

ASME-B31.1

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ASME B31.1-2001

(Revision of ASME B31.1-1998)

POWER PIPING

**ASME CODE FOR PRESSURE PIPING, B31
AN AMERICAN NATIONAL STANDARD**



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POWER PIPING

ASME CODE FOR PRESSURE PIPING, B31
ASME B31.1-2001
(Revision of **ASME B31.1-1998**)



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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.

ASME CODE FOR PRESSURE PIPING, B31

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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

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, construc-

tion, 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

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.

SUMMARY OF CHANGES

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

<i>Page</i>	<i>Location</i>	<i>Change</i>
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.

<i>Page</i>	<i>Location</i>	<i>Change</i>
97	Table 136.4	(1) In column headings, <i>Piping Service Conditions etc.</i> revised to read <i>Piping Design Conditions etc.</i> (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

<i>Page</i>	<i>Location</i>	<i>Change</i>
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) renumbered 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

<i>Page</i>	<i>Location</i>	<i>Change</i>
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 <i>E</i> (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	Appendix 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.

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.

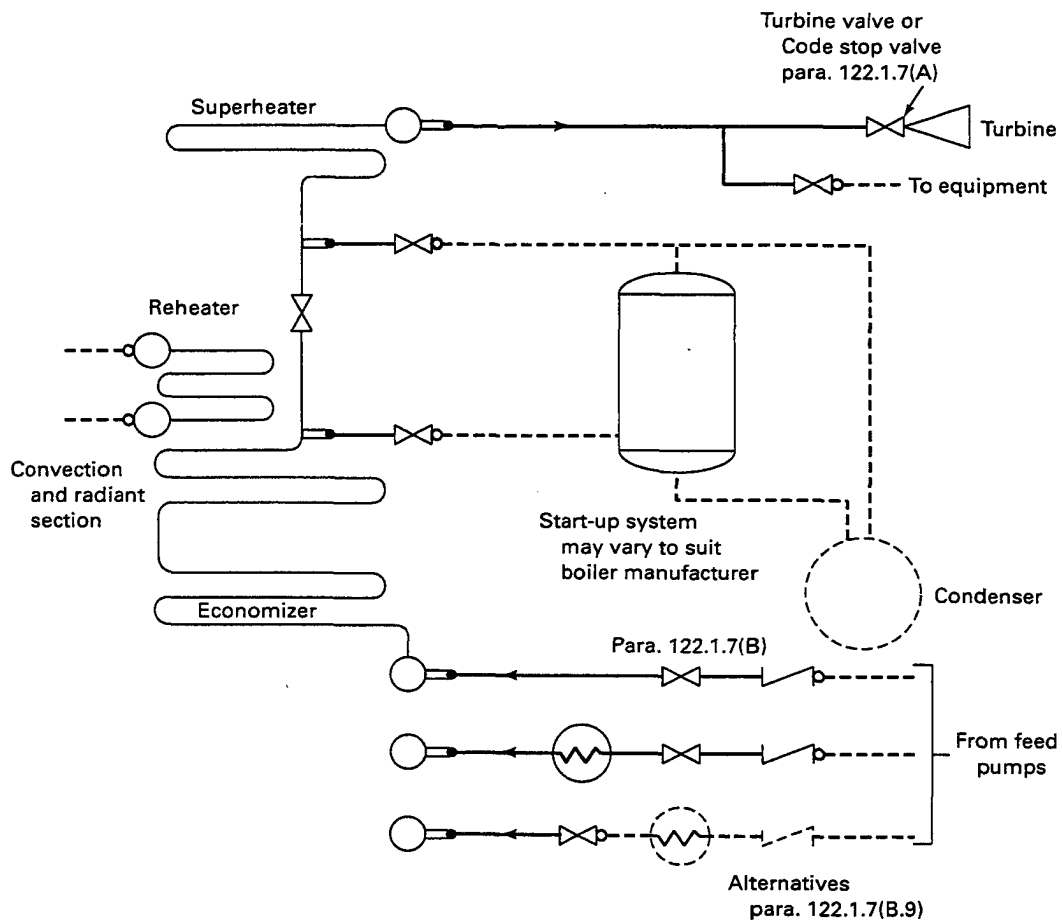
(A) This Code covers boiler external piping as defined below for power boilers and high temperature, high pressure water boilers in which: steam or vapor is generated at a pressure of more than 15 psig [100 kPa (gage)]; and high temperature water is generated at pressures exceeding 160 psig [1103 kPa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

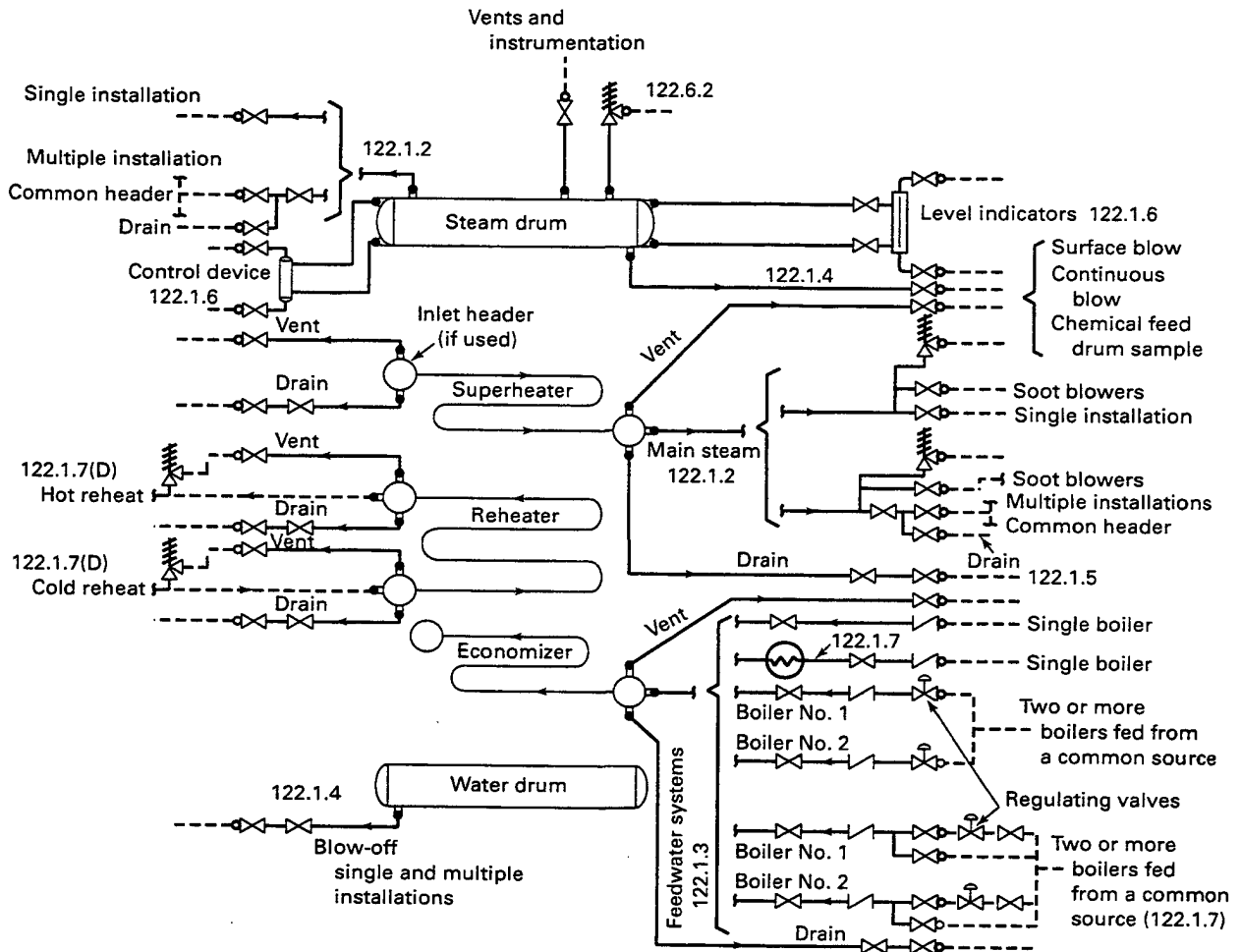
Piping between the terminal points and the valve or valves required by para. 122.1 shall be provided with Data Reports, inspection, and stamping as required by Section I of the ASME Boiler and Pressure Vessel Code. All welding and brazing of this piping shall be performed by manufacturers or contractors 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



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

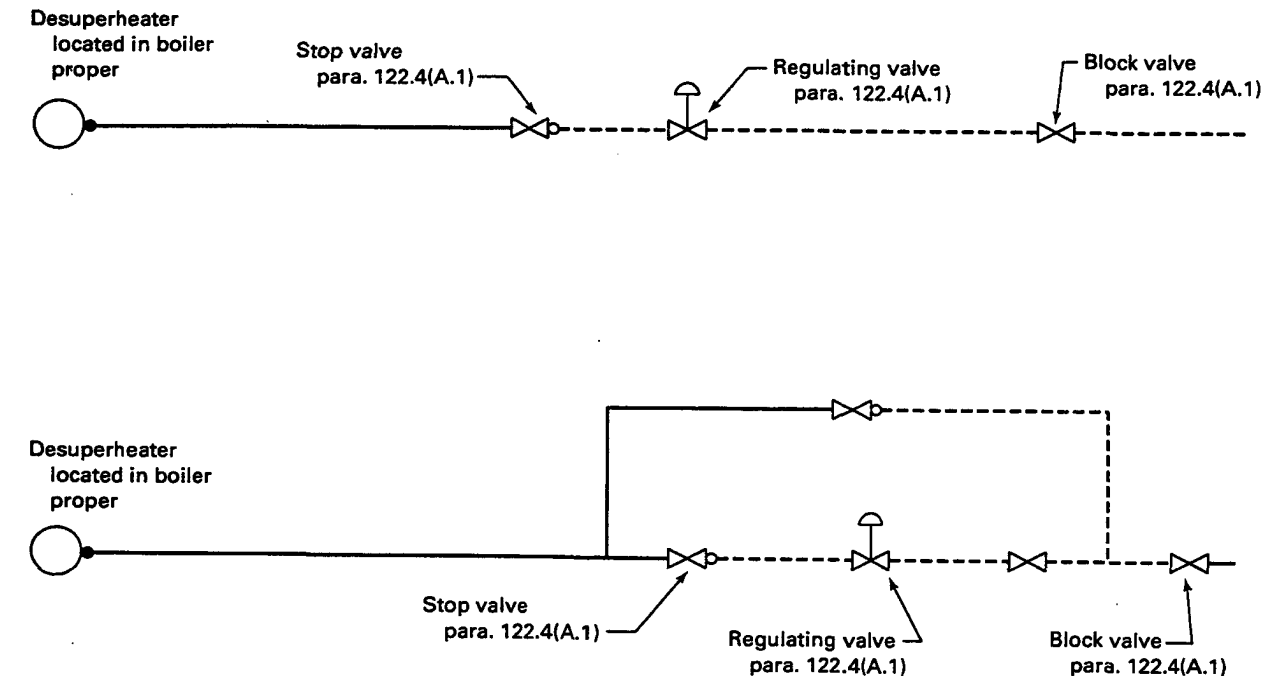
FIG. 100.1.2(A) CODE JURISDICTIONAL LIMITS FOR PIPING — FORCED FLOW STEAM GENERATOR WITH NO FIXED STEAM AND WATER LINE



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 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.
- 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



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.
- 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 $\frac{1}{2}$ 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;

(C) piping for hydraulic or pneumatic tools and their

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.

brazing: 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-

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

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

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.

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.

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, shut-down, 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 vacuum.

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.

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 butt welding fittings, specify that components shall be furnished in nominal thicknesses. Unless limited elsewhere in this Code, such components shall be rated

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.

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:

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

where

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

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

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

(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

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

TABLE 102.4.3
LONGITUDINAL WELD JOINT EFFICIENCY FACTORS

No.	Type of Joint	Type of Seam	Examination	Factor <i>E</i>
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 Additionally 100% radiographed	0.85 1.00 [Note (2)]
	(b) Single butt weld (with filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.80 1.00 [Note (2)]
	(c) Double butt weld (without filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 1.00 [Note (2)]
	(d) Double butt weld (with filler metal) 	Straight or spiral	As required by listed specification Additionally 100% radiographed	0.90 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 Additionally 100% radiographed	0.90 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 ma-

chined 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

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 [$4\frac{1}{2}$ 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 $\frac{1}{4}$ 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:

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

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

Design pressure shall not exceed

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

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

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.

TABLE 102.4.6(B.1.1)

Discontinuity Category Designation	Severity Level		Discontinuity Category Designation	Severity Level
	≤1 in. (25 mm) Thick	>1 in. (25 mm) Thick		
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.

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	0.4	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.

(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.

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

For nominal sizes smaller than NPS $\frac{3}{4}$, the thickness shall not be less than that specified for Type K of ASTM B 88.

For nominal sizes NPS $\frac{3}{4}$ 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 $\frac{1}{2}$ and NPS $\frac{3}{4}$ branches; 7 for NPS 1, NPS $1\frac{1}{4}$, and NPS $1\frac{1}{2}$ branches; and 8 for NPS 2

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.

required reinforcement = $(t_{mh}) (d_1) (2 - \sin \alpha) = A_7$
 reinforcement areas = A_1, A_2, A_3, A_4 , and A_5

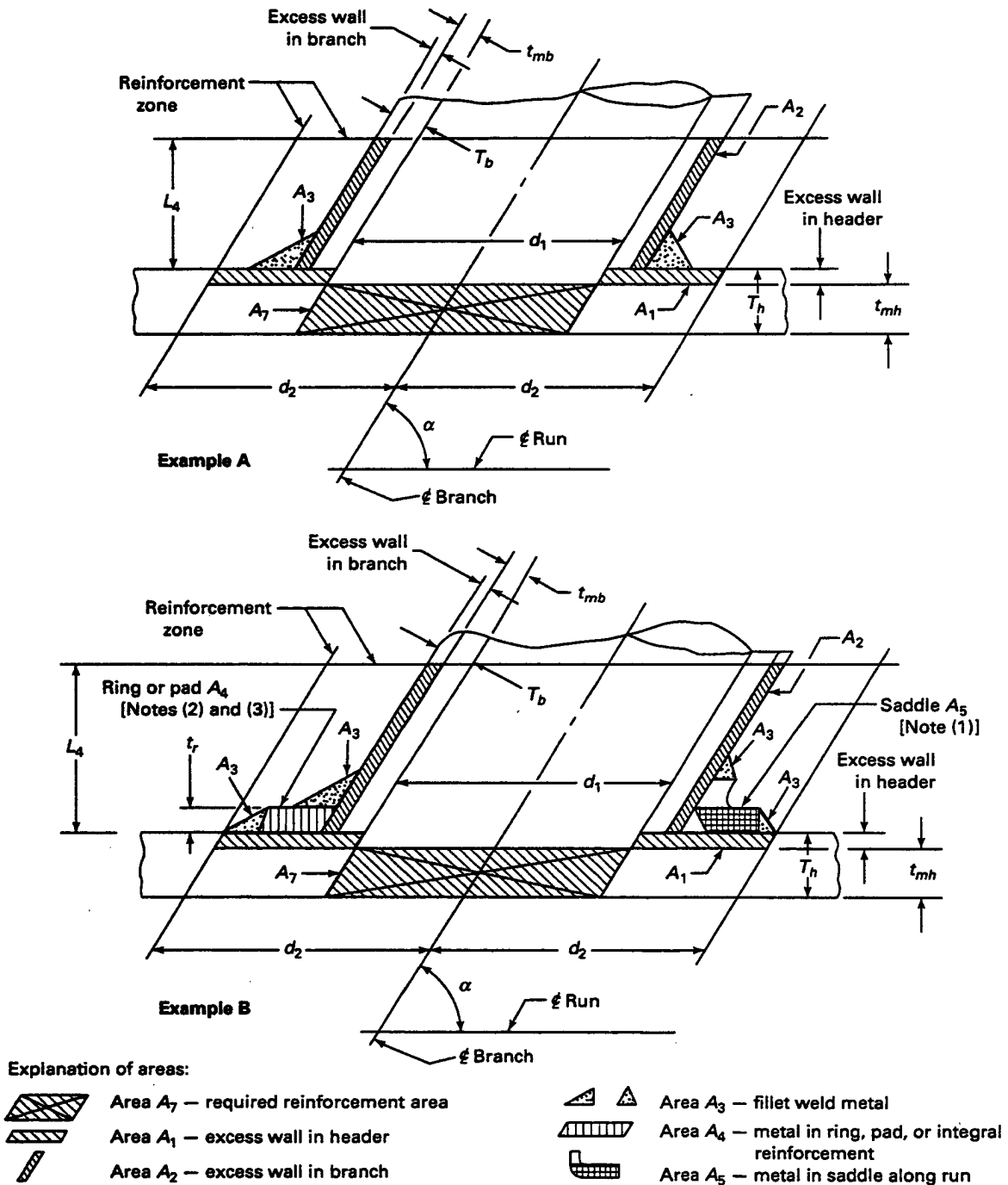
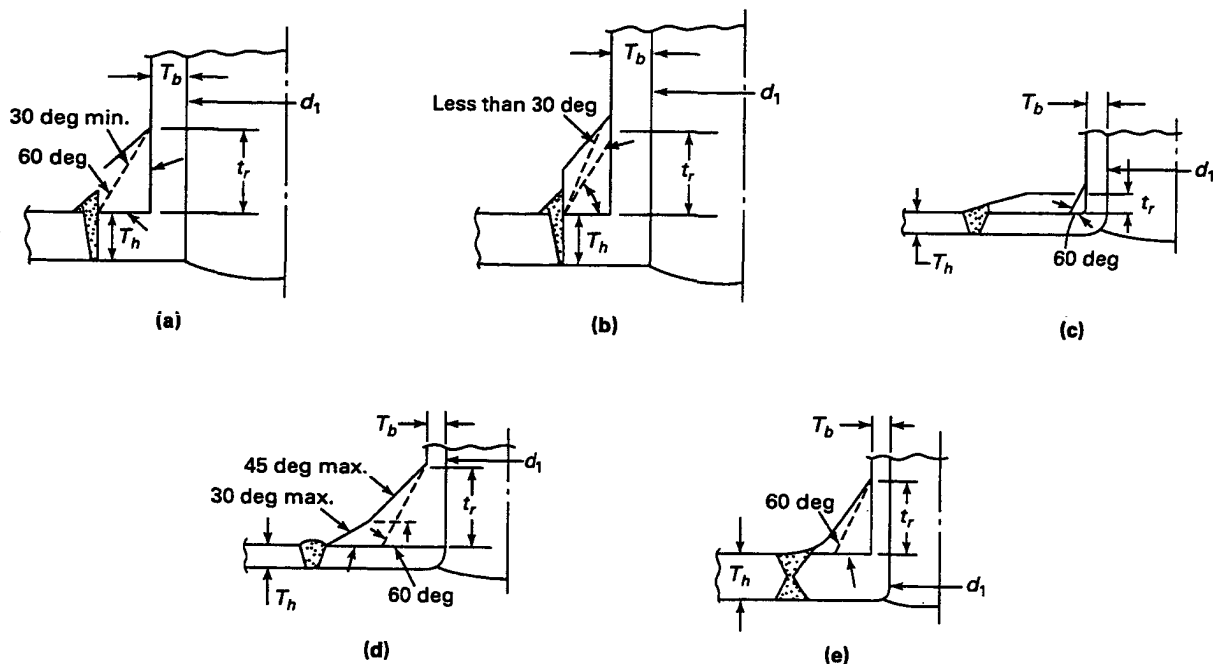


FIG. 104.3.1(D) REINFORCEMENT OF BRANCH CONNECTIONS



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 (mm²), 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.

A_5 = area provided by a saddle on right angle connections

$$= (\text{O.D. of saddle} - D_{ob})t_r$$

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 $1\frac{1}{2}$ 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 therotch.

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

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

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).

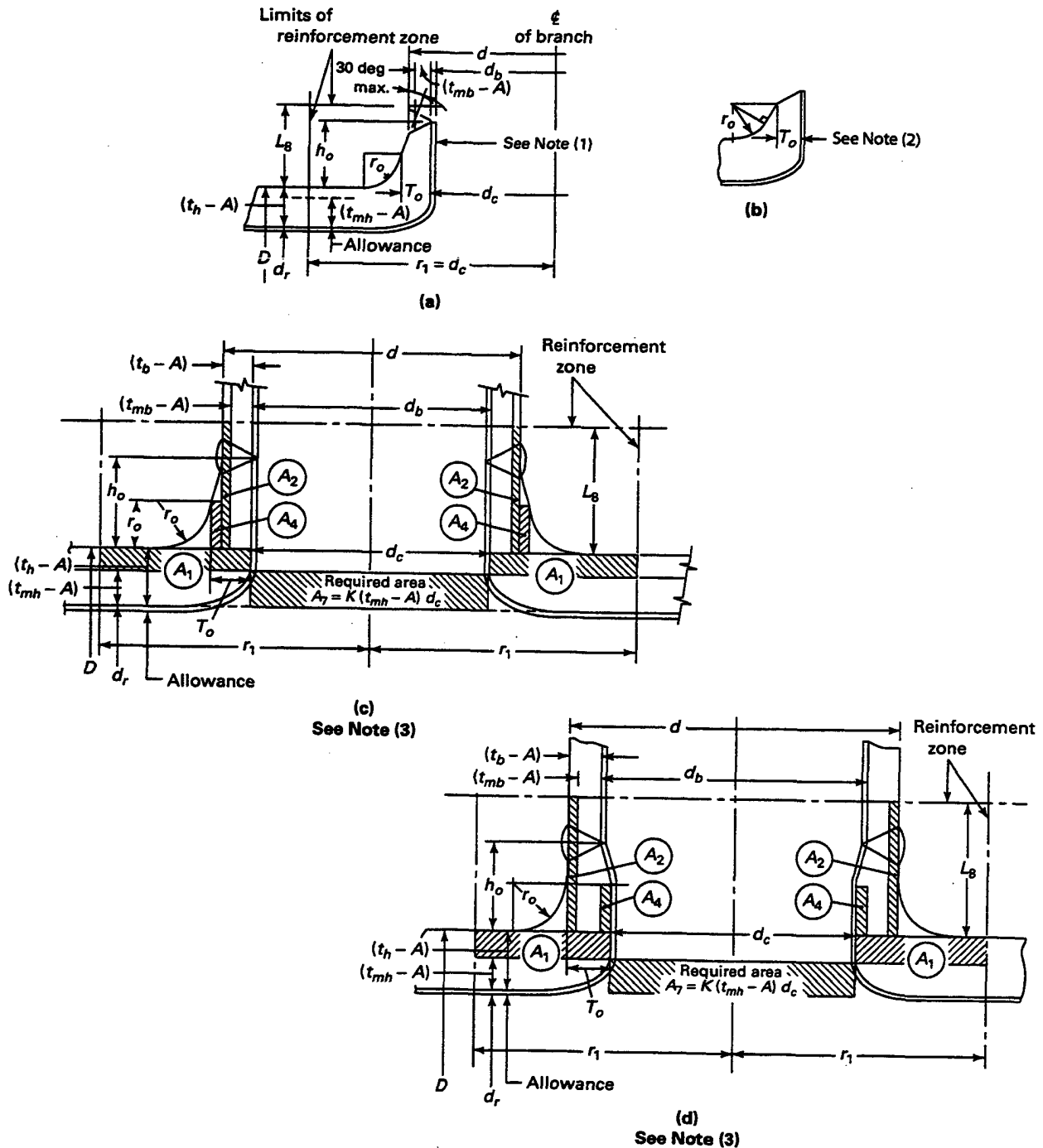
(G.3) These rules apply only to cases where the axis of the outlet intersects and is perpendicular to the axis of the run. These rules do not apply to any nozzle in which additional nonintegral material is applied in the form of rings, pads, or saddles.

(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



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

- 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,

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

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.

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

(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-

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 butt welded 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

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 $d_5 t$, 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).

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

where