-10Ni-Ti	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP347	...	S34700	18Cr-10Ni-Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP347	...	S34700	18Cr-10Ni-Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP347H	...	S34709	18Cr-10Ni-Cb	8	(4)(7)(11)	75	30	1.00
	WP347H	...	S34709	18Cr-10Ni-Cb	8	(4)(7)(9)(11)	75	30	1.00
A 403	WP348	...	S34800	18Cr-10Ni-Cb	8	(4)(7)(10)(11)	75	30	1.00
	WP348	...	S34800	18Cr-10Ni-Cb	8	(4)(7)(9)(10)(11)	75	30	1.00
	WP348H	...	S34809	18Cr-10Ni-Cb	8	(4)(7)(11)	75	30	1.00
	WP348H	...	S34809	18Cr-10Ni-Cb	8	(4)(7)(9)(11)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Fittings (Seamless and Welded) (Cont'd) Austenitic (Cont'd)	
15.7	13.4	12.0	11.0	10.3	9.7	9.5	9.4	9.2	9.1	...	...	...	...	...	...	...	...	WP304L	A 403
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	...	...	...	...	...	...	...	...	WP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.7	11.5	11.3	11.1	10.8	10.5	10.3	9.7	7.7	6.0	WP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.1	16.9	16.6	16.3	15.9	15.6	15.0	12.4	9.7	7.7	6.0	WP304N	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.2	10.2	8.5	6.5	5.0	3.8	WP309	A 403
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	10.5	8.5	6.5	5.0	3.8	WP309	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.4	10.8	9.8	8.5	7.3	6.0	WP310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	9.8	8.5	7.3	6.0	WP310	
18.8	16.9	15.9	14.9	14.1	13.4	13.1	12.7	12.5	12.2	11.9	11.7	11.1	9.9	7.1	5.0	3.6	2.5	WP310	
18.8	17.2	16.4	15.9	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.9	12.5	11.0	7.1	5.0	3.6	2.5	WP310	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP316	A 403
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP316H	
15.7	13.3	11.9	10.8	10.0	9.4	9.2	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	WP316L	A 403
15.7	15.7	15.7	15.5	14.4	13.5	13.2	12.9	12.6	12.4	12.1	...	...	...	...	...	...	...	WP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	WP316N	
20.0	10.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	WP316N	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	WP317	A 403
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.5	15.4	15.3	14.5	12.4	9.8	7.4	WP317	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	WP321	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	WP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	WP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	WP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	WP347	A 403
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	WP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	WP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	WP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	WP348	A 403
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	WP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.8	12.7	12.6	12.6	12.5	12.5	12.1	10.5	7.9	WP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	WP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Castings									
Austenitic									
A 351	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(26)	70	30	0.80
	CF3	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	70	30	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(26)	77.5	35	0.80
	CF3A	...	J92500	18Cr–8Ni	8	(1)(5)(9)(26)	77.5	35	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(13)(26)	70	30	0.80
	CF3M	...	J92800	18Cr–12Ni–2Mo	8	(1)(5)(9)(13)(26)	70	30	0.80
A 351	CF8	...	J92600	18Cr–8Ni	8	(5)(10)(26)	70	30	0.80
	CF8	...	J92600	18Cr–8Ni	8	(5)(9)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(10)(26)	70	30	0.80
	CF8C	...	J92710	18Cr–10Ni–Cb	8	(1)(5)(9)(10)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(13)(26)	70	30	0.80
	CF8M	...	J92900	16Cr–12Ni–2Mo	8	(5)(9)(13)(26)	70	30	0.80
A 351	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(10)(26)	65	28	0.80
	CH8	...	J93400	25Cr–12Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(10)(26)	70	30	0.80
	CH20	...	J93402	25Cr–12Ni	8	(1)(5)(9)(10)(26)	70	30	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(10)(26)	65	28	0.80
	CK20	...	J94202	25Cr–20Ni	8	(1)(5)(9)(10)(26)	65	28	0.80
Ferritic/Martensitic									
A 217	CA15	...	J91150	13Cr–½Mo	6	(1)(3)(5)	90	65	0.80
Bolts, Nuts, and Studs									
Austenitic									
A 193	B8	1	S30400	18Cr–8Ni	...	(10)(11)(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(10)(11)(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(10)(11)(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(10)(11)(16)	75	30	...
A 193	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																			Castings Austenitic
14.0	12.5	11.2	10.3	9.7	9.1	9.0	8.8	8.6	8.4	...	...	...	...	...	...	...	...	CF3	A 351
14.0	13.3	12.2	12.1	11.8	11.8	11.8	11.8	11.8	11.7	...	...	...	...	...	...	...	...	CF3	
15.5	14.6	13.1	12.1	11.4	10.7	9.9	9.8	...	...	...	...	...	...	...	...	...	...	CF3A	
15.5	14.6	13.5	13.2	13.0	13.0	13.0	11.7	...	...	...	...	...	...	...	...	...	...	CF3A	
14.0	12.9	11.7	10.6	9.9	9.4	9.2	9.0	8.9	8.8	8.7	...	...	...	...	...	...	...	CF3M	
14.0	14.0	13.7	13.4	13.4	13.4	13.3	13.0	12.8	12.6	12.6	...	...	...	...	...	...	...	CF3M	
14.0	12.5	11.2	10.3	9.7	9.1	8.8	8.8	8.6	8.5	8.2	8.1	7.9	7.6	7.2	6.0	4.6	3.6	CF8	A 351
14.0	13.2	12.1	12.0	11.8	11.8	11.8	11.8	11.8	11.7	11.5	11.3	10.7	9.6	7.7	6.0	4.6	3.6	CF8	
14.0	13.3	12.2	11.5	11.1	10.7	10.5	10.3	10.2	10.2	10.1	10.1	10.0	9.5	9.0	8.4	6.4	4.0	CF8C	
14.0	13.3	12.2	11.5	11.1	11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.8	10.6	9.6	8.4	6.4	4.0	CF8C	
14.0	12.9	11.7	10.6	9.9	9.4	9.2	9.0	8.9	8.8	8.7	8.6	8.6	8.5	8.1	7.5	6.4	4.8	CF8M	
14.0	14.0	13.7	13.4	13.4	13.4	13.3	13.0	12.8	12.6	12.6	12.4	12.3	11.9	9.6	7.5	6.4	4.8	CF8M	
13.0	11.9	11.4	11.0	10.6	10.0	9.8	9.5	9.4	9.1	8.9	8.7	8.6	7.9	6.8	5.2	4.0	3.0	CH8	A 351
13.0	11.9	11.4	11.0	10.8	10.6	10.6	10.5	10.4	10.4	10.2	10.0	9.4	8.4	6.8	5.2	4.0	3.0	CH8	
14.0	12.9	12.2	11.8	11.3	10.7	10.5	10.2	10.0	9.8	9.5	9.4	9.0	8.2	6.8	5.2	4.0	3.0	CH20	
14.0	12.9	12.2	11.8	11.6	11.4	11.4	11.3	11.2	11.1	11.0	10.6	10.0	8.4	6.8	5.2	4.0	3.0	CH20	
13.0	11.9	11.4	11.0	10.6	10.0	9.8	9.5	9.4	9.1	8.9	8.7	8.5	8.2	7.8	6.8	5.8	4.8	CK20	
13.0	11.9	11.4	11.0	10.8	10.6	10.6	10.5	10.4	10.4	10.2	10.0	9.5	8.8	7.8	6.8	5.8	4.8	CK20	
																			Ferritic/Martensitic
18.0	17.2	16.6	16.0	15.4	15.0	14.7	14.5	14.0	13.4	11.9	8.8	6.1	4.0	2.6	1.8	1.2	0.8	CA15	A 217
																			Bolts, Nuts, and Studs Austenitic
18.8	15.6	14.0	12.9	12.1	11.4	11.2	11.0	10.8	10.5	10.3	10.1	9.9	9.7	9.5	8.8	7.7	6.0	B8	A 193
18.8	17.2	16.0	15.0	14.0	13.4	13.1	12.9	12.8	12.7	12.6	12.6	12.5	12.5	11.9	9.1	6.1	4.4	B8C	
18.8	16.1	14.6	13.3	12.5	11.8	11.5	11.3	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	B8M	
18.8	15.9	14.1	12.9	12.0	11.3	11.1	10.9	10.8	10.7	10.6	10.6	10.5	10.4	9.2	6.9	5.0	3.6	B8T	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)									
A 193	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
A 193	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	75	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	65	...
A 193	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
A 194	8	...	S30400	18Cr–8Ni	...	(17)	...	...	...
	8C	...	S34700	18Cr–10Ni–Cb	...	(17)	...	...	...
A 194	8M	...	S31600	16Cr–12Ni–Mo	...	(17)	...	...	...
	8T	...	S32100	18Cr–10Ni–Ti	...	(17)	...	...	...
	8F	...	...	18Cr–8Ni–Fm	...	(17)	...	...	...
A 320	B8	1	S30400	18Cr–8Ni	...	(16)(18)	75	30	...
	B8	1	S30400	18Cr–8Ni	...	(16)(28)	75	30	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(23)	100	50	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(22)	105	65	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(21)	115	80	...
	B8	2	S30400	18Cr–8Ni	...	(16)(18)(20)	125	100	...
A 320	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)	75	30	...
	B8C	1	S34700	18Cr–10Ni–Cb	...	(16)(28)	75	30	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(23)	100	50	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(22)	105	65	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(21)	115	80	...
	B8C	2	S34700	18Cr–10Ni–Cb	...	(16)(18)(20)	125	100	...

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
−20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	...	...	...	...	...	...	...	...	...	B8M	A 193
20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	...	...	...	...	...	...	...	...	...	B8M	
18.8	16.2	16.2	16.2	16.2	16.2	16.2	16.2	16.2	...	...	...	...	...	...	...	...	...	B8M	
18.8	16.1	14.6	13.3	12.5	12.5	12.5	12.5	12.5	...	...	...	...	...	...	...	...	...	B8M	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 193
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
16.2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
12.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8C	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8M	A 194
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8F	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	A 320
18.8	16.7	15.0	13.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	A 320
18.8	17.9	16.4	15.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8C	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bolts, Nuts, and Studs (Cont'd)									
Austenitic (Cont'd)									
A 320	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)	75	30	...
	B8M	1	S31600	16Cr–12Ni–2Mo	...	(16)(28)	75	30	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(23)	90	50	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(22)	95	65	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(21)	100	80	...
	B8M	2	S31600	16Cr–12Ni–2Mo	...	(16)(18)(20)	110	95	...
A 320	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)	75	30	...
	B8T	1	S32100	18Cr–10Ni–Ti	...	(16)(28)	75	30	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(23)	100	50	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(22)	105	65	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(21)	115	80	...
	B8T	2	S32100	18Cr–10Ni–Ti	...	(16)(18)(20)	125	100	...
A 453	660	A & B	S66286	15Cr–25Ni–Mo–Ti–V–B	...	(16)	130	85	...
A 479	TP309H	...	S30909	23Cr–12Ni	8	(9)	75	30	...
	TP309H	...	S30909	23Cr–12Ni	8	...	75	30	...
	TP310H	...	S31009	25Cr–20Ni	8	(9)	75	30	...
	TP310H	...	S31009	25Cr–20Ni	8	...	75	30	...
A 564	630	H-1100	S17400	17Cr–4Ni–3.5Cu–0.04P	...	(16)(24)	140	115	...
Ferritic/Martensitic									
A 193	B6	(410)	S41000	13Cr	...	(16)(19)	110	85	...
A 194	6	...	S41000	13Cr	...	(17)	...	...	...
Bar									
Austenitic									
A 479	TP304	...	S30400	18Cr–8Ni	8	(10)	75	30	1.00
	TP304	...	S30400	18Cr–8Ni	8	(9)(10)	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	...	75	30	1.00
	TP304H	...	S30409	18Cr–8Ni	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bolts, Nuts, and Studs (Cont'd) Austenitic (Cont'd)	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	A 320
18.8	17.7	15.6	14.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
22.5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8M	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	A 320
18.8	17.8	16.5	15.3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
18.8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
20.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
25.0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	B8T	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	660	A 453
18.8	18.8	18.7	18.3	17.9	17.5	17.3	17.1	16.8	16.5	16.1	15.6	15.1	13.8	10.3	7.6	5.5	4.0	TP309H	A 479
18.8	17.6	16.1	15.1	14.1	13.8	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	10.3	7.6	5.5	4.0	TP309H	
18.8	18.4	17.6	17.4	17.4	17.4	17.4	17.4	17.2	17.0	16.7	16.3	15.9	13.8	10.3	7.6	5.5	4.0	TP310H	
18.8	17.6	16.1	15.1	14.3	13.7	13.5	13.3	13.1	12.9	12.7	12.5	12.3	12.1	10.3	7.6	5.5	4.0	TP310H	
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	630	A 564
																		Ferritic/Martensitic	
21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	21.2	19.5	15.6	12.0	...	...	...	...	...	...	B6	A 193
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6	A 194
																		Bar Austenitic	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304	A 479
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304	
18.8	15.7	14.1	13.0	12.2	11.4	11.3	11.1	10.8	10.6	10.4	10.2	10.0	9.8	9.5	8.9	7.7	6.1	TP304H	
18.8	17.8	16.6	16.2	15.9	15.9	15.9	15.9	15.6	15.2	14.9	14.7	14.4	13.8	12.2	9.8	7.7	6.1	TP304H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	E or F
Bar (Cont'd) Austenitic (Cont'd)									
A 479	TP304L	...	S30403	18Cr-8Ni	8	(25)	70	25	1.00
	TP304L	...	S30403	18Cr-8Ni	8	(9)(25)	70	25	1.00
	TP304N	...	S30451	18Cr-8Ni-N	8	(10)	80	35	1.00
	TP304N	...	S30451	18Cr-8Ni-N	8	(9)(10)	80	35	1.00
A 479	TP310S	...	S31008	25Cr-20Ni	8	(10)(11)(15)	75	30	1.00
	TP310S	...	S31008	25Cr-20Ni	8	(10)(11)(14)	75	30	1.00
	TP310S	...	S31008	25Cr-20Ni	8	(9)(10)(11)	75	30	1.00
A 479	TP316	...	S31600	16Cr-12Ni-2Mo	8	(10)	75	30	1.00
	TP316	...	S31600	16Cr-12Ni-2Mo	8	(9)(10)	75	30	1.00
	TP316H	...	S31609	16Cr-12Ni-2Mo	8	...	75	30	1.00
	TP316H	...	S31609	16Cr-12Ni-2Mo	8	(9)	75	30	1.00
A 479	TP316L	...	S31603	16Cr-12Ni-2Mo	8	(25)	70	25	1.00
	TP316L	...	S31603	16Cr-12Ni-2Mo	8	(9)(25)	70	25	1.00
	TP316N	...	S31651	16Cr-12Ni-2Mo	8	(10)	80	35	1.00
	TP316N	...	S31651	16Cr-12Ni-2Mo	8	(9)(10)	80	35	1.00
A 479	TP321	...	S32100	18Cr-10Ni-Ti	8	(10)	75	30	1.00
	TP321	...	S32100	18Cr-10Ni-Ti	8	(9)(10)	75	30	1.00
	TP321H	...	S32109	18Cr-10Ni-Ti	8	...	75	30	1.00
	TP321H	...	S32109	18Cr-10Ni-Ti	8	(9)	75	30	1.00
A 479	TP347	...	S34700	18Cr-10Ni-Cb	8	(10)	75	30	1.00
	TP347	...	S34700	18Cr-10Ni-Cb	8	(9)(10)	75	30	1.00
	TP347H	...	S34709	18Cr-10Ni-Cb	8	...	75	30	1.00
	TP347H	...	S34709	18Cr-10Ni-Cb	8	(9)	75	30	1.00
A 479	TP348	...	S34800	18Cr-10Ni-Cb	8	(10)	75	30	1.00
	TP348	...	S34800	18Cr-10Ni-Cb	8	(9)(10)	75	30	1.00
	TP348H	...	S34809	18Cr-10Ni-Cb	8	...	75	30	1.00
	TP348H	...	S34809	18Cr-10Ni-Cb	8	(9)	75	30	1.00

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TABLE A-3
STAINLESS STEELS (CONT'D)

Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bar (Cont'd) Austenitic (Cont'd)	
16.3	14.3	12.8	11.7	10.9	10.3	10.1	10.0	9.8	9.7	...	...	...	...	...	...	...	...	TP304L	A 479
16.7	16.5	15.3	14.7	14.4	14.0	13.7	13.5	13.3	13.0	...	...	...	...	...	...	...	...	TP304L	
20.0	17.9	15.7	14.1	13.0	12.4	12.2	11.9	11.8	11.6	11.3	11.1	10.8	10.6	10.3	9.8	7.7	6.1	TP304N	
20.0	20.0	19.0	18.3	17.8	17.4	17.3	17.2	16.9	16.7	16.3	15.9	15.6	15.0	12.4	9.8	7.7	6.1	TP304N	
18.8	16.9	15.8	14.9	14.1	13.4	13.0	12.7	12.5	12.1	11.9	11.6	11.1	9.8	...	...	...	...	TP310S	A 479
18.8	16.9	15.8	14.9	14.1	13.4	13.0	12.7	12.5	12.1	11.9	11.6	11.3	10.8	...	...	...	...	TP310S	
18.8	17.2	16.4	15.8	15.5	15.3	15.2	15.1	15.0	14.9	14.6	13.8	12.6	11.0	...	...	...	...	TP310S	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316	A 479
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316	
18.8	16.2	14.6	13.4	12.5	11.8	11.6	11.3	11.2	11.0	10.9	10.8	10.7	10.6	10.5	10.3	9.3	7.4	TP316H	
18.8	18.8	18.4	18.1	18.0	17.0	16.7	16.3	16.1	15.9	15.7	15.6	15.4	15.3	14.5	12.4	9.8	7.4	TP316H	
16.7	14.1	12.7	11.7	10.9	10.4	10.2	10.0	9.8	9.6	9.4	...	...	...	...	...	...	...	TP316L	A 479
16.7	16.7	16.0	15.6	14.8	14.0	13.8	13.5	13.2	13.0	12.7	...	...	...	...	...	...	...	TP316L	
20.0	19.4	17.8	16.5	15.4	14.6	14.2	13.9	13.6	13.3	13.1	12.8	12.6	12.4	12.2	11.7	9.8	7.4	TP316N	
20.0	20.0	19.2	18.8	18.6	18.6	18.6	18.6	18.5	18.4	18.3	18.1	17.8	17.4	15.8	12.4	9.8	7.4	TP316N	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.4	9.2	6.9	5.0	3.6	TP321	A 479
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	13.8	9.6	6.9	5.0	3.6	TP321	
18.8	15.9	14.2	12.9	12.0	11.4	11.2	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.1	8.8	6.9	5.4	TP321H	
18.8	18.4	17.3	17.1	17.1	16.4	16.1	15.8	15.7	15.5	15.4	15.3	15.2	14.0	11.7	9.1	6.9	5.4	TP321H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP347	A 479
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP347	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP347H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP347H	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.9	12.8	12.7	12.7	12.6	12.6	12.5	11.9	9.1	6.1	4.4	TP348	A 479
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.0	12.1	9.1	6.1	4.4	TP348	
18.8	17.3	16.1	15.0	14.1	13.4	13.2	12.8	12.8	12.7	12.7	12.6	12.6	12.6	12.5	12.1	10.5	7.9	TP348H	
18.8	17.9	16.4	15.5	14.9	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.6	14.4	14.1	13.0	10.5	7.9	TP348H	

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TABLE A-3
STAINLESS STEELS (CONT'D)

Spec. No.	Type or Grade	Class	UNS Alloy No.	Nominal Composition	P-No.	Notes	Specified Minimum Tensile, ksi	Specified Minimum Yield, ksi	*E* or *F*
Bar (Cont'd) Ferritic/Martensitic									
A 479	TPXM-27	...	S44627	27Cr-1Mo	10I	(2)	65	40	1.00

GENERAL NOTES:

(a) The tabulated specifications are ANSI/ASTM or ASTM. For ASME Boiler and Pressure Vessel Code applications, see related specifications in Section II of the ASME Code.
(b) The stress values in this Table may be interpolated to determine values for intermediate temperatures.
(c) The P-Numbers indicated in this Table are identical to those adopted by the ASME Boiler and Pressure Vessel Code. Qualification of welding procedures, welders, and welding operators is required and shall comply with the ASME Boiler and Pressure Vessel Code, Section IX, except as modified by para. 127.5.
(d) Tensile strengths and allowable stresses shown in "ksi" are "thousands of pounds per square inch."
(e) The materials listed in this Table shall not be used at design temperatures above those for which allowable stress values are given.
(f) The tabulated stress values are $S \times E$ (weld joint efficiency factor) or $S \times F$ (material quality factor), as applicable. Weld joint efficiency factors are shown in Table 102.4.3.
(g) Pressure-temperature ratings of piping components, as published in standards referenced in this Code, may be used for components meeting the requirements of those standards. The allowable stress values given in this Table are for use in designing piping components which are not manufactured in accordance with referenced standards.

NOTES:

(1) THIS MATERIAL IS NOT ACCEPTABLE FOR USE ON BOILER EXTERNAL PIPING — SEE FIGS. 100.1.2(A) AND (B).
(2) Use of this material at temperatures above 650°F is not approved because of the possibility of temper embrittlement.
(3) This steel may be expected to develop embrittlement at room temperature after service at temperatures above 700°F. Consequently, its use at higher temperatures is not recommended unless due caution is observed.
(4) For fittings made from A 182 forgings over 5 in. in thickness, the allowable stress values tabulated shall be reduced by the ratio of 70 divided by 75.
(5) The material quality factors and allowable stress values for these materials may be increased in accordance with para. 102.4.6.
(6) Tensile strengths in parentheses are expected minimum values.
(7) See MSS SP-43 for requirements for lightweight stainless steel fittings. MSS SP-43 Schedule 5S fittings shall not be used for design temperatures above 400°F. MSS SP-43 Schedule 10S fittings shall not be used for design temperatures above 750°F.
(8) The material quality factor for centrifugally cast pipe (0.85) is based on all surfaces being machined after heat treatment. The surface finish, after machining, shall be 250 μin. arithmetic average deviation or smoother.
(9) Due to relatively low yield strength of these materials, these higher allowable stress values were established at temperatures where the short time tensile properties govern to permit the use of these alloys where slightly greater deformation is acceptable. These stress values exceed 67% but do not exceed 90% of the yield strength at temperature. Use of these stress values may result in dimensional changes due to permanent strain. These values should not be used for the flanges of gasketed joints or other applications where slight amounts of distortion can cause leakage or malfunction.
(10) The allowable stress vlaues tabulated for temperatures over 1000°F apply only if the carbon content of the material is 0.04% or higher.
(11) The allowable stress values tabulated for temperatures over 1000°F apply only if the material is heat treated by heating to a *minimum* temperature of 1900°F and quenching in water or rapidly cooling by other means.
(12) These allowable stress values apply to forgings over 5 in. in thickness.

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TABLE A-3
STAINLESS STEELS (CONT'D)

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Maximum Allowable Stress Values in Tension, ksi, for Metal Temperature, °F, Not Exceeding																		Type or Grade	Spec. No.
-20 to 100	200	300	400	500	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200		
																		Bar (Cont'd) Ferritic/Martensitic	
16.2	16.2	15.9	15.9	15.9	15.9	15.9	...	...	...	...	...	...	...	...	...	...	...	TPXM-27	A 479

NOTES (CONT'D):

(13) The allowable stress values tabulated for temperatures over 800°F apply only if the carbon content of the material is 0.04% or higher.

(14) These allowable stress values shall be used only when the grain size of the material is ASTM No. 6 or coarser.

(15) These allowable stress values shall be used when the grain size of the material is finer than ASTM No. 6 or when the grain size has not been determined.

(16) These stress values are established from a consideration of strength only and will be satisfactory for average service. For bolted joints, where freedom from leakage over a long period of time without retightening is required, lower stress values may be necessary as determined from the relative flexibility of the flange and bolts and corresponding relaxation properties.

(17) This is a product specification. Allowable stress values are not necessary. Limitations on metal temperature for materials covered by this specification for use under B31.1 are:

Grade 6 and 8F	—20°F to 800°F
Grades 8, 8C, 8M, & 8T	—20°F to 1200°F

(18) The hardness of this material, under the thread roots, shall not exceed Rockwell C35. The hardness shall be measured on a flat area, at least $^1/_8$ in. across, prepared by removing thread. No more material than necessary shall be removed to prepare the flat area. Hardness measurements shall be made at the same frequency as tensile test.

(19) These allowable stress values apply to bolting materials 4 in. in diameter and smaller.

(20) These allowable stress values apply to bolting materials $^3/_4$ in. in diameter and smaller.

(21) These allowable stress values apply to bolting materials larger than $^3/_4$ in. but not larger than 1 in. in diameter.

(22) These allowable stress values apply to bolting materials larger than 1 in. but not larger than $1^1/_4$ in. in diameter.

(23) These allowable stress values apply to bolting materials larger than $1^1/_4$ in. but not larger than $1^1/_2$ in. in diameter.

(24) These allowable stress values apply to bolting materials 8 in. in diameter and smaller.

(25) Use of external pressure charts for material in the form of barstock is permitted for stiffening rings only.

(26) At the ferrite levels tabulated below, these materials will have significant reductions in Charpy V-notch toughness values at room temperature and below following service exposure at the indicated temperatures. This reduction indicates the potential for brittle fracture with high rate loading in the presence of sharp notches or cracks.

Ferrite Content	Service Temperature
5% and less	1100°F and above
10%	900°F and above
15%	800°F and above
20%	700°F and above
25%–30%	600°F and above
35%–40%	500°F and above

(27) This stress values at 1050°F and above shall be used only when the grain size is ASTM No. 6 or coarser.

(28) These allowable stress values apply to material that has been carbide solution treated.

(29) These allowable stress values apply for single or double butt welded pipe with radiography per para. 136.4.5.

(30) These allowable stress values apply for double butt welded pipe.

(31) These allowable stress values apply for single butt welded pipe.

(32) This material is one of the highest tensile strength materials approved for use in ASME pressure component applications and little fatigue data is available for it in the ASME database. Therefore, the designer shall consider this when calculating the allowable stress range for expansion stresses and provide appropriate design margins.

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